ANTWERP UNEARTHED

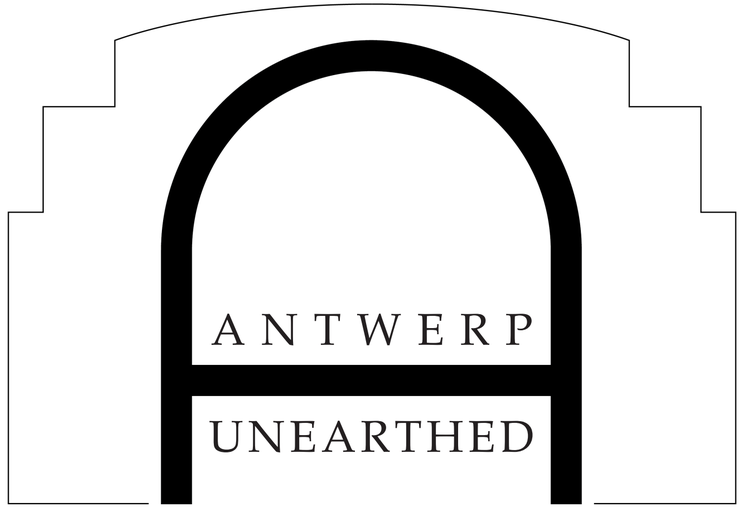
The capacity of the historic canal network beneath Antwerp
in mediating future urgencies for environmental and social infrastructures.

by
Jolt Wiersma

Globally, urban cores are facing a problem: there is a shortage of space. After evolving with little thought for changing needs and conditions, the urban fabric is unfit for new infrastructure systems. In the context of climate change and densification, the consequences are significant. It is difficult to construct more flood buffers or plant extra eco-corridors. Conflicts arise between expanding public space or preserving urban heritage. Antwerp, facing these four pressures simultaneously, has a hidden opportunity. Lying beneath the city's surface is a decommissioned network of historic canals with the appropriate intrinsic qualities for mediating the four infrastructural urgencies. Their spatial synthesis results in a unique experience. Take a journey into the hidden infrastructural layers beneath the city and experience a world where nature, water, humans, and history come together. Unearth the secrets that criss-cross deep below the streets of Antwerp.

ANTWERP UNEARTHED - Jolt Wiersma

Landscape Architecture Master Thesis TU Delft



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July 2023
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FORWORD
This book encompasses the graduation thesis of my Landscape Architecture studies at the TU Delft. The project was part of the lab 'Design of the Urban Fabric' within the 'Flowscapes' graduation studio. The focus is on landscape systems (Flowscapes) in the urbanized landscape (Design of the Urban Fabric). A side focus, particular to my supervisors, was the heritage and historical narrative component. Antwerp Unearthed is a fitting research case for these topics and I wish you much pleasure in reading about it.

ACKNOWLEDGEMENTS
I would like to express my sincere appreciation to my main supervisors, Gerdy and Leo, for their consistent support, invaluable guidance, and continuous encouragement throughout the process of completing this thesis. Your expertise and dedication have firmly shaped this work and my personal development. Your feedback and insights have been valuable to refining my research. I am grateful for your mentorship. I would also like to extend my thanks to my fellow lab students, Floor, Yael, and Zhihao, for their companionship and shared experiences. Our grown friendship and stimulating discussions have truly made my academic time enriching. Our interactions, both inside and outside the classroom, have provided a supportive environment that has eased the process of my research. I am fortunate to have had the privilege of working alongside such valuable individuals. Your contributions have played a significant role in shaping this thesis. Thank you for being an integral part of my last academic year.

I would also like to thank The Ruien Antwerp for their guided tours of the underground canal system of the city and the generosity regarding their sharing of information and photos. Further I want to thank the City of Antwerp who provided me with valuable data and statistics during the unforeseen cyber-attack on their servers. I am grateful for my fellow study-colleagues for their company during my graduation period and the motivation they have given me. Lastly I want to thank the TU Delft and the Faculty of Bouwkunde for offering an inspirational setting for my academic life.

thank you

ABSTRACT
The performance of a city is dependent on the performance of its infrastructure. As a result, the surface-level world is inseparable from the subsurface world. However, cities around the world are facing a shortage of available space both aboveground and belowground. The existing urban fabric has over time become unfit for the addition of new infrastructure systems that are required for the future. Spatial conflict problems are arising between necessary urban infrastructures, in Antwerp specifically regarding green, blue, place, and memory systems. Nevertheless, Antwerp has an opportunity: a decommissioned canal network that lies beneath the city as tunnels that can act as a spatial mediator. Establishing this potential, the main research question asks: how can the reappropriation of the decommissioned underground canal system in Antwerp spatially mediate the city's urgencies regarding environmental and social infrastructure? While the research question calls for the implementation of four infrastructural themes (green, blue, place, memory), an exploration of background theories on urban infrastructure implementation indicates a research gap regarding a systems-thinking approach. In this case, the Environmental Maximization Method (BOOM-Duijvestein, 1998), with its five design phases (inventory, analysis, maximization, optimization, integration), is useful. Together, the four infrastructure themes and the five design phases form a matrix that offers an appropriate design framework in the context of Antwerp. Antwerp Unearthed, as a plan, provides two answers to the research question of this report. The decommissioned underground canal system in Antwerp spatially mediates the city's future urgencies regarding environmental and social infrastructure by pairing external problems with internal potentials and by forming a singly functioning infrastructure system. Next to this, the plan is embedded in other aspects of the urban fabric. The findings are societally relevant because they show how to work toward adaptivity and resiliency in the context of climate change and densification. The findings are scientifically relevant because they show how to work toward a justifiable and balanced implementation of different infrastructure systems. The findings are professionally relevant because they show how to work toward integral and interdisciplinary design principles for multiple infrastructural themes.

KEYWORDS
infrastructure, space shortage, green, blue, place, memory, maximize, underground, tunnel, landscape architecture

This chapter presents the research topic and the personal fascination that triggered it (1.1). Thereafter, a brief overview of the aim of the report is given (1.2).

1 preface

1.1 fascination

Once upon a time, my parents took me to Disneyland Paris (figure 1.1.1). It was a different type of vacation than the usual scenic wilderness road trips to a Norwegian fjord (figure 1.1.2), for example. At the end of the day, I wasn't tall enough for most of the roller coasters, but I was still very intrigued to be there. How could this manmade landscape feel just as immersive as a natural landscape? A fascination was born. Although everything is artificial and systematic, theme parks succeed in creating convincing worlds that offer an escape from reality. The big difference between the scenic wilderness and a theme park is, of course, the underlying processes that form them.

FIGURE 1.1.1: Sleeping beauty castle in Disneyland Paris (Walt Disney Company, n.d.). The castle and its surroundings are made to mimic a real medieval castle in a mountain landscape.

FIGURE 1.1.2: Segla Fjord in Norway (Arctic Campers, n.d.). Natural glacial processes are the underlying force shaping the Norwegian landscape.

While an unconstrained natural system of geological, hydrological, and ecological cycles oversees the formation of a Norwegian fjord, Disneyland Paris is driven by a discreetly hidden technical system of cables, pipes, and passages. According to Disney legend, a cowboy once walked through Disneyland's space-themed 'Tomorrowland' enroute to his post in wildwest-themed 'Frontierland'. In an effort to avoid spoiling the illusion of the themed environment aboveground, Walt Disney opted for the installation of underground utility corridors in all Disney parks (figure 1.1.3). These tunnels now allow Disney to perform its behind-the-scenes park-support operations such as waste removal and costume changes.

Evidently, the world aboveground cannot function without the world below ground. That same story plays a part in cities: the urban performance aboveground relies on the infrastructure performance belowground (figure 1.1.4). While historic sewage and stormwater systems keep a city hygienic and climate secure, modern-day transportation and utility systems keep a city mobile and operating reliably. Out of sight and out of mind, hidden beneath the city is a world dominated by infrastructure networks that guarantee proper urban functioning. As a consequence of the evolving needs of cities, the scope of underground infrastructure networks has expanded.

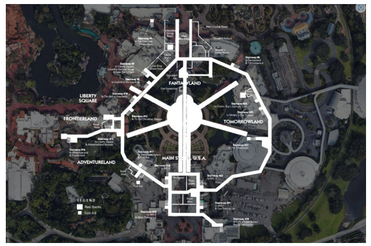


FIGURE 1.1.3: The Disney Utilidor network underneath the Magic Kingdom Park in Walt Disney World (Walt Disney Company, n.d.). The tunnels are the behind the scenes processes allowing the park to function.

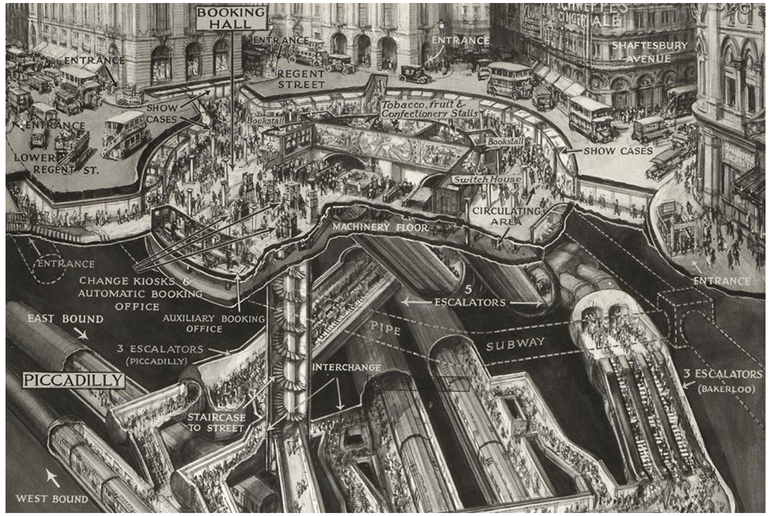
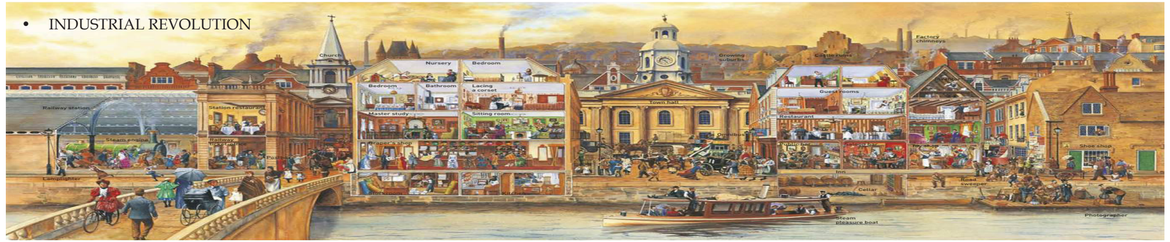


FIGURE 1.1.4: Piccadilly Circus in London (London Transport Museum, 1998). The hustle and bustle aboveground continues underneath the streets in a widespread tube (metro) network.

The functional interdependency between the surface and subsurface triggers significant changes in the design and experience of urban space. A book from my childhood, A Street Through Time by Anne Millard (1998), illustrates this spatial cause-and-effect relationship very well (figure 1.1.5). Infrastructure networks not only build up as a response to specific urban problems but also build up on top of each other physically. Their accumulation through time results in an interconnected and crisscrossed structural arrangement that forms an urban palimpsest. In this way, the underground infrastructure layers are also a testament to the narratives of a city's past.



<< **FIGURE 1.1.5:** A single street, illustrated through time (Anne Millard, 1998). The spatial elements of the past get new life as the city modifies around it.

What is the fate of the forgotten worlds underneath cities as they work toward implementing new infrastructures? Like the thematic tensions in Disneyland, how will the city of the past stand against the city of the future? What will happen to ancient Naples beneath modern Naples (figure 1.1.6)? What awaits the catacombs twisting beneath the boulevards of Paris (figure 1.1.7)? What is the fate of the unused tube-stations beneath the busy streets of London (figure 1.1.8)? Will these worlds become forgotten with the past or can they be repurposed for the future? It is this infrastructural dilemma that forms the basis for a large part of the research in this report.

FIGURE 1.1.6:
Ancient passages sit below the modern city of Naples (Borbonica, n.d.).

FIGURE 1.1.7:
The catacombs of Paris are abandoned mineshafts and crypts (Paris Perfect, n.d.).

FIGURE 1.1.8:
The tube network of London has many unused tunnels and stations (Landon, 2023).

1.2 aim

Infrastructure is defined by the Oxford English Dictionary (2023) as “the basic physical and organizational structures and facilities needed for the operation of a society or enterprise.” While a theme park plans their infrastructure based on thematic and narrative requirements, a city plans their infrastructure based on environmental and social requirements (OECD, 2019). Environmental infrastructures address environmental issues such as climate change while social infrastructures address social issues such as densification. A time-lapse of a city shows a significant spatial conflict between the implementation of new infrastructures and the management of old infrastructures. Based on increasing environmental and social urgencies in cities, it is likely that this phenomenon will be much more common in the future. Especially rapidly developing cities with expansive histories will encounter this challenge. Antwerp is one of those cities. Although it started out as a simple “town on the stream”, it has grown to an “innovative metropolis” (Stad Antwerpen, 2017). With its slogan “Atypical Antwerp”, the city aims to promote this ongoing narrative. The city reacts to the past while working toward the future, often leading to historically tinted modern interventions (figure 1.2.1). In the context of the dilemmas associated with future infrastructure development, can Antwerp take inspiration from Disneyland and redefine its required infrastructure systems beyond their typical utilitarian and practical definition? Can Antwerp treat its infrastructure as a type of landscape and its landscape as a type of infrastructure?

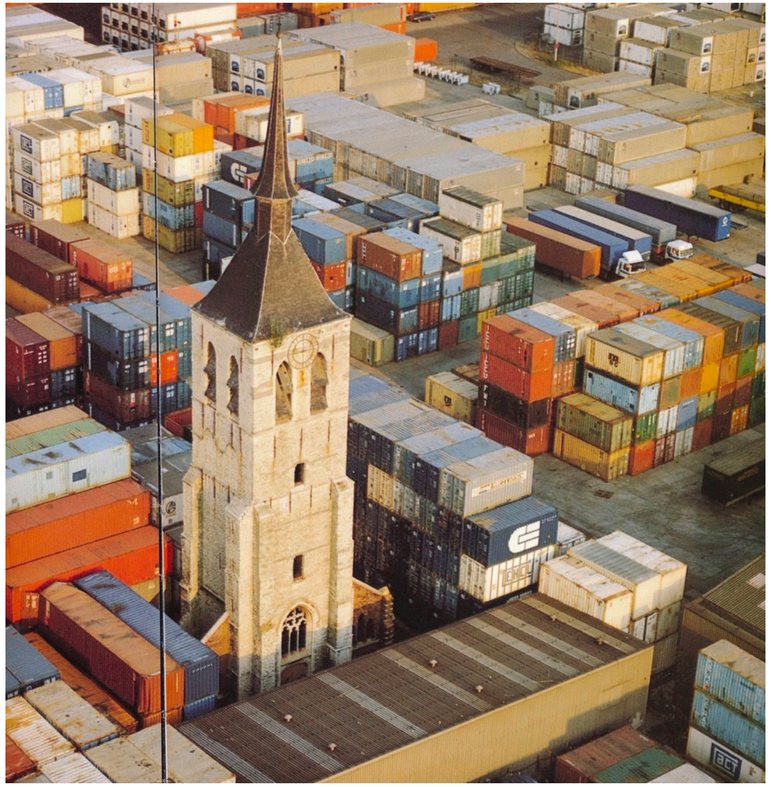


FIGURE 1.2.1: The Wilmarsdonk in Antwerp (Leysen, 2003). The old town was enclosed by the expanding harbor. Only the church tower remains as a silent witness: Atypical Antwerp.

The main goal of this report is to present the city of Antwerp with design insight on how to hybridize its future infrastructural requirements into the context of its historically tinted urban landscape. In this way both the external needs of the city and the internal values of the city can be sustained. This chapter (1) has presented the research aim and the personal fascination that triggered it. In the following chapters, the report covers:

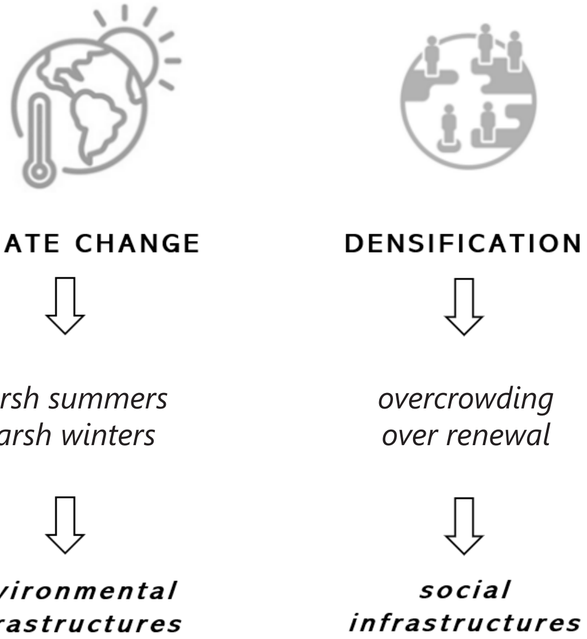
2 The introduction to the problem statement, the research question, background theories, and a design method.
3 The design experiment and its results.
4 The discussion of the findings, their limitations, and recommendations for further research on the topic.
5 The concluding summary and a personal reflection.
6 The references, including literature used for research.

This chapter presents the research covered in this report. This is initiated by defining the research problem (2.1). What follows is the formulation of the research question (2.2) and the existing background theories (2.3). Established thereafter is the research method (2.4).

2 introduction

2.1 problem

Globally, urban cores are facing a big problem: there is a shortage of available space. After evolving with little thought for changing needs and conditions, the urban fabric of contemporary cities is unfit for the addition of new infrastructure systems (figure 2.1.1). In the context of future environmental and social urgencies the consequences are significant (figure 2.1.2). Climate change is leading to harsher summers and winters (European Commission, 2023). As its effects intensify, it will become difficult for cities to find infrastructural relief through new environmental infrastructures. Densification is leading to overcrowding and -renewal (Teller, 2021). As its effects intensify, it will become more difficult for cities to find infrastructural relief through new social infrastructures.



>> **FIGURE 2.1.1:** Infrastructures are implemented in a first come first served basis (Cartoon Blanche, 2019). There is no more room left in the subsurface for important infrastructures like trees and waste bins.

^ **FIGURE 2.1.2:** Climate change requires more environmental infrastructures and densification requires more social infrastructures (own work).

Antwerp, the largest city in Belgium (figure 2.1.3), is responding to the urgencies for environmental and social infrastructures without integral success. News articles correlate the shortcomings to spatial conflicts with existing infrastructures both aboveground and belowground, especially in the context of the city's historical core. As a result, none of the essential infrastructural themes are able to materialize to their full potential (figure 2.1.4). At the Mediapark, an underground parking garage limits the amount of planted trees. At the Groenplaats, cables and pipes restrict the volume of a stormwater buffer tank. At the Zuiderdokken, parking needs inhibit the public functioning of the park. At the Leien Ring, construction of car tunnels and tram railways decreases the city's archeological assets. Noteworthy is that most of the infrastructure conflicts occur within the historic center of the city, within the Antwerp Ring Road.

“Studie geeft aan: tekort aan groen door aanleg ondergrondse parkeergarages”

“Plannen voor heraanleg Groenplaats zorgen voor heel wat vragen bij Antwerpenaren”

“Sportplein en skatepark geschrapt uit plannen Gedempte Zuiderdokken”

“Spaanse omwalling in Antwerpen eenmalig zichtbaar voor publiek”

>> **FIGURE 2.1.3:** Antwerp is the largest city in Belgium in both population and area (Google, 2023 and Rosenberg, 2019). It sits along the Scheldt River which flows into the North Sea.

^ **FIGURE 2.1.4:** Antwerps historic inner city is seeing significant spatial conflicts between infrastructure systems, according to news articles (Gva.Be, 2022a, Gva.Be, 2022, Svw, 2019, Van Beylen, 2016).

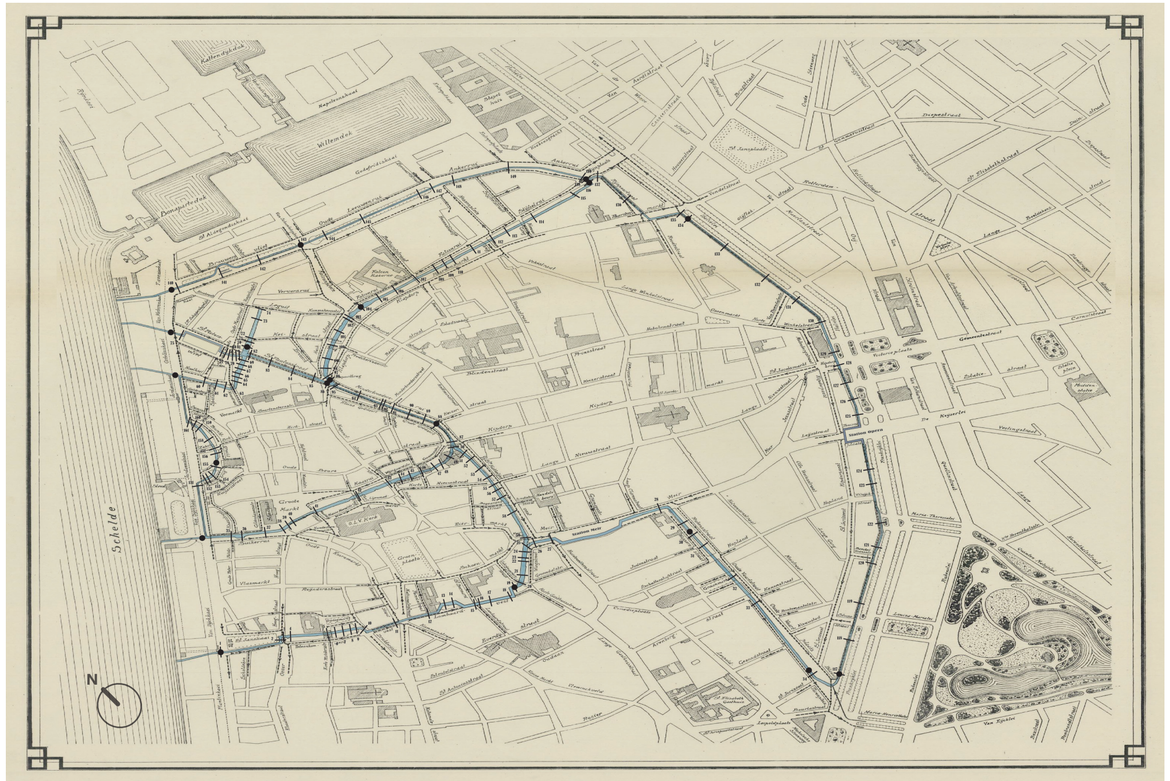
A figure-ground mapping of both the sub-surface (figure 2.1.5) and the surface-level (figure 2.1.6) of Antwerp within the Ring Road indeed illustrates the significant aboveground and underground space shortages there. As a result, the historic center does not have the infrastructural capacity to guarantee reliable environmental and social resilience. However, the figure ground maps also indicate an opportunity: Antwerp has an unused infrastructure system with the potential to mediate the spatial conflict issues. It is a network of decommissioned historic canals, locally called the Ruien, that lie beneath the city's surface as tunnels (figure 2.1.7).

FIGURE 2.1.5: A figure ground map of the underground of the inner city of Antwerp (own work) shows what space is occupied (black) versus what space is not occupied (white). Occupied space mainly includes tunnels for cars, trains, and metros but also underground parking garages and a network of sewer pipes.

FIGURE 2.1.6: A figure ground map of the aboveground of the inner city of Antwerp (own work) shows what space is occupied (black) versus what space is not occupied (white). Occupied space mainly includes buildings and roads. Trees, although also occupied aboveground space, are not included.

FIGURE 2.1.7 (next page): The Ruien are an underground network of tunnels that historically formed part of the city's sewer system (FelixArchief, n.d.). Today, they have been decommissioned, taking up valuable space in the underground. They can provide an opportunity for new infrastructures that are needed in the city.

Because the underground tunnels are vacant, they have the spatial capacity to alleviate the urgencies for environmental and social infrastructures as described before, without interfering with the other necessary infrastructure systems such as parking, utilities, or transit-systems. The network is a derivative of historic creeks that flowed through the natural landscape (figure 2.1.8). After their canalization, they functioned as urban trade arteries (figure 2.1.8). Their use an open sewer, however, eventually resulted in their covering (figure 2.1.9). Nowadays, the city's sewage no longer flows freely through the tunnels and the structure is without use (figure 2.1.10).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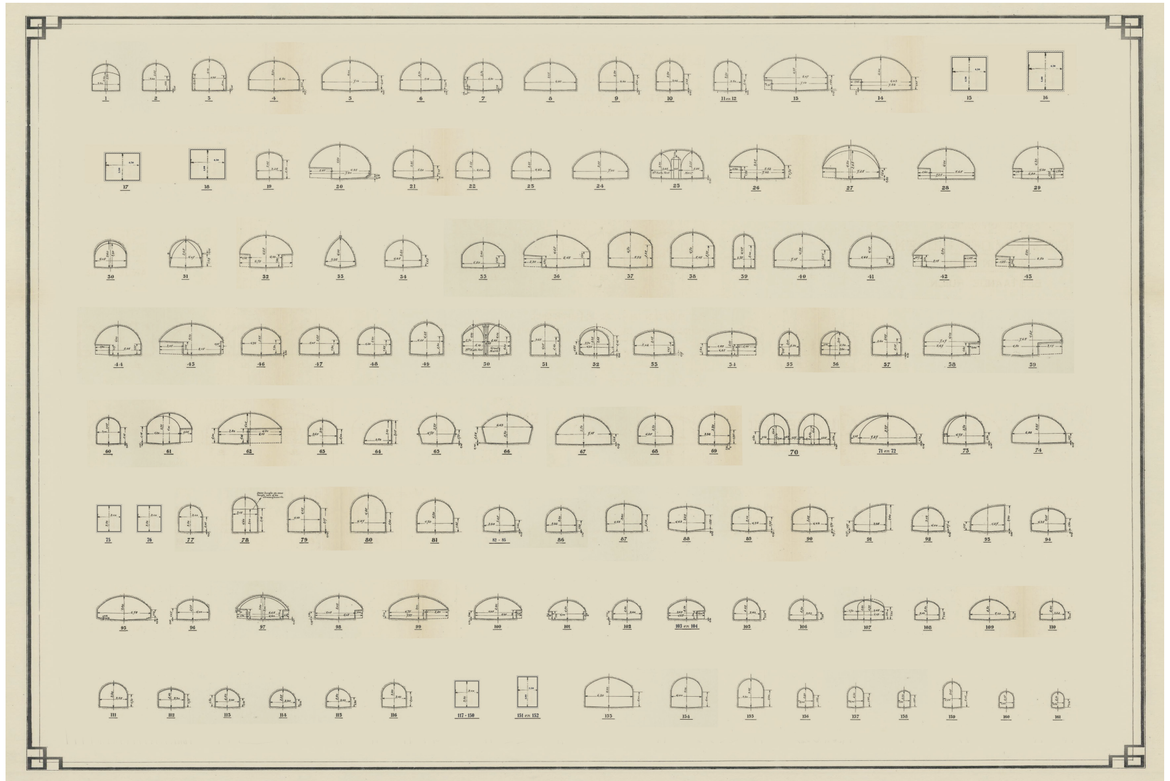


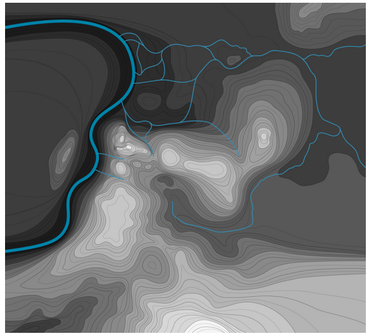


FIGURE 2.1.8: (Top) A topographic height map of prehistoric Antwerp (own work) in which natural creeks of the Schijn River valley flowed freely into the Scheldt River. (Bottom) An impression of what the prehistoric natural landscape of Antwerp looked like (Geograph, 2007)

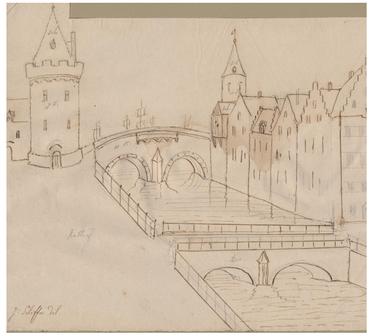


FIGURE 2.1.9: (Top) A historic sketch of the Suikerrui and the Boterrui, the canal used to as a trade artery, specifically for trade of sugar and butter products imported by ship (FelixArchief, n.d.). (Bottom) A photograph of the Koolvliet, known today as the Koolkaai, showing coal ships moored in the inner city (HLN, 2016).

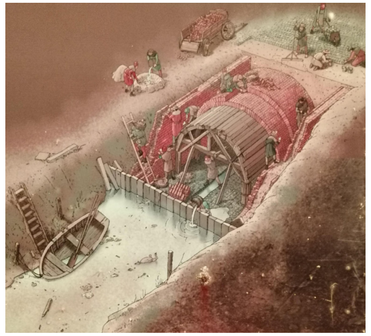


FIGURE 2.1.10: (Top) A diagram of how the canals were enclosed by a vaulted tunnel after they became overused as open sewers (The Ruien Antwerp, n.d.). (Bottom) A photograph of the construction of a vaulted ceiling on top of the unknown section of canal (FelixArchief, n.d.).

FIGURE 2.1.11: (Top) A photograph of the inside of the tunnelled canals showing the high level of sewage water and a sluice-gate that regulates its flow (FelixArchief, n.d.). (Bottom) A photograph of a Ruien Tour visitor in which is visible that the sewage water now flows through pipes on the walls (own work).

2.2 question

Aware of the vacancy of the tunnels, a landscape architectural reappropriation of the structure for the urgencies related to environmental and social infrastructure is unquestionable. The following research question can be formulated:

How can the reappropriation of the decommissioned underground canal system in Antwerp spatially mediate the city's urgencies regarding environmental and social infrastructure?

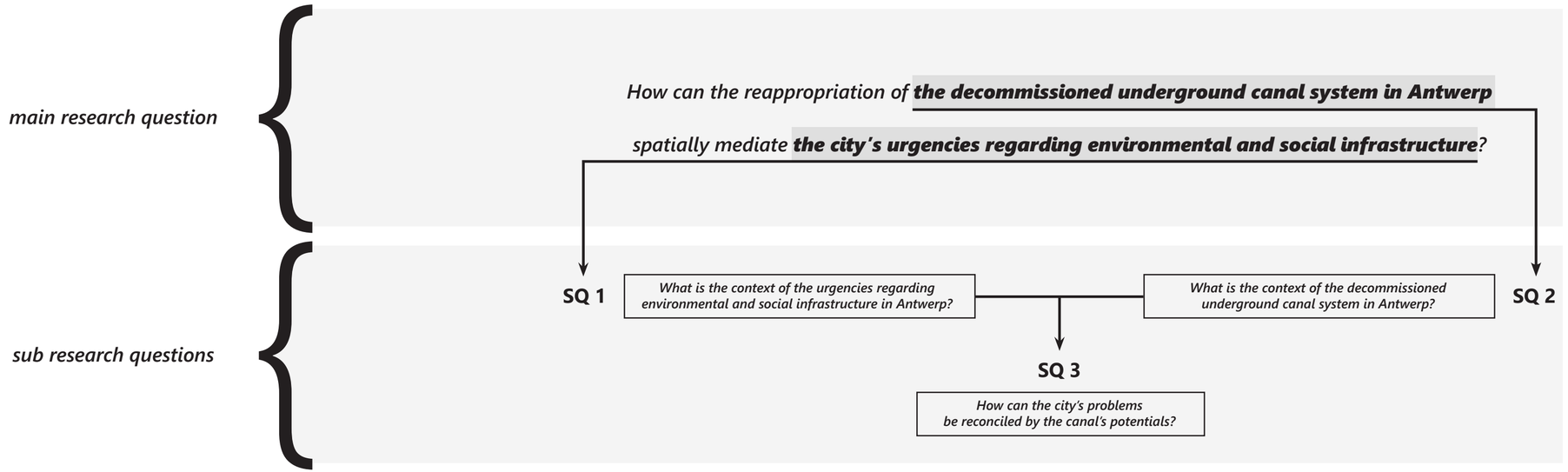
In order to answer the question, its parts must be investigated. Therefore, a set of sub-questions are put forward (figure 2.2.1).

1. ***What is the context of the urgencies regarding environmental and social infrastructure in Antwerp?***
   - More specifically, what are the city's infrastructure problems?

2. ***What is the context of the decommissioned underground canal system in Antwerp?***
   - More specifically, what are the canal's infrastructure potentials?

3. ***How can the city's problems be reconciled by the canal's potentials?***
   - More specifically, what are the design interventions for incorporating urban infrastructures into the canals?

Each sub-question provides insight for answering the main question. The first gives insight into the city's external infrastructure problems and the second gives insight into the canal's internal infrastructure potentials. Using the insights acquired from the first two sub-questions, the third sub-question gives insight into the possible design interventions for incorporating infrastructures into the canals.



>> **FIGURE 2.2.1:** A scheme showing the main research question and the sub research questions that are derived from it (own work).

2.3 theory

It is important to outline the background theories related to urban space in the context of infrastructure implementation. Urban space is considered one of the most valuable resources within cities, especially at the transition between the surface and the subsurface. This aboveground-underground border is home to the systems and networks that allow a city to function properly and serve its sustainability (Bobylev, 2009). The urban sustainability services consist of a wide variety of infrastructural provisions (Table 2.3.1), typically reacting to environmental and social perspectives on the city (Zavrl & Zeren, 2010).

- Gas/Water/Electricity	- Vegetation
- Metro	- Tunnels (car/pedestrian)
- Parking	- Stormwater drainage
- Shopping	- Archaeological ruins
- Street	- Sewer
- Sidewalk	- Reservoirs
- Public services	- Allotment gardens
- Parks	- Green roofs
- Defense	- Monuments
- Storage	- Public art

TABLE 2.3.1 Infrastructural provisions (adapted from Goel et al., 2012 and Spacey, 2023)

The environmental and social infrastructures need to find space within the urban fabric, aboveground and belowground. Due to spatial shortages, however, the infrastructure systems in cities are typically developed in a sectoral 'first come, first served' basis suggesting that, altogether, they cannot provide their full operational benefits (Bobylev, 2009). A further 'out of sight, out of mind' mentality within infrastructural engineering naturally leads to infrastructure implementation without thought for the broader context. Essentially, the development of infrastructure systems lacks a standardized and comprehensive design approach. In Underground Urbanism (2016), Delmastro et al. propose that infrastructure specialists should adapt to using "integrated infrastructure masterplans" to ensure that the long-term land use effects of multiple infrastructural systems are considered jointly.

There are limited urban examples of integrated infrastructure masterplans and thus the extent of their environmental and social feasibility is unclear. When faced with the described spatial shortages in the urban fabric, city planners prefer to develop skyward where spatial risks are more tangible than in the underground. Some cities, particularly in Asia, opt for the construction of raised skyscraper walkways acting as entirely new infrastructural layers (figure 2.3.1). Green roofs on existing buildings, often in the form of public parks and acting as rainwater buffers are a common form of integrated environmental and social infrastructure (figure 2.3.2). The High Line project in New York City, which makes new use of an abandoned freight-train viaduct, is a prime example of the integration of environmental and social infrastructures (figure 2.3.3). Integrated practices within the urban underground usually only succeed in combining up to a few different infrastructure systems. Integral piping tunnels, for example, mainly focus on the grouping of several utility systems (figure 2.3.4). In Canadian cities like Montreal and Toronto, wintertime pedestrian tunnels between buildings mainly function as mobility links, sometimes with shops (figure 2.3.5). The practice of daylighting, in which a historically culverted river is reopened and restored, mainly focuses on flood relief and ecological resilience (figure 2.3.6). In Rotterdam, the plans for transforming the Westblaak boulevard into a mixed-use park are postponed due to the lack of interdisciplinary knowledge on merging the numerous required infrastructures within the limited space (figure 2.3.7).

For a masterplan to capture the evolving functional complexities of infrastructure integration, Von Der Tann et al. (2020) call upon a more systematic approach that first maps the various infrastructural potentials and proposes different infrastructural scenarios. This requires a design mindset based on a systems-thinking design framework that outlines the specific operational criteria and conditions for the desired infrastructures before their implementation. Negotiations between themes must begin early on.

The theoretical limits within the topic of underground infrastructure implementation have implications for urban resiliency. In working toward the relief of future environmental and social pressures on the urban fabric of cities, the gaps in the research (figure 2.3.8) suggest utilizing integrated infrastructure masterplans (Delmastro et al., 2016) formed on the basis of a systems-thinking design approach (Von Der Tann et al., 2020). Essentially, infrastructural starting points should be translated into specifically defined proposals early in the masterplanning process. The proposals should form the criteria for the operation and performance of the infrastructure system, making any eventual refinements during the implementation phase easier to guide.

FIGURE 2.3.8: The reports by Delmastro et al. (2016) and Von Der Tann et al. (2020) which plead for integrated infrastructure masterplans designed with a systems-thinking approach.

FIGURE 2.3.1: An elevated walk way in Hong Kong (Yoos & James, 2016).

FIGURE 2.3.2: A typical green roof on a building (Mars, 2021).

FIGURE 2.3.3: The High Line Park in New York City (Staff, 2011).

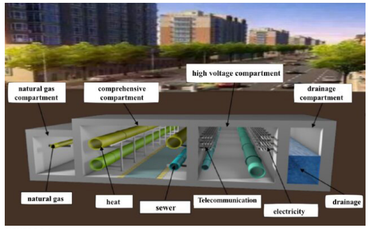


FIGURE 2.3.4: An integrated utility tunnel (Li et al., 2019).

FIGURE 2.3.5: The underground mall in Toronto (Academic Dictionaries and Encyclopedias, 1987)

FIGURE 2.3.6: A typical daylighted creek (Blyth, 2019).

FIGURE 2.1.7: The utility conflicts at the Westblaak (Gemeente Rotterdam, 2021).

2.4 method

The research question aims to find a hybridized solution to the problem of space shortage for environmental and social infrastructures in Antwerp by coupling them to the infrastructure potentials of the Ruien, a decommissioned canal network in the city's sub-surface. While the research question calls for the implementation of various infrastructural themes (chapter 2.1), the theoretical gap calls for the implementation of a systems-thinking design approach (chapter 2.3). Based on the discussed infrastructure urgencies in Antwerp, although multiple infrastructural themes are relevant, this study will focus on four main themes: green, blue, place, and memory infrastructures. They are umbrella terms for various sub-infrastructures (figure 2.4.1):

1. Green Infrastructure
Green infrastructure offers a support framework for urban environmental issues in the form of a systematic network of features like vegetated corridors or planted patches (Benedict & McMahon, 2006).

2. Blue Infrastructure
Blue infrastructure offers a support framework for urban environmental issues in the form of a systematic network of features like drainage pipes, pumps, mills and other water management related works (Bosch et al., 2016).

3. Place infrastructure
Place infrastructure offers a support framework for urban social issues in the form of a systematic network of features like parks, squares, and other public spaces (Latham & Layton, 2019).

4. Memory infrastructure
Memory infrastructure offers a support framework for urban social issues in the form of a systematic network of features like protected building, landscape, or archeological heritage (UN Task Team Habitat III, 2015).

INFRASTRUCTURAL THEMES

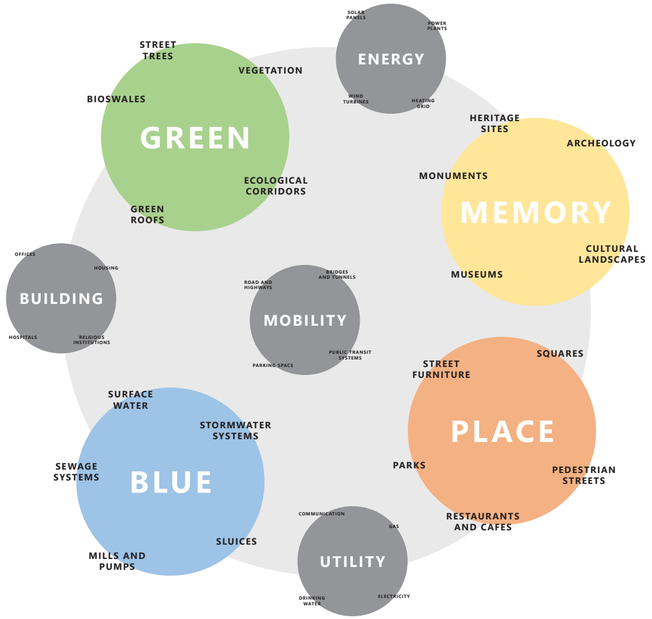


FIGURE 2.4.1: The research question calls for the implementation of various infrastructures. Infrastructure in Antwerp ranges from utilities to buildings, to mobility and to energy (own work). However, news articles mention infrastructural conflicts centered within four main categories: green, blue, place, and memory.

SYSTEMS-THINKING APPROACH

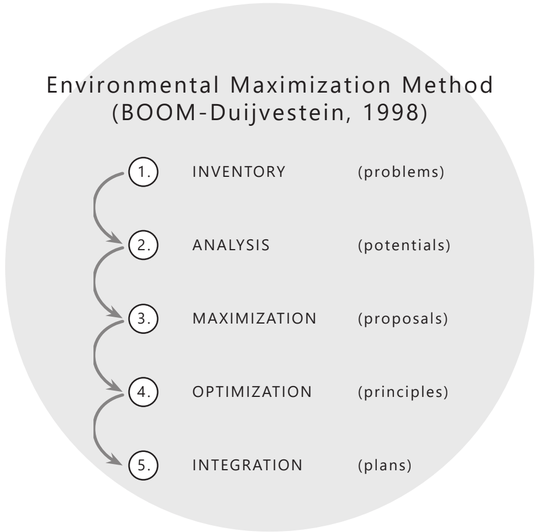


FIGURE 2.4.2: The theoretical gap calls for a systems-thinking design approach. The Environmental Maximization Method (BOOM-Duijvestein, 1998) and its 5 design phases (inventory, analysis, maximization, optimization, integration) are a useful framework for ensuring this.

Based on its systems-thinking design procedure, this study will focus on The Environmental Maximization Method (BOOM-Duijvestein, 1998) and its five main design phases: the inventory, analysis, maximization, optimization, and integration phases (figure 2.4.2):

1. Inventory phase
The inventory phase involves describing and classifying the attributes of each of the starting points. Essentially, the points are specified in order to outline problems.

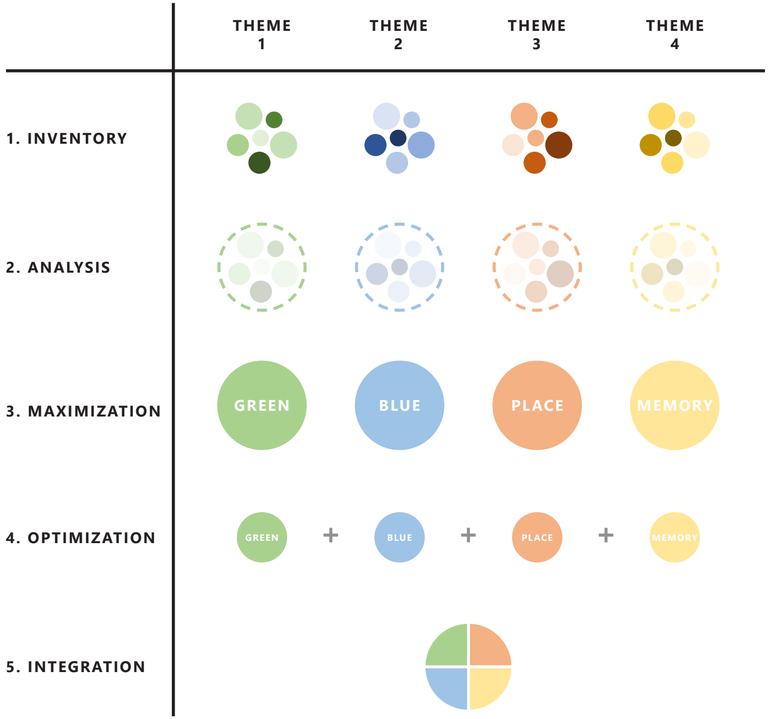
2. Analysis phase
The analysis phase involves modeling and interpreting the opportunities of each of the starting points. Essentially, the problems are studied in order to outline potentials.

3. Maximization phase
The maximization phase involves framing and systemizing the criteria of each of the starting points. Essentially, the potentials are centralized in order to outline proposals.

4. Optimization phase
The optimization phase involves evaluating and diagnosing the interactions of each of the starting points. Essentially, the proposals are refined in order to outline principles.

5. Integration phase
The integration phase involves projecting and testing the design of each of the starting points. Essentially, the principles are applied in order to outline plans.

Together, the four infrastructure themes and the five design phases can form a matrix that offers an appropriate design framework in the context of Antwerp (figure 2.4.3). By making the design expectations for the necessary green, blue, place, and memory infrastructure systems clear, the design considerations for their conflict-free implementation within the Ruien are easier to guide. Each phase of the procedure has specific strategic aims, and each strategy has specific methodologic focuses. Embedded further in each method are specific working approaches. Overall, they answer the specific sub-questions of the main research question. Table 2.4.1 gives an overview. Sub-question 1, which examines the infrastructure problems of Antwerp, is answered during the inventory phase. The approach is to map attributes using data, statistics, municipal documents, and fieldwork. Sub-question 2, which examines the infrastructure potentials of the Ruien, is answered during the analysis phase. The approach is to establish opportunities using historical landscape biographies, archive documents, and fieldwork. Sub-question 3, which examines the design interventions for the implementation of the infrastructures in the canals, is answered in the process of the maximization phase, optimization phase, and integration phase. In the maximization phase, the approach is to build criteria through using operational standards, concept brainstorming, and strategy maps. In the optimization phase, the approach is to compare interactions using map overlays, comparison matrices, and vision schemes and diagrams. In the integration phase, the approach is to implement designs using plans, sections, details, impressions, and other drawings. In the end, the method is essentially a design brief: make a spatial plan for the underground canal network of Antwerp (integration) that accommodates the green, blue, place, and memory infrastructure themes (optimization) so that they work justifiably (maximization) toward the relief of green, blue, place, and memory infrastructure urgencies of the city (inventory, analysis).



^ **FIGURE 2.4.3:** A matrix between the four themes and five phases forms the overall method of the research (own work).

>> **TABLE 2.4.1:** Each phase has an associated strategy, method, and approach that answer the sub-questions of the research (own work).

INSTRUMENT	Environmental Maximization Method (BOOM-Duijvestein, 1998)				
PROCEDURE **the instrument involves:**	1. Inventory	2. Analysis	3. Maximization	4. Optimization	5. Integration
STRATEGY **the procedure aims for:**	Research for Design: Describing & Classifying	Research about Design: Modeling & Interpreting	Research by Design: Framing & Systemizing	Research by Design: Evaluating & Diagnosing	Research by Design: Projecting & Testing
METHOD **the strategy focuses:**	Specifying the points in order to outline the problems	Studying the problems in order to outline the potentials	Centralizing the potentials in order to outline the proposals	Refining the proposals in order to outline the principles	Applying the principles in order to outline the plans
APPROACH **the method works with:**	Attribute mapping: data & statistics, municipal documents, fieldwork	Opportunity establishing: historical landscape biography, archive documents, fieldwork	Criteria building: Operational standards, concept brainstorming, strategy map	Interaction comparing: Map overlays, scoring, vision schemes and diagrams	Design implementing: Plans, sections, details, impressions, drawings
SUB QUESTION **the approach answers:**	sub question 1	sub question 2	sub question 3	sub question 3	sub question 3

This chapter presents the design experiment by following the method as described in the previous section. It starts with the inventory (3.1) which outlines the infrastructure problems of the city and therefore covers sub-question 1. It continues with the analysis (3.2) which outlines the infrastructure potentials of the Ruien and therefore covers sub-question 2. What follows are the maximization (3.3) which outlines the proposals, the optimization (3.4) which outlines the principles, and the integration (4.4) which outlines the plans. Together they cover sub-question 3.

experiment 3




inventory

3.1

The inventory phase of the method responds to the first sub-question of the research. Sub-question 1 asks: what is the context of the future urgencies regarding environmental and social infrastructure in Antwerp? Answering the question gives insight into the infrastructure problems of the city. It specifically involves describing and classifying the city's green, blue, place, and memory infrastructure problems by mapping the attributes of the themes. Essentially, the themes/points are specified in order to outline the problems.

3.1.1 A review of the existing green, blue, place, and memory infrastructure systems of Antwerp provides initial information.
3.1.2 Then, an inventory per theme, based on data, statistics, municipal documents, and fieldwork, outlines the problems.

3.1.1 existing infrastructure

Green system

The green infrastructure system of Antwerp (figure 3.1.1.1) is made up of a range of different types of natural surface cover: forested areas, street trees, and other green like planted patches and shrubbed areas. An example of a forested area is Het Rot. An example of street trees is the recently renovated Langeridderstraat according to Antwerp's Garden Street Policy. This policy aims to add more shallow depth greenery to the street profiles of the city and at the same time offer pedestrians and residents a pleasurable place to spend time (place infrastructure). For ecosystem services, these altogether act as eco-capillaries, projections of vegetation that link larger eco-complexes for the passage of flora and fauna groups. The ecosystem complexes include recognized nature areas at the municipal scale (Stad Antwerpen habitat) and at the regional scale (Natura 2000 habitat). An example of other greenery is the Stadspark which is also functions as a public space (place infrastructure) and as a water reservoir (blue infrastructure) (figure 3.1.1.2).

>> **FIGURE 3.1.1.1:** The existing green system of the inner city of Antwerp (adapted from Stad Antwerpen, 2013).

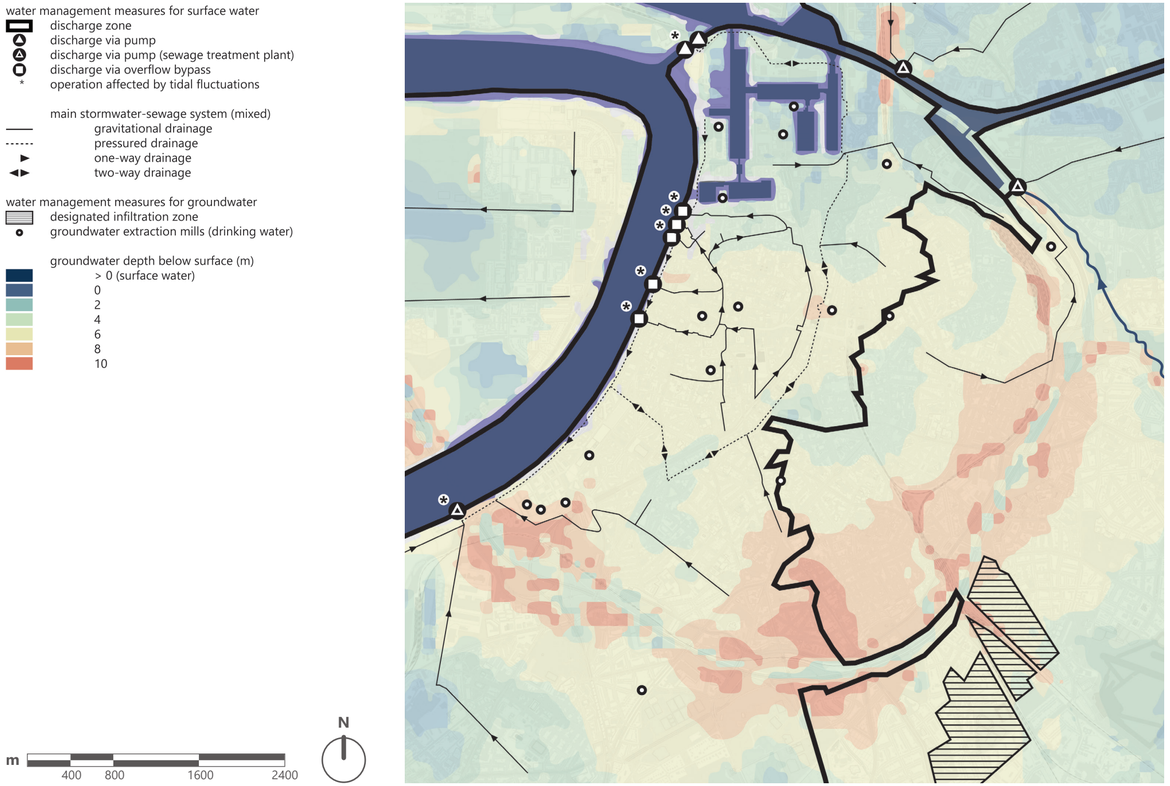
^ **FIGURE 3.1.1.2:** (Top) Het Rot, a typical forest area (Agentschap Natuur & Bos, n.d.). (Middle) A Garden Street, an policy effort for street greenery (Antwerpen Morgen, 2021c). (Bottom) Stadspark, green with a recreational function (Orrling, 2013).

Blue system

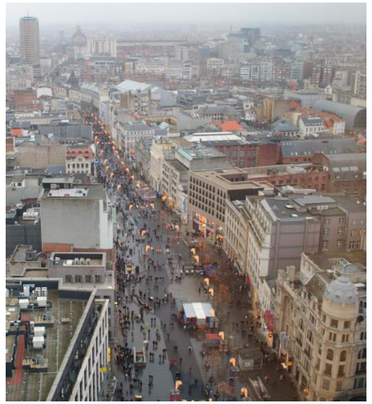
The blue infrastructure system of Antwerp (figure 3.1.1.3) is made up of water management measures for surface water and groundwater. A mixed stormwater-sewage water system with strategically located pumps, overflows, and gravitational or pressure drainage pipes ensures discharge of excess water to surface water. An example of a pump is the Royerssluis Pomp which works during heavy rainfall events to ease the pressure on the sewage system. An example of a pressure drainage pipe is the Scheldekaai Collector that collects all sewage water from the city center and transports it to a treatment plant or to a surface water pump. A series of drinking water mills and infiltration zones ensure a circular groundwater flow. An example of an infiltration zone is Het Prieel in which strict rules are set in place for the use of the space, such as restrictions on dog walking (figure 3.1.1.4).

>> **FIGURE 3.1.1.3:** The existing blue system of the inner city of Antwerp (adapted from Geopunt Vlaanderen, 2013, Water-link, 2017, Stad Antwerpen, 2019).

^ **FIGURE 3.1.1.4:** (Top) A new pump (Royerssluis) to relief the load on the sewer system ((Water-link, 2019). (Middle) The pressured sewer collector pipe underneath the Scheldt Riverfront (Denys, 2019). (Bottom) A rainwater infiltration area (Google, n.d.).



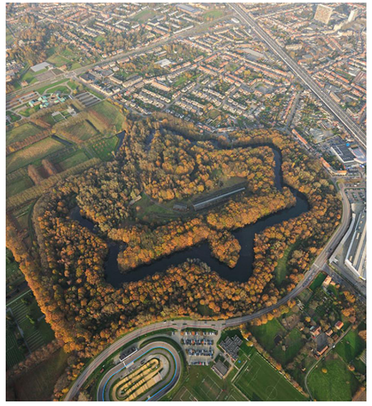
The place infrastructure system of Antwerp (figure 3.1.1.5) is made up of many different types of public spaces with the most extensive being squares and shopping streets. An example of a square is the Grote Markt with the city hall, the statue of Silvius Brabo, and a multitude of restaurant and cafe terraces/ patios. An example of a shopping street is the Meir Boulevard which is also the bussiest shopping street in Belgium. Most shopping streets extend through the historic city center. There are extensive plans for future public spaces in the city. An example is the Antwerp Ring Park in which the Ring Road will be covered by a landtunnel. Another example is the Scheldt Riverquay at which a riverfront promenade is planned (figure 3.1.1.6).

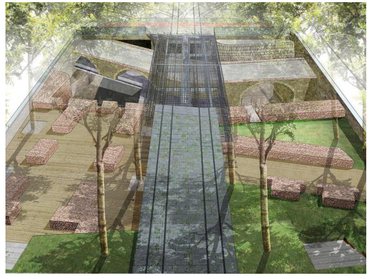


>> **FIGURE 3.1.1.5:** The existing place infrastructure of the inner city of Antwerp (adapted from Stad Antwerpen, 2013, Stad Antwerpen, 2020a).

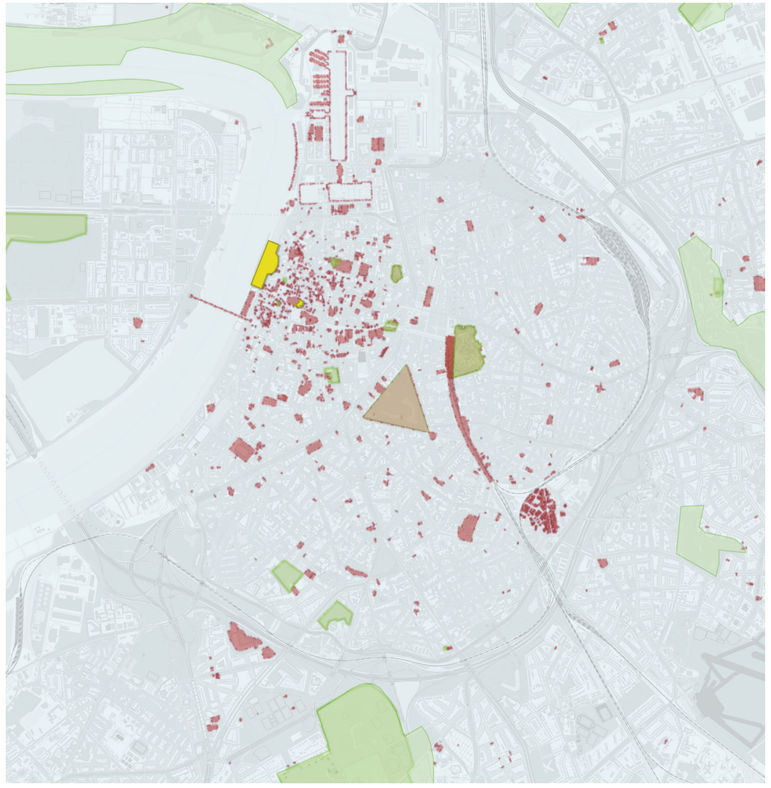
^ **FIGURE 3.1.1.6:** (Top) An impression of the newly planned Ring Park on the Antwerp Ring (PZC, 2021). (Middle) The Meir shopping boulevard, the busiest shopping street in Belgium (Smits, 2008). (Bottom) The Grote Markt with the city hall, statue of Silvius Brabo, and terraces of the many cafes and restaurants (KjkopStad, 2023).

The memory infrastructure system of Antwerp (figure 3.1.1.7) is made up of protected heritage in the form of architecture (buildings and other structures), landscapes (with cultural and historical tints), and archeology (underground structures and remnants). Many of the protected areas overlap but the largest asset of heritage is in the architecture category (figure 3.1.1.8). An example of architectural heritage is Het Steen, the former prison of the original stronghold of the city. It is now a tourist information center. An example of landscape heritage are the remnants of forts belonging to the Stelling of Antwerpen, constructed for defense during the Second World War. Many of the forts have educational purposes, specifically on topics related to history. An example of archeological heritage is the Kipdorpbrug, a medieval bridge, whose remnants have been incorporated into the public space and into a car tunnel.





protected heritage
- architecture (buildings & other structures)
- landscapes (culturally/historically tinted)
- archeology (underground structures & remnants)



>> **FIGURE 3.1.1.7:** The existing memory infrastructure of the inner city of Antwerp (adapted from Geopunt Vlaanderen, 2023, Stad Antwerpen, 2013).

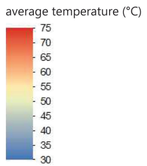
^ **FIGURE 3.1.1.8:** (Top) Het Steen, the remnants of the prison from the stronghold (Portfolio Onroerend Erfgoed, 2021). (Middle) Fort from the fort-ring Stelling van Antwerpen (Fortengordels, 2019). (Bottom) The archeological remnants of the Kipdorpbrug,incorporated into the public space (Antwerpen Morgen, 2019).

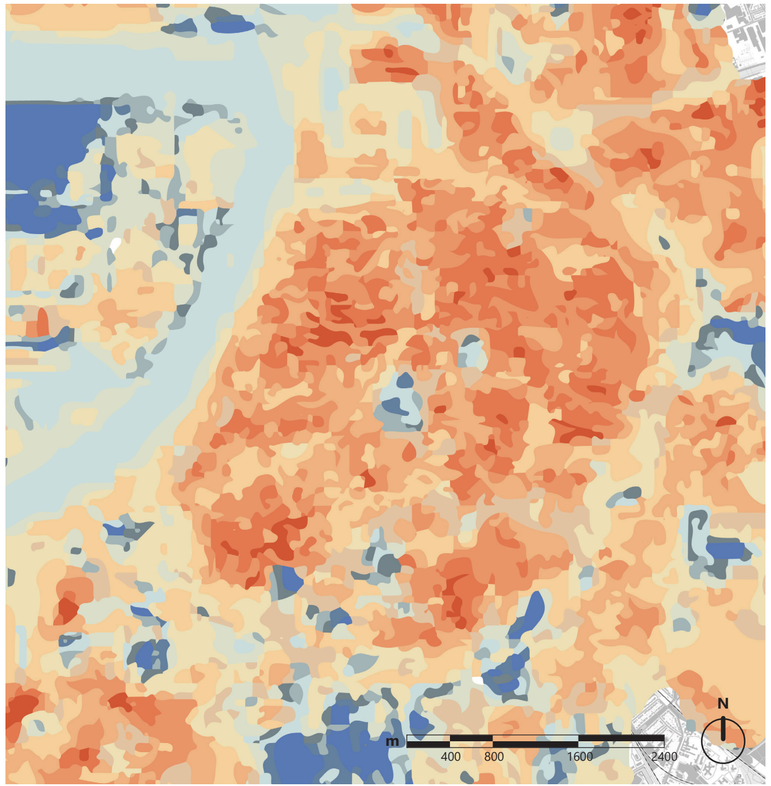
3.1.2 problems

An infrastructure problem in the city for the theme of green is heat stress and ecological struggle.

Heat stress is the urban vulnerability to high perceived temperatures (Urban green-blue grids, n.d.). It negatively impacts the health and wellness of humans. The heat stress map of Antwerp (figure 3.1.2.1) shows that there is a clear difference in the average heat stress intensity between the inner city and the outer city, divided by the Antwerp Ring. In the inner city, heat stress is more intense and occurs as scattered heat patches that reach up to 75 °C. In the outer city, heat stress is less intense and occurs more spread out with most highs reaching on average 65 °C. Examining this characteristic in the context of the existing green system of Antwerp (figure 3.1.1.1) gives an explanation. There is a notable difference in the density of forest area, street trees, and other green across the Antwerp Ring toward the inner city. The low density of these uncovered surfaces in proportion to the high density of covered surfaces decreases their overall cooling effects. Essentially, the existing green system does not provide enough relief for heat stress. The heat stress problem is the lack of exposed ground surface in the inner city.

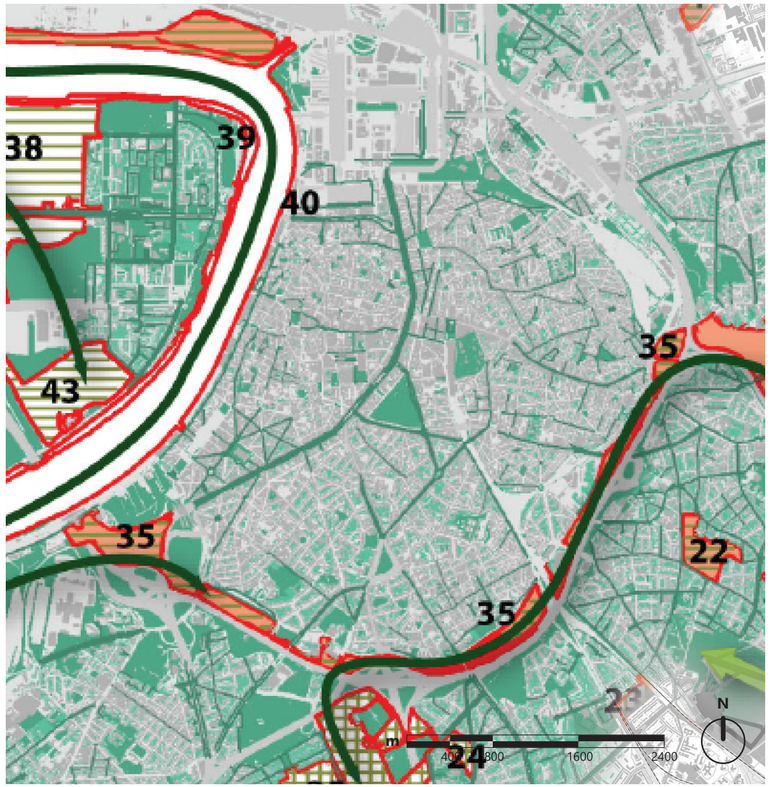
> **FIGURE 3.1.2.1:** The heat stress map of the inner city of Antwerp (adapted from Lauwaet et al., 2013).





Ecological struggle is the habitation hardships faced by living organisms (Kovalenko & Kovalenko, 2018). It negatively impacts the living potential of flora and fauna groups. The ecological struggle map of Antwerp (figure 3.1.2.2) shows that the hardships are a result of limitations related to area, maintenance, and human factors. Although these factors are most intense along the Antwerp Ring and in the outer city, they are compensated by the large density of interconnected eco-capillaries. In the inner city, however, while there are no limitations to ecology resulting from area, maintenance, and human factors, the connectivity of the eco-capillaries dwindles and drops drastically. Examining this characteristic in the context of the existing green system of Antwerp (figure 3.1.1.1) gives an explanation. There is a notable decrease in the connectivity of forest area, street trees, and other green across the Antwerp Ring toward the inner city. The lower connections decrease the possibility for habitation of flora and fauna. Essentially, the existing green system does not provide enough relief for ecological struggle. The ecological struggle problem is the low connection opportunities for flora and fauna in the inner city.

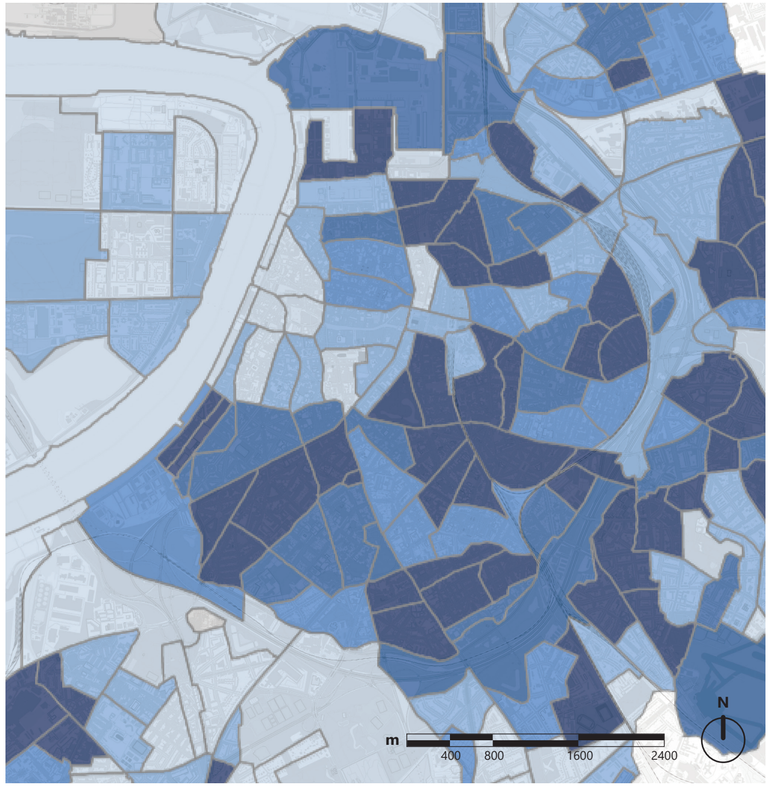
> **FIGURE 3.1.2.2:** The ecological struggle map of the inner city of Antwerp (adapted from Stad Antwerpen, 2013).



An infrastructure problem in the city for the theme of blue is flood risk and freshwater scarcity.

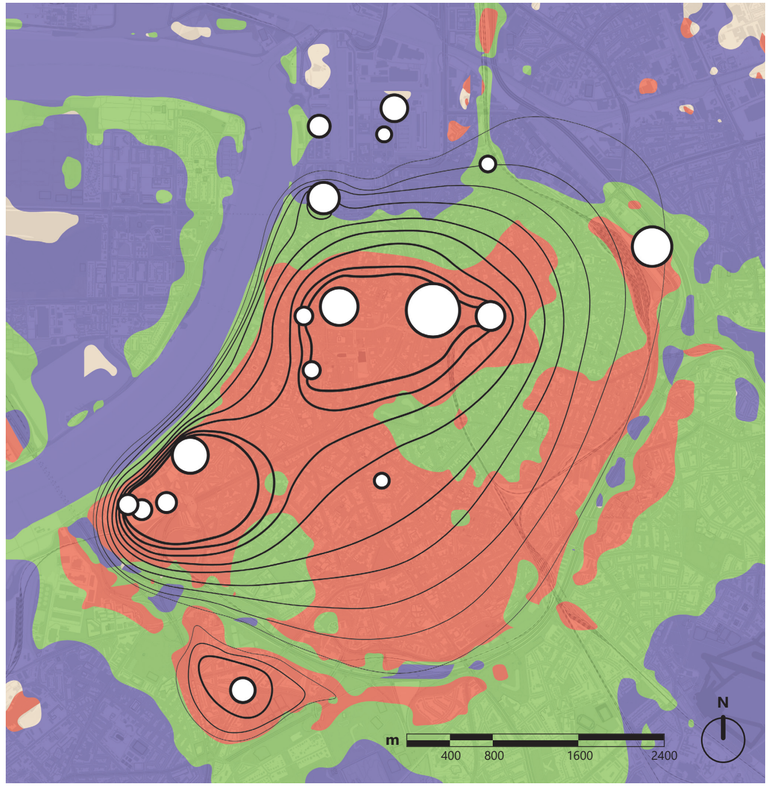
Flood risk is the urban vulnerability to flooding events from rivers (fluvial events) or storms (pluvial events) (State of New Jersey Department of Environmental Protection, n.d.). It negatively impacts the quality of life for humans. The flood risk map of Antwerp (figure 3.1.2.3) shows that a T20 (1 in 20 years) flooding event for a 2050 (future) scenario results in flood risk that occurs spread throughout the city. The neighborhoods with the highest percentage of flooded surface area are not concentrated in specific areas of the city but are scattered. Examining this characteristic in the context of the existing blue system of Antwerp (figure 3.1.1.3) gives an explanation. Although the main water drainage infrastructure extends across the city, it is a mixed system of stormwater and sewage water. The combined arrangement lowers the total volumetric capacity of the system forcing an increase in the discharge demands to surface water or groundwater. The discharge measures, however, are limited by the tidal fluctuations of the river and the minimal area for infiltration. The consequence is localized overflow of the drainage system onto streets. Essentially, the existing blue system does not provide enough relief for flood risk. The flood risk problem is the buffering of excess stormwater in the city.

> **FIGURE 3.1.2.3:** The flood risk map of the inner city of Antwerp (adapted from Stad Antwerpen, 2020b).



Freshwater scarcity is the lack of access to freshwater, usually sourced from groundwater or surface water (United Nations, n.d.). It negatively impacts the drinking water availability of cities. The freshwater scarcity map of Antwerp (figure 3.1.2.4) shows that subsidence of groundwater levels increases toward the inner city with a large area seeing levels subsiding to beyond 6 meters below the surface. In the outer city, beyond the Antwerp Ring, the subsidence decreases slowly from 3-6 meters to 1-3 meters. Examining this characteristic in the context of the existing blue system of Antwerp (figure 3.1.1.3) gives an explanation. On the one hand, the city's groundwater extraction pumps are located mainly inside the Antwerp Ring, in the inner city. On the other hand, the city's groundwater infiltration areas are located mainly outside the Antwerp Ring, in the outer city. Throughout the city, the groundwater levels are already quite low beneath the surface, between 4-10 meters and the Scheldt river is too saline to provide a fresh water source. Essentially, the existing blue system does not provide enough relief for freshwater scarcity. The freshwater scarcity problem is the replenishment of groundwater levels in the inner city.

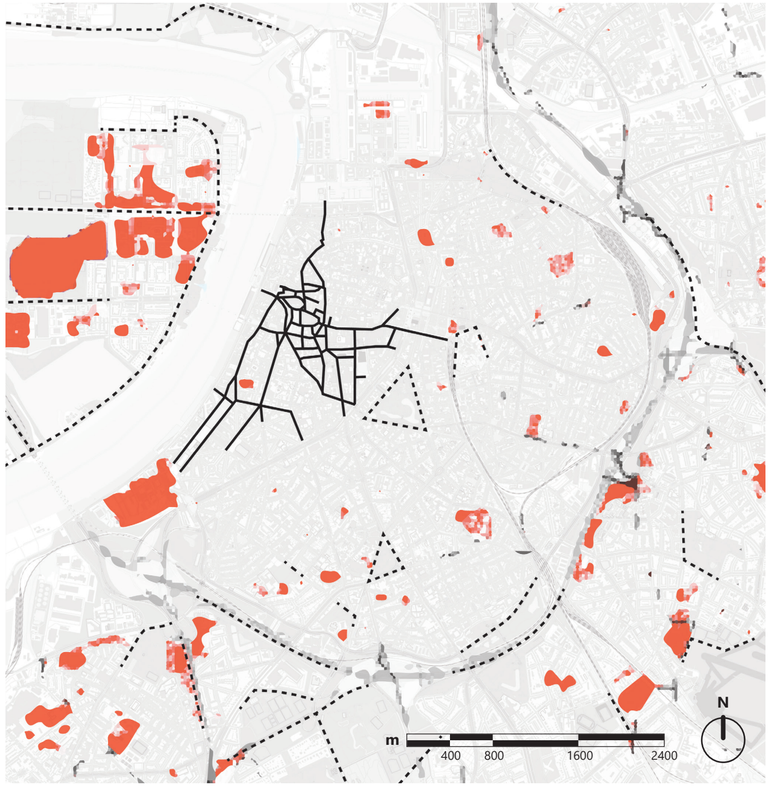
> **FIGURE 3.1.2.4:** The freshwater scarcity map of the inner city of Antwerp (adapted from Stad Antwerpen, 2019).



An infrastructure problem in the city for the theme of place is congestion strain and leisure deficiency.

Congestion strain is the urban vulnerability for reduced ease of access of urban places (Collins English Dictionary, 2023). It negatively impacts the usability of public spaces throughout a city. The congestion strain map of Antwerp (figure 3.1.2.5) shows that public space access is hindered by different types of barriers occurring in different concentrations throughout the city. While the barriers due to traffic and developmental pressures occur spread throughout the city, the barriers due to pedestrian pressures occur clustered in the medieval center, within the Leien Ring. Examining this characteristic in the context of the existing place system of Antwerp (figure 3.1.1.5) gives an explanation. Despite the high concentration of different public spaces in the medieval center, it is one of the only locations including shopping streets. Toward the Antwerp Ring and the outer city, the number of shopping streets decreases, and pedestrian barriers decrease as well. Essentially, the existing place system does not provide enough relief for congestion strain. The congestion strain problem is the walkability of the busy streets in the medieval city center.

> **FIGURE 3.1.2.5:** The congestion strain map of the inner city of Antwerp (adapted from Stad Antwerpen, 2012 and Stad Antwerpen, 2013).



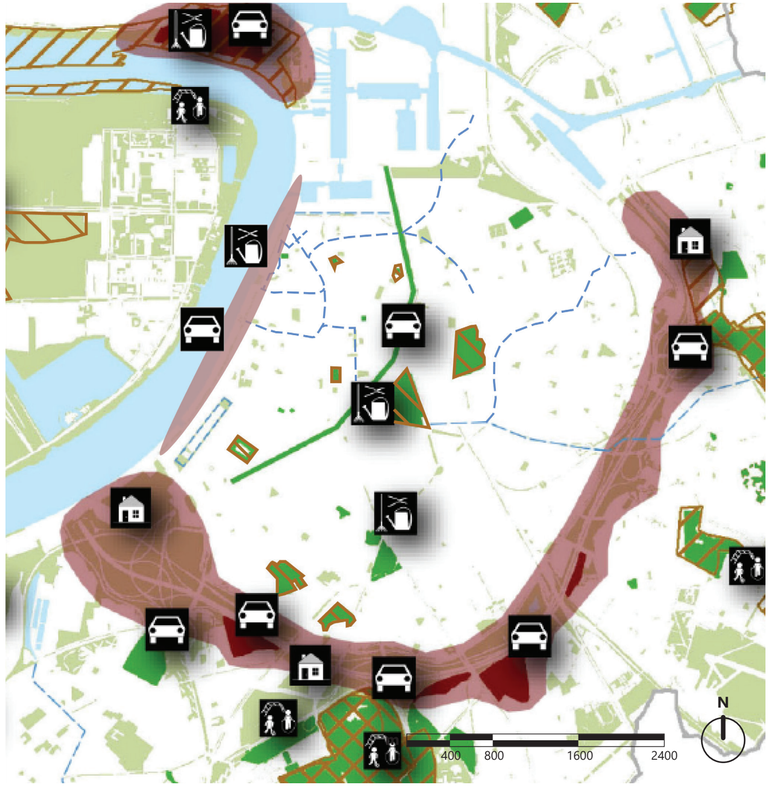
Leisure deficiency is the shortage in the number of places that offer free space to relax and unwind (The Encyclopedia of World Problems, 2023). It negatively impacts the livability of city neighborhoods. The leisure deficiency map of Antwerp (figure 3.1.2.6) shows that there are shortages of public space in terms of range standards (accessibility within 400 meters) and in terms of area standards (4 square meters per resident). Both range and area shortages are more extensive inside the Antwerp Ring than outside. Examining this characteristic in the context of the existing place system of Antwerp (figure 3.1.1.5) gives an explanation. Other than shopping streets, the public spaces in the inner city are relatively disconnected, scattered, and uniform in comparison to the public spaces in the outer city. Those are much larger, widespread, and diverse. Future public spaces, that compensate for the shortages, are planned on the Antwerp Ring and the Scheldt Quay where unused space is available. There are no plans in the inner city, likely due to the difficulties in finding extra space. Essentially, the existing place system does not provide enough relief for leisure deficiency. The leisure deficiency problem is the lack of room for additional public spaces in the inner city.

> **FIGURE 3.1.2.6:** The leisure deficiency map of the inner city of Antwerp (adapted from Stad Antwerpen, 2013).

An infrastructure problem in the city for the theme of memory is identity depreciation and heritage decline.

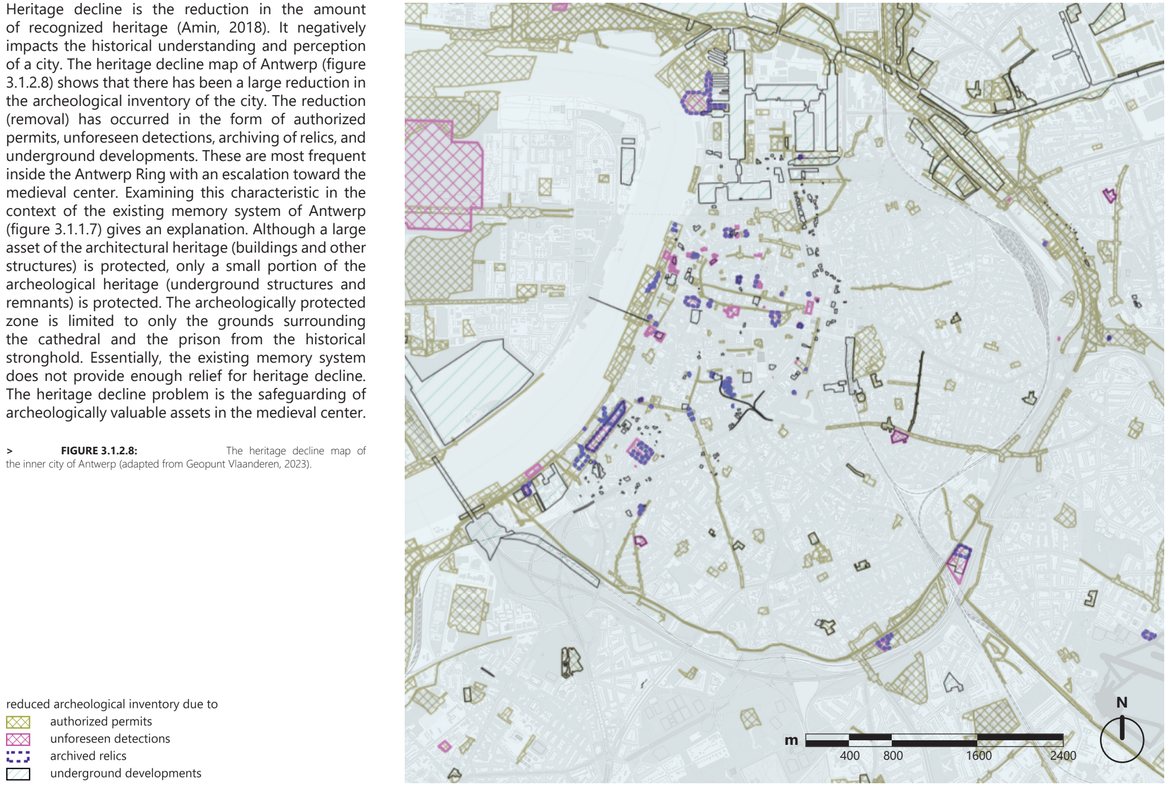
Identity depreciation is the urban vulnerability for the devaluation of the human-landscape relationship as developed over time (Cheshmehzangi, 2015). It negatively impacts the narrative and place attachment for residents of a city. The identity depreciation map of Antwerp (figure 3.1.2.7) shows that all currently remaining historically tinted landscapes are facing the various pressures that can lead to them becoming obscured (management, development, infrastructure, programmatic pressures). Although some are protected by their status as heritage or relic landscape, others are actively being obscured through being or having been suppressed or erased. The protected areas are spread throughout the city, but the unprotected landscapes are concentrated on the Antwerp Ring, the Scheldt Quay, and historic canals, essentially the inner city area. Examining this characteristic in the context of the existing memory system of Antwerp (figure 3.1.1.7) gives an explanation. While cultural landscapes are protected throughout the entire city, the inner city has an extra strong focus on the protection of buildings and other structures. Despite the abundance of historically tinted landscapes in the inner city, most attention seems to go to heritage in the form of architecture with less attention to obscured historical landscape heritage. Essentially, the existing memory system does not provide enough relief for identity depreciation. The identity depreciation problem is the blurring of culturally historically valuable landscapes in the inner city.

> **FIGURE 3.1.2.7:** The identity depreciation map of the inner city of Antwerp (adapted from Stad Antwerpen, 2013).



Heritage decline is the reduction in the amount of recognized heritage (Amin, 2018). It negatively impacts the historical understanding and perception of a city. The heritage decline map of Antwerp (figure 3.1.2.8) shows that there has been a large reduction in the archeological inventory of the city. The reduction (removal) has occurred in the form of authorized permits, unforeseen detections, archiving of relics, and underground developments. These are most frequent inside the Antwerp Ring with an escalation toward the medieval center. Examining this characteristic in the context of the existing memory system of Antwerp (figure 3.1.1.7) gives an explanation. Although a large asset of the architectural heritage (buildings and other structures) is protected, only a small portion of the archeological heritage (underground structures and remnants) is protected. The archeologically protected zone is limited to only the grounds surrounding the cathedral and the prison from the historical stronghold. Essentially, the existing memory system does not provide enough relief for heritage decline. The heritage decline problem is the safeguarding of archeologically valuable assets in the medieval center.

> **FIGURE 3.1.2.8:** The heritage decline map of the inner city of Antwerp (adapted from Geopunt Vlaanderen, 2023).



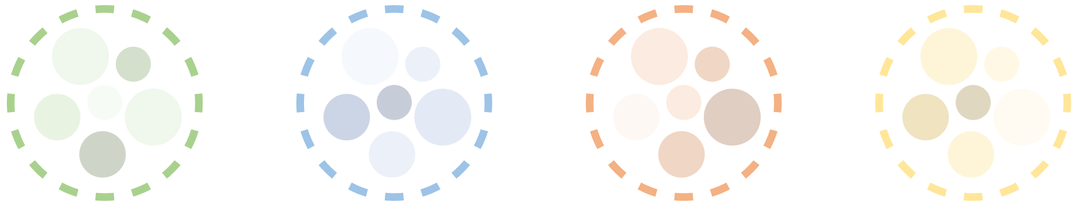
To conclude the inventory phase, and thereby answer sub-question 1 of the research, the overall findings are that:

For the theme of green, there are problems based on the lack of exposed ground surface and the low connection opportunities for flora and fauna.

For the theme of blue, there are problems based on the buffering of excess stormwater and the replenishment of groundwater levels.

For the theme of place, there are problems based on the busy streets and the lack of room for additional public spaces.

For the theme of memory, there are problems based on the blurring of culturally historically valuable landscapes and the safeguarding of archeologically valuable assets.



analysis

3.2

The analysis phase of the method responds to the second sub-question of the research. Sub-question 2 asks: what is the context of the decommissioned underground canal system in Antwerp? Answering the question gives insight into the infrastructure potentials of the canals. It specifically involves modelling and interpreting the canal's green, blue, place, and memory infrastructure potentials by establishing the opportunities for the problems. Essentially, the problems are studied in order to outline the potentials.

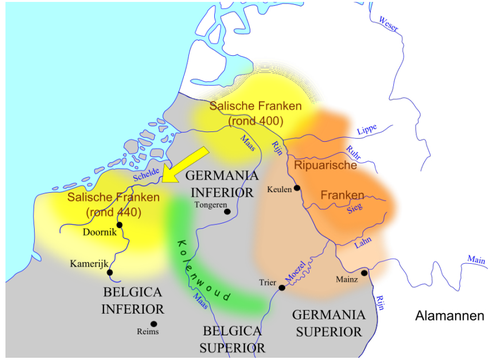
3.2.1 A review of the historic development of Antwerp and its canals provides initial information.
3.2.2 Then an analysis per theme, based on landscape biographies, archival documents, and fieldwork, outlines the potentials.

3.2.1 historic development

The Romans (-50 to 475)

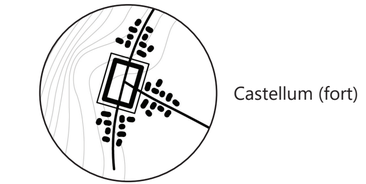
A settlement has existed at the location where Antwerp now sits since the age of the Roman Empire (figure 3.2.1.1). At around 50BC, along a land protrusion (aanwerp) on the banks of the meandering Scheldt River, the Roman army, on their way to conquer western Europe, established a navy harbor with a castellum (fort). A vicus (town) was established on nearby hills (figure 3.2.1.2). The Celtic tribes already living there were forced to integrate and take part in the battles with other tribes of the low-land region as well as the conquering of modern day England across the English Channel. At around 300AD, with increasing hostility from Frankish tribes in the northern low-lands, the Romans resituated themselves there along the Rhine River, the northern limits (Limes) of their empire.

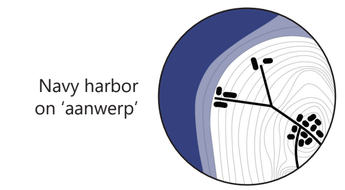
Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)

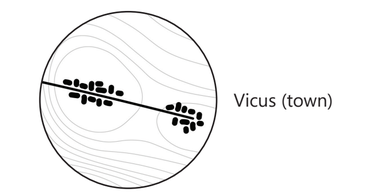


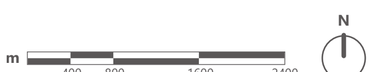
>> **FIGURE 3.2.1.1:** Antwerp between -50 and 475, during the period of the Romans (own work).

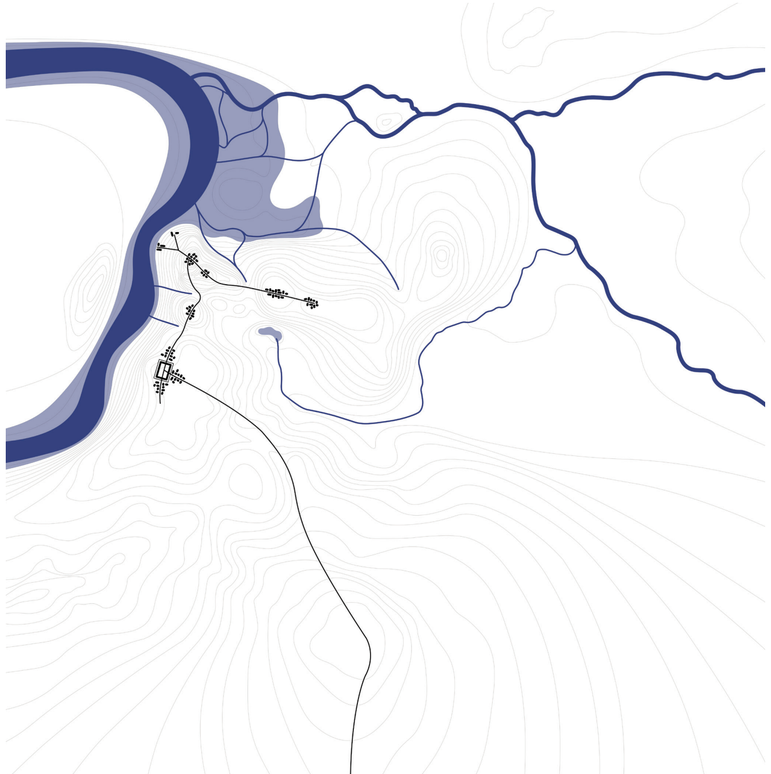
^ **FIGURE 3.2.1.2:** (Top) The Roman Castellum along the Scheldt River (Antwerpen Morgen, 2021). (Middle) A stone portraying the Roman conquest across the English Channel (Naval Encyclopedia, n.d.). (Bottom) The Frankish migration into modern day Belgium (Erren, 2013).









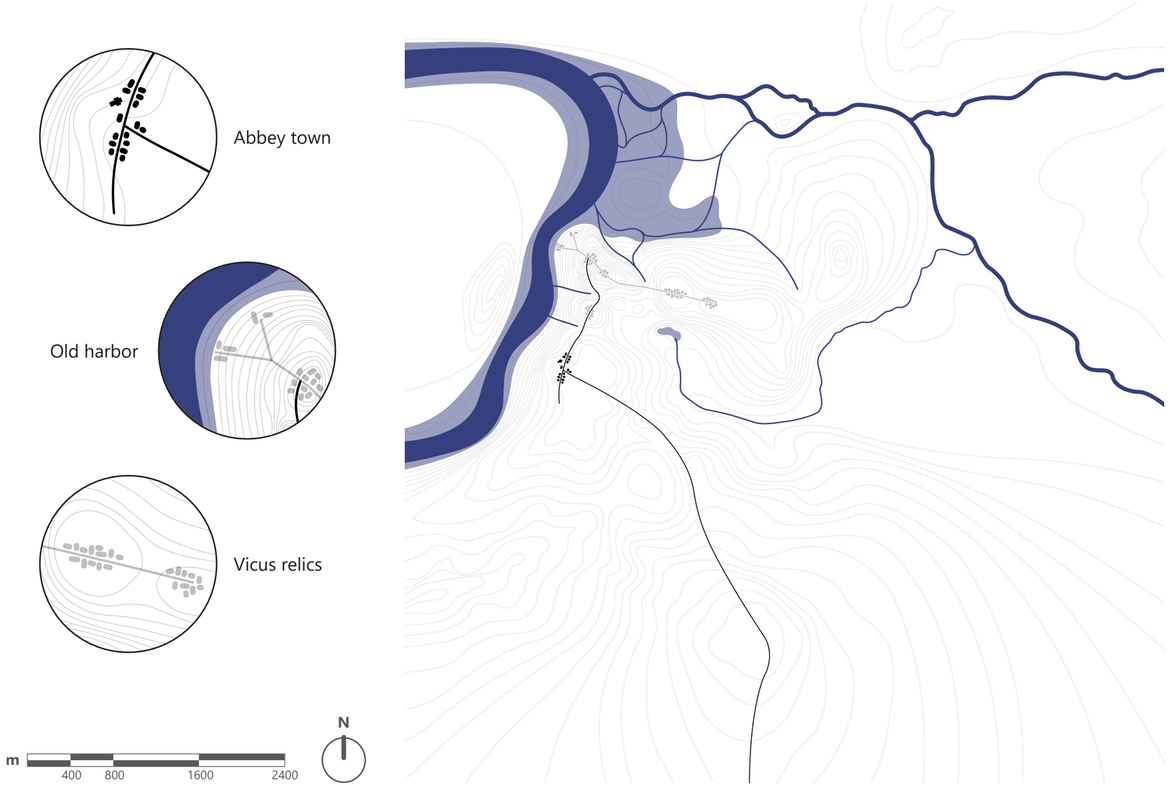


Nevertheless, between about 450 and 475, the Roman Empire collapsed and the low-land tribes were left to their fate. Altogether they moved southward into abandoned Roman territory: the Celtics migrated into modern day France and the Franks migrated into modern day Belgium. Other tribes, like the Saxons and Frisians migrated southward from northern Europe into modern day southern and northern Netherlands. In Antwerp, the Franks established a settlement with an abbey on the foundations of the old Roman castellum (figure 3.2.1.3). In 650, a bishop named Amandus arrived in Antwerp with the hopes of spreading Catholicism to the Franks (figure 3.2.1.4). With the Roman hostilities still fresh in their minds, however, as an outsider, he was received with aggression and forced to stay on a nearby hill called Caloes (modern day Kiel). Nevertheless, in 726 Amandus was able to establish two Catholic chapels that adjoined the Frankish abbey.

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)

>> **FIGURE 3.2.1.3:** Antwerp between 475 and 836, during the period of the Franks (own work).

^ **FIGURE 3.2.1.4:** (Top) The remnants of a Roman brick found in Antwerp (UAntwerpen, 2021a). (Right) The bishop Amandus who came to Antwerp (Bibliothèque Municipale de Valenciennes, n.d.). (Center) Amandus stayed in Caloes due to the hostilities of the people of Antwerp (Lauwens, 2021).



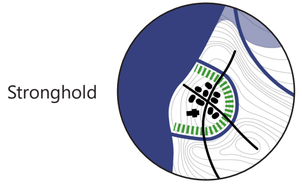
From the year 810 onward, a new tribe brought about aggression along the European coastlines: the Noormen (Vikings). With the dynamics brought by North Sea storms, the Vikings were increasingly able to sail land inward with their ships on the widening rivers. In 836, the Noormen pillaged Antwerp via the Oosterschelde and established a stronghold with earthen walls and and a small moat at the location of the old Roman harbor using material from the Frankish chapels and abbey as well as any remaining Roman relics (figure 3.2.1.5). Although the Franks tried to re-empower the area by re-building their Catholic institutions, between 888 and 891 the Saxons conquered the Noormen and, by making the region a Duchy of the Holy Roman Empire, brought Christian reign over the region instead. In 900, the Saxon dukes and duchesses strengthened the Viking stronghold by deepening the surrounding moat. This was to limit the hostilities by Frisian tribes who continued to move southward along the coastline. The Saxons eventually established a Christian church and abbey within the stronghold in 980, using material of the Catholic Frankish abbey (figure 3.2.1.6).

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)

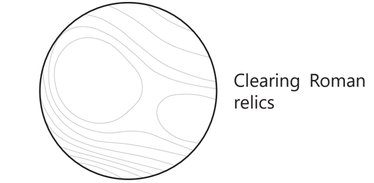
>> **FIGURE 3.2.1.5:** Antwerp between 836 and 1000, during the period of the Saxons (own work).

^ **FIGURE 3.2.1.6:** (Top left) A drawing of the stronghold as established by the Noormen (Leysen, 2003). (Top right) The migration of the Frisian tribe along the North Sea coast (Nicolay, 2014). (Bottom) An impression of the enhanced stronghold as built by the Saxons (Antwerpen Morgen, 2021b).

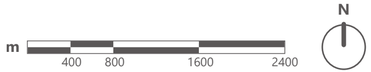
Town relics

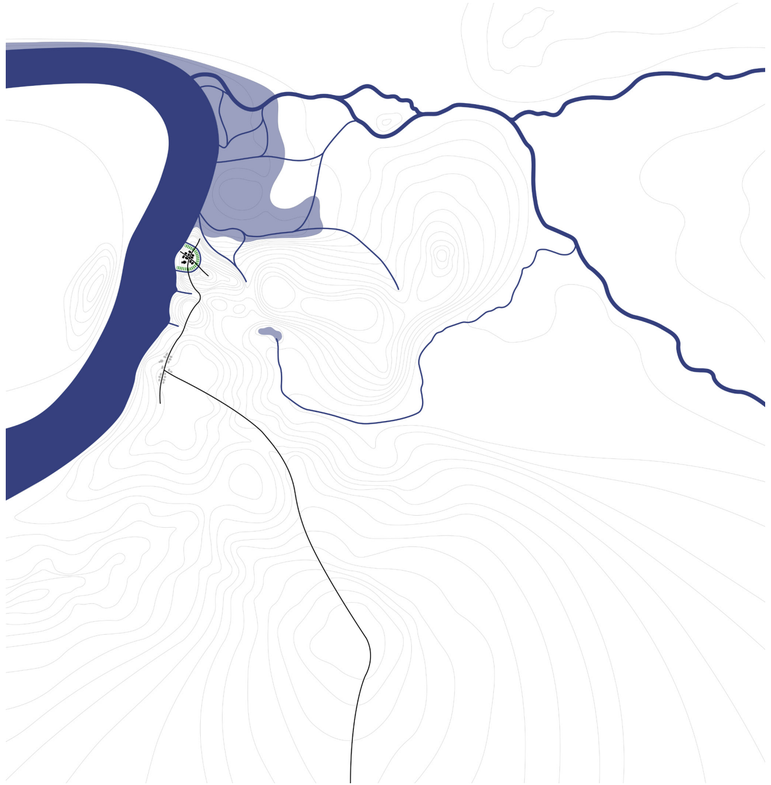


Stronghold



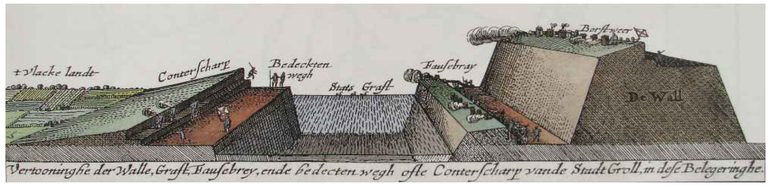
Clearing Roman relics





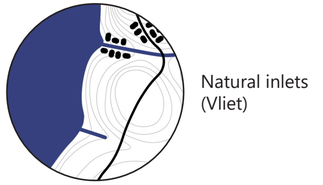
Due to the growing economic stance of Antwerp, between around 1000 and 1100 the settlement expanded to outside the stronghold (figure 3.2.1.7). To uphold Antwerp's military stance, the Saxons extended natural tidal inlets (Vlieten) along Scheldt River to form a triangular moat (Ruien) around the city. The Ruien Triangle was fed by a side arm of the Schijn River, the Falconbroek, a freshwater creek flowing from the hinterland. The stronghold itself was enhanced with a deepened ditch and an outer embankment (figure 3.2.1.8). While the main institutions, like the church, abbey, wharf, ducal residence, prison, tribunal, and knight-house, were in the stronghold, the economic institutions, like the fish, butter, sugar, bread, cheese, wine, livestock, and coal markets were in the Rui-triangle.

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)



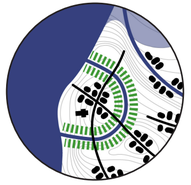
>> **FIGURE 3.2.1.7:** Antwerp between 1000 and 1100, during the period of the Ruien Triangle (own work).

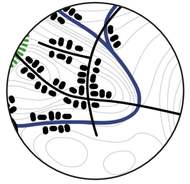
^ **FIGURE 3.2.1.8:** (Top) The Shijn River valley in the modern situation (Stadspark Antwerpen, n.d.). (Middle) A diagrammatic section of the fortification works surrounding the stronghold (Groenlo, 1627). (Bottom) The inner stronghold and its various institutions for the nobility that lived there (Antwerpen Morgen, 2020).



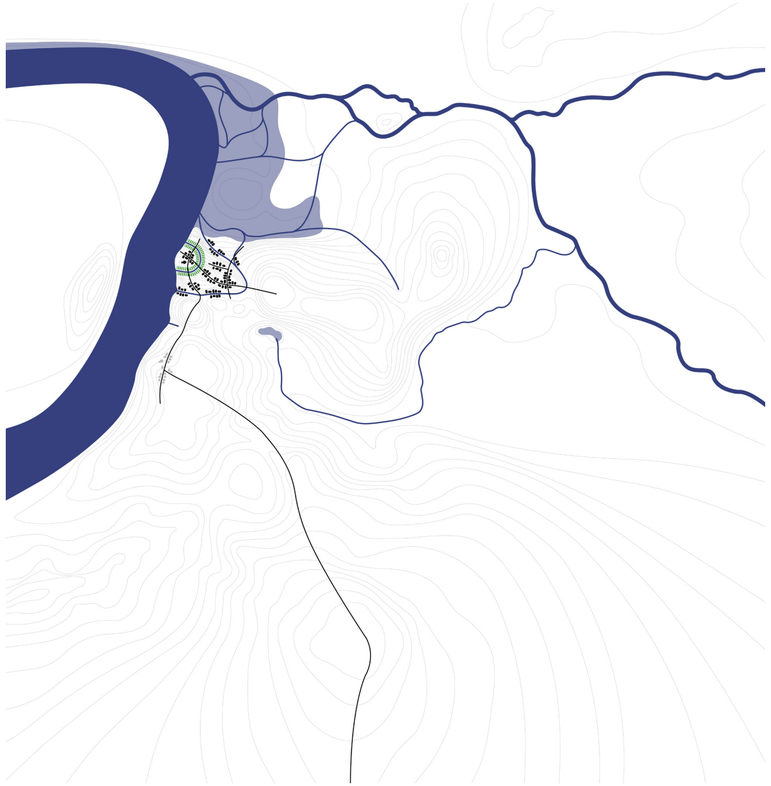
Natural inlets (Vliet)

Stronghold enhancements



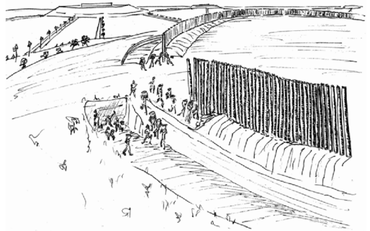


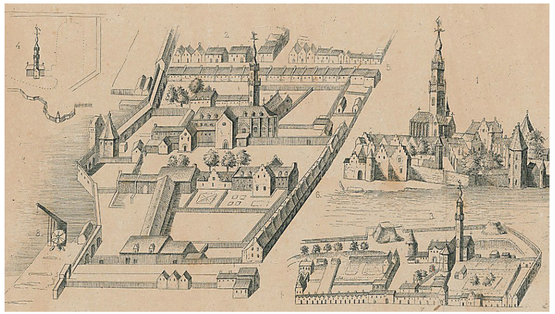
Moat triangle (Ruien)



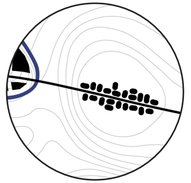
Between 1100 and 1200 changing dynamics of the Scheldt due to continuing North Sea storms caused the ditch around the stronghold to silt up resulting in its earthen wall being strengthened with a palisade: a line of wooden poles (figure 3.2.1.9). With continued expansion, new settlement cores were established outside the triangular Ruien. The village of Klapdorp was a settlement of livestock farmers that used the adjacent floodplain of the Falconbroek, called the Driesch, as seasonal grazing land. The village of Kipdorp was a settlement along a topographical ridge that led toward the croplands in the hinterland. A political shift in 1183 that formed the Duchy of Brabant brought about more demographic shifts. As a result, two more settlements emerged outside the city limits, each with a chapel from the main church in the stronghold. The chapel of Our Dear Lady was established on a small hill and quickly grew to become the new main church. The chapel of Sint Michiel was established on the ruins of the Frankish abbey and quickly grew to become the new main abbey (figure 3.2.1.10).

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)

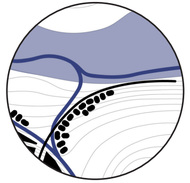




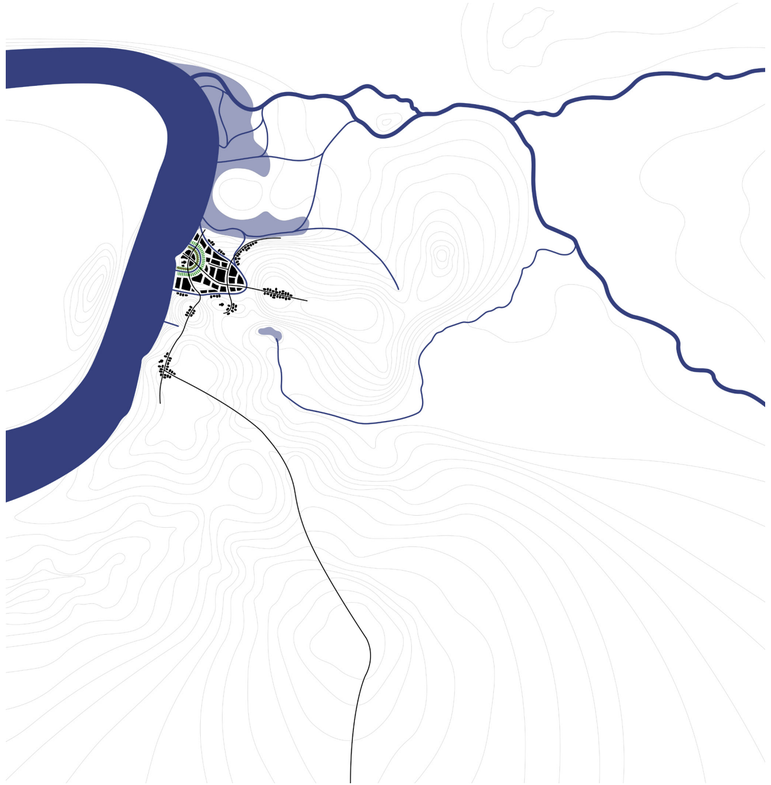
Town at Our Dear Lady church



Kipdorp town on ridge-line



Klapdorp town at Falconbroek and Driesch



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>> **FIGURE 3.2.1.9:** Antwerp between 1100 and 1200, during the period of the continued growth (own work).

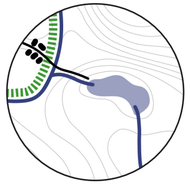
^ **FIGURE 3.2.1.10:** (Top left) The new Church of Our Dear Lady and its surrounding village (Dupré, 2020). (Top right) A drawing of a palisade wall (Erickson, 2010). (Bottom) The Sint Michielsabdij, built upon the foundations of the old Roman Castellum (Mertens, 1847).

In 1200 there was a need for enhanced fortification of the city, especially because the main religious institutions had relocated beyond the southern border of the defense line (figure 3.2.1.11). A new Rui was excavated using another Vliet from the Scheldt River. In this case, the Rui was fed by the Meir, a swampy fen-lake that, similar to the Driesch, acted as a flooding buffer for the creeks of the Schijn River. The Rui around the city was fitted with an earthen wall and a series of bridges that led to the outer villages of Klapdorp, Kipdorp, and Sint Michiel. The moat became a place for urban recreation and attracted residents for walks and other activities. The Meir became a place of folklore involving a mythical giant who was thought to live there and terrorize the city through the canals. On the northern border of the city, the earthen wall was substituted by natural defensive measures made possible by inundation of the Driesch floodplain. The stronghold was enhanced with a brick wall and defense towers (figure 3.2.1.12).

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)

>> **FIGURE 3.2.1.11:** Antwerp between 1200 and 1250, during the period of the first expansion (own work).

^ **FIGURE 3.2.1.12:** (Top) A historic map of the first expansion of Antwerp, showing the canals and the church (The Ruien Antwerp, n.d.). (Middle) An etch-drawing of the surround-city moat and a bridge across it toward the hinterland (FelixArchief, n.d.). (Bottom) An impression of the stronhold, enhanced with brick walls (FelixArchief, n.d.).



Rui moat fed by Meir Lake

Stronghold enhancements

Driesch floodplain used for defense

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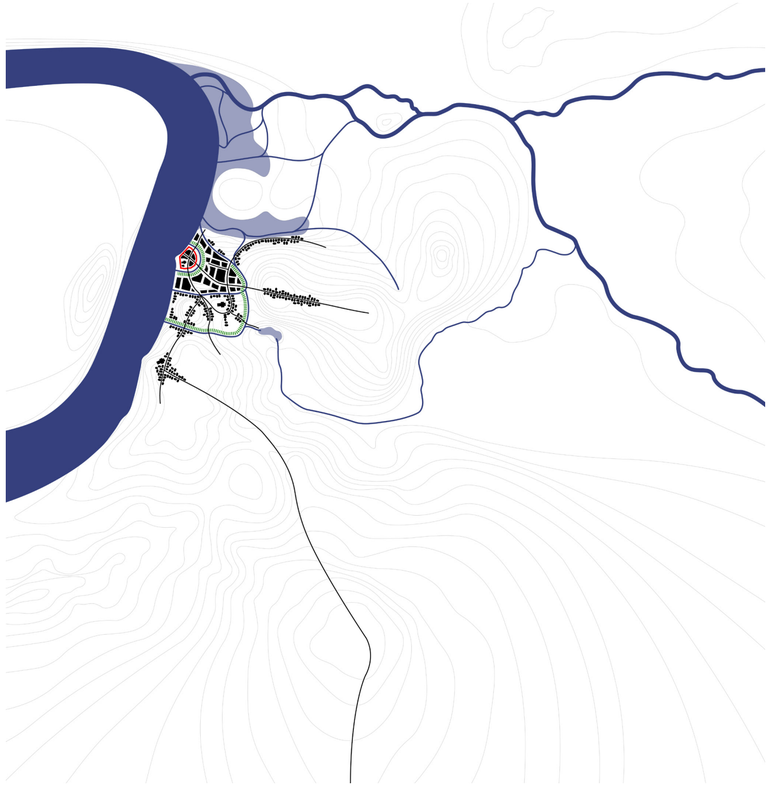
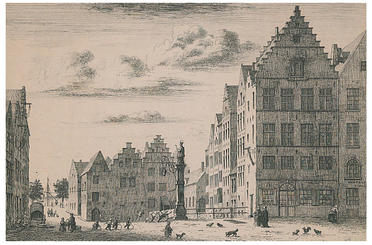


The Second Expansion (1250 to 1295)

In 1250 it became clear that the inundation function of the Driesch could not work together with the already existing livestock grazing function. Therefore, a new Rui was excavated using another Vliet from the Scheldt River. It was again fed by the Falconbroek and enclosed the part of the Driesch used for livestock within the city limits (figure 3.2.1.13). At the same time, the earthen wall on the southern defense line was upgraded to a brick wall with several city gates. With the defense function of a section of the original Ruien Triangle now redundant, it became an even busier trade and market artery. Additions to it include the weigh house, forum square, fruit, grain, peat, egg, wool, and milk markets. (figure 3.2.1.14) As a result of the military and economic prosperity, Antwerp continued to expand in population. The village of Klapdorp continued expanding along the Driesch floodplain and Falconbroek, establishing a horse market. The village of Kipdorp continued expanding along the topographic ridge establishing its own church. The Sint Michiel abbey grew to become a court-village for the nobility and, south of the Meir, a new hospice became a farmers-village for the hinterland.

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)

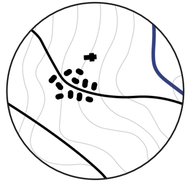


>> **FIGURE 3.2.1.13:** Antwerp between 1250 and 1295, during the period of the second expansion (own work).

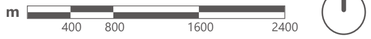
^ **FIGURE 3.2.1.14:** (Top) Three city gates that lined the enhanced defense line (FelixArchief, n.d.). (Middle) The Boterrui and Suikerrui (Butter and Sugar canal's) where butter and suggar was imported into the city from ships (FelixArchief, n.d.). (Bottom) The horse market at Klapdorp (Strecker, 2011).

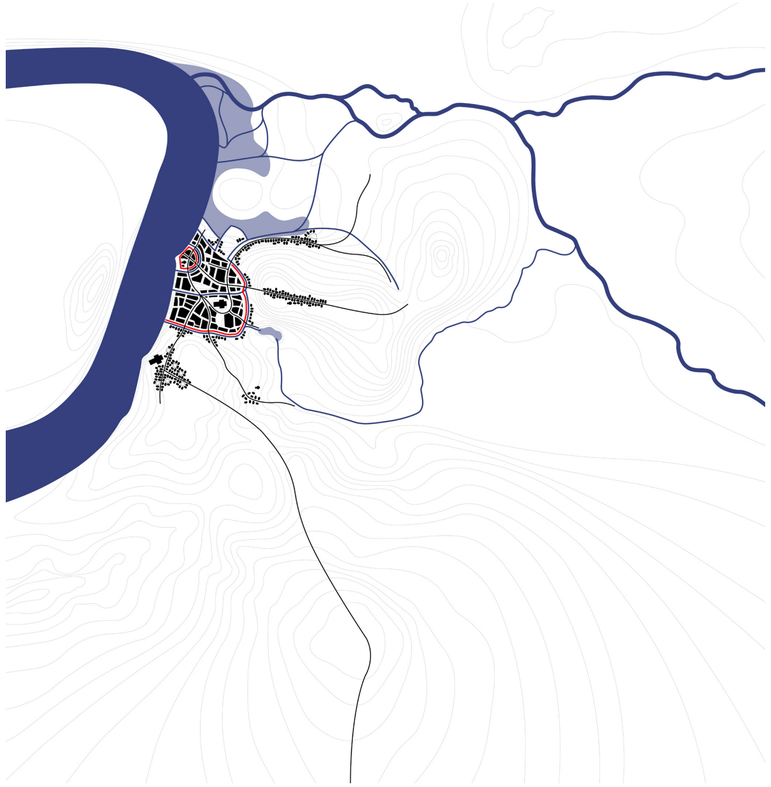
Rui moat fed by Meir Lake

Fortification enhancements



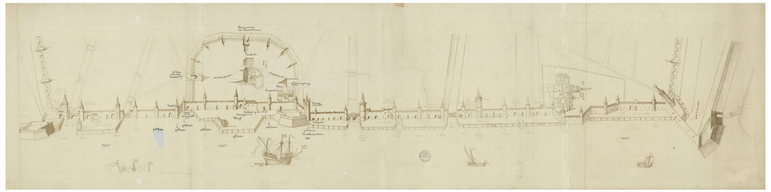
Farmers town with hospice

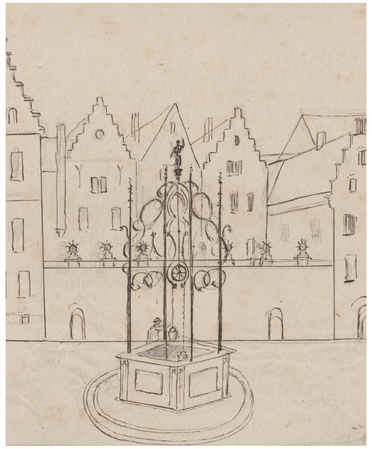




In 1295, the Duke of Brabant (Hertog Jan II) distanced his relations with the Count of Flanders (Graaf Dampierre). When the Duke of Holland (Graaf Floris V) unexpectedly extended his relations with Flanders, a joint Dutch-French invasion of Antwerp, from both the water and land sides, seemed inevitable. As a result, between 1295 and 1314, Antwerp again reinforced its fortification lines (figure 3.2.1.15). On the riverside, the fortification enhancements consisted of a brick wall stretching from the Sint Michiel abbey to the Falconbroek. To keep the wharves along the river accessible from the inner city, the wall had many gates. On the landside, the fortification enhancements consisted of a brick wall from the abbey to the hospice and of a Rui with earthen wall from the hospice to the horse market. The Driesch continued as an inundation defense fed by the Falconbroek. The earthen wall at the eastern defense line cut straight through Kipdorp and Klapdorp, placing their church and horse market, outside the city limits. The Meir became canalized and the city was fitted with various wells for the expanding beer industry (figure 3.2.1.16). The creek that fed the meir was integrated into the moat and was made extra wide so that it could act as a landside harbor (Vaartplaats), especially for grains and hops entering the city from the hinterland. The Vaartplaats also became a marketplace for products specific to the hinterland, such as bird, swine, and rabbit meat. This gave the market the name Vogeltjesmarkt (bird market) and Exotische Markt (exotic market) that it still holds today.

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)

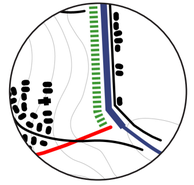




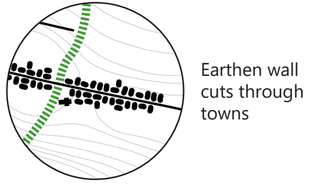
>> **FIGURE 3.2.1.15:** Antwerp between 1295 and 1314, during the period of the third expansion (own work).

^ **FIGURE 3.2.1.16:** (Top) The riverfront fortification of Antwerp, known as the Antwerp Rede (FelixArchief, n.d.). (Middle) The Oudevaartplaats and its historic market sometime after the Second World War (Unknown, n.d.). (Bottom) One of many city wells, decorated with an iron trellis and relgious symbolism (FelixArchief, n.d.).

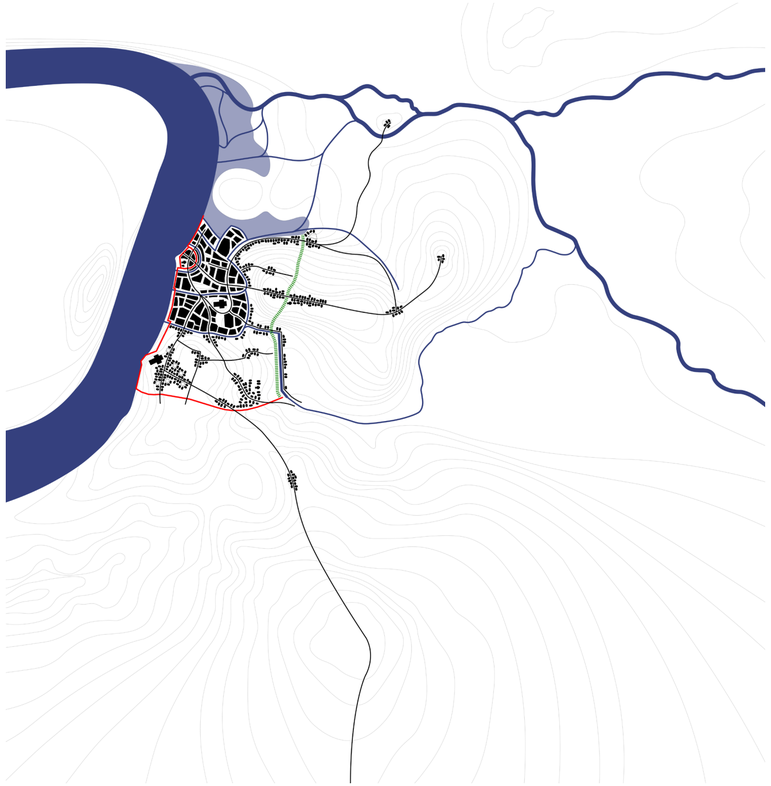
Riverside city wall with gates



Landside harbor for hinterland

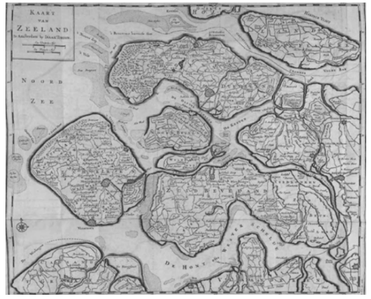


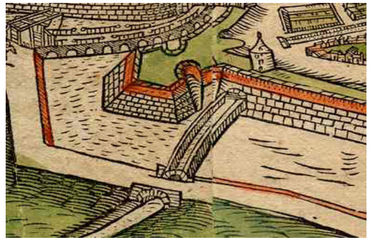
Earthen wall cuts through towns



Because of the inundation function of the northern defense line, the quantity of water available to the Vaartplaats and Meir was minimal. With the intensive water use, the creek that fed them often ran dry, becoming known as the Vuilrui (foul-rui). This flaw of the landside defense lines was a threat to the safety of the city. A lengthy period of renovations followed (figure 3.2.1.17). In 1314, the southern border was strengthened by adding an exceptionally wide Rui fed by brackish water from the Scheldt River. In 1410, the northern border was strengthened by discontinuing the inundation function and replacing it with a Rui that enclosed the entire Driesch within the city limits. Consequently, the eastern border was also strengthened: with less water demanded for inundation, more water was supplied for a new moat. To the pleasure of Kipdorp and Klapdorp, the new eastern Rui was shifted to contain the towns fully within the city limits. The defense line was enhanced with a brick wall, watchtowers, and city-gates. The old landside harbor, although enclosed within the city limits (and now known as the Oudevaartplaats), continued to function as a trading market for exotic products from the hinterland. In 1375, a storm flood closed the Oosterschelde and immensely shortened the distance of Antwerp to the North Sea. The stronger tidal fluctuations through the new Westerschelde brought increased amounts of brackish water into the city center, contaminating the production of beer in the city. The solution was to isolate the Ruien of the inner city from the Scheldt by means of sluice gates. Over time, however, the Ruien became contaminated with the buildup of urban wastes and other sewage, putting the city's beer brewers at a further disadvantage. The solution was to construct separate freshwater wells throughout the city but the leakage of contaminated canal water into the groundwater led to multiple outbreaks of disease. The Ruien were therefore fitted with thick quays and floors. Between 1491 and 1528 another solution was found by widening and deepening the hinterland creeks that flowed toward the city center so that an increased freshwater quantity was available within the Ruien. These canals include the Herentalsevaart on the Vuilrui and the Grote Vaart on the Falconbroek, both fed by the Schijn River. An extra canal, the Kleine Vaart, was excavated alongside the Grote Vaart to drain water from the Driesch floodplain to the Rui. Where the three canals entered the city, sluice-complexes inside fortification towers regulated the freshwater inflow (figure 3.2.1.18). Construction of additional sluice-gates further throughout the Ruien made it possible to build water pressure for washing out wastes and sewage to the Scheldt River at low tide.

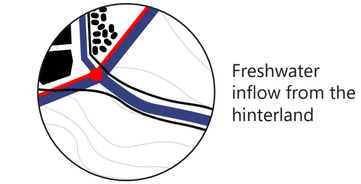
Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)



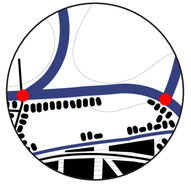


>> **FIGURE 3.2.1.17:** Antwerp between 1314 and 1542, during the period of the fourth expansion (own work).

^ **FIGURE 3.2.1.18:** (Left) A map showing the expanded size of the Westerschelde (Cruyningen et al., 2003). (Right top) The tower at Blauwtoreplein that regulated the inflow of freshwater from the Herentalsevaart (Antwerpen Doorgrond, n.d.). (Right bottom) An impression of an open sewer (Schouwenburg, 2022).

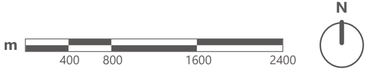


Freshwater inflow from the hinterland



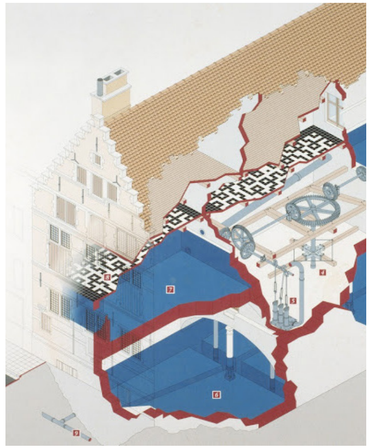
New canals to feed new Ruien

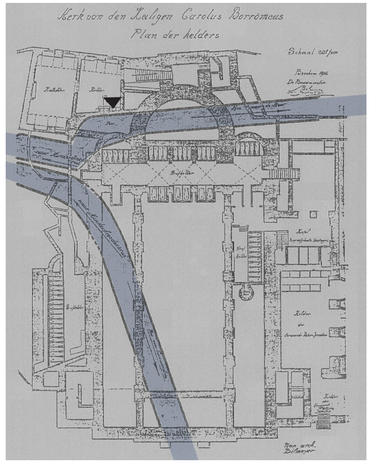
New moat partly fed by Scheldt River



The intensive use of freshwater for both beer brewing and sewage clearing caused the water levels in the new canals to decrease. To guarantee the export of beer and the protection against disease, a better solution was needed. The solution coincided with the Spanish takeover of Antwerp during the reformations between Catholicism and Christianity that would lead to the 80 Years' War. This event led to the construction of the Spanish Fortifications between 1542 and 1566 that moved the stronghold from the original core to the south (Citadel) and created a new neighborhood with Ruien specifically for beer brewers in the north (Nieuwstad) (figure 3.2.1.19). While the fortification Ruien continued to be fed by their original sources (south: Scheldt, east: Herentalsevaart, north: Grote/ Kleine Vaart), the Ruien of the Nieuwstad were fed by both a new canal excavated from the Schijn called the Dambruggevaart. The Dambruggevaart was excavated along the uphill side of an elevated country road from Antwerp to Dambrugge through the Schijn estuary. It was fed by both an existing creek flowing from uphill and a dam placed at the junction with the Schijn river. The freshwater inflow to the Nieuwstad was regulated by the Brewers House which distributed the water to all beer brewers. With this separate freshwater inflow exclusively for beer brewing, the open sewers in the rest of the city had a renewed supply of water to help in flushing the build up of wastes into the river (figure 3.2.1.20). The Spanish occupation also resulted in the Protestant Reformation which included the Great Iconoclasm. As a consequence, many Catholic churches were desperate to hide their religious possessions. Some, like the Sint-Carolus Borromeuskerk, went as far as covering a section of the Ruien to build a secret escape passage from the crypts of the church.

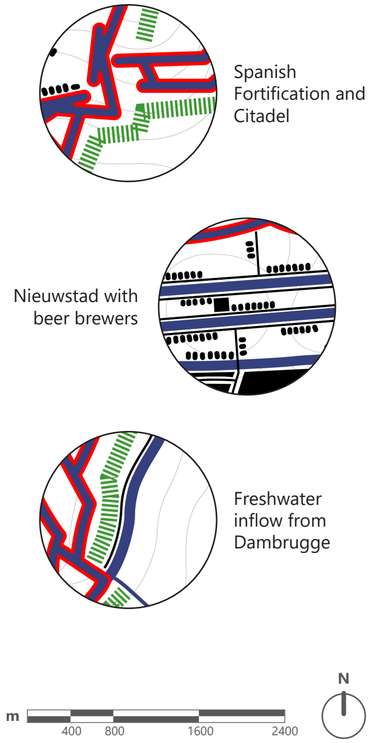
Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)





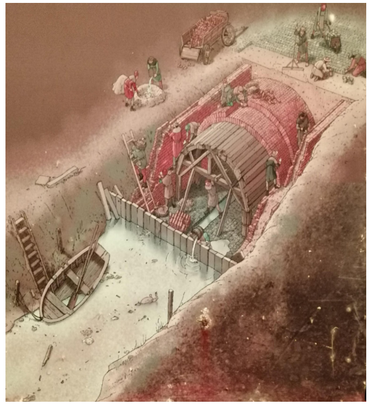
>> **FIGURE 3.2.1.19:** Antwerp between 1542 and 1792, during the period of the Spanish occupation (own work).

^ **FIGURE 3.2.1.20:** (Left top) Antwerp during the Spanish occupation (Antwerpen Doorgrond, n.d.). (Left bottom) The Brouwershuis (Brew House) which regulated the freshwater inflow for the beer brewers of the city (Brouwershuis Antwerpen, n.d.). (Right) A plan of the crypts of the Sint Carolus Borromeuskerk with its secret passage (FelixArchief, n.d.).



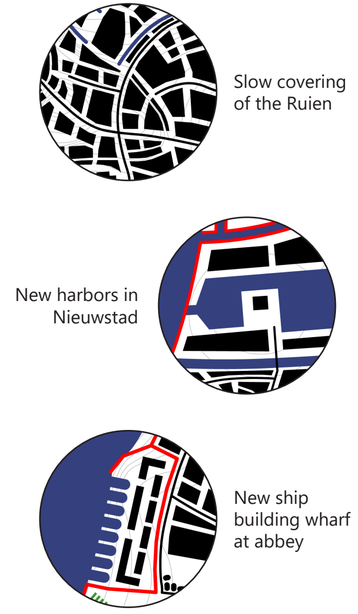
The prosperity of the city, which had given it an extensive Golden Age, ultimately dwindled when Dutch rebels were unable to re-seize the city from the Spanish. The blocking of the Scheldt River from the North Sea by their troops decreased the economic trade stance of the city and up to half of the population moved away. Only in 1792, when French revolutionary troops led by Napoleon conquered the city, was the Scheldt reopened to the North Sea. The French occupation, however, continued to make Antwerp unattractive for a renewed urban expansion (figure 3.2.1.21). Any new residents that did come to the city settled in new housing blocks built on top of covered sections of the inner city Ruien. The covering of the Ruien was initiated for hygienic reasons and the rising spread of disease from the open sewers. Tall chimneys were built on the covered Ruien to ventilate and burn away the underground build up of toxic gases. Because the covering resulted in the loss of inner city mooring places for ships, Napoleon renovated the Ruien in the Nieuwstad and replaced them with two large docks: the Bonapartedok, and the Willemdok. With these massive interventions, Antwerp was to become the visual embodiment of the French revolution across Europe. The Napoleonic Wars transformed Antwerp into a war port. In order to build a fleet of warships for battles with English troops, Napoleon demolished the Sint Michiel abbey to construct an expansive shipbuilding wharf along the riverfront (figure 3.2.1.22).

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)



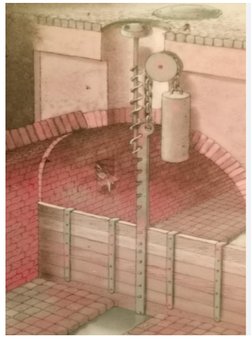
>> **FIGURE 3.2.1.21:** Antwerp between 1792 and 1814, during the period of the French occupation (own work).

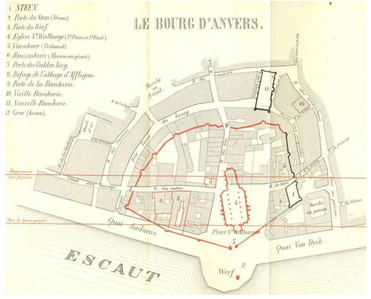
^ **FIGURE 3.2.1.22:** (Top) A diagram showing how the open sewers of the city were covered with vaulted tunnels (The Ruien Antwerp, n.d.). (Middle) A photograph of a ventilation shaft built on top of the enclosed tunnels (FelixArchief, n.d.). (Bottom) The Napoleonic ship building wharf at the site of the Sint Michiel abbey (Antwerpen Doorgrond, n.d.).



In 1814, with the downfall of Napoleon and the uprise of the Industrial Revolution, Antwerp was able to regrow as an important trade center in Europe. New demographic shifts again increased the population of the city beyond its limits (figure 3.2.1.23). The Grote Omwalling, completed in 1859, took the function as new city defense line. Its moat was fed directly by the Schijn River and even consisted of the incorporation of the downstream segment of it. The old Spanish Fortification was demolished and replaced by a ring-road (Leien Ring). The moat was enclosed in a rectangular concrete tunnel. A bastion of the defense line as well as the mouth of the Herentalsevaart were transformed into a central park for the city (Stadspark). Also during this time, the covering and renovation of the Ruien to an underground sewer system, as instigated by Napoleon, was also completed. The old sluices were modernized to vertical moving gates that could be lowered by rotating a winch at street level. With new innovations to trade and shipping, in order to maintain Antwerp's European harbor status, in 1875, the Scheldt River had to be widened and deepened. As a consequence, the riverfront was straightened, warehouses were constructed, and the docks expanded. The original land protrusions (aanwerpen) where Antwerp originated in the Roman and Viking ages disappeared completely. Only the prison from the Saxon stronghold (het Steen) remained and was converted into a tourist center in 1890. With the addition of a railway line into the city center, the number of tourist visitors increased greatly (figure 3.2.1.24).

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)





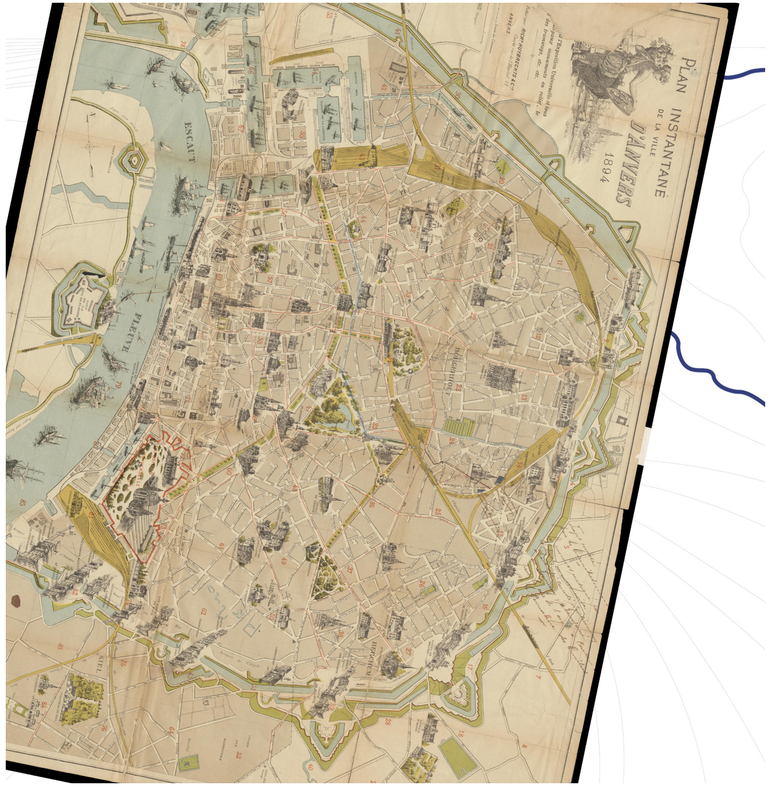
>> **FIGURE 3.2.1.23:** Antwerp between 1814 and 1900, during the period of the touristic surge (Baedeker, 1905).

^ **FIGURE 3.2.1.24:** (Top left) A diagram of a sluice-gate that regulated the sewer water and (top right) the mechanism that controlled (FelixArchief, n.d.). (Bottom left) The straightening of the riverfront which cut away the original 'aanwerp' (Antwerpen Doorgrond, n.d.). (Bottom right) A photograph of the construction of the tunnel (FelixArchief, n.d.).

Grote Omwalling

Leien Ring Road

Straightening of riverfront



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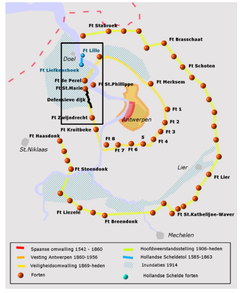
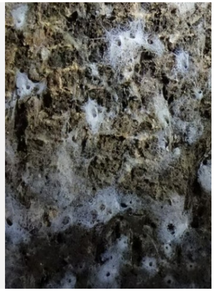
The tourist attraction to Antwerp continued into the 1900s. The covered Ruien, with stories of mythical giants and other monsters roaming the tunnels, appealed to many tourists. Once in a while, boat rides were offered to those who dared to enter the mysterious and cryptic world beneath the city. However, the sewer system that was there made it dangerous for visitors. Workers who cleaned out the tunnels sometimes died from breathing in the toxic gasses. Over time, the Ruien were closed to visitoris and it was slowly forgotten from the collective memory of Antwerp. With the decreased human visits and the sewer system triggering a periodic wet and dry cycle, various flora and fauna species made the underground tunnels their habitat. The species include spiders, rats, bats, woodlouce, insects, fungi, and drainflies. Despite the closure of the Ruien, the increased economic prosperity with other tourist attractions, especially in the medieval historic core, once more attracted an increased population and expansion of the city (figure 3.2.1.25). Because of this, the Grote Omwalling lost its defense function and was transformed into another ring-road for the city (Antwerp Ring). This, along with the innovation of air-warfare, triggered the construction of two fort-rings of the Stelling van Antwerpen starting in 1900 (figure 3.2.1.26). With the onset of the First World War, new docks were constructed as well. What followed was a period of depression and the onset of the Second World War.

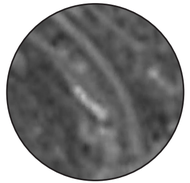
Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)



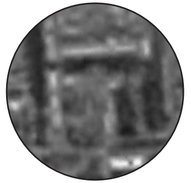


>> **FIGURE 3.2.1.25:** Antwerp between 1900 and 1945, during the period of the world wars (Google, 2023).

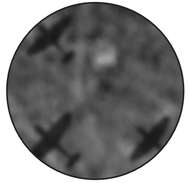
^ **FIGURE 3.2.1.26:** (Top) Tourist take a boat ride through the enclosed canals (FelixArchief, n.d.). (Bottom left) A map showing the two fort-rings of the Stelling van Antwerpen (Avontuurlijk Wandelen, n.d.). (Bottom right). Spiders, part of the tunnel ecosystem, make their home in the grouts between the bricks (FelixArchief, n.d.).



Antwerp Ring Road



New docks



Air invasion World War I

Explosive Growth (1945 to present day)

After the Second World War, many of the villages surrounding the outer defense line became annexed by the City of Antwerp (figure 3.2.1.27). Because of this, the Stelling van Antwerpen was decommissioned and new districts developed along the forts (Ekeren, Merksem, Deurne, Borgerhout, Mortsel, Berchem, Wilrijk, and Hoboken). The left shore of the Scheldt River, up until now only sparsely inhabited, became the city's post-war development district. It was connected to the medieval city via multiple tunnels, two of them excavated in extended trajectories of historic Ruien, resulting in their partial demolishing. The Ruien were renovated completely in 2001, finally isolating the sewer water into pipes fastened to the walls. The tunnel only has an emergency function: when the sewer pipes become overloaded with stormwater runoff during heavy rainfall, they will overflow into the tunnels. In that case, overflow installations ensure that excess water can flow into the tunnels (figure 3.2.1.28). Post-war flourishing continued and Antwerp's port became internationally recognized. This status brought with it a harbor expansion that made it one of the biggest ports in Europe. Overall, the historical evolution of Antwerp shows that it is a landscape driven by infrastructural needs. Time-period specific interventions lead to urban functions that have lasting effects. Form influences use and use influences meaning. These biographies perhaps have potential for future infrastructure developments in the city.

Sources: *(Binnemans et al., 1975)*
(Leysen, 2003)
(Voet et al., 1978)

>> **FIGURE 3.2.1.27:** Antwerp between 1945 and present day, during the period of explosive growth (Google, 2023).

^ **FIGURE 3.2.1.28:** (Top) The 1975 construction of the metro line required the demolishing of a section of tunnel at the Meir (FelixArchief, n.d.). (Middle) The western shore was developed as a post-war housing district (Studio Hartzema, 2018). (Bottom) In 2001, the sewer water was isolated into pipes installed with overflows (Aquafin, 2001).

Development of left riverside

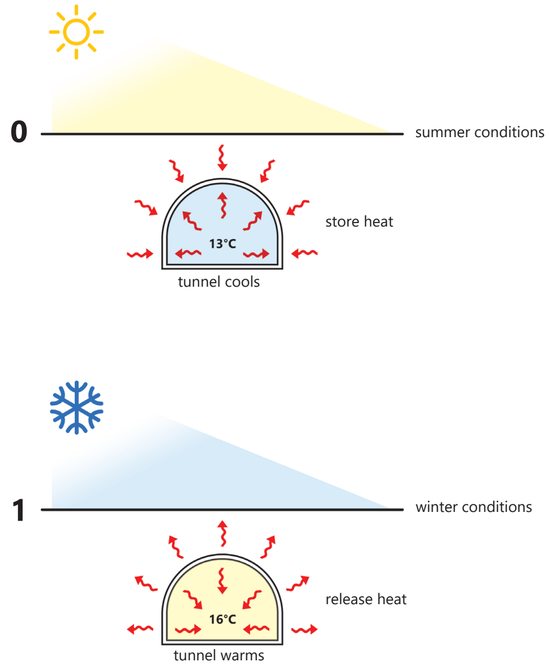
Old docks transformed

Hinterland towns annexed

3.2.2 potentials

An infrastructure potential in the tunnels for the theme of green, specifically for the relief of heat stress and the lack of exposed ground surface area (chapter 3.1), is its confined microclimate.

The Ruien has a confined microclimate in the form of a constant year-round temperature and humidity. The temperature is a direct consequence of the underground location of the tunnels and the thermal mass (heat storage capacity) of the structure (figure 3.2.2.1). During hot summers, the tunnels store excess heat captured by the heated surroundings. The result is that the tunnel's temperature cools. During cold winters, the tunnels release the heat back into the cooled surroundings. The result is that the tunnel's temperature warms. Overall, the temperature in the Ruien seasonally fluctuates between 13 °C in the summer and 16 °C in the winter. Both the summer and winter temperature are pleasurable in comparison to the outside temperature during the corresponding season. The conditions are especially pleasant in the summer since the tunnels also generate shadow. These conditions were once upon a time exposed to the city, making the Ruien a pleasant place for a city stroll (figure 3.2.2.2). Therefore, the confined microclimate of the tunnels has potential for relieving the heat stress problems of the city.

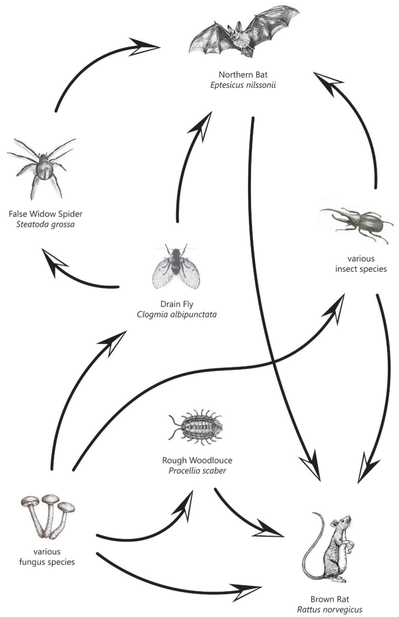


^ **FIGURE 3.2.2.1:** (0) During a warm summer day, as the soil heats, the structure of the underground tunnel absorbs the heat resulting in a cool temperature inside it, at around 13 degrees Celcius. (1) During a cold winter day, as the soil cools, the structure of the underground tunnel releases its stored heat resulting in a warm temperature inside it, at around 16 degrees Cellcius. Own work.

>> **FIGURE 3.2.2.2:** Once upon a time, the canals were fully exposed to the city allowing the water that flowed through it and the overgrowth that grew alonside it to form a pleasant microclimate for strolling and other activities of daily life (FelixArchief, n.d.).

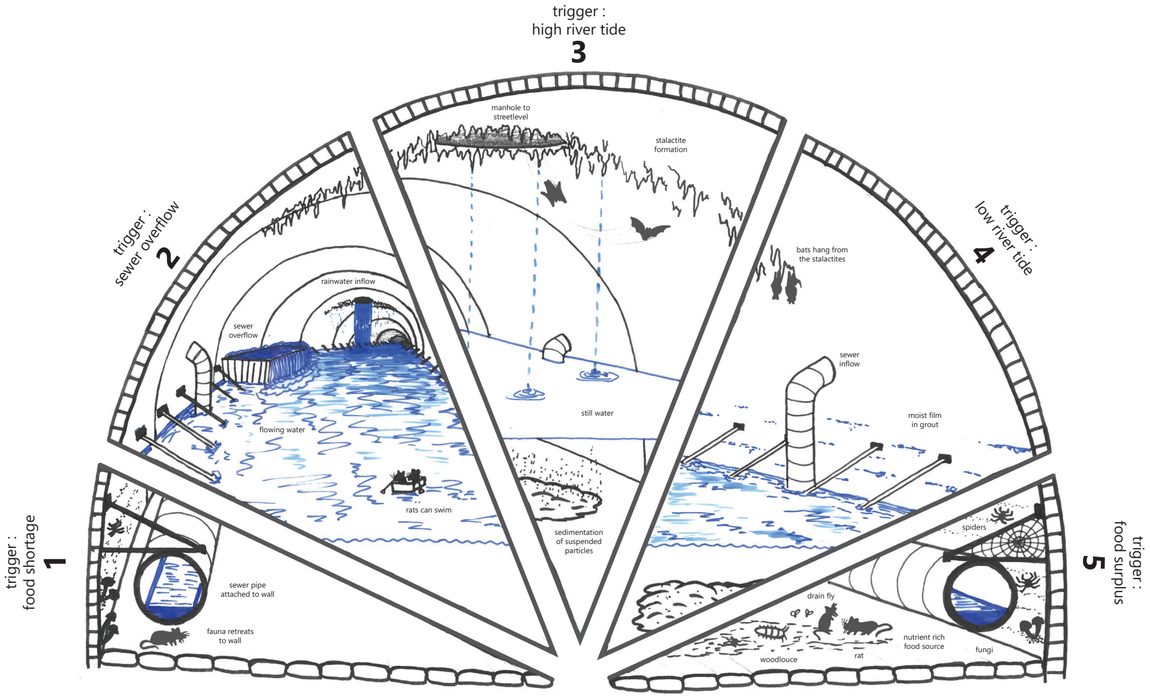
An infrastructure potential in the tunnels for the theme of green, specifically for the relief of ecological struggle and the low connection opportunities for flora and fauna (chapter 3.1), is its natural biotopes.

The Ruien has a naturally occurring biotope in the form of a unique ecosystem cycle. The ecosystem cycles are a direct consequence of the highly dynamic stormwater cycle that exists in the tunnels (figure 3.2.2.3). During rainfall events, the tunnels catch local rainwater runoff through manholes and other connected street-level gutters. In extreme cases, when the drainage pipes become overloaded with rainwater, the sewer-stormwater mixture will also overflow into the tunnels. Only when the Scheldt River is at low tide can the excess in the tunnels be drained to the surface water. The resulting fluctuations interact with the tunnel structure to form features like stalactites that attract bats, moist walls that attract fungus, and sludge buildup that attracts rats. Spiders, various insects, and crustaceans also find their habitat with these features, together forming an entire ecological web (figure 3.2.2.4). Therefore, the natural biotopes of the tunnels have potential for relieving the ecological struggle problems of the city.



>> **FIGURE 3.2.2.3:** (2) The existing stormwater cycle is triggered by the overflow of the sewer pipes if the system is overloaded. This causes contaminated water to enter the tunnels. (3) After the rainstorm, the water must be held in the tunnels until the tides in the Scheldt River are low enough to allow it to empty. During this time, sediments settle to the bottom and stalactites, the typical bat habitat, forms on the ceiling. (4) As the tunnel empties, a moist film is left behind on the walls of the tunnel, specifically in the grouts of the bricks. (5) The moist film attracts spiders and fungi to habitat in the walls and the exposed sediments attract insects like the woodlouce and rats. (1) After the food source is gone, the fauna must wait until the next cycle to begin. This results in a dynamic food chain (own work).

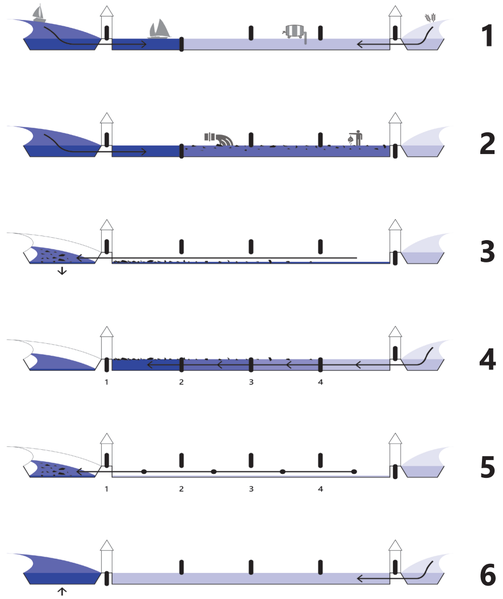
^ **FIGURE 3.2.2.4:** The ecological web resulting from the stormwater cycle includes the northern bat and the brown rat at the top of the food chain. Other species within the chain are the rough woodlouce, drain fly, false widow spider, various insect types, and various fungi types. The woodlice, insects, drain flies, and rats feed on the nutrients present in the sediments carried into the tunnel by the rainwater and the sewer overflow (own work).



wet - dry cycle with its 5 stages

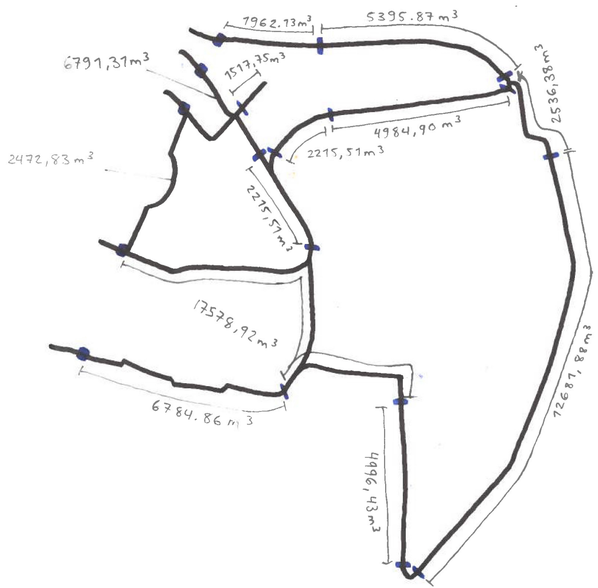
An infrastructure potential in the tunnels for the theme of blue, specifically for the relief of flood risk and the buffering of excess stormwater (chapter 3.1), is its sluice compartments.

The Ruien has a series of sluice gates that form water compartments throughout the network. The sluice compartments are a direct consequence of the historic need to regulate the inflow of drinking water from freshwater creeks in the hinterland, block the inflow of brackish water from the Scheldt River, and regulate the outflow of sewage water to the river at low tide (figure 3.2.2.5). To acquire the necessary water supply and water pressure, the sluice gates were constructed at set intervals that formed compartments with specific water volumes. The 19 historic sluice gates form 13 compartments with various ranges in volumetric capacity (figure 3.2.2.6). Therefore, the sluice compartments of the tunnels have potential for relieving the flood risk problems of the city.

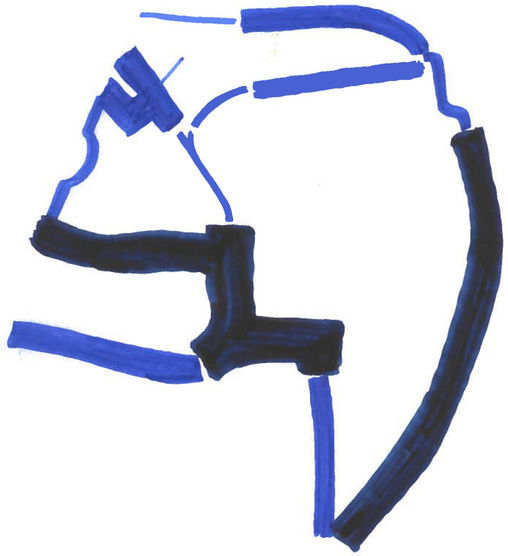


^ **FIGURE 3.2.2.5:** The freshwater and polluted water (brackish and sewer) dispersion throughout the city was regulated by sluice-gates that formed compartments. In the diagram, dark blue is polluted water and light blue is fresh water. (2) As sewer built up in the city, the freshwater inflow from the hinterland was shut. (3) At low tide, all gates were opened to the Scheldt River. (4) Not all filth can be flushed in a single time so the gates were closed one by one as pressure built up using freshwater inflow. (5) The gates were then opened one by one to flush the remaining filth. (6) As the tide rises again, the riverfront gate is closed and freshwater is let back into the city. (1) To ensure trade access from the river, the sluice compartment near to the Sheldt was allowed to be brackish. In that way, the beer brewers further in the inner city could still source fresh water for the brewing process (own work).

>> **FIGURE 3.2.2.6:** Due to the need for water pressure to allow the flushing process, the compartments were made specific sizes so that they could contain specific volumes of water. Some compartments held more water than others. The high capacity compartments were located further from the river because they needed more water pressure to flush the filth of the canals into the Scheldt (own work)



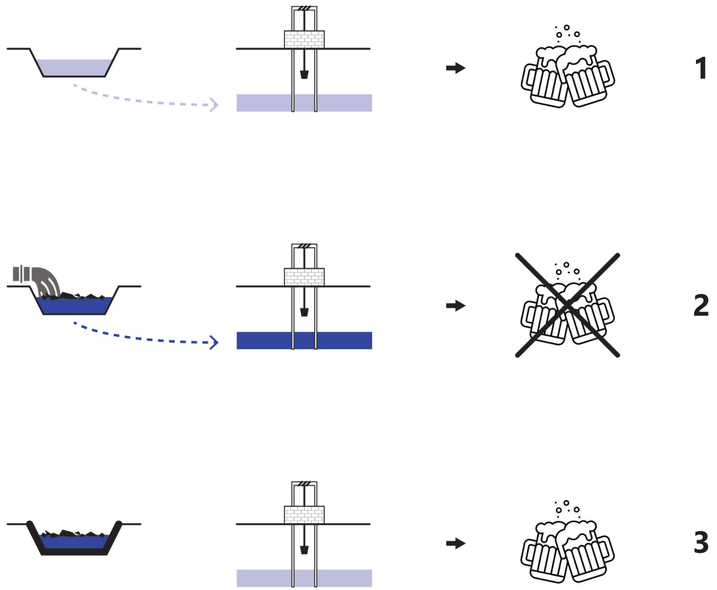
volume per sluice compartment
(m3)



volume per sluice compartment
(schematic: thick = more capacity)

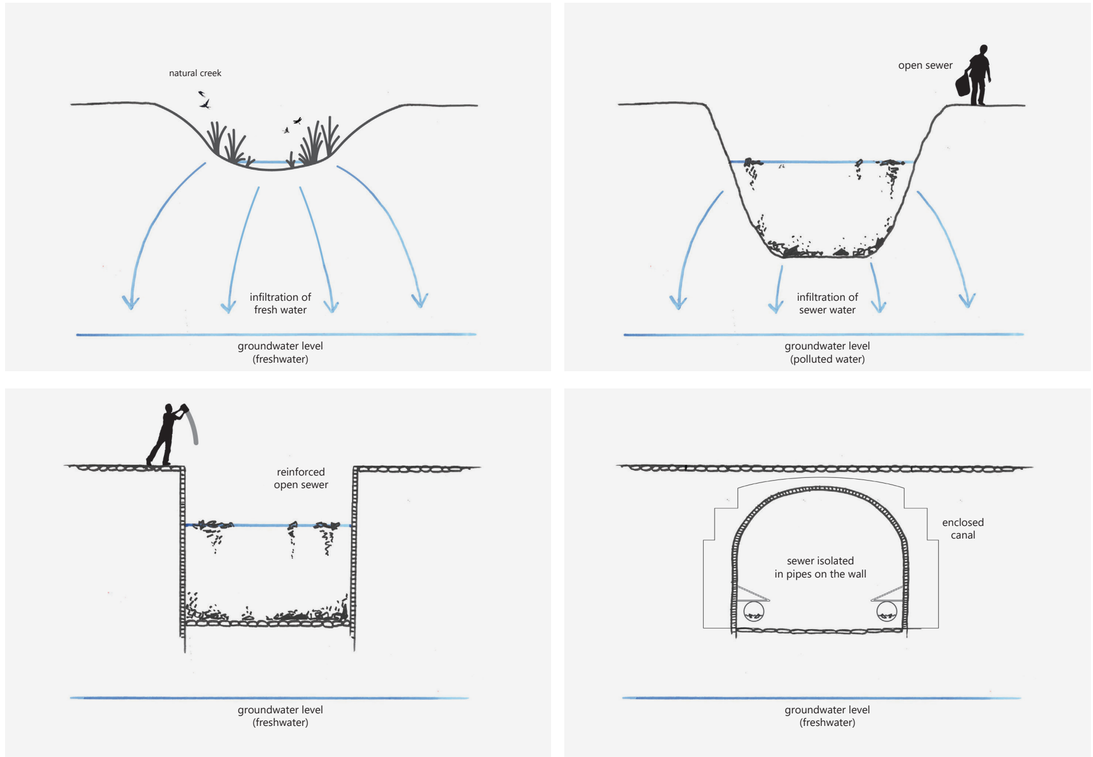
An infrastructure potential in the tunnels for the theme of blue, specifically for the relief of freshwater scarcity and the replenishment of groundwater levels (chapter 3.1), is its floor construction.

The Ruien has a floor construction that is made of a thick layer of cobblestones. The floor construction is a direct consequence of the historic need to prevent polluted water of the open sewers from leaking into the underlying groundwater and contaminating the freshwater wells of the city (figure 3.2.2.7). This was especially important to the city's beer brewers for which fresh water from the Ruien and wells was the main ingredient. The wells became contaminated by the city's sewer water, leading to outbreaks of disease. The isolation of the sewer water from the ground water, by lining the bottom of the Ruien with cobblestones was the eventual solution (figure 3.2.2.8). Nowadays, the sewer water is even further isolated within separate pipes attached to the walls of the tunnel. Therefore, the floor construction of the tunnels has potential for relieving the freshwater scarcity problems of the city.



^ **FIGURE 3.2.2.7:** (1) The creeks of the natural landscape fed the groundwater underneath the city. Wells were used to source freshwater for beer brewing from the groundwater. (2) As the creeks were canalized they were used as open sewers, contaminating the water with parasites. The polluted water infiltrated into the groundwater, thereby contaminating the freshwater source for beer brewers. (3) To guarantee the production of beer, the floor of the canal was reinforced with cobblestones. In this way, the polluted water was prevented from contaminating the groundwater and the beer brewers had a trustworthy source for freshwater (own work)

>> **FIGURE 3.2.2.8:** Detailed view of the changes brought on to the structure of the canal. (Top left) Creek with freshwater. (Top right) Canal with sewer water. (Bottom left) Reinforced Canal with sewer water. (Bottom right) Enclosed canal with sewer pipes (own work).

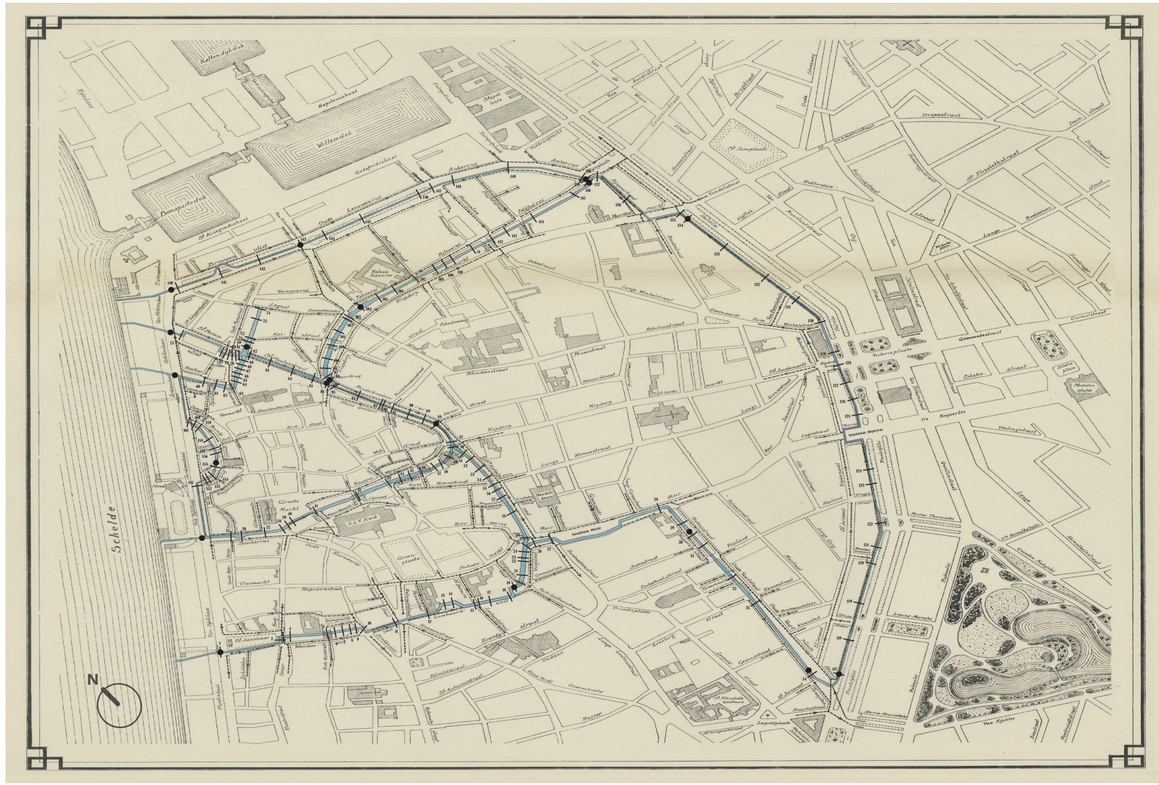


An infrastructure potential in the tunnels for the theme of place, specifically for the relief of congestion strain and the busy pedestrian streets (chapter 3.1), is its unimpeded layout.

The Ruien has a layout that is unimpeded and without barriers. The unimpeded layout is a direct consequence of its historic use as a transportation network for trade goods in which the number of obstructions had to be kept to a minimum (figure 3.2.2.9). The original sluice gates were able to completely open the canal in order to not impede the movement of ships. When the canals were covered and the sewage was moved into pipes, the sluices were locked to their open position. Nowadays, the tunnels are an unobstructed second level below the streets of Antwerp (figure 3.2.2.9). Therefore, the unimpeded layout of the tunnels has potential for relieving the congestion strain problems of the city.

>> **FIGURE 3.2.2.9:** The map of the underground canal system (FelixArchief, n.d.) shows how it passes underneath busy streets, squares, and building blocks without obstructions. The network is spread across the medieval center in a ring-like configuration following the pattern of the historic expansions of the city, enclosing different districts.

^ **FIGURE 3.2.2.10:** Photos of the underground canal system (Duncan, n.d.) show the suitability of the tunnel as an unobstructed pedestrian passage underneath barriers at street level.

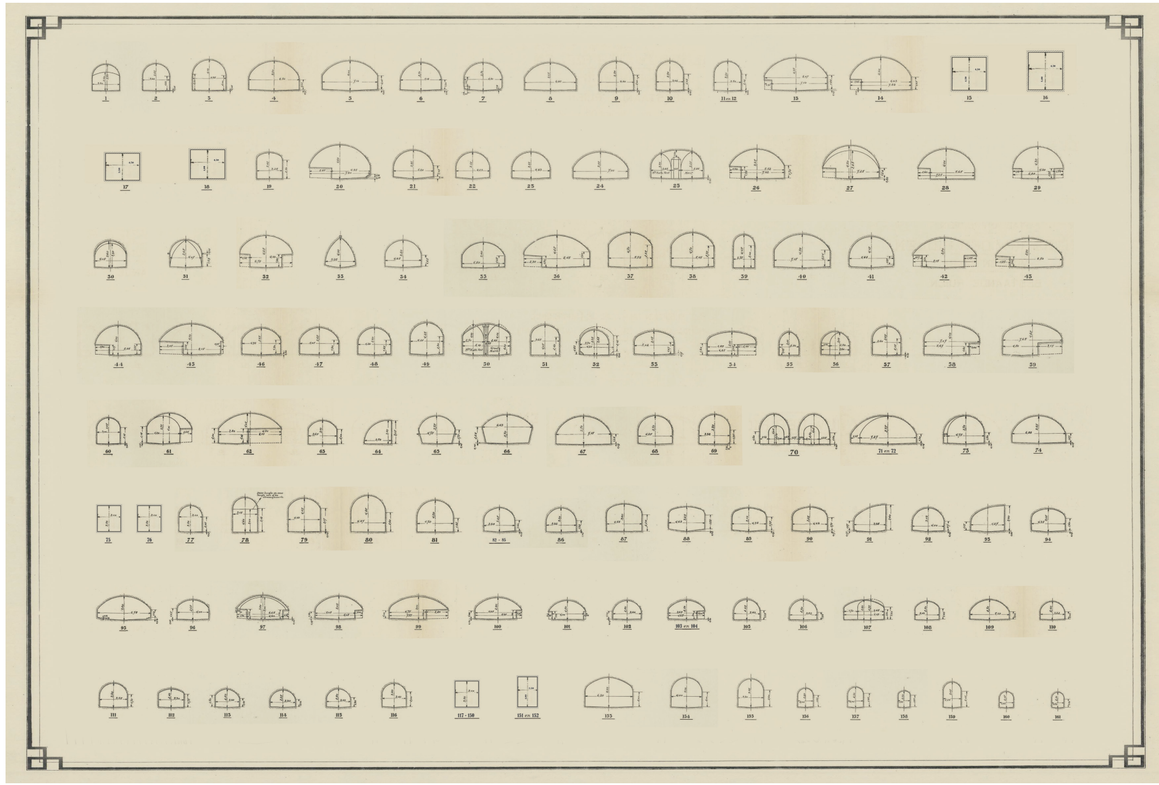


An infrastructure potential in the tunnels for the theme of place, specifically for the relief of leisure deficiency and the lack of room for additional public spaces (chapter 3.1), is its vacant floor-area.

The Ruien has a minimal modern-day function giving it a large vacant floor-area. The vacant floor-area is a direct consequence of the 2001 sewer modernizations by the City of Antwerp. The free-flowing sewer-rainwater mixture was moved and isolated into pipes attached to the walls of the tunnel structure (figure 3.2.2.11). Only during occasions of extreme rainfall, in which the combined drainage pipes are overloaded, does the mixture overflow back into the tunnels. Outside these events the expansive spaces of the tunnels are accessible with a tour guide. The tunnel sections range from between 4 meters to 7 meters wide and from 3,5 meters to 7 meters high (figure 3.2.2.12). Therefore, the vacant floor-area of the tunnels has potential for relieving the leisure deficiency problems of the city.

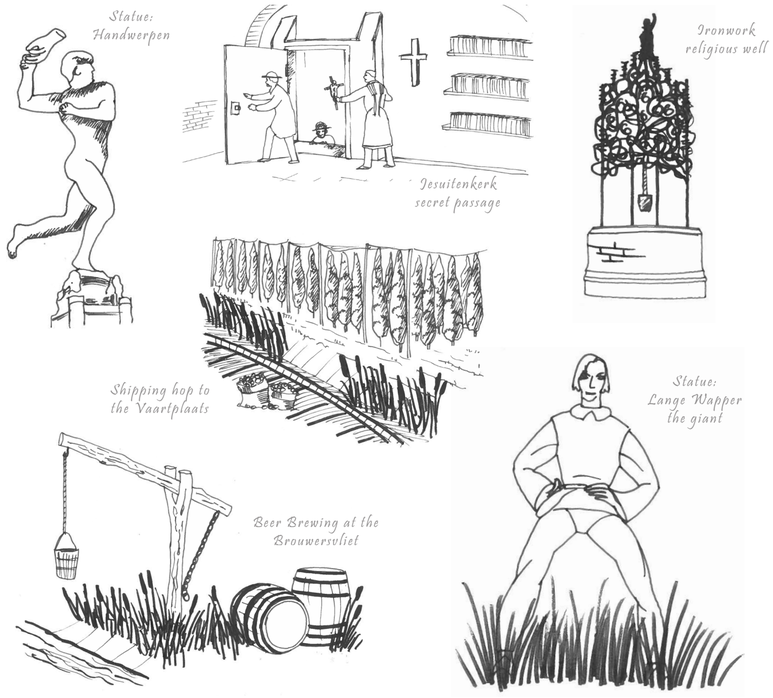
^ **FIGURE 3.2.2.11:** The sections of the underground canal system (FelixArchief, n.d.) show its dimensions and the area that each section has.

>> **FIGURE 3.2.2.12:** Photos of the underground canal system (Duncan, n.d.) show the decommissioned state and suitability of the tunnel for new uses.

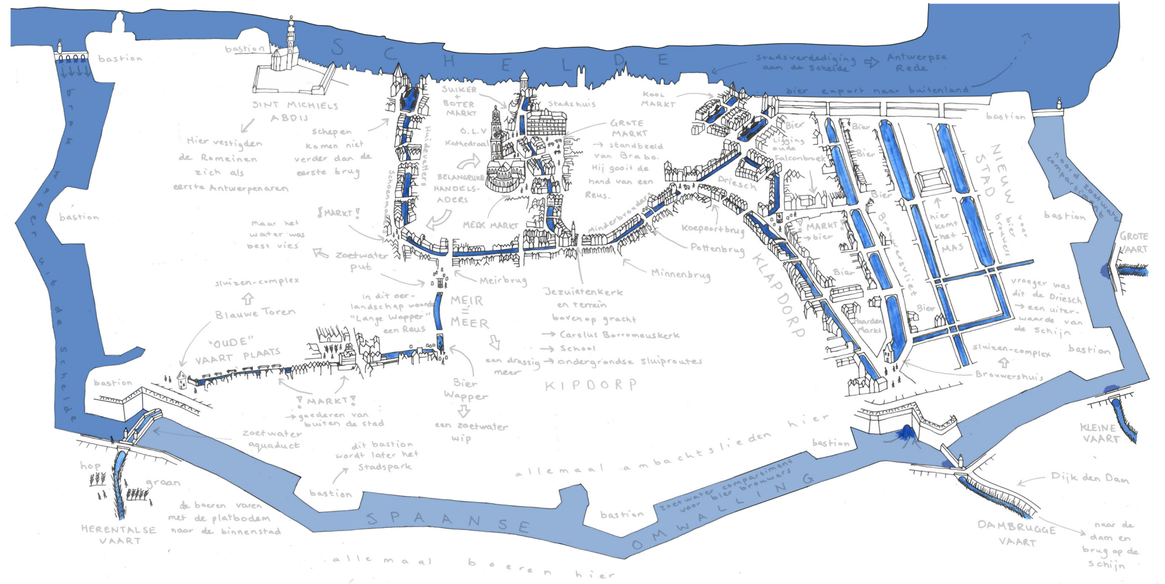


An infrastructure potential in the tunnels for the theme of memory, specifically for the relief of identity depreciation and the blurring of culturally historically valuable landscapes (chapter 3.1), is its lingering narratives.

The Ruien has historic narratives that linger throughout its trajectory. The lingering narratives are a direct consequence of the enclosing of the canals and the disappearance of the stories from the streetscape. The most significant Ruien narratives for the city were those invloving economy, religion, and mythology (figure 3.2.2.13). The economic narratives are still visible is the streetnames such as Verversrui, Wolstraat, Hopland, and Brouwersvliet among others which reference the trade of products like linnen and wool as well as hop for the brewing of beer. The religious narratives of the Ruien have to do with religiously decorated wells as well as secret passages from churches into the underground tunnels to escape enemies during the many religious revolts throughout history. The mythological narratives involve stories of monsters and a giant named Lange Wapper who used the underground tunnels to terrorize the city. A Roman soldier defeated the giant by cutting off his hand and throwing it across the city. All these microstories now lie forgotten beneath the streets (figure 3.2.2.14). Therefore, the lingering narratives of the tunnels have potential for relieving the identity depreciation problems of the city.



^ **FIGURE 3.2.2.13:** Lingering urban narratives related to the canal system are mainly related to trade economy (beer brewing), religion (secret passages and wells), and mythology (giant folklore) (own work).



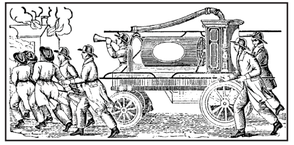
Bleeker

Leerbereider

Verver

Wolbereider

Brandblusser

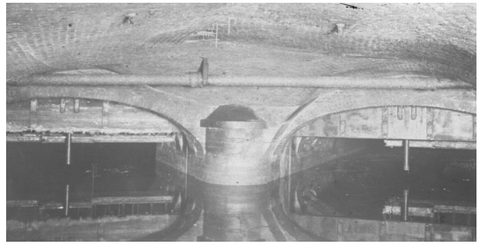


Ruienmonster

> > **FIGURE 3.2.2.14:** A mircostory drawing (Jan Rothuizen drawing) showing the narratives that played along the different sections of canals (own work). Inset drawings by FelixArchief (n.d.).

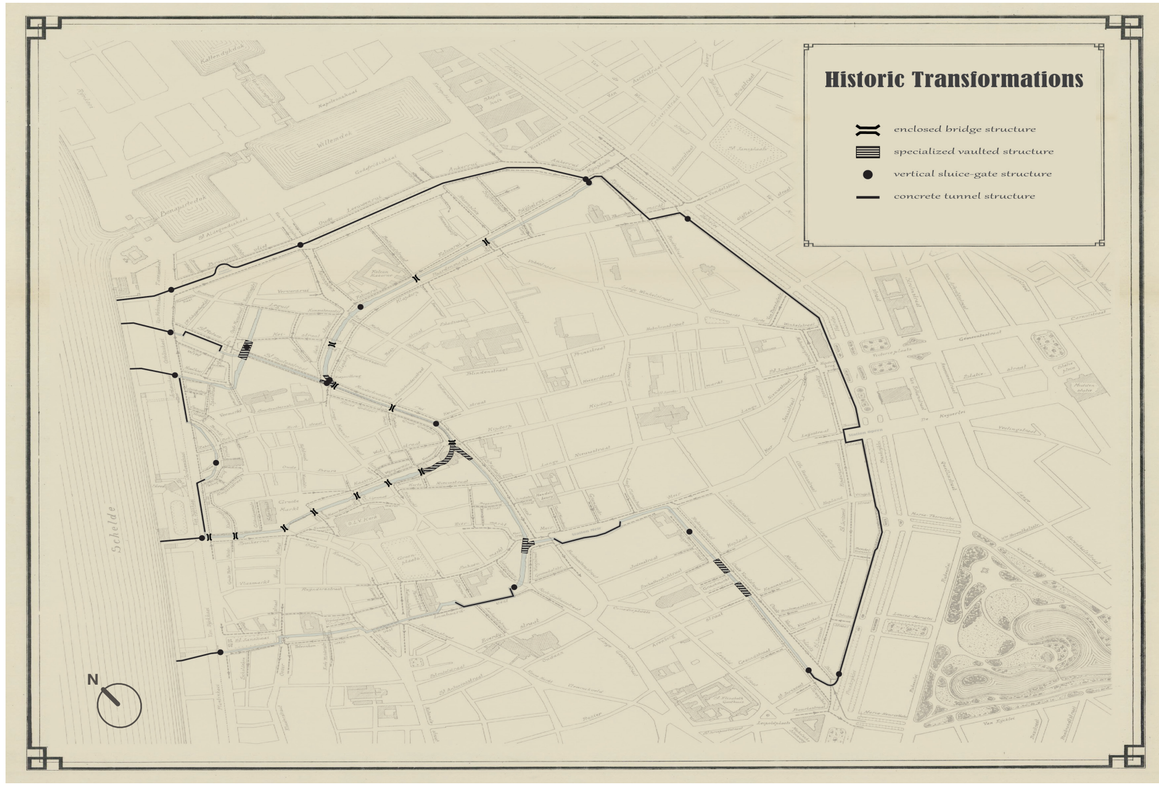
An infrastructure potential in the tunnels for the theme of memory, specifically for the relief of heritage decline and the safeguarding of archeologically valuable assets (chapter 3.1), is its physical relics.

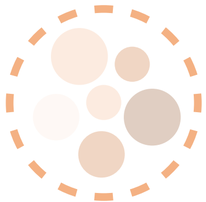
The Ruien has physical relics with archeological significance. The physical relics are a direct consequence of the enclosing of the canals and the physical encapsulation of existing structures and other features (figure 3.2.2.15). For example, all historic bridges and sluice gates are still visible in the structure of the tunnels. Next to this, the vaulted ceiling has configurations and masonry pattern specific to construction practices from specific time periods. For the secret passage from the Jezuit Church there are remnants of street signs that helped the escapees to find their way around in the tunnels. Altogether, they can provide valuable information on the evolution of Antwerp history and culture (figure 3.2.2.16). Therefore, the physical relics of the tunnels have potential for relieving the heritage decline problems of the city.



^ **FIGURE 3.2.2.15:** (Top left) Differently vaulted ceilings, arched in foreground and pointed in background. (Top right) A sluice construction at a tunnel junction. (Middle) Historic street signs (left and right) act as silent guides for the secret passages from above (center). (Bottom left) An historic bridge exposed during the 1975 construction of the metro station at the Meir. (Bottom right) Construction of a rectangular tunnel made of concrete to bypass the new metro station.

>> **FIGURE 3.2.2.16:** Map of the location of significant physical relics (adapted from FelixArchief, n.d.).





To conclude the analysis phase, and thereby answer sub-question 1 of the research, the overall findings are that:

For the theme of green, there are potentials based on the confined microclimate and the natural biotopes.

For the theme of blue, there are potentials based on the sluice compartments and the floor construction.

For the theme of place, there are potentials based on the unimpeded layout and the vacant floor-area.

For the theme of memory, there are potentials based on the lingering narratives and the physical relics.

maximization 3.3

The maximization phase of the method is the first step in responding to the third sub-question of the research. Sub-question 3 asks: how can the city's problems be reconciled by the canal's potentials? For this phase, answering the question gives insight into the design interventions for infrastructures in the canals. It specifically involves framing and systemizing green, blue, place, and memory infrastructure proposals by building criteria from the potentials. Essentially, the potentials are centralized in order to outline proposals.

3.3.1 A review of various conceptual 'brain dumps' for the canals provides initial information.
3.3.2 Then, a maximization per theme, based on operational standards, concepts, and strategies, outlines the proposals.

3.3.1 conceptual brain dumps

A brain dump refers to the process of documenting all initial information, ideas, and concepts about a topic in order to trigger design insight. They often involve word-clouds (figure 3.3.1.1). When thinking about a decommissioned underground canal system, the associations often involve, among others, darkness, disorientation, stench, and rats. With the problems and potentials noted from the previous chapters, it is hard to imagine the tunnel network as something completely different: a green oasis, an underground cistern, a pedestrian shortcut, or an educational boat ride, for example. Nevertheless, it is useful to research these ideas in order to stimulate creativity and innovation for the themes of green, blue, place, and memory. Recognizing this, the infrastructural conventions of green, blue, place, and memory systems should be summarized so that they can be responded to in the context of the underground Ruien of Antwerp (figure 3.3.1.2).

A common convention between the infrastructures seems to be the human encounter and interaction with the system. The incorporation of a human experience proves particularly difficult to apply in an underground context such as the Antwerp Ruien because of the unpleasant associations its setting triggers. Kanellopoulou (2022) argues that the perception of the sub-surface as a mainly utilitarian space gives it "the burden of being an infamous space." Therefore, special attention should be given to the subject of creating an atmosphere that triggers a new language for interpreting the underground realm below cities. There are four design conventions for creating spatial atmospheres specifically underground (Kanellopoulou, 2022):

- Give the space a sense of limit. Design with boundaries and zones to emphasize the closedness and seclusion of the underground.
- Use the space as a storytelling medium. Design with narratives and biographies to emphasize the non-visible and in-tangible characteristics of the underground.
- Accentuate the space through the act of descending. Design with verticality and escapism to emphasize the contrasts and divergence of the underground with the world above.
- Represent the space as a territory. Design with realms and world-building to emphasize the unfamiliarity and explorative aspects of the underground.

For each infrastructural theme, a particular concept leads to further word clouds. The word clouds can act as triggers for atmospheric starting points or a spatial experience of that concept. A collage that combines concept and convention gives an initial spatial impression of how a specific infrastructural theme van be realised within the Antwerp Ruien (figure 3.3.1.3, figure 3.3.1.4, figure 3.3.1.5, figure 3.3.1.6)

^ **FIGURE 3.3.1.1:** (Top) Cloud of words associated with an underground tunnel system. (Bottom) Cloud of words associated with what an underground tunnel could be. (Own work).

>> **FIGURE 3.3.1.2:** The infrastructural conventions for green, blue, place, and memory systems (sources as indicated)

GREEN INFRASTRUCTURE CONVENTIONS

According to Bosch et al. (2016), some important conventions to consider during the implementation of green infrastructure include:

- Protection & cooling: green infrastructure should provide pleasant microclimates and shadow.
- Biotopes & eco-units green infrastructure should provide habitats and links for flora and fauna.
- Purification & health: green infrastructure should provide improved air and water quality.
- Aesthetics & publicness: green infrastructure should provide urban beauty and appeal to human use.

BLUE INFRASTRUCTURE CONVENTIONS

According to (Urban Green-Blue Grids, n.d.), some important conventions to consider during the implementation of blue infrastructure include:

- Collection & storage: blue infrastructure should provide the structural means to harvest rainwater.
- Stormwater & sewerwater: blue infrastructure should provide separated storm and sewer drainage.
- Adaptive & resistant: blue infrastructure should provide resilience in both wet and dry periods.
- Engagement & visibility: blue infrastructure should provide community and educational value.

PLACE INFRASTRUCTURE CONVENTIONS

According to (Project for Public Spaces, 2018), some important conventions to consider during the implementation of place infrastructure include:

- Sociability & inclusiveness: place infrastructure should be interactive and welcoming.
- Uses & activities: place infrastructure should be multifunctional and dynamic.
- Comfort & image: place infrastructure should be safe and attractive for visitors.
- Access & linkage: place infrastructure should be walkable and connected.

MEMORY INFRASTRUCTURE CONVENTIONS

According to (Rijksoverheid, 1999), some important conventions to consider during the implementation of memory infrastructure include:

- Conservation & Repurpose: memory infrastructure should be both protective and adaptive.
- Visibility & Display: memory infrastructure should be actively legible and recognizable.
- Stability & Continuity: memory infrastructure should be narratively coherent and consistent.
- Interpretation & Display: memory infrastructure should be educational and tangible

FIGURE 3.3.1.3: (Left) Cloud of words associated with conventions for a 'green oasis'. (Right) Collage of the underground canal system of Antwerp reappropriated as a 'green oasis'. (Own work).

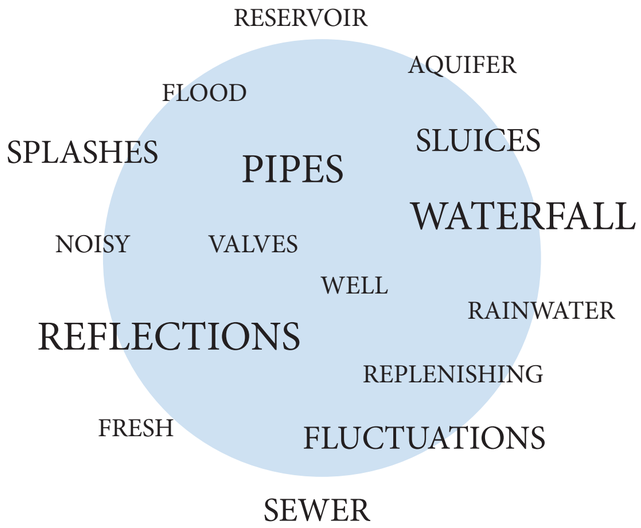


FIGURE 3.3.1.4: (Left) Cloud of words associated with conventions for a 'cistern'. (Right) Collage of the underground canal system of Antwerp reappropriated as a 'cistern'. (Own work).

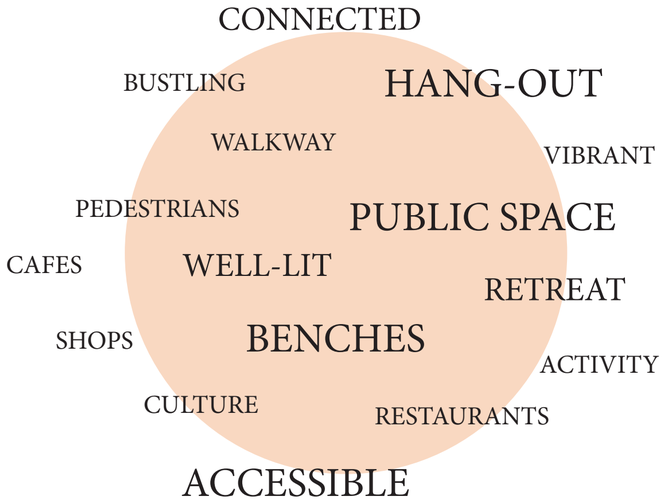


FIGURE 3.3.1.5: (Left) Cloud of words associated with conventions for a 'pedestrian shortcut'. (Right) Collage of the underground canal system of Antwerp reappropriated as a 'pedestrian shortcut'. (Own work).

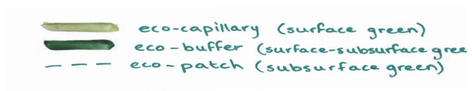
FIGURE 3.3.1.6: (Left) Cloud of words associated with conventions for a 'educational boat ride. (Right) Collage of the underground canal system of Antwerp reappropriated as a 'boat ride'. (Own work).

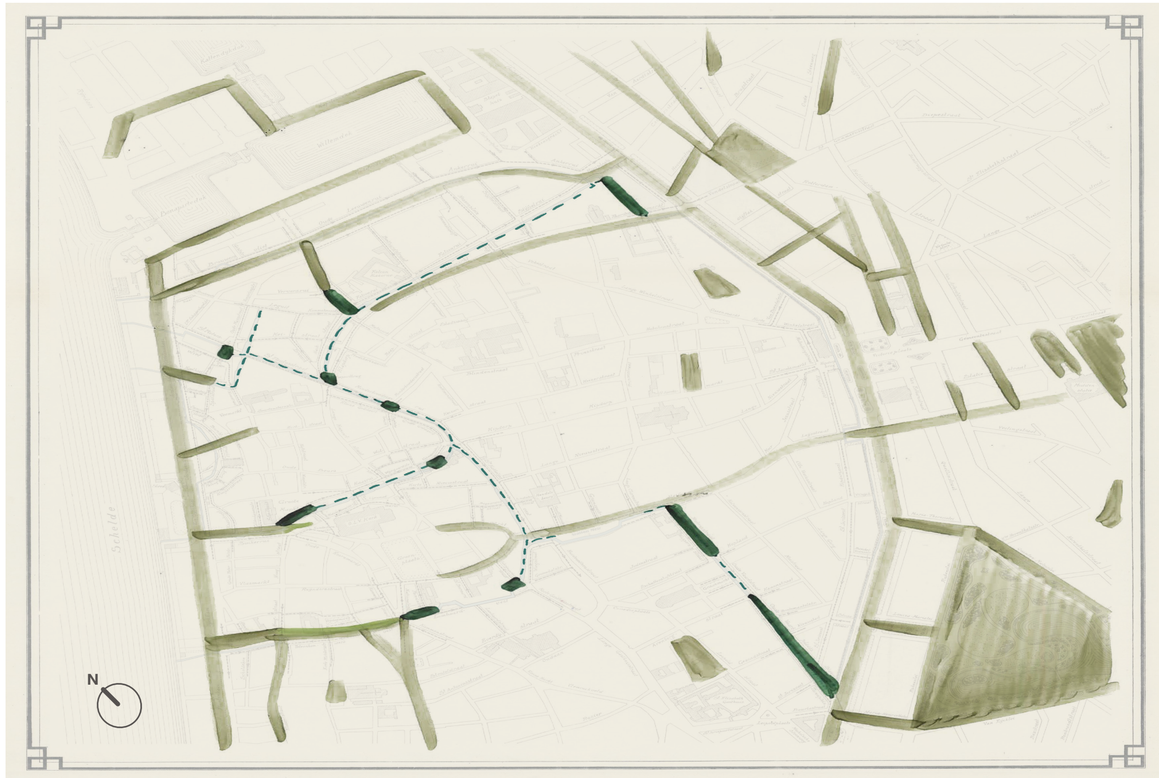
3.3.2 proposals

The green inventory of the city (chapter 3.1) indicates problems based on the lack of exposed ground surface and the low connection opportunities for flora and fauna. The green analysis of the canals (chapter 3.2) indicates potentials based on the confined microclimate and the natural biotopes. The appropriate reaction is to couple the problem with the potential and form a proposal.

The green infrastructure proposal is to uncover the canal's microclimate in order to establish a cooling regime as well as to enhance the natural biotopes in order to form interconnected flora and fauna habitats. The result is a maximized proposal for an enhanced urban green system (figure 3.3.2.1). It operates on a set of three criteria: eco capillary, buffer, and patch (figure 3.3.2.2).

Green Infrastructure Proposal





>> **FIGURE 3.3.2.1:** Map of the proposal for the green infrastructure system (Own work).

^ **FIGURE 3.3.2.2:** Criteria for the proposal for the green infrastructure system (Own work). Further explained on next page.

1. Eco-capillary

The eco-capillary works to provide an extension of the city's Garden Street (Tuinstraat) network, focusing on the 'garden' aspect. With this, ecological corridors penetrate further into the city center. The criteria in the street profile includes small-scale greenery in the form of shallow gardens, façade vegetation, and street trees in planters. The eco-capillaries occur in such a way that they connect/flow to the eco-buffers.

2. Eco-buffer

The eco-buffer works to provide a stepping-stone for flora and fauna and to expose the canal's climatic conditions to the city. With this, both flora and fauna groups as well as humans have a pleasant retreat within the historic city center. The criteria in the street profile includes uncovering the underground canal and fitting it out with diverse vegetation with a high cooling capacity. The eco-buffers occur in such a way that they connect/flow to the eco-patches.

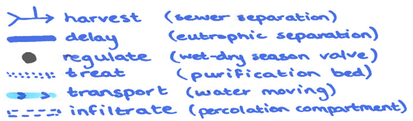
3. Eco-patch

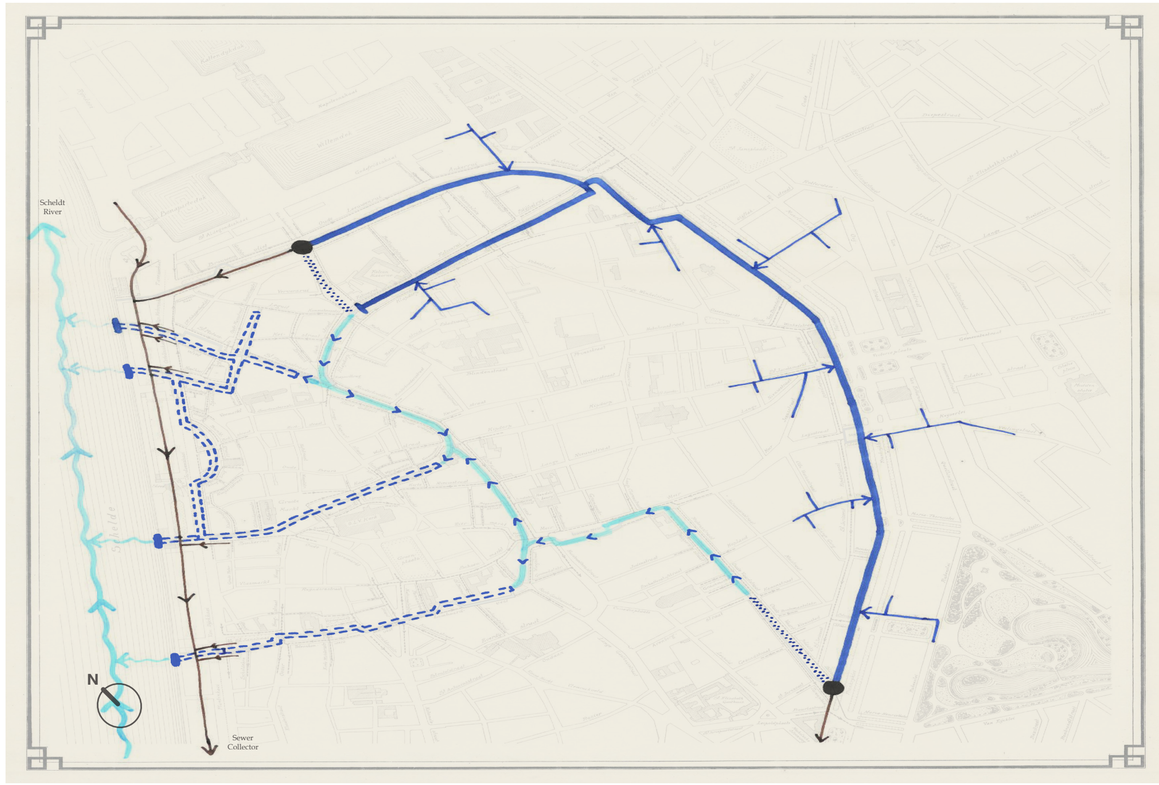
The eco-patch works to provide isolated underground habitats for flora and fauna, free from threats by outside factors. With this, the inner city becomes more attractive to biodiversity. The criteria in the street profile includes fitting the tunnel with openings to the surface-level that provide both light penetration and entryways for flora and fauna. The eco-patches occur in such a way that they work together as an ecological connection toward nearby eco-buffers and eventually the eco-capillaries.

The blue inventory of the city (chapter 3.1) indicates problems based on the buffering of excess stormwater and the replenishment of groundwater levels. The blue analysis of the canals (chapter 3.2) indicates potentials based on the sluice compartments and the floor construction. The appropriate reaction is to couple the problem with the potential and form a proposal.

The blue infrastructure proposal is to re-employ the sluice compartments in order to buffer rainwater runoff as well as to re-permeate the floor construction in order to infiltrate freshwater into the groundwater. The result is a maximized proposal for an enhanced urban blue system (figure 3.3.2.3). It operates on a set of six criteria: rainwater harvesting, delaying, regulating, treating, transporting, and infiltrating (figure 3.3.2.4).

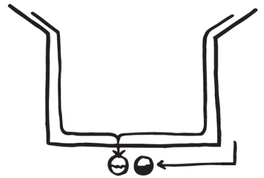
Blue Infrastructure Proposal





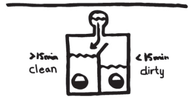
>> **FIGURE 3.3.2.3:** Map of the proposal for the blue infrastructure system (Own work).

^ **FIGURE 3.3.2.4:** Criteria for the proposal for the blue infrastructure system (Own work). Further explained on next page.



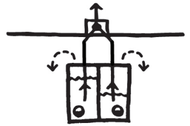
1. Rainwater harvesting

The harvesting works to separate stormwater drainage from sewage water drainage. With this, the total drainage system becomes less overloaded. The criteria in the street profile includes disconnecting the stormwater runoff from the sewage water runoff by redirecting each into detached pipes. The harvesting occurs in such a way that rainwater is collected toward the outer ring of the underground canals where its continued flow is delayed.



2. Rainwater delaying

The delaying works to flush out the accumulation of roof and street pollutants suspended in and carried along with the initial rainwater runoff. With this, the subsequent, less contaminated, runoff is isolated. The criteria in the street profile includes fitting the outer canal ring with an internal partition wall and a timed valve that allows the contents of the stormwater pipe to be separated into two tanks depending on the time at which the water quality changes (in this case 15 minutes). The disconnected sewer pipes continue through the tunnel. The delaying occurs in such a way that it captures rainwater from throughout the inner city into the outer Ruien ring which has the highest water capacity. At its outer ends the ring connects to a regulator.



3. Rainwater regulating

The regulating works to control the continued flow of previously collected rainwater. The criteria in the street profile includes fitting the tunnel with a pump for directing the collected rainwater further into the system towards the infiltration areas of the tunnels (normal wet conditions) as well as an overflow for bypassing any excess rainwater out of the system towards the sewer collector (extreme wet conditions). During dry conditions (normal or extreme), rainwater buffered in the outer ring from the previous rainfall event is used for the system, first from the clean water tank and later from the dirty water tank (at which time most suspended pollutants have settled on the bottom). The regulating occurs in such a way that the pump leads the rainwater into a helophyte treatment.

4. Rainwater treating

The treating works to provide the rainwater continuing into the system with additional (post flush) purification through a bed of helophyte plants. With this, the dissolved pollutants are absorbed and the water quality is further improved. The criteria in the street profile includes constructing a bed of helophyte plants at surface-level, fully exposed to sunlight to guarantee the most effective growth and functional potential. The underground canal remains undisturbed, with the sewer water continuing to flow through the isolated sewer pipes. The treating occurs in such a way that the flow of rainwater through the helophytes takes the longest path before it exits the bed and is transported further.

5. Rainwater transporting

The transporting works to move the cleaned rainwater from the treating area toward the infiltrating area of the tunnel. With this, the water is protected from further contaminations occuring at streetlevel. The criteria in the street profile includes keeping the canal enclosed from the surface and removing the sewer overflows from the sewer pipes. The water is free to gravitationally flow along the existing downward gradient of the tunnel. The transporting occurs in such a way that it gets evenly distributed toward three infiltration areas.

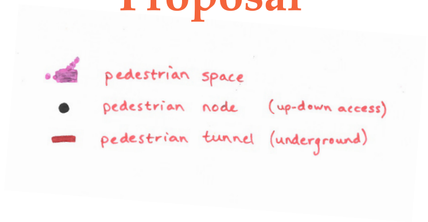
6. Rainwater infiltrating

The infiltrating works to allow the incoming water to gravitationally percolate into the groundwater sitting below the level of the tunnel floor. With this, any remaining suspended or dissolved pollutants are filtered out by the underlying sandy soil. The criteria in the street profile includes removing the cobblestone floor of the tunnel and allowing a large amount of water to build up to contribute to infiltration pressure. In case of overcapacity, the infiltration compartment can discharge the excess by opening the existing sluice gates to the river. This can only happen at low tide. The separated sewer pipes continue to the sewer collector. The infiltrating occurs in such a way that the supply of the city's main drinking water source (groundwater) is replenished.

The place inventory of the city (chapter 3.1) indicates problems based on the busy streets and the lack of room for additional public spaces. The place analysis of the canals (chapter 3.2) indicates potentials based on the unimpeded layout and the vacant floor-area. The appropriate reaction is to couple the problem with the potential and form a proposal.

The place infrastructure proposal is to utilize the tunnel layout in order to boost pedestrian access of the city center as well as to exploit the unused floor-area in the tunnel in order to increase the coverage and accessibility of public space. The result is a maximized proposal for an enhanced urban place system (figure 3.3.2.5). It operates on a set of three criteria: pedestrian space, node, and tunnel. (figure 3.3.2.6).

Place Infrastructure Proposal



>> **FIGURE 3.3.2.5:** Map of the proposal for the place infrastructure system (Own work).

^ **FIGURE 3.3.2.6:** Criteria for the proposal for the place infrastructure system (Own work). Further explained on next page.

1. Pedestrian space

The pedestrian street works to provide, like the eco-capillary, an extension of the city's Garden Street (Tuinstraat) network, focusing on the 'street' aspect. With this, city streets are more attractive and more walkable. The criteria in the street profile includes removal of car parking and new space for pedestrians incorporating seating areas and attractive greenery like street-side gardens. The pedestrian streets occur in such a way that they link existing public spaces as well as areas seeing public space shortage with pedestrian nodes along the canals.

2. Pedestrian node

The pedestrian node works to provide connectivity between the surface-level and the subsurface-level place network. With this, the pedestrian accessibility of the city is made significantly more effective. The criteria in the street profile includes fitting the tunnel with openings to the surface-level that act as entrances/exits of the underground portion of the place network. The pedestrian nodes occur in such a way that the stairways enhance the adjoining pedestrian space in both the aboveground and underground.

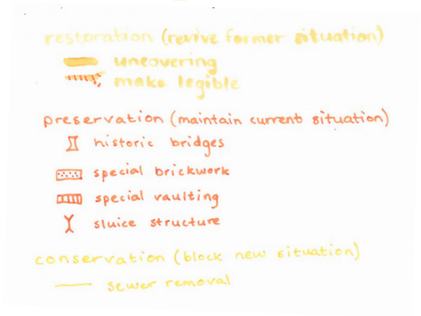
3. Pedestrian tunnel

The pedestrian tunnel works to provide public space provisions in the underground canals. With this, the tunnels become an additional place for leisure and rest within the city. The criteria in the street profile includes fitting the tunnel with a walkway and incorporating comfortable seating and pleasant lighting. The pedestrian space occurs in such a way that it flanks and intercepts areas with public space shortages.

The memory inventory of the city (chapter 3.1) indicates problems based on the blurring of culturally historically valuable landscapes and the safeguarding of archeologically valuable assets. The memory analysis of the canals (chapter 3.2) indicates potentials based on the lingering narratives and the physical relics. The appropriate reaction is to couple the problem with the potential and form a proposal.

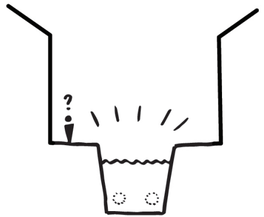
The memory infrastructure proposal is to highlight the lingering narratives in order to revitalize the forgotten culturally historical landscape as well as to accentuate the significant archeological features in order to diminish their potential for demolishing or other forms of defacing by unwanted factors. The result is a maximized proposal for an enhanced urban memory system (figure 3.3.2.7). It operates on a set of three criteria: heritage restoration, preservation, and conservation (figure 3.3.2.8).

Memory Infrastructure Proposal



>> **FIGURE 3.3.2.7:** Map of the proposal for the memory infrastructure system (Own work).

^ **FIGURE 3.3.2.8:** Criteria for the proposal for the memory infrastructure system (Own work). Further explained on next page.



1. Heritage restoration

The heritage restoration works to revive the tunnel to a former situation. With this, the historic biographies encapsulated within the tunnel are exposed and made legible. The criteria in the street profile includes uncovering the tunnel to make the old canal a part of the streetscape again. The heritage restoration occurs in such a way that the tunnels are opened wherever they are not restricted overhead by existing housing blocks.

2. Heritage preservation

The heritage preservation works to maintain the tunnel in its current situation. With this, archeological assets are kept for archeological and educational purposes. The criteria in the street profile includes protecting the tunnel from physical changes to its form and structure. The heritage preservation occurs in such a way that the relics of enclosed bridges, specialized vaults, and sluice-gates are preserved.

3. Heritage conservation

The heritage conservation works to block the tunnel from a new situation. With this, aesthetic representation and historical value for the future is secured. The criteria in the street profile includes reversing the modern-day addition of sewer pipes throughout the tunnels and removing the buildup of filth due to the sewer overflows. The heritage conservation occurs in such a way that the sewer infrastructure is put out of sight only where the tunnel structure is original (not a concrete tunnel).

To conclude the maximization phase, and thereby answer the first part of sub-question 3 of the research, the overall findings are that:

For the theme of green, the proposal includes applying criteria for an eco capillary, buffer, and patch.

For the theme of blue, the proposal includes applying criteria for rainwater harvesting, delaying, regulating, treating, transporting, and infiltrating.

For the theme of place, the proposal includes applying criteria for a pedestrian space, node, and tunnel.

For the theme of memory, the proposal includes applying criteria for heritage restoration, preservation, and conservation.

optimization 3.4

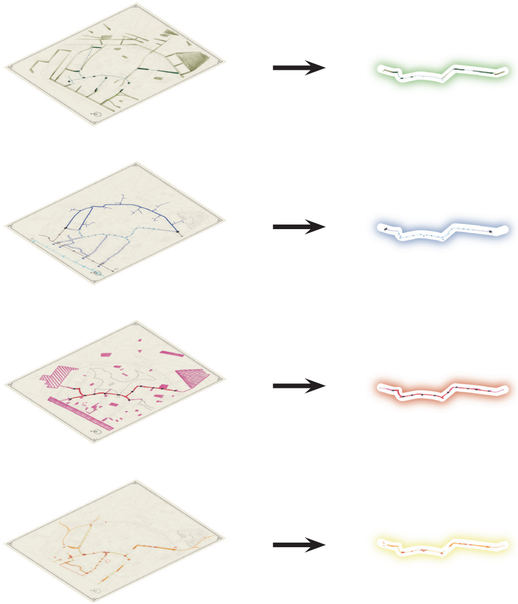
The optimization phase of the method is the second step in responding to the third sub-question of the research. Sub-question 3 asks: how can the city's problems be reconciled by the canal's potentials? Again, for this phase, answering the question gives insight into the design interventions for infrastructures in the canals. It specifically involves evaluating and diagnosing the green, blue, place, and memory principles by comparing interactions between the proposals. Essentially, the proposals are refined in order to outline principles.

3.4.1 A review of a map overlay that compares the different infrastructural criteria provides initial information.
3.4.2 Then, an optimization per theme, based on the criteria comparison and the scoring of the criteria, outlines the principles.

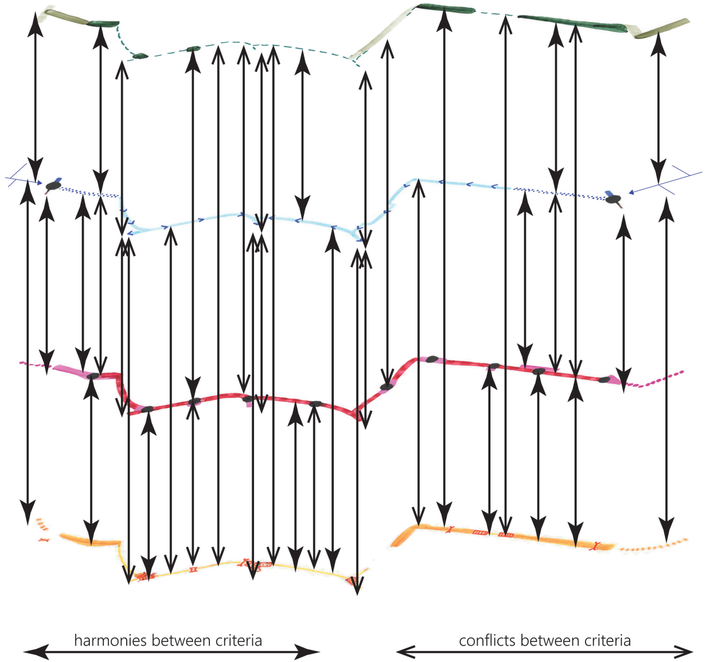
3.4.1 map overlay

Overlaying the maps for the green, blue, place, and memory systems, as formulated in the previous chapter (chapter 3.3), displays where the criteria of each infrastructure proposal interact. In order to get a clearer understanding of these interactions, the study area is limited to a smaller section (figure 3.4.1.1). This fragment encompasses all operational criteria from all infrastructure proposals at least once.

The criteria ultimately interact in various places (figure 3.4.1.2). Within each interaction, sometimes a combination of criteria will lead to conflicts and sometimes a combination of criteria will lead to harmonies.The harmonies are strengths and bring to light the opportunities between proposals (table 3.4.1.1) while the conflicts are weaknesses and bring to light the threats between proposals (table 3.4.1.2).



^ **FIGURE 3.4.1.1:** The maximization proposal are limited to a smaller, all-encompassing, study area. (Own work).



see tables 3.4.1.1 and 3.4.1.2

>> **FIGURE 3.4.1.2:** And overlay of the study area shows where the criteria of the proposals interact. Sometimes there are harmonies and sometimes there are conflicts. (Own work).

GREEN				
BLUE	The eco-capillary (Garden Street policy) already gives room to rainwater harvesting interventions. The rainwater treating is done with helophytes which are ecologically valuable in the eco-buffer. The rainwater transport can be used as an irrigation source for the eco-patches.			
PLACE	The pedestrian nodes enhance the eco-buffers by offering aboveground-underground access for flora and fauna.	The rainwater treating, specifically the helophytes, act as an enrichment and cooling feature for the pedestrian nodes and space. The rainwater delaying is not operationally restricted by any criteria of the place network.		
MEMORY	Heritage restoration and eco-buffers both benefit greatest when the tunnel is uncovered/exposed.	Heritage conservation ensures that water quality remains clean after rainwater treatment. Heritage restoration increases the prospects for capturing rainwater for the harvesting.	All memory criteria educationally and aesthetically accentuate the quality of the canal as a pedestrian space. The heritage restoration creates useful prospects (uncovering) for pedestrian nodes.	
HARMONIES	GREEN	BLUE	PLACE	MEMORY

< **TABLE 3.4.1.1:** The harmonies between proposals. The harmonies are strengths and bring to light opporunities for design principles. (Own work)

GREEN	BLUE	PLACE	MEMORY	CONFLICTS
	The rainwater delaying and infiltrating is operationally restricted by eco-patches and eco-buffers.	The pedestrian space and nodes disturb the success of the eco-patches and eco-buffers due to human presence (habitat disturbance).	The heritage conservation decreases the growth potential of eco-patches, specifically the removal of 'filth' buildup. The heritage preservation hinders the development of eco-patches and eco-buffers due to the changes required to the tunnel structure.	GREEN
		The rainwater infiltrating is restricted by pedestrian nodes and spaces because of the fluctuating water level. The rainwater treatment is threatened by the pedestrian nodes due to human presence that threatens water quality (trash buildup).	The heritage preservation hinders the functioning of the rainwater infiltration due to structural criteria. The heritage conservation, specifically the removal of the sewer pipes, is in significant conflict with the continued need for sewer drainage.	BLUE
			The pedestrian spaces and nodes, with their human presence, can negatively impact the quality of the heritage preservation and conservation efforts (graffiti and other nuisance). The pedestrian nodes are in structural conflict with the heritage preservation.	PLACE
				MEMORY

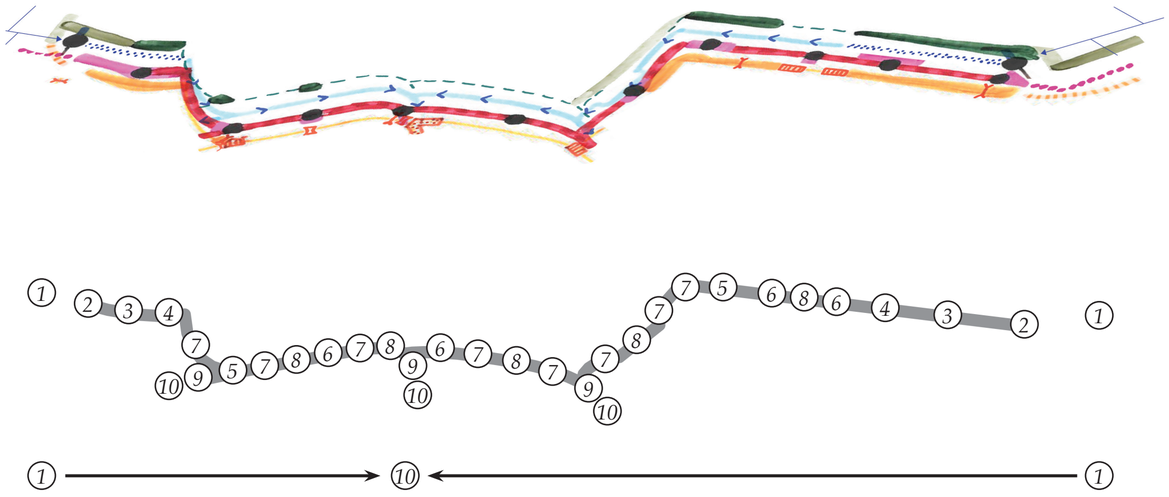
> **TABLE 3.4.1.2:** The conflicts between proposals. The conflicts are weaknesses and bring to light threats for design principles. (Own work)

3.4.2 principles

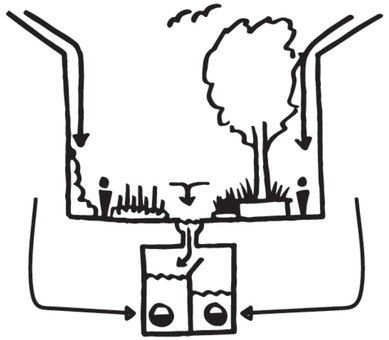
Both the harmonies and the conflicts call for refinements to the infrastructure proposals. While the harmonies result in the combination of certain criteria, the conflicts result in the prioritization of certain criteria. Overall, the combinations and prioritizations lead to 10 main principles (Table 3.4.2.1), each with an optimized representation of the green, blue, place, and memory themes. The result is a single infrastructural vision with the principles forming a coherent green-blue-place-memory system (figure 3.4.2.1). Noteworthy is that from the outer ends of the system toward the midpoint, the sequence of principles is relatively similar, from 1 to 10. At the midpoint of the system and back to the outer ends, the sequence reverses, from 10 to 1. In every principle, although there is a relatively equal balance between the theme of green, blue, place, and memory, some criteria score higher than others. As a consequence, some infrastructural themes are better represented than others. The next pages evaluate and score the principles using a spider diagram. The scores are used to give an indication of whether certain themes need more or less representation. In those cases, design insight, during the integration phase, takes the lead.

1.	Garden Street PLUS	6.	Underground Human Retreat
2.	Water Square	7.	Underground Flora / Fauna Retreat
3.	Natural Oasis A	8.	Access Point
4.	Natural Oasis B	9.	Underground Cistern
5.	Natural Oasis C	10.	Natural Oasis D

^ **TABLE 3.4.2.1:** The combination and prioritization of maximization criteria lead to 10 optimized principles (Own work) Further explained on next pages. (Own work).



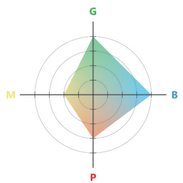
>> **FIGURE 3.4.2.1:** The 10 principles occur from the outer ends toward the midpoint of the study area in a sequence from approximately 1 to 10. (Own work).



1	GREEN	BLUE	PLACE	MEMORY
criteria	eco-capillary	rainwater harvesting / delaying	pedestrian street	heritage restoration
score (/4)	4	4	3	2

1. Garden Street PLUS

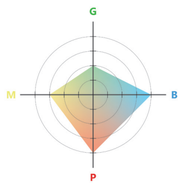
The Garden Street PLUS is an enhancement of the existing Garden Street (Tuinstraat) principles by the City of Antwerp. These include assets of the eco-capillary (green) and the pedestrian street (place). The addition in the Garden Street PLUS is a shallow street gutter for rainwater harvesting (blue) that empties into the underground canal. In the tunnel, pollutants are flushed for the rainwater delaying (blue). Sewer water flows into isolated pipes. The street groove makes the underlying heritage (the tunnel) somewhat legible again for heritage restoration (memory). To conclude, this principle scores best for operation within the green, blue, and place systems.



2	GREEN	BLUE	PLACE	MEMORY
criteria	eco-buffer	rainwater regulating	pedestrian node	heritage restoration
score (/4)	2	4	4	3

2. Water Square

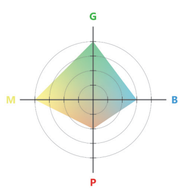
The Water Square is, as the name suggests, mainly for purposes related to water, in this case rainwater regulating (blue). With the tunnel remaining intact for this purpose, the pedestrian node (place) cannot come to justification. With a submerged pit, however, although intended for heritage restoration purposes (memory), the principle gets a pedestrian space function instead. This improves the place score. Altogether, there is little potential for an eco-buffer (green). To conclude, this principle scores best for operation within the blue, place, and memory systems.



3	GREEN	BLUE	PLACE	MEMORY
criteria	eco-buffer	rainwater treating	pedestrian space	heritage restoration
score (/4)	4	3	2	4

3. Natural Oasis A

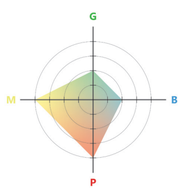
The Natural Oasis A is the first of four uncovering principles of the canal. It therefore fully justifies the criteria for heritage restoration (memory). The exposed section is ideal for plant growth allowing the formation of an eco-buffer (green) as well as helophytes for rainwater treating (blue). The pedestrian space (place) comes to the lowest justification for the reason that the helophytes are both a green and blue component, requiring the extra space. To conclude, this principle scores best for operation within the green, blue, and memory systems.



4	GREEN	BLUE	PLACE	MEMORY
criteria	eco-buffer	rainwater treating	pedestrian node	heritage restoration
score (/4)	2	2	4	4

4. Natural Oasis B

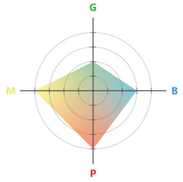
The Natural Oasis B (figure 3.4.7) is the second of four uncovering principles of the canal. It again fully justifies the criteria for heritage restoration (memory). The pedestrian node (place) is also fully justified. However, because of the priority that is has, there is less potential for the eco-buffer (green) and the rainwater treating (blue). These are, nonetheless, better justified in Natural Oasis A. To conclude, this principle scores best for operation within the place and memory systems.



5	GREEN	BLUE	PLACE	MEMORY
criteria	eco-buffer	rainwater transporting	pedestrian node	heritage restoration
score (/4)	2	3	4	4

5. Natural Oasis C

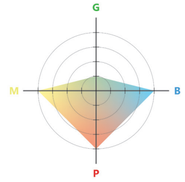
The Natural Oasis C is the third of four uncovering principles of the canal, once more justifying the criteria for heritage restoration (memory). Also here, the pedestrian node (place) is fully justified. Like with Natural Oasis B, the eco-buffer (green) has less potential because of the spatial limitation. Because the rainwater transporting (blue) has low spatial requirements, it is adequately justified. To conclude, this principle scores best for operation within the blue, place, and memory systems.



6	GREEN	BLUE	PLACE	MEMORY
criteria	eco-patch	rainwater transporting	pedestrian space	heritage preservation
score (/4)	1	4	4	4

6. Underground Human Retreat

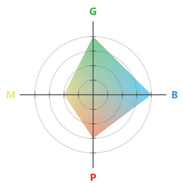
The Underground Human Retreat is a principle that functions mainly for human use. It therefore functions effectively as a pedestrian space (place). The rainwater transporting (blue) does not require large installations and therefore has low operational conflicts. Because of the fully justified heritage preservation (memory), openings for light penetration or not possible. Therefore, the eco-patch (green) is unable to find enhanced growth potential. To conclude, this principle scores best for operation within the blue, place, and memory systems.



7	GREEN	BLUE	PLACE	MEMORY
criteria	eco-patch	rainwater transporting	pedestrian space	heritage conservation
score (/4)	4	4	3	2

7. Underground Flora/Fauna Retreat

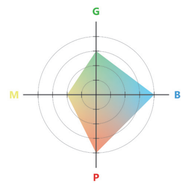
The Underground Flora/Fauna Retreat is a principle that functions mainly for use by flora and fauna groups. It therefore functions effectively as an eco-patch (green). This is only made possible by lowering the requirements for the heritage conservation (memory) which includes cleansing the tunnel of filth. Nevertheless, the visually intrusive sewer pipes can be moved from the walls and underneath the walkways of the pedestrian space (place). Again, the rainwater transporting (blue) does not require large installations and therefore has low operational conflicts. To conclude, this principle scores best for operation within the green, blue, and place systems.

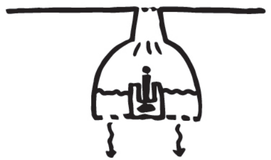


8	GREEN	BLUE	PLACE	MEMORY
criteria	eco-patch	rainwater transporting	pedestrian node	heritage conservation
score (/4)	3	4	4	2

8. Access Point

The Access Point is, as the name suggests, the point at which access is made possible between the aboveground streets and belowground tunnels. It therefore fully justifies the pedestrian node (place). Because the opening also allows light to penetrate underground, the eco-patch (green) has much potential for flourishing. The possible plant growth decreases the justification of the heritage conservation (memory) in which intrusive elements should be removed. Once more, the low spatial impact of rainwater transporting (blue) allows it to be fully justified. To conclude, this principle scores best for operation within the green, blue, and place systems.

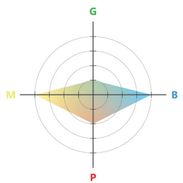


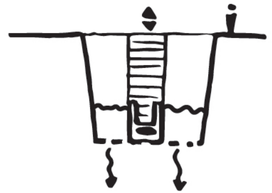


9	GREEN	BLUE	PLACE	MEMORY
criteria	eco-patch	rainwater infiltrating	pedestrian space	heritage conservation
score (/4)	1	4	2	4

9. Underground Cistern

The Underground Cistern is located where the rainwater infiltration (blue) must occur, making it the most important aspect in the principle. It is important to keep the rainwater clean and this is in line with the heritage conservation (memory) criteria that removes filth and the sewer. The storage of a large quantity of water decreases the potential for pedestrian space (place) and eco-patches (green). With the hindered potential for green, the opening in the structure for light penetration becomes optional. To conclude, this principle scores best for operation within the blue and memory systems.

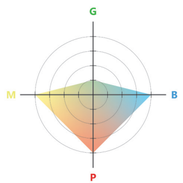




10	GREEN	BLUE	PLACE	MEMORY
criteria	eco-buffer	rainwater infiltrating	pedestrian node	heritage restoration
score (/4)	1	4	4	4

10. Natural Oasis D

The Natural Oasis D is the final uncovering principle of the canal, fully justifying the criteria for heritage restoration (memory). It also gives effective space for a pedestrian node (memory). As with the Underground Cistern, this principle is located where the rainwater infiltration (blue) must occur, making blue an important aspect in the principle. The large water volumes make it impractical for the formation of an eco-buffer (green). To conclude, this principle scores best for operation within the blue, place, and memory systems.



To conclude the optimization phase, and thereby answer the second part of sub-question 3 of the research, the overall findings are that:

The harmonies and conflicts between the maximization criteria result in 10 main principles that are spread throughout the study area. Ultimately, the 10 principles have various representations (scores) of the themes green, blue, place, and memory. These representations will change further as the principles are integrated into the existing situation (chapter 3.4) and the functioning of the principle on the location is tested. New themes might come into play as well, further anchoring the system in the urban fabric of the city.

The integration phase of the method is the third and final step in responding to the third sub-question of the research. Once again, sub-question 3 asks: how can the city's problems be reconciled by the canal's potentials? For this phase, once more, answering the question gives insight into the design interventions for infrastructures in the canals. It specifically involves projecting and testing the green, blue, place, and memory plans by implementing designs for the principles. Essentially, the principles are applied in order to outline plans.

3.5.1 Impressions, plans, sections, and details of Antwerp Unearthed provide initial information.
3.5.2 A look into the plan's extended embedment in the urban fabric gives further insight.
3.5.3 Then, a strategy for a possible construction phasing is presented.

integration 3.5

3.5.1 Antwerp Unearthed Tuinstraat

Imagine, you've spent most of the day resting in the city park, nestled within the heart of Antwerp. The park has provided a peaceful retreat from the hustle and bustle of urban life. As the day draws to a close, the skies above begin to darken. As droplets of rain gently begin to fall from above, reluctantly, you make your way back into the city with your umbrella.

As you start your journey, you find yourself strolling into a garden street (tuinstraat) (figure 3.5.1). They are typical to Antwerp, offering lush greenery and well-tended gardens to the generally barren and monotone streetscape. This particular garden street, however, carries a unique charm. As you stroll along, you notice a meandering stormwater gutter running along the road. The gutter is lined with weathered cobblestones that trigger a sense of timelessness and agedness. It pays homage to an ancient creek that once coursed through this area, bringing freshwater toward the inner city. It sparks historical memories.

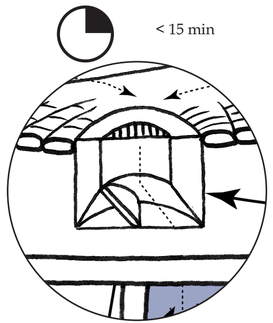
Intrigued by the historical reference, you take a moment to imagine how the creek must have flowed gracefully through the city's hinterland, nourishing the crops and sustaining the farmers. Nowadays, the crops have become flower beds for the new residents living in the garden street. The stormwater gutter acts as a modern creek, collecting and channeling rainwater that flows from the adjacent roofs and street.

As the rain intensifies, the sound of rushing water through the gutter becomes a soothing stream that accompanies you to the city center. Here and there it disappears into a drain. Many children are playing in the gutter, jumping and making splashes. Parents watch from underneath a canopy of umbrellas. It's as if the rain flowing through the gutter has brought everyone closer together. You feel grateful for the innovative system, not only serving a practical purpose in managing the city's rainfall but also enhancing the existing garden street.

>> **FIGURE 3.5.1:** A Garden Street fitted out with a stormwater gutter harvest rainwater from nearby roofs and streets. Its meandering path reflects the historic hinterland creek and during rainstorms it is an exciting addition the the streetscape, attracting children to play and thereby enhancing public space of the street. (Own work).

Rainwater is harvested from nearby roofs and the street. This is done by disconnecting the stormwater pipes from the traditional sewer pipes and letting it flow freely onto the street. On the way, the greenery of the garden street is nourished. The slope in the street profile helps to collect water toward the meandering rainwater gutter in the center. As the water collects in the gutter, it fills up and flows through the street. The cobblestones result in a gentle flow of the water, creating a soothing sound.

During the first 15 minutes of the rainstorm, the flowing rainwater takes along with it the build up of pollutants on the street, such as oils, salts, and other particles (figure 3.5.2). The gutter takes all stormwater toward a strategically positioned drain. The drain is a construction that serves as a critical connection between the meandering gutter and the underground Ruien at the point where they cross. Within the drain is a switch valve that automatically adjusts its position after 15 minutes. The water cascades into the tunnel.



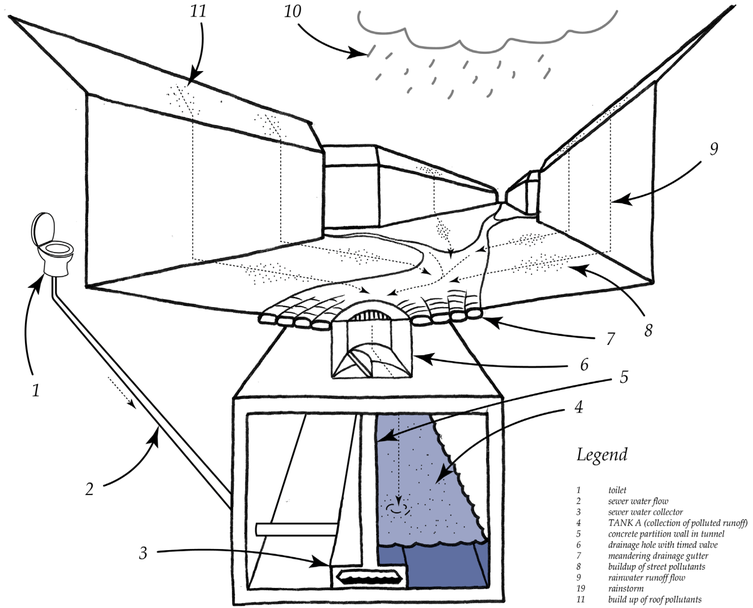


FIGURE 3.5.2: During the first 15 minutes, a valve in a drain along the gutter ensures that the more contaminated rainwater runoff is flows into a separate tank. (Own work)

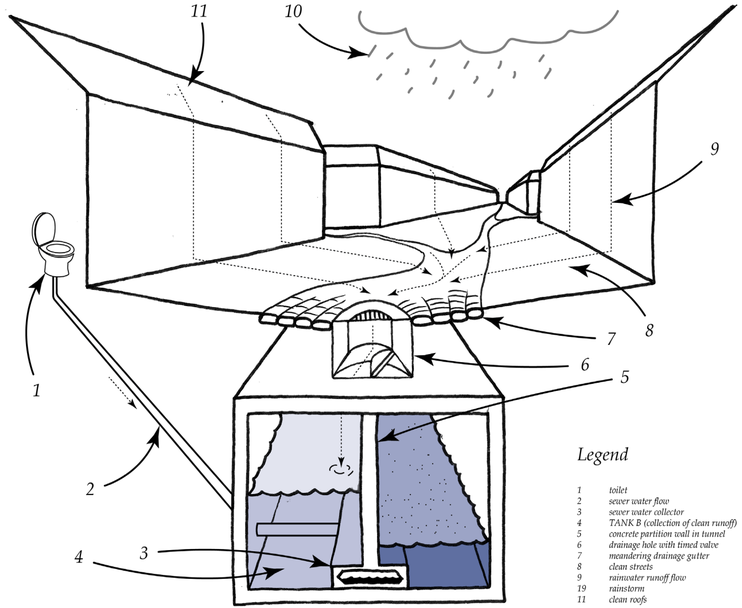
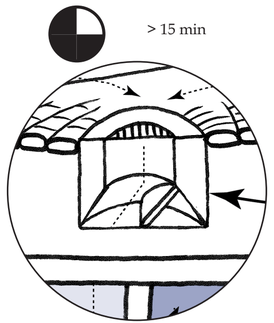


FIGURE 3.5.3: After 15 minutes, the valve in the drain switches so that the now cleaner rainwater runoff can flow into a tank separated from the contaminated rainwater. (Own work)

After the first 15 minutes of the rainstorm, the street and roof contaminants have been washed away and the runoff water is considerably cleaner. This is called the 'first flush'. After the flushing, the switch valve, recognizing the improved quality of the water, changes its position (figure 3.5.3). This allows the cleaner water to cascade into second tank in the tunnel, partitioned from the contaminated water with a vertical wall. From here, it flows deeper into the Ruien.

It is worth noting that while the rainwater harvesting system manages the runoff from roofs and streets, it is separated from the conventional sewers system that handles wastewater from sources such as toilets and sinks. Within the Ruien tunnel, an isolated concrete channel serves as a conduit for the sewer water, effectively maintaining the necessary separation between the rainwater collected into both sides of the tunnel.



Blauwtorenplein

As you continue your way into the city center, your attention is captured by a spectacular sight across the street. A towering fountain bursts from under the ground, shooting water high into the sky (figure 3.5.4). It captivates a group of children standing nearby. Having seen the rainstorm roll into the city, they had eagerly awaited its activation. Altogether they run into the pouring water. Intrigued, you decide to investigate further.

Approaching the fountain, you find yourself standing in a vibrant water square known as Blauwtorenplein. The fountain itself sits in a central circular water pit that serves as the focal point of the square. The significance of the pit becomes apparent as you learn about the history of this place. The contours of the pit reflect the foundations of a historic tower known as the Blauwe Toren, which once stood at this very location. The tower held a vital role in regulating the flow of fresh water from the hinterland creeks into the city center, acting as a sluice complex.

The towering water fountain within the pit serves as a poignant tribute to the memory of the Blauwe Toren and its important role in the city's water management. An engraving of the tower's name in the rim of the pit gives the place an educational character. The underground infrastructure requirements limits the greenery here but the unhardened surface softens the atmosphere and the mist from the fountain cools the air. The semi-hard surface materialization of the square is a soothing sight in comparison to other streets in the city and their monotone concrete slabs. The patios from the surrounding cafes spread onto the square. Metal garden chairs scattered around offer a peaceful place to sit. When the fountain is not operating, the pit becomes a place to sit as well. It becomes a distinct room within the square, providing an intimate place to meet and relax with a group of friends, for example.

>> **FIGURE 3.5.4:** A water fountain burst out of a water pit. Children play in the cascading waterdrops and the mist cools the surrounding public space. The semi-hardened surface is a welcome site for restaurants which extend their patios onto the square. (Own work).

The fountain sources its water from one of the two tanks of the Ruien tunnel that passes underneath it (figure 3.5.5). The priority goes to water from the tank with cleaner water. During wet conditions, the water is sourced from the first tank because it is actively being filled. During dry conditions, however, the water must be sourced from the second tank. Luckily, by this time, the water in that tank has had time to let its pollutants settle to the bottom. This means that the water is also much cleaner and safer to be used for a fountain in a water square. A pump underneath the pit regulates the source and fountain pressure. Via a drain that lines the bottom of the pit, the fountain water is transfered toward a post filtration in helophytes that betters its quality even further. Because of the power of the fountain, there is no greenery directly in the pit. However, the fountain itself provides cooling and the pit is encircled by large (existing) trees that provide shadow (figure 3.5.6).

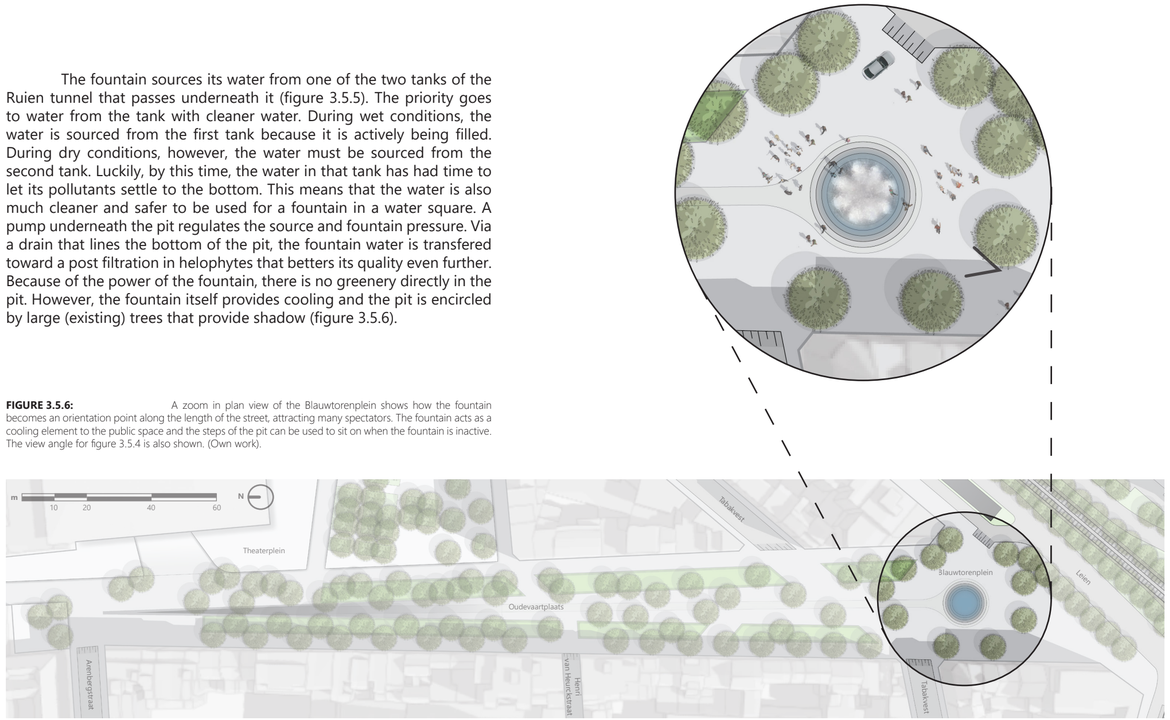


FIGURE 3.5.6: A zoom in plan view of the Blauwtorenplein shows how the fountain becomes an orientation point along the length of the street, attracting many spectators. The fountain acts as a cooling element to the public space and the steps of the pit can be used to sit on when the fountain is inactive. The view angle for figure 3.5.4 is also shown. (Own work).

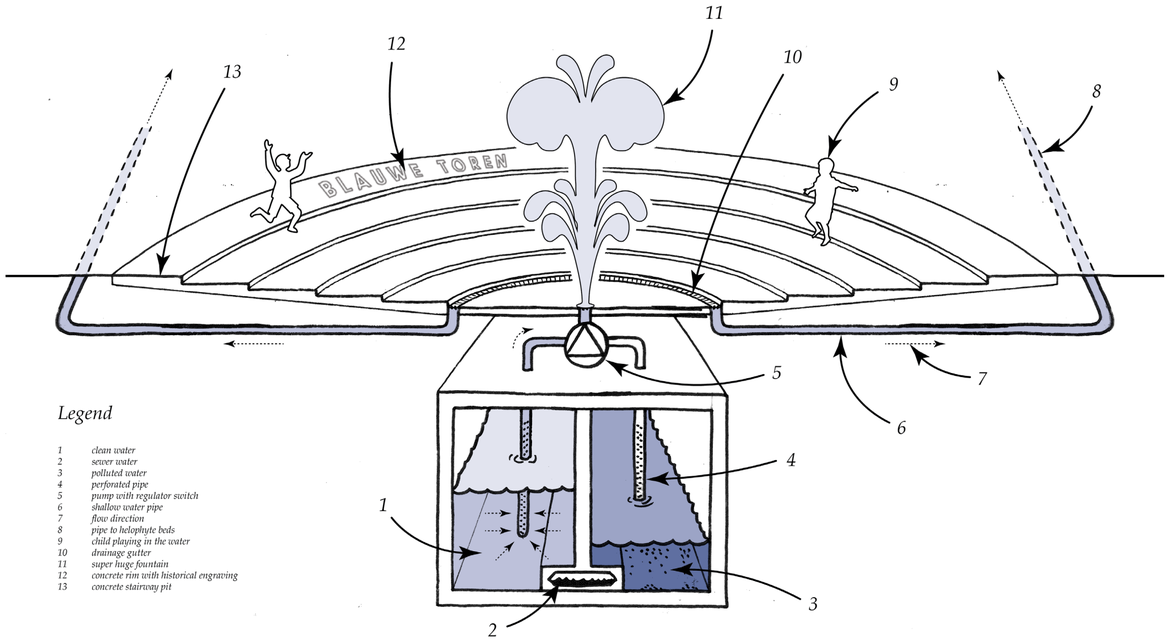


FIGURE 3.5.5: A detail of the water pit shows how the fountain sources its water and how the water continues to the next step of the system. Water is sources from the clean water tank during and after rainstorms. During extreme dry periods, the water is sourced from the more contaminated tank. The suspended particles in the water have had time to settle meaning the water is a cleaner quality than when it first entered. It is therefore safe to use for the fountain. An engraving in the edge of the pit reflects the memory of this location, a historic tower. (Own work).

Oudevaartplaats

Although the water has disappeared back into the underground, the circular edge of the water pit morphs into a long band of street paving that leads down the square. Is the water flowing underneath it? With curiosity guiding your steps, you venture further. It seems like the square is levitating above a landscape that mirrors the beauty of a grassy and flowery meadow. The colorful sight evokes a connection to the historic hinterland, a countryside landscape lost beneath the city. It serves as a subtle reminder that there is an unseen world beneath our feet, a hidden realm that adds depth and intrigue to the urban fabric.

The plants of the meadow landscape are not ordinary. They are helophytes, natural water purifiers, that play a crucial role in the water treatment process beyond the circular water pit. The plants ensure that any remaining contaminants in the water are absorbed, increasing its quality significantly. Their presence adds a touch of ecological balance to the square, attracting insects and birds.

Every Saturday, the suspended square undergoes a transformation as it makes way for the bustling 'Exotic' market that has been held in this very spot for centuries (figure 3.5.7). It is one of the busiest markets of Antwerp and the new greenery and historic reference in the paving enhances the market experience. The rich trading history of the Oudevaartplaats becomes tangible as the area becomes filled with venders, artisans, and shoppers. The meaning behind the long band of paving finally becomes clear: it is the path of the original canal that was used for the transport of goods from the hinterland to this market. The new environment rectifies the historic narratives of the market. The levitating square, with the natural landscape beneath, acts as a bridge between past and present, blending historical narratives with contemporary experiences. The place becomes a stage for new stories to unfold.

>> **FIGURE 3.5.7:** The 'exotic' market is held on the Oudevaartplaats every Saturday. The new space, on each side lined with a bed of helophytes and colorful flowers, enhances the market experience. The dark band in the center not only guides shoppers but is a historical reference to the underlying canal that used to be the trade artery for the market. (Own work).

The helophyte plants adjoining the square have a practical purpose, both for green and blue infrastructure. For the green system it works together with existing trees of the location to form an ecological buffer (figure 3.5.8). The buffer attracts fauna such as butterflies, dragonflies, and swallows. It also enhances the square, offering shadow and a pleasantly scented environment for the market, which has 14 meters width of space (figure 3.5.9). For the blue system, the helophyte plants filter the water from the water pit by having it flow through the roots in the soil bed. The bed is isolated from the existing soil using a layer of waterproof foil so that the water does not infiltrate into the groundwater before it is clean (figure 3.5.10). The flow direction is parallel to the direction of the square so that the water proceeds through the largest area of helophytes. The water also functions as an irrigation source for the helophytes. The Ruien tunnel underneath the square does not play a role in this section.

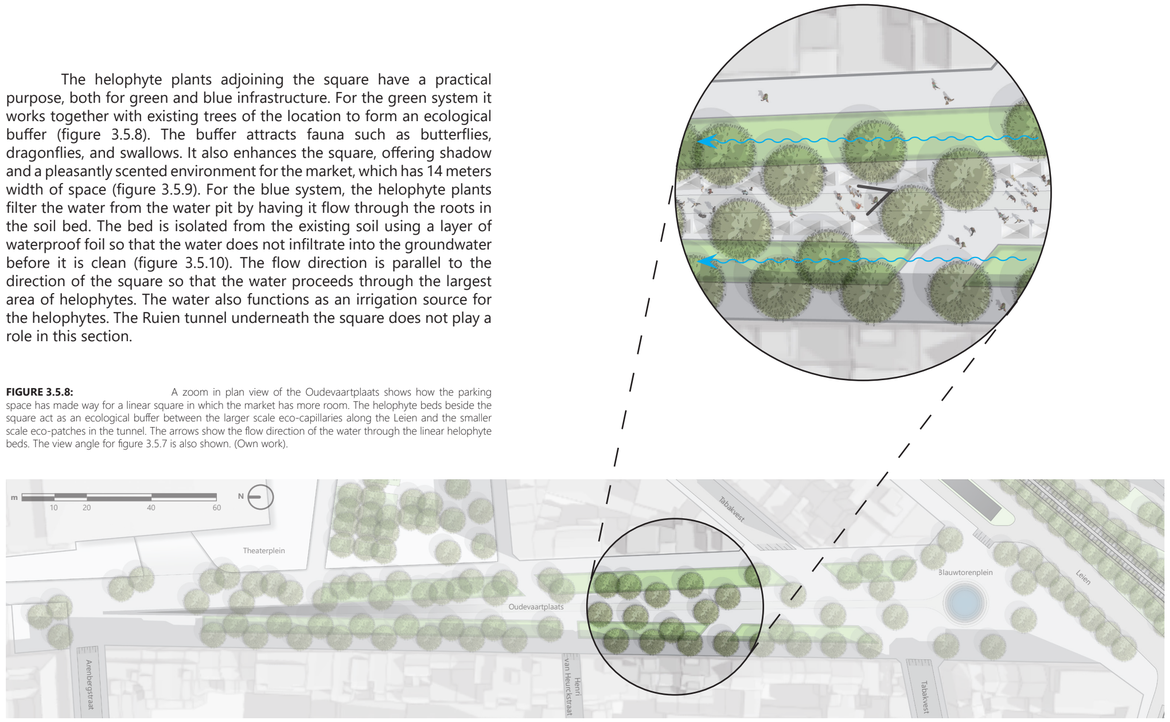
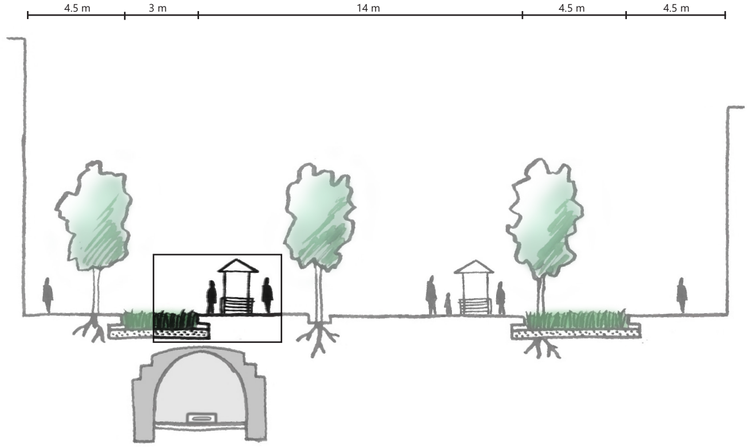
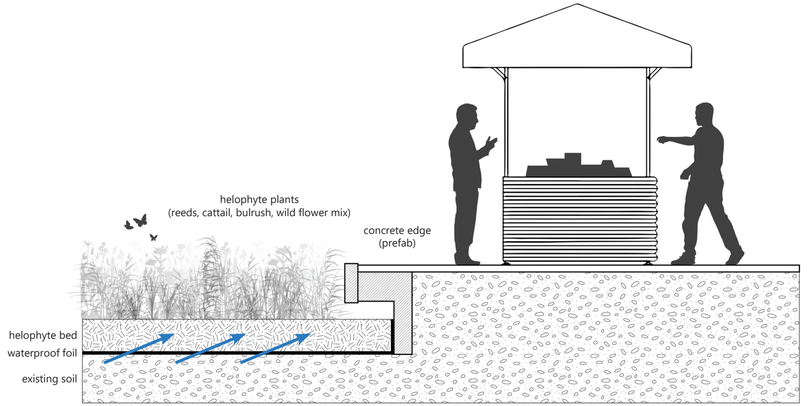


FIGURE 3.5.8: A zoom in plan view of the Oudevaartplaats shows how the parking space has made way for a linear square in which the market has more room. The helophyte beds beside the square act as an ecological buffer between the larger scale eco-capillaries along the Leien and the smaller scale eco-patches in the tunnel. The arrows show the flow direction of the water through the linear helophyte beds. The view angle for figure 3.5.7 is also shown. (Own work).



^ **FIGURE 3.5.9:** Between the trees and the helophyte beds, the market can operate in a peaceful and cool environment. (Own work).



> **FIGURE 3.5.10:** The helphyte bed attracts fauna species that use the space as an ecological buffer. Water from the water pit flows parallel to the direction of the street, through the longest stretch of helophytes. The market square levitates above the helophytes to give a sense of disconnection between past and present worlds.

Theaterplein

Onwards, the levitating square begins to slope downward, triggering a sense of anticipation and intrigue (figure 3.5.11). Diving along with it, you leave behind the peacefulness of the meadow landscape. The water, although it's not visible, is also cascading downhill. It's audible from underneath the path and it becomes louder and louder as you descend deeper and deeper. Immersed by the sight and by the noise, you surrender yourself to the allure of the unknown.

The path folds in on itself, the edges of the square gracefully curving upward into protective walls that guide you. The square, once open and expansive, now embraces you. Further down, the walls become the ceiling and you become immersed within the natural landscape underneath the square. Like a book closing, the walls shut you in and transport you to a new story of the city. With the sounds of the city above fading into the background, they are replaced by a hushed and tranquil ambience.

You have arrived in a tunnel that pierces through the natural world that the modern city was built on. The once familiar surface level of the city gradually becomes a distant memory as you venture further into the hidden world beneath the city. Beyond the portal, the ceiling of articulate but irregular brickwork is lit up by reflected water ripples. The water, finally emerging, is lit up here and there by slivers of light penetrating through small holes from the world above. The historic canal flows under the city like a creek in a cave.

>> FIGURE 3.5.11: The dark band leads to a path that descends into the depth of the meadow landscape that lies beneath the square. The edges of the square curve upward to form a channel that leads into an underground world. It is lined by plant beds that attract various animals like butterflies. At the bottom is the entrance to the underground canals system of Antwerp. (Own work, using elements from Querkraft, 2023).

As the square slopes downward, its edges curve upward to form balustrades (figure 3.5.12). These balustrades incorporate seating elements on their outer side, providing a resting place for passersby, particularly market visitors (figure 3.5.13). While most market visitors arrive on foot, many tourists prefer to come by car. Despite the removal of all original surface parking spots, there are three large parking garages directly adjacent to the square. The modifications to the square do not impede their access (figure 3.5.14). In fact, the interventions streamline the flow of cars by guiding drivers more effectively toward the parking facilities. There is no through traffic anymore: the space is entirely pedestrianized. Nevertheless, the accessibility for market vendors or other occasional logistic flows remains unaffected.

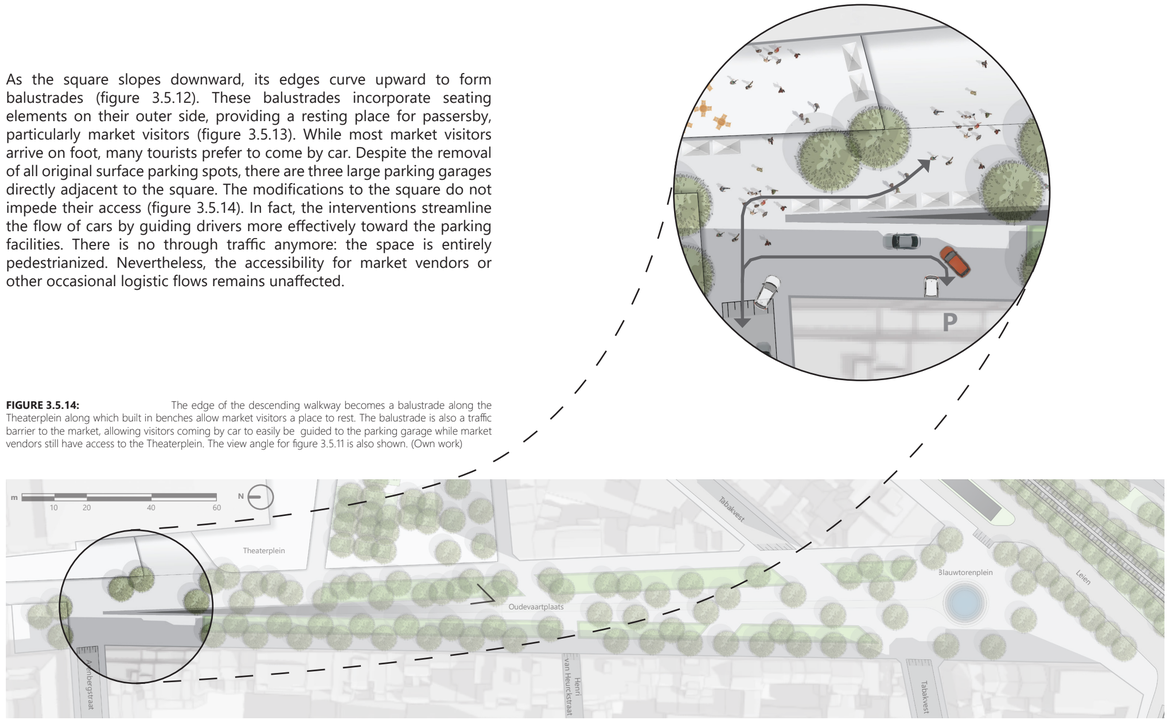
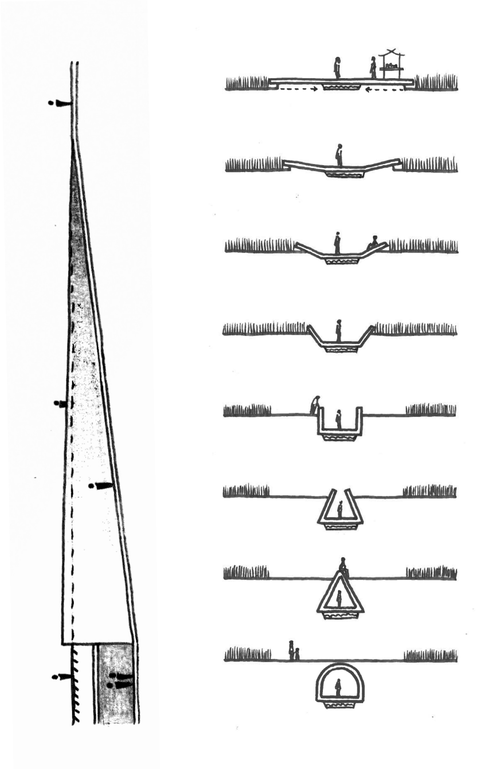
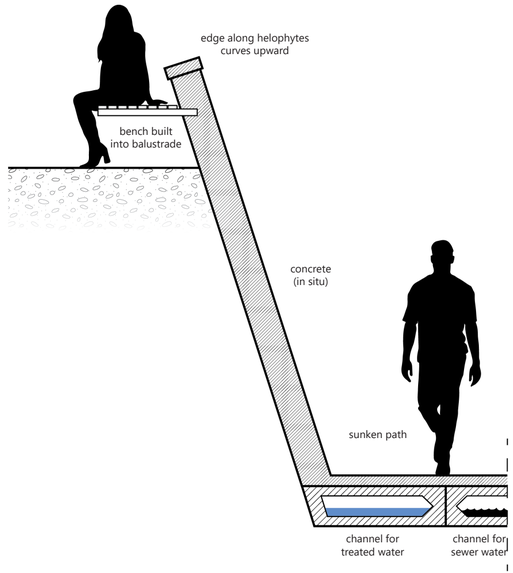


FIGURE 3.5.14: The edge of the descending walkway becomes a balustrade along the Theaterplein along which built in benches allow market visitors a place to rest. The balustrade is also a traffic barrier to the market, allowing visitors coming by car to easily be guided to the parking garage while market vendors still have access to the Theaterplein. The view angle for figure 3.5.11 is also shown. (Own work)





< **FIGURE 3.5.12:** Longitudinal (left) and cross-section (right) of the sunken path: the walkway submerges into the soil and the outer flanks curve upward, forming a wall that morphs into the underground tunnel. (Own work)

^ **FIGURE 3.5.13:** Detail of the sunken path showing built-in seating on the balustrade as well as the separated flow of water treated at the helophytes and sewer water, through isolated channels. (Own work).

Wapperplein

There's light at the end of the tunnel. After a short while through the darkness of the tunnel, we emerge from the underworld into a natural oasis surrounded by urban activity at street level (figure 3.5.15). It is nestled amidst the bustling restaurants and cafes surrounding the crossing of the Wapper and Meir streets. It is here where history and folklore intertwine with the modern day infrastructures of the city, breathing new life into the cityscape. The Wapper and Meir crossing was once home to a swampy fen-lake that served as a vital freshwater source for the city, especially its beer brewers. According to folklore, a mischievous giant called Lange Wapper lived here as well, taunting and teasing the city's residents, escaping through the tunnels.

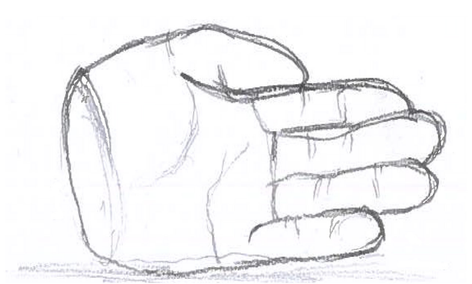
Now, these narratives are re-exposed to the modern city, inviting exploration and discovery. As we gaze upon the giant rip in the urban landscape, the historic world beneath the surface is revealed. Within this subterranean garden, a sense of peace and mystery permeates the air. It is a place where time seems to stand still, as the hustle and bustle of the streets above fades into the background. Lush greenery creates a flourishing buffer zone for both people and flora and fauna groups. The clean water peacefully flows alongside the walkway that is fitted with a giant seating staircase. It's like an amphitheater for the public space. The atmosphere of the space reminisces to the small historic harbor for the hinterland that the Meir lake used to be. The public space below almost feels like a port, as if a boat could appear out of the tunnel and take you on an adventure.

Throughout the enchanting space, various references to the giant's folklore are found, adding an element of fantasy and intrigue. Like the giant seating staircase, an oversized bench invites passersby to unwind in the surroundings, providing a momentary escape from daily life up above. On the wall, a map of the underground canal system shows the layout of the forgotten subsurface world. Lost amongst the lush overgrowth sits a sculpture of a giant hand (figure 3.5.16), as if thrown here by a strong soldier. It gestures you to follow the flow of water and continue further into the tunnels beneath the city, something only a mischievous giant would do.

>> **FIGURE 3.5.15:** The existing square incorporates the underlying canal in a subterranean garden whose mystical ambience radiates onto the street level. From above, passersby look back into the history that lies beneath their feet. Sculptures and maps call them downward for an adventure into a forgotten world. (Own work).

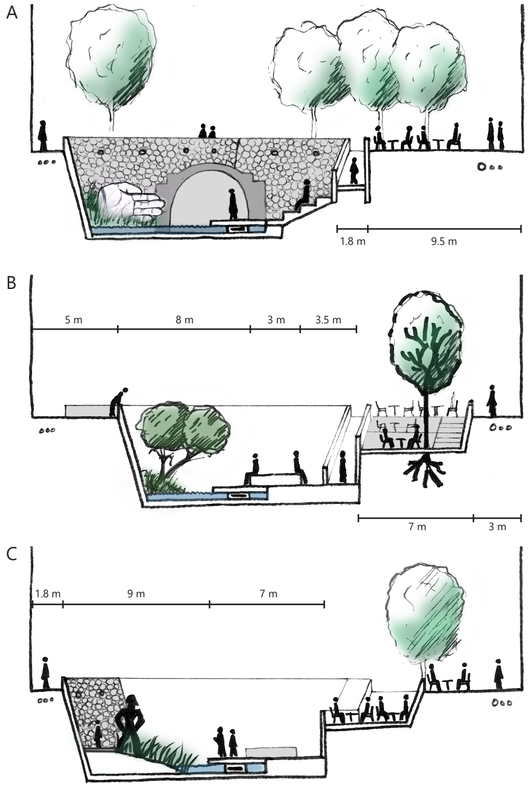
The subterranean garden exposes the interior microclimate of the tunnels to the streetscape. This allows the inherent water and overgrowth to reconquer the space and results in a significant decrease in the urban heat island effect. The tunnel-heads pierce through slanted walls made of large basalt quay-stones (figure 3.5.17). Curioius passersby can peak over the balustrade into the serene world below. The ambience of the the subterranean garden radiates onto the terraces of the surrounding cafes and restaurants in the street. They are offered new space on lowered plateaus to extend their patios. With the right lighting, a tranquil atmosphere for lunch or dining is created. It is a significant improvement to the existing situation (figure 3.5.18) in which most of the surface was hardened and vegetation was placed in planters due to conflicts with the underground tunnel. For pedestrians in the tunnel, the subterranean garden acts as a surface to subsurface access node, with ramps toward street level. The ramps make the tunnels accessible for wheelchairs.

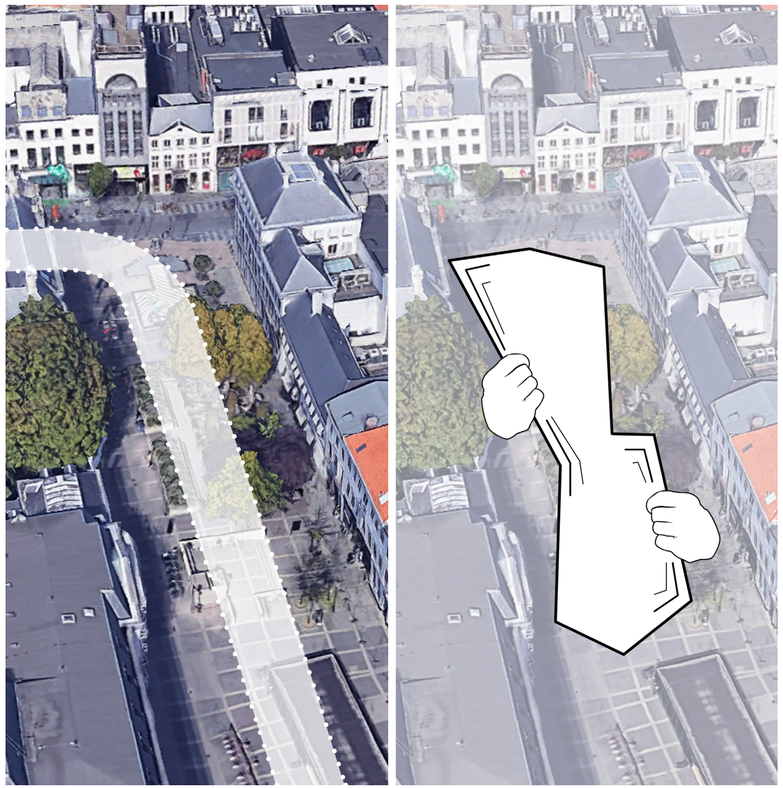
v **FIGURE 3.5.16:** A sculpture of a giant hand sits among the overgrowth like a silent witness to the mythical events of the past: a Roman soldier named Silvius Brabo cut off the hand of a giant who terrorized Antwerp and threw it across the city. It's supposedly how Antwerp got its name - hand werpen. (Own work, adapted from existing sculpture on the Meir shopping boulevard).

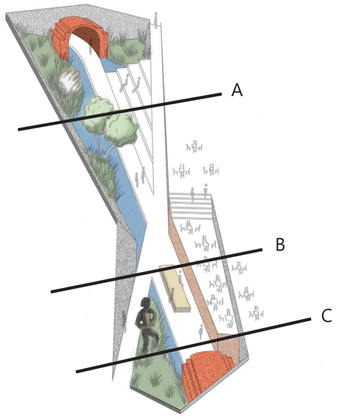


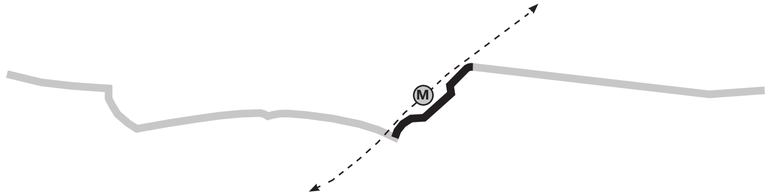
> **FIGURE 3.5.17:** Sections show how the subterranean atmosphere, enhanced with several historic references, radiates seamlessly onto street level via the restaurant patios. (Own work).

>> **FIGURE 3.5.18:** A birdseye view of the Wapper-Meir crossing shows the situation before (left) and after (right). The street is opened in a giant rip to the underlying tunnel (middle). References to the giants, like sculptures, tell their stories. (Own work, adapted from Google, 2023).









Station Meir

As the severed hand lures you further into the natural world beneath the urban world, an unexpected sound breaks the peacefulness – a distant rumble that resonates through the tunnels. It's the unmistakable noise of a metro train. Clearly, the historic canals are not the only tunnels that pass under the city. Continuing our underground journey, we arrive at a metro station beneath the Meir shopping boulevard.

Here, the meeting point between the organic beauty of the canals and the engineered marvel of the station creates a captivating and unconventional juxtaposition. Stepping into the station, our gaze is immediately drawn to the unique image of the overgrown archway and decorative iron gates that frame the natural world we just emerged from. The ironwork reflects the memory of the iron wells that once lined the Meir to source water from the underground canal. The archway is a portal to another realm.

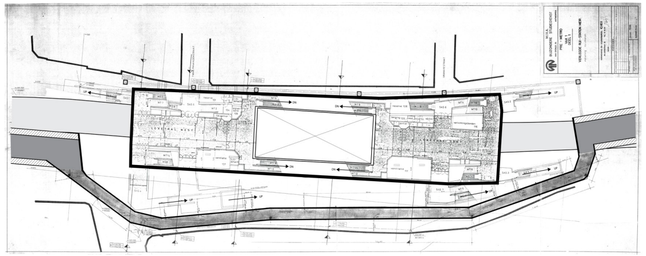
While the presence of the canal may go unnoticed by many hurried commuters, it becomes a focal point of fascination for the observant few. Nevertheless, with the connection to the metro station, the pedestrian accessibility of the city is largely extended. Rather than a rough ride in a typical metro carriage, you can experience a calm walking journey through a lush environment with enchanting historical narratives. You don't have to pay and there's always enough place to sit! (Figure 3.5.19).

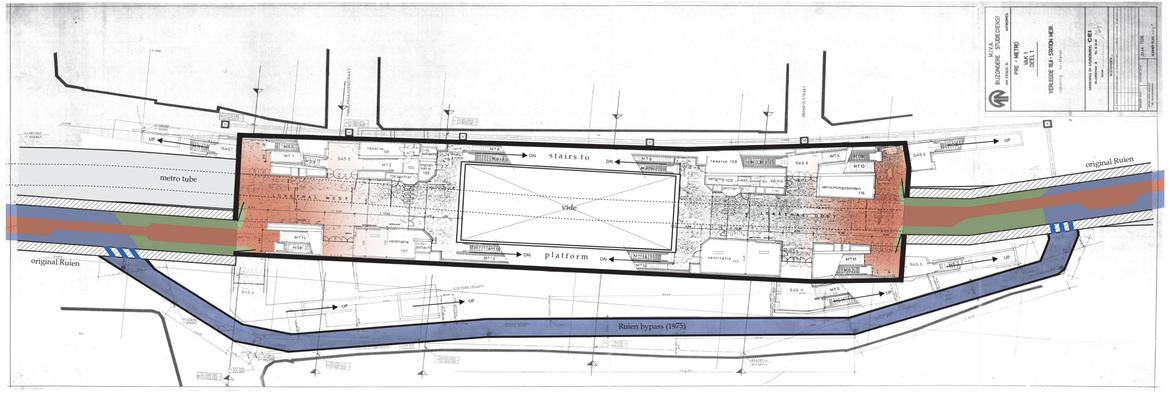
>> **FIGURE 3.5.19:** The metro station underneath the Meir boulevard allows pedestrians to bypass the busy shopping street above. Now, with a connection to the underground canal system, even more of the city is accessible and the mobility infrastructure of the city is incedentally extended. The public space of the tunnel flows into the station, the overgrowth adorning the iron gate that frames the natural world. The enchanting image is in stark contrast to the modern form of the station. Any curious passersby is immediately attracted to escape the busy life ot the modern city. (Own work).

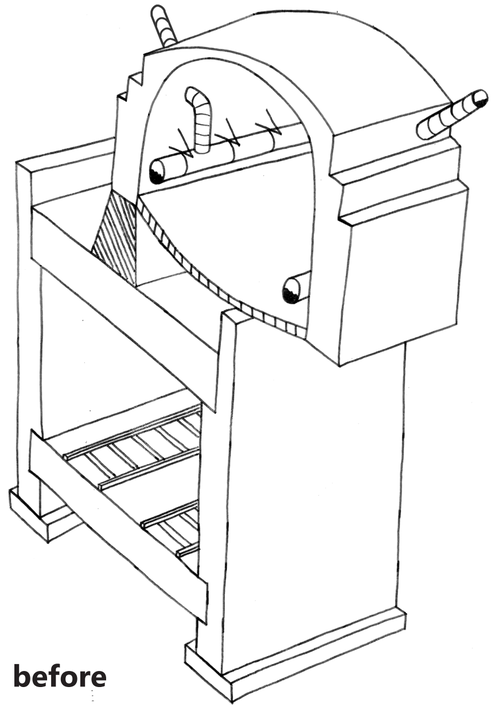
When the metro station was constructed in 1975, a new rectangular concrete tunnel was built do divert the old canal and ensure a continuing flow of the sewer water inside it (figure 3.5.20). Now, however, with the canal accessible to the public, there is an opportunity to connect the two underground networks (figure 3.5.21). The public space within the tunnel can be seamlessly merged with the mezzanine space of the station. The metro station provides convenient access to the surface level through several existing stairways and the existing bypass tunnel is used to transport the water of the canal around the station. To prevent any potential leakage of water into the metro tunnel located below, the cobblestone floor is sealed with a layer of waterproof concrete (figure 3.5.22). To fully justify the memory of the vaulted canals, the sewer pipes are removed from the walls and replaced by a channel hidden underneath but supporting the walkway.

v **FIGURE 3.5.20:** The metro station as constructed in 1975 required a bypass tunnel for the underground canal (De Lijn, 1975).

v v **FIGURE 3.5.21:** The metro station connected to the canal tunnels allows a unique juxtaposition between old and modern (adapted from De Lijn, 1975).







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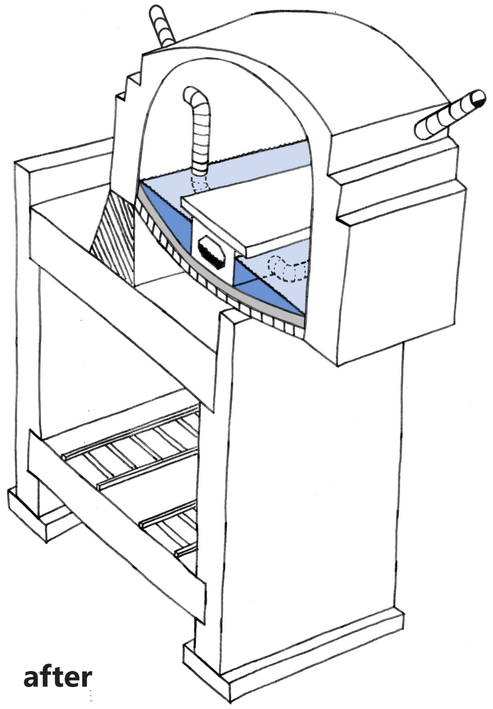


after

FIGURE 3.5.22: A 3D section of the metro and canal tunnnels. For a short distance, the metro tunnel passes underneath the canal tunnel. It was actually partially constructed from within the canal. Because the sewer water flows in pipes (left), there is no leakage threat to the metro tunnel underneath. In the new situation (right), freshwater flows freely through the tunnel, requiring a concrete layer on the cobblestone floor to prevent any accidental leaking. The sewer pipes on the wall are removed in order to enhance the visual aesthetics of the canal. The sewer flows through a concrete pipe underneath the walkway. The walkway itself hides in from view but is also supported by it. (Own work).

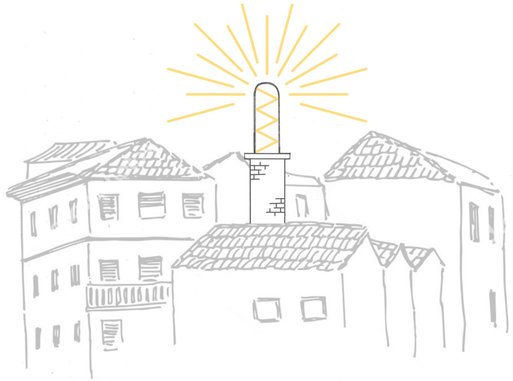
Sint-Katelijnevest

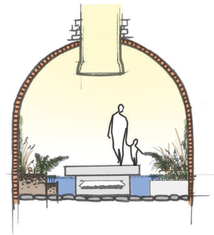
As we step through the portal in the metro station, we return to the enchanted world beneath the city. Water and plants enrich the tunnel, transporting us back in time to a natural landscape concealed beneath the modern streets of Antwerp. Here an ancient creek is reawakened, its waters meandering freely and gently. The walkway alongside it invites exploration and discovery of the depths of the tunnel. Along the way, quiet resting areas emerge, nestled amidst historic air shafts fitted out with cylindrical light shafts. They cast a mystical glow that permeates throughout the tunnel, creating lighter and darker areas.

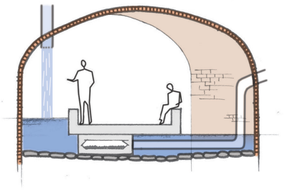
Within the lighter areas, shadows dance across the vaulted ceiling. In the darker areas, shimmering reflections cast ripples on the intricate brickwork. Here, amid the rushing sounds of falling water, we are transported to a world untouched by the hurried pace of the city above. Although we came here to shelter from the rain, you can't help but reach for the water pouring from above. The interplay of light and dark, the juxtaposition of dry and wet, and the contrast of quiet and loud give the tunnels a magical ambience (figure 3.5.23).

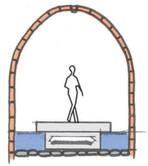
>> **FIGURE 3.5.23:** Back inside the tunnels is a peaceful atmosphere with water flowing across waterfalls and cascading from above. Scattered throughout are rest areas with seating. Light shafts in old air shafts form illuminated niches that stand in mystical contrast with the darker areas of the tunnels. There, reflections on the water highlight the intricate brickwork of the vaulted ceiling. (Own work).

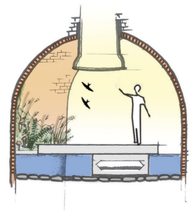
The light shafts are fitted within the historic ventinlation chimneys of the tunnel which reach until high above the housing blocks of the city center (figure 3.5.24). On its top, a simple skylight made of two-way glass captures sunlight from all directions. Its simple cylindrical-domed design does not disturb the skyline of the city. Inside the brickwork shaft, mirrors and additional two-way glass plates guarantee that light is gathered, reflected, and focussed in a downward direction. Emerging at the bottom of the shaft is a translucent pipe. Its shape is reminiscent of the many other pipes that penetrate the structure of the tunnel. From here, the sunlight radiates in all directions into the tunnel, offering a generous amount of light. In some darker areas, artificial lighting illuminates the walkway. The walkway is 1,80m wide throughout the tunnel except at resting spots where they become up to 3,50m wide (figure 3.5.25). The tunnel is not fit for large crowds but wider areas of the space allow pedestrians to pass each other.

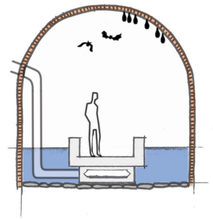


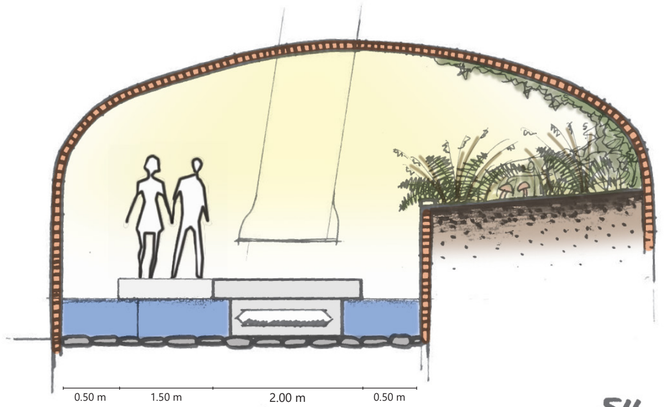












> **FIGURE 3.5.24:** The old air shafts used to ventilate the tunnels are reappropriated as light shafts to illuminate the tunnels. (Own work).

>> **FIGURE 3.5.25:** Sections of the tunnel show the play of light and dark. This creates a suspensful public space. Overall, the walkway is 2m wide with rest spaces with benches up to 3,5m wide. See page 26 for location of section. (Own work).

Sint-Katelijnevest

In the distance, there are more light shafts piercing from above. They guide us and illuminate our path as we venture deeper into the enchanting underground world. Next to this, they play a crucial role in shaping the ecosystem that thrives in this hidden realm.

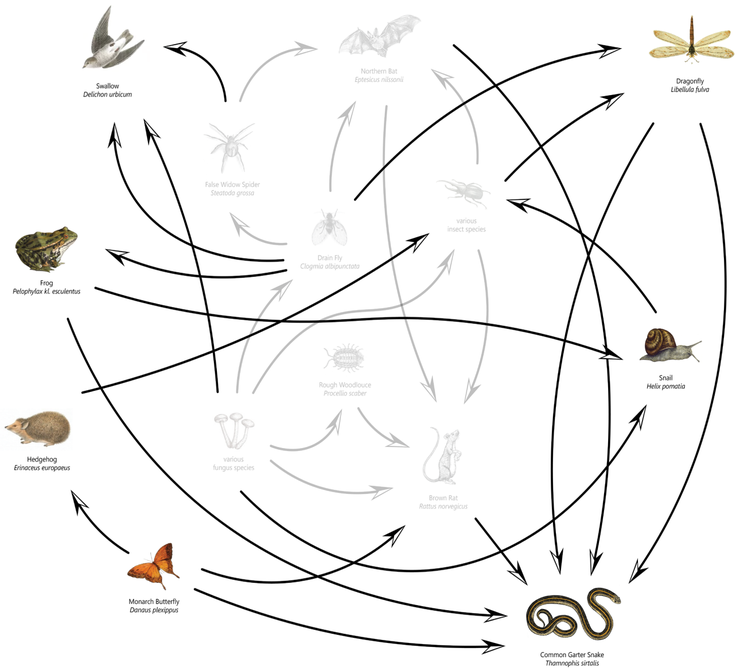
Surrounding the radiance of each light shaft, a vibrant patch of plants and flowers flourish. They thrive in the natural sunlight glow that penetrates from above. The lush greenery acts as a sanctuary for a wide variety of creatures that call these tunnels their home. Some, like bats, rats, and insects, have been longtime inhabitants of this underground refuge. However, the introduction of cleaner water and a source of light have attracted a host of new inhabitants to the tunnels. Birds, butterflies, and frogs, among others, make the flourishing patches of light-basked overgrowth their new urban habitat. Their presence adds a touch of magic to the already charming underground landscape as the croaks of frogs, melodies of birdsongs, and flutters of wings echo throughout the tunnels.

The play of light and dark is mystical for humans but essential to the delicate balance of the ecosystem. Areas with varying degrees of illumination create distinct habitats that cater to the needs of diverse species. Swallows and frogs, finding solace in the more illuminated patches, build their nests and lay their eggs, benefiting from the warmth and the shelter of the plants. Meanwhile, spiders and bats, creatures of the night, thrive in the darker recesses, weaving intricate webs between pipes and hanging from the rainwater stalactites on the ceiling. The interplay between light and dark acts as the catalyst for the entire food chain, fostering a thriving ecosystem in the middle of the city.

Among the eco-patches, spaces for rest and contemplation invite passersby to pause and indulge in the natural world. The seating blocks, nestled amidst the flourishing greenery, offer an escape from the real world. Among the butterflies, one can unwind with a book. It is a peaceful place that allows your thoughts to wander freely (figure 3.5.26).

>> **FIGURE 3.5.26:** Along the rest niches, where light shafts penetrate from above, the existing ecosystem has new opportunity to expand. Additional flora and fauna groups create an enchanting natural environment. Their sounds echo through the tunnels and the step from patch to patch forming a connected ecosystem. The space surrounding the green patches becomes a special place to unwind. The spiders don't bite. (Own work).

The new fauna groups found in the tunnel comprise a diverse range of species such as swallows, frogs, hedgehogs, monarch butterflies, common garter snakes, snails, and dragonflies (figure 3.5.27). These additions integrate into the existing food chain, which includes the northern bat, false widow spider, drain fly, rough woodlouce, brown rat, as well as various insect and fungi species. To ensure minimal disturbance from human activity on the walkway, the eco-patches supporting this fauna group are located at a distance from the walkway construction. Although some of the animals are capable of swimming in the water, they are unable to access the walkway due to the overhang (figure 3.5.28), thereby preventing nuisance to humans. Especially for the rats, a hidden rat niche is built underneath the walkway to keep them out of sight. Seeing a rat, however, adds to the experience! To facilitate the flourishing of the fauna group, the technical aspects involve the incorporation of two soil planters. One planter is submerged underwater, providing a suitable environment for waterplants, while the other is positioned above water, accommodating wall climbing plants. The retaining walls and growth trellis used in constructing these planters are cleverly concealed by the abundant plant growth, remaining hidden from view.

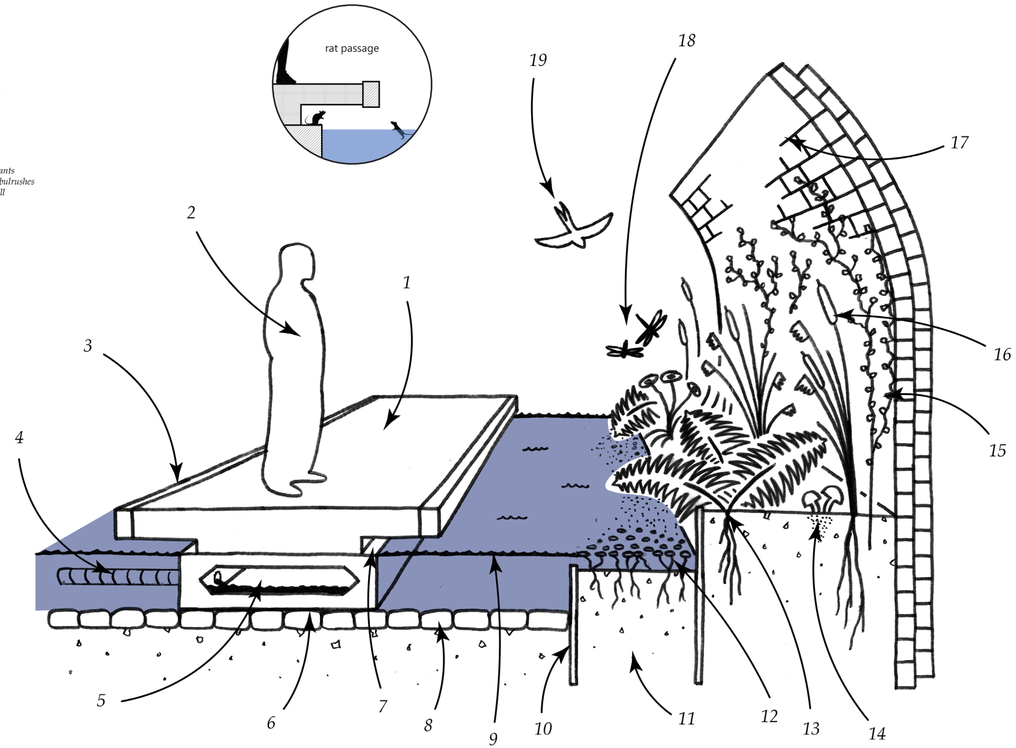


^ **FIGURE 3.5.27:** The new fauna that can enter the tunnel via the openings (colored) are an a addition to the existing ecosystem chain (light grey). (Own work).

> > **FIGURE 3.5.28:** A detail of an ecological patch showing how it flourishes in two planters separated from the walkway. The patch acts as the habitat for the new fauna species. (Own work).

Legend

1 *walkway*
2 *pedestrian*
3 *walkway edging*
4 *sewer inflow*
5 *sewer collector*
6 *cementing layer*
7 *rat walkway*
8 *cobblestone floor*
9 *water*
10 *retaining wall*
11 *soil*
12 *water plants*
13 *ferns*
14 *mushrooms*
15 *wall climbing plants*
16 *reeds / cattails / bulrushes*
17 *vaulted brick wall*
18 *dragonflies*
19 *swallows*



Sint-Carolus Borromeuskerk

As we venture deeper into the vibrant natural world under the city, we encounter a momentary dark spot where the overhead presence of buildings prevents any openings to the surface level. Here, the Sint Carolus Borromeuskerk, a Catholic Church, stands as a silent witness to the historical narratives that intertwine with the subterranean tunnels.

Due to the absence of natural light, this particular location cannot support a flourishing green patch. Nevertheless, the church itself holds a significant connection to the hidden tunnels, providing an opportunity to showcase forgotten urban memories. Throughout the tunnels, secret passages dating from the era of the 80 Years' War are put in the spotlight by strategically placed lighting. The passages are opened up, allowing them to serve as connections to the surface level. Visitors to the Sint Carolus Borromeuskerk now have a chance to peek into the natural layer underneath their feet.

The space surrounding the secret passage is transformed into an educational enclave, dedicated to preserving and sharing the captivating history of Antwerp, the Ruien tunnels, and the hidden passages that intertwine throughout. There are more of these enclaves throughout the tunnels. Others tell stories of encapsulated bridges. An amphitheatre, constructed from bricks that reflect the heritage of the tunnels, serves as a gathering place for passersby to immerse themselves in the educational experience. In this specific niche beneath the Sint Carolus Borromeuskerk, passersby witness a film that unravels the tales of Antwerp's past, exploring the secrets that lie beneath the surface. It invites locals and tourists alike to learn more about Antwerp's forgotten narratives (figure 3.5.29).

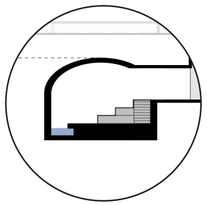
>> **FIGURE 3.5.29:** Where openings to the surface level are not feasible to to overhead buildings, an ecological patch is impossible. However, these darker spaces have the perfect ambience to tell the narratives about the memory of the tunnel system. A amphitheatre-like niche provides seating to watch a short film about the history of the tunnel and its mysterious stories, like secret passages from churches. The secret passage to the Sint Carolus Borromeuskerk is opened to allow tourists a chance to peak into the underground historic layers of the city. The historical space gives the overall public space an educational aspect. (Own work).

The film roll is projected onto the wall of the tunnel from a small projector attached to the wall. It shows an educational video about the history of Antwerp and the Ruien and comprises visuals that tell a complete story, including the connection of the tunnels with the Scheldt River, their origin as creeks, their use as open sewers, their enclosure, the implementation and use of the sluice gates, and their continued fascination by the people of Antwerp (figure 3.5.30). The existing guided tours of the Sint Carolus Borromeuskerk and the Ruien tunnels can be useful contributors to this educational amphitheatre. The amphitheatre sits in a niche in the tunnel, next to the secret passage from the church crypt and between several foundation pillars that line the tunnels (figure 3.5.31). Incorporated into the amphitheatre are steps that allow visitors to move easily between the church and the tunnel. The rainwater continues to flow alongside the pathway.

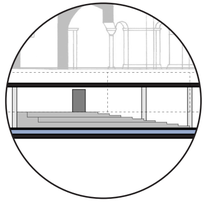
^ **FIGURE 3.5.30:** A film roll showing several important points of the tunnel's history is displayed on the brick wall of the tunnel (adapted from FelixArchief, n.d.)

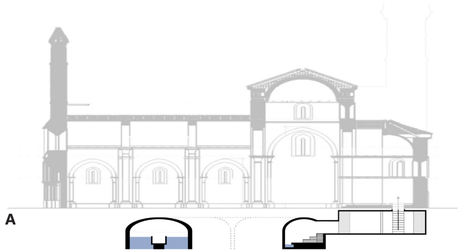
>> **FIGURE 3.5.31:** The re-opening of the secret passage allows the tunnels to become an educational addition to the existing tourism in the Sint Carolus Borromeuskerk (adapted from FelixArchief, n.d.)

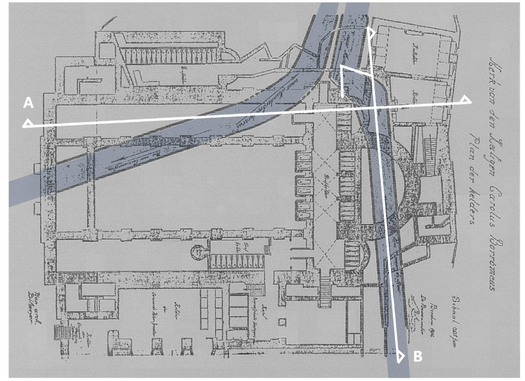
amphitheatre niche
(zoom-in section A)

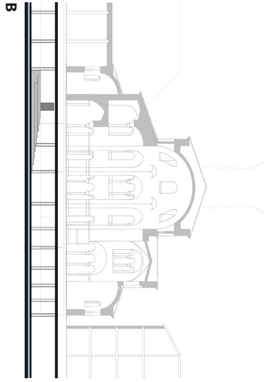


amphitheatre niche
(zoom-in section B)









Minderbroedersrui

In the depths of the tunnel, we stumble upon a peculiar sight: an opening to the surface level of the city, adorned with an overgrown spiral staircase that physically links the old and the new worlds. Like a secret passageway, the spiral staircase extends organically from the embrace of nature in the tunnel, emerging above at a typical streetcorner in the city.

Surrounding the stairwell is a peaceful space. Here, passersby are invited to pause, immersing themselves in the natural ambience. The tunnel is brought to life by the large opening next to the stairwell, which allows natural sunlight to permeate into the depths of the tunnels. Only now you realize that it has stopped raining.

The warm sunrays cast their glow on a thriving patch of overgrowth including reed, cattail, bulrush, pondwater crowfoot, mosses, ferns, sedges, vines, mushrooms, and other houseplant species that can tolerate shadowy conditions. The plants are crucial for keeping the water quality clean as the rainwater flows past and through the soil beds. The lush oasis bursts with life and many species make it their habitat. A frog hides amidst the ferns while dragonflies bathe in the light. Swallows swoop down from opening above, flying through the depths of the tunnel in search for insect food.

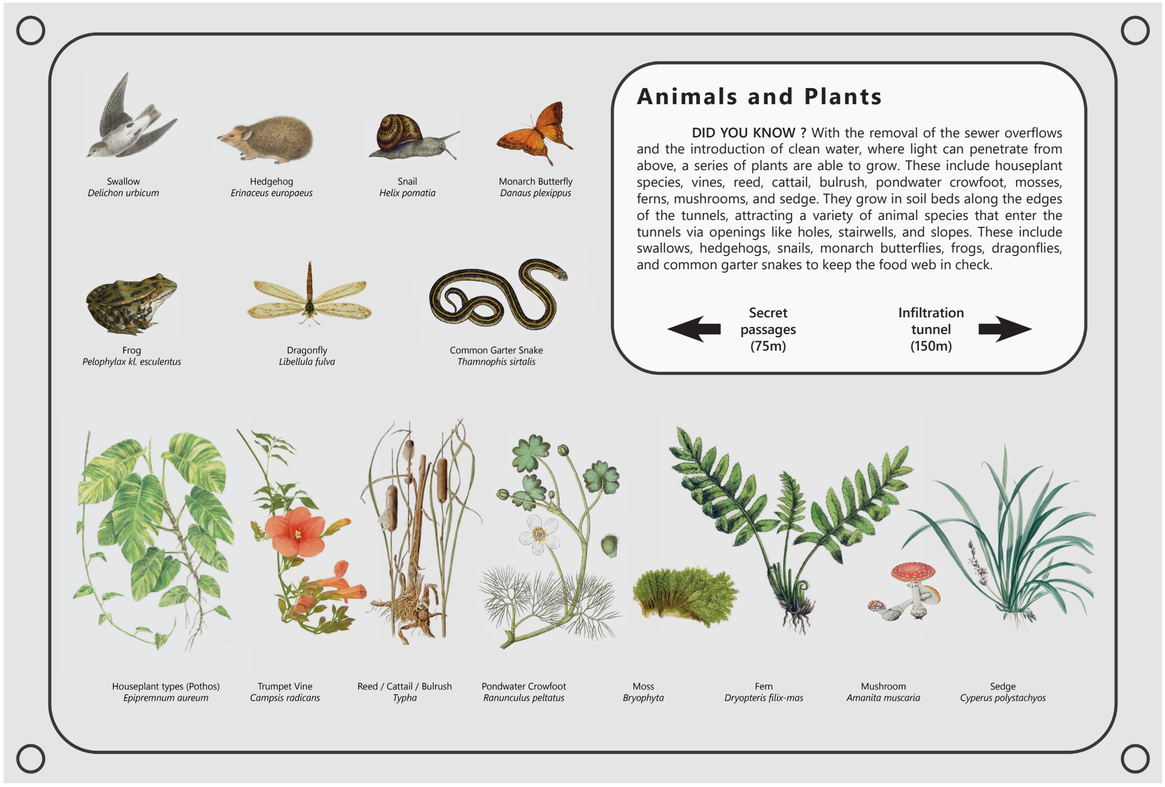
Along the walkway, corten-steel plates with information panels act as wayfinding elements and storytellers, revealing facts about the secrets of the tunnels. The new plant and animal species are listed and a visitor can pause to absorb the knowledge. They become enlightened with the thought of the nature that exists below our feet. Perhaps they'll think differently about their place in the city (figure 3.5.32).

>> FIGURE 3.5.32: Along the way, physical openings to the surface level, fitted with spiral staircases, allow access between the surface and subsurface worlds. The spiral staircase lands in an oasis of overgrowth enchanted by flora and fauna. The flora that thrives in the light are among others, reeds, cattails, and bulrush, which help keep the water quality clean. Interpretive panels give passersby information on the several aspects of the tunnel like the ecosystem qualities and the historic qualities. (Own work).

At street level, on a typical corner in the medieval center of the city, a cylindrical tube protrudes from the depths (figure 3.5.33). Its slender design and oblique position make it look like an object from another dimension. Beside it is a blend of wild and colorful flowers that stand in stark contrast to the monotone streetscape. Upon closer inspection, the overgrowth lines a cavity in the ground, with below the tunnel in which the overgrowth spreads further. The space has become the focal point of the street, serving as a meeting place and orientation point for nearby residents. Passersby can sit on the edge of the opening and listen to the sounds of nature beneath them. Through the stairwell, they gain access not only to the rest of the city but also to a new public space, expanding the possibilities for communal and educational engagement. The interpretive panels are crucial in this (figure 3.5.34).

> **FIGURE 3.5.33:** The spiral staircase emerges at a street corner, the flourishing plant life of the tunnel rising along with it. It's a peculiar sight in the rather monotone streetscape, inviting passersby to take a closer look. The balustrade incorporates seating elements to make the space a place to rest. (Own work).

>> **FIGURE 3.5.34:** Intepretive panels spread throughout the tunnels give insights into the green, blue, place, and memory aspects of the canals. They also provide wayfinding and guiding information. (Own work).



Wijngaardestraat

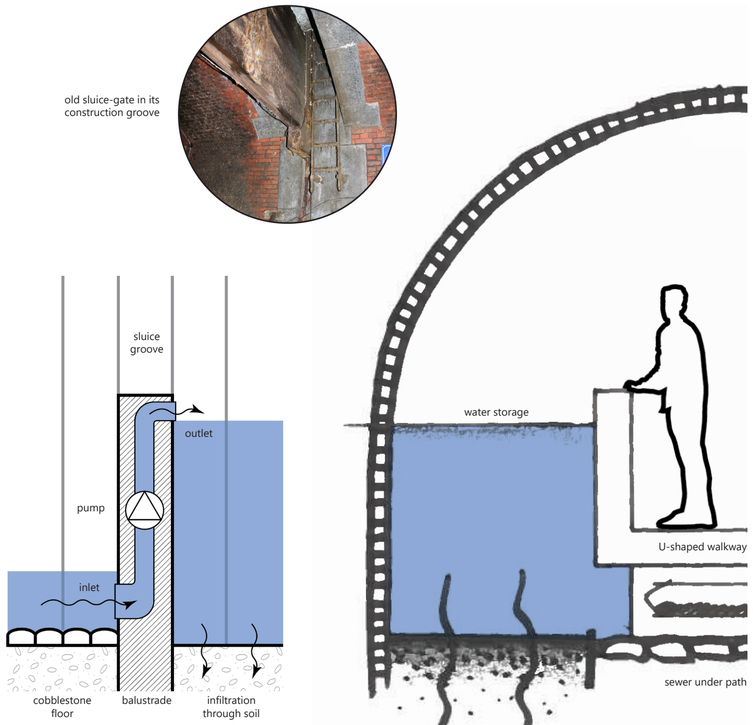
Where the tunnels branch their way further into the subterranean depths of the city, the walkway reaches its conclusion. The water, however, continues its flow beyond. Here, it is stored within an old sluice compartment of the tunnels. For a short distance, the walkway extends into the compartment, surrounded by the collected rainwater. At eye level we have a panoramic view across the surface of the water.

Sunlight penetrates like spotlights from openings above through existing manholes that dot the streets. The beams of light flicker and twinkle as the shadows of cars and pedestrians pass above. Gentle ripples on the water's surface cast shimmering reflections onto the ceiling. The distant darkness of the tunnel is illuminated by their lively dances on the intricate brickwork. It creates a magical ambience, evoking a sense of enchantment. Gazing up through the openings toward street level, you are reminded of the historical palimpsest of the city and the layers that have formed it (figure 3.5.35).

>> **FIGURE 3.5.35:** The walkway (place system) ends where the rainwater must be stored and infiltrated into the groundwater (blue system). The end of the path is a suspensful location as the tunnel continues into the darkness. Natural light penetrating through existing manholes to the surface give a magical atmosphere. The reflections on the water illuminate the ceiling with ripples. (Own work).

The old sluice compartment serves as a collection point for water. The balustrade of the walkway acts as a partition, fitting into the groove of the old sluice-gate construction (figure 3.5.36). The design allows a substantial amount of water to accumulate. Inside the balustrade, a pump transfers water from the preceding sections of the tunnel across the partition and into the storage compartment. The walkway forms a u-shaped channel that extends into the water-filled compartment, the water level reaching to just below its edge. Initially, the cobblestone floor was constructed to prevent contaminated sewer water from seeping into the groundwater. However, due to the bettered quality of the water, the cobblestones can be removed to now facilitate the process. The rainwater gradually infiltrates into the groundwater that sits a few meters below the tunnel. Consequently, the underground freshwater reserves are replenished. Meanwhile, the sewer water continues its flow through the channel beneath the walkway, heading toward the main sewer collector of the city.

The existing manholes, currently covered with metal plates, are replaced by glass plates. This allows sunlight to permeate into the tunnels but also visually captures the attention of passersby. At night, lighting elements within the rim of the manhole light up the holes. The streetscape is enhanced with dots of light that follow the trajectory of the underground tunnel. Inside the tunnel, the rim of the hole also has artificial lighting. As a consequence, at night or when it is cloudy, this section of the tunnel will still be lit up from above (figure 3.5.37).

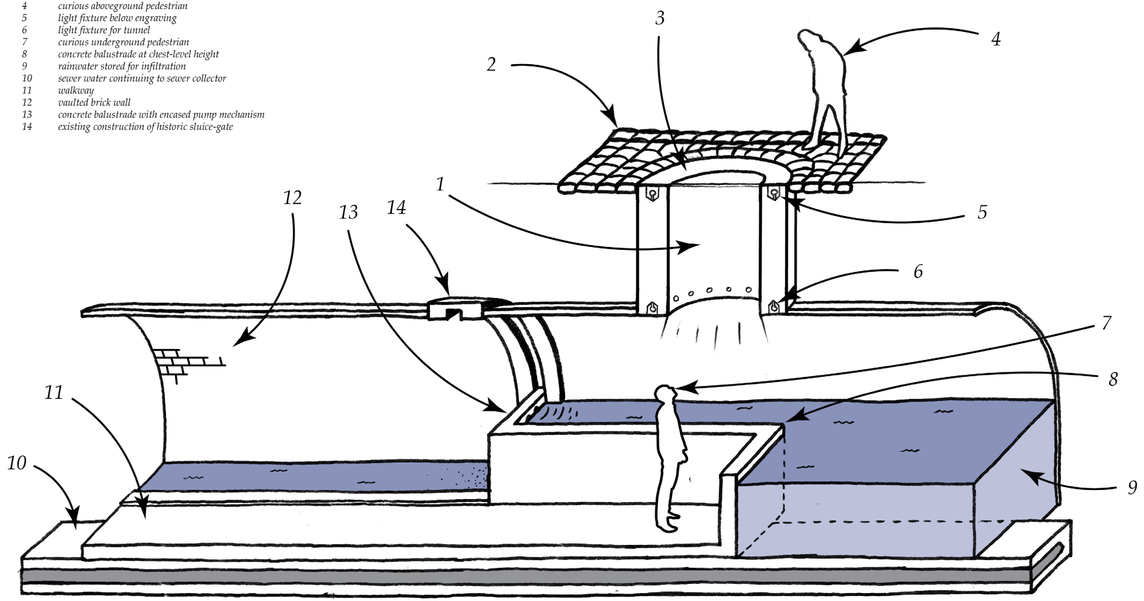


> **FIGURE 3.5.36:** A detail shows how the balustrade of the walkway is fitted into the historic groove of the sluice-gate. A pump transfers water into the compartment in which the cobblestone floor is removed. (Own work).

>> **FIGURE 3.5.37:** A 3D detail shows how the end of the walkway is a U-shaped channel and how existing manholes are opened to allow light to penetrate. The sewer channel continues its trajectory along the floor of the tunnel to the sewer collector. (Own work).

Legend

1 existing manhole as new light shaft
2 existing street cobblestones
3 glass manhole cover with engraved rim
4 curious aboveground pedestrian
5 light fixture below engraving
6 light fixture for tunnel
7 curious underground pedestrian
8 concrete balustrade at chest-level height
9 rainwater stored for infiltration
10 sewer water continuing to sewer collector
11 walkway
12 vaulted brick wall
13 concrete balustrade with encased pump mechanism
14 existing construction of historic sluice-gate



Beyond the midpoint

Beyond the mid-point of the journey, the story essentially reverses. See the following pages for a conceptual visualization.

A: Minderbroedersrui
Continuing, we now travel against the flow of water past several other eco-patches. They, again, flourish in the natural light radiating from lights shafts fitted in the old air shafts. Plants and animals jump from patch to patch, moving throughout the tunnels. It is like the tunnel under the Sint Katelijnevest.

B: Pottenbrug
We arrive at a historic bridge encased in the structure of the tunnel as the canal was covered. Here, the memory value is prioritized and an eco-patch makes way for an educational niche that tells the story of the many bridges that exist throughout the tunnels. It is like the secret passage under the Sint Carolus Borromeuskerk.

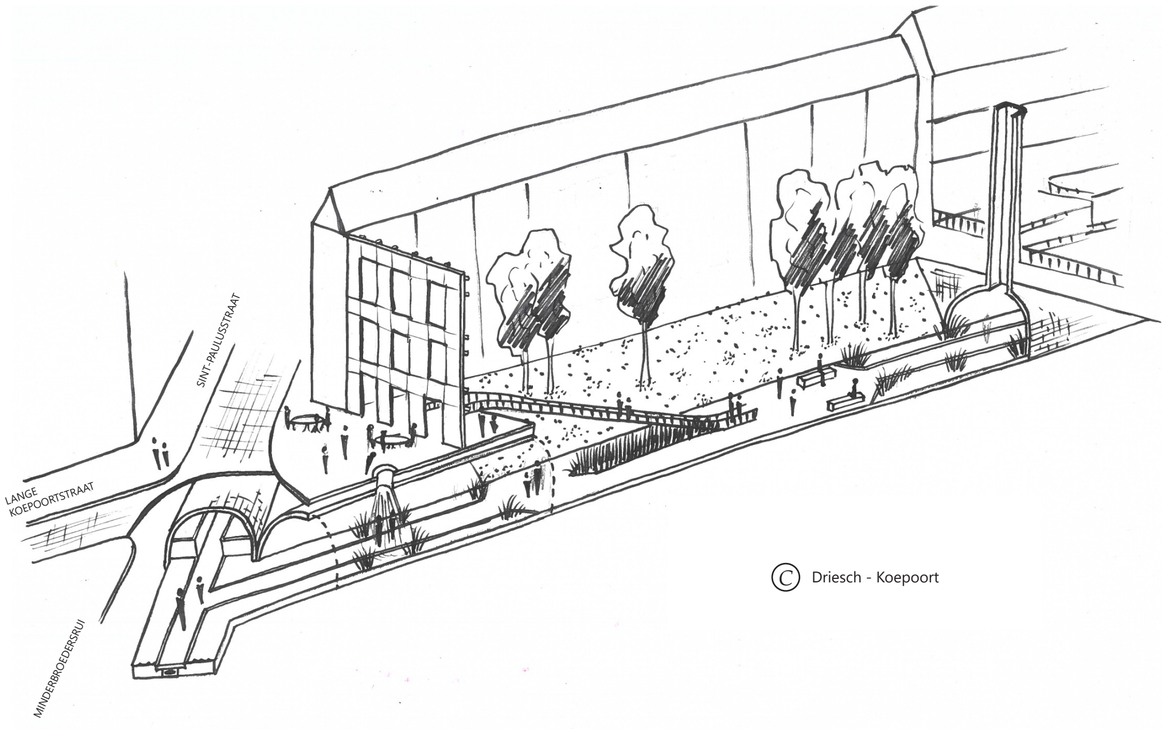
C: Driesch - Koepoort (figure 3.5.38)
Further down we emerge at another subterranean garden, this time in an inner courtyard of a housing block. Hidden behind its false façade is the natural world of underground Antwerp. It is again a mystic but enchanting site where stories of the historic swamp lake at this location come alive in an intimate setting with restaurants and cafes. It is like the uncovered tunnel at the crossing between the Wapper and Meir streets.

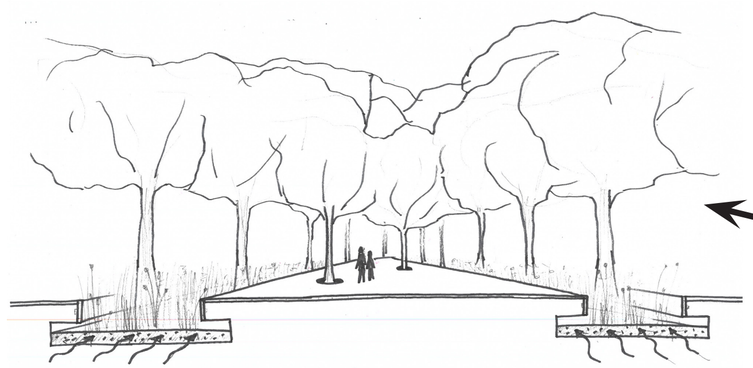
D: Falconplein (figure 3.5.39)
After a short passage, there is once again light at the end of the tunnel. Like opening a book, the tunnel unfolds itself and we open up toward the modern-day chapter of the city. Back on the surface, we arrive at another historic market square, again levitating above a meadow of helophyte plants. It is like the descent into the tunnel from the Oudevaartplaats and Theaterplein.

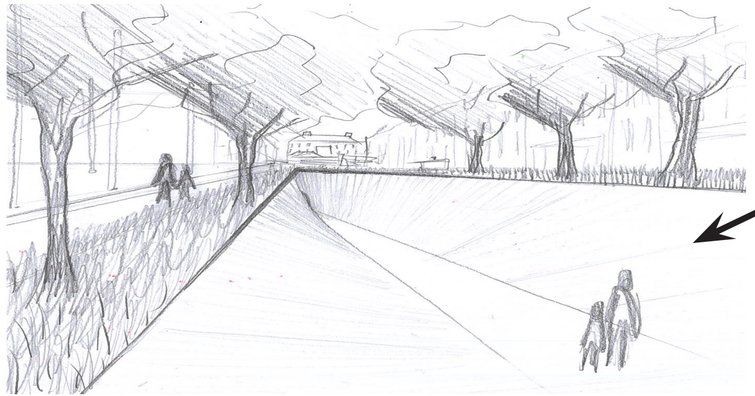
E: Brouwersvliet (figure 3.5.40)
Once more, at the end of the square, a water fountain shoots up from below out of a circular pit. The water pit sits on top of a canal that regulated freshwater inflow to the many beer brewers of the city. Nowadays, the water pit regulates the flow of rainwater collected from surrounding street gutters, directing it into the helophyte bed and into the tunnels. It is like the fountain at the Blauwtorenplein.

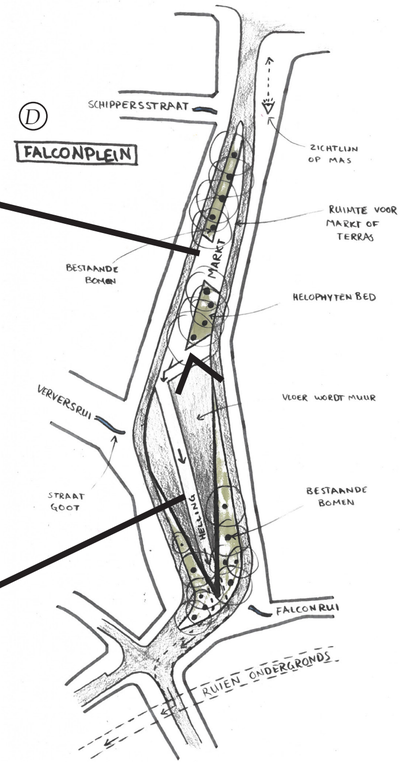
F: Tuinstraat - Museum aan de Stroom
Beyond the fountain, the network of street gutters is once again visible. They continue to harvest the rainwater that falls nearby. Again, its meandering trajectory alludes to the historic creeks of the natural landscape that supplied the inner city with a freshwater source. It is like the gutters at the tuinstraat by the Stadspark.

FIGURE 3.5.38: A 3D cutaway shows how a housing block sits atop the underground canals at the Koepoortbrug. Historically, this location was the Driesch floodplain. The private courtyard of the housing block is transformed to a public subterranean garden: and escape from the city into the uderlying nature, reminiscent of the garden at the Wapperplein. (Own work)



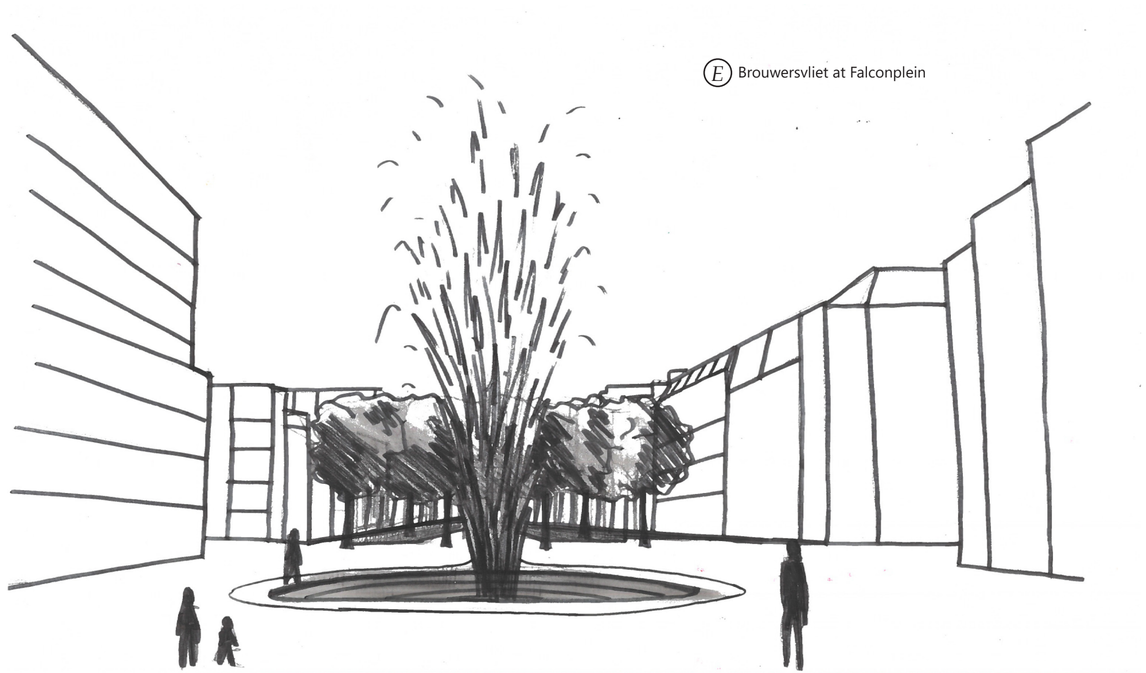


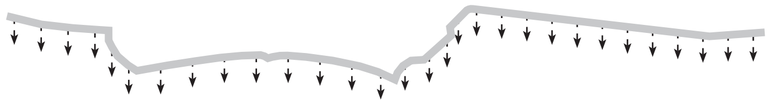




<< **FIGURE 3.5.39:** The Falconplein (plan view, right) is transformed to reflect the same narrative as the sequence Oudevaartplaats-Theaterplein. The existing market finds new life on a square levitating above a bed of helophytes acting as a rainwater filter and an ecological buffer (impression drawing, top left). The descent into the tunnels is accentuated by a sloping path that folds in on itself, the walls slowly curving upward and morphing into the underlying tunnel (impression drawing, bottom left). (Own work).

v **FIGURE 3.5.40:** An impression drawing of a water pit with fountain, similar to the one at Blauwtorenplein. The water square sits atop of the Brouwersvliet which regulated the ditribution of fresh water to the city's beer brewers. The fountain now regulates the inflow of collected rainwater into the depths of the underground tunnels. (Own work).





3.5.2 Embedment in the urban fabric

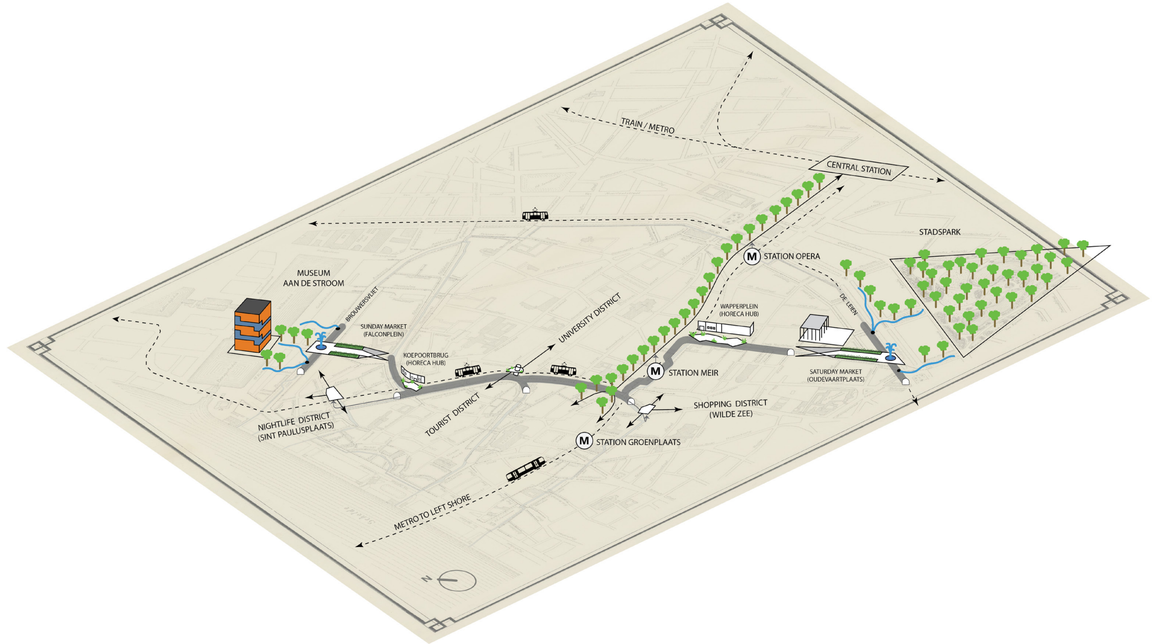
>> FIGURE 3.5.41: A an axonometric view of the canal network shows how it is incidentally connected to elements of the urban fabric like the metro station, the city park, and the city museum. (Own work).

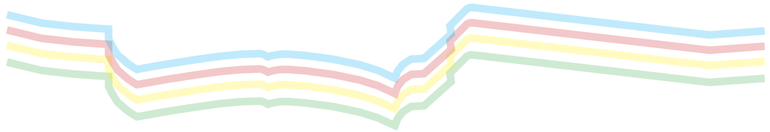
Antwerp Unearthed, as a masterplan is securely embedded within the infrastructural systems of the city. The previous sections have made that clear.

The problems, as indicated in the inventory section, are all relieved to some extent. The problems that could not be fully mediated via the required principle find rectification in other aspects of the design. For example, heat stress required the opening of the tunnel in order to stimulate plant growth at surface level. This, however, is not possible where buildings are located overhead or where the blue infrastructure takes a leading role. Nevertheless, water also has a cooling capacity. The fountain and Blauwtorenplein and Brouwersvliet are good examples of heat stress, a green issue, being mediated by blue infrastructure. The same phenomenon applies to the ecological patches: where they were hindered to to limits in lighting, the ambience proved useful for memory infrastructure. The educational niche underneath the Sint Carolus Borromeuskerk links the memory system of the tunnel with the memory system aboveground. The balance between the four infrastructure themes leads to an overall justified embedment of the infrastructures in their existing urban systems.

On top of infrastructural mediation, the Antwerp Unearthed extends integration to other facets of the city, further enhancing its value for Antwerp (figure 3.5.41).

One manifestation of this is the fact that the underground system acts as a pedestrian route through the city, passing under some of the busiest streets. Notably, it passes under the Meir, a shopping artery connecting the central station to the medieval core. It is the busiest shopping street in Antwerp and is often frequented by tourists. Additionally, the tunnel passes under the Minderbroedersrui and the Sint Katelijnevest, crucial public transit corridors for buses and trams. Street level is not walkable but with the underground pedestrian tunnels, the walkability of the city is improved. Antwerp Unearthed also establishes a connection between two of the city's most prominent attractions: the city park (Stadspark) and the city museum (Museum aan de Stroom). The underground walkway linking these locations becomes an extended part of both public spaces, embedding them more into the core of the city instead of its periphery. With several inner city entry points, the park and museum become better accessible. Furthermore, the underground system links itself to the city's metro network, specifically at the Meir Station. Considering the bustling nature of the Meir as a popular tourist and shopping destination, the subterranean pedestrian connection provides an alternative route for non-shoppers and metro travelers, like residents from the outskirts of the city, to bypass the crowded street. They can perhaps take the tram or bus by exiting the tunnel at the Minderbroedersrui or Sint Katelijnevest, vital transit corridors as mentioned previously. Overall, the public transit accessibility throughout the entire city is expanded. Moreover, the underground system facilitates connectivity with key districts in Antwerp, such as the nightlife district, shopping district, and university district. Primarily catering to young people and student residents, these districts are the primary beneficiaries of the tunnel network. The connection to the public transit system is an added value for this target group. However, a disadvantage is that this user group can cause nuisance within the tunnel and hinder the functioning of the infrastructure, like the green system (eco-patches). A surveillance system or opening hours is needed within the tunnels to prevent unwanted activity. At the Wapperplein and the Koepoortbrug, the surface level openings to the tunnel contribute to the ambience of the streetscape, harmonizing with the historic atmosphere of the city center. This atmosphere revolves around medieval history, folklore, and narratives associated with the city's historical relationship to the Scheldt River. It adds to the existing atmosphere of surrounding cafes and restaurants (horeca) at street level. The greenery of the space flows seamlessly together ith the street trees along the Meir boulevard drawing in shoppers and tourists for a rest. With this additional target group, Antwerp Unearthed becomes a network for all people of the city.





3.5.3 Phasing strategy: phasing by theme

In order to realize this project, it is important to approach it by means of a phasing strategy. The phasing can be done in two ways. The first is by means of theme (from most effective to least effective theme):

1. blue > place > memory+green (figure 3.5.42).

- Blue: Although all four infrastructure themes (green, blue, place, and memory) are represented throughout the tunnel system, some themes are better justified than others. This is particularly true for the theme of blue because its criteria rely on a cycle with inputs (rainwater) and outputs (infiltration). Removing a single part of the blue infrastructure would result in the entire blue system being disabled. It is necessary that the blue system works as is intended and it should therefore be completely implemented in the first stage.

- Place: The next most important infrastructure system in the phasing by theme is the place system. This is because its features influence the remaining systems. Memory can only come to fruition if there is a space to do so: the place system offers this with educational zones, for example. Green can only come to fruition if there are openings to the surface level for flora and fauna to enter: the place system offers this with stairwells and other openings, for example.

- Memory + Green: Memory and green are both dependent on the operation of the place system. If there are many visitors, the memory system will operate to the best of its ability. However, in this case, the green system will operate less due to possible ecosystem disturbance. On the other hand, if there are not many visitors, the green system has better potential to come to fruition while the memory system is less represented. This has design consequences for the place system: certain parts of the tunnel may have to be sectioned off from pedestrians in order to allow better operation of the green system.

Another possibility in phasing by theme is to only reserve the tunnels for either blue+green or place+memory. These combinations have proved to give the most harmonious interactions (see optimization phase: they naturally build upon and strengthen each other.

FIGURE 3.5.42: Phasing by infrastructural theme. Blue has the most impact and should be phased first. Place provides the conditions for memory and green and should be phased second. Memory and green can be phased together because their operation is reliant on the amount of visitors to the tunnels. (Own work).

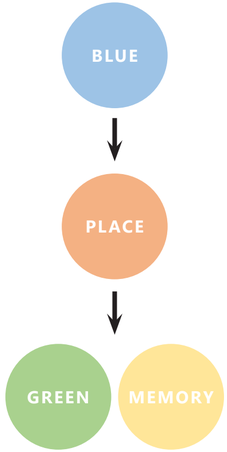
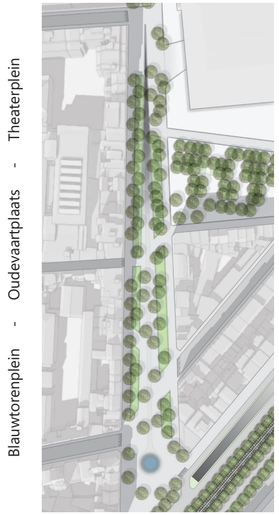


FIGURE 3.5.43: Phasing by location. The location Blauwtorenplein - Oudevaartplaats - Theaterplein can be initiated as a pilot project because it contains the vital components of each infrastructure theme (green: eco-buffer / blue: regulating, treating / place: public space, node / memory: restoration). (Own work).



Phasing strategy: phasing by location

Another way that this project can be phased is by means of location. The location can act as a pilot project that can be used to prove the viability of how the infrastructure themes work together:

2. Blauwtorenplein - Oudevaartplaats - Theaterplein (figure 3.5.43).

The sequence Blauwtorenplein-Oudevaartplaats-Theaterplein is without a doubt the most important sequence in the entire system for all infrastructure themes.

- For the theme of green, this location contains an eco-buffer of helophyte plants and trees that sits between the eco-capillary existing along the Leien Ring Road (beyond the water pit at Blauwtorenplein) and the existing ecological biotopes within the tunnel (beyond the tunnel entrance at Theaterplein). The location offers a useful stepping stone for flora and fauna from larger scale eco units to smaller scale eco units. The exposed ground surface is also significant for the reduction of heat stress, along with the fountain (blue) at Blauwtorenplein.

- For the theme of blue, this locations contains the regulating and treating of rainwater, both necessary for a post-infiltration to groundwater. Although existing Garden Streets at in the rainwater harvesting process, the water pit at Blauwtorenplein can easily capture rainwater from nearby as well. To finish the system, the bottom of the tunnel entrance at Theaterplein can easily be adjusted to allow for the infiltration of rainwater.

- For the theme of place, this location contains a water pit that transforms into a water playground and a square that transforms into a market space. There is also the public space node between the surface and subsurface. Overall, the public space is significantly enhanced. At the water playground, a fountain offers children a place to play during hot summers. At the market space, vendors and shoppers have a less car-oriented environment to stay.

- For the theme of memory, this location contains references to the historic hinterland canal that brought trade products and fresh water to the inner city. The towering fountain at Blauwtorenplein alludes to the memory of the sluice-complex that stood there. The sloping path reminds a visitor of the canal underneath their feet.

This chapter presents the answer to the research question in a discussion of the findings (4.1), their relevance (4.2), their limitations (4.3), and the recommendations (4.4).

4 discussion

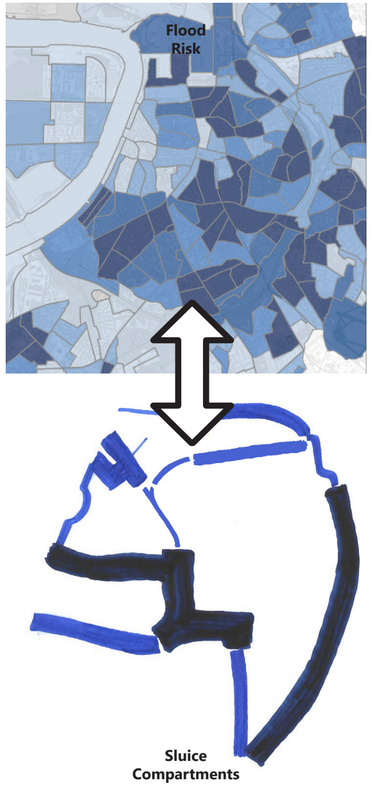
4.1 findings

This report questions how the reappropriation of the decommissioned underground canal system in Antwerp can spatially mediate the city's future urgencies regarding environmental and social infrastructure, specifically those falling under the umbrella themes 'green', 'blue', 'place', and 'memory'. A design experiment (Antwerp Unearthed) provides two answers:

- By pairing external problems with internal potentials
- By forming a singly functioning infrastructure system

PAIRING EXTERNAL PROBLEMS WITH INTERNAL POTENTIALS

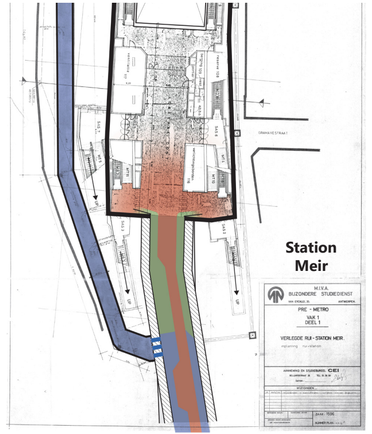
Antwerp Unearthed pairs external problems with internal potentials. The external green, blue, place, and memory urgencies of the city find relief in internal green, blue, place, and memory qualities of the tunnels: heat stress is relieved by the confined microclimate, ecological struggle is relieved by the natural biotopes, flood risk is relieved by the sluice compartments, water scarcity is relieved by the floor construction, congestion strain is relieved by the unimpeded layout, leisure deficiency is relieved by the vacant floor-area, identity depreciation is relieved by the lingering narratives, and heritage decline is relieved by the physical relics. By enhancing existing qualities, a natural and self-reliant management regime is adopted. This is more effective than creating new potentials that demand a more intense and supervised management regime. In order to pair a problem with a potential, they need to be of the same nature. Although the tunnels have many other qualities, their characteristics did not provide opportunities for the major infrastructure issues of the city as inventorized. It is necessary to find the right quality by means of a thorough analysis phase. For example, qualities related to water are, as expected, opportunistic for issue related to the city's blue infrastructure (sluice compartments > flood risk, figure 4.1.1). It is also possible that one quality works toward the relief of several infrastructural urgencies. These come to light during the integration phase. For example, qualities related the unimpeded layout primarily benefit congestion strain (place infrastructure) but also aid in providing unobstructed connection between ecological patches (green infrastructure) and a free flow of water (blue infrastructure). Water (blue infrastructure) can also be used as a cooling feature in fountains, tanking over the purpose for green infrastructure. It is also possible that a quality does not provide the expected relief. For example, the utilization of the confined microclimate of the tunnel for the relief of urban heat stress, developed more into of a service providing cooler temperatures then actually decreasing temperatures at street level. Initially, the opening of the tunnel was to expose the internal microclimate to the city and therefore decrease external urban temperatures. However, the effects are most likely insignificant.

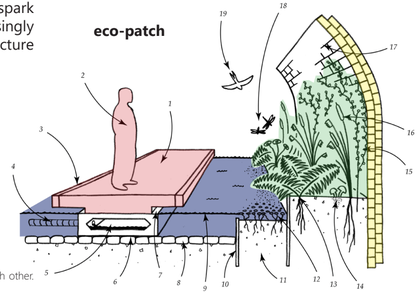


> **FIGURE 4.1.1:** The flood risk (external problem) has been paired with the sluice compartments (internal potential). The sluice compartments are a historic quality that allows a certain volumetric capacity of water to be stored. By allowing rainwater to collect in the underground compartments, flood risk at surface level is reduced. (Own work).

FORMING A SINGLY FUNCTIONING INFRASTRUCTURE SYSTEM

Antwerp Unearthed forms a singly functioning infrastructure system. The typically separated green, blue, place, and memory systems are merged into a single green-blue-place-memory system. The infrastructural systems build upon and are reliant on each other. The biotope patches are an example (figure 4.1.2). Although they function primarily for flora and fauna use in the green system (relief of ecological struggle), the specific use of helophyte plants helps work toward bettering water quality in the blue system (relief of freshwater scarcity). The same vegetation accentuates the space and contribute to a pleasant ambience, serving as important components for the place system (relief of public space deficiency). The use of plant species inherent to the natural ecosystem of the canals gives it prominence in the memory system (relief of identity depreciation). In the end, a planted patch is not just a green element but a comprehensive green-blue-place-memory component. Another example is the walkway in the tunnel. It functions mainly for human use in the place system (relief of congestion strain), but because the sewer pipe runs through a channel underneath it that supports it, it also functions for the blue system. Because the sewer pipe is hidden underneath the path instead of flowing through intrusive pipes on the walls, the walkway also enhances the memory system (relief of identity depreciation). In this case, the walkway does not provide extra qualities for the green system. At the Meir Station, all themes seamlessly flow together (figure 3.4.2). By merging multiple infrastructure systems, a larger and more effective infrastructural capacity can be facilitated in a smaller and more resourceful amount of urban space. This is more efficient than finding new space which will demand a more time and cost consuming construction process. By reappropriating an existing underground structure as a single green-blue-place-memory system, this second layer of the urban fabric becomes tangible. The unconventional mix between nature based, water based, human based, and narrative based infrastructures form a new world within the city, linked to the rest of the city in various ways. For example, the connection of the underground public space with the public transit arteries of the city (Station Meir, Minderbroedersrui/ Sint-Katelijnevest), makes it an integral part of the mobility infrastructure system of the city as well. In the case specifically for Antwerp, the underground pedestrian route connects two main attractions of the city: the Stadspark and Museum aan de Stroom. This makes the design an integral part of the tourist infrastructure as well. A singly functioning infrastructure system provides beneficial side effects for the embedding of additional infrastructure aspects of the city.





> **FIGURE 4.1.2:** The elements of the four infrastructure themes seamlessly synthesize into a single infrastructure system, building upon each other. Removal of one of the components would result in the entire system falling apart. The eco-patches and the metro station connection are an example. (Own work).

4.2 relevance

Antwerp Unearthed reappropriates a decommissioned underground canal system in order to mediate infrastructural pressures in a spatially impoverished urban fabric. Antwerp is not alone in regard to these infrastructural and spatial issues. As the problem statement mentions, this is a global phenomenon, especially in historic cities which have evolved with little thought for changing spatial needs and conditions. Antwerp is also not alone when it comes to unused historic structures that take up valuable space in the underground. An exploration into some of the oldest cities on earth reveals a wide variety of hidden but vacant subsurface structures covered and forgotten during periods of urban growth and expansion. The structures range from ancient ruins to passageways and culverted creeks (figure 4.2.1). Using Antwerp Unearthed as a case study, landscape architects around the world have a demonstrative model for how to pair the internal potentials of unused underground structures with the external problems regarding infrastructure in the city and accordingly form a singly functioning system. In this way, the design approach as outlined in this research is societally, scientifically, and professionally relevant.

SOCIETAL RELEVANCE

The societal relevance is about how Antwerp Unearthed helps toward answering the problems that society faces. What societal dilemmas does the project answer? The design experiment responds to the urban infrastructural implications of harsher summers and harsher winters amidst climate change as well as overcrowding and over renewal amidst densification. For the case of Antwerp, the integrated green-blue-place-memory system in the Ruien relieves heat stress, ecological struggle, flood risk, water scarcity, congestion strain, leisure deficiency, identity depreciation, and heritage decline. These are issues that are no doubt relevant to cities globally. The project is therefore a model to cities around the world on how to efficiently work toward climate adaptivity and urban resiliency. It is especially relevant to cities that have vacant historic structures in their underground that take up valuable space for new infrastructure systems. The research is also relevant to those cities that are unsure of what to do with vacant structures in their underground, even if there is room elsewhere for infrastructures. These cities can look to Antwerp Unearthed for inspiration. Antwerp Unearthed and its singly functioning infrastructure system can also trigger new cities to develop their own underground integrated infrastructure networks. Perhaps, in the future, all cities will be fitted out with underground tunnels that merge various infrastructures, thereby saving space elsewhere. Tunnels can also be used for other societally relevant aspects. Times of war call for bomb shelters, the housing crisis calls for new housing solutions, and the energy-transition calls for innovative ways to transport heat. The intrinsic qualities of tunnels can provide opporunities.

SCIENTIFIC RELEVANCE

The scientific relevance is about how Antwerp Unearthed helps toward a better understanding of the theories surrounding urban infrastructure implementation. What scientific dilemmas does the project answer? The design experiment responds to a research gap that exists on methods that ensure the justified and efficient use of underground space by conflicting infrastructures. The scientific recommendations were a systems-thinking design approach. For the case of Antwerp, by utilizing a method that forms a matrix between five design phases and four infrastructural themes, design expectations are made clear making it easier to guide design considerations. The maximization and optimization phase are fundamental to the method. The maximization phase forms proposals that ensure the different infrastructure themes come to their proper justice while the optimization phase forms principles that ensure the different infrastructure themes are mediated effectively. Together they ensure conflict-free, balanced, and harmonized infrastructure implementation, a valuable extension to theories within urban design and planning. This is especially true because there are no existing models of the harmonized merging of diverging infrastructural themes. The infrastructural themes themselves are also fundamental to the method. Although Antwerp Unearthed works with four themes, there is no minimum and maximum limit to the number. By adding, subtracting, or applying new infrastructural themes, new theories on how to merge them in the most balanced way come to light. In this way, the method has broad impacts on the knowledge base for conventions associated infrastructure implementation.

PROFESSIONAL RELEVANCE

The professional relevance is about how Antwerp Unearthed helps toward expanding practices within the field of landscape architecture. What professional dilemmas does the project answer? The design experiment responds to a further development of the interdisciplinary aspect of landscape architecture. For the case of Antwerp, the project merges multiple infrastructure themes into a single system by means of an extensive optimization phase involving enhancements and refinements. In practice this phase also involves a negotiation round between infrastructure specialists. The knowledge exchange not only brings to light the most effective design principle but also inspires thought outside the scope landscape architecture. In this way, landscape architecture becomes even more interdisciplinary. With greater interdisciplinary knowledge it becomes easier to integrate different starting points during a masterplanning process. Antwerp Unearthed has uncovered new principles associated with the hybridization of green, blue, place, and memory infrastructures into a historically dominated urban fabric. It is an example of the opportunities of decommissioned underground infrastructure systems and other vacant underground structures. In this way, the project expands the practical scope of landscape architecture into that of civil engineering as well as urban design. The fact that the type of infrastructure theme is not set in stone expands the scope even more. Infrastructures such as mobility and energy systems are themes important to the future but not yet within the design vocabulary of landscape architects. With the research method as applied in Antwerp Unearthed, landscape architects have the chance to broaden their insights in infrastructure implementation.

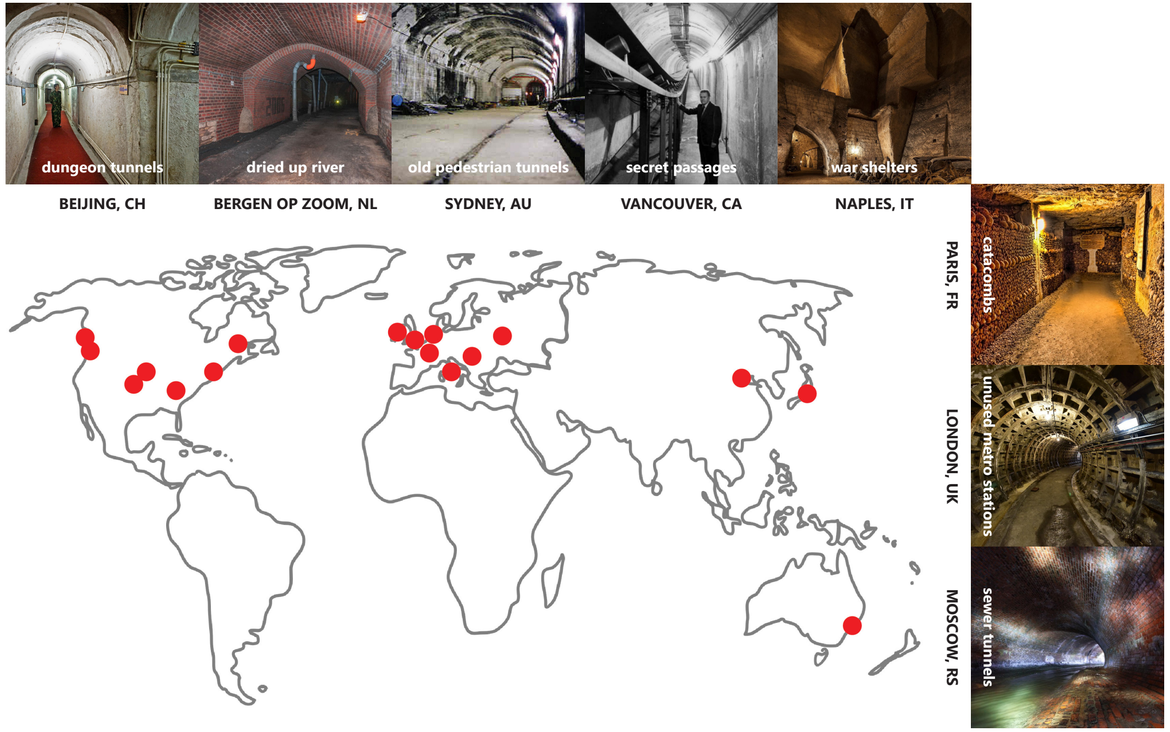


FIGURE 4.2.1: Cities are built in layers and around the world, old layers have become forgotten. The structures of these historic layers can be reappropriated for infrastructural uses. The structures range from dungeons, river canals, pedestrian tunnels, secret passages, war shelters, catacombs, unused metro tunnels, to sewer tunnels. (Sun, 2020, Droste, 2018, Yarrow, n.d., Brown, 2015, Borbonica, n.d., Paris Perfect, n.d., Landon, 2023, The Moscow Times, 2023).

4.3 limitations

Although the implications of Antwerp Unearthed are worthwhile at societal, scientific, and professional level, the design experiment is not without gaps and shortcomings. The following choices have led to limitations in the results:

- The green, blue, place, and memory systems are not the only significant infrastructure themes in Antwerp. The problem statement associates much of the spatial conflict with mobility infrastructure as well, specifically parking needs. Due to insufficient knowledge, this theme is left out. Nevertheless, the results of Antwerp Unearthed embed themselves in the public transit network of the city. Therefore, incidentally, a part of the possible needs within mobility infrastructure are acted upon.

- The results are only applicable to cities that have vacant structures in their subsurface. While this is a common occurrence in historic cities, younger cities do not have this potential even though the spatial shortage for infrastructure may be just as significant. Nevertheless, the positive results of Antwerp Unearthed may be a trigger for these cities to construct their own underground tunnels for integrated infrastructure use.

- The proposals of the maximization phase are a landscape architectural interpretation of the necessary criteria for the infrastructure systems. A specialist for green, blue, place, or memory infrastructure, such as an ecologist, water manager, urbanist, or archeologist, might come up with entirely different criteria. The proposals in this research may therefore fall short of the typical infrastructural practices and conventions.

- In the optimization phase, the study area is reduced in size for clarification reasons. It is possible that the larger study area contains infrastructural combinations between the green, blue, place, and memory proposals that have been overlooked. Perhaps these combinations would have led to different design principles than currently indicated. As a consequence, the findings could have been different. Ultimately, this is to be expected: how a design principle comes to fruition is dependent on the physical location. Applying the method of this research to other cities will, no doubt, lead to different principles as well.

- In the optimization phase, priority is given to certain maximization proposals where it stands in conflict with another maximization proposal. Therefore, in the resulting principle, certain themes will score lower and be less justified than other themes. The choice for priority is based on the infrastructure theme that acts most as a system in which removal of one component would cause the entirety to be inoperable (blue > place > green > memory). In practice, a negotiation round between infrastructure specialists would define the priority. As a consequence, the design principles would be different than currently indicated.

4.4 recommendations

Recognizing the gaps and shortcomings in the research, in order to increase its integrity, it is beneficial to look into avenues for further debate and study. The following considerations are recommended for future research:

- Work with additional infrastructure themes. Next to the green, blue, place, and memory systems associated with environmental and social urgencies, cities are also facing infrastructural requirements accompanying mobility (like parking and public transit) and energy (like heating grids and solar power), among others. Spatial shortages for infrastructure can be further resolved if research is done on how to include mobility and energy infrastructures in the design.

- Work with case study and reference projects. Although Antwerp Unearthed is in itself a case study for infrastructural reappropriation of vacant underground structures, other infrastructural projects might give additional insight. New infrastructural combinations may come to light resulting in more justified and efficient urban infrastructure implementation. Case studies can provide insight into unforeseen design principles.

- Work together with infrastructure specialists. Landscape architects do not have all the knowledge necessary to ensure a reliable working infrastructure system, especially when several different types must be merged. Disciplinary experts can guarantee that the correct conventions are applied resulting in improved proposals and a more objective prioritization of criteria.

- Work with a negotiation round within the optimization phase. When infrastructure consultants are present, it is useful to include a stage in which refinements to the proposals (such as priorities) are made through concessions and compromises. Although this may decrease the representation of some infrastructure themes, the merged system will likely be more reliable. This stakeholder involvement was outside the scope of this research.

This chapter presents the final remarks of the report. It starts with an overall summary in the form of a conclusion (5.1) and closes with a personal reflection (5.2).

5 remarks

5.1 conclusion

The performance of a city is dependent on the performance of its infrastructure. As a result, the surface-level world is inseparable from the subsurface world. However, cities around the world are facing a shortage of available space both aboveground and belowground. The existing urban fabric has over time become unfit for the addition of new infrastructure systems that are required for the future. Spatial conflict problems are arising between necessary urban infrastructures, specifically regarding green, blue, place, and memory systems. For the city of Antwerp, the Ruien, a decommissioned canal network that lies beneath the city as tunnels, provides a spatial opportunity.

Establishing this potential, the main research question asks: how can the reappropriation of the decommissioned underground canal system in Antwerp spatially mediate the city's urgencies regarding environmental and social infrastructure? While the research question calls for the implementation of four infrastructural themes (green, blue, place, memory), an exploration of background theories of urban infrastructure implementation indicates a research gap regarding a systems-thinking approach. In this case, the Environmental Maximization Method (BOOM-Duijvestein, 1998), with its five design phases (inventory, analysis, maximization, optimization, integration), is useful. Together, the four infrastructure themes and the five design phases can form a matrix that offers an appropriate design framework in the context of Antwerp.

The design experiment begins with the inventory phase in which the points are specified in order to outline problems. Antwerp has significant problems with heat stress, ecological struggle, flood risk, water scarcity, congestion strain, leisure deficiency, identity depreciation, and heritage decline. The design experiment continues with the analysis phase in which the problems are studied in order to outline potentials. The Ruien has significant potentials in its confined microclimate, natural biotopes, sluice compartments, floor construction, unimpeded layout, vacant floor-area, lingering narratives, and physical relics. The design experiment then goes into the maximization phase in which the potentials are centralized in order to outline proposals. The green maximization proposes to uncover the underground microclimate in order to establish a cooling regime and to enhance the natural biotopes in order to form interconnected ecological habitats. The blue maximization proposes to re-engage the sluice compartments in order to buffer rainwater runoff and to re-permeate the floor construction in order to infiltrate water into groundwater. The place maximization proposes to utilize the unimpeded layout in order to boost spatial access of the city center and to exploit the vacant floor-area in order to increase the coverage of inner city public space. Finally, the memory maximization proposes to highlight the lingering narratives in order to revitalize the forgotten culturally historical urban landscape and to accentuate significant physical (archeological) relics in order to diminish the chance that they are defaced or demolished by urban renewal.

The design experiment subsequently goes into the optimization phase in which the proposals are refined in order to outline principles. An overlay of the four infrastructural proposals for the Ruien shows many interactions. To get a clearer overview, the study area is constricted to a smaller, all-encompassing, section. In the end, the interactions between the green, blue, place, and memory systems result in 10 comprehensive design principles. Each principle offers a harmony between the four themes, with a scoring in a spider diagram that shows the ultimate thematic representation.

The design experiment finally goes into the integration phase in which the principles are applied in order to outline plans. The plan is called Antwerp Unearthed. Next to operating based on the 10 principles, the plan is embedded in the urban fabric in such a way that it provides additional urban benefits. The underground network is linked to metro system of the city, increasing the urban accessibility of pedestrians. The pedestrian network also links the city park (Stadspark), city museum (Museum aan de Stroom), shopping district (Wilde Zee), and nightlife district (Sint Paulusplaats), increasing the connectivity of the city. Overall, mobility infrastructure becomes an incidental part of the plan.

Antwerp Unearthed, as a masterplan, provides two answers to the research question of this report. The decommissioned underground canal system in Antwerp spatially mediates the city's future urgencies regarding environmental and social infrastructure by pairing external problems with internal potentials and by forming a singly functioning infrastructure system. The findings are societally relevant because they show how to work toward adaptivity and resiliency in the context of climate change and densification. The findings are scientifically relevant because they show how to work toward a justifiable and balanced implementation of underground infrastructure. The findings are professionally relevant because they show how to work toward integral and interdisciplinary design principles for multiple infrastructural themes.

Nevertheless, the findings have limitations in that other significant infrastructure systems in Antwerp, like mobility (specifically parking) and energy (like heating grids), are omitted. Another limitation is the prioritization of certain infrastructural themes based on a landscape architectural lens rather than on a perspective from an infrastructural specialist such as an ecologist, water manager, urbanist, or archeologist. Recommended is that future use of the method as described in this report should include a negotiation round within the optimization phase such that disciplinary specialists can come together to make concessions and compromises. Another recommendation is working with additionally relevant infrastructural themes, as well as case studies and reference projects. Ultimately, these recommendations will make the resulting principles and the final infrastructural design more reliable.

5.2 reflection

I have a creative side and a technical side. On the one hand, I enjoy telling stories and escaping into new worlds. This is a fascination that stems from my visits to theme parks like Disneyland Paris. On the other hand, I appreciate practicality and problem solving. This is a fascination that stems from a childhood book, A Street Through Time by Anne Millard (1998). My creative-technical brain has found its place within the field of Landscape Architecture. In my opinion, landscape architects redefine technical systems beyond their operational limits, allowing imaginative and experiential design to gain an active force in the transformation process. This hybridization is the basic starting point of the graduation studio "Flowscapes" within the Landscape Architecture department at TU Delft. My graduation project, Antwerp Unearthed, has a similar aim: to treat infrastructure as a type of landscape and to treat landscape as a type of infrastructure. The graduation lab "Design of the Urban Fabric" provides a fitting framework for testing this ambition. This is because a city's fabric builds upon the cultural narratives of the past but also works toward the utilitarian needs of the future. Both aspects must work together in forming a coherent living environment. The new insights that have come to light as a result of this project expand the theory on how the built environment should be shaped. In this way, my graduation project is situated firmly within the master track "Architecture, Urbanism and Building Sciences".

As a landscape architect, I have the ambition to give sentimental and practical meaning to landscapes. In order to achieve this balance, I often approach landscape design through storytelling. It is useful to reflect on how storytelling comes to fruition within my graduation project. Antwerp Unearthed investigates the capacity of the decommissioned underground canal system of historic Antwerp in facilitating infrastructural security for the future in regards to environmental and social urgencies. Storytelling finds its grounds in the pairing of the external problems of the city with the internal potentials of the tunnels. Essentially, a common dilemma of the city finds relief in the context of a common memory of the city. This makes the issue tangible and leads to a valuable educational and experiential aspect within the design. This implication of storytelling gives me the professional ambition to work on projects that react upon thematic and narrative qualities of a location. This, of course, influences my career outlooks as a landscape architect. Storytelling based design is an important component in transformation projects. Redevelopments of brownfield sites, historic cities, estate landscapes, and heritage sites, for example, often appropriate intrinsic, historical, qualities for modern, problem solving, purposes. Storytelling based design is also a strong component in projects within the leisure industry, for example the masterplanning of tourist attractions, zoos, theme parks and museum grounds. I am determined to keep storytelling a central part of my personal design method.

Antwerp Unearthed follows a more specific method derived from the Environmental Maximization Method (BOOM-Duijvestein, 1998). The method is useful and reassuring in that it pairs the different phases to clear-cut design products, in the form of proposals, principles, and plans. During the design experiment, this kept my work ordered and my narrative straightforward. Due to this well-defined step-by-step approach, it conforms to my practical design side. Therefore, the design method not only answers the research question but also provides a reliable design framework for many systematically minded designers, like me. In my professional future, I suspect to be confronted with designers who all have their own methods to design. In cases where I will use the Environmental Maximization Method again, I am curious how a round of negotiations will influence the results.

Throughout the project, I have come to realize that my systematic mind sometimes hinders my creative mind, and vice versa. While my technical design method (Environmental Maximization Method) involved clear-cut products (proposals, principles, plans), I struggled with how to represent my creative design method (storytelling). Oftentimes I approached a storytelling aspect with a plan drawing. Because I associate plans with my technical design side, the thematic and narrative features that I was trying to implement were quickly nullified by logistic and systematic features. Especially during this research project, because of the strict method, my creative mind felt delayed. Representation through eye-level perspectives and impression sketches provided an answer to this dilemma. These allowed the experiential aspect to come to fruition. They offered a canvas to express my creative side without the limitations brought forward by design principles. In this way, I could think outside the box. I realize now that I have to continue finding a balance between my creative and technical sides. With guidance from my graduation mentors, I was able to take the first step in this through 3D modelling. A 3D model allows me to express and experience and at the same time work on technical detailing. The making of a 3D model, either digital or physical, is something that I usually only considered at the end of a design experiment to present the outcomes. In this graduation project, however, I utilized models early on. A model provides the visual element important to storytelling and the physical element important to technical design. In this way, the model became a research element and I was able to expand my research by design capabilities. In the end, the biggest take away from this graduation project has been the design methods. I hope to develop them further in the future.

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