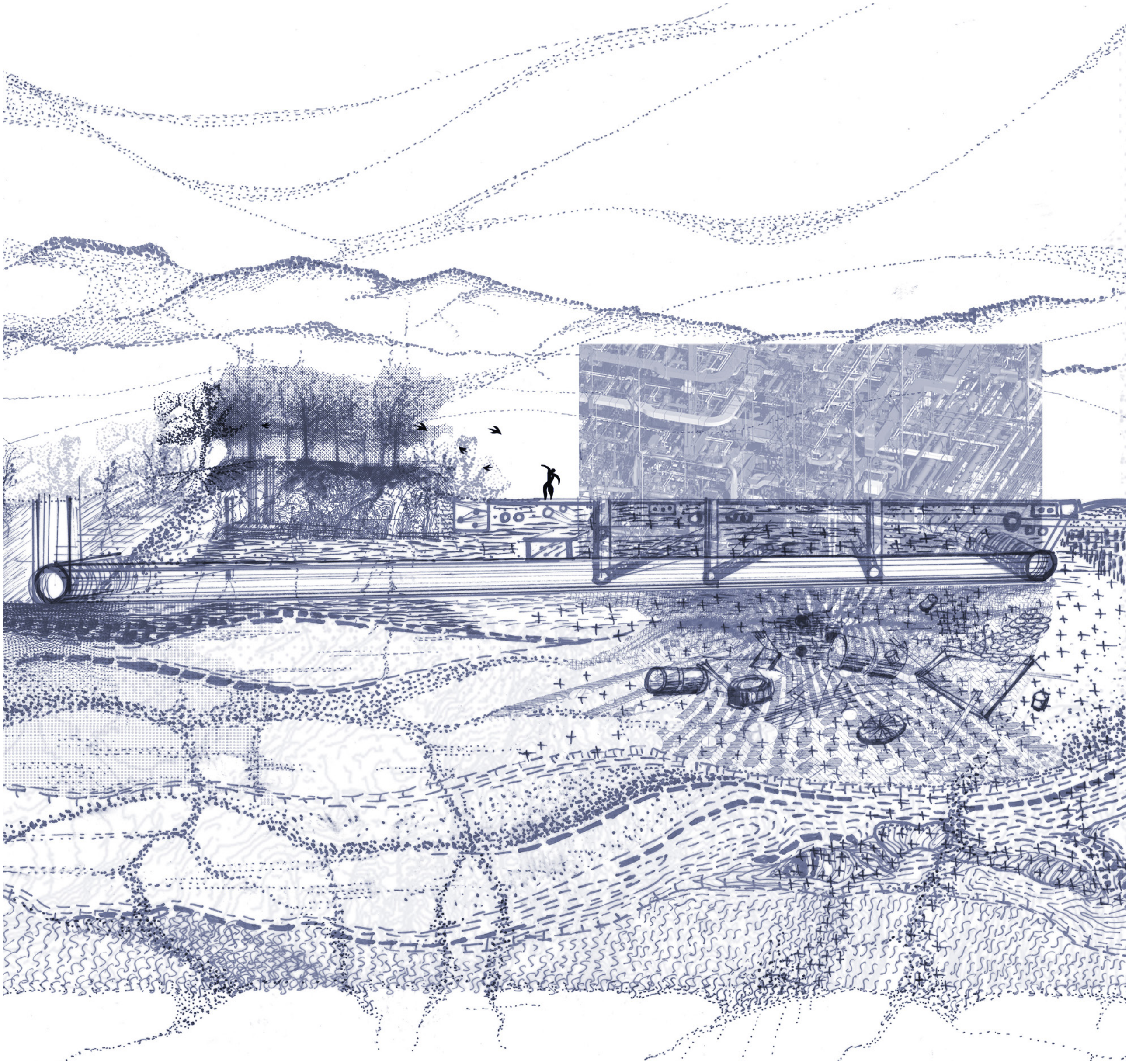

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Deep Landscape

AHO Arkitektur- og designhøgskolen i Oslo
The Oslo School of Architecture and Design

PhD thesis

DEEP LANDSCAPE

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ABSTRACT

We know very little about what is under our feet. We are used to the sight of manhole covers punctuating the streets around us, and we know that they provide access to the subterranean water system. But where does that system start and end, and how is the manmade, reworked ground made up? Humans have a history of adapting well to notions of an expanding world, but what about the closest realm in distance and time: the ground on which we stand and within which our fresh water is contained?

This thesis argues in favour of urbanism not only incorporating landscape but also actively incorporating the other, unseen half of the landscape: the underground. It explores how we could get closer to perceiving the depth of the landscape setting we inhabit. This is increasingly important in a time when human actions dominate the geological ground conditions.

The design case of daylighting of a piped underground water system to make it an open, landscape-integrated surface system reveals a need to design both visible- and invisible underground landscapes together. This exegesis thus expands on my claim that the landscape has a composed depth. The design case has been used to test this assumption and provided various findings, reflected on *a posteriori* in the exegesis to determine their implications for the landscape- and urbanism disciplines. This has further resulted in the coining of the 'deep landscape' as a term, a concept, and a strategy for design.

This thesis is positioned between the fields of landscape architecture and urbanism, and it offers insights into water and urban ground conditions in one conference paper and two published articles. It uses the term 'deep landscape' as a reminder of the inseparable context beneath our feet. The presence of water and the ongoing processes below grade, as well as the subterranean landscape modified by humans and its installations, the reworked ground, must inform and become part of landscape architecture and urbanism.

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I am enormously grateful to all of the colleagues who have been engaged and supportive along the way. For support in the elaboration of the design case, a special thanks goes to Celia Martinez Hidalgo, who was part of the designing team, as well as the representative of Skien Municipality Marja Folde, who contributed with great knowledge. Dear colleagues, thank you for all your insights and encouragement: Karin Helms, Andrew Morrison, Lisbet Harboe, Agustin Sebastian, Janike K. Larsen, Nuno Almeida, Kjersti Bjerke, Nils Roar Sælthun, Marianne Skjulhaug, Hanna Dencik Petersson, Kari Anne Bråthen, Jonny Aspen, Steinar Taubøll, Victor Bourdet, Runa Gjerland, Vaclav Grmela, Betina Amundsen, Alice Lupo, Jordi Marset, David Sanchez, Sara Cais Soler and Victor Castillo. Special thanks go to everyone I have not mentioned here by name, but who has been part of this journey. Each of you have contributed to a broader knowledge and given me opportunities to discuss, contrast and test insights throughout this research. The generosity and willingness to share knowledge I have witnessed makes me positive about what we can achieve together when facing future challenges.

To my dear family, thank you for all your patience and motivation during this time when everything has been 'all about water and ground'.

PREFACE

This study started with a fascination with water in the landscape: an ever-changing element that reflects the movements of the sky on the earth's surface. Drop by drop, it accumulates and finds its way, rippling, drizzling, flowing down hills, through riverbeds and into the ground. It is essential for living species, vegetation, fauna, and humans. The ground must be actively incorporated into urban and landscape projects to enable design that takes into account the greater water quantities that come with global warming. This thesis focuses on the underlying nature of sites and the relationships between the landscape's different elements such as water, ground, and human actions over time.[1]

Recent decades' construction activity, mining, dredging, and waste deposition have transformed the surface of the earth to such an extent that artificial ground is an important consideration for future development. Over time, this ground has become more complex, and this thesis therefore investigates the role of the 'manmade ground'[2] for landscape architecture and urbanism. The investigation opens up questions about what is beyond the visible, and it involves a rethinking of the spatial limits of a project.

This research has entailed the study of water's relationship to the ground in various settings through research, practice, municipal administration and planning. The objective when writing has been to depict the interaction of water and ground as straightforwardly as possible, to make the content accessible in a multidisciplinary context, and to facilitate further investigations that develop our notion of the landscape just below our feet.

[1] The formal aspects of landscape projects have been written on extensively, while their visual and experienced nature have made them accessible to everyone and subject to debate.
[2] The term 'manmade ground' is found in archaeology. Considering that there are living organisms in the ground that also modify it entails that it is seldom completely manmade, but rather 'modified by humans' (Edgeworth, 2016). In this thesis however, the term manmade ground is used as it refers to larger human-produced changes of the ground, such as landfills and underground technical installations.

1. Introduction

D E E P L A N D S C A P E

This chapter presents the research context, research aims and further questions. It provides a brief overview of the research approach and methods, followed by a summary of the publications, main findings, and contributions. Finally, it offers an overview and description of the guiding structure of the thesis.

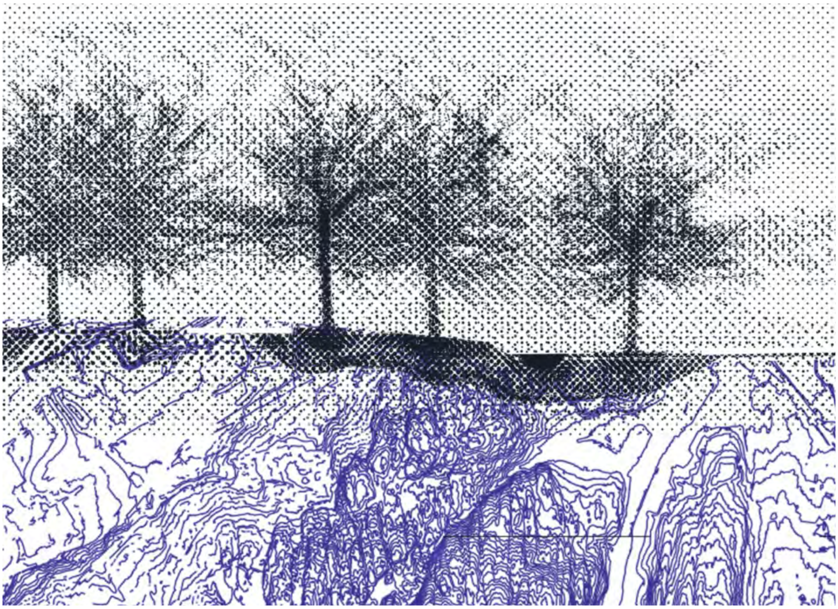

Figure 1: An early illustration of the depth of the landscape reflecting above and below grade with water, ground, atmosphere and vegetation (2015). Ill. Author.

1.1 RESEARCH CONTEXT - WATER AND HUMAN-MODIFIED GROUND IN URBANISM AND LANDSCAPE ARCHITECTURE

On 30 December 2020, stormwater triggered a quick clay landslide in Gjerdrum, 15 kilometres north of Oslo. Its effects were severe. The landslide claimed lives and destroyed homes when the quick clay ground, a mass of 1.3 million cubic metres, collapsed and ran out downstream along the Tistil Creek.

The relationship between water and ground is central for the built environment and urbanism, as the groundwater alters the properties of the ground. Through urbanisation, the impermeabilisation of surfaces hinders rain- and meltwater from infiltration and replenishing groundwater levels, and buildings and streets can suffer from changed water-related ground properties and subside, which affects construction stability. However, in Norway, not enough attention is paid to such underground dynamics.[3]

A design case of a daylighting stormwater management project was chosen to highlight the relationship between water and ground within urbanism. The initial aim of the project was to handle the rising volumes of stormwater; however, the project has been largely dependent on the varied ground conditions of the manmade grounds in the form of landfills and technical installations.

The geographical context of this research is southeastern Norway, the country's most populous area. Understanding the relationship between water and ground is relevant in this context, as it has been the site of numerous flooding[4] events.[5] There are several reasons for the southeast of the country being more prone to flooding than other areas: the sewage systems are old; there is a higher building density with more impermeable surfaces, and changing precipitation patterns with more extreme events have put increased pressure on the existing system. As a result, Stormwater Management (SWM) in southeastern Norway needs to be rethought.[6]

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[3] The design case of this research reveals this, and it is also documented in Oslo Municipality (Eriksson 2019).

[4] The European Union Directive 2007/60/EC defines flooding as the temporary coverage by water of land that is not normally covered by water.

[5] In 1995, a major flood in southeastern Norway required 7000 people to be evacuated and caused damages amounting to approximately 1.8bn NOK (200mn USD), according to the Norwegian Water Resources and Energy Directorate (Berg, 2016). In the years since, flooding has impacted the built environment and reduced mobility. In the autumn flooding of 2016, motorways were blocked for several hours.

[6] The field of hydrology elaborated research on SW in the mid-20th century. Luna Leopold's calculations on SW-runoff in relation to constructed areas are important contributions (1968). Still, it took several decades and some experiences of flooding before the need to integrate SWM into planning became a reality in Norway (see NOU 2015).

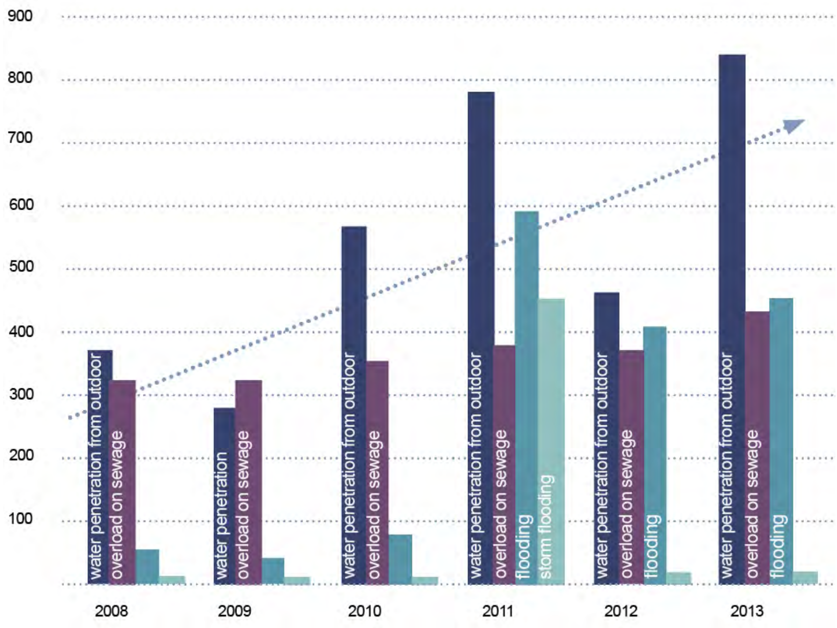

Figure 2: Showing rising insurance claims for water penetration from outdoor (blue), overload on sewage (red), flooding (green), and storm flooding (purple). Diag: Author, based on diagram by Finans Norge and source from: Sigma Swiss Re.

The area also hosts challenging ground settings with certain geological conditions, such as the presence of alum shale and quick clay, the properties of which can change in the presence of water. Knowledge of where such sediments are located makes it possible to include and account for them in design processes and inform future planning and projects. While the initial ground conditions have an impact on planning, it is equally important to recognise the changes of ground properties that urban development provoke over time – directly, such as in the form of fill mass exchanges, landfills, etc., and indirectly by changing the properties of the ground through the presence of water, affecting for example the extraction of groundwater or rendering impermeable the surface, which prevents the groundwater from being filled up.

Reflecting a rising awareness of SWM in Norway, a government white paper on SMW was published in 2015 (NOU 2015: 16). The white paper discussed SWM from a largely legal perspective, rather than as a spatial question.[7] There are, however, important spatial consequences to changing SWM solutions from subterranean systems to open solutions, as we see in many places today.

[7] The commission consisted of various professionals, but no landscape architects or urbanists, and the report made few references to these disciplines.

Spatial continuity is necessary for water, and in an urban setting, this can collide with many other interests and uses on the surface. The work of a landscape architect and urbanist may be key to realising and providing spatial definition to the SWM project as well as mediating various interests of properties, uses, social needs, ground conditions, ecology and water storage capacities into a multifunctional proposal.

Water's behaviour with the force of gravity in relation to the ground is nothing new. Internationally, there has been increasing interest in water in relation to the urban setting as flood events have grown more frequent. To highlight the dynamics between water and the territory, 'water urbanism' (Shannon, 2008) was proposed. Practical approaches on how to handle the overflow of water were made through the design of 'sponge cities', as well as the development of a range of urban SWM principles. A three-step principle of SWM has been dominant in the Norwegian context. The first step is to catch and infiltrate stormwater, the second to delay and retain it, and the third to create secure floodways (Lindholm, 2008). The third step is the municipality's responsibility, yet accessing the right competence is a great challenge. Norway has 356 municipalities, and many of them are very small. Seven out of ten municipalities have signalled that they lack the resources or people to handle these questions (Klemetsen and Stackpole Dahl, 2019). Some municipalities thus only act when they have been affected by flooding, which results in significant damages and costs. This thesis aims to facilitate terms, concepts and the detection of barriers for implementation of urban water transformation projects. The ambition is to shed light on how municipalities can proactively fulfil their responsibilities and make better-informed planning decisions, as well as to provide design strategies for urban transformation projects situated in areas with inherent ground constraints.

1.2 RESEARCH SETTING AND PROFESSIONAL BACKGROUND

The investigation presented in this thesis is based on design case research of a large-scale daylighting[8] project with embedded landfills in the southeast of Norway.

The design case in Skien, where the concave riverbed has been used as a dumping site, is illustrative for other buried creeks. The case is situated in a middle-size municipality that is representative of other municipalities in Norway in terms of resources and administrative capacity. The case study area with different ground conditions is also representative of the growing Oslo Fjord region with an urbanised coastal area within the former marine border[9]

[8] 'Daylighting' rivers and creeks corresponds to the act of reopening buried, piped and canalised rivers. The water comes in contact with daylight once again, which again enables the interaction between water, the ground, and living species.

[9] 'Marine border indicates the highest level that the sea reached after the last ice age. The height depends on where you are in Norway and varies between zero and approximately 220 meters above today's sea level' (Ramberg *et al.*, 2008).

and rich geological variety. The rivers and creeks are strategic urban elements that can restructure the urban tissue and connect the inland to the fjord. The choice of a daylighting project with creeks and rivers is illustrative of a SWM project and represents the main floodways that the municipalities are responsible for providing.

My perspective in this research was based on my background as a practitioner and scholar of landscape architecture and urbanism with experience from private practice and regional planning administration. Working as a landscape architect on the river-opening project of Kjørbekk provided an opportunity to investigate in depth a daylighting project in practice with its design process in an interdisciplinary team which has permitted questions of implementation to be uncovered.

1.3 RESEARCH APPROACH AND METHODS

The research carried out in this PhD thesis includes different research perspectives developed through literature, project reviews, and design case research. The design case of a large-scale daylighting project spanning over four kilometres has been used as an opportunity for an in-depth investigation of a real SWM project and its physical, administrative, and professional setting. Participating in the development of a project was a choice that enabled me as a researcher to pass from observer to active developer of knowledge within a design team. This knowledge cannot be obtained by a single, isolated researcher from one discipline, as the knowledge is generated in the 'making' and interaction between practitioners with different disciplinary backgrounds. As part of a design team, one has access to first-hand information and inside perspectives on the design process, e.g., through doubts and insecurities in the process. These uncertainties can help to identify present knowledge gaps.

The research explores the landscape's depth in theory as well as practice. The design case in practice has revealed questions that have created a demand for new research in order to enable a design that answers to environmental challenges. Through interaction with various researchers and practitioners from different disciplines, new knowledge emerged during the design process. The ultimate discovery that much of the design case related to the underground brought this exegesis to focus on the landscape's depth.

1.4 RESEARCH OBJECTIVE AND RESEARCH QUESTION

The exploratory research for this thesis focused on the interrelation between water and ground and its role in urbanism and landscape architectural practice. The work highlights the significance of the manmade ground in urban landscape projects and deals with the reuse of ground, with inherent constraints, in urban transformation projects.
The aim of this research is to develop and elaborate theoretical understandings of the relationship between water and ground and the implications of this

relationship for landscape architecture and urbanism. This aim relates to the overall concern of *how* a greater sensibility to the landscape's depth and underlying structures can help deliver more sustainable planning approaches.

1.5 PUBLICATIONS

This thesis is article-based and provides an overview of SWM and ground complexities through one peer-reviewed paper and two articles. The first article investigates the state of the art of SWM through the question: How has the perspective on SWM in Norway changed in recent decades? The article revealed insights on various SWM issues as well as the need for a focus on the underground. The second publication was based on an inquiry into the key issues that a SWM design research project in the southeast of Norway revealed. The last publication explored which landscape measures for improved management of SW and leachate can be employed at disused landfills. The following is a summary of the peer-reviewed publications. The unabridged versions are appended to this thesis.

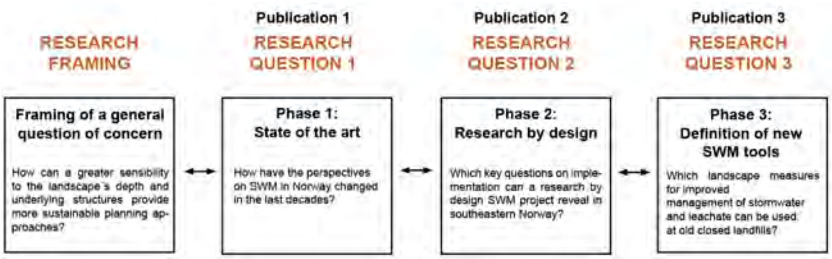

Figure 3: Overview of the thesis publications and evolvement of research questions. Diag: Author.

Publication 1:
Changing Perspectives on Stormwater Management in Norway
Peer-reviewed article: Sjödahl, E. (2018). Changing Perspectives on Stormwater Management in Norway. In A. E. Toft & M. Rönn (Eds.), *The Production of Knowledge in Architecture by PHD Research in the Nordic Countries* (pp. 197–214). Nordic Academic Press of Architectural Research.

A historical review of literature was conducted for an initial overview of the state of the art of stormwater management in Norway. The review oriented the research further toward the relationship between stormwater and the underground. The main publication used was the journal *Vann* – the most important journal for water management in the country – from its first issue (1965) until the present. The main tendencies defined through the review were:

A gap between intentions and realisation. Already in 1975, hydrologist Oddvar Lindholm suggested infiltrating more rainwater into the ground. There has been an international exchange of knowledge on this matter, but implementation into realised projects has been slow.

International attention to climate change and disasters increased awareness of water in the city at the beginning of the 21st century.[10] A general preoccupation with the effects of climate change becomes more present after flooding events, such as the major flooding of Copenhagen in 2011. The review showed a shift where water went from being considered from a technical perspective to becoming a broader societal concern involving more disciplines and demanding adapted working methods and administrative structures. Comparative studies estimated what the effects of climate change would be in Norway, and raised an awareness that adapting to greater precipitation quantities over short periods of time were important. However, there is still a long journey ahead before new SWM strategies are actively integrated into practice.

Rainwater surplus can be treated as an opportunity.[11] The NOU in 2015 highlighted rainwater as a resource. This should change the perspective, with the surplus water during floods being viewed as an opportunity for water security in times of drought.[12] In order to shift from considering flooding as a problem of excessive water to becoming a great resource, the linear model of the Norwegian stormwater management principle of 1) catch and infiltrate; 2) delay and retain; and 3) create secure floodways to handle stormwater (Lindholm, 2008); should be developed further from a linear definition to a more circular model. A more integrated reading of surface and groundwater and a shift of focus from the surface of the ground to the subsoil and the deeper aquifers are necessary. A challenge is that present knowledge and data about the underground are limited and fragmented (Beer, 2016).

A greater understanding of the relationship between water and ground in urbanism. The characteristics of subsoil are of great importance for understanding the absorption capacity of the ground and the sub-level water flows. It is also possible to expand on the closely related topics of ground, groundwater and urbanism.[13] The relationship between the ground's physical conditions, the built environment, pollution, and groundwater merit further consideration in urban planning. To obtain this, *a more integrated reading of surface and groundwater is desirable in stormwater management.*

Based on the findings, I argue for *a more active consideration of the dynamics between water and ground in urban transformation project developments.* The

[10] Floods in Copenhagen in 2011, as well as the local flooding of Nedre Eiker, Norway.
[11] The Norwegian government's white paper (NOU) on SMW was published in 2015 (NOU 2015: 16) Overvann i byer og tettsteder, som problem og ressurs (Stormwater in cities and villages, as a problem and a resource).
[12] A more active integration of SWM in urbanism would permit surplus water and its storage to become part of the city's water supply; it must become more integrated into the landscape and its built environments where the water is needed.
[13] Impermeabilisation of the urban surface causes groundwater levels to sink. Architecture is impacted when oxygen enters the ground; wooden foundations are affected and might be caused to rot. This process destabilises historical buildings, and fissures emerge in their structures and facades as a result.

review shows the need for an 'underground urbanism' that extends the present planning of the visual to actively include the underground – not only its built forms, but its dynamics of ground and water.

Finally, the question that emerges in relation to stormwater management in the urban landscape is why its implementation takes a long time.[14] This question was the starting point for the next article, which examines the realisation of a design case in practice more closely.

Publication 2:
Stormwater Management in Current Practice: From Pipeline to Landscape: A Landscape-driven Design for Stormwater Management
Peer-reviewed paper: Sjödahl, E. (2018). From Pipeline to Landscape: A Landscape-Driven Design for Stormwater Management. In M. Dehaene & D. Peleman (Eds.), *On Reproduction Re-Imagining the Political Ecology of Urbanism* (pp. 157–166). Urbanism and Urbanization.

The article by Oddvar Lindholm mentioned above shows the introduction of SWM half a century ago. It demonstrates that changes to an open SWM are relatively slow, considering that they deal with applied science with known components of water, ground conditions, and gravity. The question of why the transition to an open SWM is slow is examined further in the design case of a daylighting project. It has been used to explore the reason for the time gap between intentions and realisation. The second paper reveals key aspects of what makes the transition from a piped system to an open, daylighted stormwater system complex.
First, different juridical and administrative structures apply below- and above-grade. Below the ground, there are few constraints on organising the infrastructural installations. In contrast, at the surface, there are competing uses, interests, and property boundaries to be considered.

Second, the creek daylighting project, with its piped system, is deeply anchored in the existing building structure and attached to both public and private buildings. The network stretches over kilometres and requires a systematic change with successive implementation. This systematic change involves both the physical constructed structure as well as any immaterial juridical and administrative systems, as mentioned above.

Third, the publication on the design case demonstrates the complexities and necessity of multidisciplinary work and different working methods. The design case hosts several uses: those of humans; the rivers used by the fish and other species; stormwater management and flood control. This entails numerous disciplines in the design process, which implies a more complex multidisciplinary working-process.

[14] Considering that it corresponds to basic knowledge on water's movement in the landscape and the response to an open stormwater management is represented by the well-known initial river with its system of tributaries.

Fourth, I argue that there are different methods for calculating the cost of a SWM project. Cost depends on factors contingent on time, risk and different values; such as biodiversity, recreation, health benefits, social aspects, energy consumption, property value and water management.[15] It is also possible to calculate the cost of flooding rather than the cost of a project; by failing to provide a secure floodway, a municipality could put its economy at risk. The publication discusses the financial difficulties for municipalities when realising an entire daylighting project at once; a central element has thus been the possibility to execute various projects in one and to break down a project into practicable phases and to build slowly but steadily towards a desired design.[16]

The fifth aspect of stormwater management includes working with the entire sub-watershed in planning. This provides more SWM opportunities and would enable holding back stormwater higher up in the watershed.

The final issue of implementation that the design project revealed is the importance of the landscape's depth. In an initial design phase, knowledge of the ground conditions and composition is key. Equally a clarification of the juridical and administrative relationship between above- and below ground is needed to facilitate the transition between them.

Publication 3:
Landscape Measures for Improved Management of Stormwater and Leachate at Old Closed Landfills.
Peer-reviewed article: Sjödahl, E. (2019). Landscape Measures for Improved Management of Stormwater and Leachate at Old Closed Landfills. *Kart og Plan*, *112*(2), 138–159. https://doi.org/10.18261/issn.2535-6003

The issues framed in the design case are followed up in the last article with the question: How can stormwater be handled in large-scale landscape projects with old landfills to avoid spreading pollution through the infiltration of rainwater? The complexity of manmade ground is one of the reasons for the slow transition to open stormwater management in the design case. To facilitate this transition, the article looks into landscape measures based on project analysis in other contexts. These analyses show the importance of integrating the immediate ground into the project as well as the landscape under it that connects the site with groundwater systems. This implies thinking of landscape projects beyond their initial boundaries, both horizontally and vertically.

To explore how to handle disused landfills in relation to stormwater, the article gathers experiences from a selection of national and international transformed

[15] The TEEB (The Economics of Ecosystem and Biodiversity) referenced in the article corresponds to benefits to health, biodiversity, recreation, social aspects, energy consumption, property value and water management.
[16] Timing can be used in planning to execute two or more terrain modelling projects simultaneously, which may entail cooperation between both public and private projects.

landfill projects. The article concludes with a proposal for landscape measures for stormwater management of landscape projects in which the ground conditions are complex, or where contact between SW and manmade ground is not desired. The first landscape measure concerns preventing contact between water and the landfill by using the topography to reroute the flow of water, allowing it to circumvent the contaminated site. The second shows how water can be held in dams above the landfill to reduce water pressure on existing pipe systems. Dams are also positioned after the landfill for sedimentation, filtration, cleaning and monitoring of water before it is released into the general water system. The third measure relates to land mining, where the landfill is dug up, sorted, recycled or reused on site, or, if the level of pollution has been determined too high, sent away for treatment.

The main contribution of this article is the discussion of new stormwater management application strategies in which the inclusion of the ground is central.

1.6 CONTRIBUTIONS

Concluding from the interrelationship between water and ground that has been revealed by the research, this thesis presents four knowledge contributions that are both theoretical and practice related.

First, it contributes with the coining of ‘deep landscape’ as a term, a theoretical concept, and a design strategy. The term ‘deep landscape’ brings attention to an otherwise overlooked relationship, emphasising the underground landscape and promoting its incorporation into the design and planning of the visual landscape of the surface. It reframes landscape discourse and stormwater management practice. As a concept, it relates to the idea and principles that cover thinking about, working with, and perceiving landscape by bridging the divide between above- and underground. It is also a design strategy – a ‘deep landscape’ approach to design in general that deploys tools and landscape measures and foresees the underground interrelation in a project.

Second, the thesis demonstrates how the manmade ground entails uncertainties in an urban transformation project. Therefore, a flexible approach that allows informing and redefining the project is important, as ‘below-grade informed planning’.

Third, it proposes a practice in the use of ‘landscape measures’ as design tools to prevent contact between polluted ground and stormwater. Proposed landform modifications steer the water in relation to the ground’s properties, allowing the possibility of designing projects in which what is the above the ground correlates with the below grade, and both are designed as one.

The fourth contribution is about expanding on the general Norwegian three-step stormwater management model. Read through the lens of the ‘deep landscape’, it adds reflection on the underground and indicates where *not* to infiltrate, dependent on the ground conditions. It shows that current SWM principles in Norway must be supplemented with considerations of the ground's composition and possible pollution.

1.7 THE STRUCTURE OF THE EXEGESIS

Chapter 1 explains the theme of the research and its context, the research objectives and questions. It introduces the research approach and includes a summary of the publications and the main contributions.

Chapter 2 maps the state of the art, positions the research, and provides the background context for the design case in southeastern Norway.

Chapter 3 explains the research methodology. It explains why a design research approach with a designer as an embedded researcher was chosen to understand the gap between SWM project intentions and realisation. Finally, techniques that have been applied in the design case and served as research tools are presented.

Chapter 4 provides a more detailed description of the daylighting project presented in Articles 2 and 3. It outlines the different findings revealed through the design case.

Chapter 5 unfolds the main contributions of the thesis and discusses their significance and relationship to other research, as well as the limitations of the work and suggestions for further research.

Chapter 6 summarises and provides a reflection on the research.

Appendices: Publications 1-3:
This section contains the publications on which this exegesis is based.

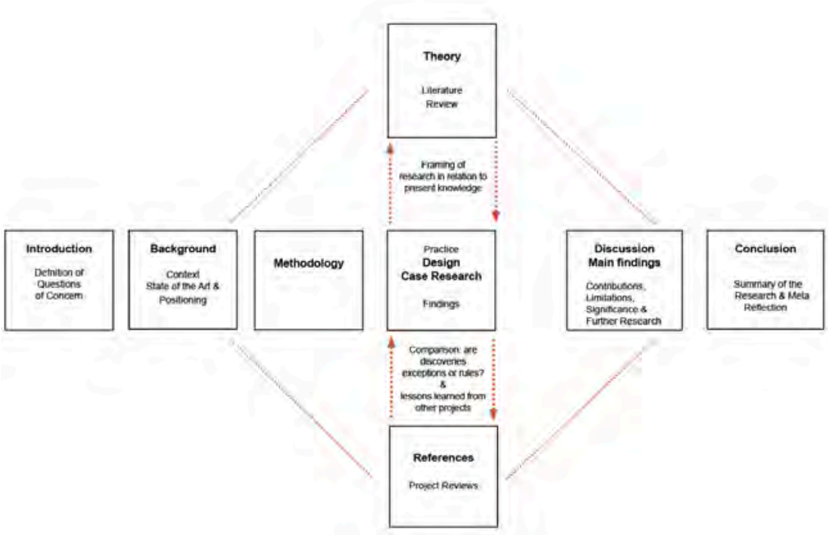

Figure 4: Overview of the structure of the thesis. Diag: Author.

2. Background

This chapter presents the theoretical discourse related to water and ground. The chapter discusses water and ground in urbanism and landscape architecture separately as they have been reflected on in different theoretical discourses and through different representational techniques to advance ways of thinking about these elements. It also discusses them jointly, underlining the importance of their interaction and identifying knowledge gaps in the interrelationship between water and the ground in urbanism. This chapter also introduces the background and context of the design case.

2.1 WATER IN URBANISM AND LANDSCAPE ARCHITECTURE

Water is all around us: salt water in the sea, fresh water in lakes and rivers, ground water, snow and ice (white drinking water); the water in vegetation and fruits (green water), lightly used water (grey water), wastewater from flushing toilets (black water); humidity and rainwater from the sky that create runoff water and stormwater.

Water as the basis for life has historically been a fundamental element in urbanisation. In Norway, houses have frequently been positioned adjacent to fresh water, rivers and ice-free fjords. The country has traditionally been ‘water-rich’, and water has been used for drinking, fishing, transport, logging, energy production, ice production, and more. Climate change has now given rise to new challenges, and periods of intense rain or drought are becoming serious matters of concern.

In Norway, rivers and creeks were long part of the urban fabric, and water from rivers was deviated to provide drinking water in central wells in urban areas. The streets were used to guide sewage water to the rivers. After industrialisation and the subsequent urban expansion, water was slowly erased from the urban landscape. It was sanitised, rationalised, and put in pipes. Whilst facilitating the provision of fresh, running water in every household meant a major improvement of sanitation standards, the canalisation of rainwater to drain the streets has also had its downsides.[17] For instance, stormwater management systems, developed in the 20th century in high density areas with sealed ground surfaces, have occasionally led to flooding downstream.

There has been varied criticism of contemporary water systems, where waterflows and their infrastructures relate to power structures (Swyngedouw, 2004; Kaika, 2005). In *Splintering Urbanism,* professors of human geography Stephen Graham and Simon Marvin investigate the relationship between infrastructure and contemporary urban development (2001), underlining the need to recognise what networks actually provide and which areas and groups of people they might exclude. The authors claim that the invisibility of installations is one reason why these infrastructures have not traditionally been studied in geography and urban history. Sociologist Susan Leigh Star argues that it is necessary to take sewage into account to understand a city and its social justice: 'Study a city and neglect its sewers and power supplies (as many have), and you miss essential aspects of distribution justice and planning power' (Star, 1999: 379). The underground infrastructure is a political element, corresponding to great economic investments and involving strategic planning of access to fresh water. Cities' ageing water systems demand investments that could prove challenging for future generations if they arise parallel to other societal issues.[18] In the US, for instance, public infrastructure maintenance has lapsed so far behind that the American Society of Civil Engineering has stated it would take 'more than a trillion and a half dollars over five years to bring it back up to standard' (Klein, 2014). This weak infrastructure could easily cease to function after major disasters, and because of the high repair costs, there is a risk that it will not be reinstated and returned to operability. This in turn would lead to segregation in which the well-off have private supplies in gated communities (Klein, 2014). Water system maintenance is also behind in the municipality of Oslo in Norway, and the 2023 budget proposes an almost 25% increase in water and sewage costs. This reminds us that access to water and maintenance of infrastructure is political and related to planning. All projects become political at the moment when they include maintenance and budgets (Kaika, 2014).

Stormwater management in relation to climate change is at odds with some cities' central water management, such as the underground transportation of rainwater. Future sudden precipitation cannot be accommodated by technical solutions underground and causes the system to malfunction. The technical solutions have reached their limits. Environmental social scientist Liz Sharp has criticised the present organisation of water systems, calling it a technocratic water model (2017). Sharp argues that people have grown disconnected from water, its sources and how it is routed to flow through invisible water installations. Sharp calls for more local engagement in water

[17] The addition of rainwater to the sewage system was initially seen as an advantage, as it helped to flush through the system.
[18] The investment for a centralised system must be budgeted for a period of 50-100 years (Stokman 2008).

issues where the management can be a combination of both centralised and decentralised elements, depending on the site. Her work is based on the 'hydro-social cycle' (Linton, 2008) and aims to revive an awareness of the water, engagement, and its re-evaluation as a condition for our existence.

The engineer and historian Antoine Picon is also critical of the present system and the absence of alternative adaptations that correspond to contemporary urbanisation. Picon examines areas of low-density urban sprawl and water systems at a territorial scale.[19] Construction and maintenance of such water management is extremely costly (2005). A society with a retrogressed economy, he argues, may have difficulties maintaining a good water supply. Other relevant literature includes the book *Water and Asphalt* (2016), edited by Paola Viganò, Bernardo Secchi and Lorenzo Fabian, which proposes a decentralised territorial model of water- and mobility structures as an isotropic network. This demands locally autonomous water structures to avoid the challenge of a territorial supply system.

Kelly Shannon and Bruno de Meulder coined the term 'water urbanism' (2008) to highlight the value of integrating the logic of water into urbanism.[20] According to these urbanism scholars, contemporary urban planning fails because it treats water as a 'separate system'. They argue for a more resilient urbanism that concerns itself with water and works with the forces of nature rather than fighting against them. They have applied their knowledge in various landscape and planning projects, with special attention to the effects of climate change and rising sea levels in delta areas in East Asia, arguing for a soft engineering approach in which interventions adjust to the natural logic of water.[21] 'Landscape urbanism' projects fuse landscape, larger-scale structures and built environment into a single system (Waldheim 2006).[22] Landscape architect and urban planner Pierre Bélanger defines 'landscape as infrastructure' and argues that infrastructure services can be an integrated part of the landscape (2016). In this thesis, the definition of landscape as infrastructure can help the different fields of landscape architecture and engineering to approach one another and interact on common ground.

In urban planning, 'green infrastructure' signals a distinction from the older term 'green space planning', where open space goes from being an amenity to a necessity that is strategically planned into an interconnected network. 'Infrastructure' implies an area that requires maintenance and restoration over time, in contrast to a nature reserve or a green space. It corresponds to an

[19] Territorial low-density urbanisation demands many metres of pipes per household.
[20] *Water Urbanism* is a publication of an eponymous thematic collection and recompiles ongoing research from several universities worldwide.
[21] Kelly Shannon describes the culture in southern Asia and the lessons to be learnt from the old ways of relating and adapting to and living off the water. To understand the strong water-related culture, it is important to note that before the rainy season, one-third of the land is submerged; during the rainy season, more than two-thirds is under water.
[22] Landscape urbanism and the close relationship between landscape and urbanism can be found in French landscape architecture tradition long before the 21st century (Bava and Picon 2022).

ecological framework that aims to achieve environmental, social, and economical sustainability (Benedict et al. 2002). Hence, green infrastructure corresponds to a multifunctional network that includes water and can be related to as a blue-green infrastructure (Gledhill and James 2008; Selman 2008).[23] This approach is not new; already in the late nineteenth century, landscape architect Fredrik Law Olmstead was integrating water into the green infrastructure in the design of the Emerald Necklace Park system in Boston, where the objective was to improve the 'muddy river' (1894). As a public figure, he promoted water as an active player in planning. The green plan for Oslo from the mid-20th century was initially designed with the intention to link the natural areas of Marka[24] to the fjord with a network passing through the urban areas. It was based on a path system; only later was the water integrated with the intention of unearthing the buried rivers (Haukeland 2013).

In the Dutch context, several natural catastrophes prompted water planning practitioners to adapt their infrastructural strategy. For instance, landscape architect Dirk Sijmons' project 'Room for the River' returns space for the river's dynamic changes over time. This shift implies a change in planning in terms of scale and hierarchies of importance. It also changes the relationship between humans and their landscape from domination and control of the water to a position of subordinance in which humans must adapt to the logic of the water.

Extreme events demand work with the whole watershed. For rivers passing over national borders, this international cooperation is necessary to handle both water surplus and water shortages. This change of scale from a municipal concern to a national concern can be discerned in the projects of the French landscape architectural practice AgenceTer, which follows river dynamics across national borders (Bava et al. 2011).

Rapid urban expansion in China in recent decades has led to challenges with stormwater management and flooding. The term 'sponge city' was introduced by the Chinese government in 2013 to define a blue-green infrastructure with integrated areas that can host surplus water and prevent the city from flooding (Ka Shun Chan 2018). Large-scale water-based planning projects have been carried out in China by the professor of landscape architecture Kongjian Yu. His strategic mapping projects cover the entire country in terms of water presence and synthesise an 'integrated map of areas to be conserved to promote healthy ecological systems and water management' (Saunders 2012). Included are inundation areas, the quantity and quality of fresh water, risk of soil erosion, and biodiversity conservation. Water systems are key in this planning for structuring the urban development and prioritising the values of non-built areas.

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[23] Blue-green infrastructure: the blue represents rivers, creeks and other water bodies, and the green represents open landscape elements and vegetation.
[24] 'Marka' is the recreational forested reserve of Oslo.

Thinking and representing water

The climate crisis raises questions about our surroundings on a global level, for example, what happens when years of drought dry out rivers and lakes (Yao et al. 2023). In relation to planning and landscape architecture, questions arise about our representational approach to water, which in its turn enables design. Depending on representation, the field of intervention for design will vary. 'A representation is not about […] depicting reality, but about making knowledge' (Kahn 2021: 195). Designers can seldom handle larger-scale questions that have not been visualised first. Visualisation is key in co-design processes to clarify the context and action. What is not represented in analysis and mapping rarely becomes part of the design. If a central element is overlooked in the design phase however, such as underground installations that interfere with the design, this might change the project in later phases – even on the construction site. Visualising the dynamics of water and its changing levels over the year, including extreme events, can be emphasised by water being marked at multiple levels in plans and sections. Drawing multiple levels helps situate proposed projects in relation to a shifting context. Nonetheless, maps typically still represent water as rather static.

Geographer Denis Cosgrove writes about how our thinking has been formed by the conceptual grid of modernity, which has emphasised boundaries and separation (1999). Much of our planning still adheres to boundary principles, defined by the surface of the ground; it abides by property limits and defined areas. 'Today in the landscape, as in every other field, intellectual and practical, the most intriguing question lies precisely at the boundary – which is of course no longer a boundary' (Cosgrove 1999: 136).

Figure 5: Early drawings of water's presence in the landscape (2015). Ill: Author.

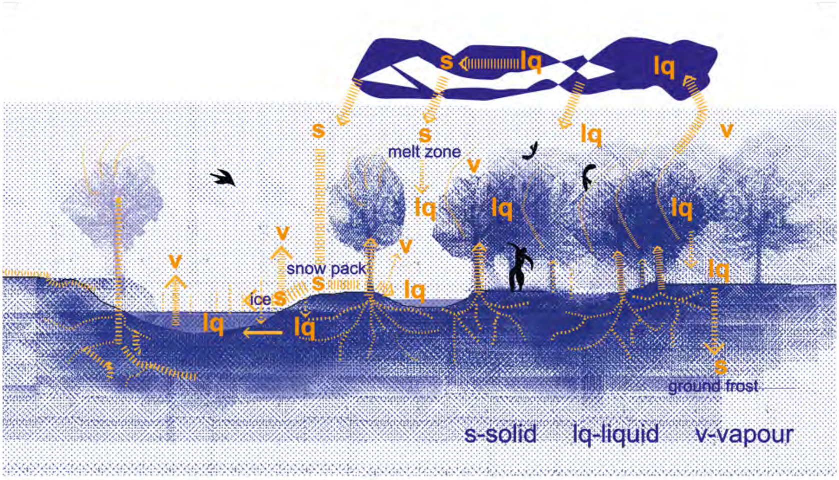

Figure 6: The movement of water as vapour, liquid or solid bridging the grade of the ground. Part of the presentation 'Suspended Water', presented in 'Landscape as Necessity' USC (2016). Ill: Author.

Geographers Philip Steinberg and Kimberly Peters describe the slow movements, processes, and changes of the ground and its groundwaters in 'wet ontologies'. They explain that 'the earth as a configuration of multiple materials opens a vision of the world as being mobile and emergent, not in a state of being but in a state of becoming' (Steinberg et al. 2015: 127). They advocate a definition of the sea that reaches from its surface to its depths. 'The vertical element of volume is all too often abstract and dematerialised… and the temporality that is employed to reintroduce "motion" to matter has the unintended effect of signalling a periodic sense of time that minimises the chaotic underpinning and experiences of place' (Ibid: 247). Steinberg and Kimberly assert that the world is not stable and static, but in change, with connection, flows and openness rather than entities contained within borders. They equally challenge 'horizontalism' and argue for a 'vertical world of volume' (Steinberg et al. 2015).

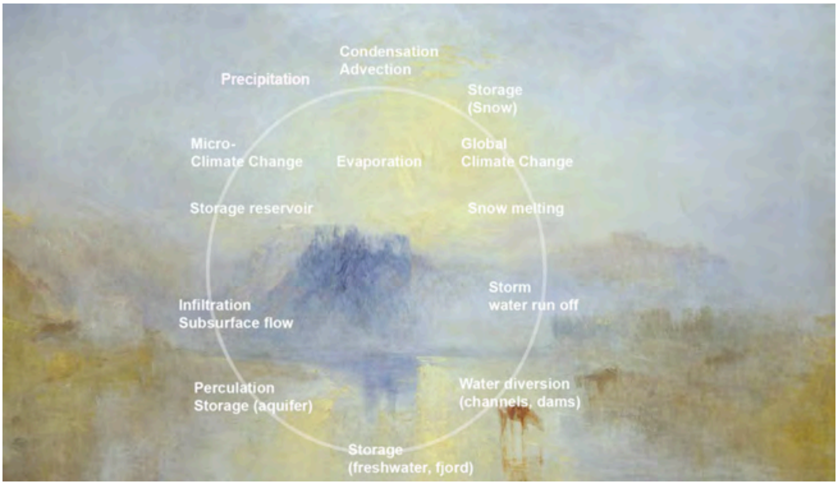

Figure 7: Illustration of the omnipresence of water. Ill: Author on painting by Turner and diagram from 'Advances in Urban Ecology' (Alberti 2008).

One way to understand successive changes is to visualise how things are and register alterations over time. The changing presence of water has been illustrated in the works of architect and landscape architect Anurada Mathur and architect and planner Dilip da Cunha (2009), who drew on experience from India's monsoon landscapes. Da Cunha's statement that 'Water is everywhere' (2014: IV) changes how water is perceived and represented; rather than statically defined blue entities on a map, it becomes dynamic and omnipresent. Water is an entity present in almost everything (even us – humans are composed mainly of water). A challenge is the groundwater's invisibility and its variation over time. Although it might be reflected by the vegetation at the surface, the presence of water cannot be determined by observing the landscape's surface, and if it is not visible on maps, it is easily neglected in design.

Geographer Marie Tharp drew out the invisible in her groundbreaking work by defining what could not be seen on the bottom of the sea. Working in the 1960s, she revolutionised the puzzle of the ocean floor by adding sections that together allowed a new reading, a comprehensive picture of the non-visible ocean floor. The sections were generated with information gathered with boats and sonar equipment with which the depths were measured. This is an example of a working method that interpolates and assembles bits and pieces of knowledge into a greater whole. Today, 3D-scanning of the ground makes it possible to define the composition of the first metres of the underground. New technologies by NASA have also made it possible to define previously inaccessible groundwater levels around the globe.[25] This entails new possibilities to incorporate knowledge on groundwater into planning.

Figure 8: Geographer Marie Tharp, at work mapping the untravelled ocean floor. By adding sections, she enabled a completely new reading of the non-visible underwater ocean topography. Ph: Lamont-Doherty Earth Observatory.

2.2 GROUND IN URBANISM AND LANDSCAPE ARCHITECTURE

The ground can be defined as the solid surface of Earth. It may consist of geologically formed rocks, loose eroded masses, soils and human-modified grounds. Depending on discipline, different parts are in focus: the geologist's concern is the mineralogical composition of rocks and its geological processes. Hydrogeology is 'the study of the movement of water through the subsurface geologic environment' (Smith L 2015) and also deals with the aquatic

[25] Gravity Recovery and Climate Experiment (GRACE) registers the presence of water at the Earth's surface. It detects month-to-month changes, which shows a large-scale dynamic of the planet's water presence. 'Monitoring changes in ice sheets and glaciers, near-surface and underground water storage, the amount of water in large lakes and rivers, as well as changes in sea level and ocean currents provides an integrated global view of how Earth's water cycle and energy balance are evolving – measurements that have far-reaching impact on our understanding of the Earth system and important applications for everyday life' (California Institute of Technology 2002).

geochemistry.[26] The soil is the interest of the pedologist, biologist, ecologist, biodiversity professional, and the farmer, and it is central for food production and our existence. The 'living soil' consists of minerals (of geological origin: clay, silt, and sand); organic matter (plant-, animal-, and microbial residues); and living organisms (such as bacteria and fungi). The landscape architect is concerned with the relief, permeability and fertility of the ground. The environmental geologist is concerned with the human impact on the Earth's systems, for example 'manmade ground' and possible pollution.

The architect is concerned with the solidity of the ground and can project the underground as sequences of spaces. In urbanism, Patrick Geddes related the territory with its ground conditions as a guiding support for human activity and settlement in the late 19th and early 20th century. Landscape architect Anne W. Spirn criticises urbanism for losing its relationship to its grounding conditions as its climatic, geomorphic, and biotic context. She describes the landscape as a built-up surface in constant change, modified by humans and by natural processes. According to Spirn, under the surface there is a more 'enduring structure to which all organism within that landscape respond'; she calls this 'deep structure'. Her concept of deep structure includes the notion of 'biome and physiographic regions' as well as the 'physiographic region, with its rock types, geologic history, and climate' (Spirn 1993: 9). Spirn's work is more timely still in a situation of climate crisis, where changed climate and water patterns reveal the notion of the deep structures more clearly, with rivers reclaiming their original paths and wetlands returning wetlands, despite having been drained and built upon.

'Deep structure and its surface' are both mentioned above; the archaeologist defines the surface modified by humans and its historical strata; in archaeology, the 'manmade ground' is the ground reworked by humans over time. Archaeologist Matthew Edgeworth from Leicester University calls the upper layer of the artificial ground 'the archaeosphere' (Fig. 9), a combination of cultural and naturally occurring ground (2014). Edgeworth differentiates between manmade ground and human-modified ground, taking into account the work done by organisms in the 'living soil', which also modify the ground alongside humans. The ground is thus seldom strictly 'manmade'; instead, it is the result of various processes of change (Fig 9).

[26] At present, hydrogeologists are seldom directly involved in general urban planning in Norway. However, they may be involved in infrastructural tunnelling projects where the ground conditions directly affect what is being built.

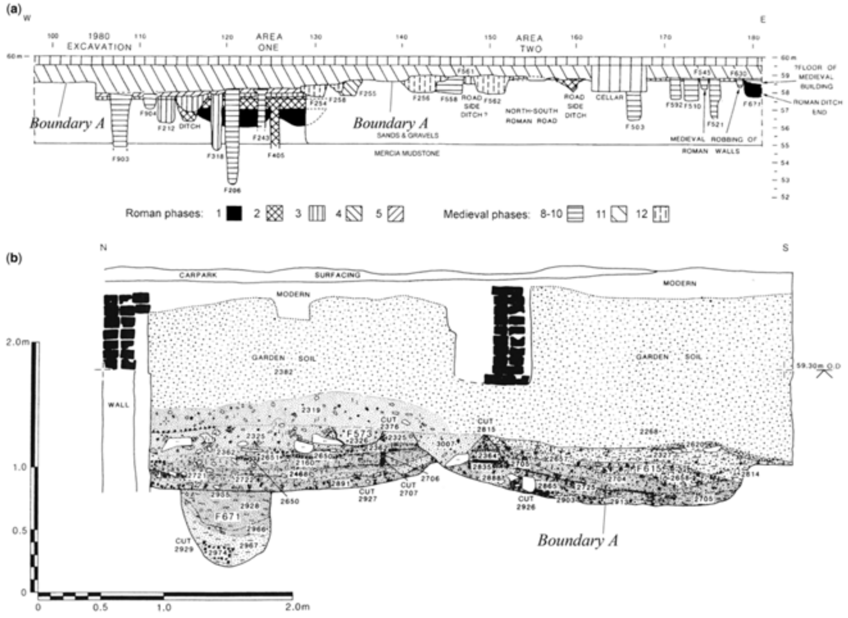

Figure 9: Description of the underground with deposits from human activity down to 'boundary A' and the earlier geological layers. Illustration by Matthew Edgeworth (2014) based on the archaeological survey of Leicester (Lucas, 1981).

Human activity means that the layers are no longer static strata; instead, they are reworked, moved, and exchanged. The main categories of 'artificial ground' can be defined in relation to the different human actions that have taken place. This provides different types of grounds: *worked ground*, which is cut or excavated; *made ground*, formed by deposited material; *infilled ground,* which is first cut or excavated and then filled in with deposited material; *landscaped ground,* which has been significantly remodelled; *disturbed ground*, a complex result of mineral extractions and infrastructure works (Rosen Rosenbaum and McMillan, 2003).

Professor of landscape architecture Alan Berger describes the territorial effects of the manmade wastelands in his book *Drosscape*, which illustrates the consequences of deindustrialisation on the landscape in horizontally-layered maps, diagrams, and aerial photos (2006). In his later book *Designing the Reclaimed Landscape* (2008), Berger aims to relate theory on ground composition to design practice; information on what is in the ground is key in facilitating an environmental design. Similar wastelands have been created in Norway. In the wider Oslo region, landfills on top of old, buried creeks (such as the Kjørbekk site) are not uncommon, and similar situations can also be found elsewhere. When rivers were routed into pipes between the 1960s and the 1990s, the dried up, concave riverbeds left behind were frequently seen as opportune places for dumping waste.

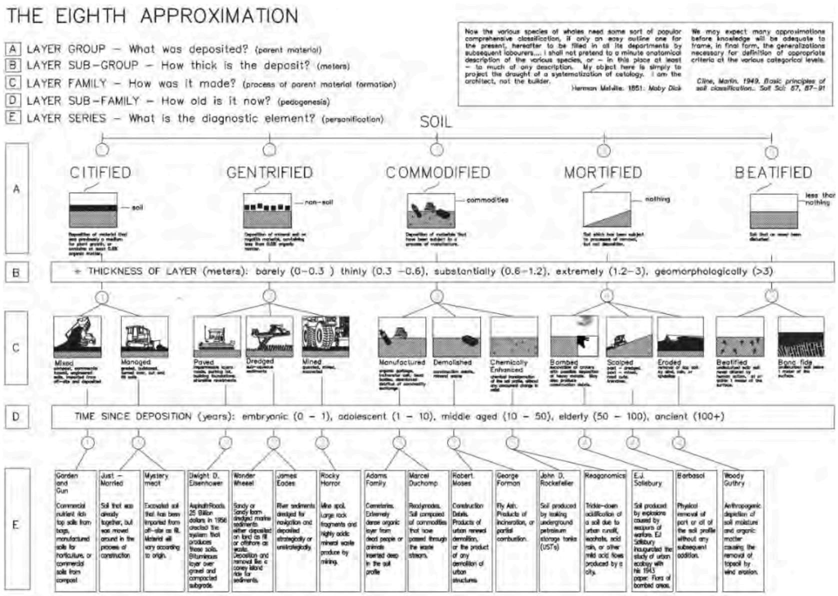

Figure 10: Seth Denizen defined an ‘Urban Soil Taxonomy; the Eighth Approximation’ where the soil is classified in a matrix in relation to how it was made: citified, gentrified, commodified, mortified or beautified. This is related to ‘What was deposited? How thick is the deposit? How was it made? How old is it now?’ etc. Diagram: Seth Denizen, 2012.

Landscape architect Seth Denizen synthesised several national definitions of artificial ground in ‘Urban Soil Taxonomy; the Eighth Approximation’ (2012) (Fig.10). The organisation of the categories follows the landscape architect’s need for information in a project, such as: What was deposited? Is it toxic or not? What are its qualities? How old is the deposit? How was the deposit made? These questions are the basis for determining which type of landscape intervention is appropriate.

Fransje Hooimeijer and Linda Maring have developed additional working methods for integrating the subsurface in the development of urban projects (Hooimeijer and Maring 2018), defining a systems approach called the S*ystem Exploration Environment and Subsurface* (SEES). The matrix they developed includes the subsoil of civic constructions, energy supplies, water, and the subsoil characteristics; it functions with the different layers of the urbanised areas, unifying the subsurface conditions with the planned aboveground activities (Fig.11). SEES has been tested in project development in Netherlands to determine what is important for a project team to consider when working on urban ground. While these considerations refer to human activities in relation to the ground, the upper crust of the earth hosts microorganisms that remodel and shape the ground. Without them, all fallen leaves, trees and branches would remain intact, resulting in impervious forests. The remodelling of the ground must thus be complemented with the processes of change that are not driven by humans, but rather generated by other living organism and ecological processes. The overview is meant as an operational tool for urban development and can be supplemented with a perspective of effects for other species to be taken into account in order to promote biodiversity in those operations.

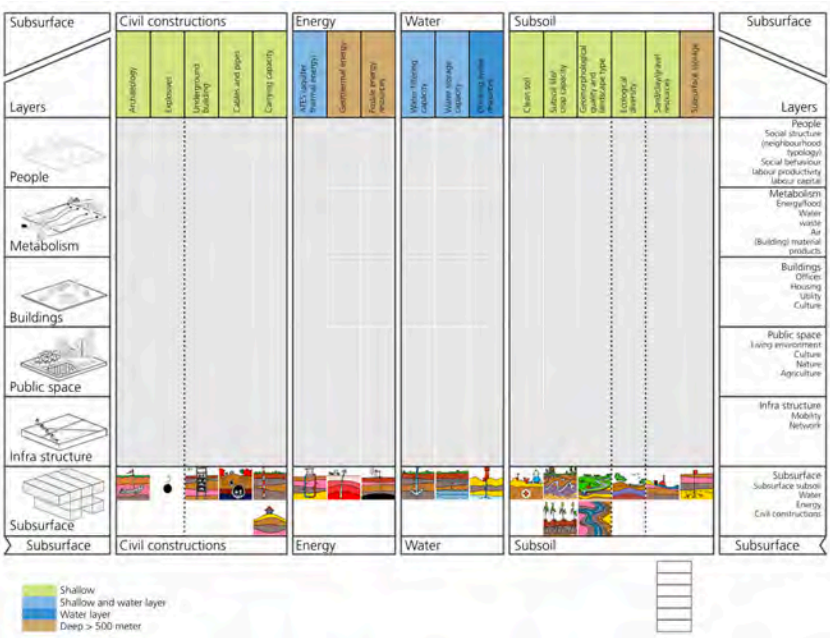

Figure 11: Hooimeijer and Maring developed System Exploration Environment and Subsurface (SEES) with the aim to integrate the subsurface in development of urban projects. Diag: Hooimeijer and Maring, 2018.

Different urban approaches to the underground

Different urban approaches to the ground can be observed throughout history. Urban form can relate to the ground – by adapting to its topographical relief, to its greater landscape elements such as water courses, to humanmade structures from former agricultural patterns, etc. Architect and PhD in urban design and planning Panos Mantziaras questions how architecture has been informed by its context of soils and asks whether architecture on limestone differs from architecture on silt ground, and whether the city developed on unstable, humid ground is different from one that takes form on dry, rocky ground (Mantziaras 2016: 15).[27]

Historically, fortresses have been located in strategic, high positions adapted to the topography and offering good surveillance of the surrounding landscape, as well as to control access (Fig.12). Existing topography also informed Oslo's old road systems, which follow the ridges of the landscape to provide dry streets and make use of the inclination of the terrain for smooth transitions for vehicles and pedestrians. This is an urbanism that adapts its forms to the topography.

Figure 12: Fortification of Morella, where the built adapts and fusions with the terrain and its topography. It later became a village with concave-formed streets winding concentrically up the mountain (1822). Plan: Archivo Historica Militar. Madrid, Spain.

[27] From The 'Sol de Villes, Resource et Project'. 'Est-ce que l'architecture sur les limons est différente de celle sur le calcaire? Est-ce qu'une ville sur un sol instable et humide est ou devrait être différente par rapport à une ville sur un sol sec et rocailleux?' (P Mantziaras 2016: 15).

Another approach has been to alter the terrain to create a desired topography. This has been done on a small scale in Norway in the steep fjord landscapes. The built environment in form of the classical 'klyngetun', corresponding to a cluster of buildings, recomposes the ground and its topography to create common horizontal areas in the centre.

Urban development that follows the geometries of agriculture is often closely related to the ground properties and inclinations. Drainage systems and water courses have shaped city development and its successive growth over time. Architect Ph.D Katarina Wiberg points out in her thesis *Waterscapes of Value*, that divisions of land in Denmark was done in relation to the properties of the landscape. It aimed to distribute land in relation to the capacity of exploitation, access to water, the terrain and its slopes and its agricultural capacity in terms of soil, sun and wind (Wiberg 2018). In Norway, the landscape's properties from the fjord to the mountains have guided the initial narrow plot structures, starting at the fjordshore to provide access to transport of goods and fishery, continuing uphill to encompass farmlands, pastures, forest and seasonal grazing areas on the mountaintops. These structures provide the possibility of a variety in production, making these farms sustainable in a mountainous area.

An alternative to this is the geometry of the land survey grid of the midwestern United States, also called the Jefferson Grid. It was introduced by Thomas Jefferson after the American Revolution in 1785 as a rational form for rapid management of the territory. The grid has a north-south orientation regardless of topography, ground conditions and the presence of water (Fig. 13).

Figure 13: The Jefferson Grid applied in the territory of Kansas. The orientation of the grid is north-south, regardless of topography, ground conditions and water presence. Aerial ph: Google Landsat / Copernicus Data SIO, NOAA, U.S. Navy, NGA, GEBCO (2023).

Another grid is Ildefonso Cerdá's isotropic grid in Barcelona, which related to the ground and its topography. It was oriented to correspond to former rivers; the iconic street 'Las Ramblas' is positioned over an old river, which has enabled massive trees to grow there. The grid's orientation perpendicular to the waterfront permits excess rainwater to flow back into the sea and the winds from the sea breeze to ventilate the city.

Urban designers such as Cerdá and Adolphe Alphand integrated the underground into urban planning in the 19th century, using the street for various forms of underground infrastructure. In the planning of Paris, even the trees had an underground infrastructure of prepared continuous underground ditches with good soil that provided an interconnected network for living organisms and rainwater (Lanton 2017). When planning the expansion of Barcelona in the mid-19th century, Cerdá highlighted the importance of the street as the bearing structure for urban design and installations. He divided the city into a grid of 'infrastructural streets' (vías), and 'in-between streets' (intervías) that outlined future building plots. His primary focus was on the street with its infrastructure, and his secondary focus was on the built environment. The grid relates to an organised underground infrastructure of sewers and cables as well as the underground space needed for planting trees; the resulted is a predictable structure and built geometry.

Another type of infrastructural installation found in some low-density areas in Norway does not take into account urban development over time, but instead selects the shortest route to supply points (Fig. 14). The result is an angular geometry inconsistent with the plots above the ground. When the area is further densified, construction above the ground is limited as it must relate to the underground. Changing subterranean infrastructure is often expensive, and new buildings are thus positioned over the existing infrastructure, with consequences for maintenance emerging over time.

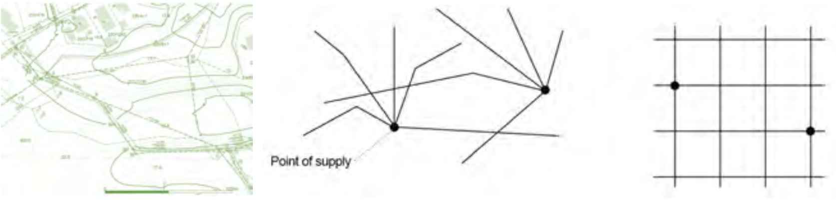

Figure 14: Left: An ad hoc installation solution as an example from the design case redrawn as a principal diagram in the middle, contrasted on the far right with an installation that follows the street structure, such as in e.g. Barcelona. These two types of installation contrast an urbanisation that is planned for (right) and the non-planned urbanism sometimes found in peri-urban areas (left and middle). Plan left: Skien Municipality. Diag: Author.

In 1911, architect Eugène Hénard drew a vision of 'The Cities of the Future', where the city and its transport- and supply infrastructures expanded down into the streets and created a continuous construction between the underground of the buildings and streets (Fig. 15). A few years later, architect Harvey Wily Corbett perforated the street and added vertical bridges, creating a multi-layered city in which it became difficult to discern which layer was the original ground level (Fig. 15). While Eugène Hénard's and Corbett's sections show spatial definition and functions in different layers of the vertically expanded city, the section of Haussmann's sanitation project shows the materiality of the multi-layered manmade ground in between the city's underground installations (Fig. 16).

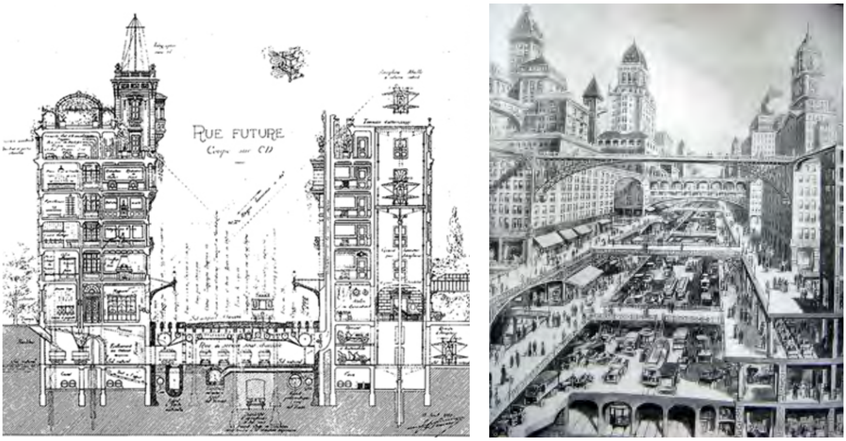

Figure 15: Eugène Hénard's Cities of the Future. (1911); and an idea for a future city by Harvey Wiley Corbett from 1910. Both show a city that extends vertically. In Corbett's version, it is even difficult to distinguish which level corresponds to the ground level, as bustling life and sunlight are present on various levels. Ill: Eugène Hénard's Cities of the Future, published in American City, January 1911. 'Project for New York' Harvey Wiley Corbett published in the New York Tribune, 1910.

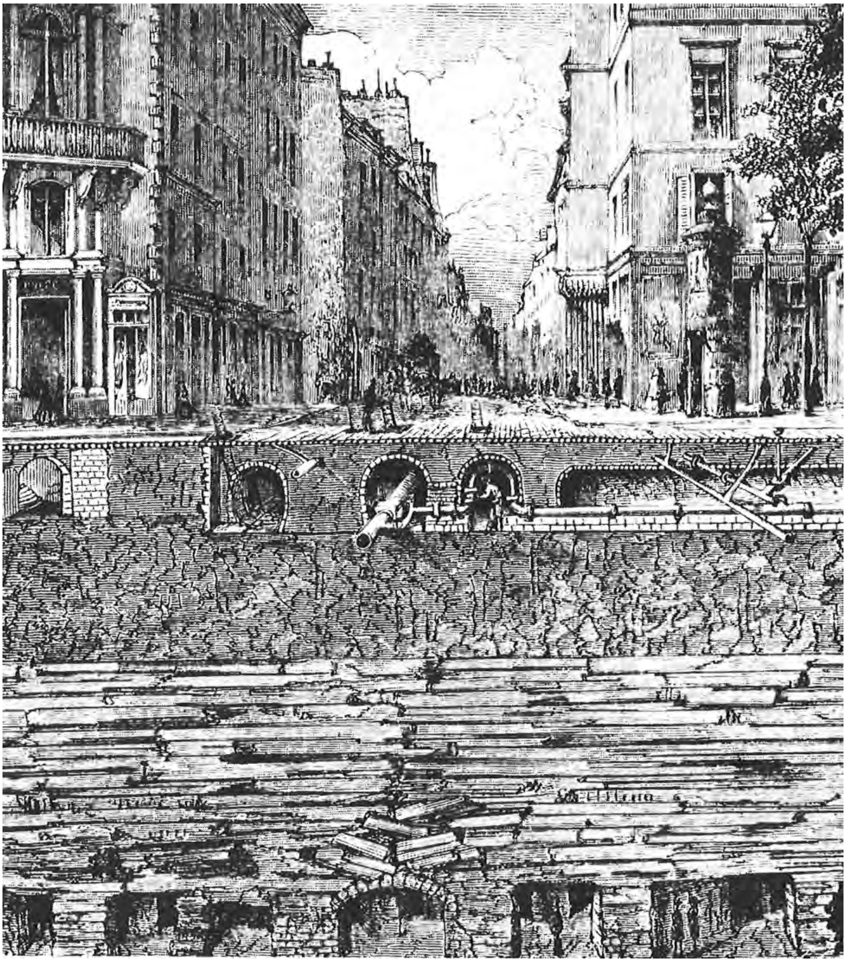

Figure 16: Illustration of Paris' underground during Haussmann's sanitation project. From the 1986 book On Streets by Stanford Anderson, p. 94.

In 1932, French architect Édouard Utudjian presented the idea of underground urbanism, arguing for the necessity of the urban planner to think deep, to avoid the underground development of cities to be done through random necessities, but instead according to a predetermined plan of a greater whole (1965).

The book *The Urban Soil*, edited by Panos Mantziaras and Paola Viganò, offers an overview of the role and transformation of the soil over time. The investigation is inspired by the statement of Bernardo Secchi that the urban project is a project of soil (1986).

Further the French urbanists Sabine Barles and André Guillerme later wrote about underground urbanism, urban soil, and the changing composition of the ground (Barles, Guillerme, 1995). To grasp the city's ongoing physical transformation and constant exchange of materials, Barles has centred her research on the metabolism of the city, which is key to handling its footprint and future ground complexities and avoiding complications from toxic landfills.

Thinking and representing ground from different disciplinary perspectives

The lack of ground considerations has been commented on by Robin Dripps, professor of architecture. Dripps argues that architectural maps define the ground as empty, such as 'figure-ground maps' (2021). In these, the white 'ground' provides neither information nor resistance with which the built structures are supposed to enter into dialogue (Fig. 17). 'A site, in contrast to a ground, is quite simple. This is undoubtedly why the idea of a site becomes so appealing to architects and planners' (Dripps 2021: 76). She argues that it is easier to relate to a site representing certainty than to a changing ground condition. When the ground is understood as much more than a plane, it will transform how architecture engages with and around it. To adapt and interact with its environment, architecture needs a definition and working methods to incorporate the ground. Below is shown examples of various historical maps that allow the character of the ground to be revealed (Fig. 17). Here, the ground is not represented neutrally, but as possessing inherent forces, suggesting ongoing transformations directly related to the built environment.

Figure 17: The maps show the relation between the built and the ground. Map to the left: Kartverket (Amtskartsamling) Østfold: Hand drawn 1:600, C. A. Storm, P. Wilster, H. H. Scheel, I. Peucker, 1703. Top right: Figure-ground map. Below right: Kartverket (Amtskartsamling) Akershus: Hand drawn 1:20000, J.N. Hertzberg, 1859.

Dripps argues in favour of shifting away from the architectural object 'as an autonomous, abstract formal ideal and privileges the existing physical and political context that a design would have to engage' (Dripps 2021: 88). This change would imply a more significant variation in architecture, creating a need for creative answers to demanding conditions and underlines the need for ground-specific architecture and consequently an urbanism that builds on ground-specific conditions.

Hydrology studies the interrelation between water and ground in its natural setting. The figure below is a geometrical characterisation from 1967 by geologist AD Howard (Fig. 18). The ground conditions guide and form the water, and the water shapes the ground by erosion on its path; this shows the interrelationships between water and ground at the earth's surface. Understanding this water- and ground dynamics can help facilitate design that can endure over time.

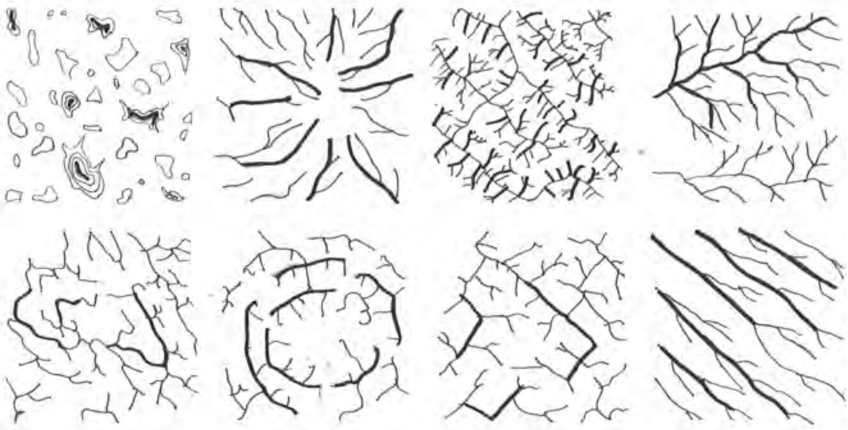

Figure 18: Example of basic drainage patterns. The form of the water is guided by the conditions of the ground and sculpts the ground by erosion. Drainage patterns from top left: multibasinal, radial, trellis and dendric. Below left: contoured, annular, rectangular and parallel. Drawing: Author, based on illustration by Howard, 1967: 2248.

Mapping by layering territorial horizontal information about the content of the landscape's surface has been utilised extensively in urbanism, while the vertical graphical synthesis of processes and change has generally been used less.[28] Here, the natural sciences have the potential to inform and provide working methods for a more ecologically sound urbanism. Two hundred years ago, Alexander von Humboldt made his famous deep sections and *tableau physique*, which described the geology, botany, climate and the interrelation between the disciplines of geology and biology and how they related to the climatic context (1807). Patrick Geddes' development of the Valley Section (1909) relates the landscape relief and different properties to the human

[28] In the landscape setting of Norway with its pronounced topography, hazards such as rockfalls, avalanches, landslides etc, are often related to the relationship between water and ground. This can best be understood with deep sections that reveal the interrelation between water and ground below and above the ground.

activity that it facilitates. A more frequent use of sections in urban planning could help reveal the composition of the ground and the interaction between the layers, approaching the different underground processes at work.

In landscape architecture, the knowledge of the ground composition is a premise for selection and growth of the planned vegetation. Ian McHarg pioneered the landscape transect that was sometimes combined with perspective drawings and a sequential section describing the water, ecology and the vegetation's relation to the ground composition and the dynamics of change.[29]

Architect and environmentalist Stephanie Carlisle and architect and landscape architect Nicholas Pevzner write about the performative ground, describing the deep section as the foundation for integrating the underground in order to create a performative landscape project (2012). Departing from landscape architect McHarg's original explorations, they trace three primary types of deep section – *the landscape transects*, *the sequential section*, *and the structural section.* The landscape transect shows the landscape context in its entirety, with its topography and geomorphology. The sequential sections show sequences and changes over time, such as the project development for Fresh Kills by landscape architect James Corner and ecologist Nina Maria Lister, as well as the project presentation by Anuradha Mathur and Dilip Da Cunha (2009). Lastly, the structural section shows how things are built. Carlisle and Pevzner conclude that 'With more and more landscape projects today being built over infrastructure, over unstable soils, or even atop capped landfills, it is critical for landscape architects to deepen their understanding of complex site dynamics' (2012: no pagination).

In *La synthèse écologique* from 1980, ecologist Paul Duvigneaud demonstrated an interactive spatial relationship between the ecosystem and ground (Fig. 19). This visualisation is an important tool to facilitate the integration of ecosystems and human activity into design. This reflects a vertical graphical synthesis and the interaction between entities.

[29] The layering technique that McHarg used was probably inspired by Jaqueline Tyrwhitt, who expanded on the ideas of Scottish ecologist and urbanist Patrick Geddes (Shoshkes, 2017). Jaqueline Tyrwhitt conducted multidisciplinary regional planning research with a broad scope that included: industry, agriculture and nutrition, population, housing and recreation, health and education as well as uses of waste. (Shoshkes, 2017). McHarg attended Jaqueline Tyrwhitt's courses when she was the director of the Association for Planning and Regional Reconstruction (APRR) in London during the Second World War. One of her analysis techniques was overlaying different thematic maps in the same scale to find correlations. When inserting Jaqueline Tyrwitt in the overview of the urban history, the vision passes from individual independent great names to a network of thoughts where the ideas are carried further and developed from one author to another.

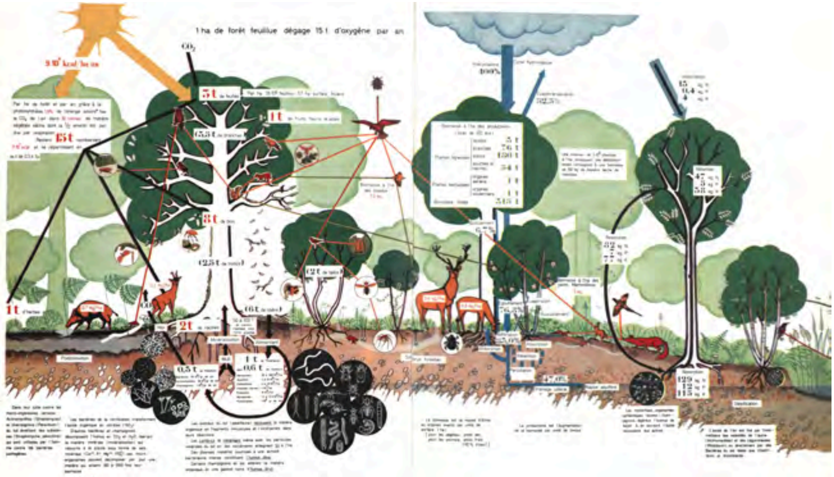

Figure 19: In ecology, the deeper section has been central for showing the different ongoing processes. Diagrammatic section showing the forest ecosystem of upper Belgium from La synthèse écologique by Paul Duvigneaud, (1980: Illustration 11).

System diagram sections of the urban metabolism show the quantitative relationship between the entities in the exchange from water to energy to gas emissions and develop this further to encompass the urban context of the manmade metabolism of the city (Fig. 20).[30] This type of diagram shows how self-sufficient a city is. The diagram can serve as a systematic overview to identify leverage points and indicate where to define alternatives to create greater environmental effects. The diagram illustrates zones of the vertical layering and the depth of the landscape.[31]

[30] Ecologist HT Odum used systems thinking earlier to describe ecosystems with their energy and matter flow (1957).

[31] 'L'écosystème urbs: l'écosystème urbain Bruxellois', from Duvigneaud, P and Denaeyer-De Smet, S (1977: 589).

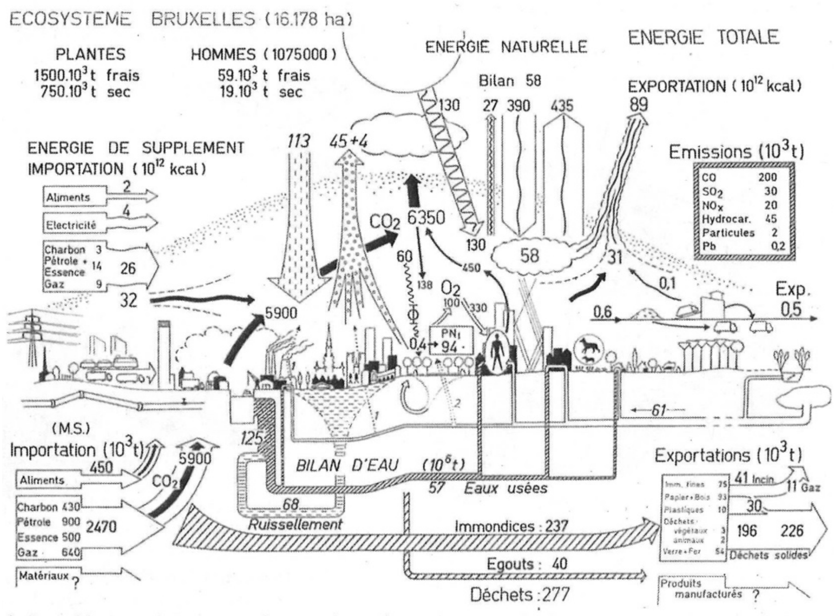

Figure 20: The system diagram of the urban metabolism of Brussels' Ecosystem shows the quantitative relationship between the entities in exchange from water to energy and to gas emissions, 'L'écosystème urbs: l'écosystème urbain Bruxellois', from Duvigneaud, P and Denaeyer-De Smet, S (1977: 589).

2.3 KNOWLEDGE GAPS OF WATER AND GROUND IN URBANISM

Drawing inspiration from the scholars and practitioners presented above, this research investigates the dynamic and changing relationship between water and the urban ground. Water urbanism has extensively explored the influence of water on urbanism. The territorial structuring aspect of water is highly present, as are quantitative aspects in terms of flooding and sea level rise. Less pronounced however is the relationship between water and the ground, where water changes the properties of the ground, and the ground, modified by humans, changes the properties of water. In the field of urbanism, ground conditions are important in the establishment of safe settlements, but rapid urbanisation often means that the site's ground conditions are not considered properly in urban propositions. Architect Solà-Morales argued that cities 'by growing fast and all at once, have lost their relationship to the ground, which later sets a high price to be paid' (Morales 1987: 25).[32] Katrina Wiberg also points out that 'contemporary settlement patterns, planning and ownership practices do not embed landscape practices and the dynamic logics of water'

[32] Translated by author.

(Wiberg 2018: 135). With regard to water, this becomes obvious in extreme events that provoke floodings.

Historical buildings are often situated in favourable locations in the landscape, and long-term experience of the ground conditions, winds and micro-climate have guided the selection of the site. In more recent urbanisation, then, the best plots are often already taken and other factors have guided the built environment. With technological advancements over time, the question has changed from 'if' to 'how'; i.e., 'if' an area is suitable for a certain programme to 'how' technical solutions may be implemented to compensate for challenging ground conditions. The effects of climate change and an increase in extreme events are a strain on technical solutions. An example that illustrates the 'modern' paradigm is still found in the recently developed Oslo harbourfront, where high-rise buildings rest on unstable ground. To compensate, a technical solution was implemented in which a thousand steel pillars anchor the buildings to the bedrock; however, the sinking sidewalks follow the dynamics of the ground and detach from the buildings (Lande, 2014). Perforating the clay ground with pillars also changes the pressure in the ground and alters the properties of neighbouring plots (Fig. 21). These planning and building choices have a great effect on each building's ecological footprint, as a significant part of the building is located underground. Thus, human activity that affects the ground – such as groundwater extraction, the reduction of refill of groundwater due to impermeabilisation and subterranean waterways severed by built volumes in the ground – influences the ground properties, both at the site of intervention and at neighbouring grounds, as well as the groundwater properties, and this represents a missing knowledge vector in planning.

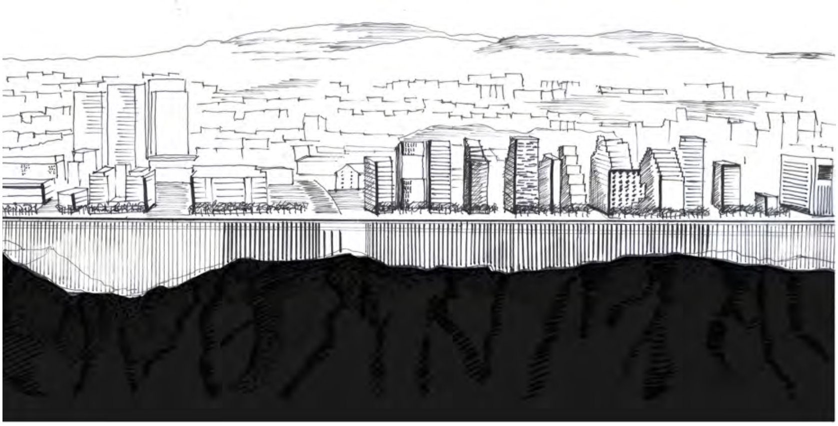

Figure 21: Illustration of the underground constructions at the Oslo harbourfront. A large part of the construction for buildings in this area is found underground to compensate for the poor initial ground conditions. Ill. Author, based on a section from the research project COST suburb.

Professor of landscape architecture and planning Anne Whiston Spirn problematised the lack of knowledge of water and its relation to the ground via work she conducted with her students in west Philadelphia in the 1980s. Spirn was using the permeable surfaces of vacant plots to infiltrate and replenish the groundwater levels; at the same time, the plots became opportunities for community cultivation lots (1984). She showed that in urbanism, lacking knowledge about the ground's dynamics and about how water and the ground interrelate, results in challenges across scales, from destabilisation of the buildings due to changing ground properties when impermeable surfaces alter the groundwater tables to sinking cities due to groundwater extraction. Spirn's work with local stakeholders made them aware of the issues meriting concern whilst also providing the local municipality with possible landscape measures to handle these issues.

Understanding the landscape's 'deep structure' helps define the premisses for a landscape project that goes beyond the surface. While knowledge of how the landscape is built up and composed is basic knowledge in landscape architecture in the form of deep structures, its integration into urbanism and architecture must still be developed further. The representational tools mentioned above correspond to the foundation for our theoretical understanding, translated into spatial definition. Visual representation is fundamental for the incorporation of the ground into the design processes. This thesis highlights the need for this representation whilst at the same time underlining that achieving a coherent picture is complicated, as information in Norway is incomplete and scattered, and reassembling it within a design process with defined time limits is highly challenging.

Observing and understanding long-term effects of water management has been a challenge. The work of Jane Wolff shows the changing dynamic between water and ground in the California Delta. Water has been controlled and channeled, and as a result, there is no longer sediment filling and fertilising the fields, the groundwater is sinking, and the land is subsiding (Wolff, 2003). Once the river is channelled, the ground dynamics change. The continuous transformation will strongly affect the future of the people living in the Delta; Wolff's work makes this accessible through maps, drawings, text, photos and vocabulary.

The project examples referred to by Spirn and Wolff relate to humanmade crises. The controlled river management created undesired secondary effects, and the price was sinking territories. Spirn's example of the modern technocratic and managed water structures that polluted lands with lead from vehicle runoff and sinkholes that emerged due to impermeabilisation of the landscape surface are examples of the non-planned or neglected relationships between water and ground. These examples relate to local interventions and projects but seeing them as a whole in relation to other projects with ground challenges casts light on a broader reading on the interrelation between water and human-modified grounds and the need for new approaches. This is explored further in this exegesis via the assumption that landscape has depth. Understanding the effects of changing ground properties due to water practices is fundamental for urbanism and its built environment. Other scholars were also looking into this theme at the time of my research, such as Seth Denizen (2019), who has been conducting research on Mexico City and the reasons and effects of the sinking ground condition. The literature review reveals various concerns about the soil, the ground and water. What remains to be developed further, however, is knowledge about the interaction between water and human-modified grounds and its implications for urbanism.

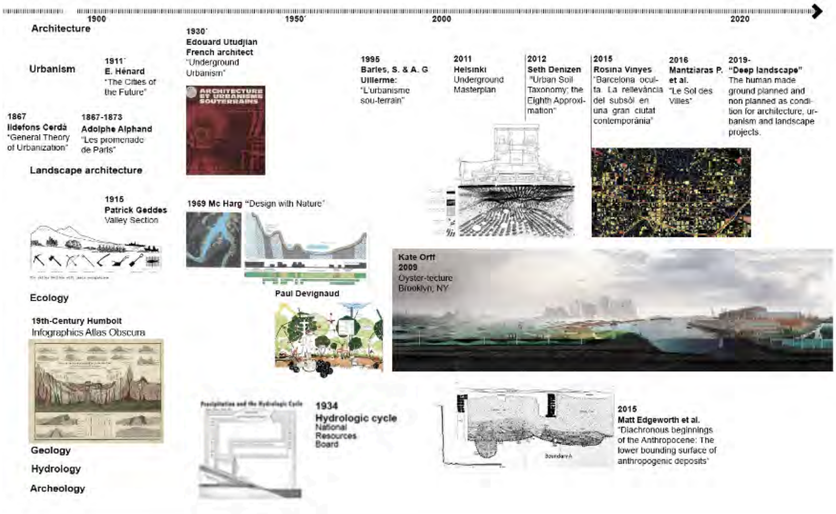

Figure 22: The figure shows polymaths for whose work the underground has been important. The overview shows examples ranging from landscape architecture, ecology, geology, hydrology, archaeology and urbanism to sociology. Illustration icons of: A section from Atlas Obscura, illustrating the composition of the Earth, Alexander Humboldt (19th century); Valley section, Patrick Geddes (1909); Hydrologic cycle, National Resources Board (1934), Underground Urbanism, Edouard Utudjian; Design with Nature, Ian Mc Harg; La synthèse écologique, Paul Devignaud; Sectional perspective of Oyster-tecture Kate Orff (2009); Urban Soil Taxonomy, Seth Denizen (2012); Barcelona Oculta, Rosina Vinyes (2015); Diachronous Beginnings of the Anthropocene, Matthew Edgeworth et al. (2014). Diag: Author.

2.4 CONTEXT OF THE DESIGN CASE IN SOUTHEASTERN NORWAY

This section provides contextual background for exploring the depth of the landscape with the chosen design case: the daylighting project Kjørbekk, in Skien, in southeastern Norway (Fig. 23). The Oslo Fjord region is an area with urban growth and ongoing transformations on manmade grounds. Various peri-urban areas in the region have relatively recent plans for urbanisation, and in many places, the coordination of underground infrastructure in relation to future urban development has not been consistent.

Figure 23: Location of the design case in southeastern Norway. To the far left: map of southern Norway's watersheds. Source: Map from master course Sp(C)lash 2017 at AHO. Middle: Skien River watershed. Source: Map: NVE. To the right: the sub-watershed of the creek Kjørbekk that runs out in the Skien River. Map: Worksonland.

The site has a historical depth with a multi-layered ground whose rich geology is representative for the Norwegian context around the Oslo Fjord; there are marine deposits and quick clay (Ramberg, 2008), as well as a history of settlements from the Iron Age (Brunsvig, 1928) and currently agricultural landscapes that have successively been transformed into industrial and commercial areas. The themes presented below relate first to the specific context of water, ground, and climate of the region; second, to the juridical setting for the water and ground, and finally, to the ground modified by humans.

Water and ground in southeastern Norway – A geological view

The effects of the last Ice Age are still noticeable in Norway. Today's rivers and topography reflect the Ice Age shaping of the land geometries from the northwest to the south in southeastern Norway (Fig. 24). Even the dynamics of today's ground reflect the ice that covered the land with a thickness of two to three kilometres; thus, the ground in this region is still rising (Ramberg, 2008). At present, land rise (4mm/year) and sea-level rise cancel out one another in the case study area, in contrast to other Norwegian coastal cities along the North Sea, where the rising sea level is a concern.[33]

[33] While sea level rise is of great importance, it is not studied further in this research as it entails a different hydrological setting than the river dynamics.

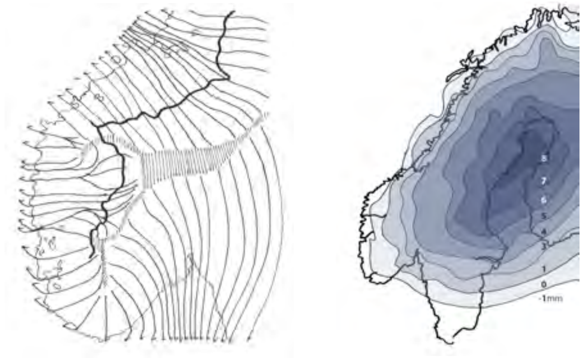

Figure 24: The effects of the Ice Age are still noticeable today. To the right, the perimeter of Scandinavia with the thickest ice at the Gulf of Bothnia, which gradually diminished towards the west coast of Norway. The annual rate of uplift is indicated as mm/per year, from maximum 8 mm at the Gulf of Bothnia to sea-level rise on Norway's west coast (modified from JF Dehls et al.). To the left, an illustration of the ice flow from the Ice Age. The blue arrows correspond to today's land formations and rivers. Ill: Author based on the book 'The Making of a Land'(Ramberg et al. 2008: 271).

The last Ice Age created ground with hanging groundwater: different compositions of the ground, with layers of clay composition deposits alternating with the moraine and sand, created permeable and impermeable underground layers that give rise to these hanging groundwaters. When the ice melted, the land began to rise; the coastline thus moved seawards and the former seafloor was exposed. At its highest, the sea was up to 220 metres above present sea level (Ramberg et al., 2008). This is relevant when designing stormwater management in southeastern Norway, as challenging ground conditions with quick clay may be present in these areas up to 220 m.a.s.l., and not all quick clay presence is registered on official maps.[34]

[34] Quick clay is predominantly registered in areas where there has been construction or where hazards have been detected.

Effects of the climate crisis in southeastern Norway – A climatological view

Climate change redistributes water and triggers changes in the hydrological cycle and the water balance. In the northern latitudes where the project is located, this means more extreme conditions (Fig. 25): heavier precipitation and greater quantities of rain in shorter periods of time (European Environment Agency, 2017).

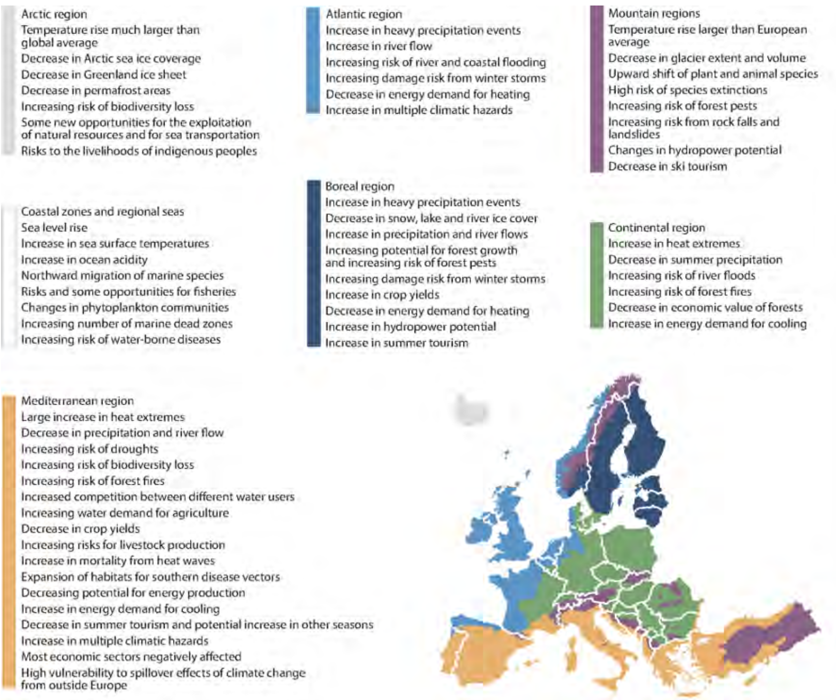

Figure 25: Map showing the observed and projected climate change impacts for the main biogeographical regions in Europe. Map: European Environment Agency (EEA), 2017).

The figures below show the historical evolution of one hour of precipitation and the augmented quantity of rainwater from 1965 to 2015 (Fig. 26). The graph on the right shows the rising frequency of one hour of precipitation with more than 5 mm of rain in Oslo.

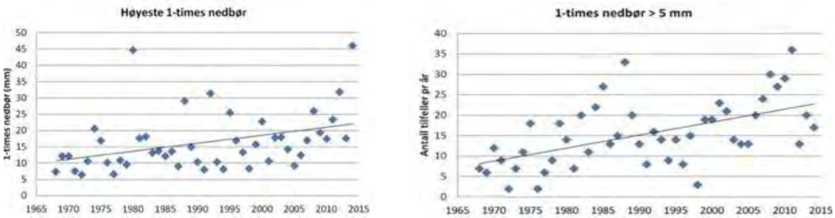

Figure 26: The diagrams show the rising frequency of heavy precipitation in short periods of time. Historical evolution of one hour of precipitation at Oslo-Blindern, registered between 1968-2014. To the left, the quantity of rain within one hour. To the right, the frequency of rain with more than 5mm of precipitation within one hour. Diag: Hanssen-Bauer et al. 2015.

Specific to cold climates is that the water is retained on the ground as snow and ice. Longer periods of temperatures around zero degrees Celsius result in ice-covered ground and little infiltration.[35] Seasonal changes to ground conditions in the form of ice make a great difference for the ground's infiltration capacity. Heavy rains are rare in winter, as the air is cold and cannot hold much humidity. However, rain in urban settings at the beginning of the year, when the ground is frozen and the urban pipe drainage system is clogged by ice, make other solutions than infiltration a necessity. The warmer temperatures due to climate change, result in shorter periods during which the snow melts slowly on the ground and fills the aquifers in areas where the ground is permeable. The rain that falls later in spring does not help to fill the groundwater to the same extent as vegetation in bloom transpires water out into the atmosphere before reaching the groundwater. At the same time, southeastern Norway has experienced summer droughts in recent years, which is a new phenomenon in a country where water has historically been in abundance. As a consequence, retention of water in the landscape is slowly becoming a question of concern for farmers in the Oslo region.[36]

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[35] The International Panel on Climate Change (IPCC) warns that climate change will provoke more droughts (Jiménez Cisneros et al. 2014), and stronger seasonal variations have been forecasted (Kovats et al. 2014). Higher temperatures have had a stronger effect in the mountainous regions of central Norway than in the rest of Europe, with decreases in glacier size and snow cover. In the Atlantic region on the west coast, the main effects are sea-level rise, an increase in heavy precipitation and river flows, and winter storms.

[36] The research project on nature-based solutions NATURACT showed these tendencies in the case study area of Hølen in southeastern Norway. It has also been a historical practice of irrigation dams in Asker Municipality, which was known for vegetable farming.

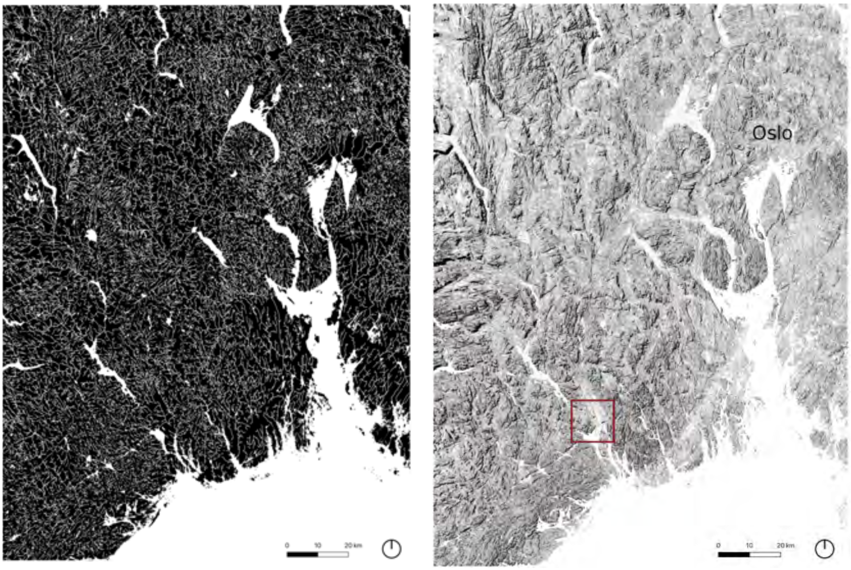

Figure 27: Left: Map of the water network of the Oslo territory. The fine network of tributaries has been erased in some areas by the human activity of urbanisation or cultivation. Right: Topographical map. Darker shades indicate higher altitudes and square the area of the design case 'Kjørbekk'. Maps created with GIS Information downloaded from Norge digital, 2019.

Historically, the ground and waterways have been modified for different purposes, such as the use of the waterways for transportation and logging, for irrigation, for agricultural drainage or urbanisation. Dams were built locally to provide water for domestic use, ice production, mills for grains and sawing, etc. The earlier dams were often built out of wood or stone blocks. In the last 100 years however, large dams have been built for hydropower, which accounts for 89% of Norway's energy production (Statistics Norway, 2023). The water structures have successively changed into a more manmade system.

In urbanised areas, creeks have often been drained and routed into pipes. Therefore, a less dense tributary system of creeks is often visible here. The map above left, with white rivers shown on the black ground, shows how Oslo's urban area has erased the river's tributaries from the surface at the northern end of the Oslo Fjord (Fig. 27). The map reveals the relationship between water, topography and the ground, as well as the effects of urbanisation, which simplify the rivers' initial geometries. On a regional scale, the interaction between ground conditions and human activity has created the different water geometries over time.

Planning and the legal setting above- and underground – A regulatory view

In the regional plan for Oslo and the Akershus Region,[37] densification is organised in relation to mobility infrastructure and land uses, without specific consideration to water and ground conditions (Fig. 28).[38] The main infrastructure is found at the bottom of valleys, as it is easier to build infrastructure on the flat terrain and because areas above approximately 220 masl (the level of old marine ground) are reserved for Marka with recreation, freshwater supply, and forestry (Bryhni, 2023). Urbanisation patterns are thus found in the low land and in relation to the infrastructure and the river valleys.

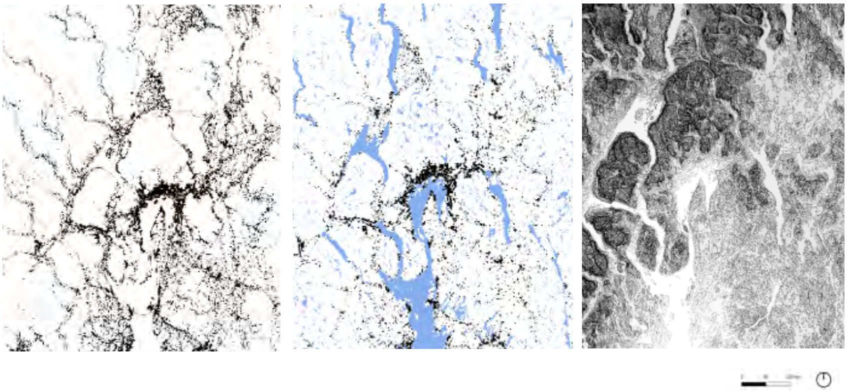

Figure 28: The map to the left shows how the built environment (black) and the infrastructure (red) are concentrated in the valleys and along the fjord. The map in the middle shows water presence and the built environment. The map to the right shows the topography and read together, they show that infrastructure and the built is mostly found in the valleys in areas under +220m.a.s.l. The built environment is more scattered in the areas with less pronounced topography to the east. Maps: Worksonland, created out using GIS Information downloaded from Norge digital, 2018.

The same logic is present in areas with topographical differences in the larger Oslo Fjord region, such as the design case, in Skien. These low points coincide with the presence of water run-off following heavy rains and areas designated for densification. Thus, some of the indicated areas for densification coincide

[37] The Regional Plan of the Oslo Region was published the same year as the Official Norwegian Report on SWM (2015), but the regional plan does not have specific considerations in terms of a change of general strategy in relation to the flood-challenged areas indicated (Regional Plan for Areal and Transport in Oslo and Akershus 2015).

[38] This is in contrast to other regional planning such as the French 'Schéma de cohérence territoriale' (SCoT), which incorporates several thematics and sees their interrelations and their spatial relation across scales (Folde 2019).

with areas with a flood risk. This demonstrates clearly that landscape aspects must be more actively integrated into Norwegian regional planning (Fig. 29).[39]

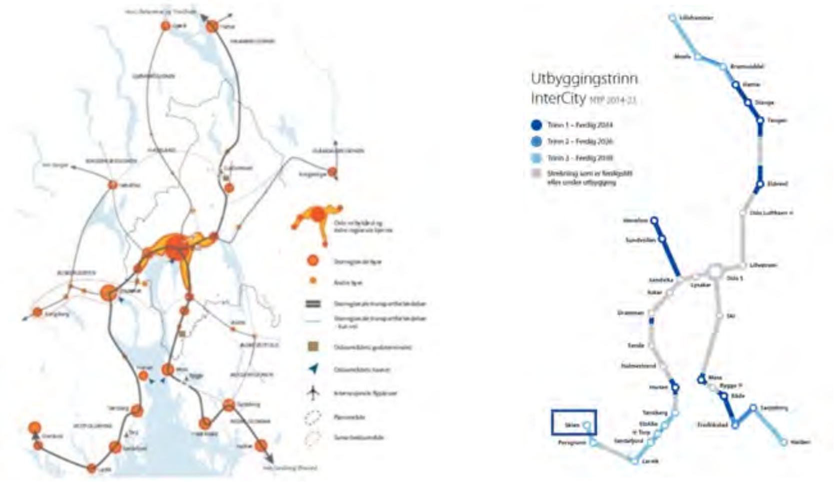

Figure 29: To the left, illustration of the regional planning from 2015, with the greater cities in orange. The black lines in between are infrastructural connections (Oslo is the larger circle in the centre). The design case area Skien is located far in the southwest. The illustration to the right shows the plan for a future train, Intercity; connections (2016) linking Skien to Oslo in just over one hour. Maps: The Regional Plan of Oslo by Akershus County Council & Oslo Municipality, 2015.

Currently, region urban planning in Norway primarily relates to land use and transportation. However, Norway recently designated water regions based on the catchment areas,[40] in order to handle water issues on a greater scale. The 2021 goal for the EU Water Framework Directive was to obtain a ‘high’ or ‘good’ water quality of surface- and groundwater across the constituent countries (WFD).[41] Norway has not yet fulfilled this goal. One of the most efficient measures for improving the water quality in rivers and streams is to go upstream, beyond administrative boundaries, and identify the sources of pollution. One such source is the disused landfills, noted below as manmade ground.

Manmade grounds in Norway – A constructed landscape

From the 1960s to the 1990s, rivers in various urban valleys in the greater Oslo region were routed into pipes, and the riverbeds were filled in to generate

[39] Marja Folde’s work on public project-driven urban development shows a gap between the number of aspects taken into account in the French regional plan SCOT in comparision to the Norwegian regional plan ATP (2020: 42).
[40] Norway is divided into nine water regions with runoff to the Norwegian coast or with runoff to Sweden or Finland. These regions are administered by the designated county municipalities (Forskrift om rammer for vannforvaltningen, 2007)
[41] Norway has signed this directive. A water resource plan is elaborated every six years, and it provides measures that should be implemented to facilitate fulfillment of the goals.

buildable square metres.[42] The concave ravine landscapes and river valleys were considered perfect dumping sites.[43] The logic at the time was that this would secure the neighbourhoods for hygienic reasons, eliminating dirty and foul-smelling rivers and protecting children. The case study's site condition, with an urban creek valley used as a waste dump, turned out to be no exception. Similar cases are to be found in Oslo: Rommen, Grønmo, Stubberud, Kjelsrud – all of which are old landfills and are now a part of the urban fabric.[44]

Urban artificial, manmade ground has sometimes been further transformed by physical, chemical and biological processes over time (Galinié 1999). A site's use history tells us if toxins are likely to be found, and if so, which: shipyards (TBT, heavy metals, PCB/PAH, DEHP); fire training areas (PFOS/PFOA dioxin, PAH); auto repair (PFOS/PFOA, DEHP, siloxanes and heavy metals); old plant nurseries (DDT, dieldrin, endosulfan), and so on (Hønsi 2019).[45] Alarmingly, these are found in our environment and have severe effects on our health. When they spread, we find them in our water and food. If the toxins are water soluble, water can transport and mobilise them.

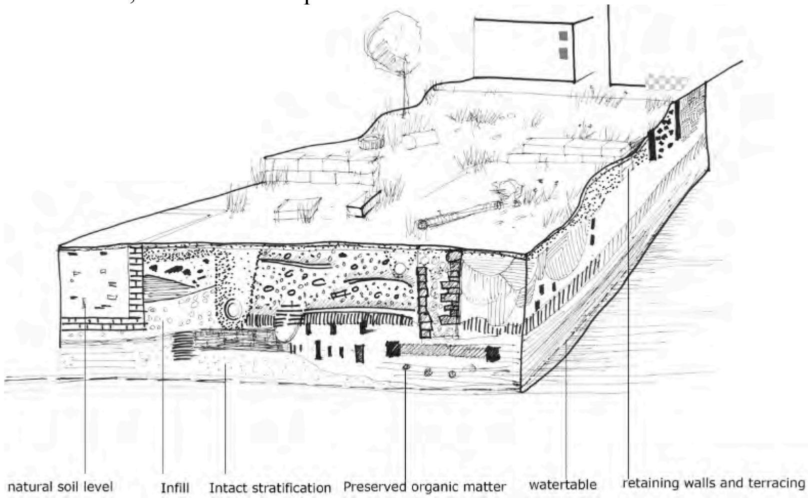

Figure 30: Different types of archaeological deposits in an urban context showing that a complex manmade ground contains an accumulation of traces from human activities and installations over time. Ill. Author based on drawing by Elizabeth Hooper (Edgeworth, 2014)

[42] In the case of the creek Hovinbekken in Oslo, the argument for piping the river in 1958 was facilitation of housing development, street constructions and new high tension cables. Further arguments were that: 'The stream carries sewage and is hazardous to health, and it must be expected that this condition will persist. The open stream was considered dangerous for children, and there are repeated demands from housing associations to close the stream. Waste and scrap in the open stream were also considered an increased risk of flooding.' (Moland 2017: 43)

[43] From conversations with Dr. Torunn Hønsi, a researcher on environmental impacts who has research and fieldwork experience with pollution control with the County Governor

[44] Even if there are important initiatives for recycling waste in Norway, the total amount of waste increased 3% from 2015-2016, corresponding to 11.4 million tonnes. (Statistics Norway, 2023).

[45] Registered toxicity can vary with the seasons and after precipitation, which can dilute the concentrations of toxins. Multiple samples for water quality are therefore needed to achieve reliable results.

The manmade ground created as a result of production processes has received notably little attention in urbanism practice, considering the number of sites defined as contaminated. The mapping started with the growing environmental concerns of the 1960s and 1970s. However, there is a technical gap of registration between when industrial production began in the 19th century and when ground pollution began being registered in Norway. At present, there are 2 100 registered closed landfills in Norway (Gustavsen and Jansson 2018). The number of registered dumps is low compared to neighbouring countries with similar number of inhabitants (Fig. 31).[46]

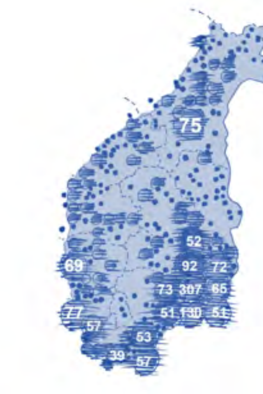

Figure 31: Map showing areas with old landfills in southern Norway. The number indicates the count of landfills in the area. A point equals approximately 1-5 landfills, and the intermediate circle is similar to 5-20 landfills (Gustavsen and Jansson, 2018). Ill. Author based on graphic by Tom Bob Peru Aronsen (2018).

Historical photos prepare us for what might be found in the manmade ground where urban expansion is taking place. The photo below shows waste management practice in the Oslo region from last century, where areas and ravines outside the towns were used as dumping sites (Fig. 32).

[46] Norway has 5 600 registered contaminated sites, Denmark has 30 000 and Sweden has 85 000 (Gustavsen and Jansson 2018).

Figure 32: Stubberud municipal landfill, Oslo, Alnabru. In the background, farmland and hay formations are visible. A creek bordered by vegetation runs through the middle of the field and disappears under the fill. Ph: Foto Kompaniet, Oslo byarkiv, 1938.

These dumps and industrial activities have created contaminated grounds and changed the water quality in the Oslo region (Fig. 33). The areas above the marine border correspond to the non-urbanised land, which has good or fairly good water quality, while the lowlands, where agriculture, urbanisation and human activities are represented, mainly have moderate and poor water quality. This shows a need for planning and design strategies for humanmade contaminated grounds related to transformations in these areas.

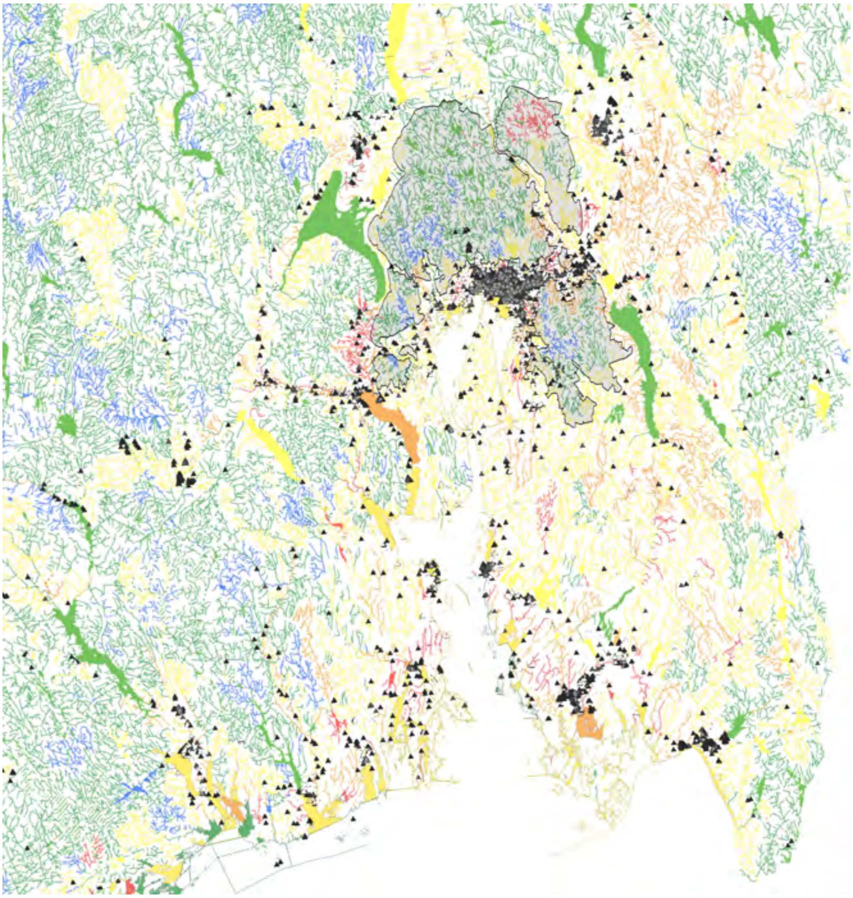

Figure 33: Polluted grounds (black triangles) and water quality in the Oslo region. The quality is graded as follows: blue is very good quality, green is good, yellow is moderate, orange is poor and red extremely poor. Shaded area in the center corresponds to the natural reserve 'Marka'. Source: Norge digitalt 2023.

3. Research Methodology

3.1 RESEARCH DESIGN

This chapter describes the methodology utilised for this research and explains the reasoning behind the choice of design case, as well as its benefits and limitations. The different phases of the research, the research questions, and the methods and primary techniques used are presented in an overview in this chapter.

Knowledge is often produced where disciplines intersect in a design phase, and following the design case as a designer and researcher has been key to gathering vital information within the research team that would have been challenging to access from an outside perspective. The research was carried out in an exploratory, sequential, reflective design process, and the research questions evolved from the general question: Which insights on landscape and planning levels can the implementation of a SWM solution in a case in southeastern Norway reveal? Landfills were encountered in the old riverbed during the design process, and as work to find a durable technical SWM solution progressed, another question was formulated: Which landscape measures for improved management of stormwater and leachate can be employed at disused landfills? In the later stages of the research came an inquiry with a reflective perspective: How can a changed perception of the context stimulate simultaneous design of above- and below grade?

The open framing of the research questions made it possible to position the investigation to span various fields of knowledge, and it also enabled some answers to be found in other disciplines involved in the design case. In the work at hand, however, the questions that have been developed further are those central to landscape architecture and urbanism.

Positioning the Researcher

The design case on which this research is based crosses the borders between the disciplines of landscape architecture and urbanism. The research has been informed by work in a realm where public and private practice, education and research intersect. I am a landscape architect, an architect and urbanist, and a founding partner of the office Worksonland Architecture and Landscape, which develops urban, architectural and landscape projects. Whilst I have operated from my professional perspective of landscape-based urban planning across scales, the research has permitted me to take a reflective position, to reconsider situations and develop new knowledge.

I have held a variety of positions throughout my professional career, with experience as a practitioner in public administration on the regional level from the Generalitat Valenciana in Spain and as a researcher in the Municipality of Lørenskog in Norway at the start of this research. These different contexts have taught me how public planning differs from private design practice. As an example, private consultants are frequently engaged for the duration of a determined project time, whilst public planners follow a project and its maintenance closely over time. The public entity, therefore, has essential knowledge of their different projects in a long timeframe.

The educational setting has permitted exploration of water and ground and imaginaries thereof; it is less bound by technical dimensioning, detailed pipe heights, and political, economic, and juridical constraints than practical settings. At the start of this research, I was teaching students of landscape architecture and architecture together with Sabine Müller, a professor with a deep interest in water, and working on projects across scales from the Oslo region to local projects that engage the socio-historical values of water, its productivity, and an exploratory research approach to imaginary futures. Müller later became co-supervisor of this thesis. My experience teaching landscape and urbanism at different universities in Spain, Sweden, and Norway has allowed me to investigate water in different cultural and climatic settings, which has helped to contrast the specificities of the Norwegian case to situations elsewhere. However, not having the initial knowledge of Norwegian ground conditions of quick clay, alum shale, landslide risk, and rockfalls made the first encounter with the ground landscape an eye-opener. While not having been trained in the Norwegian context and not having practiced extensively in Norway meant a certain distance to how things usually are done, it has also meant a freedom and allowed me to see more readily how things could be done differently.

The relationship between the different complementary knowledge perspectives of architectural practice, education and research are shown in the following diagram by Ute Groba, doctor of architecture (Fig. 34). It shows how education can provide up-to-date knowledge and skills concerning practice. Practice, in turn, can provide topics to be tested in an educational setting and supply research with relevant questions in the fields of architecture, urbanism and landscape architecture that are closely related to contemporary societal needs. Research offers the academic environment new knowledge and provides practice with informed design decisions.

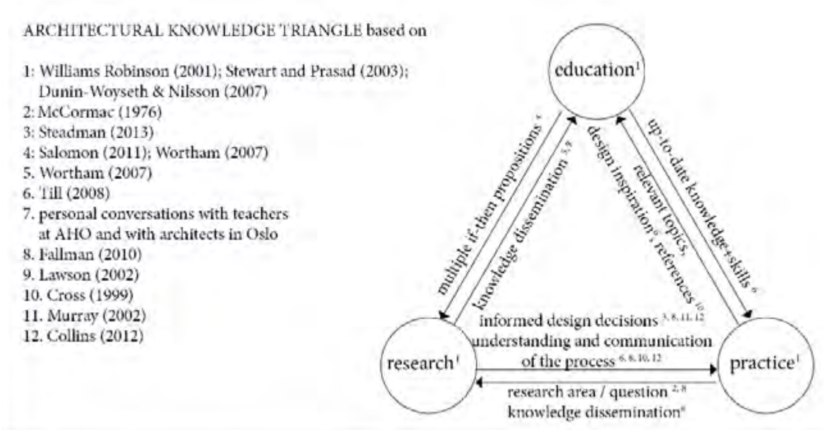

Figure 34: Diagram showing the relation between education practice and research Diag: Groba, 2016.

However, practice differs depending on whether it is public administration or private. Public administration can be a client whilst also carrying out its own projects and maintaining them over time, and the decisions regarding the projects to realise are politically motivated (Fig. 35). Private landscape architecture practices on the other hand are usually dedicated to a project for a specified commission period. One challenge for large-scale public projects is creating continuity over time within an administration and across various political mandates; the latter aspect has also been highlighted by the Centre for International Climate Research (CICERO), which has shown that there is a lack of political support for climate adaptation in municipalities in Norway and suggested the creation of a separate climate adaptation fund that makes the administration more predictable in their long-term goals (CICERO 2022).

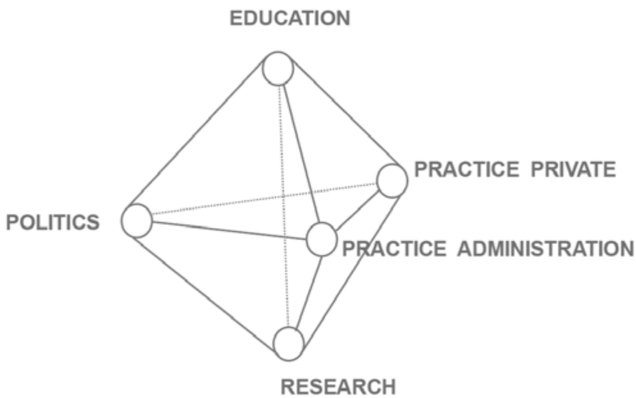

Figure 35: Diagram of the relationship between research, education and practice in private practice and administration. Politics are directly or indirectly related to all of these sectors. Diag: Author.

Following the design case as both a designer and researcher has been invaluable for revealing in-depth information in the research team that would have been difficult to access from an outside perspective. Often, the knowledge produced in a design phase is generated where disciplines intersect, and arriving at it in other ways is thus impossible. The research was carried out with dynamic relationships where my role shifted from that of educator to practitioner to researcher and back again. While changing roles helped me view the practice with a new perspective, the time constraints of practice make it difficult to retract and reflect on the work from a distance in an ongoing design process.[47] This distance and outside perspective are often easier to regain following an intensive project phase. The writing of this exegesis has enabled this by broadening the view and offering reflection on the case *a posteriori*.

The study of the physical structures and ongoing processes of the landscape has been a central theme in the new joint landscape architecture programme at AHO and the University of Tromsø. I have been involved in building up the programme as well as educating students in it. Teaching has been carried out with landscape architects, as well as with hydrologist Nils Roar Sælthun and ecologist Kari Anne Bråthen – this collaboration has permitted us to open the discussion between disciplines and allow the landscape projects to be informed by ecology, hydrology and geology, as well as cultural settings. This interdisciplinarity has been a reminder that it remains much to investigate on the ground.[48] It has given me the insight that we are designing with uncertainty, and it urges a humble attitude with regard to what we are missing. A knowledge limitation was ascertained when seeking to accelerate changes to culturally anchored ways of managing stormwater in the old, traditional fashion with piped systems. One challenge is that the leverage points for the system transformation are often complex, and their timeframes are longer than a project period.[49]

In addition to teaching, I have conducted research on water and ground in other settings, which has helped broaden the discussion on water and ground and the testing of findings with the help of different disciplines. Being an external expert for other research projects, attending and presenting at conferences and taking part in a large research project exploring large-scale, nature-based solutions related to water, ground and culture in representative case studies in Norway have been enriching and served as comparative cases. One funded research project is being carried out with five other research institutions with

[47]Bryan Lawson describes the design process as formulating, representing, moving, evaluating and reflecting from an outsider perspective (2005: 291). Here, it is important that reflection happens by stepping back from the design process. A time gap from the action of design to reflection helps create a distance and an observer's position to the project. Reflecting on the design work from an outsider's perspective permits one to see what parts of the design work can be generalised. Taking a step back and zooming out from a problem also helps the reformulation of the initial design question. As such, the designer's work is not only an answer to a question but a redefinition and reframing of a given situation.

[48] The living organisms and interconnectivity within the ground remain to be comprehensively defined.

[49] The longer timeframe can correspond to education anchored in older paradigms of SWM with their corresponding methods.

water, ground, environmental science, climate science and cultural heritage expertise.[50] This has permitted me to compare findings to other research cases and validate the relevance of the insights in relation to a larger setting (Fig. 36).

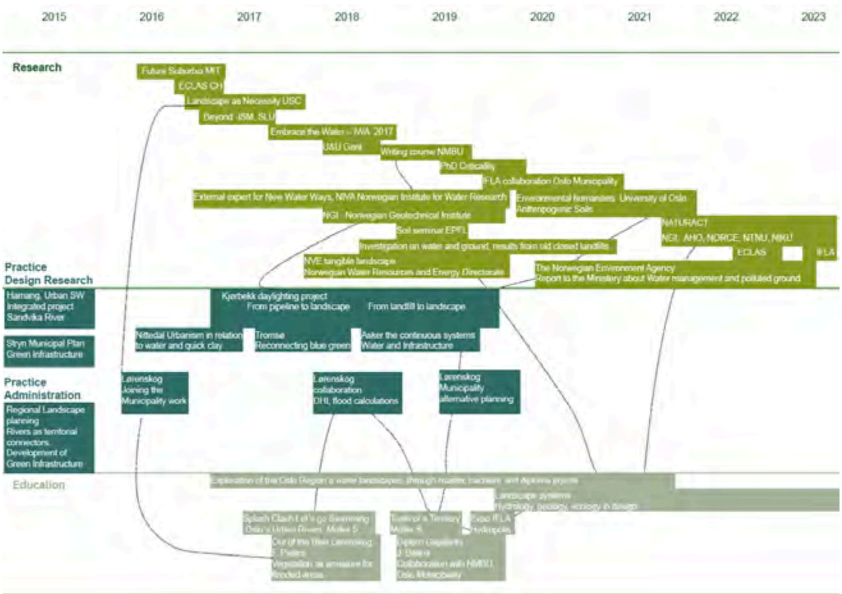

Figure 36: Collecting knowledge and experience on water and ground
The above diagram shows activities carried out in research, education, practice design research and administration between 2016-2023. All works above are collaborations with many people who have provided valuable input and broadened my perspective. Diag: Author.

In the design case, consultants involved were from Uniresearch, the Norwegian Geotechnical Institute, Worksonland and the consultancy firm Multiconsult. Central figures from the municipality were the hydrologist Dr Gunnar Mosevoll, who has great experience in water systems, and the architect and urbanist Marja Folde, who is knowledgeable about strategic water management and urban planning. In the project team, Celia Martinez Hidalgo, architect PhD, provided essential knowledge on hydrology, urbanism and landscape. The design team shared a common anchoring in the Catalan tradition of urbanism research and practice. The notion of 'the urban project'[51]

[50] The research project NATURACT is being carried out with five other research institutions: the Norwegian Geotechnical Institute (NGI), which is leading the research; the Oslo School of Architecture and Design (AHO); Norwegian Research Center (NORCE); the Norwegian University of Science and Technology (NTNU), and the Norwegian Institute for Cultural Heritage (NIKU). The project spans the scale from the local context to global climate calculations.

[51] The urban project is more precisely defined and offers an alternative to traditional normative urbanism with its general plan. The concept of the urban project refers to an urban intervention that is conducted through a defined project that defines the public space and the landscape, where the void is seen as a structural element of the city. (Cortes, 2002)

was important as a strategic motor of change and restructuring the existing urban tissue, where landscape structures and public space guided urbanism. While this tradition has influenced my approach to landscape and urbanism, I am also aware that Norwegian urbanism and planning systems arise from different sources.

Research design choices and the value of design case research

This section describes different ways of working and conducting research related to practice and their different degrees of research involvement from project development, case study, and practice-based research to design research, and it recounts why design research has been chosen for this research. An important distinction between executing projects in practice and research lies in the question of whether new knowledge is obtained through work with the project, or if pre-existing knowledge is being applied. (Galdon and Hall 2022). The description of the different design practice below depends on the involvement of research in practice and whether the research practitioner participates inside or outside the design process.

Case study

A case is a project embedded in a context. In landscape architecture and urbanism research, it is often a project dealing with specific climatological conditions, geomorphology, hydrology, etc., urban development over time, and the cultural anthropological context. A site and a case are thus necessary to contextualise the research. Under such conditions, a case study can both generate and test theory (Flyvbjerg 2006).

The case study can be used in an exploratory way (Yin 2014) and for testing and generating hypotheses and theory development (Denzin and Lincoln 2018). A case study is useful for describing, evaluating, comparing, and understanding a real case phenomenon. Studying cases frequently sharpens and even changes research questions (Gillham 2000). The expansion of knowledge from a single case to a general insight can be done through a comparison of the insight with other cases and theories. However, as Yin (2014) suggests, it is possible to extract general knowledge from single critical cases. In this research, the design case shows the project as prompting questions rather than showcasing solutions. It demonstrates the need for systemic changes, the development of multidisciplinary working methods, and new design principles.

A design case is chosen to study de facto complexity and the constraints of project realisation. The complexities of a site – with challenges such as dam bursts, pollution risks, further climate mitigation and adaptation, and biodiversity design – correlate to the rising complexity in landscape design projects over time. A design case can take in and help reveal the embedded complexities. A daylighting project with creeks and rivers serves to illustrate an urbanism where the waterways are the guiding structures for planning. This SWM project, with its objective of creating secure floodways, corresponds to a societal concern and the public obligation to create secure flood infrastructure. The case study area is representative of the growing Oslo Fjord region with its rich geological variety, and it was chosen as it is representative of a mid-sized municipality in terms of resources and administrative capacity.

The case study of Kjørbekk is a pragmatic case with the potential to reveal new perspectives and theoretical understanding. Hans Eysenck argues that "sometimes we simply have to keep our eyes open and look carefully at individual cases—not in the hope of proving anything, but rather in the hope of learning something!" (1976: 9). The design case of Kjørbekk is used in this way not as a prof but a case that reveals questions of concern. However the chosen design case has been compared and contrasted with the literature and with other cases in the greater Oslo region and internationally to determine what is unique about it and what may be generalised (Fig. 37).

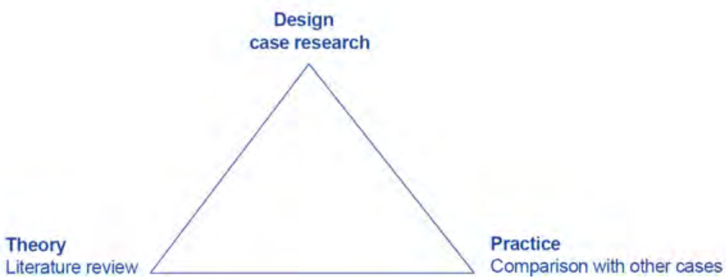

Figure 37: Illustration showing how one design case relates to a greater setting of cases and theories. What the design case shows can be compared in literature reviews or within other design cases to enable a broader conclusion. It can help define whether a case is unique or an indicator of a general concern. Diag: Author.

Practice-based research

In an era of rapid technological changes, climate crisis, societal challenges and biodiversity threats, practice – including design practice – must evolve. Practice-based research occurs through the study of projects developed in practice. In their book *The Changing Shape of Practice*, Michael U Hensel and Fredrik Nilsson write that 'research is no longer seen to aim first for theory building before informing practice. Today, frequently the focus is directly on practice' (2016; XVI). They further argue for research in practice to 'change old myths' and 'adapt to new situations where old recipes don't fit' (Ibid: XV, XVII).

‘Practice is always transforming due to changing needs, different conditions and circumstances to be met, emerging new design problems and therefore new questions to be asked and new questions to be made’ (Ibid: XV). Thus, an adaptive and ‘designerly way of thinking’ is an appropriate working method for various societal questions where old working methods are no longer applicable as the initial questions or context have changed considerably.

In design-case research, the investigator takes an active role in the project development as a designer and questions current practices, models, and modes of doing. The questions posed during the process are used to delve into and expand on the present knowledge base. The type of knowledge that a design case provides is related to the case itself, but it also includes its process and the knowledge created in collaboration between disciplines.

A practice-based design case is valuable, as it affiliates the design researcher with a design team with all of its interdisciplinary expertise and the municipality perspective, as well as gives access to data; these would not have been revealed to a single researcher working alone. At present, the increasing complexity of design cases makes it difficult to investigate a reality-based case study without the expertise and involvement of other fields. Participating in a design case is key to understanding the dynamics of project development well; for example, why and under what circumstances projects stop in relation to the incorporation and realisation of new knowledge in practice.[52] From here on, I refer to the case study used for design in this research as the ‘design case’; this will be explained in further detail in Chapter 4.

Overview of the research phases

The diagram below shows the four different phases of the research and the research questions, methods and primary techniques used in the research.

The first phase consists of general observations on flooding in the greater Oslo region, a literature review, and article writing. Phase 2 corresponds to the start of the design case with fieldwork, an analytical and descriptive phase, and article writing. Phase three corresponds to design development, encountering obstacles, and article writing. The final phase is a reflection on the design case, an expanded literature review, and consideration of new concepts (Fig. 38).

[52] In case study research, it is difficult to detect the communication that has occurred during the design process and see which alternatives have been evaluated with an outside perspective.

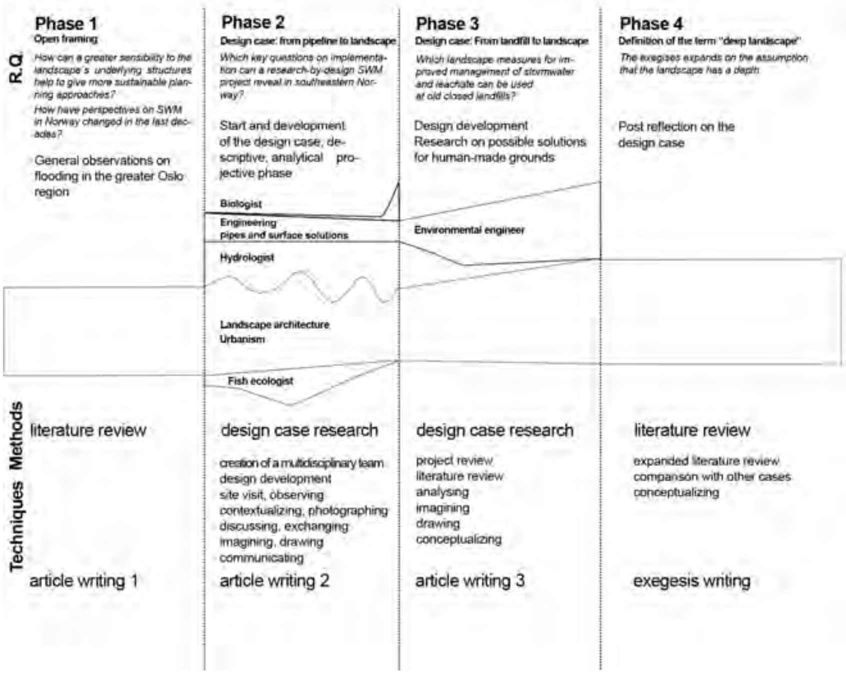

Figure 38: Diagram showing different research phases, methods and techniques used in the research, from the literature review in the first phase of the design case study to a literature review to contextualise the findings in a theoretical setting in Norway and internationally. Diag: Author.

Literature review

The first phase of the research was a literature review to determine the state of the art for the researched topic, SWM, in landscape architecture and planning in an international setting.[53] The review reveals current tendencies in theory and how these relate to the present situation in Norway. The timeframe for the literature research was mainly from the 20th century until the present, with a focus on recent publications: books, articles, conference proceedings, steering documents, PhD dissertations, newspaper articles, reports and central municipal web pages and reference lists by central scholars.

The review led to the inquiry into why knowledge of SWM in urbanised areas was not applied more in practice, considering that research and knowledge have been accessible for more than half a century. The review then focused on the Norwegian setting and the publication *Vann*, read by SWM practitioners in the public and private sectors. A synthesis of the readings revealed new perspectives that focus on the ground and underground urbanism (presented in Article 1).

[53] International setting with a main focus on European, American and Asian references.

Design case research in practice
The second phase corresponds to the start and development of the design case with a focus on SWM 'Kjørbekk, from pipeline to landscape'. It contained descriptive, analytical and projective steps with the involvement of various professionals such as biologists, engineers, hydrologists, fish ecologists, etc. In this phase, fieldwork was used to contextualise the question of daylighting and create a common understanding of the questions of concern. In this phase, Article 2 was written about the questions of implementation of the SWM in a Norwegian municipality.

Case reviews to inform the design case
The third phase is also a design case research, but it focuses on the ground in terms of how to transition 'from landfill to landscape'. I investigated different landscape measures to handle SW at old closed landfills. The investigation was extended to projects with similar issues in other contexts. Project- and literature reviews were used to provide new insights, with the objective of discovering what lessons could be learned from them. It is relatively easy to access plans and sections for well-known international landfill projects such as in Fresh Kills, US and those in Garraf, Spain. However, discovering what *has not* worked in projects over time proves more challenging. Additional project reviews of Norwegian projects in the same climatic conditions as the design case were also conducted. Ground-truthing via site visits that reveal maintenance challenges for old closed landfills has been relevant for the research at hand. The knowledge production of this design phase involved a further literature review and the input of environmental engineers, and resulted in Article 3.

Reflection with a distance to the design case
The last phase corresponds to the exegesis writing as a post-reflection on the design case after completion. This phase involves zooming out from the details of the design case to position the work in a wider theoretical context. The findings of the design case are compared with other cases, and the main insights are conceptualised and contextualised. Findings are contrasted through an expanded literature review with a national and international context to define their contribution value.

The design research field has evolved from Donald Schön's definition of 'knowing in action', where knowledge is revealed through the action of designing (1983). A decade after Schön's publication, Frayling defined different additional relationships that the researcher in art and design may have with what is being designed; specifically, he proposed '[r]esearch *for, into or through* art and design' (1994). In landscape architecture or urbanism, research *for* design can correspond to preparatory work such as documentation, maps, and information on water quantities and qualities, registration of uses, senses, and site qualities. These inputs are then synthesised and evaluated in terms of their importance and the phase in which the project is. Other project examples can be investigated in order to generate knowledge on how to deal with challenges in a project. Following Frayling, this would correspond to research *into* design. Finally, research *through* design corresponds to knowledge produced through the method of designing.

The design situation in landscape architecture and urbanism is complex and shifts between the different modes of research proposed by Frayling. Even the initial phase of research *for* design is selective, creative and propositional. When design is carried out in a multidisciplinary team, the different modes of researching are sequential and constantly shifting between research *for, into* and *through* design. It is not merely a single designer's decision, but in a 'co-design', the design decisions are made cooperatively by various individuals with different disciplinary backgrounds. In that sense, the isolated and controlled action of design research and its different modes are fluid and changeable, depending on the phase of design and the unpredictability of the design tasks.

The illustration below shows how the design process evolves from being the task of an individual, reflective practitioner to that of a multidisciplinary team with different methodologies and attitudes to design, where new knowledge is needed throughout the design process (Fig. 39, far right). This unpredictability also requires new ways of thinking in relation to a linear planning process for a project, where time is balanced with new knowledge needed to respond to the challenges.

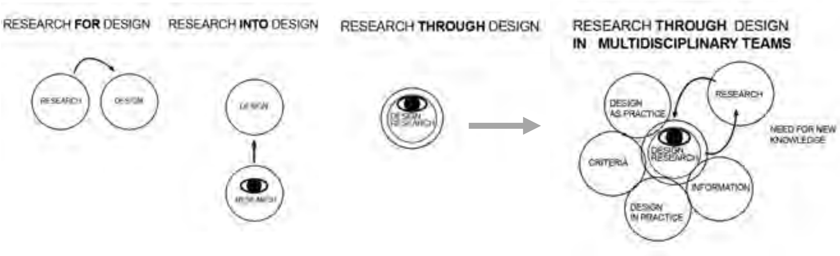

Figure 39: The above illustration shows Frayling's definition of different research modes as research for, into, and through design. On the right is a reinterpretation where these different modes are interwoven in design research. Ill. Author.

3.2 THE DESIGN PROCESS AS GENERATOR OF KNOWLEDGE

Lucy Kimbell (2011) argues that design can be undertaken in many different ways, such as 'design-as-practice' and 'design-in-practice'. The former refers to a more incorporated and routinised design action, while the latter indicates that the action of designing has an emergent nature. A benefit of design research is that 'design-in-practice' results in a more dynamic working method than the application of ready-made solutions to given formulas. Design-as-practice is a feasible option when the questions raised within the project can be answered with routinised answers, while more complex projects with uncertainties for which there are no ready-made solutions demand design-in-practice. According to landscape architect and researcher Miriam Garcia (2022), we are transitioning from 'design' to 'research by design', a process in which ready-made solutions cannot be applied. Increasing unpredictability means that there is a need for new models as well as a new methodology. The diagram below left shows a relationship between theory and practice in a society with time to spare (Fig. 40). The theory is interpreted and translated into practice. The diagram to the right corresponds to a society with the pressure of time and unforeseen challenges in which theory on crucial questions is missing. This corresponds to the second phase of the design case, 'from landfill to landscape', where encountering landfills within the project site revealed new design questions for which new research and developed knowledge was needed.

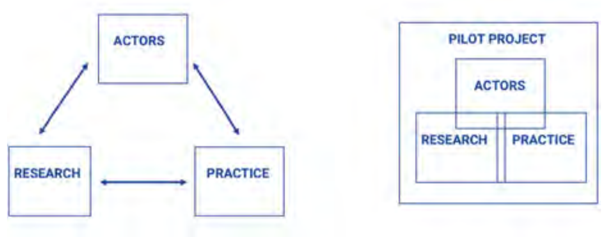

Figure 40: Evolution of research modes from separate but related actions within research, practice and actors to embedded research within the pilot project, including research, practice and actors within the design process. Diag: Author.

When encountering knowledge gaps, different mindsets are noticeable within a project team in practice. One of these is that a project is impossible to carry out if ready-made solutions do not fit the questions posed through the project. Another position is a research approach in which the knowledge gap makes developing the project more interesting, as it might reveal other knowledge gaps and lead to greater insights. Other attitudes were present in the design case as well. How the gaps are handled depends on leadership and dynamics in the group and on how we relate to risk. Standardised solutions exist within urban design to simplify design and aim to guarantee to a degree how the project will be executed. The downside of this is that they might limit the development of new measures, as they build on already tested and proven facts. The risk exists that old, ready-made solutions will be used even though they do not fulfil the new demands.[54]

[54] Pilot projects are key for the possibility to employ new solutions that can be followed up with necessary competences, to enable drawing conclusions in a longer timeframe. In the municipality of Malmö in Sweden, the leader for water and sewage Peter Stahre experienced that the greater changes in stormwater management were only enacted when traditional solutions were not feasible (Stahre, 2008).

Shifting perspectives of the landscape architect

Fletcher et al. point to the rising complexity of stormwater management projects as a growing area of concern that has successively integrated various additional disciplines over the decades (Fletcher et al., 2015: 534). Stormwater management ranges from isolated concerns about subterranean piping to questions related to flood mitigation in the landscape, integrating recreational areas with social, aesthetic and ecological concerns according to Fletcher. Further issues of concern may be added, such as freshwater storage in the ground, water security, biodiversity, economy and alternative decentralised water management models. For this broadening perspective, more disciplinary inputs are needed in the design process.

In the design phase, the landscape architect often adopts shifting perspectives in order to enable a variety of disciplinary perspectives to be incorporated, and the input is woven together into one design in the design process. This role of the landscape architect has resulted in a generalist profile. Professor of landscape architecture Ian Thompson defines the discipline of landscape architecture as an intersection between theoretical knowledge in the natural sciences, art and humanities, and social sciences (Thompson 2017). While urbanism and landscape architecture both work with social aspects, landscape architecture also incorporates the life sciences and is therefore central in mediating the built environment with the environmental processes (Sijmons 2021: 128). Natural science knowledge and the ongoing processes in landscape architecture complement the urbanism discipline in an era when designed elements are tested by extreme events and the effects of climate change.

Professor of landscape architecture Anita Berrizbetia created a graph showing new fields that have become involved in landscape architecture project development over time and led to more disciplines influencing the design process in practice (Fig. 41). However, other disciplines, such as water and sewage engineering, have not seen the same increase in multidisciplinarity, as such systems have historically been dealt with as separate and technical.

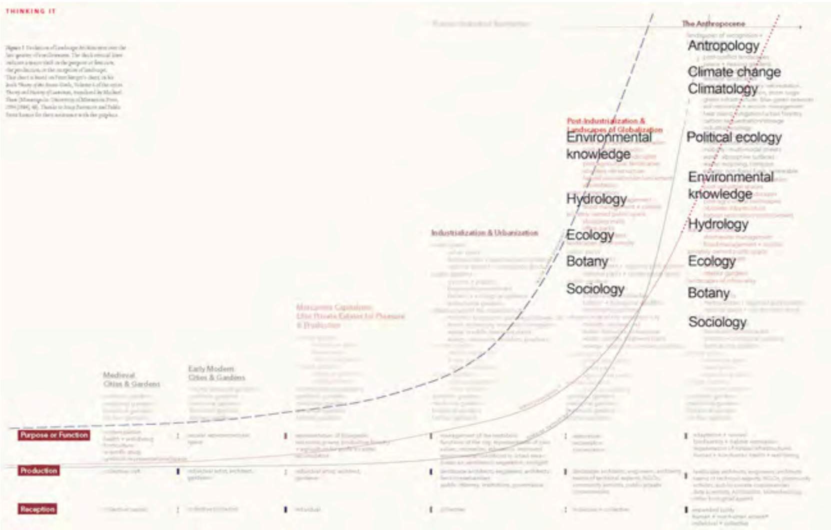

Figure 41: The broadening field of landscape architecture brings in more disciplines and opens up multidisciplinary working processes. Re-elaborated illustration by Author based on a diagram from Anita Berrizbeitia (2018) shows how the rising complexity of projects is inviting more disciplinary perspectives into the design process.

The design process of above and underground is interdisciplinary work
A daylighting project is an interdisciplinary project in which the grade of the ground corresponds to a disciplinary division. The underground is in the hands of the water and sewage engineers, and the aboveground landscape is traditionally managed by landscape architects. The fish ecologist handles what is below the surface of the water, while the biologist works mostly with the species that exist on the surface of the landscape. The general hydrologist working with urban hydrology mainly looks at the water at the surface, leaving out groundwater streams and permeability of the geological ground composition. In interdisciplinary work, each discipline must expand its area to incorporate knowledge from the other disciplines. For the landscape architect and urbanist, this means a territorial expansion on the horizontal as well as the vertical plane.

Each discipline has its own vocabulary, working method and tools. The role of the urban planner and landscape architect is often to weave the different input together in order to provide a holistic, integrated design proposal (Fig. 42). This includes regulations on stormwater management as well as the hydrologist's knowledge about water dynamics and dam bursts, the fish ecologist's knowledge about the form and design of a creek for fish habitats, and the geo-environmentalist's input on the toxins in the ground.

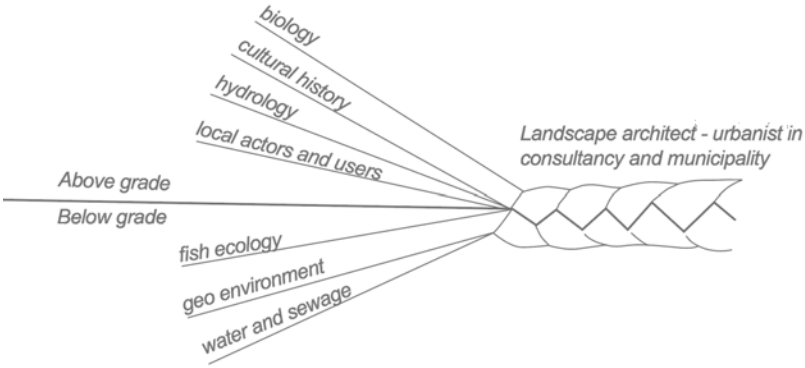

Figure 42: Diagram showing the integration of the various disciplines of the design cases into a single design. The disciplines are organised in relation to their initial main focus above and below grade. Ill: Author.

Multidisciplinary work habitually employs a variety of methods. Transparency in the different processes used is important to enable knowledge exchange between disciplines. For example, the hydrological calculations made with advanced technology are complex and calculated in a computer program, making the content difficult to relate to for the rest of the working team. Quick estimations to evaluate different options are valuable in the early stages of a project. In the past, hydrology relied on rules of thumb for estimations in the early stages of a project; today, these have been substituted with detailed multiparameter inputs that are difficult to see in their entirety, and critical examination of the results is thus not always easy. The case study showed the need to combine old and new methods at different stages of a project. In early phases, approximations and agility for evaluating various options are essential, and later, more precision can be added.

In this research project, the municipality and landscape architect promoted interaction between the disciplines. The landscape architect needs the other disciplinary inputs for design. Basic design criteria were defined in order to determine the most important landscape consideration, with the aim of encouraging the convergence of the work by all disciplines when seeking solutions. To ensure coherent feedback in interdisciplinary work, the methods utilised need to be coordinated and the information provided in a format to which the other disciplines can easily relate. Timing is also an important aspect in relation to when what kind of information is relevant.

Profession	Method	Design Tool	Design criteria
Hydrologist	Calculation of water flows. Observation of neighbouring rivers and local precipitation patterns.	HECRAS diagrams	Ensure that the new creek has a sufficient volume for the calculated water quantities.
Landscape Architect/Urbanist	Research by design. Repeated field trips in different seasons, from winter to summer. Project reviews to learn from other projects in terms of concepts, durability and maintenance aspects.	Plan and sections to describe present and future scenarios. Auto Cad, Drawings, Text Diagrams, Illustrations Models	Definitions of design criteria that include technical, urban and user aspects (here, 'user' is used in a broad sense and includes different species).
Water and sewage engineering in the municipality	Calculation of the dimensioning of the pipe system based on past experiences and maintenance.	SOSI maps corresponding to the municipal digital system.	Provider of information on the present situation and test of a feasibility study for different solutions.
Water and sewage engineering consultancy	Daylighting system: calculation of the open water system	Auto Cad, Civil 3D Plan and sections	Dimensioning and connections between present and future systems.
Cultural-historical values	Representation of cultural values, fieldwork and archives	Text and maps	Put into context the old hydraulic infrastructure
Biologist	Fieldwork mapping of vulnerable areas, species and invasive species.	Text and maps	What is to be maintained as valuable species, and which species are to be prevented from spreading?
Fish ecologist	Field trips. Description of principles, observation and archival work to define the possible fish life that has been in the creek and that could be reintroduced.	Text and diagrams	Ensure that the floodway formed can accommodate the fish. In early design, the longitudinal section is key. In this case, ponds must be established along the waterway to ensure water in dry periods.

Figure 43: Table of different disciplines' working modes and tools in the design case. The variety of methods and vocabulary challenge communication in multidisciplinary work. Table: Author.

The diverse knowledge base of the landscape architect implies that s/he often takes a generalist position in the design team and links the different inputs from different disciplinary perspectives into the design. This is a central position for moving the design forward. In the present design case however, there was a danger of a dam burst, and the daylighting design solution was responsible for addressing this, which positioned the consultancy firm at the top of the organigram. This means that the designing landscape architect was positioned below the consultancy firm with the challenge of steering the process (Fig. 44).

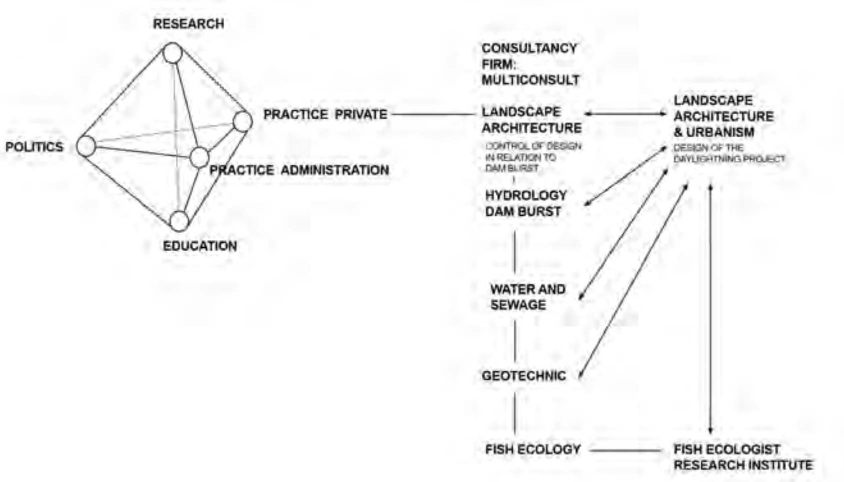

Figure 44: The design phase of the daylighting project. Ill: Author.

In the second phase of research, more knowledge was needed in the search for 'landscape measures on SWM for old, closed landfills', and special competencies were added in environmental engineering from the Norwegian Geotechnical Institute. This phase corresponds to an in-depth design study conducted by a smaller research group, as represented in the figure below (Fig 45).

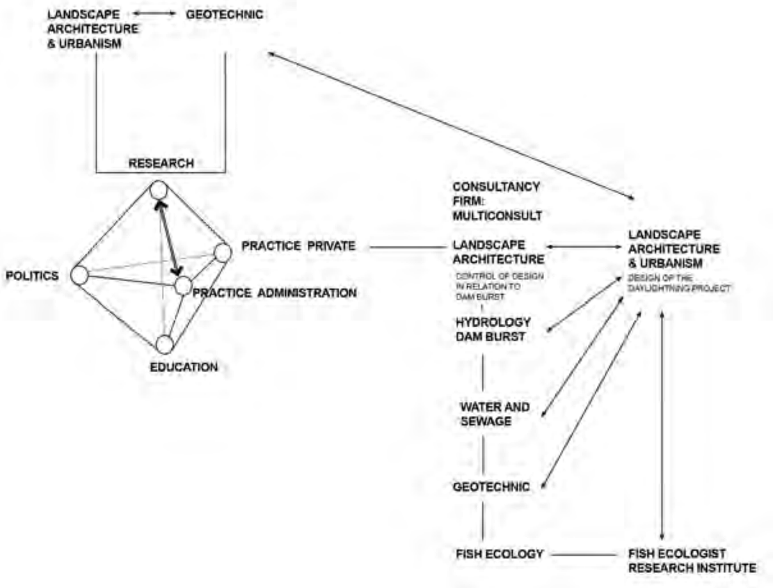

Figure 45: Second phase measures for improved SWM. Ill: Author.

3.3 TECHNIQUES FOR KNOWLEDGE-PRODUCTION

Design and project methods comprise different techniques and tools for knowledge creation. Professor at the Centre for Interdisciplinary Methodologies Celia Lury argues in favour of using the verb that reflects an action when defining the design process. The *do-ing* illustrates the essential parts of design research, and the verb is thus central. It explains the actions that create a relationship between the initial questions, the working process, outcomes, and validity (Lury et al. 2018). The active verb forms used as titles for the subsections below illustrate the importance of this *do-ing*. The techniques used in the design phase are then defined.

Mapping

Searching, selecting, assembling, visualising, interpolating, schematisation, synthesising, ground-truthing

Mapping is used in design research to understand a site and its context in order to inform the design process. Searching and selecting of what is considered relevant information is done in relation to questions of concern, and then assembled and visualised. If information is missing, approximations can be made using interpolations based on what is given. The mapping is not neutral; choices are made on what to include, what to exclude, and how to interpret the present reality. The imagining of a future project is already taking place during the mapping stage. In his text 'The Agency of Mapping: Speculation, Critique and Invention', James Corner underlines that the fabrication of maps is a project: 'selection, schematisation and synthesis make the map already a project in the making' (Corner 1999: 216). The maps provided by the municipality show the present context as well as what is missing. For instance, looking at the underground system, the mapping revealed that some houses are not connected to the sewage network. Public culvers cross under private buildings and a school that is positioned on top of a disused landfill. Maps can show where we are in the processes of change, what depends on what, and what is at stake. An interpretative reading of the context was used to scrutinise and reveal correlations and trends of change; this entailed layering of maps of the physical, hydro-geological setting; land uses, and vegetation. Ground-truthing was later used to review and complement the mapping, as well as for the creation of maps that insert accessible information into new maps.

The layering method of description is useful in the early stages of a project, when it can help gain an overview and define the key questions for the project's realisation. Later project design phases however demand more precise definitions to communicate the three-dimensional interactions and how to design the transition from an underground system to a surface system.
The plan-layering techniques in which maps of the same scale are placed on top of one another are widely acknowledged and used in urban planning, where they contain green- and water structures, built environment, infrastructure, traffic planning, energy supply, waste management, climate, predominant

wind, etc. Sectional layering is less present. However, this vertical sectional reading is key, as water follows the laws of gravity.[55]

Figure 46: Field trip along the creek Kjørbekk with the entire project team (2017). Ph: Author.

Fieldwork
Visiting, observing, annotating, photographing, discussing, exchanging, sensing, comparing, contextualising, questioning, and imagining on site

Being on the site permits sensing, a collection of impressions that complements the mapping elements selected. This is done by observing; annotating; photographing; discussing; exchanging; perceiving sound, wind, temperatures, and smells; comparing; contextualising; questioning and imagining on site. Site visits enable a deep mapping that enriches the spatial reading of a site and all its other dimensions (Pearson and Sanks 2001). Visits reveal the presence of light, materials, rhythms, dynamics of movements and how the place is used by the humans and species that inhabit it. Site visits and walks allow the designer to create a relationship of scale between humans and the context and link representation to reality. Joint site visits with the interdisciplinary team in the design case gave the opportunity to bridge the differences in vocabulary in a visualised, real context, which permitted questions and doubts to be more easily represented and clarified directly on-site.

Drawing
Visualising, observing, contextualising, interpreting, discussing, exchanging, comparing, adjusting, redrawing.

[55] A vertical reading of green corridors can also help determine the species for which they are appropriate and which developments could encourage more biodiversity.

Drawing lends verbal and imaginary possibilities to a spatial definition. It is an iterative process where ideas evolve and are informed by other disciplinary inputs. Rudolf Arnheim defined visual perception as a cognitive activity, stating that the modernist era has created a '…split between sense and thought…' (Arnheim 1969: V). Drawing helps reconcile this gap, functioning as a visualisation and helping to transform information into a physical proposition and form. In the design case the hand-sketched drawings were used to explain and discuss different possibilities or digital precise representations of e.g., technical aspects such as pipe heights and intersections of infrastructure, and they were then observed, contextualised, interpreted, discussed, adjusted and redrawn (Fig. 47). The drawings has also permitted a more precise exchange of ideas, adding more definition to the verbal exchange, which makes it possible to compare different design options with greater precision. In the process of drawing, an approximation is developed and successively modified with increasing accuracy and more details. If a constraint is resolved, this might be the starting point that prompts design and experimentation with different possibilities. Non-designers in the team commented on the proposal and its validity in relation to their disciplinary knowledge and experience. Feedback given in the interdisciplinary conversation provided new insights that will be tested with given and updated criteria.

The design model in which research is part of the design process is more important in projects that deal with new settings and uncertainties. Depending on how the drawing is done, it will prompt different questions. The drawing in itself is a tool to develop deeper knowledge.

Figure 47: Working meeting with drawings, sections and height profiles of present and future riverbed and infrastructural installations, Skien 2017. Ph: Author.

Participation, communication and implementation

Exchanging, listening, explaining, visualising, discussing, comparing, adjusting, redrawing.

Throughout the project phase, there was communication with stakeholders from the secondary school located at the site, property owners, entrepreneurs and the public. Local stakeholders from the site and entrepreneurs participated in project meetings in which the project was explained and discussed. The municipality played a central role in this work. A dialogue was initiated with the owners of the quarry, Nenset, as a one kilometre-stretch of the floodway was being proposed on the northern side of the sand quarry. Meetings were organised to discuss the re-establishment of the terrain that was planned after the quarry's closure. Ideas were exchanged, propositions were compared, and adjustments were made to the project, and it was thanks to this collaboration that part of the project was drawn.

The Kjørbekk project was presented to the public in an exposition in central Skien organised by the municipality, where the landscape architects used models to visualise and communicate the project (Fig. 48). The daylighting project was also presented to politicians in Skien as well as the Norwegian Environmental Agency. However, the complexity of the technical underground of the Kjørbekk project has prompted many initial questions of a technical nature, which has entailed limitations for stakeholder involvement in the project in terms of time.

Figure 48: The Kjørbekk project presented at Bylab, Skien in May 2018. Ph: Marja Folde, Skien Municipality.

In summary, engaging in design case research is key for obtaining in-depth knowledge about the implementation of projects-in-practice. In the design process, the designer, who brings together different disciplinary perspectives, is crucial for providing a design that unites them. The chosen project is a typical project, a ‘case’. It starts with a risk and becomes an opportunity for a multifunctional urban project. It involves the daylighting of a river on a former dump to handle a typical stormwater issue, and it is representative of various municipalities in Norway.

As the project is a multifunctional project involving aboveground disciplines – planning, biology, fish ecology, etc. – as well as underground disciplines – geology, water and sewage engineering – the landscape designer necessarily acts as a mediator between above and below-grade. Hence, the context guides the research toward design solutions that negotiate below-grade conditions with above-grade measures and *a deep landscape approach*.

4. Design Case and Research Findings

A RIVER DAYLIGHTING DESIGN CASE RESEARCH

Figure 49: Illustration showing the sub-catchment area of Kjørbekk when it runs out into the Skien River. Ill: Author.

This chapter expands on the daylighting project presented in Article 2. It provides additional background and a higher level of technical detail, defines particular phases, and outlines additional findings revealed through the design case.

The design case shows the transition from an underground stormwater system of pipes to a system that is integrated into the surface of the landscape, revealing how deeply anchored the underground stormwater system is in old underground installation networks (Article 2). The project evolved from concerns about a dam burst and a SWM project, 'Kjørbekk, from Pipeline to Landscape', as a problem-solving project to extract valuable knowledge for problem-framing. Furthermore, the research evolved from SWM concerning old, closed landfills, 'Kjørbekk, from Landfill to Landscape', including the development of landscape measures as broadly applicable practical and methodological tools, whilst also generating knowledge about manmade grounds and their implications (Article 3).

Finally, this chapter describes concerns related to planning of the urban ground. It expands on insights made during the design case and during the writing of this exegesis through synthetic thinking with national and international perspectives.

4.1 FROM PIPELINE TO LANDSCAPE

DAYLIGHTING THE RIVER: INITIATING URBAN TRANSFORMATION

This section starts with the historical background of the disappearance of creeks and rivers. It describes the need for a daylighting project and the construction of new landscapes above- and underground.

Figure 50: Historical map of the area from 1936 showing the valley of Kjørbekk before it was filled in. Single-family houses have been built to the north but no industrial activity has been installed yet. Here, the area of the sand quarry 'Nenset' to the south of Kjørbekk is seen before the sand masses were removed. Map: Municipality of Skien

Figure 51: Aerial photo showing the design case area of Kjørbekk, south of Skien, with single-family housing and industrial buildings. In today's landscape, the creek is not noticeable when entering the urbanised area. Google Earth 2023.

Kjørbekk is a tributary creek to the Skien River, situated southwest of the centre of Skien. The creek gave its name to the industrial area through which it flowed. Initially, the natural water system consisted of rivers and creeks on the surface, and water ran in relation to the shapes of the landscape. With urban expansions, stormwater management was changed to a manmade underground system of pipes that create their own inclinations regardless of the existing natural surface. While the closing of the river seems unmotivated today, these historical urban changes followed the logics of the time in which they are conceived; numerous cities took similar measures for sanitary reasons, as rivers were used for transporting sewage. The controlled, buried creek also opened up for a more independent urban development that did not need to heed the river's geometries and could build up to and beyond its borders.

The underground stormwater system with its defined dimensions cannot cope with present volumes of rainwater, however. When humans control water and route it into pipes, channels and culverts, we also monopolise it, cutting off access to it for other species and processes that require water and reducing the possibilities for biodiversity. Returning water to the surface again allows more significant volumes of rain to be handled in floodable areas, whilst also facilitating new functions, aesthetic values, and habitats.

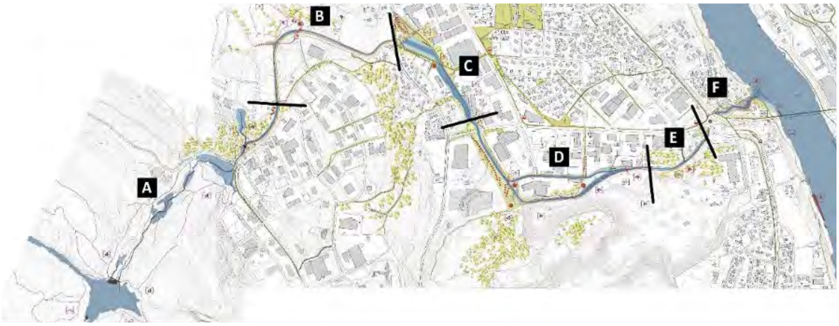

Figure 52: The most important considerations – besides the different landfills in Kjørbekk – commented on in sections. Map: Municipality of Skien from preliminary project 2015.

A.) In the first area, the risk of dam failure had repercussions for the entire project and its dimensioning (Fig. 52). The local design strategy was to provide natural wave breakers within the waterway. B) Lack of public land is a challenge in this area. C) In this part, public land is available, allowing for a park and a varied programme of activities. D) In this section, the trajectory of Kjørbekk should be coordinated with the future development of the industrial area so that the flood bed and the water may become part of the inhabited and usable landscape for those who live and work in the area. E) A strategic entry point to the future creek and path, with bus stops, hiking networks and existing bike paths. F) Finally, a design facilitating natural cleaning of the water is included in this section before the water reaches the Skien River.

Figure 53: Photos taken along the buried creek Kjørbekk, Skien (2017). Ph: Author.

The daylighting project initially took form in response to concerns about the lack of proper floodways in the event of a dam burst at the old Hvitsteintjern freshwater reserve, at the top of the watershed, as well as challenges related to the maintenance and capacity of the old pipe system. In relation to water quantity, the design case demanded a design that could accommodate situations ranging from no water to a dam burst, i.e., changing situations and extremes.

A new SWM suddenly became urgent when an old cracking culvert was discovered at the bottom of the sub-catchment area, where the piped creek ran through a zone with a disused landfill (Fig. 54). The leachate had accelerated the breakdown of the concrete, and the pipes were overloaded by increasing quantities of rainwater. The ground of the old landfill was unstable and challenged the underground pipe system running through it; lateral movement detached the system of pipes from its culverts, causing manholes to shift horizontally and become disconnected from the underground pipe system. The repair costs for each of these constructions, which were up to 15 metres deep, were an essential factor, and repairs in the unstable terrain of old waste might be short-lived, as the landfill was still in motion. The municipality had to decide whether to carry out repairs on a non-functional system that could not accommodate larger volumes of water or recreate a new SWM system on the surface.

Figure 54: Sectional illustration of the vertical manholes imbedded in the unstable masses of the landfill, which are suffering from the lateral movement. Because of the poor condition of the cracking pipe system, leakage water can enter the pipe through which the creek Kjørbekk flows. The section also shows the challenge with the landfill close to the larger Skien River, as groundwater might flush the pollution into the water streams. Ill: Worksonland.

From a technical concern to a strategic, multifaceted urban design
Skien's planning department chose the open system and conducted a preliminary study with the proposal to open Kjørbekk in 2015, and an open competition was announced[56] (see Article 2). Responsibility for the project was

[56] The commission was obtained through a Europe-wide public competition by Worksonland Arkitektur og Landskap, Uni Research and Multiconsult. It was published on TED on 10/18/2016 with the identification number 2016/S 201-364527.) The project is included as a pilot case in the Norwegian Climate Change Adaptation Programme 'I-front' from the Ministry of the Environment (Miljødirektoratet – http://www.klimatilpasning.no). In turn, it is represented by Multiconsult on the Klima 2050 platform – Centre for Research-Based Innovation.

later transferred to the water and sewage department, which had the information on the underground systems. The project was developed further in collaboration with the municipal planning department. Although the project's roots were technical, the municipality developed it into an urban strategic project with social, environmental, and cultural dimensions. The corridor for the creek comprises a network of systems: stormwater management to adapt to climate change, an ecological corridor and a new axis for biodiversity, and a public system of recreational spaces comprising itineraries and trails. A landscape infrastructure capable of retaining, filtering, and transporting water, generating a new landscape of urban and territorial cohesion.

Opportunities emerged with the creation of a local, non-motorised mobility network. The establishment of the floodway and areas for the water to expand relates to the urban fabric and its floodable land. The new riverbed was designed to activate and interact with the adjacent urban fabric and programmes, such as enterprises and the recreational areas of the Skogmo public school, residential areas, sports fields and courts, existing public transport stops, and bridges and connections to other existing or planned routes and cycle paths. Some areas emerge as central along the linear park, such as the union between the creek Kjørbekk and the Skien River and the connections with public routes. In the future, these will be parallel to the Skien and connect it with the city centre.

This case shows a SWM project that was initiated because conventional solutions following the old logic of an underground piped system were no longer possible. The project shows how a SWM project can be key for initiating urban transformation projects in which various values besides water management are taken into account.

Daylighting the direct relationship between water and ground

The Norwegian three-step principle for stormwater management are: catch and infiltrate, delay and retain, and create secure floodways (Lindholm, 2008). The research takes into consideration the ground conditions and shows how the ground composition can complement the present stormwater model. As the dynamics of water relate to the ground, the geological setting of the case study area was the starting point for this project. The four-kilometre-long creek Kjørbekk shows samples of different ground conditions that are representative of various geological conditions typical of southeastern Norway. The ground conditions guide the water and the project development. Where there is bedrock, there are few design possibilities for infiltration. The area of the dam Hvitsteintjern to the west, where Kjørbekk starts, is bedrock (Fig. 55). From there, the water runs through bedrock with a thin moraine cover that is mostly covered with spruce vegetation (55:1). The ground here has little permeability, but the vegetation holds back and slows down the runoff water from light rainfall.

Further downstream, the creek flows into an area of marine deposits (55:2). The land here is used for cultivation. At present, the creek runs under this area in pipes before crossing beneath the industrial area. On the northern side, there are river deposits on top of clay, at the single-family housing area (55:3). Hanging ground water may be the explanation for variations in groundwater levels in the old riverbed (55:4).[55]

To the south is a sand quarry, also created during the Ice Age (55:5). Infiltration in the lower parts of Kjørbekk is better than in the bedrock at the start of its course. However, the lower part of the catchment may be saturated by groundwater, and capacities for infiltration may be limited; the falling rain will only infiltrate if the space is not already occupied by groundwater from earlier rains. For the SWM project, this entails that water storage is to be accommodated in landscape volumes in addition to the infiltration. The situation in the sand quarry is the opposite, and the ground is extremely permeable, draining to such an extent that no water from Kjørbekk will reach the Skien River and restore the aquatic habitat unless this particular segment of the channel through which it flows is sealed with clay.

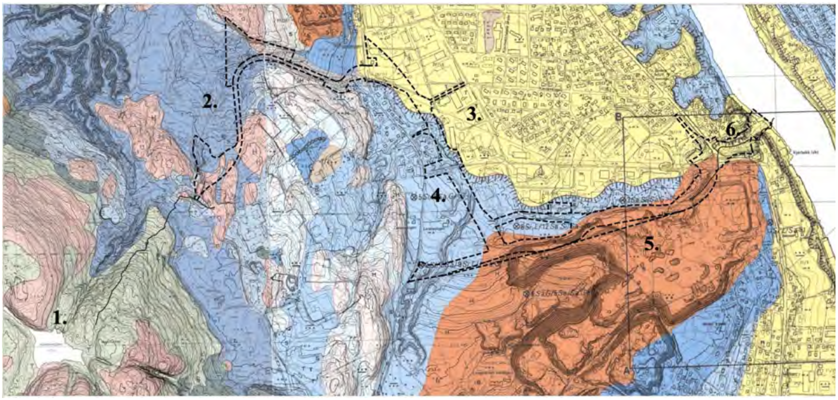

Figure 55: Geomorphology of Kjørbekk. Showing areas of: 1) bedrock, 2) marine deposits, 3) river deposits on top of clay, 4) the old riverbed with hanging ground water, 5) sand deposits. Map: Quaternary geological map Skien BCC 028-10.

[57] In the area of Kjørbekk, the layering of hanging groundwaters is assumed to be relatively horizontal, as they were formed in a slow process from the last Ice Age. The inclination can be estimated by the direction of the melting ice cover; the larger moraine pockets that were once under the ice and are now visible in the landscape by the moraine hill of 'Geitryggen' to the north, indicating the ice direction. Zooming out, this can be seen in the greater landscape forms, and in correlation with the overall ice movements corresponding to the land formations and rivers of today.

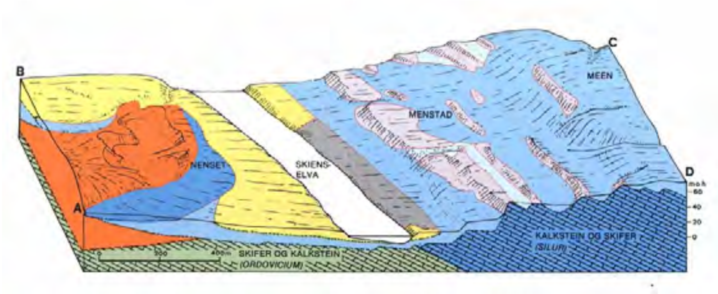

Figure 56: Illustration of the ground conditions at Nenset sand quarry and the outlet of Kjørbekk towards the Skien River. The diverse ground conditions imply that the rainwater reacts differently when it meets the ground, running on the surface or disappearing into the ground when it reaches the sand deposit.

The important relationship between water and ground in this project is particularly evident where water can destabilise quick clay, or where water percolates through contaminated ground, which increases the risk of spreading toxins. In the Kjørbekk case, there is quick clay at the Menstad bridge, where Kjørbekk meets the Skien River (55:6). This was investigated when road authorities were planning construction of the bridge (completed in 1991). While the marked areas with quick clay are not within the proposed riverbed, its presence here should be noted, as not all quick clay areas are mapped out at present. Buildings have been constructed over Kjørbekk's former path, meaning that new paths for the creek are necessary. Digging to open up a new watercourse entails a risk of emptying hanging groundwater pockets, which can change the properties of the terrain and provoke the ground to subside, causing damage to buildings and infrastructure constructed there.

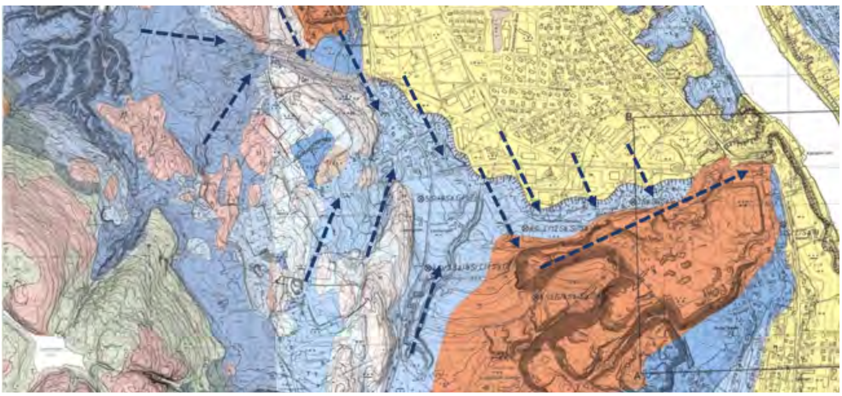

Figure 57: The arrows on the map represent the movement of the groundwater in relation to the topography and the original natural path of Kjørbekk. The drawing of directions of hanging groundwaters is a speculation, based on the visible landscape and knowledge of how the landscape was formed in deep time. Reworked map: Author.

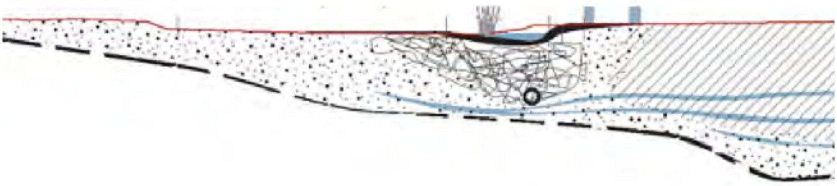

Figure 58: An early guess section of the path of the buried creek, which passes through manmade landfills and various geological ground conditions with hanging groundwaters. In some areas the landfill reaches a depth of 15 m. Section: Author.

There are no comprehensive maps of the groundwater and its changes over time, but registrations have been made when drilling holes for earlier projects for wells, infrastructure or building construction. Groundwater flow direction can be estimated with the help of the observed landscape, the general inclination of the bedrock, and the path of the former creek and its tributaries, but it is still merely an estimate based on what can be observed.[58]

Water and ground are interrelated. In a long-term perspective, the Ice Age formed the ground slowly. However, water can change the ground relatively rapidly with quick clay and through everyday erosion. Water and ground are mapped together, as the form and velocity of water are related to the ground, and the presence of water can change the ground's properties.

[58] It is sometimes possible to see groundwater traces on the surface. Differences in temperature between groundwater and surface ground on cold days can indicate where the groundwater is located when it melts the frost on the ground surface, but the more the site is urbanised and impermeabilised, the more difficult it is to read it from the aerial picture.

A design for extremes: From no water to flooding

The design case involves extreme situations, ranging from no water to a dam burst, as well as challenging everyday situations that may arise if SW is not handled properly on the local level. A dam burst would cause a flood wave, threatening housing and the industrial area to the north (Fig. 59). The project thus includes a flood path that routes the water flow to the south and through the Kjørbekk valley. In the urban area, the hydraulic level was designed for four water flows: the minimum, the maximum, the usual, and the maximum compounded by a dam break: Qa= 0.06 m³/s, Qb= 1 m³/s, Qc= 1.5 m³/s, Qd= 6 m³/s. In order to steer the water overflow, the terrain is elevated in the curves at point A to keep the water on course and prevent flooding (Fig. 59). The terrain is also moulded at point B to keep the water on the moraine, as unstable masses downhill could otherwise easily be forced into motion by the water.

Natural ground and low maintenance were proposed for the riverbed. This defined the slopes, both longitudinal and transversal, so that the speed of the water would not cause erosion. Where space was available, the section was widened to reduce speed.

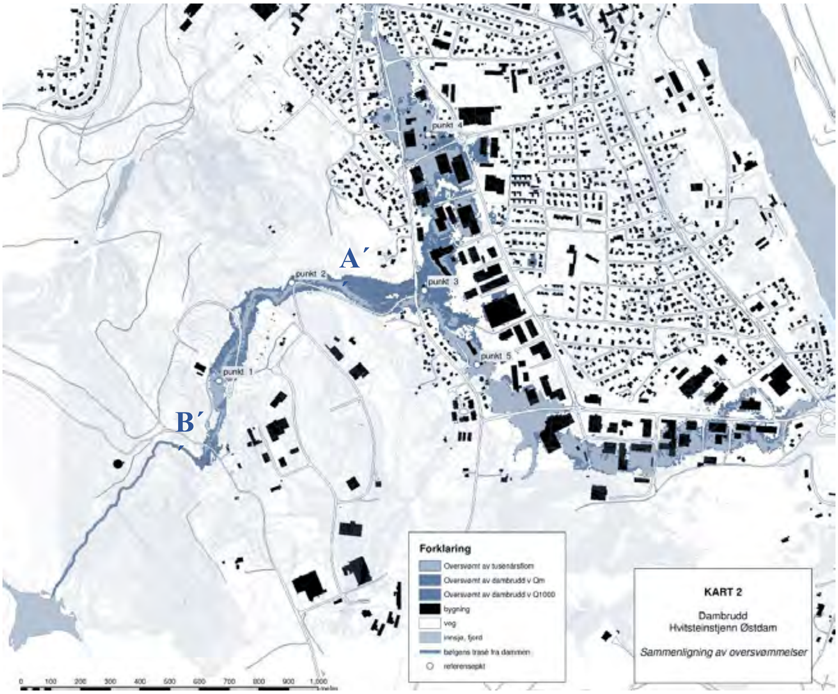

Figure 59: Illustration of the effects of a dam burst. Map: Multiconsult 2007.

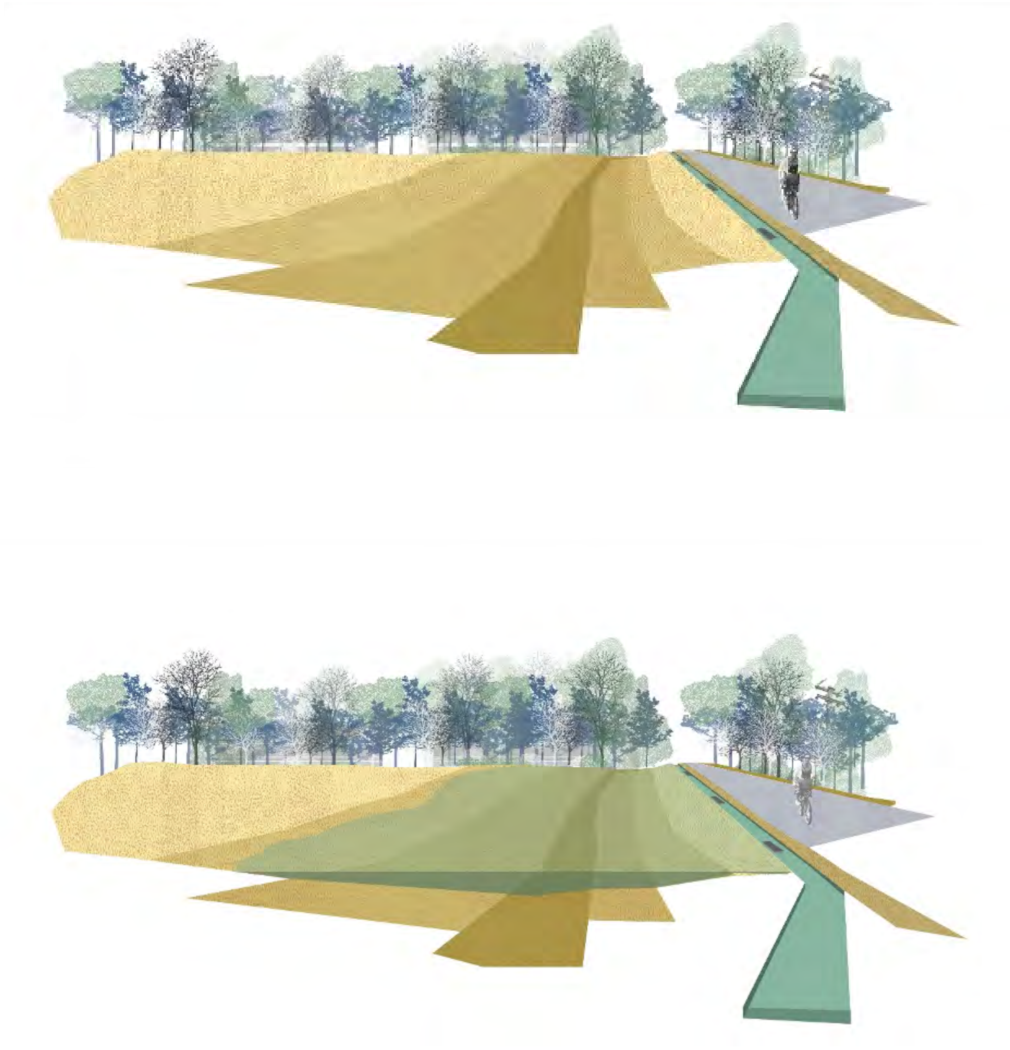

Figure 60: Illustration of the water's expansion possibilities along the watercourse Kjørbekk. The other dark blue areas also have a water retention and expansion capacity. Ill: Worksonland.

The design criteria for the floodway were as follows: A variation of the longitudinal section was needed to create a variety of water movements in order to oxygenise the water and to facilitate visual and biological diversity. - When the transversal section was elaborated, it became clear that a wide section was desirable in order to facilitate access from the lateral areas, reduce erosion, and create a greater surface area to contain the water volumes (Fig. 61). While the fluctuation in water quantities was important, all sections of the riverbed should be centred on a V-shaped depression that accumulates and maintains a water minimum during dry periods. The creek and its floodplain should preferably be guided through public land to avoid expropriation and increased project costs. The longitudinal section of the creek should be varied and not too steep, in order to facilitate ecological diversity by allowing fish to swim upstream and provide a diverse habitat.

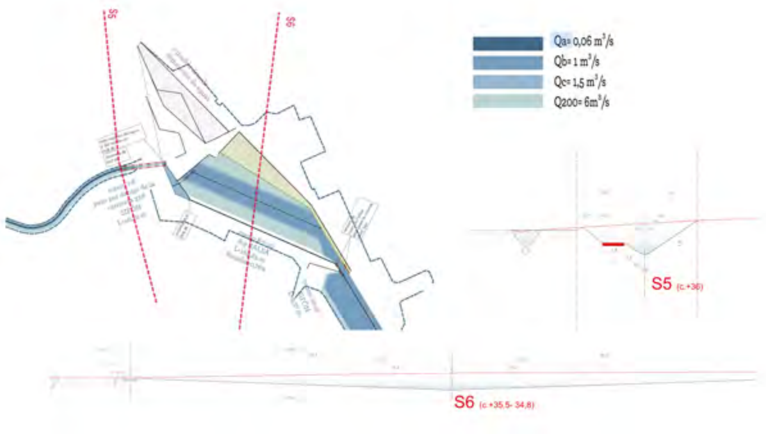

Figure 61: Plan and section of the illustrated area above, with a dynamic water presence, showing a planned inundation area with different water levels. Plan and sections: Celia Martínez Hidalgo, Worksonland 2018.

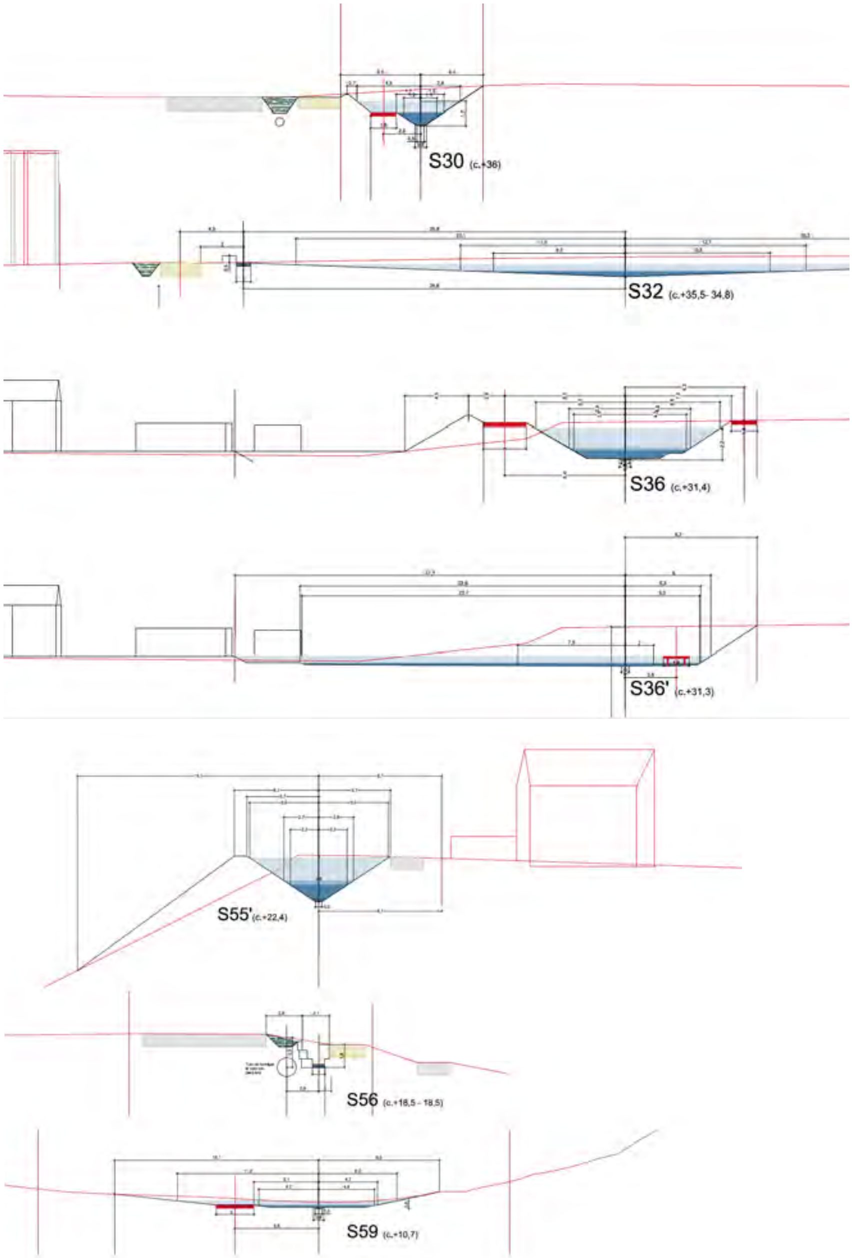

Figure 62: In order to enable a design of the transition from below- to above the ground and define the project's technical constraints, numerous cross-sections were made in the initial phase of the project, localising the heights and locations of elements above- and below ground. Sections: Celia Martinez Hidalgo/ Worksonland.

The total catchment of Kjørbekk is 3.11 km^2, and the catchment area of Hvitsteintjern is relatively small (0.55km ^{2}), meaning that the creek runs dry several days a year. Opening the dam would make it possible to maintain a stable water flow throughout the year, but to do that, it would be necessary to empty it, thus sacrificing the recreational bathing area as well as a freshwater reserve that the dam provides. Another possibility for lowering the water pressure on the dam whilst at the same time conserving its perimeter would be to fill it partly with artificial islands, which would reduce the water volume. This would also change the ecological conditions in the dam and advance the growth process of vegetation in the water, which would successively result in the dam's disappearance.

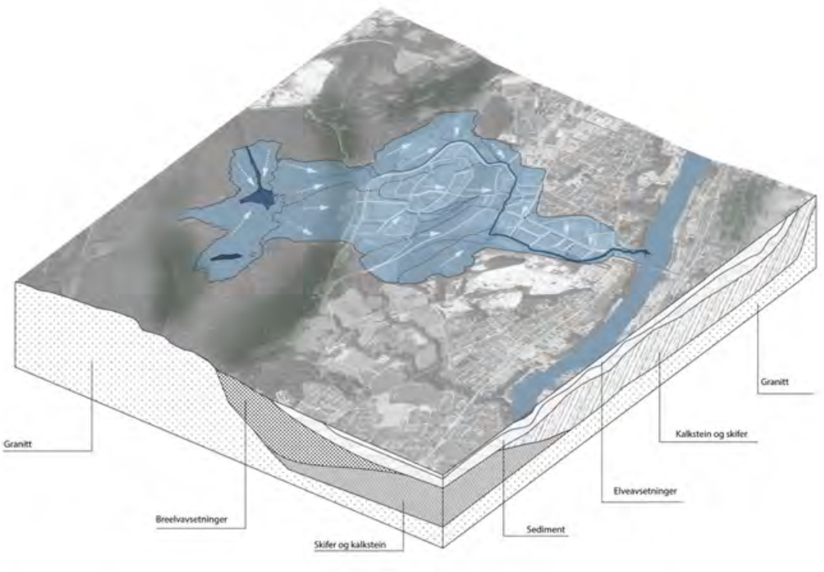

Figure 63: Illustration of the isometry of the watershed at Kjørbekk, in total 3.11 km2. Ill: Worksonland.

The municipality decided to preserve the dam, meaning that the new riverbed had to handle situations ranging from no water to great volumes of water from a dam burst at 6 m^3/s; i.e., a design for extremes was required. The advantage of this choice is that the water-related habitat remains at the dam, preserving an extra freshwater reserve as well as the recreational functions.

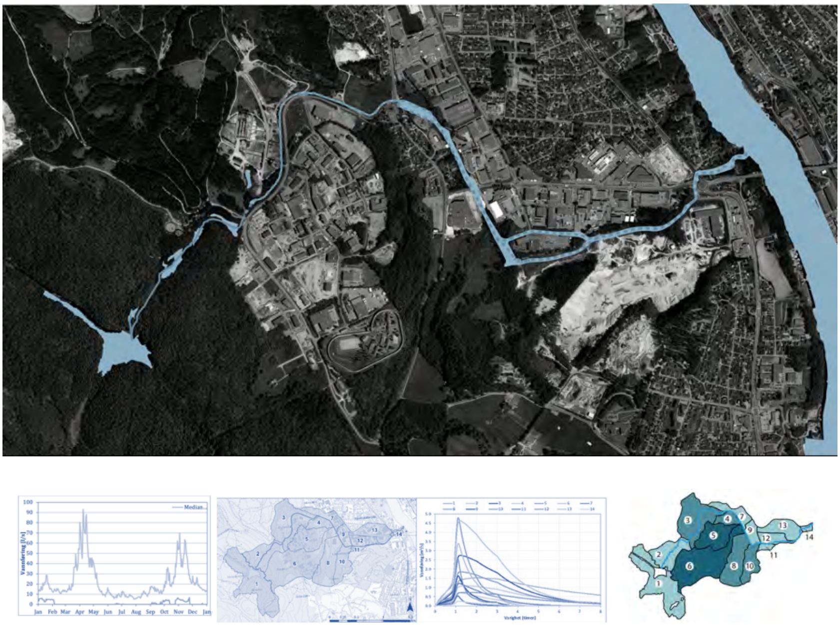

Figure 64: Illustration of a new path for the creek, 2018 Ill: Celia Martinez Hidalgo, and Worksonland.

64.1: Water flow in Kjørbekk valley (l/s). The median value shows that the creek is dry a few days per year. Graph: Multiconsult 2017.

64.2: Illustration of the sub-watershed and water dynamics.

64.3: Diagram of the catchment area and the 14 sub-catchments that constitute the Kjørbekk valley waterflow in m³/s. Graph: Multiconsult 2017.

64.4: The illustration shows which sub-watersheds provide the most water; the darker they are, the more water they provide. Ill: Worksonland.

The diagram on the above right shows the waterflow created by precipitation for each sub-watershed (Fig 64.3). This is expressed in the plan; the darker the colour, the more water is provided (Fig 64.4). Here, the challenges are in the newly industrialised area, labelled *5* and *6* in the diagram (Fig 64.4) and corresponding to the industrialised area Rødmyr. The impermeable surfaces create increased runoff that floods the horizontal plain of Kjørbekk, as the water today does not reach the Skien River.

The orthophotos below illustrate how the area of Kjørbekk was urbanised with industrial and large-scale commercial buildings. In the high-lying area of the watershed, the industrial zone Rødmyr replaced the former woodland with impermeable surfaces and large-scale buildings, resulting in an acceleration of the runoff water both due to impermeable surfaces and the reduced capacity of what was once woodland.

Figure 65: The orthophoto of the industrial area of Kjørbekk in 2004 shows that it has expanded with the industrial area Rødmyr to the west. This is situated on the slope within the catchment area between Kjørbekk and the dam Hvitsteintjern. In 2004, it still consisted largely of forest. Map: Google Earth, 2019.

Figure 66: The orthophoto of Kjørbekk in 2015 shows that Rødmyr was transformed from a forest area to a fully developed industrial area with mostly impermeable surfaces. Map: Google Earth, 2019.

Figure 67: Map of impermeable surfaces in 2018. Ill: Celia Martinez Hidalgo.

Figure 68: Map of permeable surfaces in 2018. Ill: Celia Martinez Hidalgo.

Urban expansion with industrial and commercial functions and parking areas has resulted in large, asphalted areas, creating increased and accelerated water runoff (Fig. 67). The hydrological strategy was thus to reduce the additional water flow by retaining the water within the entire watershed, providing continuous watercourses throughout the urban fabric. The design reduces the velocity of the runoff using open daylighting solutions that provide greater areas of infiltration. A floodway was designed with a capacity to catch, retain and create flooded areas in order to counter greater water quantities.

Planning parameters were developed to hold back water on site where possible using water management principles such as green roofs, opening up or replacement of a certain percentage of the ground with permeable pavement, incorporation of garden areas, vegetation along the plot boundaries, infiltration trenches, permeable pavements, rain gardens, infiltration basins, and increased use of trees in the urban design (Fig. 69).

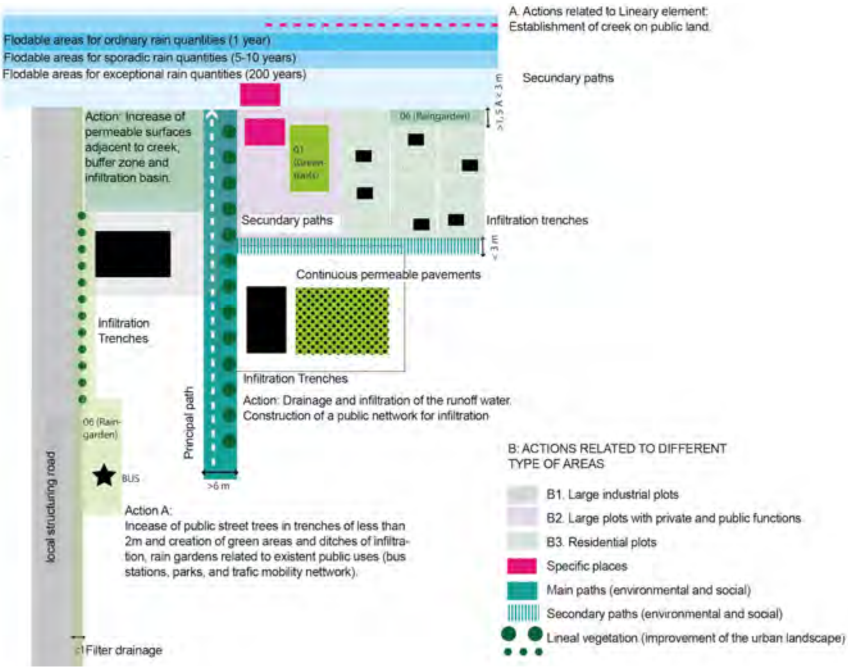

Figure 69: Diagram of regulation principles in relation to the water management within the watershed and in relation to the riverbed and the different water levels. Diag: Celia Martínez Hidalgo, 2018.

Stormwater management as a system at the surface demands continuity; an overall plan that defines the stormwater management and its waterways is thus a necessity. In the Norwegian setting, various juridical clarifications would be necessary to facilitate this. (For more on the juridical aspect, see the section in Chapter 4.3 ‘Planning and juridical frameworks impact how change happens’).

The designs prompted questions about the climate change coefficient[59] in the calculations of the hydrological situation; this number has been rising as knowledge on climate change has evolved. In 2008, researcher on the interaction of hydrology and climate Paul CD Milly and colleagues wrote that 'Stationary is dead' (Milly et al. 2008).[60] This changes design; rather than fabrications intended for exact quantities, design should be flexible, resilient, and adjustable to accommodate extremes.[61]

Stormwater management: Permeability beyond the surface

Urban hydrology has traditionally focused on the behaviour of water on the surface of the landscape. In SWM, the ground surface's infiltration capacity is calculated and classified with a coefficient from 0 to 1. The case study has shown that little attention is dedicated to the existing groundwater levels in the calculations. The hanging groundwaters are a specific additional challenging feature in the case study that makes infiltration capacity even more difficult to predict. Groundwater levels are rarely integrated in calculations, as data is lacking in many places in Norway, and the levels themselves vary over time. Nonetheless, they play an important role; if the ground is saturated by groundwater, a permeable surface is of little help.

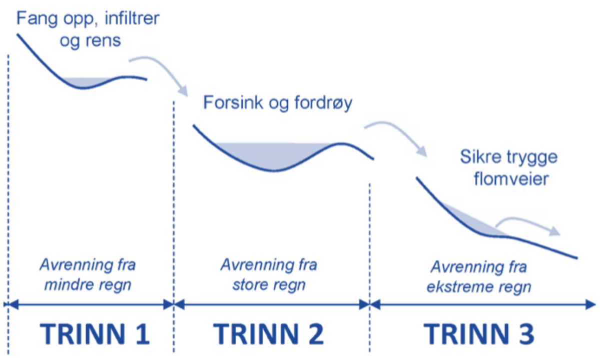

Figure 70: Diagram of Oddvar Lindholm's three-step strategy for SWM (Lindholm et al. 2008).

[59] The 'climate change coefficient' is added in hydrological calculations to accommodate for future climate changes. There are different coefficients dependent on the estimated changes foreseen.

[60] 'How did stationarity die? Stationarity is dead because substantial anthropogenic change of Earth's climate is altering the means and extremes of precipitation, evapotranspiration, and rates of discharge of rivers. Warming augments atmospheric humidity and water transport. This increases precipitation, and possibly flood risk, where prevailing atmospheric water-vapor fluxes converge' (Milly et al. 2008: 573).

[61] The water calculations within the landscape are not a millimetre science' Jan Stenersen, water and sewage engineer. At present there are several values used as climate change coefficients, dependent on different temperature-rise scenarios. This means that a very precise calculation gives a relatively wide variety of water quantities dependent on the coefficient that has been used.

A finding from the design case is that urban hydrology focuses primarily on the landscape surface and might include the underground pipe network, but in general little attention is paid to the physical context of the underground with its material composition and groundwater levels. The design case indicates the need for a supplementary reading of the landscape's depth in urban hydrology for various reasons. First, the surface is just the start of the landscape, and its permeability depends on the deeper ground properties; i.e. whether there is bedrock or sand. Second, the freshwater perceivable at the surface is only a small part of the whole freshwater presence – approximately 1% is surface- and other freshwaters, 30% is groundwater and 69% glaciers and ice caps. Another aspect to be added is the vertical depth of the SWM at the site, in order to include the hanging groundwaters and the groundwater levels. This is relevant in order to foresee the effects of excavation and not inadvertently empty e.g. a ground water pocket that will provoke the land to subside when the area around what is now the riverbed is constructed.

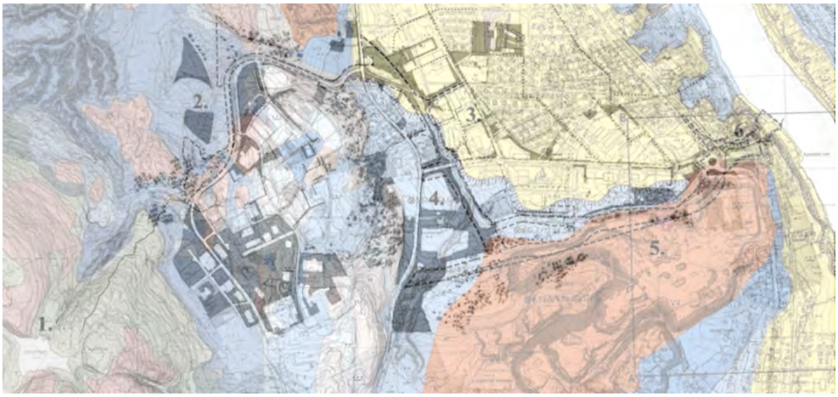

Figure 71: Combined map of permeable surfaces and the geological context that shows where water will and will not infiltrate after extensive rains. Map: Author.

Solid water, stormwater management in a cold climate

In general, little attention has been devoted to the cold climate conditions in Norway in relation to accommodating stormwater and finding specific urban design solutions for the winter season. The climatic conditions along the coast, thus at Kjørbekk, can hover around 0°C during the colder months of the year;[62] there is thus a fluctuation between rain and ice, and the various states and stages of frozen and permeable ground must be taken into account in the project. In urban areas, cold climate drainage has been tested on the principle that the underground temperature is higher and running water can be found

[62] There are different cold climate conditions. Where there is permafrost, for example, rain that falls on the frozen ground freezes and does not run off immediately. The behaviour of water in a cold climate depends on various factors, e.g. the temperature of the ground, air, snow, and rain. A layer of snow on the ground will cause water to behave differently than when it is frozen.

there even if the surface is frozen. Therefore, connections to the underground water systems via mediums that do not freeze are being tested.[63]

The frozen and snow-covered ground with clogged pipe systems raises questions about the relevance of the ground's permeability and underground calculated pipe system for stormwater management. The project team discussed experiences with cold climates in relation to stormwater management. Large volumes of runoff water may result if rain falls on frozen ground without vegetation and with little structure and rugosity that can slow the water down (e.g., agricultural fields inclined towards the built areas). One possibility for accommodating water when infiltration is not possible is retention at the surface in concave formations created in the landscape. Cultivation patterns that slow down water movement by elaborating the ground and planting structures may thus be favourable for SWM downstream. Agricultural practices within urban watersheds are large, managed areas, and they could potentially become a part of urban SWM strategies; another effect would be the slowing down of SW velocity in the summer and prevention of topsoil erosion. Mixed cultivation with multiannual crops can produce structures parallel to the contour lines; this is desirable as they slow down SW, reduce erosion, increase biodiversity and build up the soil. Agricultural practices could become a part of urban stormwater management strategies, as agricultural land represents large, managed areas.

The design case shows that dealing with stormwater management in urban areas demands using a broader perspective and including other land uses, such as agricultural land and forested areas, to reduce the runoff that enters the urban settings often present in the valleys.

[63] Landscape architect Mari Bergset at UiT and Tromsø Municipality carried out pilot projects on SWM design in cold climates. Mari Bergset, Marianne Skunke and Alf Haukeland have also worked with students to look into development of the blue-green- and white infrastructure in cold climates (Mari Bergset et al. 2017). Other universities in Norway have researched cold climate adaptations of SWM, such as the Norwegian University of Science and Technology (NTNU) and the Norwegian University of Life Sciences (NMBU), where e.g., water purification processes were tested in cold conditions.

Water and the role of vegetation

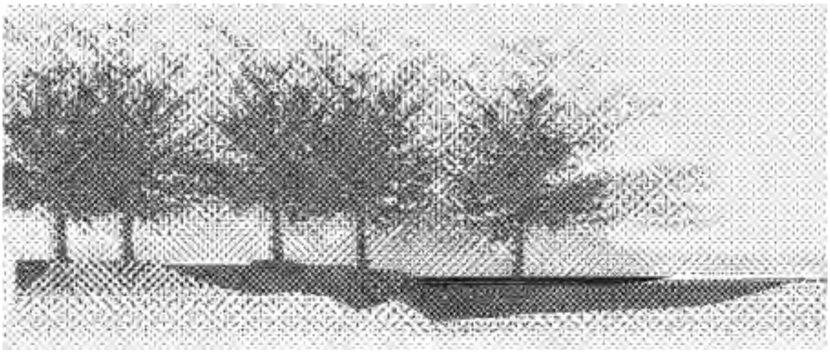

Figure 72: Illustration of the relation between water, ground, atmosphere and vegetation. An illustration of a humidity scanning of the vertical territory. Ill: Author

Trees are 'water managers'; in light of this, vegetation in the hydrological calculations could be developed further. A beech tree, for example, can take up almost 500 litres of water each day (Wohlleben et al., 2016). Trees' roots also help water infiltrate the ground. While vegetation was not included in the hydrological calculations – this might be because water consumption rate values for vegetation fluctuate over time depending on species, season, and the tree's age – vegetation's capacity for transpiration, interception and guidance of water is important and has great potential as a factor in contemporary urban hydrological estimations (Fig. 73).

Land cover	Transpiration	Interception	Total evaporation
Conifers	300-350	250-450	550-800
Broadleaves	300-390	100-250	400-640
Grass	400-600	-	400-600
Heather	200-420	160-190	360-610
Bracken	400-600	200	600-800
Arable*	370-430	-	370-430

*assuming no irrigation.

Figure 73: Overview of the evaporation losses (mm) from different types of vegetation (receiving 1000 mm annual precipitation). Table: Author, based on source: Tom Nisbet (2005): Water Use by Trees: Forest Research, Edinburgh.

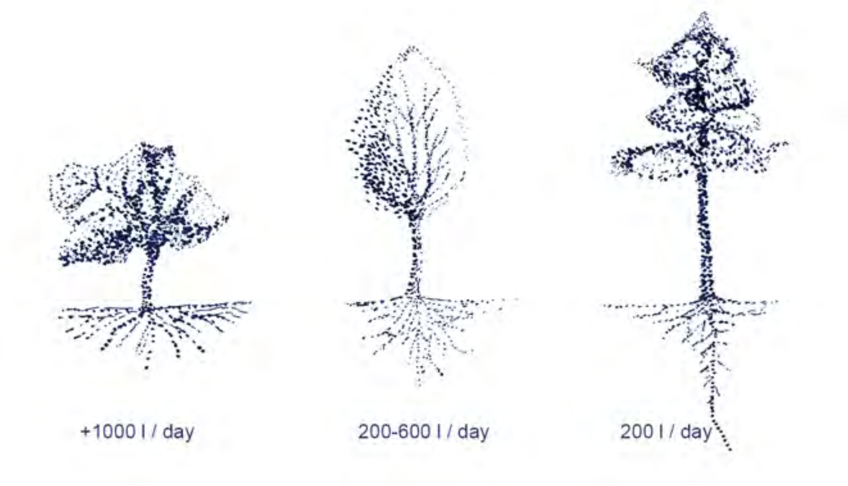

Figure 74: Illustration of different trees and their water absorption capacities. The exact amount of water that a tree can take up varies in relation to various factors such as species, age and size, its growth conditions, soil type, development of root system and the season. Ill: Author.

Figure 75: Illustration of the different natural areas and the possible re-establishment of habitats along Kjørbekk. 1. Blueberry forest, where spruce is the dominant tree species. Perennials and large ferns. 2. Deciduous forest. 3. Hay meadow. 4. Mixed forest. 5. Grey alder hedgerow forest and floodplain forest to spread further. 6. Birch forest. 7,8,10 Watercourse with purification. 9. Rich mixed forest. Ill: Worksonland.

SWM can be used actively to create more ecological gradients and for habitat design. Many modifications have been made to Kjørbekk in its long industrial history, and numerous habitats have been erased. Bringing the water back to the light opens up for new species and possibilities to enrich local biodiversity.

The large-scale daylighting project is located in an industrial area on the outskirts of the central municipality with very limited resources with which to realise a daylighting project and maintain it over time. The design strategy has thus been to build on the existing vegetative resources and biodiversity, leaving the full-grown trees when possible. The piped creek has changed the water presence, but the trees today still reflect a time when water was running along the surface. The meadows with concave terrain forms will be sown with seeds from nearby cultural landscape fields. After remodelling the terrain along the creek, the focus has been revegetating it, and the creek Kjørbekk has been used as the spreading corridor for planting seeds. These fields flood only briefly and can be used for grazing. Using the creek for planting presents certain challenges in terms of invasive species.[64] The illustration above shows future habitat types, building on biologists' fieldwork. The vegetation in relation to the riverbed has been chosen with consideration for the extreme fluctuations in the volume of water. The tributary outlets along the Skien River are now of particular importance, as many of the areas along the coast where fish could reproduce in the past have been removed. The illustration below shows the different phases of transition, vegetation, groundworks and water quality control (Fig 76).[65]

[64] These will be handled with different techniques, depending on how they spread.

[65] During the process of change, water testing must be done so that leached water that is not cleaned at the site is led to a purification plant when necessary.

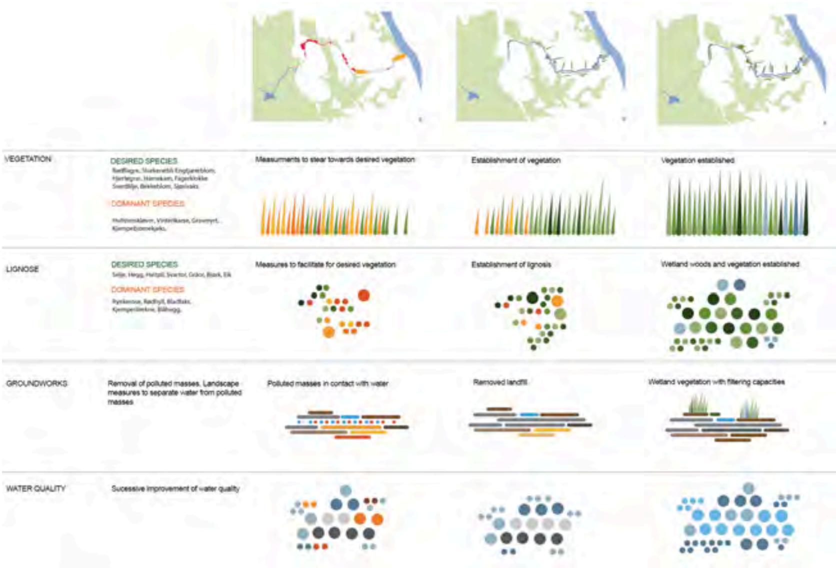

Figure 76: Illustration of the different phases of transition from the present, the interventions and the desired future of vegetation, groundworks, and water quality. Ill: Worksonland.

In summary, the design case indicates that vegetation's capacity to take up water is not taken into account in the SWM calculations, as it changes over time, as the vegetation grows and environmental circumstances change. However, incorporating a simplified estimation of the vegetation's effects would be beneficial, highlighting the role of the vegetation as infrastructure in the urban environment and strengthening its position in urban transformation.

4.2 FROM LANDFILL TO LANDSCAPE

Figure 77: Landfills in pink: to the west, Kjørbekk II and to the east, Kjørbekk I. The water from the former drinking water source at Hvitsteintjern runs openly for one kilometre. It flows three kilometres in underground culverts before finally emptying into the Skien River in the east. Plan: Worksonland.

A lack of information on the underground condition

The design case revealed a lack of information on the manmade ground.[66] There may be several explanations for shortcomings in the mapping: old infrastructure may have been removed from the map of the actual functioning system despite remaining in the ground, as physically removing it is laborious and costly; underground installations by private entities are not always included in the public maps, and information might be costly or slow to obtain. Other gaps in registration may correspond to the underground installations carried out under a different government regime – for example, the strategic military constructions such as bunkers, etc. during the Second World War. Historically, the need to protect systems that supply essentials such as fresh water, heat, electricity, etc., from sabotage has meant limited open access to information on the underground. The municipality, however, would require a complete overview during project development.

The design case of Kjørbekk, where buildings have been positioned on top of disused landfills, is not a solitary case, as the recent housing project on a landfill in Skedsmo Municipality in the Oslo region demonstrates.[67] The health issues among inhabitants there illustrate the need for a more precise representation of the underground – both its original conditions, such as the presence of quick clay and alum shale, as well as the manmade ground. The

[66] The design case reveals the ground, in the form of landfill, in the former river valley. This is not uncommon: the creation of manmade ground has been documented in numerous Norwegian municipalities by Torun Hønsi; this includes both landfills and pollution from industrial activity (Hønsi 2017).

[67] Some municipalities in Norway, such as Trondheim and Stavanger, have prohibited construction on former dumps, whilst others, such as Sandnes, investigate the possibility of building 1000 housing units on the site of a landfill that was active from 1953-1990 (Gustavsen and Stokka 2018).

information is highly relevant for future planning, project phases, and individuals purchasing existing houses.

Comprehensive maps of contaminated sites may be missing in Norway. Systematic registrations were only carried out long after the first dumps with toxic chemical compounds were established. Dumping areas and their composition are thus not always registered, and there is an information gap between the map of contaminated areas and their real presence. What we know about the underground can be seen from the perspective of the ground as value or waste. When the ground has been seen as a resource, the national geological institutes have been established early on to map a country's mineral resources.[68] However, mapping of the manmade, contaminated ground starts after its creation and may be incomplete.

A site's outer limits on the surface do not necessarily correspond to its underground area of influence and effect; landfills affect the area beyond these boundaries. Methane gas pays no heed to the perimeter of the dump site; it can be transported through the drainage gravel of pipes and led into buildings half a kilometre away (Nilausen 2001). Special design and maintenance of underground pipe installations are a necessity when crossing through old landfills. The movement of gas demonstrates the need for increased awareness of what is underground beyond the perimeters of the intervention site; elements such as water and pollution render the site limits irrelevant as plot borders. The fluidity of pollution and water entails an expansion of the notion of site from where it first appears to where it disappears. Andrea Kahn and Carol Burns present the notion of site as the perimeter of an 'area of control' to which it is associated and an 'area of influence' (including physical as well as immaterial forces that act upon the site), and the 'area of effect' is the area outside the initial site that the intervention has impacted (2015, 2021).

Influence and effect become interwoven in soil recovery projects, and the time lapsed between them is erased. For example, a phytoremediation intervention on a site reacts to incoming polluted groundwaters. It can take up residual compounds, and in doing so change the properties of the passing groundwaters before it leaves 'the area of control'; it thus has a significant effect on the surrounding areas.

From GIS maps to the creation of 'Guess Maps'

The case study shows a lack of documentation of the manmade ground, which has been a challenge when it comes to including the vertical depth and the manmade ground conditions in the project development. Visual representation of the underground is critical for the interdisciplinary communication in meetings and workshops in the design process, allowing the different disciplinary inputs to converge and facilitating the handling of the non-visible

[68] NGU – Geological Survey of Norway – was already founded in 1858.

depth of magnitudes and locations of elements. In the early stages of a project, planners and workers must often guess what they will find underground or simply deal with the issues as they emerge on site. Tests may be conducted in cases where more information on the underground is needed, but they are costly, demand special technical equipment, and they are time-consuming. There may be unmapped landfills if there are old, buried creeks,[69] or pipes whose presence on the site has not been registered. Maps and the de facto situation may differ as the result of excavator operators installing pipes where it was feasible when they were on site rather than following the map precisely.

Figure 78: Sectional perspective of Kjørbekk II as an approximation of the underground of old landfill and recycled and remodelled ground. Sectional perspective: Worksonland.

[69] In the Oslo region, farmers produced food for the cities and received waste that was dumped in concave landscape forms such as ravines. (Chief planner of Asker Municipality Tor-Arne Midtbø, conversation, 2 July 2021).

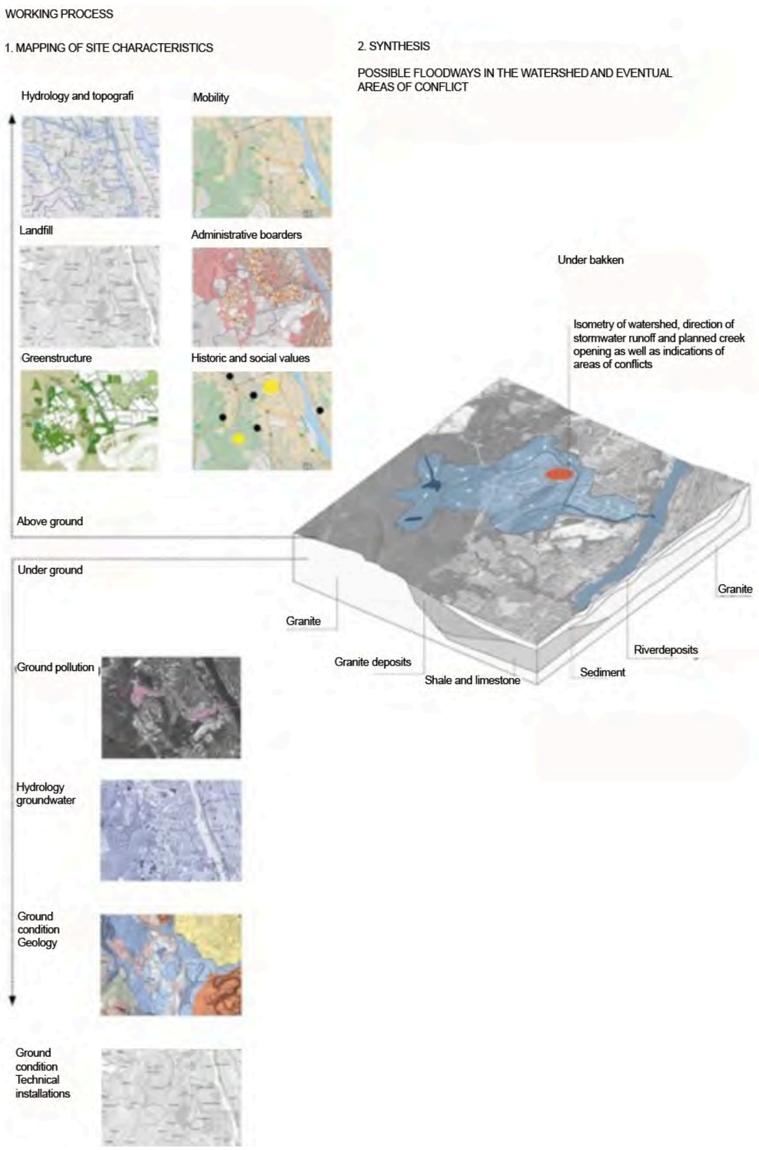

Figure 79: Overview of the working process with challenging underground conditions. Collection of the site conditions above- and below ground. Diag: Author.

When converting an underground system to a surface system, it is essential to define the exact heights of the pipes underground, as well as where and how they will be connected to a surface system. For example, in the design case, a high-voltage powerline that crosses the planned riverbed defines the level for which the watercourse must be designed, and a private electricity company owned the cables. In cases such as this, municipalities may not have information about the precise location and heights of the piping. While such information may be requested, this is time-consuming and delays the process, and possibly incurs extra costs. Understanding the magnitude of the old landfills, with their perimeter and depth, was necessary in order to propose a feasible intervention. Should the landfill be dug up and sorted, or was it inaccessible because it was too deep? What did it contain, and what was the degree of decomposition?

A map with the necessary information did not exist in the design case; a 'guess map' with the best estimates possible was thus produced based on the accessible data (Fig. 80).
New maps were created to estimate the magnitude of the landfill. To approximate the volume of the landfill, the old topographic map from when Kjørbekk was still flowing in its riverbed was digitalised and subtracted from the present terrain. Excavations were then conducted in the landfill area to ascertain the ground's composition.

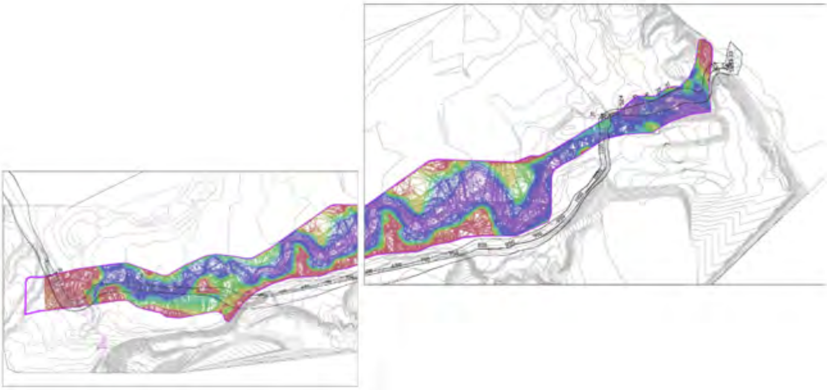

Figure 80: Illustration of a 'guess map' made to estimate the magnitude of the waste deposit by subtracting the historical topographic map from today's topography. Map: Multiconsult 2017.

Figure 81: Water purification at Kjørbekk's outlet to Skien River. The clean water runs in the middle and on the sides; the water is slowed down and filtered through vegetation before reaching the main watercourse. Plan: Celia Martinez Hidalgo.

In order to use the landscape as infrastructure, an accurate description of the underground is needed to reconnect the underground waterways with the landscape above and to know where – and where not – to infiltrate. Three-dimensional modelling of the underground helps designers and planners make informed decisions in projects, for example, where to direct floodways, in which ground to hold and infiltrate water and refill groundwater levels, and where to build or avoid building.

Figure 82: Illustration of Kjørbekk at the level of the power transformer. Here, the water is controlled in an elevated channel to avoid the need to change the position of the high-tension installations that are found underground close to the surface. Ill: Worksonland.

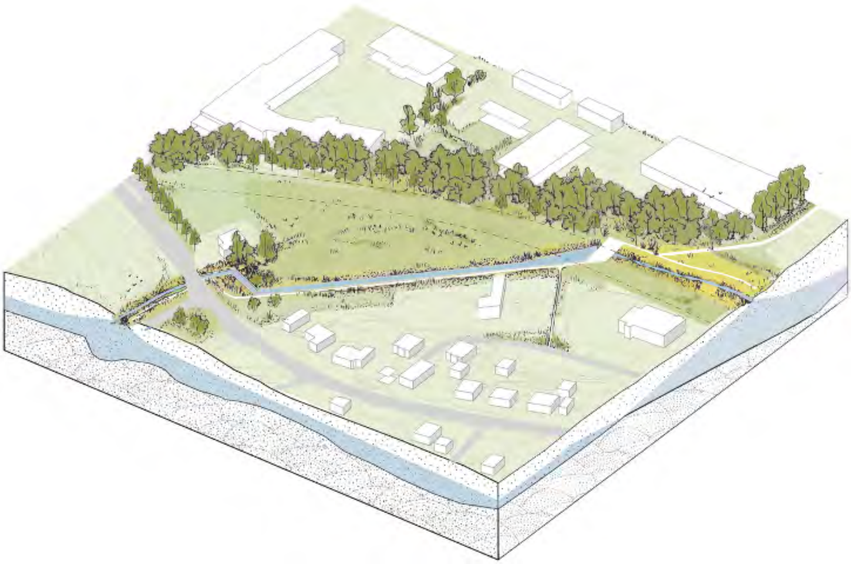

Figure 83: Area close to the power transformer, where the water is guided in a channel. Ill: Worksonland.

Unanticipated underground issues can change a project significantly, however. Not knowing about the underground during construction can be challenging, and there may be repercussions for society, for example, if water, gas or internet connections are severed.[70] Lacking knowledge of the underground also makes working processes laborious and expensive, as new information that emerges may require that projects be reworked. A design incorporating an underground with inherent constraints is not entirely predictable and introduces uncertainties to the project.

Various causes of unpredictability in the design process

The design case demonstrates that designing with unpredictability in mind is a necessity. Climate change factors are ever-evolving, and many things will change while a waterway for SW is being established and rendered functional; it is thus essential that the design can accommodate the uncertainties, e.g., where the floodbed can expand and retract over time. The design must be robust, adaptable and resilient, allowing various water levels. Unforeseen manmade ground with large, landfilled areas, cables etc. might also overturn initial design propositions. In the design case, the cable crosses the new waterway at a high level near the power transformer, which entails that the riverbed cannot be routed under the ground. Therefore, the design at this point controls the water in an elevated channel to avoid the necessity to change the position of the subterranean high-tension installations (Fig. 82).

An incomplete picture of the underground increases unpredictability in the project. While some uncertainty is certainly normal and part of the project process, reducing avoidable uncertainties is a positive pursuit that helps keep project goals feasible. Keeping a record of what we humans have produced in recent history is relatively easy; it could be done via registration in a single database and thus simplify future project development by reducing unpredictability.

Building permits were granted for buildings that affected the project area during the project phase. This reflected a necessity to first establish the regulation plan and then the project. However, this bound the project to a defined area of intervention which made it more difficult later to redefine the watercourse by going outside the area of the regulation plan and detour one of the landfills.

Working with uncertainties entails new working methods and a shift from linear to more open design processes in which criteria may change. This corresponds to a paradigm shift in which dynamics and risk management become central to the project (Martinez Hidalgo et al. 2019). Unpredictability may have both spatial and temporal consequences and change the direction of a project, even leading to preferable solutions for SWM waterways beyond the initially defined project area. Openness is thus vital when dealing with solutions offered by the design research process.

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[70] When the Tangen motorway bridge (Bærum Municipality) in the Oslo region was torn down in 2018, several internet fibre cables were cut off, which resulted in several days of disconnection.

From hydrological cycle to toxicological cycle

Initially, water management and volumes were a major focus in the design case. When identifying the magnitude of the landfill however, the perspective shifted to include the elements that change the water qualities and their effects on the water.

Looking at water from the perspective of an urbanist and landscape architect, it is easy to stop and not venture beyond the visible water of rivers and lakes. Nevertheless, most fresh water is found in the ground. When considering the quantity and quality of water, the urban hydrological cycle must expand to include the groundwater; however, grasping this is difficult in the early phases of a project, where the designer does not have data on groundwater levels.[71] Groundwater levels vary over time, depending on the season and recent rainfall. Stations that monitor water levels over time are thus valuable for understanding the dynamics of its presence.

Today, hydrological diagrams show water's movement from the hydrosphere of the oceans, evaporation, condensation, advection, precipitation, accumulation in snow, snowmelt, sublimation, deposition, surface runoff, channels, and reservoirs of streams, rivers, swamps, ponds, and lakes. The general hydrological cycle is differentiated by space and time.[72] One challenge today is understanding how the water cycle changes as a system in relation to climate change, where extreme droughts and floods are among the consequences.

Waste management practices of the past, where refuse was dumped outside the cities with an 'out of sight, out of mind' logic, are challenged by a moving element such as water. Including manmade ground in the handling of stormwater is key to avoiding the spreading of pollutants, as 'pollution of the groundwater is pollution of water everywhere' (Carson 1962: 30). When water percolates through toxins, they can easily be transported back to us in our drinking water. Already in the 1960s, Rachel Carson highlighted the effects of our actions on the environment. Groundwater and its movements are still seldom an integrated part of urban planning, however. The European ambition to recreate good surfaces and groundwater across the constituent countries within a set timeframe has also proven difficult. Therefore, it is important to see hydrology in relation to our human-modified grounds and determine whether a toxicological water cycle is present.

Design with manmade ground requires depth information

How to work with ground modified by humans depends on how that ground was created. Landfills differ from brownfields and are normally more

[71] Bore holes are often related to earlier constructions and found in areas with buildings or infrastructures. In areas with homogeneous ground conditions, it is possible to extrapolate and create a picture of the groundwater. Bore hole data do not always register the water level; the bore holes in the project area, which were made for energy, do not do this. They are also so deep that they can easily cross through different levels of groundwater.

[72] 'The planet's water system is best characterised by variability rather than uniformity over time and space' (Marsh et al. 1981: 153.)

heterogenic. Dumping grounds created at a time when toxic waste was not yet separated from household waste are complex to handle, as the composition is generally diverse and more difficult to foresee. Risk assessment of a landfill depends on several factors, such as its initial position in relation to the watershed and to the groundwater, the ground conditions, whether the waste is stabilised, and what type of waste has been dumped. Substances found in brownfields usually relate to the past productive activity on the site. Once identified, there are different possible remediation activities, depending on the type of waste: biological, technical, or chemical. Other processes can be used, and the contamination can be bound, extracted, or neutralised (Ortiz Bernad et al. 2007; Okkenhaug et al. 2016). Enabling the design of landscape measures as well as processes that take place in the landscape (biological, physical or chemical)[73] requires working with the landscape's depth.

Water landscape measures for polluted terrains

A number of landscape measures were developed to prevent contact between water and landfill in the design case. Additional biological and chemical measures may be added in relation to the identified contamination, however. Given the heterogenic composition of the dump, however, it has been difficult to estimate the proper component with which to match it at this stage. A strategy to reduce the infiltrating water quantities as much as possible has thus been chosen as a primary measure.

To evaluate the effects of different stormwater measures, an overview of methods used in disused Norwegian landfills was carried out. The mapping was followed by site visits to disused landfills in the Oslo region, which revealed the challenges of technical solutions using membranes when watercourses are guided over landfills; unstable ground conditions have meant that these watercourses have not endured over time. As a consequence, this design proposal has avoided technical solutions using membranes when guiding the watercourse over unstable landfills and instead used the landscape as an open infrastructure, thus favouring solutions in which the landscape and the possibility to shape it have been central in guiding rainwater away from the landfill to be handled on non-polluted ground.

The design case is one example of the need for below-grade conditions and the landfill to inform and change the regulation planning. The creek Kjørbekk could be steered around the landfill via a deviation higher up in the watershed. Guiding the water down to the next creek to the far north would be an undesirable solution, however, as this also contained an old landfill. An option was to guide the water using a method inspired by the Keyline design (Fig. 85) and lead the creek over the public land to the north before turning it eastward towards the Skien River.[74] This would entail changes to the strict regulation

[73] Mainly biological measures were proposed in the project, but there were also physical and chemical measures, depending on the feasablility for a large-scale project.

[74] Keyline design by PA Yeomans, author of *Water for Every Farm*. Yeomans defined a technique in which the local topography is used to determine the most appropriate areas for retaining the water with the greatest efficiency, less construction and fewer modifications of the terrain (the keyline). This is a large-scale

plan; it was, therefore, challenging to effectuate within the timeframe of the daylighting project.

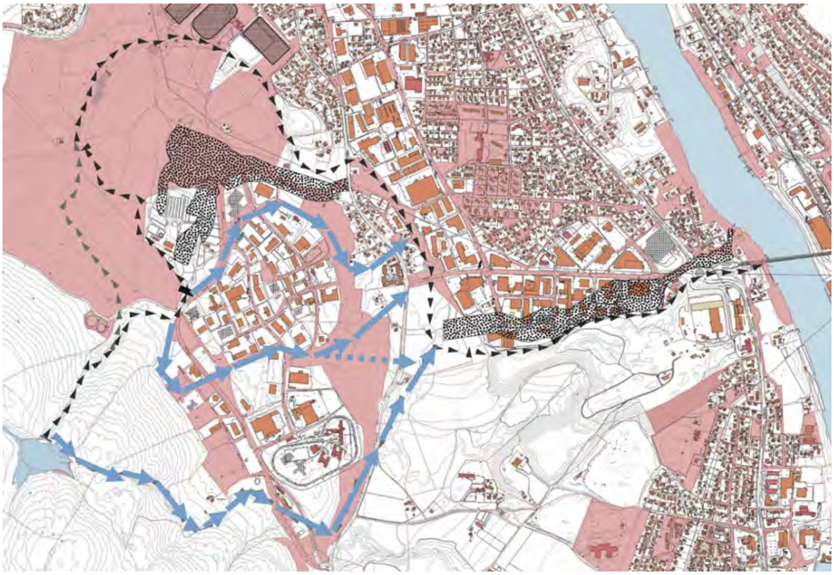

Figure 84: Illustration showing alternatives for routing Kjørbekk around the area where the landfill is situated. The area in pink shows public land (June 2017). Ill: Celia Martinez Hidalgo/ Worksonland, 2017.

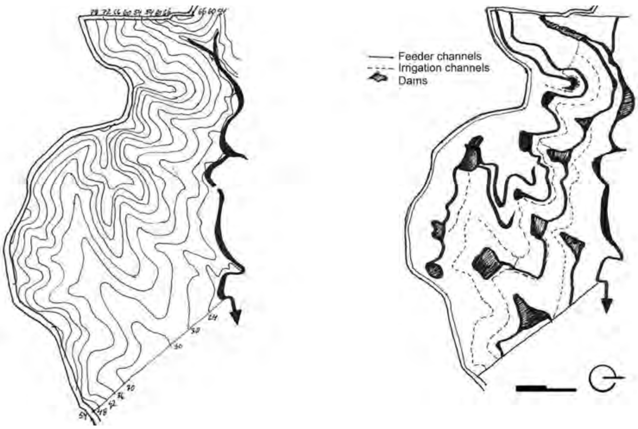

Figure 85: Illustration of the Keyline design. based on PA Yeomans illustration, from the book 'The Keyline Plan, The Challenge of Landscape, Water for Every Farm from' 1981. Ill: Author.

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intervention technique that initially facilitated bringing water to dry valleys, improving the local climate and possibilities for agriculture. However, the technique can be used for various purposes, such as leading the water, holding it, harvesting and distributing it.

The investigation included the study of different landscape-based SWM techniques. Conceptual drawings of the landscape measures used in disused landfills are presented below (Fig. 86). The first illustration demonstrates landscape measures where contact between water and landfill is avoided. This might be done by using the topography to change the direction of the water; here, it is deviated before reaching the old landfill, and other areas of public land are used in order to circumvent the contaminated site (Fig. 86.1).

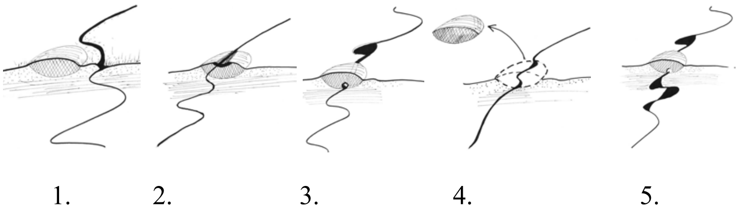

Figure 86: Illustration of different ways of handling SW in relation to old landfills.

1. Deviate the water course higher up in the watershed, 2. Guide the water over the landfill with a membrane between landfill and water, 3. Repair old pipe with trenchless pipe lining combined with a dam to reduce overload of water, 4. Landfill mining, 5. Water purification after the landfill. Ill: Author.

Topography and landscape modelling

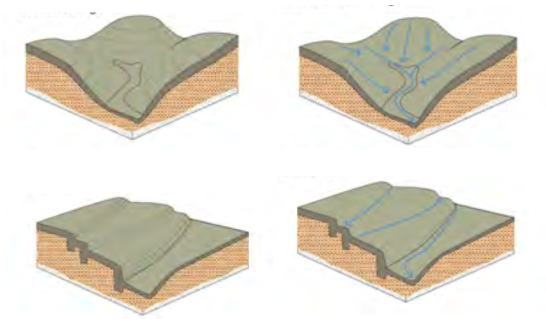

Figure 87: Diagrams showing how the terrain is remodelled to lead stormwater away from landfills. Above are the principles of forming the terrain into concave shapes to redirect the stormwater. Below are terraced principles to guide the stormwater (grey corresponding to the original ground, orange to waste, brown to soil cover, and blue arrows to direct the water). Ill: Worksonland.

When the first option is not feasible, a second option is to go over the landfill (Fig. 86.2). The complication is that the unstable ground and the membrane are positioned on settling ground, and ground movements create tension and, over time, holes in the membrane. If there are different types of dumping grounds, their components and stability can guide the path for the location of where to create the new waterways. The third illustration (Fig 86.3) shows the option of repairing the piped system. A 'soft tube' is inserted into the pipe. Once in place, it hardens, creating a new, waterproof membrane on the inside, which reduces the water capacity. Therefore, to reduce the pressure on the pipe system, dams are formed before the water reaches the landfill. The fourth option (Fig 86.4) is landfill mining, where the landfill is dug up, sorted, recycled, recovered, sent away to be treated if it is determined too polluted, or otherwise reused on site. The last illustration shows water purification and the dam's function for reducing waterflow and for control, sedimentation, filtration and cleaning before the water is released into the system (Fig 86.5).

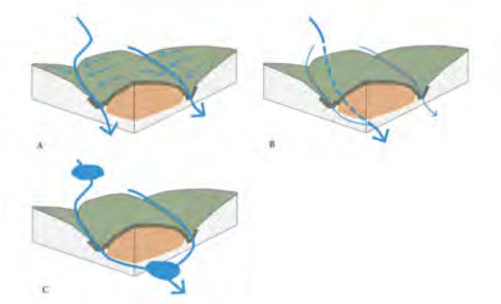

Figure 88: A. Diagrams showing how to guide the freshwater around the landfill with ditches at the periphery of the landfill that collect the stormwater. Fig B Landfill with an old piping system on the valley floor. Fig C. The water pressure on an old collapsing pipe system in landfills is challenging. The illustration shows how the water capacity can be increased by creating dams before the landfill and a filtering system after the landfill. Ill: Worksonland.

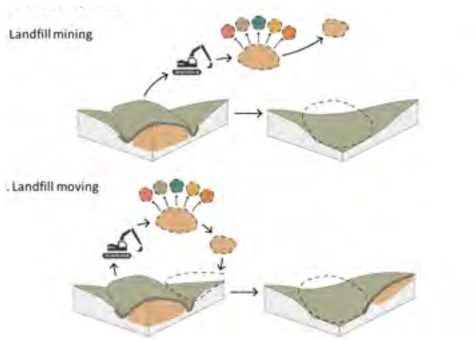

Figure 89: Diagram showing the process of landfill mining and sorting the manmade ground. Ill: Worksonland.

A combination of landscape measures was proposed for the Kjørbekk project (Fig. 90). Below is a description of the process, starting from the outlet to the Skien River. Landfill mining is used close to the Skien River, as the landfill might be in constant contact with the Skien River and the groundwater (A). Built structures have left few alternative ways to reach the river than through this point. The second step (B) shows excavations where the masses are handled and sorted. The next step is analysing the pollution and sorting the masses according to the pollution type. The masses with contamination levels deemed acceptable are moved to the old landfill Kjørbekk II, where they are treated on site and controlled over time.

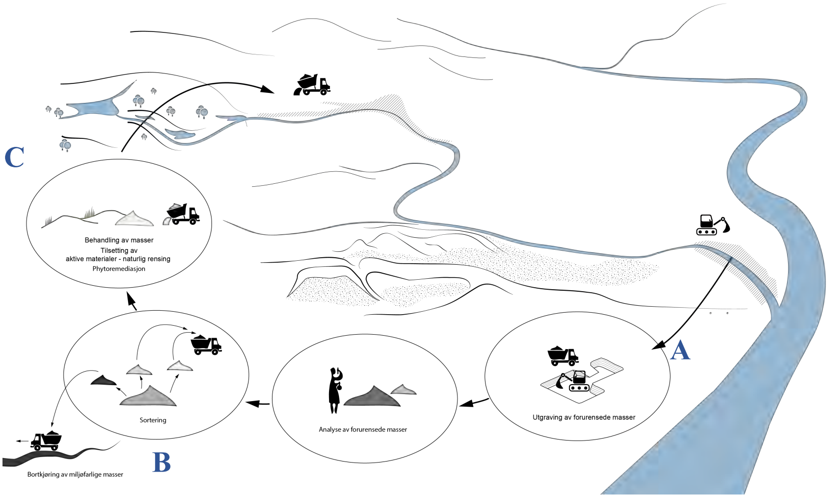

Figure 90: Working process for handling the manmade ground. From landfill mining of the landfill close to the riverbank (A) to analysis and sorting of the waste (B). Heavily polluted ground is handled separately at a waste disposal facility while the rest is reused on site at the level of the old, closed landfill (C). Ill: Worksonland.

4.3 THE MANMADE UNDERGROUND AS A VECTOR FOR URBAN PLANNING

The manmade ground needs to guide where to build or not, where water can be infiltrated or not, and to define where ground needs to be recovered to improve water qualities in our running waters, what uses are appropriate for the type of ground conditions found, and how these can vary when the properties of the ground change over time. In the design case, there are buildings that have been built on top of old waste dumps. The low price of the terrain containing landfill might even have prompted the development there. Building permits were granted for industrial and logistic programmes. Today, however, there is a challenge in that the city is growing, and the building functions are changing as the area evolves. In the case of Kjørbekk, one of the plots on top of the old landfill in the industrial area has become the site of a public school. While specific technical solutions for the landfill context were employed for the construction, the sinking terrain might still weaken the construction and piped systems, leading to disconnection from the infrastructural supply system.

The design case is an example in which the manmade ground has not been considered in long-term planning and where health can be affected. Infrastructural installations are inaccessible, in the ground under the built environment, and when maintenance is needed, it is complicated and costly.

The manmade ground affects planning in both positive and negative ways. When the manmade ground is known and integrated into the planning, it can become part of the transformation project and elaborated and planned for over time. A negative effect, however, is e.g., when the manmade ground as underground infrastructure does not allow the intended planning and dictates how the landscape at the surface will be designed. The location for planting trees on a street is an example where the design might be conditioned by the below-grade manmade landscape and its infrastructural installation instead of the lived and experienced landscape at the surface.

Figure 91: The conversion of internal to external drainage entails interventions to the existing buildings. Ill: Author.

Causes of underground change

There are a variety of reasons for inertia and resistance to change when transitioning from an underground run-off system to a surface system. First, other disciplines pay little attention to SWM systems when they are located underground, but once guided in a continuous system on the surface of the landscape, these systems compete with other uses. Second, there is the challenge related to an administrative structure that corresponds to the old functioning system. When changing from an underground to an aboveground system, responsibilities and maintenance activities, as well as costs, must be redefined. Third, key for open stormwater management is the cascading system, where retaining water high up in the watershed or on roof tops helps slow down the runoff. The complexity increases however when going from single project interventions to redesigning entire established systems; one is a defined project site, and the other, a variety of daylighting project interventions stretching over kilometres that should collect water from the whole sub-watershed and at the same time collect the rainwater from a myriad of pipes on already built underground networks. A fourth reason for a slow transformation is the interrelation with other systems, such as the logic of the architectonical solutions of each building. For example, some of the buildings with flat roofs have internal drains leading to the underground pipes and will require new roof geometries that can conduct rainwater to the outside of the building; at present, a challenge to the solution of rebuilding the roofs is that public investments are not permitted on private properties in Norway. Once the water is led to the exterior of the building, the water can flow into an open solution, be retained locally and further connected to the surface system of the neighbouring plot in order to gradually become a new surface system. Local retention ponds must be created before the whole new SWM system on the surface is put into place; if these fill up before a continuous system has been installed at the surface, drainage to the old pipe system will be necessary.

This research also addresses the question of a systems transition between below- and above grade for physical and spatial structures. The following section provides an overview of the leverage points of transformation and discusses its transitional phases.

Designing the transition phasing

Given the complexity of the transition to a new SWM system for the sub-watershed, a conversion phase design is a necessity. The design case showed that a double functioning system is needed during the transition phase from a subterranean- to a surface system. Both systems must be in place until the open water system is completely established and the roof inclination of buildings that previously drained in the centre of the building has been adjusted in such a way that all buildings can drain on the outside and connect to the new surface system.

The diagrams below show how the transition can be realised by separating it into independent phases. Each part aims to slow down the runoff water, decreasing the pressure on the existing underground system until the whole surface system is realised. The design of the phasing is key in enabling complex large-scale projects, with all their inherent uncertainties.

The design case of Kjørbekk highlights the transformation process over time, rather than an isolated project to be executed. A strategic plan that defined a clear idea whilst permitting a flexible process, adaptable in time and form, was thus vital (Martinez Hidalgo et al. 2019).

Figure 92: Project proposition from 2016 including water management for the whole sub-watershed. Plan: Celia Martinez Hidalgo.

1. Introduce forest-based measures 2. Local retention areas 3. Local retention system 4. Restore sand quarry

5. Work with tributary creek and paths 6. Remove toxins 7. Reduce flow velocity 8. Connect to surface water

Figure 93: Overview of the order of actions for the different interventions to achieve surface water management. Diag: Author.

Area	Measure	Attention	Actors	Condition
1.	A/ Removing of landfill B/ Water filtration and vegetation C/Create acess to the river		Skien municipality	1/2
2.	A/ Nenset sand quarry restauration B/ Educational area C/Removing of landfill	Species threatened by extin-tion whose habitat is the sand quarry: diptera and wasps. Rare speies of Epipactis atrorubens (Rødflangre)	Nenset sandtak - NorStone AS High school Skogmo	1/A, 2C
3.	A/ Reallocation of creek and establishment of path B/ Creation of water-thresholds C/ Establishment of floodplain forest D/ Establishment of water channel E/ Establishment of meadow	Potential for more rare species	Private OBS	
4.	A/ Reconnecting the creek B/Area for masses to be reelaborated on site			
5.	A/ Landscape measures of water velocity reduction in the forested ares			

Figure 94: Table showing measures, interdependencies, actors and aspects of special attention. Diag: Author.

Realising large-scale system changes may prove challenging, as such projects depend on a variety of factors. Separating the project into various, feasible parts that together become a total stormwater management has been important. Timing is a crucial issue as some interventions must be performed before others, and some might be dependent on private actors and require scheduling. Funding is also a central issue, and it is frequently easier to handle if a project has been subdivided into feasible and more manageable parts for the city administration.

On the planning level, creating a surface water management system for the entire sub-watershed was presented as a base for all future regulations and building permits. This was done to assure that even if realising the project took time, it would not be challenged by a planning that does not take the future open water system into account.

First steps were taken to reduce the volume of water in the creek during heavy rainfalls in order to facilitate the creation of a system before the whole floodway was established; this corresponded to independent landscape measures in the forested area (Fig. 93.1). Such measures can be implemented from the beginning, when conflicts of interests are few and the economic investment relatively modest. Local retention areas for water in the form of a dam were then proposed (Fig. 93.2). This retention dam would later become part of the larger project (Fig. 93.3). During the construction period, the dam retained the water during events of heavy rain, thus offloading the system. When the limit has been reached, the overflow is conducted into the pipe system until the new surface system is established. Once the sand quarry has been closed, the restoration will incorporate one kilometre of the new floodway as part of its project (Fig. 93.4).

A reestablishment of a tributary creek and connection to an existing path system was then proposed. The tributary connection passes through private ground and is dependent on the timing of the plot's development (Fig. 93.5). Polluted ground masses that come into contact with the water are removed (Fig. 93.6), and non-toxic masses are reused within the project site. Opening the watercourse and floodway with water steps is used to reduce water velocity (Fig. 93.7). Once the floodway is established, the creek Kjørbekk is connected to the surface system (Fig. 93.8).

The design case showed that with a good overview of various ongoing interventions, multiple projects can be executed at the same time; this may be an efficient way of reducing costs for each intervention. The surface needed per intervention can also be reduced via design for multifunctionality. In terms of resources, the 'cut and fill' balance is also central in a project that extends for several kilometres. In general, the masses are remodelled on site, but also here the cooperation between various ongoing projects – such as nearby infrastructural projects – may facilitate a local soil balance (Okkenhaug et al. 2019). The excessive masses of one project can be paired with the deficits of another. This is feasible in a municipality in which communication is good and information about ongoing projects is shared.

Planning and juridical frameworks impact how change happens

Planning and juridical frameworks are significant for facilitating the transition to open stormwater management. At present, the municipal administrative system separates above- and underground management; funding follows the same division. In terms of urban planning, definition of the visible landscape is generally also prioritised more highly than definition of the underground. There are also legal differences between above- and underground planning.

In 2015, the government whitepaper found that the Norwegian law does not define stormwater, and there was no overall legislation about it. The topic was spread over various laws and codes, mostly in relation to regulating the effects of stormwater on various activities and whether economic sectors are negatively affected by stormwater (NOU 2015).[75]

With a creek-opening project such as Kjørbekk, where the aim is to move from a subterranean system to the surface of the landscape, it is important that the juridical setting facilitates the transition. One present challenge for stormwater management, for example, is that runoff water is classified as sewage water. While this can perhaps be explained by practices of the past and runoff water being considered dirty when passing through urbanised areas, all stormwater is now classified as sewage water, even if it flows through woodlands or gardens. There is thus a contradiction between the classification of waters at present, the urgent need to avoid overloading sewage systems, and the principles of handling the water directly in the open landscape. An open SWM system often comprises different parts above- and underground. When the open water system crosses road systems, it often needs to be guided under roads in a constructed pipe. Its legal status then changes from an open creek following the laws of 'The Water Resources Act';[76] when it is conducted through a pipe, it follows the law of 'The Pollution Act'. The classification has implications for responsibilities. According to the Pollution Act,[77] the owner of a piped stretch of the river is responsible for damages that occur if the pipes has not been sufficiently maintained or have insufficient capacity (Taubøll 2022: 104). Present juridical framework can limit new, innovative solutions; i.e., new types of solutions to improve the situation might be held back if an actor is held responsible for the change, regardless of whether the intention was to improve the situation. This may reduce the creative potential of a project.

Working with both public and private land to create a whole stormwater management system is a necessity. This is also challenging with the present legal system, where public investments on private ground are not permitted in Norway. To facilitate the creation of a continuous stormwater system at the surface, its status as a common good must be clarified and prioritised.

Furthermore, juridical definitions need to incorporate the fluidity of an element such as water, where the 'area of control', differs from the 'area of influence', and the 'area of effect' is outside the initial site that the intervention has impacted (Kahn & Burns, 2021). This is relevant both for water and landfills with its pollution. Professor of law Steinar Taubøll[78] has remarked that when approving a building site, one must not only assess the safety of the site in

[75] The Water Resource Act aims to maintain balance in the hydrological cycle and prevent flooding and inundation. Preventing water from running into its natural watercourse is prohibited. Interventions to watercourses that may reduce their capacity, including blocking or channelling them, or that may have negative consequences in the event of heavy precipitation, are prohibited. Any intervention that can lead to considerable damage or inconvenience to common interests is not permitted. Changes in the waterway thus require authorisation from the national watercourse authorities.

[76] Vannressursloven.

[77] Lov om vern mot forurensninger og om avfall (Forurensingsloven).

[78] Steinar Taubøll is a professor at the department of Property and Law at the Norwegian University of Life Science (NMBU).

question, but one must also assess whether construction at the site might increase natural hazards for other sites ‘land exposed to danger or significant inconvenience as a result of measures’ (Taubøll 2022: pbl. § 28-1). This is relevant when it comes to stormwater, as there is often an imminent possibility that new development will increase the risk of flooding downstream. The ground conditions can also be changed by the presence of water, for example, when water is extracted from the ground or prevented from infiltrating. However, the lack of surveillance of the underground over time is a challenge to the possibility of detecting gradual changes and their causes.

In countries dependent on groundwater for drinking water and cultivation, authorities may monitor changing groundwater levels more closely than in Norway. According to Norwegian law however, use of groundwater should not exceed its capacity to be refilled (Norwegian Water Resources Act §44). The right to groundwater belongs to the landowner above it, if no other circumstances have been defined. If there are multiple owners, they collectively share the right and obligations respective to their percentage of ownership (§44). This is the case regardless of the precise underground location of the greater freshwater reserves within the area of concern.

In relation to the ground, many countries around the world still apply laws according to a ‘first-come, first-served’ principle, or what is known in a legal context as ‘first-in-time-first-in-right’ (Tengborg and Sturk 2016). This means that the first to exploit the underground often does so to optimise profits at the cost of more holistic strategic decisions and fair distribution of resources (Volchko et al. 2020). As an example, it is currently not necessary to acquire permission to drill geothermal wells in Norway, but one is required to inform the municipality afterward. This is an obstacle for a holistic planning of the underground where projects above- and below grade are planned in relation to each other, as a perforated ground of installations can complicate future infrastructural underground projects.

Main findings from the design case

In the design case, the transition from an underground system where stormwater flows through pipes to an open surface system in the landscape reveals two systems divided by the grade of the ground. Planning for above- and below ground must be simultaneous to facilitate projects that transition between them. Enabling the transition requires thinking with the landscape’s depth. A design including both the present system that is anchored underground as well as the design of the visible and desired new watercourse embeded in the above landscape. The design process has continuously oscillated between above- and below grade and led to the ‘deep landscape’ approach.

Above- and below grade belong to different municipality administrative units. The water and sewage department deal with the underground piped systems, and the park department is responsible when water is managed in the open landscape, as well as for its maintenance over time. These entities have different budget systems, different maintenance bodies, and different juridical- and urban planning settings. Simultaneous planning of the surface and the subterranean would make it possible to take the effects and interferences of an action on both into account, rather than decisions for one grade inadvertently being made at the cost of the other and its future possibilities.

The design case shows a spatial condition shared by above- and below grade and an interest in removing practical obstacles that arise from their disconnection. Situated in a suburban area where the underground installations were made before today's urban expansion was integrated in the planning resulted in an incoherent relationship between the infrastructure underground and the urban development at the surface.

Water and ground:
The design case has shown that water and ground are inextricably interrelated when the landscape is used as infrastructure. An expanded view of the landscape, including the dynamics between water and ground – both the initial properties and the reworked, manmade ground – is thus a necessity. This was significant for enabling more predictable urban development and for understanding the effects when water's presence changes due to urban interventions or climate effects. Urban hydrology focuses on the surface of the landscape and might include the underground network of pipes, but generally, little consideration is given to the physical context of the underground, i.e., its physical composition and groundwater levels. The case study indicates that a supplementary reading of the landscape's depth should be considered in urban hydrology in Norway.

Water, ground and visualisation:
The case study shows a lack of documentation about the manmade ground, and visualisation is the first step to enabling its design. 'Guess maps' with accessible data were made during the design phase, and different methods of visualising the urban underground will be developed to permit the ground and groundwater to be included in planning. Norwegian municipal planning currently relies heavily on 2D plans in SOSI-files[79] of the territory and less on sectional and volumetrical representations.

Water and manmade ground:
The research has shown that expansion of the Norwegian three-step principle of stormwater management is not appropriate for places with manmade grounds. Developing this model would facilitate the transmission of knowledge and critical thinking about how the site itself needs to inform the types of principles that are suitable and what new principles are needed. The manmade ground of the landfill shows a historical lack of care for the ground

[79] The SOSI-system is equivalent to the GIS system.

as its own entity with inherent qualities. The resulting ground has become an archive of various processes; it has been used for disposal, and once the waste was covered with new soil, it was 'out of mind'.

The design case showed the need for landscape measures for improved stormwater management at old, closed landfills to tackle the challenge of preventing interaction between water and polluted ground. To avoid contact between water and landfills, a combination of landscape measures (topography and landshaping) and technical measures (of land mining) should be explored as possible tools for addressing the dynamic complexities of manmade grounds that are not appropriate for infiltration. This would be of importance for humans and our fresh water sources, as well as for other species.

The design case has demonstrated that valuable lessons can be learned from other disused landfills. Smaller municipalities and practitioners may find it difficult to find time in their daily work to develop new principles, and collaborations with researchers and greater administrative entities would facilitate further development. It would be highly valuable to establish networks and create common systems for gathering knowledge about manmade grounds and landscape measures that work, and about how to handle them in the context of urban uses. There is a long timeframe for observation and evaluation of maintenance of landfills over time. With this in mind, collaboration between municipalities, researchers and other bodies is key to advancing empirical knowledge.[80]

Water, ground and urbanism:
The design case is a systems change, and inertia was revealed in the transition from an underground stormwater management system to a surface stormwater management system. This is due in part to insufficient knowledge about the underground composition, as well as different administrative entities, juridical differentiation, and diverse design cultures above- and below grade. There is thus a need to enable joint planning of what is above- and below ground. This would facilitate future transformation projects in areas with inherent ground constraints. Underground urbanism is complicated when the underground conditions are not known, and mapping them is a first step. The second step could be to plan ahead with an underground masterplan that takes into account future projects. The third could be to integrate the underground plan with the surface plan, as the underground installations condition the aboveground design.

Water and vegetation:
Trees have the capacity to take up water and to create porous ground through their roots that can lead water into the ground and retain it. The roots of the vegetation also provide a certain 'armature' for the ground, holding on to it and

[80] A network can also facilitate the reuse of masses within a municipality; where e.g., masses from larger infrastructural projects can be masses that are abundant in other projects.

preventing soil erosion. The case study showed that the contemporary urban hydrological calculation used in the design case did not consider vegetation as a factor. To develop this, the hydrological quantitative calculations are to be further developed to incorporate elements with fluctuating values.

Water and cold climate:
The design case has shown that little consideration has been given to specific cold climate conditions in Norway in relation to accommodating stormwater and finding good urban design solutions for the winter. This becomes more central with longer periods of temperatures hovering around 0°C with frozen grounds. To date, little has changed in the street design in relation to cities with temperate climates. Even through snow and ice are not permanent states, design and planning must take them into consideration to ensure universal accessibility.

In conclusion, the design case has shown that there is a need for a framework that facilitates joint handling of what is above- and below-grade. In general, new design processes and tools are needed. The research strives to narrow the gap by outlining alternative approaches. These are presented in more detail in the next chapter.

5. Research Contributions

This chapter outlines the main contributions of this thesis, discusses their significance and relationship to other research, considers the limitations of the work, and offers suggestions for future research.

This research highlights the increasingly important role of the human-modified ground and its implications for design and planning as we undertake more urban and post-industrial transformation projects. The thesis provides new terminology that allows greater attention to the relationship between urban development and manmade ground conditions.[81] The conceptual term 'deep landscape' provides discursive understandings as a starting point for a more profound design method in practice.

Ground conditions have been a guiding factor for urbanism in the past, and water has been central to urbanism (Shannon et al. 2008). This thesis, however, focuses on the interrelation and dynamic relationship between water, ground and its manmade challenges. This relationship entails a non-stable situation that should be considered in urbanism. It gives a different reading of the boundaries of the context and conditions in which urban transformation projects are situated. Most freshwater is found underground; infiltration and the holding of water occur below grade, and a great part of the ground's chemical conditions are also related to subterranean conditions; this suggests the need for a reading of the water context that goes from a horizontal, territorial, multiscalar reading to an additional vertical reading and thus adds depth to the territory.

The first contribution of this research is through its emphasis on the landscape's depth with the term 'deep landscape', which highlights the

[81] The interrelation of water and ground and their changing properties influences urbanism. Cities dependent on groundwater reserves for fresh water may suffer due to ground subsidence if this water is pumped up and the volume of water is extracted from the ground. An example in Oslo is impermeabilisation of the ground's surface, which changes the groundwater presence. When the groundwater table sinks, cracks in constructions and facades ensue. Many older buildings in Oslo have wooden raft foundations that are exposed to oxygen when the groundwater is gone. As a result, they rot, which destabilises the construction (Article 1).

importance of considering the continual processes of change in the ground when designing in landscape architecture and urbanism.

The second contribution concerns below-grade informed planning and includes a description of different relationships to the manmade underground in urban planning. Here, a descriptive and analytic method is introduced that identifies previously overlooked relationships between water and ground to contribute to practice and theory.

The third contribution is 'landscape measures' developed to prevent contact between polluted ground and stormwater. This furthers practical method development of below-grade design strategies and is applicable when a project is situated on manmade landscape conditions.

The fourth contribution is the supplementation of the Norwegian three-step stormwater management principle with human-modified ground as a factor to facilitate the complete integration of water and ground (including manmade ground) in planning (Fig. 95).

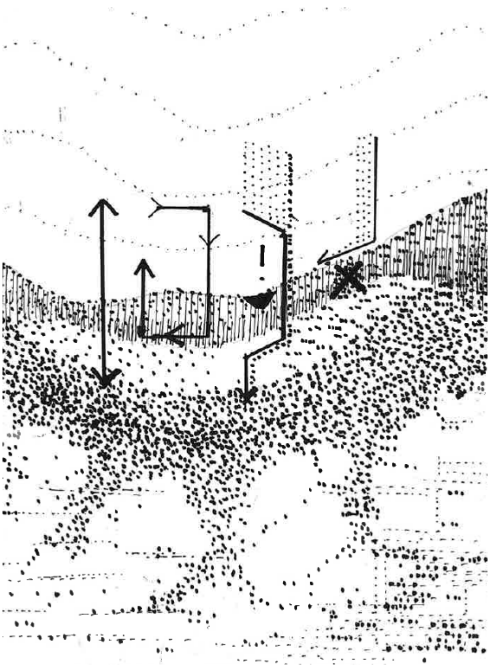

Figure 95: Illustration showing the contributions' relationship to the deep landscape. From left to right: 'Deep landscape as a concept bridging the above- and below ground landscape. The second contribution concerns below-grade informed planning, while the third contribution 'landscape measures' is preventing contact between polluted ground and stormwater. Furthermore, the fourth contribution supplements the Norwegian three-step stormwater management principle related to polluted ground. Ill: Author.

5.1 THE DEEP LANDSCAPE

This section explains the contribution of the deep landscape as a term, a concept, and a design strategy. Thinking through the lens of this term has contributed with below-grade informed planning, new landscape measures for improved SWM, and the expansion of the Norwegian three-step SWM principle, explained in greater detail in this chapter. A shared feature of these contributions is that they include the forgotten underground and propose adapted design principles in which the neglected underground is incorporated. I present the deep landscape as a concept that raises awareness of the urban underground landscape with its processes of change over time, adding the notion of greater depths and volumes of different entities that reflect the underground landscape and its continual transformations.

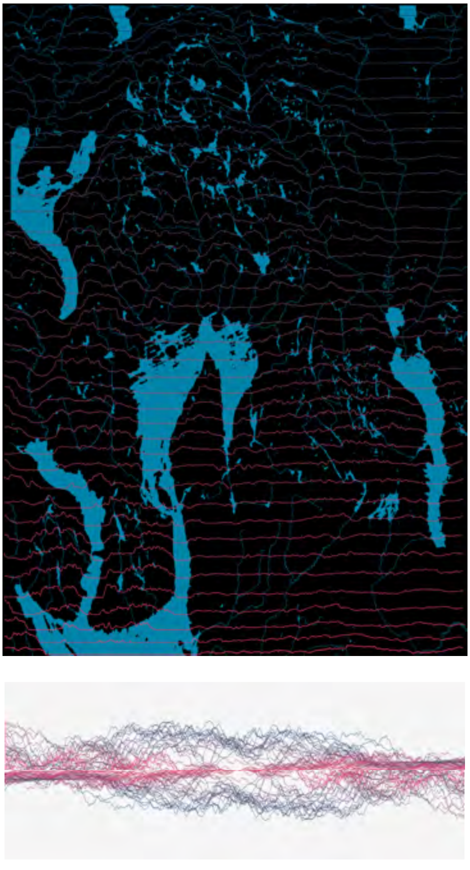

Figure 96: Above: Plan and sequential sections of the great Oslo territory. Below sections of this territory reflected by its imaginary continuum in the below-grade landscape. Ill: Author based on GIS information from Norge Digital.

An expanded view of the landscape

The *landscape* in 'deep landscape' relates to the description of that landscape as everything under the sky. The term 'deep' underlines this landscape's inseparable underground continuum.

'Landscape' includes everything that a landscape is defined by[82] and hosts above grade as well as its manmade ground and geological strata, mineral properties, soft and hard consistencies of rocks and sediments, living organisms such as fungi, microorganisms and bacteria, which are biological processes that continuously re-elaborate and transform the ground; water as humidity, rills, underground watercourses and groundwaters, the roots of trees, the air, and human remains. It is not used as merely a section and a representative fragment, but as an idea of its range and interconnectedness with the landscape above, underground compositions, changing properties and slow movements. This reflects the German word for landscape (*Land-schaft*) and the making and reshaping of the land – the human interaction with the ground (Antrop 2013).

In Norway, notions of the landscape in planning documents are mainly defined by landforms and water, vegetation, land use and development, the cultural history in the landscape, cultural references, and spatial-aesthetic conditions (e.g. *Veileder i metode for landskapsanalyse i kommuneplan* 2011). The landforms primarily refer to the visual landscape and the topographical forms that geology presents. Municipal planners' site analysis considers the visual composition, sight lines, connections, landmarks, usages, accessibility and biodiversity. In this context, the landscape is often reduced to the visual and accessible.

The European Landscape Convention (Florence 2000) states: 'landscape is part of the land, as perceived by local people or visitors, which evolves through time as a result of being acted upon by natural forces and human beings'. This perspective presents the landscape as an observed entity being transformed by natural forces (wind, water, ice, plate tectonics, etc.) and humans. It is a human-centred approach that emphasises the 'perceived landscape', where other species and the nonvisible underground are implicitly included in its description.

The term deep landscape has the potential to open up questions about what is beyond the visible; it entails a rethinking of the spatial limits of a project. The emphasis on *landscape* in 'deep landscape' underlines the direct relationship between the lived landscape above ground and its ground conditions. The visible landscape is predominantly the starting point for planning and projects. Adding the notion of *deep* opens for reflection on the connections to the visible

[82] It is formed by its abiotic (climate, geology, geomorphology, hydrology, pedology), biotic (vegetation, fauna, living organism) and anthropical context.

lived landscape. The concept aims to link the landscape and its depth in all vertical dimensions.[83]

Adjectives have been added to the word landscape in the past – natural, cultural, rural, urban landscapes are some examples (Antrop 2013). The adjective deep is connected to the landscape's physical, cultural and chronological aspects. The noun 'landscape' emphasises the relationship to our lived everyday lives and how that in extension affects our surroundings, where new landscapes are created in relation to our lifestyles. Adding the adjective 'deep' proposes an expansion of the landscape reading from where we stand to a context that goes beyond its first appearance.

The 'deep' in deep landscape is a real and associative term. It is spatial and physical when defining depth. The actual depth refers to the operational depth of the underground composition, a space available, for example, for below-grade percolation, absorption, etc. It is also an associative term for imaginative dimensions. This section first discusses the landscape's physical depth and then comments on the deep landscape as an imaginative term.

'Deep' as a physical depth

The deep landscape does not stop at the perceived visual landscape; it also incorporates its physical depth. The case study reveals the importance of the different geological compositions of the area of intervention as well as the manmade underground and its relationship to the lived landscape throughout the entire development of the daylighting project. The rainwater transitions from the sky to the above landscape and infiltrates into the ground, and water management is translocated from under to above grade.

Physical depth is created by processes. Often, such changes are not perceptible to us within a human lifetime. Doreen Massey reminds us, however, that we are in the midst of these ongoing processes: 'Even the mountains move', she remarks in her book For Space (2004). What appears stable is in movement and even if this movement is slow, it has a significant effect. Geology is in constant transformation and is therefore inevitably attached to the present. In a Norwegian context, the isostasy[84] is present as land rise. It is a relatively slow process, with a few millimetres of change annually. However, it is relevant in relation to climate change effects and sea level rise. Southeastern Norway for example is currently seeing land rise from the last Ice Age. At present, these two effects are mutually neutralising. On the western coast of Norway however, only the sea level is rising, and is thus a greater threat there. The isostasy also creates effects of horizontal movements, and the rebound from the former glaciers that existed in the fjord valleys can today trigger rockfalls.

[83] The vertical dimension reaches both downwards into the underground and 'deep geomorphic structures' as well as upwards to include climatic layerings and biotic processes; i.e., it encompasses above- and below grade.

[84] 'Isostatic depression: Large-scale down-warping of the crust in response to an increase in mass (weight) on the surface in areas of continental glaciation. Isostatic rebound: The uplift of the earth´s crust […] from large-scale depression' […] (Marsh and Dozier, 1981: 611)

Professor in hydrology Nils Roar Sælthun underlines water's role in the landscape's transformation. He argues that: ‘Water in liquid and solid form is the ultimate landscape architect. In the large scale of time and space, the earth is continuously changed by the competing forces of tectonics, water and wind. It is only in the later part of the Holocene that humans have had an increasing impact on the landscape’ (Sælthun, 2021: 86). Understanding the logics of interaction between the water and ground of a territory is key for landscapes with hazards and challenges of flooding and drought. In the Norwegian setting, even the natural initial ground conditions with quick clay, alum shale, avalanches and rockfalls can be challenging when triggered into movement by water. It is thus vital that the design includes how water is handled and guided to slow down or accelerate processes of change. In relation to manmade grounds, their composition and the underlying initial ground condition[85] are central in the decision for a design approach.

However, depending on the geology, it might not be enough to read the watershed by the surface topography. The visual landscape does not always indicate how the water will flow and where it will end up. There may be a significant difference between the ground’s topographical watershed at the surface of the landscape and its real watershed (Fig. 97). When hydrologists speak of the ‘topographical watershed’, they only refer to the shape of the visible landscape. When they speak of the ‘real watershed’, the depth of the ground is included. The dynamics of the real watershed depend on the composition of the ground. If impermeable ground is covered by permeable ground, the watershed will not necessarily correspond to the line topographically defining the watershed at the surface, but find a new guiding topography underground.

[85] Leachate water might drain through and stay under a landfill or seep further down to the groundwater through sand, porous rock formations or faultlines.

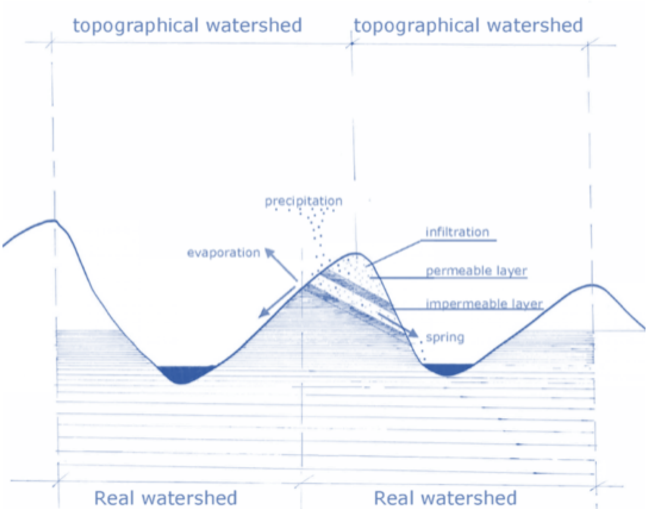

Figure 97: Difference between the real watershed and the topographical watershed. If the terrain below the surface line is manmade, containing e.g. pipes for stormwater management, it also creates a different runoff pattern than what the surface indicates with its topographic inclinations. Ill: Author based on ill. by Musy & Favre, 2001.

The real watershed is particularly important in karstic areas where there are various underground cavities and a relatively impermeable rock composition. This composition does not provide an even underground water level, but rather guides water through the underground cavities, the geometries and inclinations of which are defined by geological creation and transformation processes over time.

In the design case, the hanging groundwaters are a challenge to predictability in the project. Also elsewhere, the manmade ground with pipe systems, underground drainage and culverts also creates other inclinations and relations under the ground than those on the surface (Tjallingii 2012).[86] Hence, knowledge of the physical depth of the underground composition, both initial and manmade, is critical for a foreseeable design of the future water's presence and how the ground properties will change with the design intervention.

Urban transformation often occurs on ground with a history of prior construction. This is no surprise: humans reorganise an estimated 57,000 million tonnes of ground annually, three times more than what the world’s rivers transport in sediment per year (Price 2011). This means that recent decades’ construction activity, mining, dredging, and waste deposition have transformed the earth’s surface to such an extent that it has its own geological

[86] If rainwater is drained into the underground from the street, however, there may be great seasonal variations in its capacities. In the autumn, manholes may be obstructed by leaves, and in the winter, they are often clogged by snow and ice.

entity, developed in the time of the Anthropocene (Crutzen and Stoermer 2000), and it is thus essential to consider in future development.

My use of the term deep expands on Spirn's concept of deep structures (Spirn, 1993). She distinguishes between deep structures (defined by geomorphic, climatic and biotic processes) and surface structures (natural and human-modified). The manmade ground has reached such complexity that it can steer the development of the visible and lived landscape as well as affecting the deep structures, defined by Spirn, with its own force.

The scale of geology and its formation in deep time differs significantly from that of the heterogeneous and mutable composition of the manmade ground. A number of human-made geologies were created inadvertently, composed of waste accumulated over time. The composition of the manmade ground is primarily non-visible, and the exact magnitude and location of elements are rarely directly observable.

Archaeologist Matthew Edgeworth coined the term 'archaeosphere' (2014)[87] for this human-modified geological layer on the earth's surface. The archaeosphere '[…] was first laid down in small isolated patches, but as human population increased, these patches have steadily and exponentially grown in extent, frequency and thickness...' (2014: 105). The existence of the archaeosphere relates to human culture and knowledge and reflects humans' relationship with the environment.[88] It is becoming a composition of manmade geology on its own, an urban world 'made geologic' (Hirmer, 2013).

Edgeworth defines the archaeosphere with its lower limit as 'Boundary A', the oldest 'surviving physical trace of human modification of the environment at a particular location', a base of archaeological stratigraphy (2014). The deep landscape includes the manmade ground and goes beyond boundary A while considering an environmental perspective of the manmade ground and its effects on the surroundings.

The design case of Kjørbekk reveals a landfill with a depth of up to 15 metres and a thin top-layer of soil that is eroding. If stormwater runs through the landfill, it washes the leachate water out and can have environmental effects on both the above landscape of fauna and vegetation as well as deeper aquifers. The comparative case study of the landfill of Garraf corresponds to a depth of approximately 80 metres and illustrates the manmade ground's influence on the underlying geology and waters. The Garraf landfill is positioned on top of a karstic ground, which implies a need to consider the depth of the landscape

[87] As defined by Matthew Edgeworth, the archaeosphere '[…] is still in the process of formation, and therefore inherently incomplete' (2014: 105). The upper boundary is open and in constant change and 'future formations of the deposit are partly contingent upon present human decisions and actions, including those of the scientific and academic community.' (Edgeworth 2014: 106).

[88] This gives insight into our long-term footprint and that what might seem efficient and time-saving in the short term may create problems in a long-term perspective; landfills are one example.

in relation to water that percolate through the landfill. Through water, manmade ground interacts with the deep geological structures and deeper aquifers' water qualities.

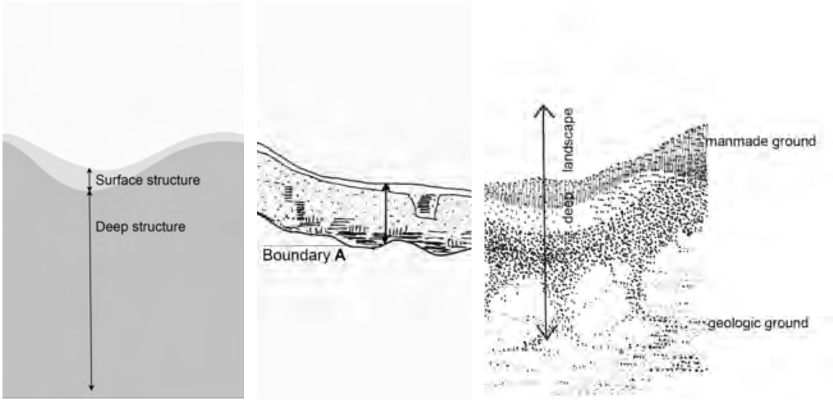

Figure 98: Ill. left: Spirn defines the ground as composed of the surface structure (light grey) and the deep structure (dark grey). Ill. middle: Illustration showing the humanly modified ground defined by archaeologist Matthew Edgeworth as the volume between the 'Boundary A' and the surface. Ill. right: Showing the 'deep landscape' that bridges the above- and below landscape, including the manmade ground. Ill: Author.

The 'deep landscape' emphasises the concept of the manmade ground as an own geological entity with a depth of its own created in the Anthropocene. Its composition relates to human history and each era's relations to the environment. The manmade ground is directly related to the deep structures through processes of change. Hence, it is not only informed and conditioned by the deep structures but also interacts upon them. Both through direct physical changes and indirectly through the effects of global climate change with the impact of changed water presence. Deep landscape includes the above landscape, the manmade ground and the deep structures. Between these, there is a constant interaction, through the media, like water and gas.

The definition of the deep landscape goes beyond the boundary A[89] and the surface structure in depth and unites the manmade ground with the underlying deep structures (Spirn, 1993) that it affects. Moreover, 'deep landscape' outlines the landscape through the processes and effects that emerge from the manmade changes. At a global scale, the effects of manmade climate change do not stay local and bound to a boundary. They are not attached to a local physical intervention but are noticeable through the omnipresent climatic

[89] The boundary A, signify 'the soil horizon between 'natural' subsoils below and anthropogenic deposits above, marking the first surviving trace of human impact on the landscape at this location' (Edgeworth, 2014:95).

change of temperatures and water presence that acts upon the depth of the landscape and changes its properties.

When I use the term deep, I am referring to geological creation and the human-modified ground that archives traces of human activity, not as separate elements but with a consideration of the interaction between them and the above landscape (Fig. 99). This manmade physical depth is increasing in complexity over time and needs to become part of the vertical definition of a site. A deep landscape approach indicates that we need to think deeper and include to the landscape interpretation the manmade ground, the deep structures and their interrelation to inform our design and planning of the landscape above grade.

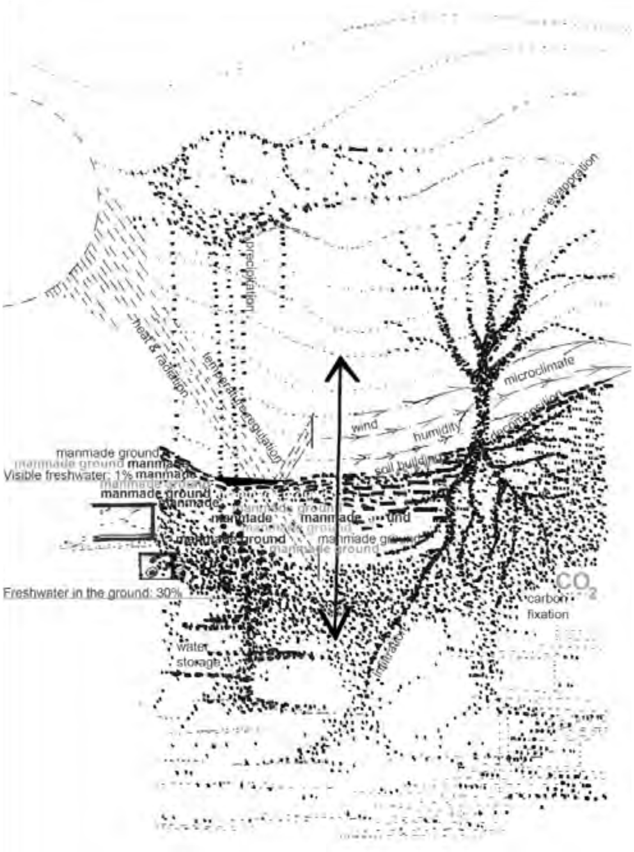

Figure 99: Illustration showing the processes that bridge the above- and below grade landscape. Water processes, infiltration, evaporation, temperature regulation, carbon fixation, decomposition and soil building. The vertical dimension reaches both downwards into the manmade underground and 'deep geomorphic structures' as well as upwards to include climatic layerings and biotic processes; i.e., it encompasses above- and below grade. Ill: Author.

‘Deep’ as an unmeasurable and imaginative term

Deep refers to ‘deep time’, a geological concept first defined by the Scottish geologist James Hutton in the 1700s and reintroduced by John McPhee in his book Basin and Range (1981). ‘Deep time’ extends back to the creation of the geological context. Understanding time dimensions is challenging and detaches from human existence and geological and planetary phenomena. Deep time is so far in the past that it largely goes beyond ‘mortal time’. The term deep landscape acknowledges the unknown depth not by precise definition but as unmeasurable and including its existance. When merging humanistic reading with science, it helps to go from science to sense and make incomprehensible and untouchable time apprehensible. Scientists seldom draw out what they do not know, and the content of the deep landscape thus risks exclusion if it is not approximated with a 'best guess' definition. The term deep helps to include the unmeasurable without need for detailed definitions.

The invisibility of the below grade stimulates the imagination. When we do not have access to all the information on the underground, we must use the imaginary, combine what is known with what is most probable and create a complete picture of what is at hand. Depicting what is not yet formed in our minds is demanding, however, setting evidence must be conveyed in planning. The invisible challenges our imagination and when things are out of our sight, the story must be told and translated in an illustrative way. Comprehensive maps of the manmade underground will not be available within the near future; thus, introduced at an early stage of planning or project development, the term ‘deep landscape’ can prompt questions and responses that facilitate imagination of the depths and dynamics of the ground, adding a phase of informed conjuncture that constructs a greater understanding of the context’s depth. This urgent demand might prompt additional registrations and more charting in order to facilitate maps containing more knowledge and less speculation, which would in turn render project development and planning more predictable.

Deep also refers to the non-physical depth of the landscape and its immaterial relationships to culture and time. A number of disciplines use the term thickness to refer to the non-physical dimension of culture as part of space. Anthropologist Clifford Geertz includes the social-cultural relationship to space via what he calls ‘thick mapping’, which describes how the space is used as well as why, and what it means to use a space in a certain way. Professor in landscape architecture Thaïsa Way argues for thickness in the reading of a site by incorporating the various memories that the site reveals (Way 2021). She argues that conventional ways of describing a site draw primarily on what can be seen and thus registered and described. ‘While useful, it sustains a limited view of what landscape architecture, as a way of thinking, might offer urban research’ (Ibid: 215). These readings of the thickness of a site refer to its invisible relationships. In the case of manmade ground, thickness reflects our relationship to the environment indirectly in that we have used it with or without being conscious of the effects. There are numerous historical examples; dumping grounds for instance were commonly used on the outskirts of cities. The ground left behind is an archive of each generation's relationship with its environment.

A deep time imagination of the future in planning and design can provide us with more insights. Professor of landscape architecture Ian Thompson argues that our present capacity to project imaginaries of the future is fundamental. Without imaginaries of the future, 'We would not be able to see possibilities, and that would mean that we had no freedom of choice' (Thompson 2019: 279). The designer's capacity to project imaginaries (Thompson 2019) relates the project to the future. Depending on design choices, a project will affect the near- or the deep future. If the deep structures are changed, the deep future landscape will be affected.

The term 'deep' can provide a reflection of what a long-term impact on the environment implies. Modifications made to the deep time structure will not be rectifiable by humans in our lifetimes;[90] the manmade ground produced in the Anthropocene will also become a remain of a deep future. 'Deep landscape' provides an association to the imaginary in time, invisible space and values. Without it, we continue to ignore what cannot be recognised and physically touched.

5.2 A DESIGN METHOD: ACCOUNTING FOR SPATIAL AND TEMPORAL CHANGE

The term and concept deep landscape has implications for the landscape architecture, architecture and urban planning practices. The notion of the deep landscape includes the ground, its fresh and dirty water, manmade ground and soil compositions, pollution, and the infrastructure of cables and pipes, and it emphasises the relationship between the visual landscape and the underground. In landscape architecture, the underground, with its geology and soil composition, has long since been considered part of the project, as it conditions where living species can and cannot thrive. In urbanism, however, the relationship to the ground has been more static. A deeper landscape thinking that encompasses the processes of change of the landscape is thus essential.

The deep landscape goes beyond 'below-grade planning', defining how the underground is read and informs the planning above, as well as the mutual impact that above-ground planning and the underground have on one another over time. The term deep landscape prompts awareness and a perception that

[90] The use of nuclear energy also relates us to the notion of deep futures. In the publication 'Making the Geologic Now' (2013), Jamie Kruse reflects on the effects of nuclear power on the present and future in the chapter 'Power of Configuration: When infrastructure goes off the rails'. He cites Tim Morton in 'Zero Landscapes in the Time of Hyperobjects': 'The design we must do in an age of hyperobjects will inevitably take them into account, because we can't unthink our knowledge of them. This means that design must account for thousand, ten thousand, and hundred thousand year timescales. It must account for Plutonium 239, which remains dangerously radioactive for 24 100 years.'(2013: 221)

the visible landscape is mirrored and continues as a non-visible landscape, and that the two are deeply interdependent.

A design method driven by deep landscape thinking

A "deep landscape" approach to design reads the properties of the ground and thereafter proposes a design adapted to its conditions and desired ground transformations. A deep landscape design method in complex urban settings has an ever-changing design perspective that oscillates between above- and underground in order to design with both, to balance and improve their interrelations. Water is in constant movement (as is the soil, which is composed of living organisms that continually transform and remodel the ground). This demands an expanded way of thinking of a site, where time and desired successive changes become more important parts of projection and planning. Deep landscape thinking includes living organisms and time. This can best be illustrated by a tree as a living species that links above- and below grade. Its roots are dependent on underground planning, and it has spatial effects both below and above the ground.

The physical depth contains a complexity of the human-modified ground that broadens the field of concerns for landscape architecture and various other disciplines that describe and work with it. The physical composition of ground, groundwater, installations, living species and sometimes pollution demands increased interdisciplinarity and a reconsideration of site limits. Andrea Kahn and Carol Burns distinguish between three areas - area of control, area of influence and area of impact (2021). The perimeter of impact (e.g. in stormwater management, carbon sequestration and pollution) may extend beyond the site limits, both horizontally and vertically in the site's 'depth'. The area of influence should thus be more clearly reflected in urbanism.

Due to its 'invisibility', the description of the ground as an integrative landscape is important for its incorporation in future projects. The imaginary depth has implications for project development. In relation to physical depth, the description of the deep landscape demands an investigation of the often-disparate elements that compose the above- and underground, as well as planning of their interaction. Above- and underground cannot be separated in a landscape project design. Urban planning must integrate the underground and its installations strategically as an important common good, maintaining them over time to perform for future generations. Because it takes times to recover the manmade ground via natural processes, the ground with its soils must become part of urban planning. The imaginary is part of the deep landscape project, both in its unknown physical composition and in the conception of its future.

Additional design research to further the theoretical dimension will be carried out on landscape architectural projects and urban transformation projects, adding vertical thinking that can follow the water's paths, read the manmade grounds and the soils and integrate them into the project with the aim of planning for the built environment as well as for the water and ground of the future.

Deep Landscape:

a term	a concept	a design strategy / method
term = 'a word or expression that has a precise meaning in some uses or is peculiar to a science, art, profession, or subject'	a concept = 'an abstract or generic idea generalized from particular instances'	strategy= 'a careful plan or method'
The term "deep landscape" refers to an expanded physical and imaginary view of the landscape. It is a term that brings awareness to an otherwise overlooked relationship.	*The concept of "deep landscape" is a way of perceiving, thinking and working with the landscape that goes beyond the visual surface and includes the landscape's ground , depth and processes of change.*	*A "deep landscape" approach to design reads the properties of the ground and thereafter proposes a design adapted to its conditions and desired ground transformations.* *-A 'deep landscape' design method has an ever-changing design perspective that oscillates between the surface and the underground in order to design with both and to balance and improve their interrelations.* *-Due to its 'invisibility', the description of the ground as an integrative landscape is important for its incorporation in future projects.* *-The imaginative is part of the project, both in relation to its unknown physical composition as well as the conception of its future.*

Figure 100: Table summarising 'deep landscape' as a term, a concept and a design strategy. Table: Author.

The significance of a deep landscape approach

The term 'deep landscape' refers to an expanded physical and imaginary view of the landscape. It is a term that brings awareness to an otherwise overlooked relationship. The concept deep landscape incorporates the invisible and the dynamics of the ground. It demands an expanded understanding of landscape, including what is not directly visible, such as the underground. The concept urges landscape architects and planners to include it, even if the information is scarce and fragmented. A deep landscape approach is significant for design as only what is defined in the design process can be used in design.

A greater sensibility to the landscape's underlying structures is significant to encourage more sustainable planning approaches. This is key from an environmental point of view with a sustainable use of the land. This entails the question of which ground interventions and built environment correspond to which types of ground. A planned intervention is thus evaluated in relation to the ground properties. If suitable, the site can be constructed and the built environment adapted to the specific ground condition.

It is significant that the design strategy includes the properties of the ground and is adapted to the site's specific conditions. This means that landfills and polluted grounds inform the urban development. This later becomes significant in terms of economic sustainability, as challenging manmade ground conditions do not need to be overcompensated with technical solutions for the built environment but can be recovered over time.

Planning for the reclamation of land with challenging ground conditions is paramount in order to avoid future greenfield developments and secure good water quality. This is significantly facilitated by more concise mapping of the manmade ground with challenging or unforeseen ground conditions, such as older infrastructural installations of pipes, bunkers and tunnels. The absence of concise mapping may put a project budget at risk. It is also important that new installations are built in correlation to a long-term vision of the underground in order for present investment to be valid in the future. From a social and health perspective the care for the land and its ground and waters creates a more equal, just and healthy living environment.

5.3 JOINT PLANNING OF ABOVE- AND BELOW THE GROUND

The following section presents different planning relationships between the above- and underground. The first of these are Ildefonso Cerdá and Jean-Charles Adolphe Alphand's ideas about the underground in the 19th century, which were formulated in a time of industrialisation and massive urban growth in major European cities. Cerdá and Alphand both foresaw street sections that involved infrastructures both above- and below the ground; a planned form of urbanisation that incorporated underground installations as a public good under the public street, regardless of initial low density, and were designed with future growth in mind. This is a planning projected from above and downwards – an **underground-dependent planning**.

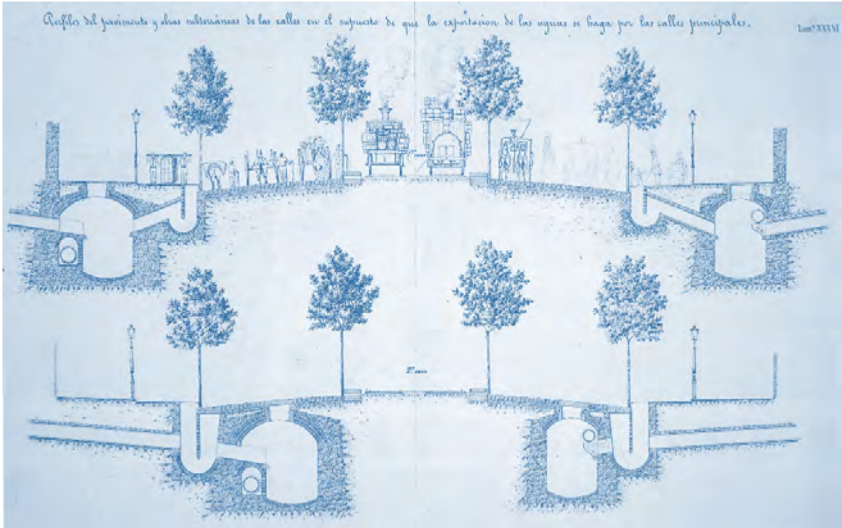

Figure 101: Ildefonso Cerdá's historical definition of the street (vía) section for Barcelona with planning for infrastructure above- and underground. Sect: Cerdá et al., 2018.

The design case shows a second type of planning that stands in contrast; an **underground-independent planning** in which the surface and the underground are planned separately. In this practice, the underground infrastructure follows the shortest route between installation points rather than using streets and mobility networks as infrastructural corridors. Such planning can be found in low-density, peri-urban areas, where the underground installations were not planned with future urban transformation and changes of uses on the surface in mind.

A third type of planning of which the design case became an example is **below-grade-informed planning**. In the design case, it was revealed that there was a need to change regulation planning and create new, safe paths for water in relation to what was originally defined in the existing planning documents. Hence, what was found underground informed the planning. The underground masterplan of Helsinki is an example of a below-grade informed planning. The urban plan from 1911 by the town planning architect Bertel Jung already shows how the planning with green structure adapts to the underground conditions and guides where to build and not. The built environment is found on the bedrock, and the peat fields are used for large open spaces such as parks.

A fourth planning approach is to acknowledge challenging ground conditions without adapting the planning to them; instead, technical building solutions are selected to compensate for the challenges of the ground. An example of this **technical ground-approach** is found in the recent development in the Oslo Harbour, Bjørvika (Fig. 19).

The demanding ground conditions in Bjørvika entailed a need for more than a thousand steel core pillars encased in concrete to anchor the street and some of the built environment to the bedrock as compensation. This is an expensive solution with a large underground environmental footprint. In addition, the solution conditions what can be constructed underground in the future (e.g., new tunnels). As the area is Oslo's main infrastructural hub however, it is highly probable that the need for underground infrastructural construction will arise in the future.

From underground urbanism to a joint planning of above- and underground

French architect Edouard Utudjian argued for the need to develop the underground according to predetermined plans in the 1930s. He saw that spatial expansions were being made underground, such as transportation systems, underground parking systems, underground infrastructures and architecture, but that they were not coordinated, and he thus proposed an Underground Urbanism. Various efforts have since been made to make underground urbanism possible. Other architects have focused on the void of the underground. Architect Rosina Vinyes presented maps of Barcelona's underground architecture in her thesis, entitled 'Hidden Barcelona: The relevance of the underground in a large contemporary city' (2015). While access to an overview of what has already been built underground is an important step to enable future underground planning, few cities worldwide have developed an underground master plan. One of the first was Helsinki. According to the City of Helsinki, the plan, which was updated in 2021, will be used to manage the planning of infrastructure and tunnels underneath the urban development (Vähäaho 2014). The strategy for infrastructure is based, inter alia, on the structure of the ground and the depth to the bedrock. The underground is viewed as an entity of finite resources that demands good planning.

Currently in Norway, geotechnology research groups focus primarily on the technical aspects of the underground. The underground built environment of water, energy and underground constructions follows a 'first-come first-served' logic, which makes it difficult to prioritise, make strategic decisions, and share resources fairly (Volchko et al. 2020). This research underlines the need for urbanism that elaborates and plans the above- and underground simultaneously (Fig. 102).

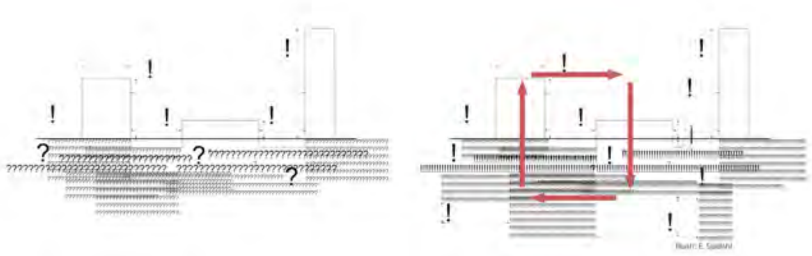

Figure 102: The illustration to the left shows a planning approach with a very well-defined aboveground landscape and, separately, the landscape below the ground with various unknown elements. To the right is a planning approach in which there is mutual, planned interdependency and definition above- and below the ground. Diag: Author.

Design 'for, into and through' the ground

Frayling's design definitions of research *for, into and through* art and design may offer a parallel reading to the relationship between design and ground (see the methodology chapter of this thesis for more on Frayling):

1. Design *for* the ground: research is conducted to gather information that can inform and guide design interventions that relate to the ground.

2. Design *into* the ground: observation and description of the design process from other projects that deal with challenging ground conditions. The objective is to evolve and merge the methodologies for joint design of the above- and underground to one.

3. Design *through* the ground can be related to the action of design with the landscape, including its depth and ongoing processes. The proposed projective changes to the properties of the ground are part of the project and the planning.

Design *for* and *into* the ground are used extensively in landscape architecture. Design *for* the ground corresponds to observing and analysing site specificities that inform a project. Design *into* the ground corresponds to land-forming as an important spatial transformation of the landscape, whilst design *through* the ground corresponds to the change of properties of the ground through the proposed project. The last approach becomes more central when underground challenges increase in complexity. Static information on the ground's condition is insufficient for informing a project's development and implementation. A plan for recovering and rebuilding of the urban soil is also necessary. Time is a key factor for all the ground's processes, such as phytoremediation and the rebuilding of soil with organic matter, etc. The organisation of these time factors connects the processes to the field of planning. Thus urbanism informed by 'designing *through* the ground' incorporates the processes of recovery of human-modified ground and its soil.

The significance of planning above- and underground simultaneously

Urban planning has worked to define legislation and drawings of the visible landscape but has defined little or nothing about the subsoil. Taking the underground into account will become more critical as time passes. Planning will encounter more complex ground conditions for a number of reasons. One significant reason is that the easily-built land areas are already built and the EU objectives for 2050 'Zero-Land-Take' entail that no new areas shall be developed, but that land will instead be reused with all its inherent constraints (Decoville and Schneider 2016). As threats to biodiversity are concerned (IPBES 2019), change in land use is one of the most significant causes of species extinction, making it necessary to re-use urban brownfield land instead of taking new land. Urbanisation on agricultural land is also a threat to soil and food security (Marmo 2012). Thus, future constructions will largely be on manmade ground and unearth some of our old, buried sins.

Considering the challenges of the manmade ground, it is not enough to circumvent the problem and inform what will be positioned on the surface of the landscape; actively planning for its recovery over time is key.

Conscious management of the ground and its soils can also enhance its capacity to capture and store carbon, create a ground-recovering of manmade ground, and become a habitat for a variety of species. Landscape architect Kate Orff offers a perspective on other projects dealing with the ground. Her work incorporates the large-scale dynamics of the ground, for example the 'mud-management project' in the San Francisco Bay Area in which the sediments of mud are used as an ecological infrastructure, connected through system thinking across scales and actors. AgenceTer also projects with the soil, which is seen as the fundament of nature in the city.

Deep landscape thinking considers basic technical infrastructure such as underground installations. The urban manmade ground is less elaborated, however, and still predominantly seen as the exception found on site rather than as part of the project. This is more important still as budget overruns are frequently the result of unforeseen ground conditions and unknown technical installations.

The manmade installations are basic supply infrastructure for inhabitants' health and well-being, as well as major investments. Solid knowledge of the ground composition and a strategic plan for its future are key.

If the underground and its installations are not planned in conjunction with future projects, the underground conditions will eventually become a steering factor in what can be obtained in future projects both above- and below the ground. Further, designing with the depth of the landscape is significant for the future handling of fresh water. By starting to define both quantitively and qualitatively awareness of groundwater can help securing basic resources for water supply.

Designing the underground is, after all, a challenging task that requires new approaches and tools. It is not merely a question of additional complexity during the project phase, but concerns fundamental initial conditions and planning for the recovery of the ground. Hence, the re-use of land, densification, climate adaption, open stormwater management, and biodiversity enhancement will all need to be jointly planned, and the subterranean and the surface landscape simultaneously considered.

5.4 LANDSCAPE MEASURES FOR IMPROVED SWM AT DISUSED LANDFILLS

Landfills have been used all over the world, and one might thus expect there to be a wealth of knowledge and approaches related to preventing water and polluted ground from interacting, yet landfill expertise has remained the concern of a relatively small group of professionals.[91] Experiences are collected by the entities that handle waste, but this knowledge has yet to be translated into practicable understandings and measures across disciplines, as it largely directly concerns the health of people who live close to landfills, or indirectly concerns the quality of the groundwater that we consume.

Figure 103: Illustration of the imagined Kjørbekk landfill with the piped creek in the bottom of the former riverbed. Ill: Worksonland.

[91] In the design case, the department of water and sewage did not use a specific design for pipe drainage that prevents gas from being transported from the landfills and out into the general supply system.

Landscape measures for improved stormwater management at disused landfills

Low maintenance over time was an important planning concern in the design case. Typically, disused landfills are only supervised at the start – in Norway, for a period of 30 years – and their environmental impact is meant to be stable over time. This is one reason why the environmental mitigation and protection principles are based on 'low-tech' approaches that mainly use landscape modelling that remains stable over time. Several cases of disused landfills in the Oslo region have shown that synthetic membranes are not sufficiently durable to separate watercourses from landfills;[92] settling ground creates tensions and the membranes rupture after only a few years. The technical solution in which water passes over the landfill with the use of membranes was evaluted during the design phase and subsequently avoided for this reason. The principles developed diverted the water higher in the watershed and guided the freshwater around the landfill, modelling the terrain locally to lead the water away by rounding the terrain into concave forms or terracing it to avoid a runoff velocity that would erode the covering layers of the landfill. To avoid an overload of water on the landfills, dams can be introduced to collect the water upstream, outside the landfill, and sever interaction with the landfill. Dams can also be placed downstream, after the landfill, to permit sedimentation and various stages of purification and control of the water quality.

The significance of improved stormwater management at disused landfills

Old landfills are often found close to closed rivers, as dump masses were used to level the concave riverbeds in preparation for agriculture or urban development.[93] There are at least 2000 disused landfills in Norway; this indicates that developing design knowledge of how to handle SW in these conditions is key to providing good freshwater quality and attaining the goals of the Water Directive. Norway currently lacks the capacity to receive the waste from all old dumping areas in special treatment facilities, and moving the landfills also entails various risks, for example potentially harming workers' health, as well as inadvertently facilitating or accelerating the spread of pollutants. Moving dumps is complex, and developing methods that can

[92] According to S. Sidselrud in EBY, Oslo municipality, 'There are major challenges associated with using a membrane to draw water over landfill in open ditches, as the unstable and varied composition of the landfill creates ground conditions that give rise to subsidence. Experience from using the membrane shows that after five years it is no longer suitable for liquids, since the movement of the ground and breaks in the membrane' (M-1405|2019).

[93] Water quality researchers K. Haarstad and T. Mæhlum (NIBIO) have published research on leachate from municipal solid waste landfills in Norway and its evolution over time. Research from 2008 that includes a decade of sampling showed that all samples tested for 12 pesticides 'exceeded the maximum limit values for the sum concentration of pesticides in drinking water, and six compounds exceeded the environmental toxicity limit' (2008). In co-publications with H Knutsen et al. from 2019, they emphasise that 'To prevent landfills from contributing to future PFAS emissions, proper management strategies are key, such as developing low-cost leachate treatment facilities, including PFAS in leachate monitoring, better understanding of leaching mechanisms from waste...' (H Knutsen et al. 2019: 1970). In relation to this, the reduced quantity of SW that percolates through the landfill and risks spreading toxins also facilitates management of the leachate.

handle water from the landfills on site is thus essential for reducing the present spread of pollution and controlling its effects on fresh water.

5.5 EXPANSION OF THE NORWEGIAN PRINCIPLE OF STORMWATER MANAGEMENT

For a holistic SWM, it is desirable to include the full water cycle in the planning: to follow water throughout its entire path in order to incorporate it and its underground movements into the design. The design case has shown the need for a supplementary reading of the landscape's depth to be considered in urban hydrology. At present, urban hydrology in Norway mainly focuses on the surface of the landscape which sometimes include the underground network of pipes, but generally little consideration is given to the physical context of the underground; i.e., its physical composition and groundwater levels. However, during extreme events when the groundwater level becomes saturated, infiltration is not possible and flooding can occur rapidly in areas where this does not normally occur.[94]

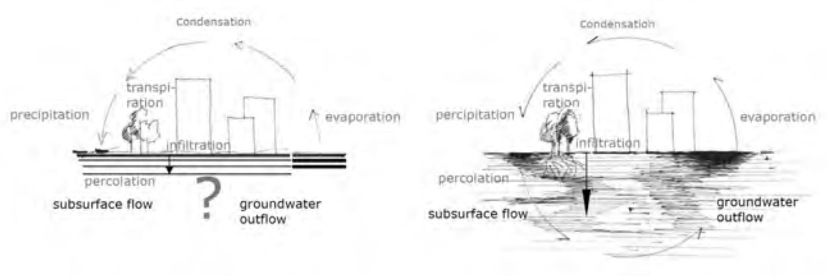

Figure 104: Illustration of the water cycle. To the left is the urban version, with a conceptual border separating above- and below grade and a focus on the surface. Urban hydrology mainly focuses on this with its quantitative elements of water on the surface and in the primary underground installations. To the right, a water cycle that includes the underground and its ground conditions, groundwaters and subsurface flows. Ill: Author.

Contemporary SWM practice in Norway is based on the three-step principle of urban hydrology and mainly focuses on the surface of the landscape. However, consideration of the underground and its infiltration capacity is significant, not least because of the increasing complexity of reused manmade ground in urban contexts. Some of these terrains have been rendered toxic by past uses and should not come in contact with rainwater, as that may lead to the spread of pollutants and groundwater contamination. Therefore, the general recommendations in Norway for stormwater – catch and infiltrate, delay and

[94] Experiences from the flooding in Västerås, Sweden in 2023, where flood streams were created in a very short time as the ground was saturated, and the later rains caused flood streams to grow rapidly. Risk engineer Johan Ahlström, Västerås Municipality.

retain – are not desirable measures on polluted grounds. This research contributes to current Norwegian SWM principles by introducing the manmade ground and outlining principles of where NOT to infiltrate.

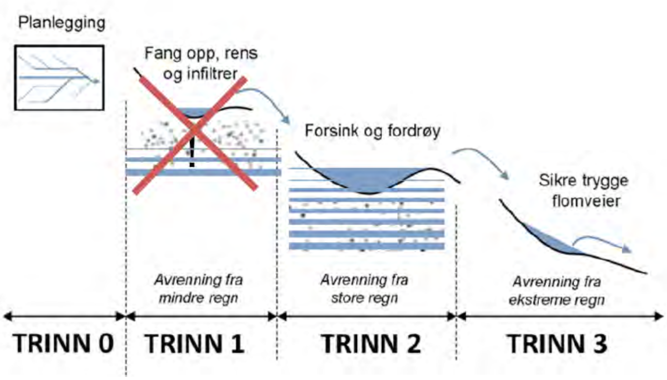

Figure 105: The three-step principle (Lindholm, 2008, with addition of step 0 by Kim Paus). Diagram in which manmade ground is included indicating that the ground is not always suitable for infiltration. Diagram modified by the Author and presented at the Climate Change Conference in Oslo 2018.

A broader perspective on SWM that includes complex underground conditions

In Article 1, it is shown the main tendencies in the discourse on stormwater management in Norway in recent decades. As early as 1975, Oddvar Lindholm suggested infiltrating more rainwater into the ground instead of using the combined sewage system. He developed the Norwegian three-step principle for SWM: 1) catch and infiltrate, 2) delay and retain, and 3) create secure floodways (2008). Hydrologist Kim Paus added step zero to the Norwegian principles; this corresponds to planning, which is the central part of water urbanism (2008). My research takes into consideration the ground conditions and shows how ground composition can complement the present stormwater model.

Working with the groundwater is essential for maintaining the freshwater supply to avoid drought, create climatic stability, and keep the ground moist for cultivation, conserving the ground's properties and living species. The freshwater reserves can be refilled during rainfall by slowing down the water as it runs through the landscape. This can be done by orienting it towards subterranean aquifers, or by retaining the water when the underground layers permit infiltration.[95]

[95] In the 12th century, the Sri Lankan king Parakramabahu I proclaimed: 'Let not a single drop of water fall on the hill and flow into the sea without it having served the people'.

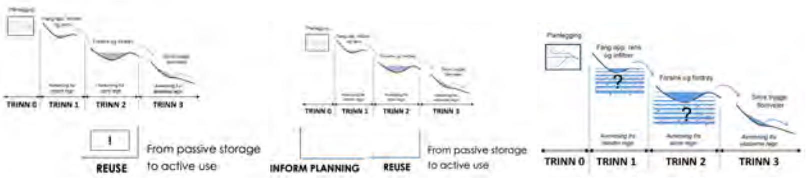

Figure 106: From a linear to a circular use of rainwater. Diag: Author 2017. Diagram presented at the Climate Change Conference in Oslo in 2018 (Diagrams left and middle). The diagram on the far right represents the ground and groundwaters. Diag: Author.

The significance of developing the Norwegian SWM principles

More conscious rainwater management is of global significance as temperatures rise and precipitation patterns change and irregular events grow more frequent, entailing periods of drought and heavy rainfall (IPPC 2022; Leten, 2023). The stormwater management principles have been widely adopted in professional practices in both public and private sectors. The proposed changes are thus significant for the foundation on which ongoing projects will be carried out in Norway. Reassessing the spread of contaminants via circulating groundwater is key and would help Norway achieve the goals of the Water Directive: to provide good or fair water qualities in all terrestrial water bodies.

Norway has historically been a water-rich country, where relatively little effort has been required to maintain a constant water supply. However, recent summers have seen longer periods without rain, and even tendencies of drought (summer 2018, early summer 2023). Therefore it is significant that more attention is given to the limitations of the idea of linear rainwater management. The model needs to be supplemented with holding the water in the landscape, not only for stormwater management and the reduction of flooding, but also as solution for local use and water security.

Water is changeable, crossing borders and redefining boundaries in the landscape. In Norway, the introduction of water regions based on watersheds is meant to facilitate planning that is more coherent with water dynamics. A second step is to incorporate watershed planning more directly into municipal planning. Even if interventions related to water occur on small and defined project sites, they affect the water downstream. The logic that the implications are broader than the site limits when handling water also entails that it might prove easier to perform interventions on properties located upstream to reduce flooding downstream. This involves significant rethinking of the spatial limits of a project and how interchanges of services could be effectuated.

It is important to expand Norwegian planning to territorial (water region) scales and at subterranean depths in order to meet the future challenges of climate change. This was demonstrated in 2023, when the extreme event 'Hans' provoked flooding in residential areas as well as landslides. The Norwegian landscape contains challenging ground conditions with quick clay, rockfalls and landslides and demands planning that includes the subterranean depths and how they are affected by the changed precipitation patterns.

The stormwater management suggested in this thesis expands on the Norwegian principles in place (Lindholm 2008; Paus 2018) in order to build on an approach that is already being applied in practice. Greater complexity related to urbanism can be found in the work of Kelly Shannon (2006) and Paola Viganò (2008). Yet there is a difference between these approaches and what I suggest when it comes to the application and adaptation of stormwater management principles in relation to manmade ground. These findings are supported by numerous scholars who have studied challenges to urban areas related to their ground conditions (Denizen 2019; Volchko et al. 2020).

5.6 LIMITATIONS AND POTENTIALS OF THE RESEARCH

A limitation in the design research has been the lack of comprehensive data on the underground. However, this has also revealed the present shortcomings in the handling of information about the ground's recent history.

The complex handling of the polluted ground in the design case and prevention of the spread of pollutants has been a major focus overriding other aspects of the research such as further investigations on the elaboration capacity of the living soils. Here, there is potential for research on how to recover and build up the soil and how different types of soils can hold water and change the water qualities, as well as investigations into its capacities for carbon storage.[96]

This thesis elaborates 'deep landscape' as a concept that arose after the design case, as a conclusion of where the inherent constraints are located in an urban transformation project dealing with terrain reuse. The contribution of this research is not an answer that may be applied in all design cases. The case study focuses on the southeast of Norway, and the insights gained in the design research are not directly transferable, as they correspond to specific local conditions in the landscape and their legal and economic contexts. It is, however, a reminder of what is important to consider in projects that deal with terrains with intrinsic constraints. The term deep landscape is inherently abstract as a reminder and an idea, without a direct physical and concrete existence, as this will be analysed and conceived in future cases. However, the deep landscape concept has been relevant in other ongoing research conducted parallel to the writing of this exegesis that deals with natural hazards such as

[96] Soil contains almost twice as much carbon as the atmosphere, living flora, and animals combined.

quick clay, avalanches, flooding, erosion, drought and rockfalls. There, the deep landscape concept facilitates an awareness of the processes enabled by water and ground and includes them in design.

5.7 FURTHER RESEARCH

Work on the design case revealed a need for further research to develop theory, methodology and practice, as shall be presented below. The term deep landscape is a result of 'synthetic thinking' related to the design case during the writing of this exegesis, and it will be tested further in future projects. Additional design research to further the theoretical dimension will be carried out on landscape architectural projects and urban transformation projects, adding vertical thinking that can follow the water's paths, read the manmade grounds and the soils and integrate them into the project with the aim of planning for the built environment as well as for the water and ground of the future.[97] Further theoretical and practical research should be conducted on how to integrate more of the deep landscape approach into contemporary urbanism to plan for the mutual interdependencies that link the underground and the landscape's visible layer and open up for a more long-term, resilient planning.

Blue-green infrastructure is a mainstay of urban stormwater management. Water and ground concerns are already found in the project of the muddy river of Olmstead mentioned earlier. The unearthing of the rivers incorporates the earth as an element, as eroded particles in the river and as manmade ground that cover piped rivers (sometimes in the form of manmade landfills).
However, the notion of blue-green infrastructure could be taken further in theory and practice by considering the depth of the landscape and its function as a blue-green and *brown*[98] soil infrastructure, relating to the ground and its capacity to store water, and the building up of its soils, carbon storage, as well as the need to consider and prevent land from erosion. The concept of blue-green infrastructure would benefit if supplemented with a brown infrastructure indicating the significance of its depth for its performance.

Further methodological investigations that relate theory to practice would be valuable. The design case revealed inertia in the change from an underground system to an open-air system (Fig. 107). Therefore, additional research on transitional design methods of systems that account for all project phases, from start to finish, is a necessity. This entails shifting focus from the initial and final visions for the project to all its transitional phases, which are vital for its realisation.

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[97] Integrating more of the underground to handle contemporary climate challenges will be necessary for the future. Freshwater infiltrates into and rehydrates the ground, it fills up aquifers and is purified or contaminated in the ground. The ground is vital, hosting fertile soils that contain living organisms and vegetation; it is where carbon is stored and bound, and where underground resources are carefully managed or spoiled. The ground is fundamental for our food security.
[98] Brown relates to the fertile and living soil and is in contrast to anthropogenic brownfields.

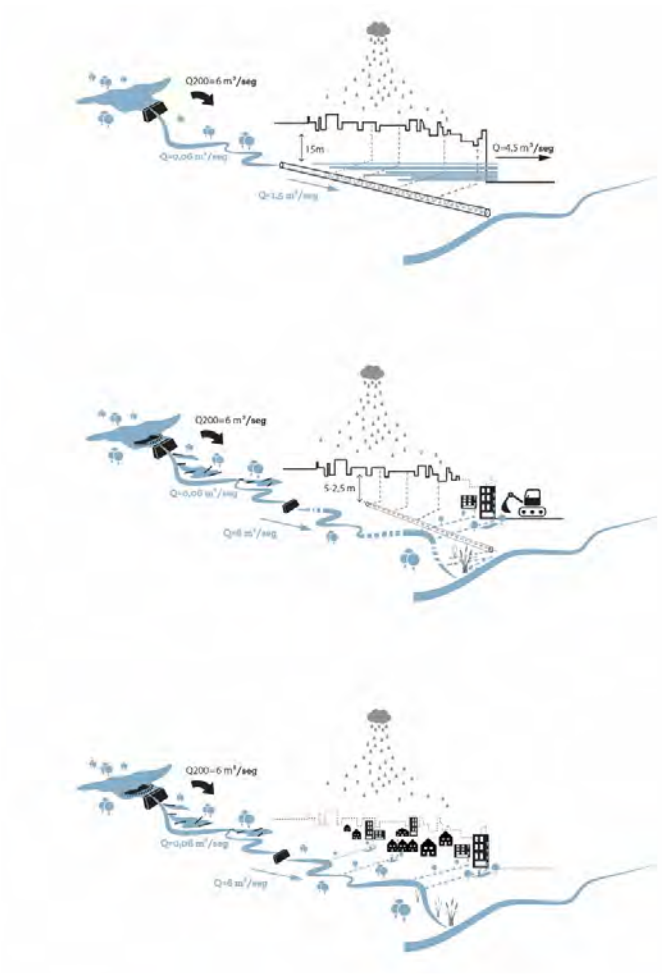

Figure 107: The design case was redefined from a 'project design' to a system change in which the transition phase required its own design due to its complexity. Ill: Celia Martinez Hidalgo.

Norwegian urbanism relies heavily on maps and plans. Taking into consideration its pronounced topography and complex ground conditions (with quick clay, rockfall hazards, landslides, etc.) as well as manmade grounds, it would help to develop more methods that rely on volume and sectional thinking that includes the landscape's depth both above as well as under the ground.[99] To facilitate the joint planning of above- and below ground, further

[99] At present, the sectional representation includes above all questions of visual perceptions, accessibility between the built environment and terrain, and stormwater management.

research is also needed to determine current juridical and administrative obstacles and investigate possible improvements thereof.

Further development of design tools as general principles of stormwater management is a critical matter. This research has contributed with landscape measures to handle stormwater in relation to polluted ground. Other principles are to be developed, however, that adapt general principles of stormwater developed internationally and nationally to local conditions. New stormwater management principles are needed for challenging ground conditions, both naturally occurring, e.g., quick clay, and those that are a result of human modifications such as pollution and landfills. The research lines suggested are as follows: additional principles related to polluted grounds; specific principles for cold climates; how to expand the hydrological cycle to include the underground; how stormwater can promote biodiversity and include vegetation[100] in the principles; and further research on transitioning from linear to more circular water use in areas where water is scarce.

Further investigation into landscape measures that support ground recovery work would facilitate the work of landscape architects. Recovering polluted ground is a slow process, and more research is valuable for transferring knowledge between projects in order to expedite and expand the transfer of knowledge on how different ground masses with light pollution can be incorporated into designed projects, and how different processes and landscape approaches can help bind pollutants.

A rising use of Nature Based Solutions (NBS) with vegetation creates a need for more knowledge on the purification capacities and alternative techniques for cold climates. A definition of the NBS limits of handling manmade toxic ground would provide a good guidance for design. Further development of dynamic engineering calculations that incorporate living species of vegetation for water management and erosion control would also be desirable.

In order to deepen the concept and method of deep landscape, landscapes will be represented with the component parts of their depth.[101] The design case demonstrates that managers of the underground have a fragmented view of the

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[100] Besides the capacity of each different species, how they are planted in relation to terrain should be considered in order to slow runoff water and reduce the effects of erosion. Further research should be carried out on species and plant combinations that are suitable in relation to stormwater management in a cold climate, as well as their capacity to purify water from polluted grounds.

[101] Different archives are maintained by different public and private entities, and changes made over time are not registered in their entirety. 'Guess maps' with the most probable picture of the underground landscape must frequently be made at the beginning of a project. This is time-consuming, and the information is incomplete at best, leading to increased costs and delays later in the building phase. The first step would be creating a holistic system and format, allowing municipalities to gather all information, including permits, construction or any digging project data on the ground into a single, coherent, comprehensive picture of the underground. Civil constructions, technical installations, ground properties at present, etc., would be included. Further investigations should be conducted on how the legal framework can evolve to more actively encompass simultaneous planning of above- and underground.

manmade underground, including its composition and how it is defined in depth. A complete integration of the urban underground into city administration- and urbanism practice would make future urban transformation projects more predictable. Further research on relevant data that reflects the underground composition, the assemblage and visualisation of this data, and the dissemination of accumulated learnings over time would be valuable in facilitating this. Here, the following further research lines are suggested: visualisation; tools and methods that expand the landscape's depth; investigation of the application of new technologies involving 3D-scanning of the ground, and global monitoring of groundwater levels. Including the underground in planning change and organising and reassembling the pieces of information into new, complete pictures will make it easier and more predictable to incorporate the missing half of the landscape into design work.

6. Conclusion from Surface to a Deeper Landscape

INCORPORATING THE OTHER HALF OF THE LANDSCAPE IN URBANISM

This exegesis shows that landscape has depth, and that taking that depth into account in planning is a necessity. Landscape interventions on the surface affect the underground as much as they are conditioned by it. To bridge the division between the landscape above- and underground, this thesis looked closer at the interrelation between the ground and water and the modification thereof in relation to urbanisation. The design case analysis of a daylighting stormwater management project has shown that the transition from a below-grade to an above-grade system demands that the conversion phase itself is designed, and that the landscapes above and below the ground are perceived as one.

In an era when terrain reuse is an increasingly greater concern, actively integrating the underground into planning is more important than ever. Recycling sites is key to minimising greenfield development, securing biodiversity, and creating food security. The ground is also where organic matter is created, and where carbon is captured and stored, and it is the habitat of many species.

When rebuilding on previously urbanised land, the installations accumulated over time entail increased complexity. Urbanisation changes both the ground and water, creating new conditions for the urban setting. On a larger scale, urbanisation modifies the ground, for example when impermeabilisation prevents the groundwaters from filling up, or when freshwater extraction changes the groundwater levels, which can cause the ground to subside. Now more than ever, manmade ground needs to become part of future urban projects.

I propose the term 'deep landscape' to emphasise the connection between the above- and below grade landscape, and to promote integration of the underground landscape into design and planning. The term 'deep' is physical and acknowledges the unknown, and helps to approach the unmeasurable depth of the underground. The deep landscape is an extension and inseparable part of the visible landscape as an underground continuum; an idea of its range and its interconnectedness with the above landscape, with underground compositions, changing properties and slow movements. 'Deep' refers also to the imaginary depth of the landscape and its immaterial relationships to culture and time.

In landscape architecture, knowledge of the water and ground already exists and defines what will grow and thrive. However, landscape projects developed in relation to manmade contaminated grounds and with a high density of technical installation are a more complex context. In urbanism, the ground has mainly been considered relative to resistance and capacities to host the built. Professor in architecture Robin Dripps comments that:

Ground is where human artifice and natural processes comingle for the benefit of both. Our myopia and misrepresentation of something so essential seems inexplicable. The reductive representation of ground within architecture, urban planning and even landscape architecture representation is just as strange. (Dripps 2021: 98)

Thus, the term deep landscape brings awareness to an otherwise overlooked relationship between the ground, water and human interventions. As a concept, deep landscape encompasses a way of thinking about, working with, and perceiving the landscape's physical and imaginary depth. This both helps to define the landscape's relationship to deep time and its invisible underground.

A 'deep landscape' approach can also be used as a design strategy, by reading the properties of the ground and thereafter propose a design adapted to its conditions and desired ground transformations. A design method with an ever-changing design perspective that oscillates between the surface and the underground. Due to its 'invisibility', the description of the ground as an integrative landscape is important for its incorporation in future projects. The imaginative is part of the project, both in relation to its unknown physical composition as well as the conception of its future.

The deep landscape perspective helps expand the present general Norwegian three-step stormwater management principle with the notion of where not to infiltrate water, dependent on ground conditions, e.g., whether the ground consists of quick clay or is polluted. Furthermore, the deep landscape perspective helps conceptualise design tools as landscape measures for improved stormwater management to be used when dealing with disused landfills. In sum, the deep landscape lens has contributed to a description of various approaches to planning with the underground and to highlighting what is below-grade not merely as background, but as part of the project.

A design case was used to enable in-depth research that made it possible to take part in the design process, where knowledge was produced at the intersection between disciplines. The design case was not used to provide answers, but rather to reveal central questions. Even if the design case was specific to the setting in the southeast of Norway, the challenge of urban manmade grounds and their changing properties in relation to water is applicable elsewhere. Comparisons with other urban transformation projects internationally reveal similar ground challenges.

Various landscapes processes pass through the grade of the ground, water, energy, carbon capture and vegetation with trees bridging above and below grade and prompt its joint reading. Due to the complex ground conditions of the design case in this research, the focus has centred on the relationship between the above- and underground. However, deep landscape has the potential to expand upwards and include a variety of aboveground relationships to provide for example microclimates for shade and humidity – highly relevant for humans in heat islands or as refuge for species in a changing climate.

Climate change affects the presence of freshwater globally. With less snowpack at higher altitudes, there is a noticeable decrease in the replenishment of groundwater throughout the year. Working with the ground and how to retain freshwater and slow down its movement on its way to the ocean is thus vital. Further research is needed on how to integrate more of the underground in design for the purpose of managing contemporary climate challenges.

Further research should address the integration of deep landscape strategies into present urban planning. Central questions concern the accessibility of relevant data, the assemblage and visualisation of this data, and the dissemination of learnings. Enhanced integration of the urban underground into city administration and urbanism practice would increase predictability in future urban transformation projects.

The initial question of how greater sensibility to the landscape's underlying structures can encourage more sustainable planning approaches has been reflected in the deep landscape approach: it can serve as an instructive mindset that is generative in an urban landscape restructuring process, and it may also be used as a strategy to provide input on the ground and a desire to define and search for available information and estimate unavailable information based on the clues given by the landscape's surface. This is significant for a sustainable use of ground and water and for the design of its recovery. The deep landscape approach creates awareness, opens up for new questions and helps us reimagine the landscape beyond the visual. The manmade ground in the Anthropocene era is not an exception, but rather part of the project development. This invisible realm under our feet grounds us to the earth and cannot be ignored. The notion of the deep landscape prompts inclusion of the ground with its imbedded history from the start, and all its relations to the landscape in which we live.

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Publications

PUBLICATION 1

Changing Perspectives on Stormwater Management in Norway

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CHANGING PERSPECTIVES ON STORMWEATHER MANAGEMENT IN NORWAY

Elisabeth Sjödahl

ABSTRACT

Climate change in Scandinavia leads to more rain over shorter periods of time, giving water management a central role in future urban planning. The aging sewage systems and urban growth in the Oslo region, as well as water supply safety and the lowering of groundwater levels, are factors that are forcing planners to rethink stormwater management (SWM). This article reviews literature that reveals how SWM thinking has changed over the last decades in Norway. The review provides insight into what is specific for the Norwegian context and gives perspectives on the development of trends within SWM.

KEYWORDS

Stormwater management, landscape architecture, infiltration, climate change, groundwater.

STORMWATER MANAGEMENT IN A NORWEGIAN CONTEXT

Climate change creates new precipitation patterns with more intense rain, which together with urban growth results in more intense run-off water. The risk factors in relation to human settlements depend on how SWM is handled, and on how infrastructure is implemented in the territory. A paradox of the northern latitudes with heavy precipitation is the decreased amount of groundwater. The melting snow that previously filled up the groundwater levels has now gradually been replaced by warmer winters with rain and quick run-off water that does not fill up the aquifers to the same extent, and the snow that falls in the seasons when the plants have started to grow is taken up by the vegetation before it reaches the deeper ground. In addition, the long periods with temperatures around zero degrees create frozen ground surfaces with ice cover that results in a high run-off coefficient and clogged stormwater infrastructure. The prolonged periods of shifting between snow and rain, or snow that melts during the day and freezes again during the night, also creates demanding circumstances for pedestrians and traffic safety.[1]

While this study deals with Oslo, the conditions vary across the country:

Norway's climatic change challenges are represented in three main regions by the European Environment Agency (EEA):

- The Boreal region around Greater Oslo has a prediction of raised precipitation and an increased frequency of heavy rains and less snow and ice on lakes and rivers.
- In the mountain regions in the central part of Norway, the effects of raised temperature are stronger than in the rest of Europe and imply a decrease in glacier size and snow cover.
- In the Atlantic region at the west coast, the main effects are sea-level rise and increase in heavy precipitation and river flows as well as winter storms.[2] This means that the SWM has specific local conditions to account for.

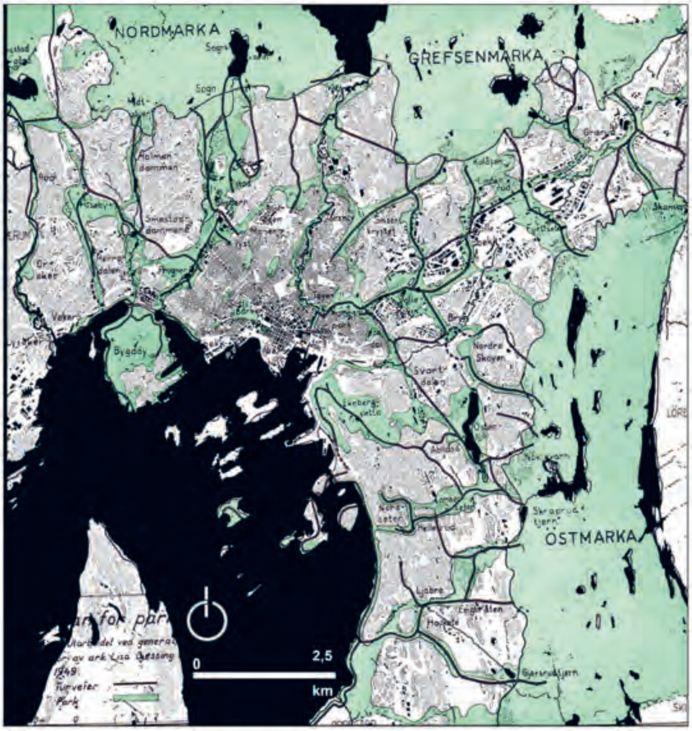

Figure 1. The superposition of the park system from 1950 with the actual urban situation of 2016 that erases some of the former planed park structure. From the Oslo general plan of 1950 elaborated in the period of planning director Eirik Rolfsen and today's situation based on GIS maps from GeoNorge 2016; illustration elaborated by the author in 2016.

A HISTORICAL BLUE-GREEN BACKGROUND TO OSLO

The Norwegian landscape architect Marius Røhne[3] started at the planning office of Oslo in 1916 and established a park plan for Oslo in 1916–17,[4] which provided the base for future planning of a green structure for the city of Oslo, developing an integrated park system that connected the Marka natural reserve with its mountains and woodlands with the sea.

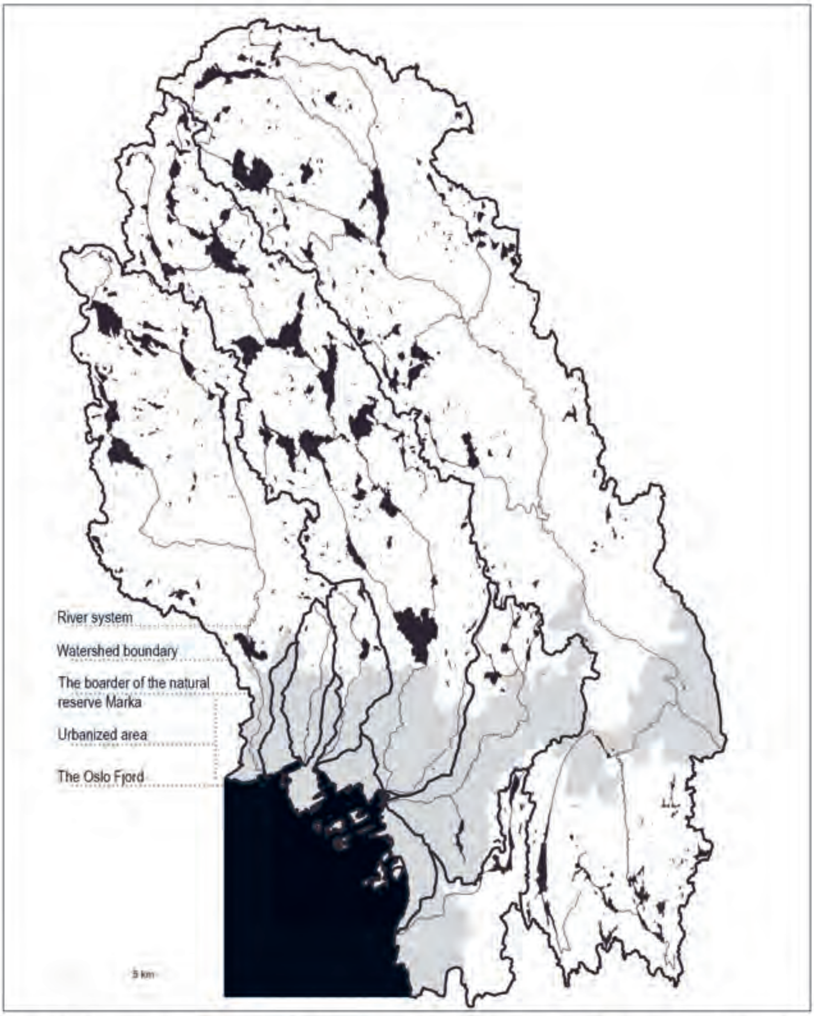

Figure 2. Illustration of Oslo's watersheds to the north, with its waterways that lead down to the urban areas and the fjord (in grey the urbanized area of the Oslo municipality delimited by the line of the Marka natural reserve to the north and south-east). Map elaborated by the Master Course "Sp(C)lash – Let's go swimming" in 2017 at the Oslo School of Architecture and Design.

Harald Hals, the city's urban planning director during the period 1926–47, saw the value of Oslo's green structures. In the years after his education as an architect, he had been working in the United States in Seattle and Chicago until 1911. From this time Harald Hals could have been inspired by the Boston "Emerald Necklace" (1878-1896), by Frederick Law Olmsted where one third of the park was established as a flood control and water quality project. This is shown in Olmsted's map of 1881, "General Plan for the Sanitary Improvement of the Muddy River", which indicates the water management aspect of the project.[5] However, over the decades, the clear green-structure of Oslo that guides the water from the higher levels of the natural areas of Marka has been gradually erased by urban development. In addition, Oslo has recently been one of Europe's fastest growing cities, where the main urban pressure is now found not in the municipality of Oslo, but in the surrounding regions, where clear green structures and floodways are to be defined.

REVIEW OF LITERATURE

The review of literature on stormwater management aims to reveal the change in thinking in Norway during the last decades. The review is mainly based on the journal *Vann* (Water), which is the Norwegian Water Association's publication.[6] This is a central publication for Norwegian professions related to water management. It contains scientific articles, as well as descriptions of technical facilities and investigations carried out, and offers practical advice and guidance. It has provided regular information about the activities of pivotal water-based environments in Norway and important academic events in Norway and abroad. The journal started one year after the inauguration of the Water Association in 1964. The review also utilizes the recent report published by the Norwegian Ministry of Climate and Environment, "Stormwater management in Cities and Villages: A Problem and a Resource",[7] which provides an additional overview of the Norwegian literature in relation to stormwater management.

The research is carried out through literature reviews asking: What have the main tendencies been in the discourse on stormwater management in recent decades in the Norwegian context, as reflected by central publications? In addition, a supporting question is: Which are the transferable thoughts in international readings and approaches to Norwegian SWM with relevance today? Based on the review, a set of perspectives on SWM over recent decades were identified that can be seen as phases of a development leading to the rapidly changing situation today.

STORMWATER MANAGEMENT IN RECENT DECADES
WATER QUANTITY AND QUALITY

In the 1970s, a research program for the purification of waste water was developed in Norway (prosjektkomiteen for rensing av avløpsvann, PRA). The main purpose of the program was to provide a better basis for the significant investments that were made in the waste water sector and to reduce water pollution problems that had been discovered in the lakes, fjords, and sea. In relation to this program, the Norwegian Water Resources and Energy Directorate (NVE) initiated a project where urban hydrological stations were installed to measure urban run-off.[8]

> Heavy rains are only corresponding to a small part of the yearly rain. The sewage system that leads rainwater is therefore not designed for the peak volumes that the heavy rain gives.[9]

The project revealed that the combined sewage (CS) system, which was the norm at the time, resulted in pollution, as the sewage system and treatment plants could not take the overload at heavy rains and thus let the rain and sewage go directly to the sea without cleaning. In Oslo, the CS overflow is still a problem, while some parts of the sewage system have the old combined system.

The concern in the discourse at that moment was mainly focused on the quantity and quality of the water, as well as the industrial sewage problems.[10] There are publications that suggest retention ponds, such as civil engineer Gunnar Mosevoll's PRA 2 report "Rainwater Overflow and Retention Ponds".[11] Here the suggestion is that the overflow system should be put into operation once the net is saturated as a reserve volume parallel to the general system. In this first phase, Stormwater management was viewed as a technical hydrological question.

THE IDEA OF INFILTRATION

The next phase revealed in the literature study was also a part of the PRA research project, where engineer Oddvar Lindholm suggested in 1975 to infiltrate more rainwater into the ground.[12] He later estimated that there are around twenty housing districts in Norway with an open SWM, and that there were approximately sixty at the end of the 1970s in Sweden.[13] He refers here to Westinand and to Malmquist and Hard.[14] The article shows that there is an international exchange of knowledge between researchers, but that the implementation of research into practice is taking its time.

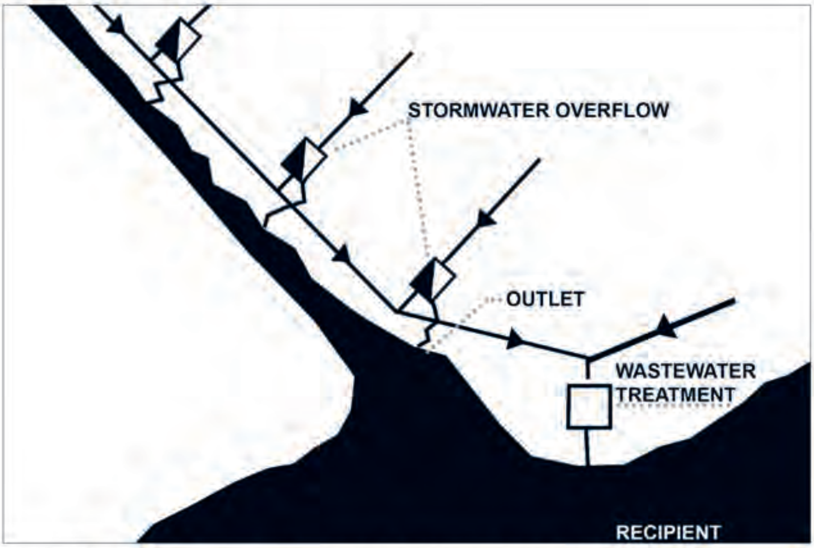

Figure 3. Source: stormwater overflow system from Mosevoll, 1975, PRA 2 "Regnvannsoverløp og fordrøyningsbasseng". Illustration based on diagram, p. 12, translated by the author in 2017.

In 2008, Lindholm published a three-step guideline for SWM, introducing the logic of trying to infiltrate as much water as possible close up to the source where it falls.

The principle is based on an open solution where the first step is to catch and infiltrate, then delay and retain, and, finally, to create secure floodways. This system has become the guideline for the stormwater management policies in many municipalities. The quantity of rain, of 20 millimetres of precipitation, is to be caught and infiltrated where it falls, on rooftops, permeable ground, et cetera, and up to 40 millimetres is to be delayed within retention ponds and areas that can be temporarily flooded. When this capacity is exceeded, the rain is to be guided into safe floodways. The exact quantity and time frame are to be determined in each area of intervention. The guideline thus exposes a key question of responsibility for Stormwater management: while each municipality in Norway (426 municipalities for a population of 5.3 million people) is charged with evaluating the water quantity within its borders, the actual stormwater management systems often transgress municipal boundaries, leaving individual municipalities with responsibilities

Figure 4. Illustration based on Oddvar Lindholm's SWM strategy of "The Three Step Principle", Norsk Vann Rapport R-162, p. 8. Further elaborated by Oslo Municipality SWM 2013–30, "Tre trinns princippen". Traced and translated by the author in 2017.

for only parts of the overall system. In addition, the fragmented government system means that few municipalities have full competence within the field.

The articles in *Vann* demonstrate that the question of water quality was the most central from the 1970s to the mid-1990s. In the 1990s, Norway's biggest LOD (Local SWM) project, the Gardermoen Airport, and its consequences for the groundwater became vital to the discourse.[15] The SWM was to be handled on the surface, but the airport activity with de-icing chemical treatment for the planes, fuel, and oil, et cetera, implied a risk for drainage of toxic contaminants' down to the groundwater.

NATURAL DISASTERS AS ENGINES FOR CHANGE

In recent years, there has been an increase in articles dealing with stormwater management from the year 2000 up until today. At the beginning of the 2000s, the focus in the *Vann* journal increasingly dealt with the question of flooding. Climate change is becoming a more central theme, and in 2010 the Norwegian Ministry of the Environment presented a report on "Adaptation to a Climate in Change".[16] The question of flooding became accentuated in 2011 when Copenhagen had its extreme rain event, resulting in extensive flooding. This promoted articles like "What If the Monster Rain from Copenhagen on the 2nd of July 2011 Had Fallen in Norway?"[17]

This article summarizes the societal effects of the flooding and refers to an evaluation report from the Copenhagen Fire Department[18] that revealed that several critical infrastructures were hit hard by water damage, including emergency centres, the main hospital, the police, and the railway service.[19] In Norway, a comparable rain event, "Frida", fell over the smaller town of Nedre Eiker in 2012 and dropped 70 millimetres in forty minutes. The overall consensus in the debate was that secure floodways had to be provided in the urbanized areas of Norway.[20] As a result, and as an example, Nedre Eiker started to use GIS as a relatively simple way to show the floodways at the property level.[21]

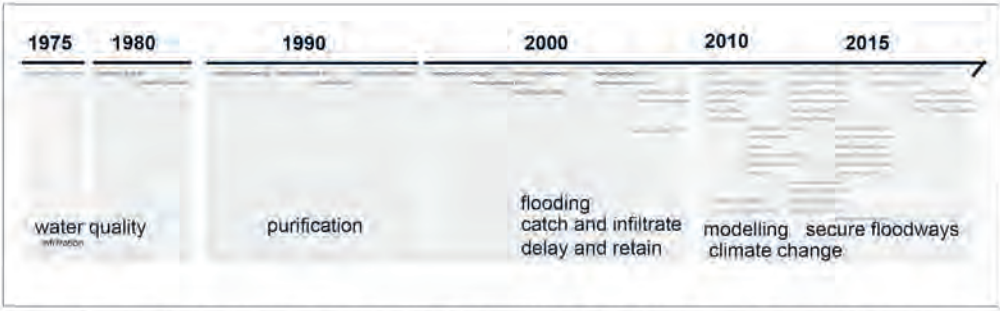

Figure 5. Overview of articles in Vann which deal with SWM. Illustration by the author made with Zotero and Photoshop in 2017.

STORMWATER MANAGEMENT TODAY
STORMWATER MANAGEMENT AS PART OF LANDSCAPE ENGINEERING

The current literature converges on a set of themes. First, the landscape is increasingly seen to have a capacity to deal with stormwater, which can also introduce new qualities within the urban setting. Leading proponents within the landscape architectural field of "water urbanism" Bruno De Meulder and Kelly Shannon argue that "visions for territories can be designed for resilience, remoulding landscapes and reconstructing settlements to bend from hazards but not break".[22] Aligning with the development on Stormwater management in Norway, they criticize a hard engineering approach and argue for a "softer" engineering method that reads the territory and its existing logics, and one in which interventions adjust to the natural logics of water. This, they state, is a realistic landscape engineering form where future challenges can be dealt with, and adapted to: nature's own forces.

The Societal and Economic Question of Stormwater Management

Second, a focus on the wider societal consequences of stormwater management events has emerged. In Norway, a major flood in south-eastern Norway in 1995 resulted in damages that amounted to about 1.8 billion NOK (200 million US dollars).[23] The consequences of flooding were also seen in August 2016, when heavy rains stopped traffic on one of the nation's most important roads in Oslo for several hours. The temporary collapse of mobility caused delays in the flow within the city, including transportation of goods, shutting down evacuation routes and access to hospitals, et cetera. The greater flooding events make the importance of SWM clear for all inhabitants, planners, and politicians, as it transforms from being a technical hydrological issue to a real conditioning event for everyday life. In a neoliberal planning regime such as the Norwegian one, this indicates that there is a need for a stronger juridical framework that strengthens the status of the cities' flood structures, in order to secure values.

The greater flood events are often exposed in the daily media, but in terms of costs it is rather the sum of the small stormwater damages to a wider range of households that represents the greater expenses, such as sewage overflow that is drawn back in the sewage system at moments of heavy rains and floods the cellars.

The city of Malmö can serve as an example of how such events lead to real change. Professor Peter Stahre commented that in some projects at the Municipality of Malmö, it might have helped to move towards a landscape-based stormwater management, because it was very difficult and costly to solve the stormwater management in a traditional way. Here, the open solution was the only economically reasonable way to solve the stormwater issues.[24] The question of economy could be developed further through a comparative cost calculation of traditional versus landscape-integrated stormwater management: its maintenance and its long-term economic effects.

There are a broad scope of ecosystem services based on water. As water is one of the fundamentals for life, it therefore has an outstanding position in terms of value. On the other hand, the economic effects of stormwater management can be relatively easily valued in the implementation of SWMwithin the landscape structures, versus traditional tube systems. In Oslo, this investigation is started with the work of evaluation of the ecosystem services "Values of Urban Ecosystem Services: Four Examples from Oslo".[25] As an example, this project compares the cost of implementing SWM in a traditional and a landscape-integrated solution, in the newly built area of Ensjø in Oslo. This can give clear argumentative tools for practitioners that promote landscape-based SWM solutions in their daily work.

SWM Can Become a Part of Cities' Drinking Water Security as Decentralized Systems

Third, the fresh water supply of a city can depend on one single system or be divided into a multisource system, which is a fundamental question for the cities' drinking water security.[26] Recent years of threat in cities has raised the issue of water security higher up on the agenda. This is especially the case in municipalities that receive their major intake from one fresh water source.

In the case of Norway with its rapid urban growth, this may lead to a more direct interaction between buildings and the landscapes of water that surround them. Here, increased run-off because of urbanization can be turned into an advantage in terms of water supply for an urban region that is in need of it. The idea of a "linear stormwater management" can be summarized in three steps: 1. catch and infiltrate, 2. delay and retain, and 3. create secure floodways.[27] Using stormwater for drinking water in the Norwegian context can seem absurd at first as there is an abundance of water. But taking into consideration that Oslo has been close to water shortage in recent summers, and that an alternative water supply is being evaluated as the water tunnel project that opens up to the next water reserve Holsfjorden 2.5 kilometres to the north-west of Oslo, a circular use of stormwater presents itself as a viable solution. A circular use of water would permit the stormwater management to become an integrated part of the built-up environment, which is to be further investigated within the Norwegian context.

Figure 6. Illustration of the urban underground with its groundwater, made by the author in 2017.

"Underground Urbanism": More Active Consideration of Groundwater in Planning

Fourth, while research has found that groundwater was addressed in various articles as part of a bigger picture, in 2016 a reading of the territory from the perspective of the groundwater appeared in the article "Surface and Ground-

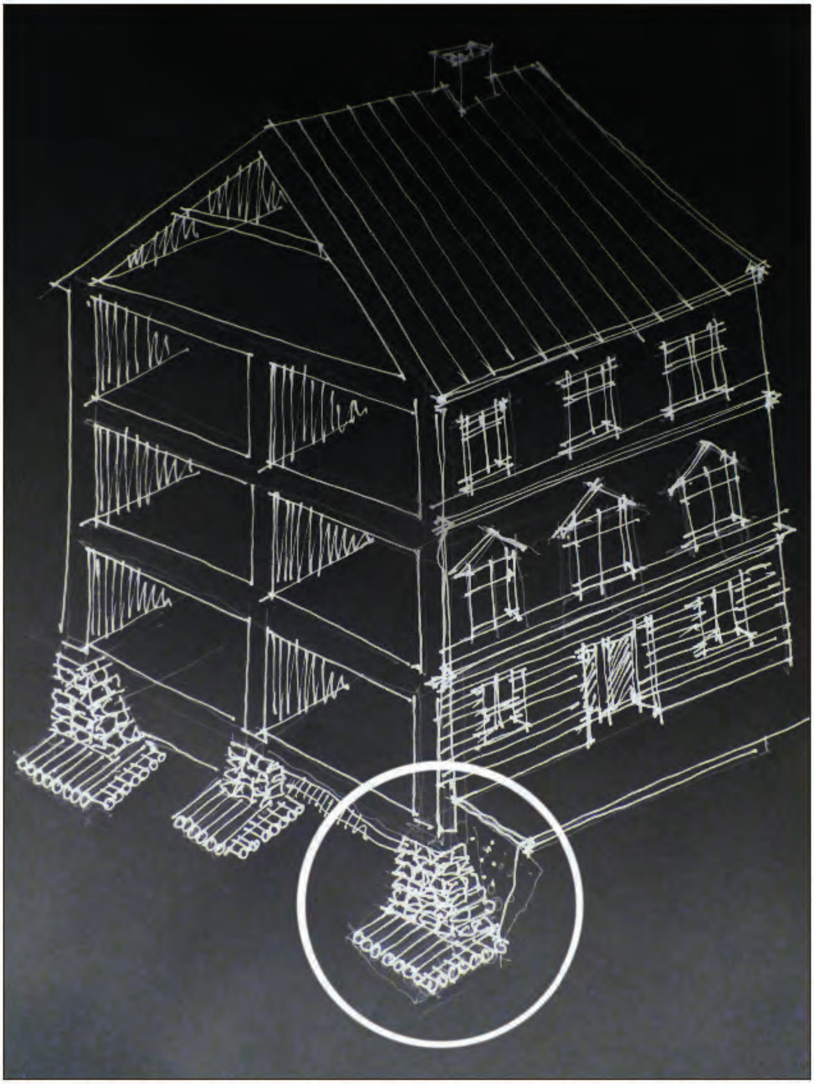

Figure 7. Older houses in Oslo, lower part constructed on fundaments of wood called treflåter; illustration by the author in 2017.

water: Interaction and How to Better Exploit the Interaction" by Hans de Beer. He suggests that the city's underground is important for an adaptable and sustainable urban development, not least in relation to how we handle stormwater. He argues that in contrast to the visual expressions in the cities, we see a significantly lower valuation of the importance of the subsoil among those who plan, develop, and manage our cities. "Stormwater management has traditionally focused a lot on the water's movement on the surface. Fortunately, today we see a turn towards a more holistic approach, where the potential of the subsoil is given more importance."[28]

Knowledge about the characteristics of the subsoil is of great importance in understanding the absorption capacity and the sub-water flows. This is especially true in Norway with areas of quick clay that can be destabilized by water, and where solid soil can become liquid and start to move. The ground component of alum shale, as in the Oslo region, can also be affected if in contact with water, where it swells and releases heavy metals.[29] As illustrated by Beer's article, the general principle in the municipalities' use of the three-step principle of linear stormwater management is to first have a clear overview of the site- and soil-specific characteristics. Beer concludes, "today's knowledge and data about the underground are unfortunately, limited and fragmented. This prevents cost-effective and sustainable urban development, not least implementation of nature-based solutions for stormwater management".[30]

One of the important effects of groundwater decline in the Oslo area is that the ground loses volume, and oxygen enters the ground and changes its properties.[31] When the water does not cover the building foundations, oxygen reaches the wooden foundations causing them to rot, which destabilizes the buildings.

The groundwater affects various other factors in the Oslo region beyond the lowering of the groundwater table and its effect on older building foundations. For instance, the movement of pollutions from one site to the general water system, such as older waste dumps that, with the progression of urban growth, are being integrated into the urban fabric. In addition, the urban expansion that is taking place underground, with garages, storage, et cetera, increases the risk of modifying and cutting off the underground water system flows. Further, the lowering of the groundwater table affects local wells and the possibility for thermo-well installations. Based on these issues, there is actually a need for an "underground urbanism" that puts into context the already built and the planned future installations in relation to the natural underground systems.

SWM as a Widening Field of Concern: From a Technical Question to a Central Societal Question Involving Many Professions

Finally, the review of the literature reveals that a major challenge in the relationship between water and city is that water crosses not only administrative borders, but also – increasingly – disciplinary ones. Solving the stormwater problem within the landscape rather than in separate pipes requires an opening of the disciplines, which includes hydrology, civil engineering, environmental engineering, and economics, as well as urban planning, landscape architecture, and architecture.

The integration of stormwater management in the landscape means that several disciplines have to collaborate closely.[32] The fact that the work implies a multidisciplinary approach means that there is also a need for structural changes within the planning administration system, and a clarification of each entity's responsibility in terms of SWM.

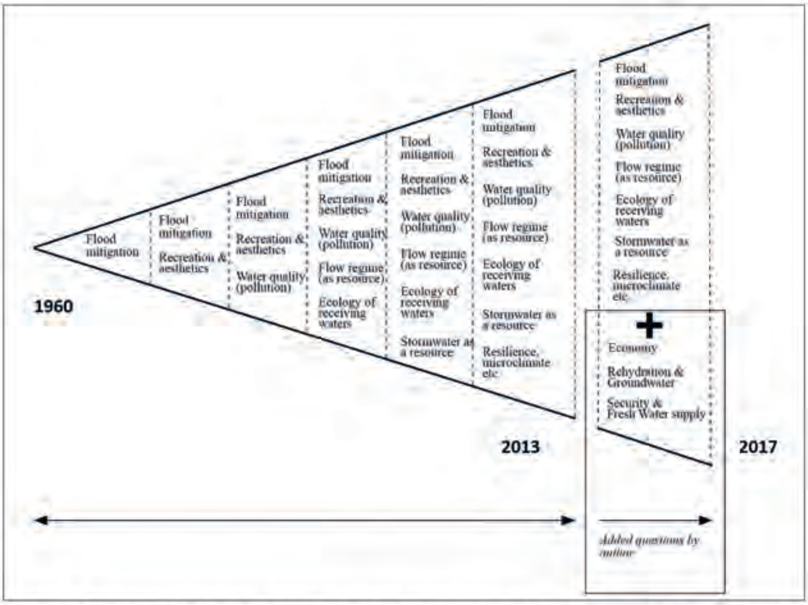

Figure 8. Illustration of the evaluation of storm water-related issues by Fleicher et al p. 534, based on an adoption from Whelans et al 1994.

The scarcity of space in urban areas, and the recognition of broad use of the blue-green structures in planning, requires even more functions to be integrated along with the management of stormwater.

The situation in Norway illustrates how stormwater management is becoming a widening field of concern. SWM has undergone important changes in recent decades: from a focus on flood mitigation, to the integration of a variety of conditions, such as recreational, environmental, and health aspects.[33] At each stage, new terms have been coined to describe the evolving set of parameters, such as best management practice (BPM), sustainable urban drainage systems (SUDS), water-sensitive urban design (WSUD), integrated urban water management, and so forth. In relation to the literature review, even more aspects can be added, such as social, economical, fresh water security, and rehydration of the ground.

DISCUSSION

As the literature study has shown, there are different phases in stormwater management, not clearly chronological, but partly overlapping and interwoven. The literature has mainly been restricted to central Norwegian sources in order to reflect the tendencies on SWM within the Norwegian setting. This might have excluded international publications that could have provided other contrasting insights and approaches.

The study has revealed that the number of experts on SWM has increased over time, and that the field is getting more multidisciplinary. Future reviews should incorporate this broader perspective, analyzing the different sources of publications.

CONCLUSION

The trends within stormwater management in Norway show that in the 1970s there was a general focus on the quantity and the water's quality, while the sewage system was made of combined pipes that were not dimensioned for the heavy rain peaks. Already in the 1970s, Lindholm put forward a case for dealing with the stormwater through infiltration. The years around 2000 saw the introduction of the three-step principle of: 1. catch and infiltrate, 2. delay and retain, and 3. create secure floodways.[34] This linear use of stormwater and its potentials to become a circular use of the water is worth researching further. This would help to deal with water scarcity, and the stormwater can become a part of the solution to the cities' drinking water security with a decentralized system.

Today, stormwater management is increasingly more present in municipal planning. However, the fact that research articles on the effect that built-up areas have on the stormwater – that it can aggravate its effects up to six times according to international studies[35] – were published in the 1960s demonstrates that it is not only a question of having the knowledge, but also the time that is needed for its application.[36]

Current issues within Norwegian stormwater management include drinking water, groundwater, and economic aspects as a widening concern. Overall, current trends and theories suggest that stormwater management is to be resolved within the urban landscape: further research on principles and practices for social and spatial landscape and architectural solutions as well as cold climate specificities are to be developed further.

Stormwater management has become a widening field of concern, moving from a technical question to a central societal question involving many professions. There is a need for adaptation of the administrative system that facilitates tasks such as stormwater that crosses both municipal and administrative borders. There is equally a need for an "underground urbanism": an urbanism that takes the underground characteristics and already built environment into a more active consideration within planning. In the case of stormwater management, the relation between the ground's physical conditions, built environment, pollution, and groundwater merit further consideration in urban planning.

NOTES

[1] Gunnar Mosevoll, *Hva gjør vi når regnet styrter ned?*, *Vann*, 49/3 (2014), pp. 382–91.

[2] European Environment Agency, 2017. *Climate Change, Impacts and Vulnerability in Europe 2016*, EEA Report, January 2017.

[3] The politician Fernanda Nissen worked for social reforms; she was active in the late nineteenth century and equally underlined the importance of the town's green spaces. See Jonny Aspen, *Byplanlegging som representasjon: en analyse av Harald Hals' generalplan for Oslo av 1929* (2003), pp. 231–32, AHO, Oslo.

[4] Ibid.

[5] Anne Whiston Spirn, *The Granite Garden: Urban Nature and Human Design* (New York: BasicBooks, 1984).

[6] Vannforeningen.

[7] Norwegian Ministry of Climate and Environment, *Stormwater managment in Cities and Villages: A Problem and a Resource*" (2015).

[8] The measures were not completely reliable as they did not have the capacity to register extreme precipitation.

[9] Gunnar Mosevoll, PRA 2: *Regnvannsoverløp og fordrøyningsbasseng*. PRA-brukerrapport, (1975), p. 12.

[10] Themes of concern in the PRA 2, p. 2, are: 1. The quantity and quality of the sewage water; 2. Cleaning of sewage water and sludge treatment; 3. Use of recipient for disposal for sewage water and sludge; 4. Transport system; 5. Emission of polluted water in recipient; and 6. The industries' sewage problems.

[11] Mosevoll, PRA 2: *Regnvannsoverløp og fordrøyningsbasseng*.

[12] Oddvar Lindholm, *Forurensinger i overvann*, PRA 4.7, *Vann*, 10/4 (1975), pp. 297–307.

[13] Oddvar Lindholm, *Overvann – kilde til forurensning av grunnvann?*, *Vann*, 17/2 (1982), pp. 177–82.

[14] Lisbet Westin, *Miljömessige aspekter på dagvattenhandtering-Litteraturgenomgång* (Stockholm: Statens Råd för Byggnadsforskning, 1977); Per-Arne Malmquist and Stig Hård, *Grundvattenpåverkan av dagvatten infiltration* (Göteborg: Geohydrologiska forskningsgruppen, 1981).

[15] Torbjørn Damhaug, *Rensing av spillvann og forurenset overvann fra ny hovedflyplass*, *Vann*, 27/1 (1992), pp. 17–20; Svein Bøe, "Aktuelle rensetiltak for oljeforurenset overvann fra flyoppstillingsplasser", *Vann*, 30/1 (1995), pp. 147–52; Per Kraft and Roger Roseth, "Overvann med avisingsmidler på Gardermoen – laboratorieforsøk som grunnlag for prosjektering av jordbaserte renseanlegg", *Vann*, 31/2 (1996), pp. 196–207.

[16] Norges offentlige utredninger, *Adapting to a Changing Climate*, Official Norwegian Reports NOU 2010: 10 (15 November 2010).

[17] Oddvar Lindholm and Simon Haraldsen, *Miljøgifter i overvann fra tette flater, renseanlegg og overløp – Case Indre Oslofjord*, *Vann*, 48/2 (2013), pp. 223–29.

[18] Copenhagen Fire Department (2011).

[19] The fire department in Copenhagen received 180 different alarms during a four-hour period, relating to issues such as: flooding of the basement of the police headquarters resulting in telecommunication failures, flooding of the main hospital resulting in the need to evacuate trauma patients without functioning elevators, flooding in the basement of a prison with a risk for the power supply which put security at risk, and a general power failure that affected 10,000 inhabitants.

[20] Jarle Bjerkholt, Lars Buhler, and Oddvar Lindholm, *Hva hvis monsterregnet fra København 2. juli 2011 hadde falt i Norge?*, *Vann*, 48/3 (2013), pp. 361–70.

[21] Rune Bratlie, *GIS finner flomveiene*, *Vann*, 48/2 (2013), pp. 272–77.

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[29] Ibid.

[30] Ibid., p. 189.

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[34] Ibid.

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PUBLICATION 2

Stormwater Management in Current Practice: From Pipeline to Landscape: A Landscape-driven Design for Stormwater Management

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From Pipeline to Landscape – a Landscape-Driven Design for Stormwater Management

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The creek-opening project "Kjørbekk: From Pipeline to Landscape" is a case study and a chapter in the author's PhD thesis on stormwater management (SWM) in the greater Oslo territory. The dissertation is an investigation into how SWM and an associated landscape perspective can inform urban development from the territorial to the district scale through implementation of a designed project. This chapter focuses on how SWM can be a structuring element and how ecosystem services can help to reposition water as a fundamental consideration in planning, and to ensure a balance between natural values and urban pressure.

The PhD as a whole includes different research perspectives on SWM, developed through education, critical research, and design practice. The Kjørbekk creek-opening project has been researched from a landscape practitioner's position within a project group including hydrologists, geo-technicians, civil engineers, a fish ecologist, and a biologist.

This project, situated in a mid-sized municipality in Norway, reveals dimensions of a possible system change as well as issues of regulation and economy relating to its potential implementation.

Background

Frequent news on flooding in the Oslo region has increased awareness of the need to rethink rainwater management in urbanised areas (ref). Climate change effects will bring more precipitation in briefer periods of time (EEA report 2017), which necessitates reconsideration of current planning practice. This is the case in Skien, a municipality with 50,000 inhabitants 100 km southwest of Oslo. The area of Kjørbekk in the southwest part of the municipality is named after the creek that formerly ran through it. Today the Kjørbekk creek is unseen in the urbanised area, as it was buried as a piped sewage system in the 1970s. This was done in many urban areas and satellite cities in Norway at the time and for a number of reasons: to increase sanitation, to gain land for development, and even to ensure children's safety (Moland 2017). However, the piped stormwater (SW) infrastructure has since exceeded its capacity and does not accommodate increasing quantities of intense and heavy rain. This dilemma forms the basis of this project .

Kjørbekk creek had originally flowed through various landscapes, from the natural areas of the dammed Lake Hvitsteintjern to the west, through urban areas with single family housing, industry and major business areas, before crossing under the highway and discharging into the Skienselva river.

Image: Historical map showing the creek Kjørbekk before implantation of industrial area. approx. 1950. Source Skien Municipality

The pipes that replaced Kjørbekk creek were positioned along its course on the valley bottom. The valley was filled in with excavation material from the new industrial area alongside waste that would otherwise be directed to a garbage dump. This infill was later partially built upon with new industrial buildings.

Illustration of the waste areas (marked in pink) that corresponds to the old creek. The green areas corresponds to public property, elaborated by author 2017.

Today this infrastructure is highly unstable, and in some places, the terrain has sunk by half a meter. The rigid pipe system cannot handle the stress of lateral movements of the terrain, causing breakage and disconnections. The toxic domestic waste infill exacerbates the situation and provides the additional challenge of potential water contamination.

This project aims to remediate this situation and is supported by funds from the Environment Directorate for Climate Change Adaptation. Skien municipality is a member of the National Climate Change Network, which emerged from the *Fremtidens Byer* (Cities of the Future) program. "Kjørbekk: From Pipeline to Landscape" is the municipality's pilot project in this network.

Method:

Research by Design is used to investigate the implementation of SWM management, with the purpose of uncovering additional knowledge on the analytical and mapping phases of the project. The research also includes an element of Action Research, in which participation in a multidisciplinary team permit me to map reflections on SWM from various professional perspectives. These include the planning perspective of the municipality and its rationale on the regulation on SWM on and underground, as well as the hydrologist's knowledge on water dynamics and dam burst, the fish ecologist's knowledge on the form and design of a creek for fish habitats, and the geotechnologist's input on the toxins in the ground. As a landscape architect and urban planner, my role was to weave the different inputs together and provide form for a wholly integrated design and planning proposal.

It is possible to study each of these professional perspectives individually, but the research revealed the collective reasoning on what is the most important in each specific case, and how the different knowledges are brought together in a project. Donald Schön explains how design knowledge is "knowing-in-action", revealed in and by actually designing (1983). He describes the design process as "seeing, moving and seeing", where the doing is triggering the thinking. The process evolves the intentions of the project, and the output successively defines the research questions more precisely.

Each phase within the Kjørbekk project process opens up new perspectives, each giving rise to new questions. These include deeper inquiries into areas such as site-specific information about waste, or how local biodiversity and invasive plants influence the opening of the creek as a water corridor for seeds.

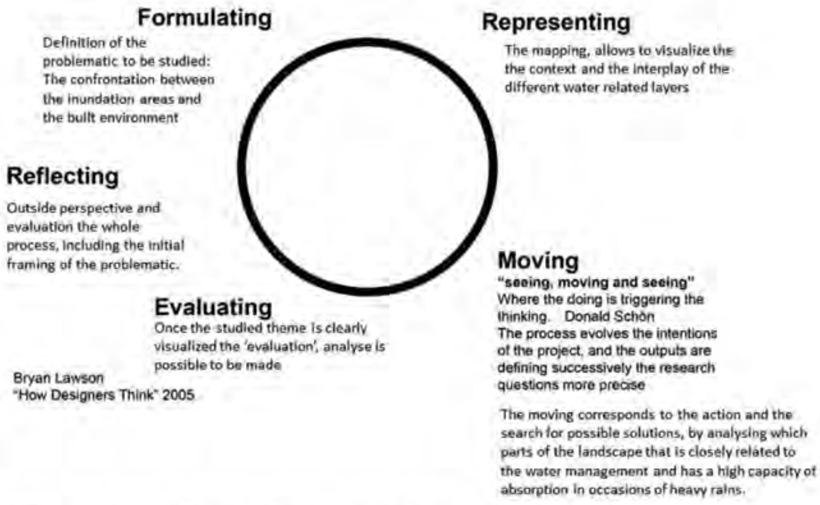

Illustration of the design process as described by Bryan Lawson, elaborated by author 2016.

Bryan Lawson describes the design process by formulating, representing, moving, evaluating and reflecting from an outsider perspective (2005, p.23X). Important here is that reflecting happens by taking one step back from the design process. A time gap from the action of design to reflection helps to create a distance and an observers position towards the project. To reflect on the design work from an outsider's perspective permits one to see what parts in the design work that can be generalised. It equally helps the design, by taking a step back and zoom out from a problem, to reformulate the initial design question. As such, the designer's work is not only an answer to a question but a redefinition and reframing in a given situation. A technique within the design process to create a new perspective is to change scale. At the moment of zooming out, new possibilities are often revealed.

The change of perspectives happens to a certain extent in a design phase where the different scales of the intervention are interwoven. All parts are interlinked across scales. For instance, when a design detail in the Kjorbekk project changes, it can alter the whole section and have influences two kilometres away where the creek has to pass under the level of the infrastructure.

The design phase has to remain "fluid", which is the opposite of the distanced reflecting phase. This means that the "seeing, moving, seeing" has to be done in a way where new opportunities appear. This is seldom a straight line of actions, where the design phase is reflected upon *posteriori*.

Sigrun Langner describes the design process of long-term large-scale projects as open-ended and draws parallels to navigation. "The metaphorical comparison with 'navigation' emphasizes the process of gradual advancement in response to given and shifting conditions, as opposed to a 'finished' design concept or product. The process of navigating involves continuously determining one's position in relation to a set of conditions or context." (2014: p.17)

In the Kjorbekk project it has been important to gradually develop a shared understanding of the greater goals of the project and of what the destination is. How to get there is a collaborative work where each discipline used their particular methods. Today, in multidisciplinary work, the challenge is to combine different working methods and work together. With the reopening of a 4 km creek, there is a need for having both the capacity to understand the creek's role within the urban fabric as well as an understanding of the SW system that is to be connected to the future creek. Thus, it is important to clearly establish the overarching goal of the collaboration , and from there each discipline can add their information to the project elaborated through their methods and programs. In the Kjorbekk project, certain disciplines have a tendency to focus narrowly on issues. However, the landscape architect, as a designer, is more of a generalist who has to articulate the overarching vision which permits zooming out and reimagining the project as a whole.

Process: The reparation of the antiquated SWM system at Kjorbekk has been shown to be extremely expensive and complicated (1,5 million NOK per manhole in 2017) as the pipes are in some areas 15 meters below ground. In response, the municipality initiated a preliminary scoping project in the summer of 2015 to show how a possible creek-opening could take form. This was based on the estimations of Gunnar Mosevoll, the former chief water engineer in the municipality. Mosevoll's work showed a great difference in water flow quantities ranging from 6 l/s during the driest season of the year to 6 000 l/s corresponding to a potential dam burst.

The preliminary scoping project was to serve as a foundational resource when the municipality announced a call in 2016 for a multidisciplinary team to design and plan the creek-opening project. The task defined by the municipality consisted of the transformation from closed to open SWM management by using the landscape as infrastructure. The blue-green structure along the corridor was to be strengthened and restored, and new paths should be established to connect the natural areas as an integrated green corridor between the river and the natural area of Hvitsteintjern.

The municipality explicitly stipulated a request for multidisciplinary teams to apply which should consist of experts in landscape planning, urbanism, fish and plant ecology, hydraulics and eco-hydraulics, flood safety and flood calculation, watercourse restoration, regulation planning, wastewater systems, and sustainable water technology for climate adaptation.

The call was announced in Doffin, the official Norwegian database for public procurement. A core team was created with the assistance of the consultancy firm Multiconsult. This consisted of a fish ecologist from Uni-research in Bergen, a regulation planner, a hydrologist, a civil engineer and a project manager from Multiconsult. The landscape and urbanism qualifications were fulfilled by the author, a landscape architect and planner from Worksonland Architecture and Landscape, and architect Dr. Celia Martinez Hidalgo. The Multiconsult team, having previous experience with dam burst calculations and risks, had the main responsibility over quality control and project management. The multidisciplinary nature of the project was further reflected by the municipal project management team. The planning department initiated and developed the project, but oversight of the design phase and regulation was transferred to the water and sewage department.

There was a clear will to integrate research into the project, as it was a funded pilot project, and call applicants were asked for relevant publications. Education and experience opportunities were to be made available to students, including establishing relationships with relevant research and teaching environments. Communication skills and graphic competence were equally emphasised.

Illustration from the preliminary project 2015.

The preliminary project subdivided the four kilometre long creek into six areas according to character and particular challenges:

A. In this first area, the risk of dam failure should be of high consideration, and should include possibilities for facilitating natural wave breakers in the waterway;

B. Lack of public land is a challenge in this area;

C. Here, public land is available, allowing for a park and a varied program of activities. In dialogue with the municipality, new boundaries would eventually be suggested in order to facilitate various different local interests;

D. In this section Kjørbekken's trajectory should be coordinated with the future development of the industrial area, so that the water would become functional and positive for the cityscape;

E. An area for possible entry to the future creek and path, with bus stops, hiking networks and existing bike paths;

F. Finally, a design facilitating natural cleaning should be included in this section before the water reaches Skienselva.

The competitive advantage for our team was in creating design strategies based in local context, founded on the natural and economic conditions of the site. The funding ability of a mid-size municipality is limited. Therefore, the design strategy was to utilise the existing context as much as possible, and to make minimal interventions with as big a positive impact as possible for the inhabitants and the area's biodiversity.

The project that started in February 2017 had as an ambition to have drawings ready for construction in autumn 2017. Therefore, the municipality promptly arranged a fieldtrip on site with all involved partners. The walk was important for getting to know the site as well as establishing common ground for the collaborators. "Walkers can generate knowledge, exchange ideas, and discuss their experience with other walkers of different professional backgrounds" (Schultz, 2014).

Each expert made a chart on what information they needed at what time in the process to complete the work. This was used to produce a schedule and to program the individual and collective work. Meetings were documented to reflect the stage of the project, and to inform what the next steps would be. Workshops were organised to integrate different aspects of the project.

In the working process, each discipline used their specific working methods to produce new information. The biologist, for example, engaged in fieldwork. The hydrologist collected data from the meteorological institute and nearby rivers, as well as went on fieldwork for the evaluation of the dam and the risk of dam failure. The architect and landscape architect combined fieldwork with design processes that elaborated upon possible solutions in relation to the input from the other contributing disciplines. The work started with an analyse of the landscape. "Because landscape is by definition a complex unity of parts, transforming a site first implies considering all its components and the relationships before attempting to change anything" (Bava H., 2009, 124p).

This process made it clear that different disciplinary priorities collide, but through a design perspective a set of design criteria emerged:

- A variation of the longitudinal section was needed to create a variety of water movements in order to oxygenise the water, and to facilitate for visual and biological diversity.
- When the transversal section was elaborated, it became clear that a wide section was desirable in order to facilitate access from the lateral areas, reduce erosion, and create a greater surface area to contain the water volumes.
- While the fluctuation in water quantities was important, all sections of the courseway should be centred on a V-shaped depression that accumulates and maintains a water minimum during dry periods.
- The creek and its floodplain should preferably be guided through public land to avoid expropriation and thus increase project costs.
- The longitudinal section of the creek should be not too steep, in order to facilitate ecological diversity by allowing fish to swim as upstream as possible

The fact that the Hvitsteinstjern dam was in bad shape made it a primary necessity to consider for dam failure[1]. The hydrologist ran hydrological estimations and scenarios in HEC-RAS.[2] The generated hydrological model was based on the natural terrain together with the proposed opened creek. Once the model was established for the new floodway, it was also used to simulate a dam failure after the new measurements of the depth of the dam. These important hydrological calculations were only provided late in the process, therefor the work process has been relatively slow, a fact that was exacerbated by lacking information on the existing underground SW system.

One of the challenging characteristics of this specific watercourse was the great range in potential quantity of water, from dam failure to a situation where the river can go completely dry a few days of the year. This gave critical input to the design in terms of how areas hold and contain water in order to permit fauna to survive when the creek is dry.

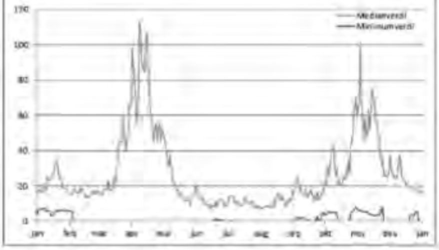

Illustration of water flow in the Kjorbekk creek along the year (l/s), yellow-median value, grey-minimum value. Made by Multiconsult in 2017.

[1] The calculation of the damburst from 2007 made by Multiconsult was here used as a base.

[2] A computer program created by the US Department of Defense, Army Corps of Engineers in 1995 to elaborate the water flows of rivers and and harbours.

HEC-RAS corresponds to: "The Hydrologic Engineering Center" (HEC) and "River Analysis System" (RAS).

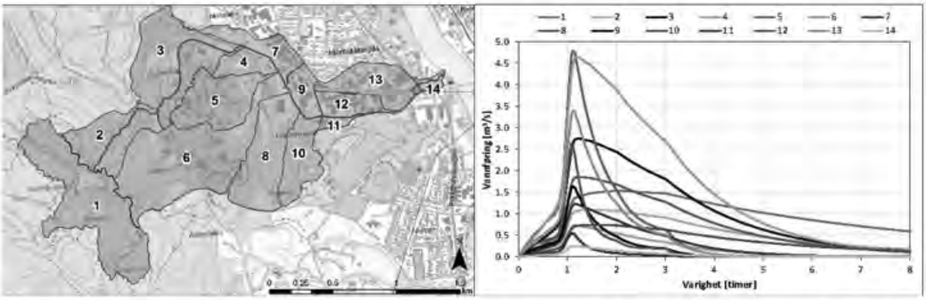

Illustration of the catchment area and its subzones with correspondent water flow (m3/s) Made by Multiconsult in 2017.

Illustration of the effects of dam failure elaborated by author in 2017, on the basis of the estimation done in 2007.

Normal and minimum water levels for Kjørbekken were calculated using regional hydrological analyses. Flood drainage for Kjørbekken was calculated using regional flood rate analysis and precipitation drainage modelling. In view of climate adaptations, a climate factor of 1.4 had been applied to dimensional flood watering.

As existing installations are to be found underground, a 3D model of the system and the landscape was established in Infraworks[3]. The model had been used in the design phase to verify the superposition of various systems such as the sewage system, the fresh water system, the rainwater system, energy

[3] Infraworks is a software by autodesk that permits working with infrastructure design in "real world" setting.

infrastructural systems, former waste dumps in relation to the new water way, and the presence and location of existing valuable species in the area.

An initial geotechnical report was done in 2007, which showed the extent of waste deposits, and excavation tests raised doubts about the reliance of the perimeter of the dump. This lead to a study of old topographic maps in order to re-estimate the perimeter and volume of the dumped waste. Documentation of groundwater was missing during the process, which made it difficult to estimate the movement of toxins from the waste dumps.

Topographical map showing the trace of the Kjørbekk river from Hvitsteinstjern in the west to Skiens elva in the East, elaborated by author 2017.

One month into the project the sense of urgency waned. Rather, it was determined to begin with a regulation plan for the whole area. This was made evident by the fact that during the project process, several building permits were issued in the area that went against the creek-opening project. One of the projects that did not incorporate the open Kjørbekk creek was a large industrial facility positioned directly on top of one of the tributaries to Kjørbekk. Another was a municipal school that had newly installed pipelines running over the creek bed at a depth that conflicted with the proposed longitudinal section of the creek.

During the project, an additional difficulty arose. The Kjørbekk area was found to be completely lacking in flood infrastructure, but the municipality has a legal responsibility to provide safe floodways. The water and wastewater engineers of the municipality made a calculated cost analysis of providing this infrastructure based on linear meters of pipe installation against the cost of a linear structure of open creek. This grossly simplified cost comparison in linear meters of each entity, however, and did not include a sufficiently broad picture of the risk of inundation nor the positive ecological and social outcomes of the proposed blue-green structure.

In the project development phase, it thus became critical to make evident the benefits of doing a landscape-integrated solution, including the positive health effects of the blue-green structure in terms of recreation and social cohesion. Other benefits of such a solution include rising property value in the area, increased biodiversity, enhanced floodway facilitation, and climate change adaptation. Further, it would increase general awareness of the water qualities in an open system in line with the EU water framework directive (Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy), and facilitate integration of blue-green infrastructure with the establishment of an alternative car-free network of movement.

In order to facilitate for the inclusion of such perspectives in the process, calculations on the basis of the TEEB[4] (The Economics of Ecosystem and Biodiversity) elaborated by the Netherlands National Institute for Health and Environment, system can be carried out. These evaluate benefits in health, energy consumption, property value, recreation, social aspects, and water management. The aim of this was to valuate future aspects of the proposed blue-green system, but also to evaluate how a TEEB system calculation would work in an actual SWM system. The water management consists in the calculation of the reduced risk for flooding and number of households that would be affected by flooding. The capacity of storage of rainwater in the landscape is equally calculated to estimate the reduction of investment in SWM.

[4] https://www.teebstad.nl/user/reset/5261 latest used dec. 2017

Findings:
The implementation phase brought the question of economy to the fore and the possibilities of project actualisation. This part comments on three economical aspects of the project: 1) the cost of a project depending on how the calculation is done; 2) the opportunity to execute two (or more) projects in one; and finally, 3) the economic aspect of *how* to execute the project.

Firstly, the costs of expenses per linear meter of piped SWM versus landscape integrated SWM revealed the need for an alternative calculation. What would it cost if a landscape-designed floodway is not chosen, and what would the redevelopment expenses be resulting from consequent flooding damages? Here the ecosystem services becomes equally valuable when estimating the costs and positive values of the project in terms of health, energy consumption, property value, recreation, social aspects, and water management. In relation to the TEEB water management calculation, there are a few aspects that can be added, such as maintenance of a system over time (especially concerning the great depths of the buried SW system), and the purification costs of SW. The greater amount of water created by SW run-off demands equivalent expansions of the purification plants capacity to absorb the peaks created by heavy rains.

Secondly, it became clear that having a good overview of short and long term interventions can make it possible to execute several projects at once, which can be an efficient way to reduce the cost per intervention. For instance, a 300m stretch of new riverbed in Kjørbekk was executed by being incorporated into a section of a new bicycle lane. This became a feasible way to consolidate expenses while executing a project, as labour costs associated with having people on-site and with machinery required to perform both projects is far greater than the total material value of the final surface forms. As another cost-sharing example, when a fresh water pipe-system has to be added within the area, the terrain remodelling could be done in such a way that the SW is collected on top and guided towards the creek and river system. If the destination creek stretch is not already remediated, a local retention riverbed or pond can be created to capture the water.
In a longer-term example, the southern part of the Kjørbekk creek crosses through a sand quarry. This terrain must, by Norwegian regulations, be re-established after mining to an inclination of 1:2 and replanted with local species. This means that an extra one-kilometre stretch can be integrated into the overall creek-opening project if this post operational re-modelling of the quarry terrain is collaboratively planned well in advance.

This leads to the third economic aspect – how to execute the project. Long-term coordination would require an enhanced overview of planned and on-going processes, such as a digital map database that registers future works in order to coordinate the many different interventions within a municipality. In this project, it was found that information on executed projects was missing within the municipal database. This made the working process slow, as it was especially time-consuming to update information on underground installations that were not easily accessible. Today, the digital maps of the municipality are constantly updated with projects as they are completed.

As well, the implementation of a system change itself has to be done in steps, as there are many short- and long-term, and small- and large-scale interventions to consider as part of the greater whole. In some cases, municipal subsidies would be the cheapest alternative to create change in the existing urban tissue. For example, a singular building that drains down to 5m under the new riverbed cannot be an exception that forces changes to the bigger picture and demands a new subterranean system. Here it would be more cost effective for the municipality to offer incentives that would encourage such a private building owner to build a roof that externally drains stormwater to ground level.[5]

The Kjørbekk project revealed that one of the greater costs of the creek-opening project relates to the movement of earth materials (soil and clay), which could be elaborated as a redistribution-project in itself. Once the municipality has the layout of the whole project it could be organised in such a way that materials are dug out and filled up in coordination with the overall mass distribution plan. The knowledge of where infill can be removed and where it needs to be turns the creek valley into a long-term terrain shaping and management project. The plan would be refined and evolve over time with the aim of lowering the need for extraneous transport and increasing the local sourcing of earth materials.

In terms of design, this water project strongly links local intervention with the large structural scale of the landscape. Even the smaller detail of a sidewalk can redirect SW flow from one direction to another. This demands an ability in the design process to constantly shift scales.

[5] In a stormwater management project in Oslo the general cost of up scaling the capacity of the pipe system of an area of 30 000m2 was estimated to 57 million NOK. The cost of a rehabilitation of the existing system, together with the implantation of rain beds would be around 25% of that cost. In this calculation, the subvention of private raingardens with 70,000 NOK each was included. Even though the cost would be more advantaged, and the public ground not large enough to take the superficial water, the municipality can not today juridical make investments on private ground. (ref. B. Braskerud lecture, VAV Oslo.Dec. 4th 2017).

Conclusion:
Being a part of a multidisciplinary design team provided greater insight into the variety of perspectives of the practical work of a surface- and landscape-based SWM project. The design process was important in revealing additional challenges to the mapping and analysis phases of this SWM project. The design phase revealed more questions, created more interactions with various entities involved, and showed the complexity of project implementation. "(T)he way towards a sustainable urban drainage is not always so easy and it often takes an unexpectedly long time" (Stahre 2008; p.3). There is a gap between theory and practice. For example, Luna Leopold stated in the 1960's, that the built environment worsens SW runoff up to six times.
There are many similarities between the creek- and river-opening projects of Trondheim, Oslo, and Skien. Various rivers in Norwegian urban settings have been buried for sanitary reasons. In the case of Skien, however, an additional complexity was added as buildings were constructed atop the old riverbed and waste deposit, further complicating the transformation to a surface creek runoff system. The fact that building permits have recently been given to build over the most important tributary creeks shows that there remains a need for an understanding of the landscape's logic in relation to the built environment. While Skien Municipality intends to create a sustainable society, it is belied by these recent building permit allowances, which shows that the easiest solution is the cheapest in the short run and follows a logic that acquiesces to the old system. There is great resistance in the system for the implementation of change.
In terms of financing, it is better to divide the projects into economically feasible phases, and to build slowly towards the desirable solution in a greater time perspective.
Lessons from the Kjørbekk projects show not just a project process but also dimensions of a wider system change in planning for urban water management. When the conventional way of working becomes impossible by being insufficient or too expensive it triggers change (Stahre, 2008). Such change includes both physical structures (such as when interior drainage of roofs transform to exterior systems through the changing of architectural roof-forms) as well as changes to expert and planning practice (such as the need of an extended scope of water and wastewater engineering) when the SWM has to be solved in the landscape.
There are judicial and administrative questions raised in relation to the potential system change of SWM that are still to be solved in the Norwegian setting; What happens when the landscape *is* an infrastructure? Does all the land need to be owned by the public when crossing through private entities? This has not been a question for the water and sewage-engineer working underground until now. Also, insurance companies currently cover the damages in cases of flooding. This has changed internationally, and it is most likely to change in Norway with increased flooding occurrences. This would accentuate the economical calculation on the risk side of the project and the costs of not doing a creek-opening project such as Kjørbekk to provide floodways.

The real economic force of the municipality is to be found in the traditional planning tools such as the regulation plan, in which future interventions can be conditioned in order to accommodate SWM predicated on the landscape.

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PUBLICATION 3

Landscape Measures for Improved Management of Stormwater and Leachate at Old Closed Landfills.

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Landscape Measures for Improved Management of Stormwater and Leachate at Old Closed Landfills

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Abstract

River re-opening strategies of piped streams are used to accommodate greater quantities of stormwater. However, experience in Norway has demonstrated challenges in applying standard principles of local infiltration and retention of water, when the former valleys have been used as dumping grounds. The water that come in contact with the waste can spread contaminants to adjacent areas. The aim of this investigation has been to collect experience on a selection of nationally and internationally transformation projects of landfills, where the landscape has been used as an active tool to deal with the complexity of the polluted masses in relation to stormwater.

Keywords

stormwater management, landfill, pollution, landscape as system

Introduction

The question of stormwater management in relation to old landfills is of importance since there are more than 2100 of them registered in Norway.[1] Climate change and heavier precipitation in the northern latitudes will result in more water being transported through these old landfills and subsequently an increased risk of leakage of

1. In Norway, the old landfills are registered in the national database (www. grunnforurensning.miljodirektoratet.no), but case studies show that there is a gap between the number of existing contaminated grounds, such as landfills, and registered ones (Hønsi 2017). Norway has 5600 registered contaminated grounds, landfills included. In comparison, Sweden (85,000 contaminated sites) and Denmark (30,000 contaminated sites) register far more, which indicates a severely under-reported number of contaminated sites in Norway (Gustavsen and Jansson, 2018).

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contaminants.[2] Urban growth is also a factor forcing municipalities to find measures to handle old landfills. These garbage dumps were formerly 'out of sight', buried in the outskirts of cities, making it possible to ignore the great quantities and toxicity of the waste production (Pollak 2007). However, these dumping grounds are now becoming visible as cities expand and new infrastructures are to be built on the affected ground. A major challenge is their mixed composition of polluted substances, which can spread out through leachate and gases in the environment over time.

Recent permissions have been given to build on the border of an old landfill in Skedsmo municipality, east of Oslo.[3] The inhabitants have complained about headaches and nausea.[4] One reason that methane gases are being found within the buildings is the proximity to the landfill. The drainage of the piped water systems that passes through the landfill and supply the houses, creates a direct connection and guides the gases into the building through the gravel of the drainage system. This means that it is not only the buildings that are directly on top or at the border of a landfill that can be affected by gases, but even buildings at half a kilometre of distance (Nilausen, 2001).This is an important factor to take into account within planning and design of water supply systems.

At the landfill, the methan gases can be collected by the upper containment layers via a gas drainage system and then reused for energy production. This article will not explain this process in detail, but rather focus on the management of stormwater.

Gas emissions and subsidence of the waste masses makes these areas unsuitable for building and for facilities that require perfectly flat land, such as soccer fields. Parks, golf courses, and frisbee lanes would be acceptable programs, when the top layer is made thick enough. It may even be suitable to grow and cultivate light harvests for bioenergy; however, forests with larger trees and deep roots might challenge the impermeability of the landfill, risking the emissions of gases and dangerous leaching.

Before the introduction of municipal garbage collection and an increased public awareness of environmental issues, there was a tradition of simply burying rubbish where it was not easily seen. This included uses in construction, as well as backfill and the filling of valleys, quarries, kettle holes and ravines with waste material. Local streams were piped through culverts with poor durability through these sites; these, in turn, were degraded by chemically aggressive leachates. From 1950–1990, most of these landfills were without any artificial sealing and leachate collection and control. Cities near the coast also sometimes used beaches as disposal grounds and washouts. Some dumped waste directly into the sea and fjords. 'Wild dumps' were places close

2. The mean annual precipitation (1971–2000) for Norway is estimated to be 1600 mm, and has increased by ca. 18 % since 1900…The intensity and frequency of heavy short-duration rainfall has increased in recent years (Hanssen-Bauer et al., 2015, p. 10).
3. The final building phase of the housings at Brånåsen, Skedsmo, was completed in the 21 century.
4. Methane gas has been found in such concentrations within a wall of one building that it caught fire (Gustavsen and Jansson, 2018). Measurements have also proven high values of the carcinogen benzene within some of the houses (Norwegian Institute of Public Health, 2018).

to roads and next to ravines, lakes and fjords where members of the general public would simply jettison their garbage. Today this type of dumping is punishable under environmental laws.[5]

Leachate from landfills can enter the environment and spread into groundwater aquifers, lakes or seas, either directly or via municipal sewage plants. According to the Norwegian Environment Agency's official reports, half of such leachate goes directly into adjacent bodies of water untreated (NOU 2010: 9, p. 85). Additional aspects of the effects of this pollution are reflected in the EU Water Framework Directive (WFD), according to which Norway is committed to ensuring good quality in all water bodies before 2021 and to stopping the discharge of environmental pollutants by 2020 (NOU 2010: 9, p. 11; White paper 14, 2006–2007).[6] The objective of resolving the issue of water pollution in such a short timeframe seems difficult to attain, especially considering that not all old landfills are registered, and that the time and costs necessary for the implementation of ground recovery projects are high. Therefore, low-tech solutions for reducing the spread of pollutants in relation to stormwater will be investigated here, guided by the following question: How can the landscape be transformed to prevent leaching of contaminants? Can there be reduced contact between rainwater and old landfills?

Contamination spreads most often when pollutants come into contact with water. High solubility and high water flow result in high levels of environmental pollutants. Thus, the spread of contamination depends mainly on two factors: the solubility of the environmental contaminants, and the water flow within the polluted masses. To address the problem of the spread of contaminants through increased precipitation, the goal of this research has been to find conceptual landscape measures that isolate and prevent the spread of pollution.

The need to address this problem became clear when investigating a case study of a river opening project of Kjørbekk, Skien. Another case study of a neighbouring municipality to Oslo, in Lørenskog, showed that intentions towards climate-adapted stormwater management are included in the planning documents; however, the completion of the newly built Winter Park does not necessarily comply with these intentions (Sjødahl, 2016).[7] This gap between intention and realisation has a variety of origins. The reason investigated here is the availability and application of

5. From conversations with Dr. Torunn Hønsi, a researcher on environmental impacts who has research and fieldwork experience with pollution control with the County Governor.
6. An Official Norwegian Report (NOU) from the Ministry of Climate and Environment has in 2010 presented a report on the conditions to achieve a safer nontoxic environment ('Sammen for et giftfritt miljø – forutsetninger for en tryggere fremtid'). However, various environmental pollutants are still in use.
7. The intention of climate-adapted stormwater management is to open the buried creeks, minimise impermeable surfaces in urban developments, and recreate permeable surfaces where they are already established; in terms of the realisation of new products, the intentions are not as clearly indicated – for example, the new Winter Park to the north of Lørenskog station, which encloses the creek in pipes under the 35,000 square meter building. The building's roof surface creates considerable runoff, resulting in an exacerbated inundation situation downstream.

knowledge regarding handling stormwater in relation to old landfills. The primary aim of this work is therefore to collect information on executed projects where the landscape was used as an active tool to deal with the complexity of old landfills in relation to water.

Method

The primary method of investigation is analysis of published documentation of the executed projects of transformed landfills.[8] The following case studies were selected on the basis of their representation of different landscape strategies and their relevance for Norwegian conditions: Fresh Kills, New York, USA, as a project that elaborates several processes in order to achieve landscape recovery; Grønmo landfill, Oslo, as a landscape formed in order to avoid infiltration and guide water away from the landfill; Bens Landfill, La Coruña, Spain, showing a strategy of partially removing the landfill by landfill mining; El Garraf landfill, Barcelona, Spain, exemplifying the integration of different technical systems into one landscape.

Table 1. Description of selected landfills.

Name	Location	Period	Area	Volume / Weight	New Uses
Fresh Kills	USA	1948–2001	930 ha (45 % is landfill, 418 ha)	150,000,000 tons	Recreation
Bens	Spain	1970–1996	60 ha	1,000,000 m^3	Recreation
Garraf	Spain	1974–2006	64 ha (12.5 ha executed)	26,600,000 tons	Recreation Agriculture
Grønmo	Norway	1969–2007	53 ha	4,300,000 tons	Recreation

Next, a conceptualisation was made to reflect the strategies used. Paula Viganó defines the project as a 'knowledge producer', with conceptualisation understood as an abstraction of space and time where the 'Design activity develops concepts and utilises and reinterprets concepts from other fields' (Viganó 2016).

This work synthesises principles from the case studies into conceptual drawings, describing the differences between the main principles and offering a broader vision and definition of possible landscape measures. The objective is for this synthesis of the concepts to serve as a base for future design and to be developed further in relation to site-specific circumstances.

8. The study applies to old dumps, and not to requirements according to the new landfill regulations.

In terms of old landfills, both geotechnical conditions and the development of methane gas are important issues that must also be considered, but these are not described here.[9]

The Landscape Project as a Process of Change: Fresh Kills, New York, USA

Project designed by Field Operations in collaboration with ecologist Nina Maria Lister.

Fresh Kills, located on the west side of Staten Island, New York, USA, was the world's largest landfill site, active from 1948 until 2001 During that time, it received 150 million tons of solid waste.[10] The landfill had destroyed much of the land and the original rich ecosystem in the area; revitalising the ecosystem was therefore an important part of the recovery process.

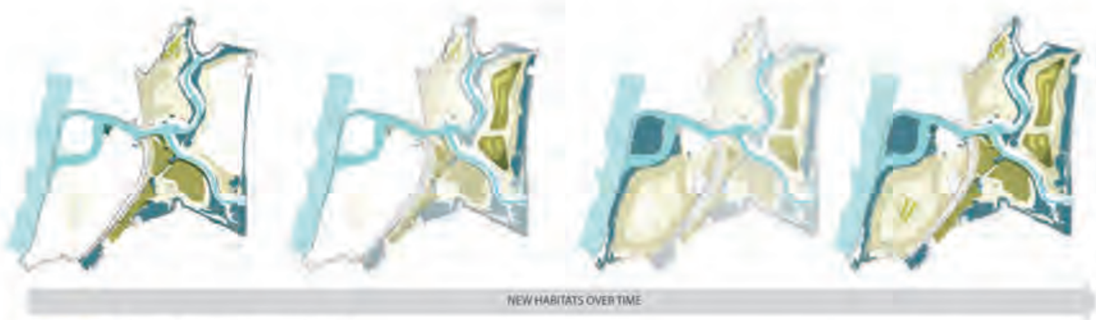
A project of this size necessitates various processes: technical and landscaping, but also political, financial and temporal. James Corner, referring to David Harvey in his text 'Terra Fluxus' in *The Landscape Urbanism Reader* (2006b), argues that 'future urbanization must derive less from an understanding of form and more from an understanding of process—how things work in space and time' (2006b, p. 29). David Harvey states that the challenge for designers is not the giving of form alone, but the rise of 'more socially just, politically emancipatory, and ecologically sane mix(es) of spatio-temporal production processes' (p. 29). A project of the size and complexity of Fresh Kills is only feasible through its division into phases to be developed over time.

The approach has been to develop the project in three ten-year periods. Beginning by closing the existing area as a landfill without public access, the first measure was to restore the wetlands, meadows and forests. Next, accessible areas for the public were established, with meadows for recreation, a network of roads, as well as sports and park areas. The first phase was important for raising awareness and thus to catalyse new public and private investments in the area. More restaurants, cultural and educational facilities, and urban agricultural areas are to be developed to attract more people. After 30 years, the site is to be transformed completely into a park.

The top cover layer of the landfill hills has been shaped to collect and guide the rainwater through a drainage system that slows the water down and reduces erosion. The leachate is collected in recovery wells and guided to a leachate treatment plant. To avoid infiltration between the landfill and its surroundings, cut off walls are planted in the periphery down to the low-permeability ground layer.

9. The relationship between water and gas production is such that too much water in a landfill stops methane production, while the complete absence of humidity stops the process of decomposition (conversation with Tarje Tobiassen, manager of Grønmo landfill, 2018).

10. Fresh Kills received at most 29,000 tons of residential waste per day. Of the total area of approximately 930 hectares, slightly less than half corresponds to the former landfill sites. The remaining 55% consists of meandering streams, marshes, wetlands, grasslands, meadows and forests.



Active Recreational-Field Sports
Active recreational uses that occur outdoors and require the construction of playing fields. Playing fields are assumed to be permeable. Structured seating for visitors assumed.

Passive Recreation
Passive recreational uses that occur outdoors on permeable surfaces. Related structures include decks and piers
Cultural
Uses with a cultural or educational component. This category includes uses that could occur on permeable surfaces (e.g., open fields), as well as uses that could require the construction of buildings.

Linear Recreation
Active recreational uses that occur outdoors and would be limited in area to linear, paved paths.

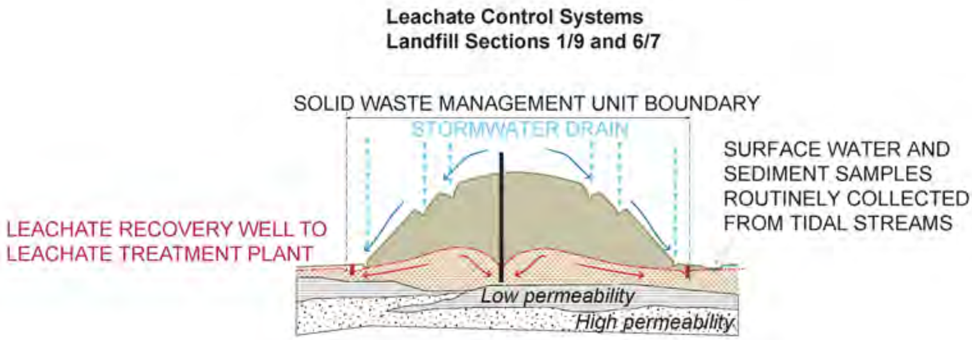
Habitat with People
New habitat to be created, or existing habitat to be enhanced, which includes the potential for use by the public. Related structures include boardwalks, decks, and [paved or unpaved] trails. No accessory buildings.

Art Feature
Constructed elements that are not related to a defined use but are aesthetically interesting. Not assumed to generate auto, transit, or pedestrian trips.

Habitat without People
New habitat to be created, or existing habitat to be enhanced, which would not have the potential for public use. In some cases these areas would be fenced off or otherwise made inaccessible. Habitat would be protected and left undisturbed. No accessory buildings.

Figure 1. Illustration showing the process of change over 30 years.
Illustration by: Celia Martinez Hidalgo. (Based on the Fresh Kills Park, Project Description, 2008).

STORMWATER BASINS AND DEGRADED WETLANDS FOR POTENTIAL IMPROVEMENT



FRESH KILLS LANDFILL INFRASTRUCTURE

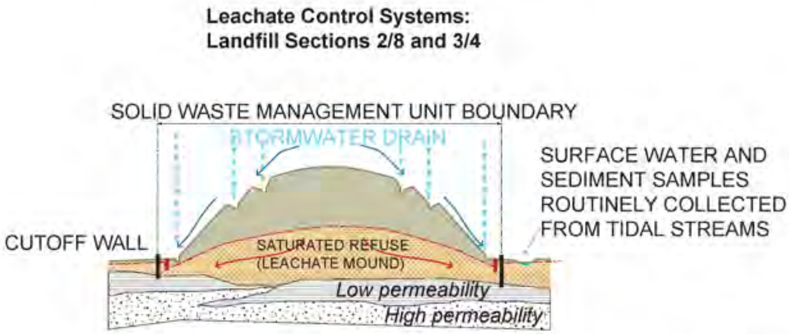


Figure 2a. Illustration of the leachate system of Fresh Kills. Above to the left the section of the control system with leachate recovery wells, and to the right barriers created with cut-off walls. The stormwater is slowed down by a drainage system that is formed so as to reduce erosion. Illustration by: Celia Martinez Hidalgo (Based on the Fresh Kills Park, Project Description, 2008 p. 129 1–7 a,b).

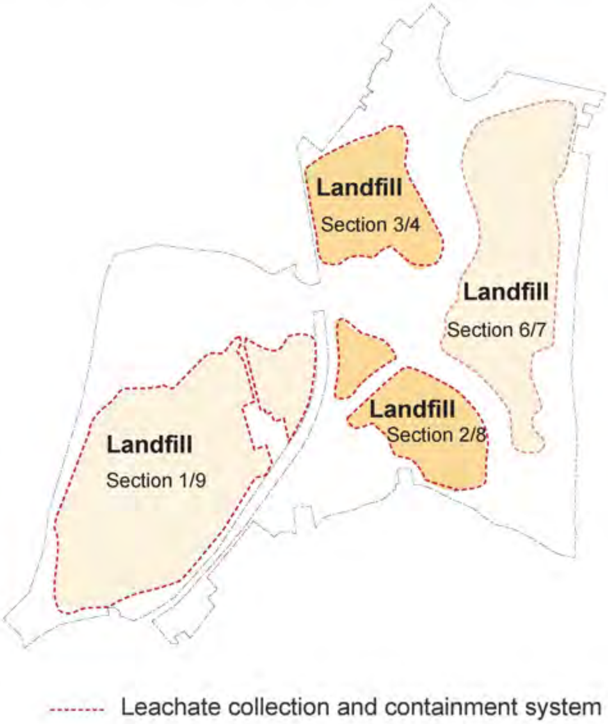


Figure 2b. Illustration of the leachate collection and containment system; the different landfill units with their perimetral leachate system.
Illustration by: Celia Martinez Hidalgo (Based on the Fresh Kills Park, Project Description, 2008).

Figure 2c. Illustration of Fresh Kills. To the left, the division into four waste management units that have been elaborated in different phases. To the right, the stormwater management with runoff, stormwater basins and the tidal wetlands on the coastline.
Illustration by: Celia Martinez Hidalgo (Based on the Fresh Kills Park, Project Description, 2008).

Modelling the Landscape in Order to Reduce Water Infiltration. Grønmo Landfill, Oslo, Norway

Grønmo was Oslo's main landfill from 1969 until it was closed in 2007. Raudmyr creek flowed through Grønmo, at the bottom of the valley, but was piped in 1972 before the valley was filled with waste. Altogether, more than 4.3 million tons of urban and industrial waste were deposited there.

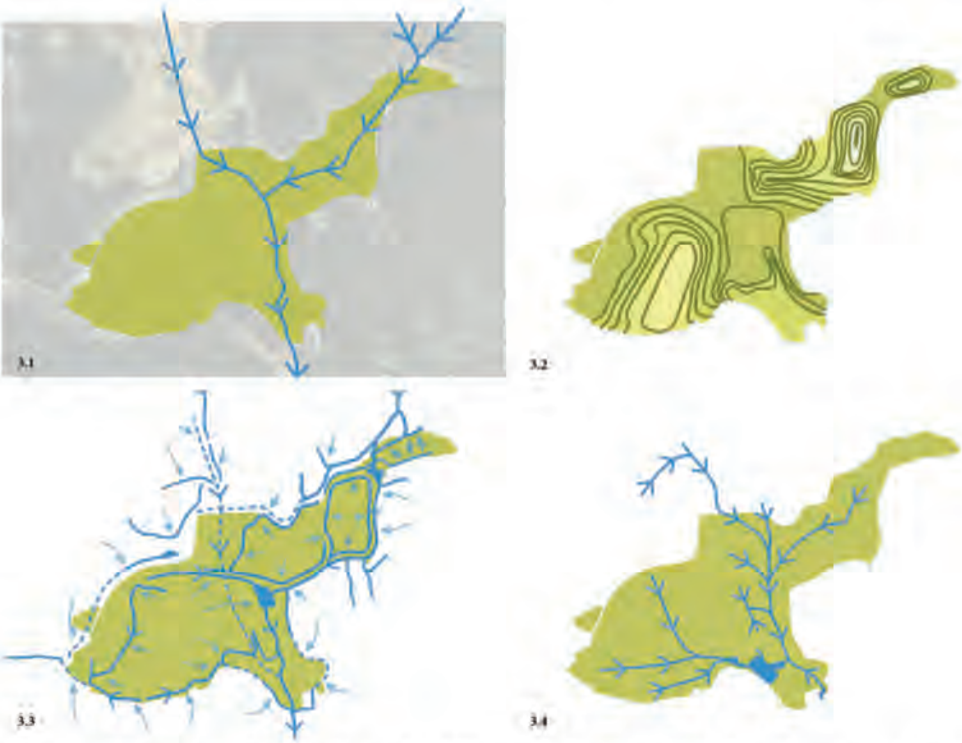


Figure 3. Illustration of the Southern landfill area of Grønmo, Oslo. 3.1, Illustration of the path of piped Raudmyr creek. 3.2. The new topography of hills created with the landfill. 3.3. Local runoff system. 3.4. Flow diagram of leachate and dams.
Illustration: Worksonland.

In order to prevent rainwater from percolating into the landfill, the topography has been formed with slopes and peaks. This ensures runoff towards the periphery and avoids increased production of leachate.

Grønmo landfill is located at a low point in the surrounding territory. In order to avoid the penetration of clean water from outside the area into the polluted landfill, a system of ditches have been established (fig 3.3). Some of them are designed as streams and have been expanded at three locations into ponds, increasing the capacity of the system.

The topography has been changed and raised by the large amount of waste to the extent that it is no longer possible to connect the piped Raudmyr creek to the open stormwater system. The creek is therefore still enclosed in a pipe beneath the landfill.

The pipe has reduced capacity due to ageing, and its position relative to the landfill has resulted in cracking, leading to contact between the water and the polluted masses. The pipe has therefore been repaired from the inside, further diminishing its capacity. To compensate for this loss of capacity, ponds have been added. The older part of the landfill has been transformed into a golf course, while the newer part is designed to handle the stormwater by guiding it away from the landfill. Planted with grass, there are plans for it to be incorporated into the surrounding recreational facilities.

Removing the contamination by landfill mining: Bens Landfill, La Coruña, Spain

The closure and transformation project of the Bens Landfill in La Coruña, Spain, began after an accident occurred in 1996 wherein parts of the landfill masses collapsed into the urbanised area of Portiño port below, killing one person. The catastrophe occurred because the landfill was not properly compacted, and it had reached its limits. Destabilisation was further exacerbated by fires in the preceding months (Nebreda, 2011).

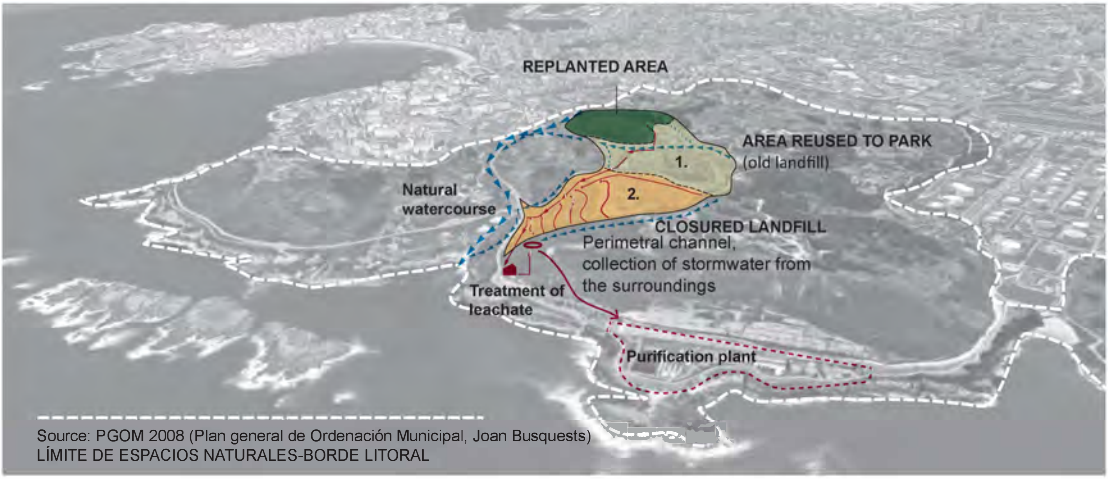


Figure 4. Aerial view of the Bens landfill, with areas 1 and 2 marked.
Illustration: Celia Martinez Hidalgo.

For the recovery of the area, the landfill was divided into two zones. Area 1 was located on the upper part of the landfill, with leaner slopes and better views of the surrounding landscape; this area was therefore transformed into a public park. To accomplish this transformation, the method of landfill mining was employed, entailing the digging up of waste and moving it to a nearby treatment plant to be sorted by type and recycled or re-deposited into area 2. This area was re-structured with the masses from area 1; a gas collection system was installed to harvest energy. The masses were stabilised and covered, and the landscape was formed into terraces and slopes to handle the stormwater. While the gas production is still active, the area 2 is inaccessible for the public.

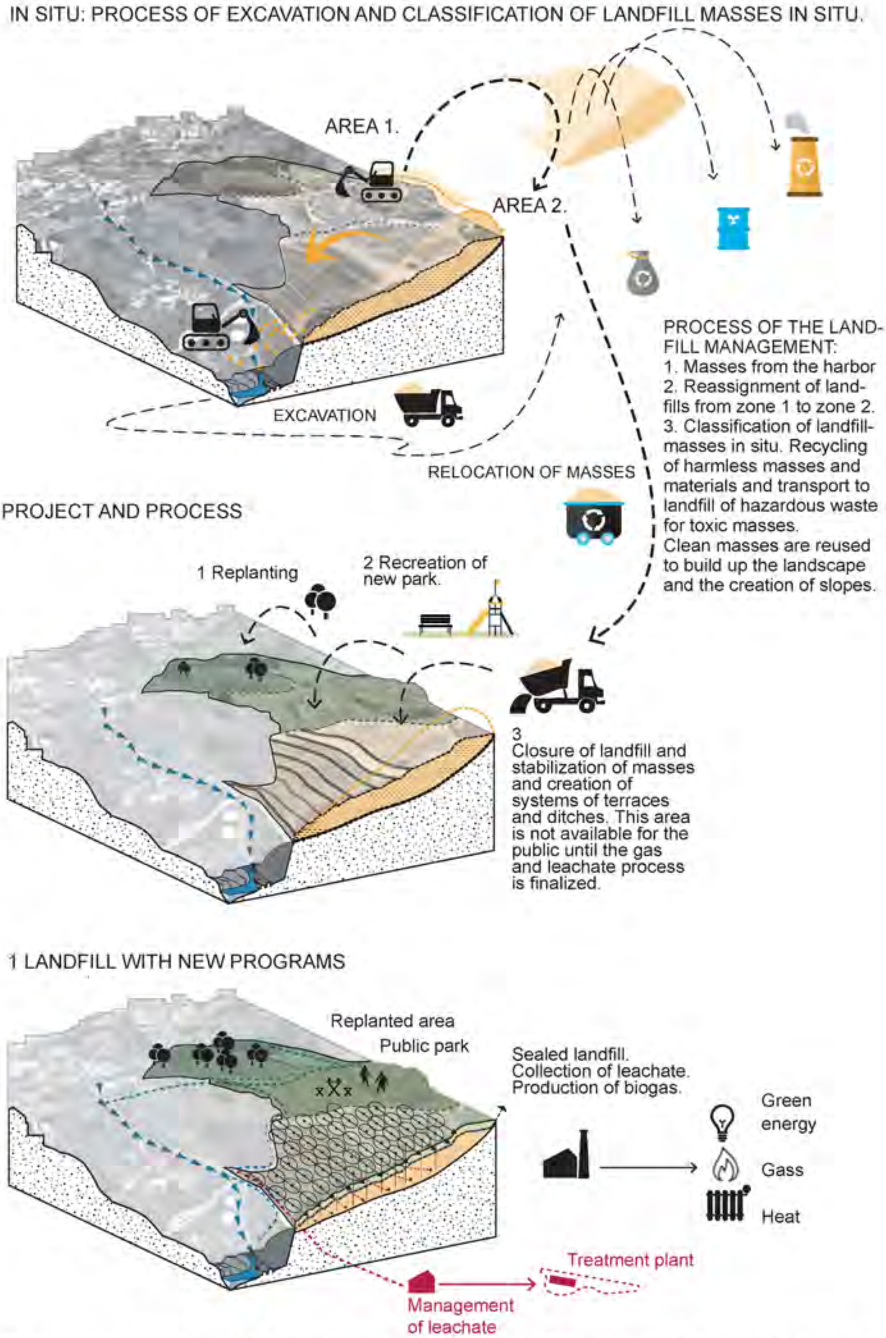


Figure 5. Illustration of the working process of landfill mining and land moving. Area 1 is transformed into a public area. After digging out and sorting the landfill masses, the area is converted into an urban park that is accessible to the public when the project is completed. Area 2 becomes a closed area with restricted use. This zone will not be open to the public until the production of landfill gas and leachate is eliminated.
Illustration by: Celia Martinez Hidalgo.

The main focus of the project was to separate clean water from contaminated water, avoiding infiltration of clean water to the landfill masses and minimising the volume of leachate that needs to be cleaned. The stormwater in area 1 is collected in a ditch that lies along the perimeter of the landfill; from the ditch, the water is diverted to an existing stream leading into the sea. Contaminated water from area 2, as well as potentially polluted water from area 1, is transported through a system of dikes and through a subsurface network. The contaminated water flows into a sedimentation pond before being passed on to a treatment plant for purification. Removing the contamination via landfill mining is done in order to minimise the explosion risk, repurpose the land, and concentrate the masses for gas extraction.

Landscapes as Systems. El Garraf Landfill, Barcelona, Spain

Project designed by: Enric Batlle, Joan Roig, and Teresa Galí-Izard

The restored landscape of the El Garraf landfill is part of the green infrastructure of the metropolitan area around Barcelona. The site connects to the corridor between the Llobregat river valley and the natural park of Garraf, turning an artificial landscape into one of agriculture. The site, totalling 60 hectares, has been a Barcelona's landfill for 30 years and has accumulated waste to a depth of 80 meters. Leachate water has infiltrated the karstic ground and contaminated the groundwater resource of Castelldefels aquifer. The landfill contributed 20% of Barcelona's greenhouse gas emissions (Zeunert, 2017).[11]

The main strategy in this case study was to develop a landscape logic that integrates all aspects necessary for the transformation of a landfill into a landscape with one and the same structure. The agriculturally inspired terracing divides the landfills into stabilising fractions that avoid the erosion and landslides caused by unstable ground. This approach also provides the necessary inclination for access roads and corresponds to the pattern of gas installation, which, in turn, is automatically served by parallel access roads. The inclination of the terraces guides the stormwater to lateral collectors that are used for the irrigation of the planted areas. The regeneration of the landfill area and its transformation into an agricultural landscape is based on three elements: landscape modelling, water systems, and vegetation.

The terraces are inclined in line with the longitudinal axis of the valley. A system of open ditches run parallel to the zig-zagging access road and collect the water from the terraces, directing it into the canals surrounding the landfill. These canals have several functions: to collect the water from outside the landfill and prevent it from entering the dump; to collect rainwater from the sealed landfill through the ditches parallel to the access roads; and to lead the water to reserve tanks located at the bot-

11. Methane gas (CH_4) has 25 times the global warming effect compared to carbon dioxide (CO_2). 'Recent calculations suggest that atmospheric CH_4 emissions have been responsible for approximately 20% of Earth's warming since pre-industrial times' (Yvon-Durocher et al., 2014).

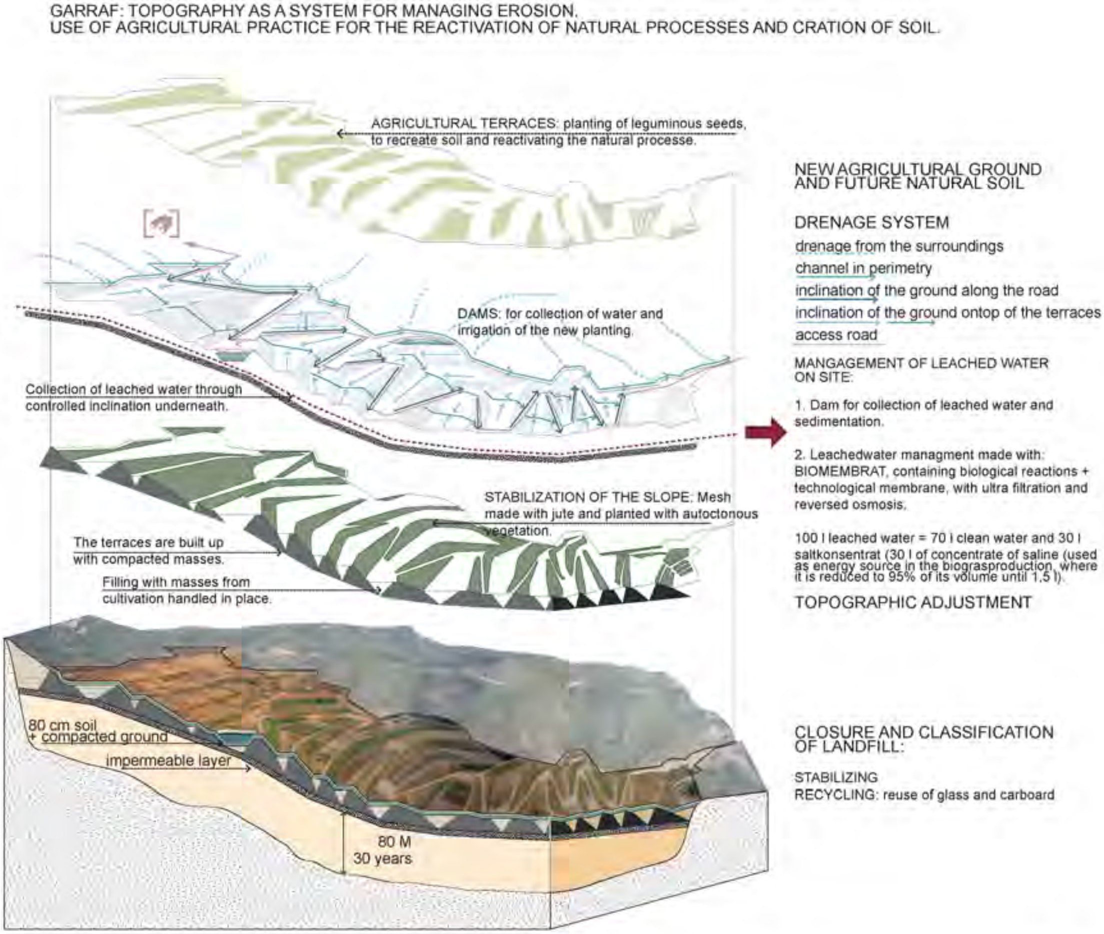


Figure 6. Illustration of Garraf landfill, the landscape as system from above: terraces and access roads as erosion control, system of stormwater management, and cultivation terraces.
Illustration by: Celia Martinez Hidalgo.

tom of the landfill, where it is then stored until it is used for the irrigation of the created agricultural terraces. The modelling of the topography separates clean water from contaminated water. The clean water is prevented from infiltrating the landfills, thus minimising the volume of leachate that needs to be cleaned. Leachate from inside the landfill is collected and guided to the sedimentation pond and wastewater treatment plant.

Agricultural principles have been used as a strategy for initiating natural processes in order to re-establish the soil.

Pasture has been established on the horizontal surfaces of the terraces, along with local low-water consumption species such as pine, evergreen oak and grass. Bushes have been used to protect the slopes from erosion; trees also provide shade along the path (Zeunert, 2017). The regeneration of the landfill area has transformed it into a landscape based on agricultural principles with landscape qualities where the usage of livestock provides benefits by maintaining and regenerating the soil (Batlle, 2011).

Results. From Landfill to Landscape: Four Strategies

Landscapes can take on key roles in some of the more technically oriented infrastructural installations: guiding water, filtering and purifying water, creating barriers and preventing pollution from reaching water courses and groundwater, erosion control, collecting greenhouse gases that can be used for energy production, and starting the process of restoring polluted areas. The ways in which landscape can be used as infrastructure depends on how it is modelled and shaped – the types of soil layers that exist, the degree of permeability, the inclination of the slope, and the types of vegetation that are planted.

Analysis of the various case studies shows that each specific landfill has its own context, challenges and background, but that taken together they share the common goal of closing and stabilising the landfill masses and separating clean and polluted water. Such use of landscape can be achieved either through organic forms, as seen at Grønmo, or through more organised, logic-driven systems, as at El Garraf. Landscape measures, used in different combinations in the studied cases, take into account four different aspects: guiding the water away from the landfill, removing the landfill, using the project to initiate processes, and using the landscape as a system.

Topography and Landscaping to Avoid Contact between Water and Landfill

All the cases studied here use their respective topographies to close and stabilise the waste. The garbage is partly sealed (some water should percolate; by sealing the waste completely, the problem is only passed on to coming generations. With some infiltration, the landfill body will leach pollution gradually and the pollution can then be treated), rendered impermeable, and modelled into a new landscape. The stormwater is led away from the landfill as soon as possible to avoid infiltration and contact with the waste material, minimising the volume of leachate and the transport of pollutants. The landscape of a landfill can be unstable and sink as a result of the decomposition processes of organic matter. The landscapes are therefore formed in pretensioned, concave shapes that can lead the water away even when the terrain is settling.

As observed at Grønmo, the first strategy is to form the terrain into concave shapes with slopes of at least 5% that redirect the stormwater from the landfill. Ditches in the perimeter of each concave shape lead the water out of the landfill area.

In the case of El Garraf, terrain modelling follows a system of terraces, each having a ditch that collects the water from the terrace and effectively directs it to the perimeter of the landfill where it is collected. Adapted to the conditions on site, this approach not

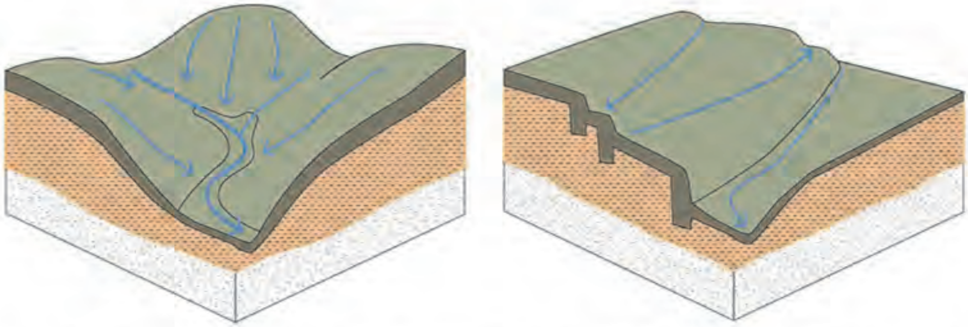
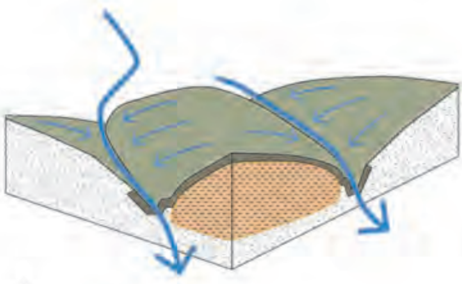


Figure 7. Formation of the landscape into concave shapes to redirect the stormwater. To the left, the principles of forming the terrain at Grønmo, and to the right, the terraced principles of Garraf (grey corresponding to original ground, orange to waste, and brown to soil cover and the blue arrows the direction of the water).

only stabilises the terrain and minimises the risk of erosion but takes into account other factors, such as stormwater management, gas extraction and access roads.

It is also important to ensure water from the surrounding areas does not come into contact with the landfill. Two main strategies were adopted to this end: First, a system of perimeter ditches that followed the periphery of the landfill collected both the superficial stormwater from the landfill and the water from the surrounding areas. This prevented the water outside the landfill from being contaminated and turning into leachate. In most cases, the ditches were designed as streams and thus leant a landscaping quality to the projects.



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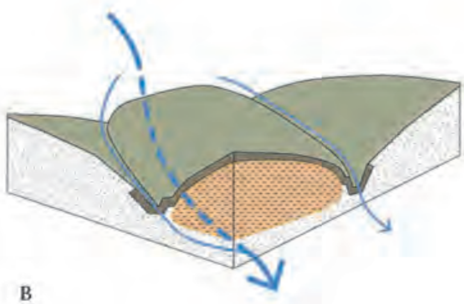

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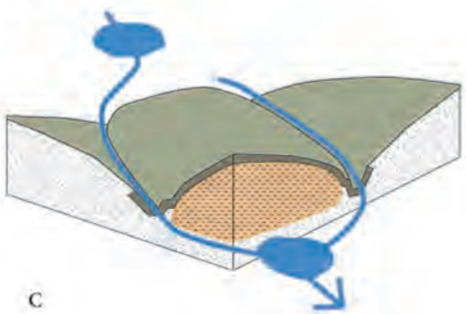

C

Figure 8. Fig. A. Ditches at the periphery of the landfill collect stormwater. Fig. B. Landfill with old piping system in the valley floor. Fig. C. Stormwater system with incorporated ponds to provide more capacity and longer retention.

Second, most of the streams in the case studies were diverted into pipes and buried when the landfills were established. Today, many of these pipes are broken in several places due to age, the chemically aggressive leachates, and the settling of the masses; they leak and forecasts indicate that they do not have the capacity to handle future rainfall projections. In some cases, as at Grønmo, the changes in the topography have been so significant that it is no longer possible to open the old creeks; therefore, the water continues to flow in pipes. To seal the leaks, the pipes have been repaired from inside with soft tubes which then harden and act as pipes *within* the pipes, diminishing their original capacity. To provide more capacity for stormwater along the waterways, most of the projects analysed have incorporated ponds. At the Grønmo landfill, several sedimentation ponds were added alongside the ditches, before the water reaches the recipient Raumyr creek, to ensure that the ditches could handle greater amounts of precipitation. In Garraf, the water was repurposed to irrigate the planted areas of the landfill.

If a site is not suitable for infiltration due to changed topography, infrastructure and/or landfills, it is important that other options remain open in order to handle stormwater within the watershed. In her book *Granite Garden*, Anne Whiston Spirn writes that '[w]ater pollution or flooding problems at one place may be generated somewhere else, and a solution to the water supply problem may, in the end, aggravate water pollution. The most effective, efficient, and economical solutions to urban water problems are frequently found upstream of where the problem is felt most forcefully' (Spirn 1984, p. 154). There are agricultural keyline technics[12] that can redirect the water higher up in the watershed in order to circumvent the landfill.

Dig Out the Landfill

In some cases, new uses are not compatible with an existing landfill, which means it needs to be removed. Digging out is also an alternative if a landfill is in constant contact with water (whether groundwater or surface water), or if the ground needs to remain stable, as in the case at Vinstra, Norway, and the implementation of new road infrastructures (Berg, 2014).

Project as Process

The process of restoring landfills and transforming them to create new uses, such as public parks, flower meadows, golf course or forest takes time. James Corner considers this to be 'process over time', one of four themes of importance in *Terra Fluxus*: 'the staging of surfaces, the operational or working method, and the imaginary' (Corner 2006b, p. 28). The Fresh Kills project, for example, clearly shows the idea of

12. The keyline technics have been elaborated by P.A. Yeomans's in his book *Water for Every Farm/ The Keyline Plan*, 1981.

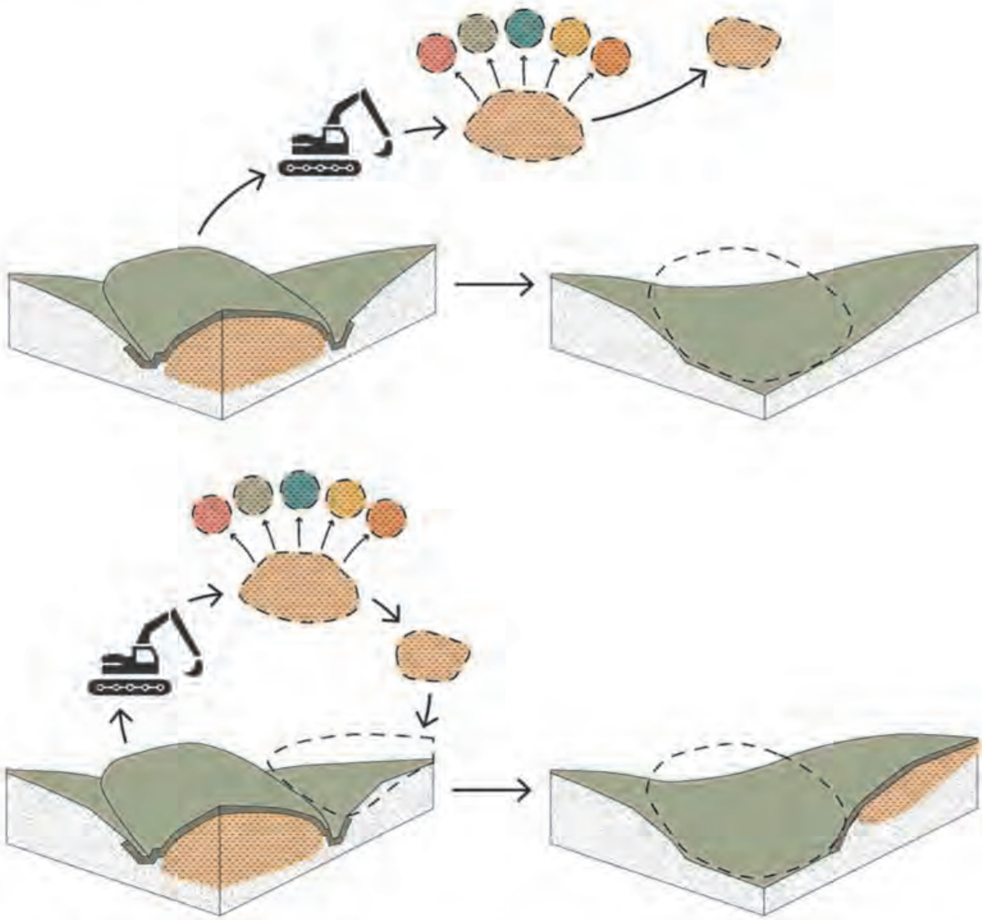

Figure 9. To the left, landfill mining, where the masses are sorted into fractions and used off-site. To the right, landfill moving, where the masses are sorted and some is reused on-site. Illustration: Worksonland.

'process over time': the project's execution was divided to span a timeframe of thirty years. Programs and different uses of the land were successively introduced so the public could begin to use and become aware of the newly accessible site. Continual economical input is equally necessary for the project, as well as the fundamental reintroduction of the ecosystems and how they change over time. Considering the magnitude of the project, it needed to be organised into phases. The type of design and form is related to both the scale of the project and the processes of landscape recovery. The architecture is realised by equipment facilities and paths where 'earth, water and plants [...] have the capacity to define space at a reasonable cost on a scale appropriate to vastness of creeks, wetlands and mounds' (Corner 2006a, p. 20).

Development over time also provides opportunities to learn from previous phases, whether things develop in the predicted way or changes are needed.

Possible landscaping measures to avoid the spread of pollutants include interventions that redirect water or remove contaminated masses in contact with the watercourses. To be successful, the measures undertaken must take into consideration the characteristics of the particular landfill in question, which is also in constant transformation (due to decomposition processes that can subsequently reduce the landfill's volume, the fluctuating quantities of released methane gas, etc.). When working with nature-driven processes that have already begun, the results of one project are of great interest to others in order to inform estimations, schematics, and expectations of a successful transformation. Such results, especially during the first decades of monitoring, document the different factors that are fundamental to foreseeing processes of change. If the human impact on ecosystems is not tracked and monitored, failures in various projects and retrofitting measures to improve performance will not be detected (Johnson & Hill 2002). Monitoring is a challenge, however, since the landscape architect is often only active during a project's initial phase and is seldom involved in long-term follow-up. Even the administration of such projects has its challenges considering how quickly society changes and the ever-changing administrative municipal body. Given this, a 30-year perspective is quite a long timeframe in which to observe and learn.

Due to a lack of documentation, this analysis does not reflect the composition of the underground in the various projects discussed. Nevertheless, the karstic ground in Garraf and the fault lines under the Grønmo landfill may impact the impermeable barrier beneath the landfills, leading to the spread of pollutants.

If it is not possible to avoid solubility or water flow, it might be possible to purify the leachate from the masses by using landscaping measures such as treatment wetlands, ponds, vegetated buffer strips, and soil filters. In addition, it is possible to add sorbents. This might be done by adding masses that bind to the contamination, but this is not covered by this study (see Ortiz Bernad et al. 2007, Okkenhaug et al., 2016).

In the United Nations World Water Development Report 2018, Nature Based Solutions[14] (NBS) for Water are argued for: 'Upscaling NBS will be central to achieving the 2030 Agenda for Sustainable Development.' It is important, though, that the 'blue-green solutions' for climate adaptation, together with increased precipitation, do not worsen environmental conditions insofar as the stormwater that passes through contains soluble pollutants from the old landfills. James Corner asks, '…[D]o they really believe that natural systems alone can cope more effectively with quite formidable problems of waste and pollution than do modern technological plants?' (Corner 2006, p. 27). Persistent organic pollutant (POPs) compounds are of such a composition that they are not biodegradable; therefore, the limits of Nature Based Solutions must be defined. When identifying the complexity of decomposition of certain non-biodegradable chemicals, the following question arises: Do their advan-

14. 'Nature based solutions (NBS) are inspired and supported by nature and use, or mimic, natural processes to contribute to the improved management of water' (UN World Water Development Report 2018, p. 2).

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tages compensate for the complexity of their decomposition as waste? To avoid leakage from the landfill into surrounding areas, landscaping measures may be integrated into the project, such as wetlands, sorbents, and sedimentation ponds with phytoremediator vegetation. However, for exceptionally toxic leachates, conventional technical water treatment needs to complement these natural landscape barriers.

Conclusion

Our society needs to undertake rapid changes in order to fulfil the environmental goals of improved water quality and the reduced transport of pollution, while at the same time facing the climate change challenges of heavier precipitation in the northern latitudes. This article presents active landscaping measures that reduce the contact between stormwater and old landfill masses, in turn reducing the transport of pollutants.

The goal of the research is to synthesise and conceptualise knowledge acquired in former landfill landscaping projects. The observed categories of landscape measures are: deviating water courses, and removing parts of the landfill. The working methods are: time and process in the project development of complex projects, and combining all the constructed systems of the landfill necessary (stormwater, gas collection, stabilisation, access, erosion control, etc.) into one landscape structure. These landscape measures have the capacity to reduce leachate and the spread of contaminants.

The visualisations of illustrated concepts are intended to function as grounds for further development and a basis for interdisciplinary dialogue in cases where stormwater measures need to be adapted and further developed to fit the characteristics of each new project site.

Further research on the spread of pollution is needed to cover landscape measures in relation to groundwater and the possibility of using sorbents.

The case studies demonstrate the challenges that landfills pose over long timeframes,[15] and it is therefore important to revise our approaches to the production and reduction of waste and to study urban metabolism.

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15. Today, it is expected to take 30 years to complete the monitoring of old landfills, but it could still take up to 100 years (Gustavsen & Jansson 2018).

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Elisabeth Sjödahl

DEEP LANDSCAPE

This thesis argues for urbanism not only to include the landscape, but also to actively include the other, unseen part of the landscape: the man-made underground. At a time when human actions dominate the urban geological ground conditions, and the reuse and transformation of terrain is becoming an increasingly greater concern, it is more important than ever to actively integrate the underground into the planning of urban transformation projects. This requires new approaches to perceiving the depth of the landscape setting we inhabit.

The thesis presents a design case to test the assumption that the urban landscape has depth. The design case, which includes daylighting a piped underground water system in a valley formally used as a landfill, demonstrates a need to design the visible and invisible underground landscapes as one. Landscape interventions on the surface affect the underground as much as they are conditioned by it. Taking this depth into account in planning is a necessity, and the thesis coined the term 'deep landscape' as a concept and a strategy for design.

Elisabeth Sjödahl is landscape architect, architect and urbanist. She holds a landscape degree from the Technical University of Catalonia (UPC) Barcelona and an architectural degree from the *École d'architecture de la ville et des territoires Paris-Est*. She is currently an Associate Professor at AHO and co-founder of a new landscape architecture program. Past teaching at the Royal Institute of Technology (KTH) Stockholm and the Technical University of València (ETSA). She has experience from regional landscape planning, private practice and is a founding partner of the office Worksonland. She currently carries out multidisciplinary research that explores human cultural, water and ground relations across scales.

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