Using Evidence Based Design to create Storm Water Management Solutions Supporting Human Well-being

– A case study approach

Användning av evidensbaserad design för att skapa dagvattenanläggningar som stödjer mänskligt välbefinnande – En fallstudie

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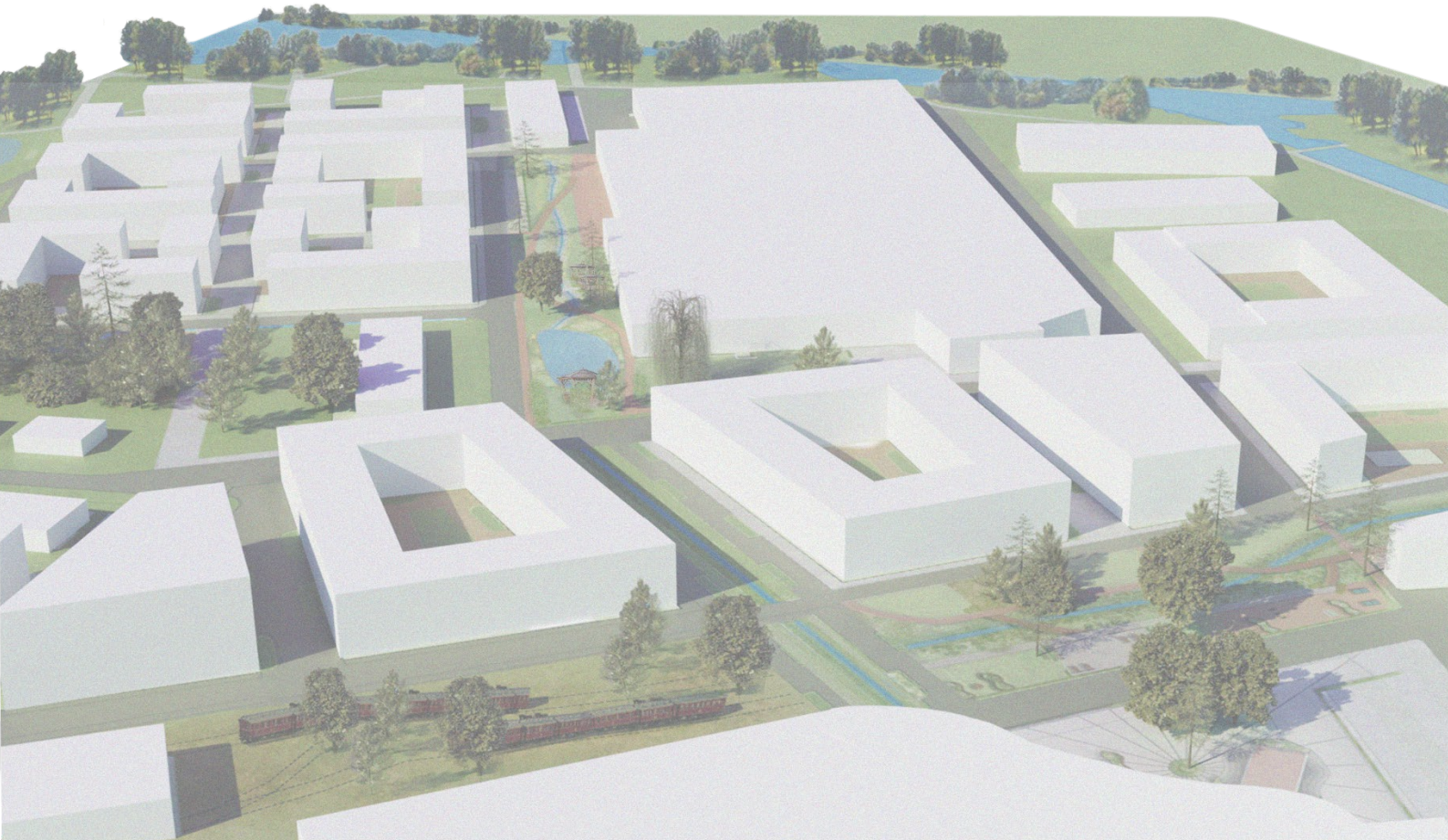

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Abstract

Climate change is expected to increase the intensity and frequency of precipitation around Europe which increases the risk of severe flooding in urban situations. As cities densify, the amount of infiltrateable surfaces in the cities reduces which also increases the risk of flooding. Open stormwater facilities are important but often take up space in the city. It's conceivable that blue-green infrastructure has to bring multiple values including stormwater management, biodiversity and human-wellbeing. The aim of this thesis is to explore the possibility to combine stormwater facilities and health supporting environments for people in residential areas. The goal is to implement current research within environmental psychology and stormwater management through a design proposal in Kristianstad's planned new area, Nya Udden.

This thesis investigates the opportunity to use evidence-based design (EBD) as a method to combine stormwater management and health-supporting green areas. The method is thus based on a literature retrieval, site visits and a design proposal where the findings are tested.

It was found that the use of EBD can facilitate the work and bring important guidelines in the design process. It is however important that the understanding for different EBD is clear and used in an appropriate context.

Bioswales seems to be an effective solution since it is a stormwater facility that both diverges, infiltrates and detain stormwater. It can also be incorporated in greenspaces and contribute to human-wellbeing. Water squares and retention ponds also provide values for humans and are an effective stormwater management.

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1. Introduction

Background

Climate change is expected to increase the intensity and frequency of precipitation across Europe in the coming decades (IPCC, 2021). The cities are also becoming increasingly densified, which results in a greater proportion of hardened surfaces leading to a higher amount off runoff in the event of precipitation (Strom et al., 2013). The combination of these factors increases the risk for severe flooding. This has been seen in Sweden the last year where cities have suffered a lot of material damages due to flooding. Severe cases of flooding are not only a risk for monetary costs but also for humans' life. In Germany, there was flooding the summer of 2021 that caused about 200 casualties (Horvatovic, 2021). Apart from the direct hazards from flooding, inadequate stormwater management also poses an environmental risk. Runoff water in cities collects pollution in the form of heavy metals, nutrients and debris which eventually can end up at the recipient (Marques & Hogland, 2001). City planners, landscape architects and the construction industry thus have an important role to play in adapting our cities to these new conditions, so that cities can become more resilient to the effects of climate change (Lindberg et al, 2020).

Space is scarce in cities and different actors and functions need to share that space. Parking lots, housing, offices, parks, roads, and stormwater facilities are some examples of functions that needs to be fitted in the city. It is conceivable that functions in the city should aim to fulfil multiple values. A blue-green infrastructure is a way to define and plan a connected network of nature and water as a functioning ecosystem within and/or outside cities. These ecosystems also provide ecosystem services such as water treatment, pollination, and recreation (Din Dar et al., 2021).

Moreover, the outdoor space could be designed to improve human well-being (Stigsdotter et al., 2017; Bengtsson & Grahn, 2014; Hartig, 2007; Grahn & Stigsdotter, 2002). There are several studies that explain the positive relation between green environments and human health. For an example did Ulrich (1984) proved in his study "View from a window" that patients with a natural view from

their hospital room recovered faster than those without natural views from their windows. Many other studies also show similar effects that nature has on humans (Stigsdotter et al., 2017; Bengtsson & Grahn, 2014; Kaplan, 1995; Bratman et al., 2012; Shin, 2007). Since stress and mental health conditions are increasing in Sweden, health supporting environments could be a public interest to combat the increasing trend. Even though mental health is affected by many factors, it is suggested by Ulrich et al. (1991) that urban environments can induce stress in humans as they are "hostile" in nature to humans as we evolved from the savannah and have specific preferences where we feel safe. This is an argument for why health supporting environments in cities could be beneficial to humans.

Kristianstad – Nya Udden

Kristianstad has a history of flooding due to its low altitude. Parts of the city are located below sea level and much of the city is right above sea level making it vulnerable to flooding. Both from the lake Hammarsjön and the river Helge Å that lies next to Kristianstad, but also from cloudburst. The summer of 2021 Kristianstad suffered heavy material damages due to cloudburst (Kristianstadsbladet, 2021).

A new residential area is going to be built in Kristianstad called Nya Udden. The area requires well thought out plans for water management. Kristianstad also sees opportunities for development of green recreational areas at sites that can contribute to human well-being and connect Nya Udden to the rest of Kristianstad.

Aim and purpose

The aim of this thesis is to combine the design of stormwater management and design based on research that explains the relation between green environments and human well-being in residential areas.

The goal is to implement current research within environmental psychology and stormwater management in Kristianstad's planned new area, called Nya Udden.

Research questions

- How can open stormwater facilities in residential areas be designed to add values for people's well-being based on research?

- How can this through a design proposal be implemented in Kristianstad's new planned area Nya Udden?

Method and material

This thesis is divided into three parts, a literature retrieval, site visits, and a design proposal. The literature study summarizes and discusses stormwater management solutions and research about the positive relation between outdoor environments and people's health. The collected literature will then form the basis and principles that constitute guidelines for the design proposal.

Literature retrieval

The literature retrieval aims to gather information and theories that are in line with the research question and are divided into two parts: green environments' effect on people's health and stormwater management.

The literature that are retrieved is retrieved in three different ways.

1. Literature that we know about
2. Literature that was suggested by our supervisor
3. Snowballing new literature from retrieved literature.

The first part in this thesis will provide literature within environmental psychology and humans' need in green environments. Focus will be on established theories that are based on research. The literature on stormwater management will mainly focus on identifying the basics of stormwater management and which stormwater management facilities that are proven to work.

Site visits

Site studies are conducted to complement the theoretical viewpoint of the literature study with practical knowledge and already implemented solutions. The goal of the site visits is to find examples where stormwater solutions work not only for stormwater management but also provide values for people. Data collection aims to identify different types of stormwater facilities.

The main criteria for the sites we chose for the site visits is that the site must be designed with water management in mind. With consultation with people within the field and our supervisor we got a few recommendations of sites to visit. Bo01 and Augustenborg are chosen for the site visits since they complement each other. Bo01 was designed with stormwater management from the start. Augustenborg had problems with flooding and therefore redesigned the outdoor environment to protect the area from further flooding. The last site that was selected is Rotterdam, Netherlands. The city is built below sea level and is exposed to extreme flood risks. The sites within Rotterdam that were examined were recommended by Scheltema that works at Rotterdam municipality.

The site visits take place in five different areas, two in southern Sweden, *Västra hamnen* (Bo01) and *Augustenborg*. The other three areas take place in Rotterdam (Netherlands), *Benthemplein, Bellamyplein* and *Natuurspeeltuin de Speeldernis*. The Netherlands has long experience of both stormwater management and architecture and can therefore be seen as a leading source of inspiration.

The site visits begin with an inspection where stormwater facilities are examined in each area. During the inspection, the relation between the stormwater facility and added values at the site are analysed. The literature retrieval provides the theories and tools to determine what is considered added values for people (Biophilia and PSD for instance). The stormwater facilities that provide multiple values are then summarized and further analysed with literature as support. Each site is presented with its stormwater function and how they relate to other added values with a focus on recreation and human well-being. Examining existing areas with different functions can inspire new projects. This can also be viewed as EBD (Brown & Corry, 2020). The design proposal is based on site specific analysis', material and guidelines from Kristianstad municipality, the findings in the literature review, and site visits.

Limitations

The design proposal aims to focus on EBD within the category green environments that promote human well-being and how it can be designed in combination with facilities of open stormwater management. Therefore, a detailed construction and capacity of the implemented stormwater facilities won't be presented on a deeper level such as collection volume capacity, substructures and materials, specific elevation, vegetation beds and water flow speed.

The implemented stormwater management is limited to the work area.

2. Literature retrieval

Evidence based design

When using research as a tool for design it's called Evidence-Based Design (EBD). The idea of evidence-based practices originates from medicine. Medicine practices must nowadays be grounded and based on research that proves the desired effect of the medicine. In landscape architecture the practice of EBD has mostly been implemented in different kinds of healthcare settings where the approach of EBD increased exponentially in recent years (Pilosof et al., 2021). However, there is a lack of use of EBD in public areas. Furthermore, some claim contemporary landscape practice is still to a large extent using beliefs rather than facts (Brown & Corry, 2011). It´s suggested, just like medicine, that landscape architectures must take the leap into evidence-based practice to design sites that are optimal for its purpose (Brown & Corry, 2011). There are certain models that have been developed based on research that aims to work as tools and guidelines in the designing process. The definition of EBD in this thesis means all research that can be used as a guideline in the designing process and is limited within the subject of stormwater and environmental psychology.

One shortcoming regarding EBD is that the method is more theoretically developed and isn't into some extent established in practical work (Bengtsson, 2018). In contrast Brown and Corry (2020) argues that by studying functional sites, one could conduct a study that convert the physical elements from a site into research which can later be used as EBD. Another shortcoming is that different models of EBD become too "hard" stencilled that it will be at the expense of a designer's creativity (Bengtsson, 2018). Other limitations of the EBD are that it can be a time-consuming process since many landscape architects isn't trained to work with EBD. Moreover, sometimes projects are too complicated or too simple for the use of EBD (Brown & Corry, 2020). Decisions about different design proposals are most often influenced by lack of time, limited resources and policies (Hamilton, 2003). When EBD is used in the "right way", it could instead save time (Phiri, 2015). A basic strategy when designing an outdoor environment is to always start from the

conditions of the site. Research from EBD needs to be in line with the intended design. It´s up to the designer to make decisions about which research may be relevant in the use of EBD.

Green environments effect on people's health

Blue and green urban settings both have a restorative impact on humans and can be seen as providers of psychological health services. One explanation could be that nature elements contributes to the feeling of "belonging to some-thing greater than oneself" (Bratman et al., 2012; Antonvsky, 1991). It also invites to social contexts and activities. There are thus good reasons why to investigate and maintain both blue and green urban settings (Subiza-Pérez et al., 2020). This chapter will mainly present the relation between green environments and health based on basic theories and models within research (EBD). Design with blue urban settings means in this thesis stormwater facilities. There is a lack of specific research between human health and stormwater facilities. Therefore, later in this thesis, research that explains the relation between green environments and human health will be analysed along with stormwater facilities at site visits (see chapter *Site visits*).

Stress recovery theory and Attention restoration theory

The relation between green areas and health promotion is mainly derived from two theories, the Attention Restoration Theory (ART) (Kaplan, 1995) and the Stress Recovery Theory (SRT) (Ulrich et al., 1991). The ART is explained by the direct attention that is energy consuming and the fascination that isn't energy consuming. Direct attention means that your focus needs concentration, it could be things like driving the car, excluding disturbing sounds, making decisions in your working life and so on. Since direct attention consumes energy there is a possibility that it could lead to mental exhaustion if there is no or less recovery from it. The fascination on the other hand could be a way to find recovery from an energy consuming day since it catches your attention without requiring a focused attention. The fascination is divided into two categories, *soft fascination* that lightly catches your attention and *hard fascination* that fully catches your attention. Soft fascination could be the sound of rippling water or swaying branches from trees and are often experienced when spending time in green natural environments. Hard fascination could be things like watching a concert or an exciting football game. Being in danger also triggers hard fascination. During evolution, survival has been more beneficial in response to sudden events compared to the ability to maintain concentration for a longer period. Therefore, we are much more sensitive to direct attention compared to fascination. (Kaplan, 1995).

The SRT is described even further back in the history of human evolution. It holds affective responses that have categorized humans due to survival. Examples of affect-controlled signals are fear, anger, and joy. Humans have been shaped to react in certain ways for survival purposes depending on the environment. SRT can therefore explain why some environments or events are threatening (stress) to our well-being. These imprinted effects have also led to humans creating preferences for certain environments. Water is in general an appreciated element, an explanation could be that water during human evolution has been crucial for survival. Urban settings are in general quite far from our natural preferences since they often lack green areas and many dangers like cars and unknown people are always present, which is why they could induce stress in people when never getting the chance to leave for their "natural habitat". This could put people in a permanent "fight or flight" mode (Ulrich et al., 1991). The SRT has been confirmed to be credible in different settings like prisons, schools, workplaces, and residential areas (Thompson et al., 2012; Moore, 1982; Shin, 2007).

Perceived sensory dimensions

The ART and SRT forms the foundation for further studies where the relation between green areas and health promotion has been explored in different contexts. Grahn and Stigsdotter published a study in 2010 where eight Perceived Sensory Dimensions (PSD) were presented with stress recovery qualities (Grahn & Stigsdotter, 2010). People in general prefer the dimensions, *serene, space, nature, rich in species, refuge, culture, prospect* and *social* in a green urban environment. The result has become an important platform for further studies and has been used as a tool for especially health garden design and in healthcare settings (Stigsdotter et al., 2017; Bengtsson & Grahn, 2014). PSD like *serene, rich in species*, *nature* and *refuge* has been rated as the most *restorative* among people that suffers from stress (Stigsdotter et. al., 2017; Bengtsson & Grahn, 2014). Moreover, PSD like social and culture can instead be seen as *instorative,* which means they are developing instead of recovering (restorative). It could for instance be an environment that supports learning something new and in a curious way discover the surroundings (Hartig, 2007).

The use of the eight PSD in a green area could cause contradictions since some PSD tend to stand against each other. A place that is secluded and protected (serene, refuge and natural) doesn't always align with a place that is social and cultural. Therefore, the size of the surface matter when implementation of the PSD is used as a tool for design. Stoltz (2019) presents a PSD-model (some concepts of the original PSD are changed) in a *color-wheel* that shows the relation between the

different PSD and how they stand against each other. The model can be used as a tool when analysing space and different PSD values (figure 1).

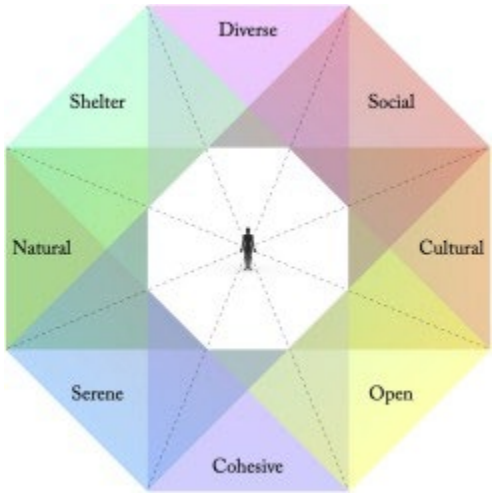

Figure 1. Color-wheel that shows the relation between the 8 PSD (Stoltz, 2019).

Biophilic design – 14 patterns

Scientists and designers have for decades worked with different aspects in order to identify the positive relation between nature, human biology and the built environment that seem to have a positive impact on humans. Biophilia is the innate biological connection between man and nature. The phenomenon explains for instance why natural incidents such as why crackling fire captivates us and why gardens can have restorative impacts on human health. Moreover, biophilia explains why nature can reduce stress, increase creativity, mindset clarity, and improve our well-being. Even though the concept of biophilia has been around for thousands of years with ideas like The Garden of Eden and The Hanging Gardens of Babylon the term biophilia made a breakthrough by Edward O. Wilson in his book "*Biophilia*" (1984). He suggests that biophilia has had a significant role during evolution. The better the environment is for survival, the stronger our bond is to that type of environment. Even though the theory of biophilia is widely accepted there are critiques. De Block and Joye (2011) claim that much of the conceptual and empirical work of biophilia is sloppy and the idea has been accepted in both popular and academic literature without much critique on the concept. De Block and Joye (2011) don't, however, deny that the love of life (biophilia) has had an impact on evolution but rather states that the idea is greatly simplified. Throughout history biophilia is also reflected in architecture where different buildings have been inspired by the forms of nature. Furthermore, biophilia may help to explain why certain parks or buildings are more satisfying over others (Browning et al., 2014).

Browning et al. (2014) presents 14 patterns of biophilic design based on patterns known in nature that somewhat are theorized or suggested to be restorative or improve desirable qualities in different contexts. The human connection with nature is vital to maintain a healthy environment that characterized humans through evolution. Therefore, these patterns can work as a tool that implements biophilia in the urban situation and contribute to a healthier environment (Browning et al., 2014).

Biophilic design provides a useful toolbox when designing. Each pattern gives examples of elements that can be incorporated in the design to achieve different goals in the design. All patterns are not relevant in this thesis, therefore a selection of relevant patterns is presented in the table (1).

Biophilic patterns	**Example**
Visual connection with nature (pattern 1)	Seeing natural elements such as flowing water, insects, animals, trees, and plants have a calming effect on humans.
Non-visual connection with nature (pattern 2)	This pattern includes all other senses except the sight. Auditory, haptic, olfactory, gustatory. This could be hearing rustling leaves in the wind, petting an animal, or tasting berries.
Presence of water (pattern 5)	Introducing water to a site provides a calming effect. The water should be unpolluted. High turbulence water can in contrast be perceived as dangerous and discomforting.
Biomorphic forms and patterns (pattern 8)	Oragnic patterns and forms are preferred by humans over straight lines. They seem to captivate our interet and makes up comfortable.
Refuge (pattern 12)	Just like in PSD, this refers to a "safe" place where one could feel separated from the surroundings.

Table 1. Biophilic patterns.

An important pattern for the design part is the presence of water (pattern 5). This pattern suggests that the visual connection with water could be both relaxing and stimulating, reducing both blood pressure and heart rate (Browning et al., 2014). By creating open stormwater management, making the water management systems visible in the urban context could therefore be a way to increase restorative values in the cities. Open stormwater management will however not always consist of presence of water and give the same value as a lake or the sea. But it could still constitute elements of water that have positive effects.

Using EBD in residential areas – from a health perspective

There are several aspects of the ideal design in residential areas. Sometimes these aspects become complicated and difficult to meet since there are many interests that should interact with each other. It could be interests like roads and traffic, buildings, stormwater facilities, green areas etc. Beyond this, the green areas also contain demands of functions such as biodiversity, places for children's play, venue areas, design for different target groups, a feeling of safety, accessibility etc. It is thus difficult to meet all different types of requirements, which means that it is at the expense of a fully functional design within each category, not least green environments. EBD needs to, as mentioned earlier, look at the site's needs and target groups to determine what type of research that's relevant to apply to get the desired outcome. Theories and research, that is mentioned in the previous chapter, should be used in the right context to get a desired outcome. In this chapter, the use of EBD will be discussed from a well-being perspective in relation to residential areas.

The four roles

Eva Kristensson (2007) discusses the use of the residential yard based on four roles, the *living room*, the *view*, the *playground,* and the *venue*. Local parks and residential yards can provide equal values and functions. Depending on the size of the residential yard and local park they can fit more or less the same values and functions. Therefore, it's important to look at green areas in a larger perspective so that the park and residential yard can complement each other and provide values that the other entity is missing. This thesis chooses to start from the four roles when discussing the residential areas and will work as a guideline to define different users and needs at a site. However, an important difference between the residential yard and local parks is the privacy level and the accessibility. Access to local parks is suggested to be within 300 meters of the dwelling (Kristianstad kommun, 2019). It is thus located further away from the dwelling and is more public compared to the residential yard. A residential yard however is more private and can therefore be more suitable when designing a restorative space for instance. Local parks have in general better conditions to implement or maintain large vegetation compared to smaller residential yards since large trees cover sunlight and view from windows.

Living room

The outdoor living room can be described as an area for recreation and activities that´s compared to the experience in an ordinary villa garden. It could be activities like barbequing, picnic, hanging out with friends/family, enjoying the sun, cultivation etc. However, to fulfil appreciation and the experience of these activities, spaciousness has shown to be a central factor. There must be enough space to implement different kinds of functions and values, thus there should also

be space between these, otherwise a feeling of intrusion can occur (Kristenson, 2007). As mentioned earlier, Stoltz (2019) presents the PSD in a color-wheel and how they stand against each other, which means that all PSD could be difficult to fit in if the surface is limited. Moreover, Brown (2008) also claims that the diversity of park values decreases with the size of the park. These findings are all in line with each other. Unfortunately, many residential yards and local parks often have limited surface. It is thus a challenge to design and fulfil functions and values which is fully based on principles of EBD. However, smaller green areas are still better than no green areas at all (Browning et. al., 2014). A proposal to achieve functions in the residential areas is to prioritize the most important needs and design for them. In case of several local parks that exists near by a residential area, it's important to connect the accessibility between them. Moreover, an option could be to give different characters in different areas (local parks and residential yards). For instance, one area might focus on children's play and social/physical activities, another area could aim to be restorative with PSD as refuge, serene, rich in species and nature. The use of biophilic design claims that biodiversity (same as the PSD rich in species) is more important than the quantity of plants/green space (Browning et. al., 2014). Thus, space is not always the most important factor. Good creativity and quality in the design may have a great impact on the experience at the site.

When designing a residential yard, private outdoor areas are significantly appreciated, or if no private areas, at least clear room division that contribute to a cosier remote place where a feeling of not being too exposed can occur (Kristensson, 2007). This explanation can be compared to findings in health gardens where a combination of PSD serene, rich in species, refuge and nature are determined as the most restorative. More specifically these PSD can be described to be a place with a view and presence of an enclosed and open area and diverse sensory experiences with an entrance consisting of a dense vegetation (Stigsdotter et. al., 2017). However, the research has generally been tested on people with stress-related ailments or diseases. But since stress is an increasing problem in Sweden (Folkhälsomyndigheten, 2021), implementation of remote cosy areas in residential areas can be seen as a suitable quality in the outdoor environment. As mentioned before, residential yards might be more suitable since that kind of green area in general is more private, enclosed, and safe compared to local parks.

View

It´s demonstrated that green views are more restorative compared to a non-green view (Ulrich, 1984). But when to compare different kinds of green views and preferences in the design, different aspects can be discussed. Kristensson (2007) summarizes that a nice view in the residential yard should be well maintained,

consists lots of green, especially vegetation of garden nature (fruit trees, berries, flowers etc.) and have a well thought out design.

What characterizes the view of the residential yard is that it is visible every day all year around where people live, and it is often seen from a window, balcony or the patio. As soon as you step outside the door, the view becomes something more than just a vision. Studies show that the positive experience of nature is much more than a view, it is what´s perceived with all your senses, especially the sound and smell (Li, 2018; Grahn & Stigsdotter, 2010; Cerwén et. al., 2016).

When designing a view towards a green area based on biophilic guidelines (Browning et al., 2014), as mentioned earlier, the green area should contain as much wild nature as possible that consist biodiversity (PSD, rich in species) (Grahn & Stigsdotter, 2010). As a secondary option simulated nature can be used when wild nature isn't possible. Even if a small proportion of the residential yard or local park is green, it is still better than nothing. Human seem to appreciate biodiversity above quantity of green space. Therefore, a variety of species should be considered when planning for vegetation and plantings (Browning et al., 2014). Furthermore, it is good to uphold preferred view lines from different positions, especially from a seating level (Browning et al., 2014). The view towards the housing area should also be designed in a way that gives view qualities all year around, this often means a well-planned choice of plants and a well functional light setting that gives opportunities to experience a place even though its dark. Furthermore, light contributes to orientation and a feeling of safety (Fuxén & Fagrell, 2015).

Venue

The social context is central for the experience of the residential yard. If the social environment isn't comfortable, it's hard to enjoy the site. The residential area is also a place where the neighbours either intentionally or deliberately encounter each other. Usually, people appreciate good communication with their neighbours as it creates well-being and safety in the area. But the desire to be able to regulate communication yourself is important (Kristensson, 2007). The design of Alnarp rehabilitation garden is based on a theory of Aaron Antonovsky (1991) that highlights the importance of a human's experience of a feeling of a context. This is consistent somewhat with Kristensson that also mentions that activities in the residential yard can strengthen the community for the residents. Furthermore, it should offer, as mentioned before, different kinds of activities and have regular events that give a use of the residential yard. Well-designed entries that open opportunities for meetings are also important (Kristensson, 2007). As a landscape architect, it could be difficult to plan for certain events and to know what kinds of

activities that is wanted in the residential areas. Dialogs with the locals are therefore crucial in order to find out these answers.

During the last decade, the interest in cultivation has increased a lot since organic and local produced food is on the agenda. Cultivation also has been used as a therapy activity in healing gardens and has shown good results in relation to increased well-being (Grahn & Stigsdotter, 2002).

Playground

Children seem to create preferences for nature during a limited time in their childhood and are mostly connected to the landscape type they had growing up. For instance, children that spent their childhood in an urban context doesn´t to the same extent have the same positive relation to more wild natural environments. Many children grow up in urban areas and as a landscape architect, it's important to think of what preferences for nature that can be made for these children (Adevi, 2012). Therefore, it´s important to focus on the playgrounds and the design in general in residential areas since it affects the children's preferences and thus the understanding of nature. Malmö, in Sweden it has been highlighted how cultivation can be used as a creative activity for children. Cultivation can be a way to teach the children about how things grow and on the same time open for social activities. The senses and interests to explore the soil, plants, compost and much more increased among the children. The cultivation was especially valuable to those children who find it difficult to focus in the classroom (Bergemalm, 2019).

Children need to be given opportunities to play because it is important for the child's personal health development (Jansson, 2013). Even though playgrounds have become much more prioritized in urban settings since the middle of the last century, there has been a setback and reduction in playgrounds in recent decades. Underlying reasons are limited economic resources and that the planning standards 1987 were removed from the planning and building law (plan- och bygglagen) if increased safety standards were introduced. Since children prefer to investigate and create their own playground, it is discussed if the playground should be more a free space for children to explore rather than a constructed playground (Jansson, 2013). But free spaces in combination with a densified city forces playgrounds into a limited area. Furthermore, the playground must face other challenges such as accessibility and how to meet different target groups. The last trend is to create fewer but larger playgrounds and sometimes in combination with other interests like barbeque-areas and football fields. However, when smaller playgrounds are removed, fewer local playgrounds nearby are available, which could lead to less play opportunities. In these cases, it´s important to offer other types of areas that could work as a playground, for an example green areas with vegetation and open

space. To create useful playgrounds or areas for play in a residential yard, it's important to understand the context and relation with other local playgrounds (Jansson, 2013).

Märit Jansson (2013) mentions three main aspects that should be considered when designing a playground:

- To find opportunities for physical challenges
- To be able to have an impact and change things
- To be able to find new places or create one that's calmer and not focused on a physical challenge.

Natural environment is often appreciated by children and contributes to meet these designing aspects. It's important though that the vegetation can withstand wear from the children. A physical challenge in a natural playground could be to climb a tree, lose materials like stones and sticks can work affordances to build and create something new. Also, with vegetation it´s possible to find spaciousness that can create different zones.

Furthermore, the playground isn't just a place for children's play, it could also be a place for a venue (Kristensson, 2007). Adult people at the playground are usually parents or kindergarten teachers. Qualities like, opportunities for the adult to join the play, seating areas and proximity to the playground are important factors. If the adults like the playground, it's more likely for them to regularly visit them which also increases play for the children. Considering playgrounds for kindergarten kids, it's important that the surface isn´t too small, and the walk from the kindergarten to the playground should be not too far away and friendly to walk (Jansson, 2013).

Other aspects to be considered when designing playgrounds is to make sure it's not too exposed to the sun, it should be durable, useful all year around where each season can be taken advantage of and have different options for play that suit all ages (Jansson, 2013). As mentioned before, the security aspect has become carefully developed in order to avoid children getting hurt at the playground. Risks and security aspects are however something that can be discussed and looked at from different perspectives. Japan for instance, use water as an element creatively in play environments (Wennerström, 2019). The risks are seen as a positive part of the children's development. They are allowed to play by the water but under the supervision of an adult. Furthermore, the natural environment gives the children opportunities to explore small creatures that in the long term gives them understanding for nature and the circle of life. Here in Sweden, water among children is mostly seen as something that is too dangerous (Wennerström, 2019).

Stormwater management

Flooding due to cloudburst have increased exponentially during the last years. The main reason for the flooding and the damages followed is caused by the increased hardscaped surfaces due to urbanization. The hard surfaces exclude natural infiltration, and the water is led with high velocity to wells that can't handle a large amount of water, which causes flooding. Flooding's are expected to increase even more with predictions of increased frequency and intensity of cloudburst due to climate change (IPCC, 2021).

Historically the main goal of water management has been to remove the stormwater runoff from the site to the recipient as quickly as possible to protect the local site. This has been done by directing all water to the drainage system, swales or just to the closest water body. This has had negative effects on the water quality and the environment. More modern ways to handle surface runoff is to retain the stormwater with open stormwater facilities on site (Strom et al., 2013).

There are different strategies to handle stormwater in urban areas. One way is to collect water on-site in basins. This can be done by either retaining or detaining (explained later in this chapter) the water, reducing the water quantity later downstream. The water can also be collected on site to be used as a resource, like for irrigation. Another strategy that doesn't involve collecting the runoff water is infiltration, letting the water soak into the ground. Some of the infiltrated water continues to runoff horizontally (subsurface runoff) and some continues down vertically which eventually refills groundwater deposits. Since infiltration both refills our groundwater as well as reducing the surface runoff infiltration is viewed by many to be the best method to manage stormwater and should be used when possible (Ferguson, 1994).

The infiltration rate is mainly affected by two factors. The slope of the surface and the soil structure. The steeper the slope on a surface the less water has time to infiltrate into the surface before it runs off. Soils with larger pores (like sand and gravel) have a higher infiltration rate than soils with smaller pores (like loam and silt). Problem is that cities are built mostly by non-permeable surfaces which hinders the infiltration (Strom et al., 2013).

It isn't the total amount of rain that affects whether there is a flood or not, but the volume of rain during a time period, it is called rain intensity. A light rain for a long period can generate just as large volumes of water as an intense rain for a short period. The high intensity rain are the rains that most often create problems in cities when the water doesn't have time to drain away.

The graph (figure 2) shows two rain runoff curves. Any runoff above the dashed line will not be able to be taken care of on site and results in flooding. Both curves represent the same high intensity rain, but the red line shows how the runoff would be in a hardscaped environment with little stormwater facilities. The green line shows how the runoff could look with stormwater facilities on the site. The goal is to reduce the peak flow and get a lagging curve. Methods on how to reduce peak flow is presented later in this chapter.

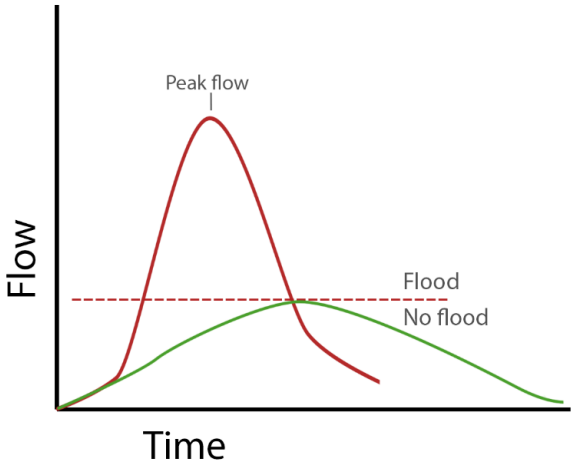

Figure 2. (Härstedt, 2021).

There isn't only a need to manage the amount of water, but also the quality of the water. In the event of a cloudburst in urban environments, the first surface runoff contains the highest concentration of pollutants. The longer the rainfall lasts, the lower the concentration of pollutants in the runoff occurs as the pollutants have been washed away at an early stage. This phenomenon is known as the "First Flush". It is important to handle the water during the first flush in an efficient and safe way so the pollutants aren't spread out to the recipient. The runoff water carries pollution in the form of sedimentation (sand, silt), heat, and soluble particles. By planting vegetation in the way of the runoff, the velocity of the runoff decreases, and the water loses its ability to carry larger particles like sedimentation, dropping these particles. A narrow lawn that is placed before a well or infiltration facility (filter strips) is often sufficient to reduce the amount of pollutants to reach the drainage system (Strom et al., 2013; Lange et al., 2021). Some of the soluble particles, like nutrients and heavy metals can be absorbed by the plants root system, stopping them from reaching natural water bodies like streams and lakes and polluting ground water (Lange et al., 2020). Infiltration systems are also effective to reduce the number of pollutants in water. When examining the long-term evolution of infiltration basins, Denchesne et. al. (2005) found that even after 21 years of operation, the measured infiltration basin had acceptable levels of pollutants at a 30 centimetres depth. It is however unclear how much pollutants that have infiltrated down to the ground water along with the infiltrated water. Most of the pollutants are stored in the top layer of the soil. Apart from treating the water quality, the plants will also store water in its roots, trunk and leaves making urban vegetation an asset in stormwater management (Strom et al., 2013).

Open stormwater management – Design strategies

Open water management systems focus mainly on retention or detention and water quality treatment but could also, as mentioned before, bring other added values like an improved biodiversity and social health values. Since the open water management is officially visible, it also brings an understanding in a pedagogic way that highlights the importance of water management (Stahre, 2004). From a landscape architect point of view, there is room to be creative in order to fulfil several values, especially the social and aesthetic ones. However, construction of stormwater facilities are costly and therefore certain success factors need to be considered before it´s built. One important step is to first identify the need of the site and then what purpose the facilities should serve. Which functions are desirable, perhaps it could be pollution reduction or delaying according to Blecken (2021). The site should be in focus when planning for stormwater solutions. By being aware of the conditions of the site and allowing the design of the facility harmonizing with these, the chances increase of creating a facility that operates over time. The site also needs a well thought out technical solution, otherwise the desired outcome might not be reached. For example, are the facilities going to have a permanent water surface or dry up between the rains, aspects of accessibility, safety, and maintenance. A lot of thing need to be planned and well thought out, communication issues can often be a weakness. Dialogue between different technology areas should be started in the early stages of the project, already when the basic design principles and the technical structures begins to be defined according to Blecken (2021). In this chapter, focus will lay on to present open water management solutions that can be applicable in residential areas.

Green roofs

Green roofs consist of a growing medium and vegetation, often sedum plants. They support a habitat for plants to grow on the roof of the building structure while the protect the underlying structure (Strom et al., 2013).

The runoff retention is significantly affected by the slope degree. It´s important that the slope isn't too steep or

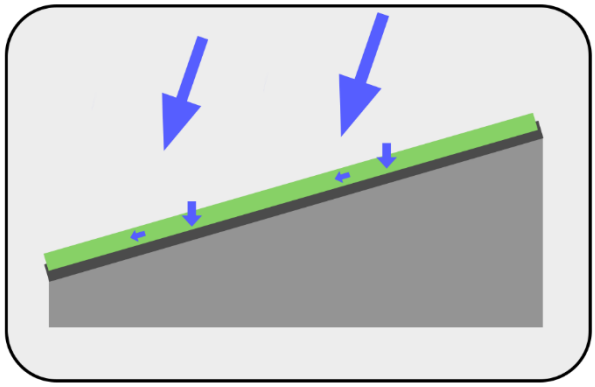

Figure 3. Runoff and infiltration on a green roof (Härstedt, 2021).

almost no water will be retained. The water absorption capacity is during a longer period able to absorb 50 % of the rainfall. However, during longer periods of rainfalls and cloudburst the green roofs absorption capacity gets significantly limited, but the the flow peak will be reduced according to Blecken (2021). Green roofs also have an isolated effect on buildings and improves the microclimate. Normally the roof water is directly led to the drain system from the drainpipe. However, infiltration of roof water on lawns can simply be done by adding a downspout disconnection. It's also important to remedy the abundance of water through a well that goes to the drain system (Stahre, 2004). Green roofs also have a certain pollution reduction. In addition to the green roofs' ability to delay water, they are also often used for aesthetic values for roofs that are visible from above, which can be seen as a restorative effect (Ulrich, 1984; Blecken, 2021).

Permeable pavements

Permeable pavements are used to slow down stormwater runoff and often have a substructure of slightly coarser material such as gravel and hollow stone made of concrete or permeable asphalt coatings. The use of permeable asphalt has been shown to have a lifespan of up to 15-20 years with little maintenance if the street/ road is moderately trafficked. The coarser material infiltrates the water and leads it either to a suitable drainage system or back to the ground. It´s important that the slope isn´t too steep, as the area for infiltration is limited and the risk of clogging increases. When permeable pavements are built on private land, there is often a lack of maintenance and clogging that deteriorates the infiltrator ability are therefore common. Regular maintenance is necessary and usually involves vacuum cleaning and high pressure washing (Blecken, 2021).

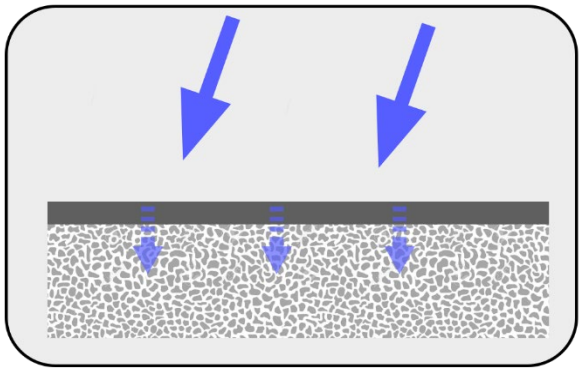

Figure 4. Runoff and infiltration on permeable pavements (Härstedt, 2021).

Detention basin

Detention basins can be designed in different ways. One type is magazines in the ground that is filled with a coarser material. Another could be an open basin

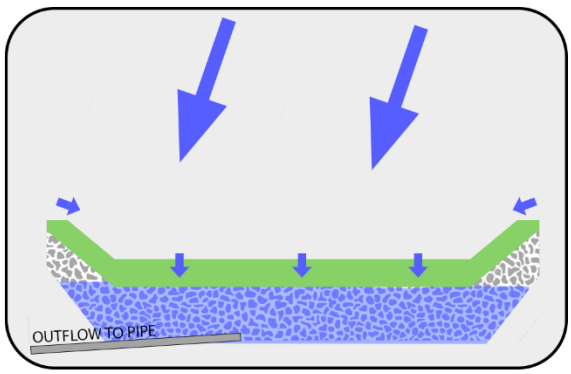

Figure 5. Delay in a detention basin (Härstedt, 2021).

that can fill up. They aim to delay the stormwater but could also have some pollution reduction functions (Blecken, 2021). The absorption capacity of water is relatively limited, but the construction can for instance be useful for flood protection and smaller dimensions of downstream sewers (Blecken, 2021). Drainage of the water takes place by returning it to the ground (percolation) or diverted through an adapted drainage system. As with permeable surfaces, settlements are a common problem. Clogging can be minimized when using non-woven fabric, filter strips, or a well-designed filter well, then the lifetime can be significantly increased (Stahre, 2004).

Swales

Swales is a shallow ditch system that normally consists of a grass-covered surface. The function is often a combination of an infiltration surface and an open diversion system. It is important that the slope of the swale isn´t too steep as machine lawnmowers need to be able to access it. At the downstream end of the ditch, it is recommended to place a dome well that in case of overflow can lead the water to a drainage system. In special cases, the swale can be designed with a hard bottom that reduces the risk of damage from erosion when the flows are strong. Due to the soil characteristics and sedimentation in the stormwater, detention basins are sometimes constructed underneath the swale. This intended to function as a temporary infiltration surface (reservoir) before the water infiltrates into the ground (Stahre, 2004). Since the swale usually consists of a slightly sloping lawn (with no water), there is lots of possibilities to be creative and create a place that also support social and recreational values.

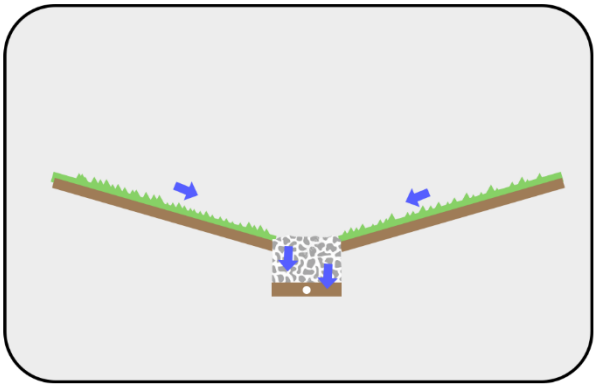

Figure 6. Infiltration and delay in a swale (Härstedt, 2021).

Retention pond

A *retention pond* with a permanent water mirror is designed entirely depending on the surrounding environment. The detention pond has many other added values that are both recreational and promote biodiversity. A retention pond also has good pollution reduction effects. But the management aspect is considerably more extensive. Furthermore, the safety aspect needs to be considered. The pond bottom should be flat. It may also be appropriate to set up fences in some places or separate the pond with vegetation. In contrast to detention basins, retention ponds bring a presence of water to a site even during dry periods (Stahre, 2004).

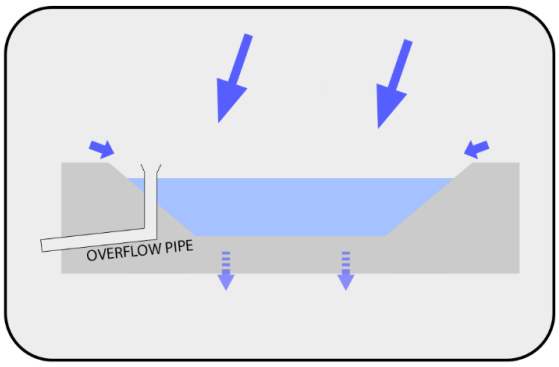

Figure 7. A retantion pond that can overflow and lead on the water (Härstedt, 2021).

Bioretention

Bioretention, also called *raingardens*, are a very appreciated construction among landscape architectures because it often contains aesthetic values such as plants. It's important though to choose plants that could manage both dry and wet seasons. Pollution treatment is the main reason why to build a bioretention from a stormwater management perspective. The plants and the filter material have shown good qualities of pollution reduction. Clogging could be a problem, therefore it´s good to have something that partly collects the sediment that comes with the stormwater. It could for instance be a filter strip or a pile of coarser material that reduce the velocity of the runoff. With time clogging will appear anyway. However, in order to remove pollutions that have been collected in the bioretention, the biofilter sometimes must be replaced. When this is done, it is also a good opportunity to add new plants. Bioretention has a very limited delay effect. It could function a one-year-rain, but usually no more than that (Blecken, 2021). Bioretention can also mean retaining water inside of the plants body (Strom et al., 2013).

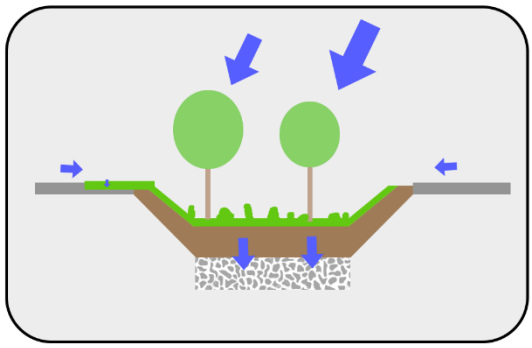

Figure 8. Infiltration and runoff to a bioretention area (Härstedt, 2021).

Bioswale

Bioswales are a combination between a bioretention facility and a swale. Essentially, they are a swale with a biofilter that reduce the runoff velocity and provide vegetation that can further treat the runoff (Irvine & Kim, 2018; Blecken, 2021). Bioswales are often used in urban contexts and are therefore generally smaller than a swale. Making it hard to distinguish from a raingarden.

Floating treatment island

Floating treatment islands can be implemented in existing ponds to improve the cleaning ability of e.g., nutrients and metals. It also has a habitat function which also brings recreational and biological values (Calheiros et al., 2020). The *Floating treatment islands* isn't yet very common in Sweden according to Blecken (2021).

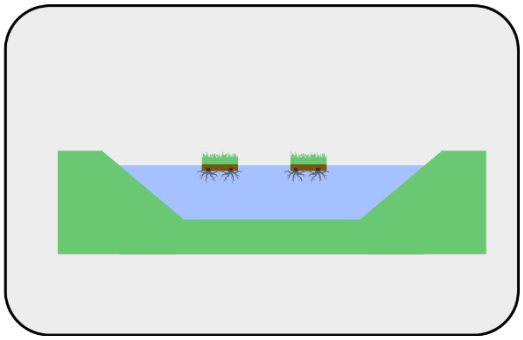

Figure 9. floating treatment islands (Härstedt, 2021).

Filter strip

Filter screens act like a treating screen before the runoff water runs into a stormwater facility. The purpose of the filter strip is to partly slow down the water. As the water's velocity decrease it also lose its ability to hold larger sediments. The sediments are then released onto the filter strip instead of going into the stormwater facility which decrease the risk of clogging (Yu et al., 2013).

Stormwater channels

Stormwater channels may be suitable for construction, especially in hardscaped environments with topographical conditions that require an open stormwater system. However, they are costly and need to be carefully designed so that they don't constitute barriers and accident risks. Furthermore, the canals are rarely filled with water, which can be seen as a disappointment to people that live in the local areas. In addition to this, the canals also collect some rubbish, which means regular maintenance is needed (Stahre, 2004).

In addition to the facilities listed above, there are also stormwater facilities that consist of a slightly larger open facility that can advantageously be integrated into larger parks or nature areas. Examples of such facilities are wetlands, special floodplains, and large delay dams. These types have a significant cleaning effect compared to ponds for instance (Stahre, 2004). However, they won't be presented

more specific here since this thesis focus on stormwater facilities that can be used in residential areas.

3. Site visits

The purpose of the site visits is to collect inspiration from different kinds of stormwater solutions and look for added values that they can provide with a focus on recreation.

Bo01 – Västra hamnen

Figure 10. Bo01 in Västra Hamnen (Lewin, 2021).

2001 Malmö hosted a housing exhibition to showcase a top modern new district in Västra Hamnen. The whole district was supposed to be ecological, self-sufficient and climate neutral. Bo01 was also a pilot project for further development with innovative environmental solutions. Today the area has grown to become one of the most popular residential areas in Malmö. Bo01 was chosen to be one of our site visits because of its philosophy on stormwater management. The goal of the stormwater management at the site is to have an open stormwater system. This would expose the water to the residents and give extra values like increased biodiversity and better well-being for the residents. When Bo01 was in the planning phase there were discussions of how it could be appealing. The result was a large

Figure 11 Bo01 Locations (Härstedt, 2022)

focus on water, vegetation, light and art (Malmö Stad, 2003). This led to a stormwater system that was put on surface level to expose the water to the residents. Most roofs are green, reducing the runoff to the ground. The runoff water leaves the roof through drainpipes that leads on to gutters placed along the streets in the area. The water is directed through the gutters to retention basins or bioretention basins that later in this thesis are referred to as *water points*. Those are spread out through Bo01 and aim to have multi-functional purpose. The water is then lead from the water points to the recipient (Öresund) or the saltwater canal that runs through Bo01. The saltwater canal is then connected to Öresund.

Water points

Spread out over Bo01 there are so called *water points* that works as retention basins which is purifying the water and retains it before it moves further in the water management system. There are two types of water points, lesser points and greater points. The greater points are larger and works as smaller parks/squares and are places for staying (figure 12). The lesser points are smaller raingardens that are spread out across the area, sometimes alone and sometimes incorporated in other plantings.

Figure 12. (Lewin, 2021).

In general, Bo01 doesn't have any filter strips that capture stormwater sediments from the streets. Instead, the pollution is flushed into the raingardens. Problem is that they can easily get clogged which requires change of the biofilter frequently and is also costly.

1. Grassland

This waterpoint is one of the most hardscaped waterpoints in the area. Half of the waterpoint is gravel, the other half is different kinds of rocks. There's fountain on the rocky side with a stone pillar in the middle. Here the water can flow and create a rippling sound. Almost all the vegetation on this site are different kinds of grass.

Figure 13. (Lewin, 2021).

Additional values for people

Even though most of the site have hard materials it doesn't feel like an urbanised area. Instead, it feels like an oasis in contrast to the hardscaped surroundings. The fountain has very prominent biophilic value (Browning et al., 2014). The tall boulder (figure 13-14) has a natural rock surface (biophilic pattern 1). The water (biophilic pattern 5) runs with a rippling sound (biophilic pattern 2) from the top of the boulder, down into a carved-out canal on the rocky ground. The canal has an irregular shape (biophilic pattern 8) which gives it the look of that the water have been eroding the canal naturally rather than man-made. This can create a sense of soft fascination (Browning et al. 2014; Kaplan, 1995).

Figure 14. (Lewin, 2021).

We judge that the strongest PSD are shelter, natural and serene. Even if these values are the most prominent, they are not strong enough to make the site considered as fully restorative. One explanation is because the site is too small and exposed.

Lessons learned

- The stormwater retained in the raingardens can be used in water art to create a more pleasing environment. This can provide comforting sounds as well as aesthetics.
- High grass can provide a soothing sound that mask noise. Which goes in line with findings in research (Cerwén et. al., 2016). If planted in the water it can provide water treating functions as well (Lange et al. 2020).

2. Flooded lawn

This water point is the most naturalistic one (figure 15). The area is only 8x8 meters which makes it the smallest one of the ones included in the site visit. Half of the area is covered in grass that slopes down into a raingarden with a pond. This also allows the lawn to flood during cloudbursts. The park is bordered with a 40 cm high concrete wall.

Figure 15. (Lewin, 2021).

Additional values for people

Even though the waterpoint is tiny it still provides a few different functions without feeling cluttered. With the varied vegetation and the dead wood on the lawn the site feels very natural (biophilic pattern 1 and 5) (Browning et al., 2014). Like it is cropped out from nature and placed in Bo01. The pergola is one of two" man-made" constructions on site and offers a walkway out above the water, giving a feeling of connection with the small piece of nature. The site has good stormwater management values and provides a restorative view when passing or maybe even when sitting under the pergola. The site is too small to define most of the PSD values. But the PSD rich in species and natural can be seen to some extent.

Lessons learned

- Lawns can slope into a raingarden for a naturalistic design
- A pergola extending out above the water creates a connectivity to the waterscape.
- Little nature is better than no nature and a small site could still give great values if its rich in species/diversity which goes in line with research (Browning et. al., 2014; Kristensson 2007).
- A small site can give a strong identity if a strong design is given to it.

Saltwater canal

The saltwater canal is the last part in the stormwater management system (figure 16). The canal runs from south to north and divide Bo01 from Västra hamnen. There are three sites along the canal that we've investigated further. There are seating areas along the canal, the northern outlet, and the waterfalls. They all have different types of values and combines recreational values and stormwater management.

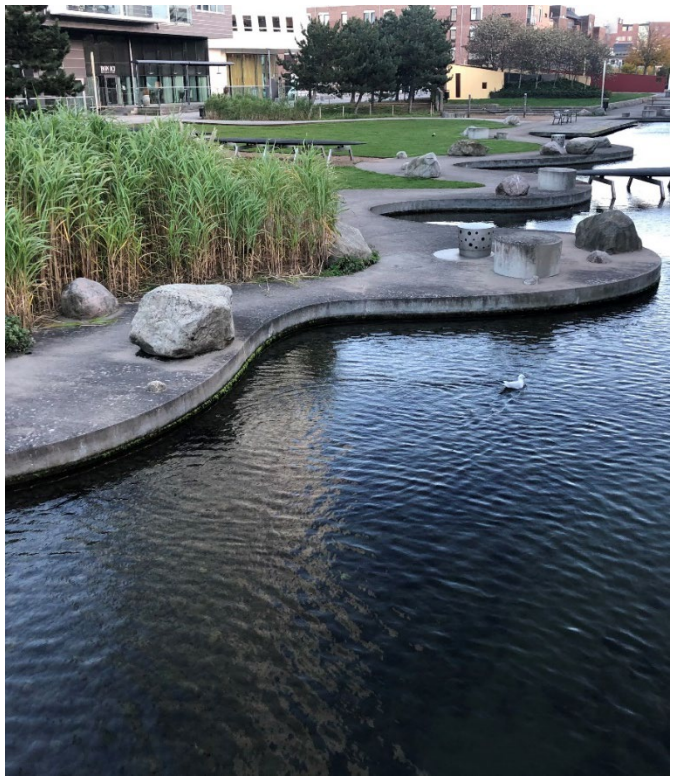

Figure 16. (Lewin, 2021).

3. The waterfall

At the foot of Turning Torso there is a bridge that crosses the saltwater canal, acting like one of the main entrances to Bo01 (figure 17-18). On each side of the bridge there are waterfalls that connects the lower-level canal to the elevated part of the canal. An effective way to reduce pollution at the recipient is to collect the sediments at a dedicated site.

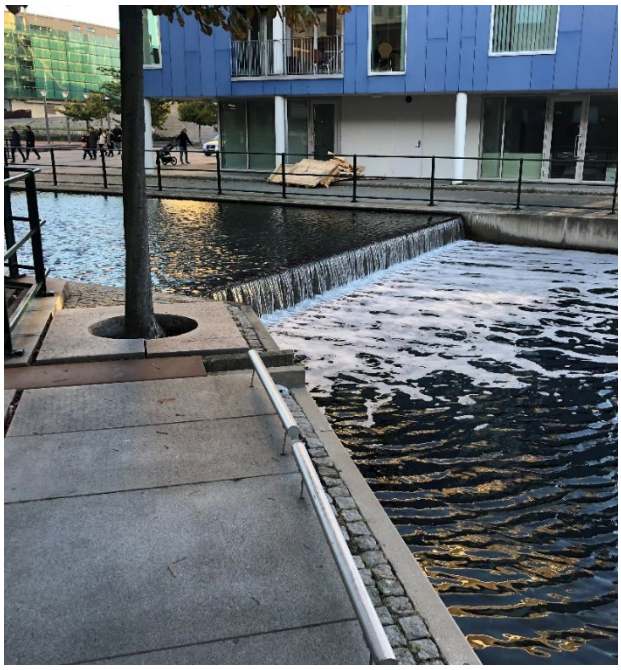

Figure 17. (Lewin, 2021).

Additional values for people

Figure 18. (Lewin, 2021).

The water itself gives a recreational value (biophilic pattern 5) throughout the park that stretches along the canal. Different parts of the canal provide different recreational values. Here is a great example of how the use of water management (treatment) can provide recreational values for people. Even though this isn't a place that you stay, the waterfall is next to one of the main entrances to Bo01. The water provides both non-visual contact (biophilic pattern 2) with nature and obvious presence of water (biophilic pattern 1) (Browning et al., 2014). The sound, apart from having a positive effect of people's health also masks the sound of nearby streets which otherwise can have a negative effect on people's health (Kaplan, 1995). This is a simple construction that have great benefits for people and the water quality. The waterfall also purifies the water from larger pollutants, like trash. On the negative side, that creates an untidy impression which in contrast could have a negative effect on people's well-being. PSD can't adapt properly on this site.

Lessons learned

- Waterfalls can be combined to reduce sediments as well as to create soothing sounds and aesthetics.
- To create completed experiences of PSD there most be more added on in the design than just the waterfall.

4. The intimate canal

The northern outlet from the canal is a lot more intimate than the rest. Here private gardens face the canal, and a narrow gravel pathway lets the public walk along the canal. Figure 19-20 shows a walkway that lies above the detention garden which then connects to the gravel path. The outlet from the raingarden leads into the canal, making a rippling soothing sound (biophilic pattern 2) (Browning et al., 2014).

Figure 19. (Lewin, 2021).

Additional values for people

This part of the canal is the most serene of them all. We perceive it as a semi-private place because it is adjacent to the private gardens that have lookout over the site. The wooden jetty/bridge is constructed above the bioretention basin (figure 19-20) which creates an illusion of that you're walking out into the water rather than along the shore. The raingarden has an outlet in shape of a small waterfall that creates a water ripple sound which enhance a feeling of serenity (biophilic pattern 1-2 and 8) (Browning et al., 2014). When it comes the PSD, the most prominent PSD found where diversity (Stoltz, 2019) from the very different architectural styles. It's open with nothing blocking your vision and yet serene with the rippling water and the feeling of a hidden-gem back alley which goes a bit in line with research (Stigsdotter et. al., 2017).

Figure 20. (Lewin, 2021).

Lessons learned

- Raingardens can be placed underneath walkways to create a stronger connection to nature.
- Water outlets can be used to create rippling water sounds.
- High detail level and different natural materials may contribute to more serene/cozy/idyllic character.

5. The seating area

The seating area is located most south of the three sites. And contains one bench and a combined bench/table furniture as well as informal seating such as concrete slabs and boulders. On this site the water management and biophilic design are well incorporated in each other (figure 21-22). The canal brings a presence of water while the edge of the canal is curved in natural patterns (biophilic patterns 5 and 8). There is natural material on site (biophilic pattern 1) (Browning et al., 2014). One neat detail was the pebbles in the canal which brings an even more natural feeling to it. The combination of water and vegetation gives room for habitats. There were many different birds on the site like swans and seagulls for instance.

Figure 21. (Lewin, 2021).

Additional values for people

The seating is placed on the less busy side of the canal which gives the site a little bit more secluded feeling. It isn't possible to see people's expressions on the other side of the canal, which also provide more privacy feeling. The site has PSD like open and cultural and to some extent social values. Social values is however difficult to judge since we don't know how the place normally is used. The grassland on the left side on the (figure 21) provides shelter for the back and gives a rustling sound which can be soothing. The raingarden-water outlets from Bo01's water managing system gives both a green element to look at and treats/detain the water.

Figure 22. (Lewin, 2021).

Lessons learned

- Raingardens can contain high grasses can creates soothing sound as well as offer protection and a secluded feeling for people.
- The raingardens on the west side offer a variety along the streets as well as they detain and treats the water. It is also the only vegetation in the viewshed.

Augustenborg

Augustenborg is an appartement area in Malmö, Sweden which was built around 1950. Historically the sewers were combined with gray water and black water in the same pipes. With heavy rainfall the sewer systems could easily be overloaded, and the water would push back up to toilets and flooding basements. To combat these flooding problems that were common in Augsutenborg, *Malmö Stad* launched a project called Eko-staden Augustenborg with three main goals (Beckmann, 2020).

- Create an ecological stormwater management where all the runoff would be taken care of locally on site rather than load the combined sewers. The water that couldn't be taken care of on site would be routed directly to the recipient (Malmö canals).
- Contribute to a social and ecological sustainability through creating an exciting and varied urban landscape where the water management could be a main element and contribute to an increased biodiversity and increased general health on the residents.
- Develop the components of the stormwater management system so in the future they could easily be adopted and implemented into new sites. Thus, the project could act like inspiration to other national and international projects.

Figure 23. Retention pond in Augustenborg (Lewin,2021).

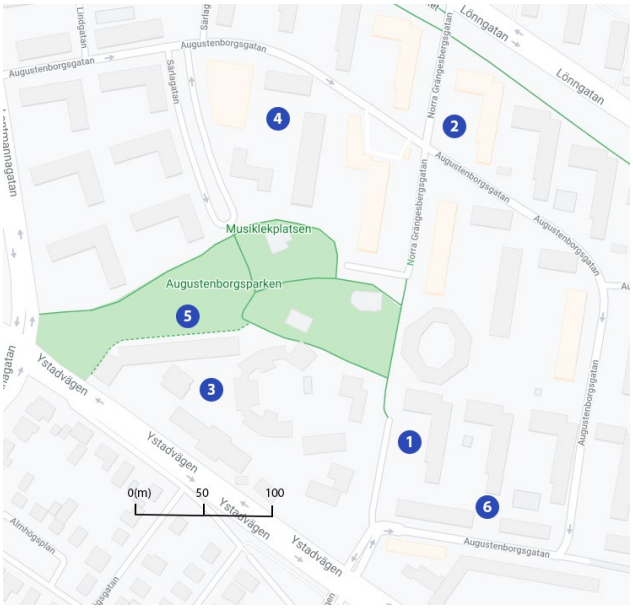

Figure 24 Augustenborg locations (Härstedt, 2022)

1. Ponds in the residential yard

These ponds are located in a residential yard and can absorb large amounts of water (figure 25-27). In case of heavy precipitation, excess water is led on to a nearby swale and then to a detention pond. Ponds has a good cleaning and delay ability as well, but the maintenance is costly since it for instance collects rubbish and needs to be cleaned of pollutions regularly. When there is no rainwater, the pond is filled with fresh water in order to maintain the aesthetic value.

Figure 25. (Lewin, 2021).

Additional values for people

When discussing restorative environments, the most wanted PSD are serene, rich in nature and refuge. Those PSD can be found especially around ponds that's embedded in vegetation. Both ponds in this residential yard have fountains which provide a rippling sound which can be perceived as soothing (Cerwén et. al., 2016; Browning et al., 2014). Moreover, they contain biophilic values like nature element (biophilic pattern 1) that stimulates your senses (biophilic 2) and presence of water (biophilic pattern 5).

Figure 26. (Lewin, 2021).

Lessons learned

- Retention ponds contributes to added values like biodiversity, and restorative qualities and can be designed as regular ponds.
- Costly to maintain
- Resting areas with the retention ponds in sight and the fountain within hearing range can create a restorative feeling.

Figure 27. (Lewin, 2021).

2. “See but not seen”

A small park is located in the outskirts of the residential area that we included in the site visit. The park lays between a street and an appartement building. Diagonally across lays a path that opens up to a smaller square with seating opportunities. Here hedges protect the back and there is a view out over the pond (figure 28-29).

Figure 28. (Lewin, 2021).

Figure 29. (Lewin, 2021).

Additional values for people

This site has good balance between view and shelter and rich vegetation that attracts insects and birds which are restorative PSD (biophilic pattern 12) (Browning et al., 2014; Grahn & Stigsdotter, 2010). Furthermore, the sound of the grass can be seen as something comforting (biophilic pattern 2). The pond has a natural shape (biophilic pattern 8) that contributes to a natural character and creates a distance barrier to the road. Moreover, the sound from the roads can be perceived as disturbing. However, if the pond would not have had rippling water (biophilic pattern 2 and 5), the sound from the road would have been more distracting.

Lessons learned

- Enclosed areas with rich vegetation and a principal of "seen but not seen" is a good outline for a restorative environment in small spaces.
- Ponds can be used as a barrier to the road which can include masking sounds for traffic and creates a natural distance giving a feeling of safety.

3. School yard

A multifunctional retention facility in the school yard of *Augustenborgskolan*. The detention basin can collect a large proportion of water and during dry periods be used as a gathering place or venue since it´s located very central. The place is still useful even if it´s filled with water for socializing. The current water mirror can be seen as something aesthetic (biophilic pattern 1 and 5) (Browning et al., 2014). Regular cleaning of leaves and rubbish is required. The aesthetic look is quite urban with few plants and can be perceived as dull.

Figure 30. (Lewin, 2021).

Figure 31. (Lewin, 2021).

Additional values for people

The venue (figure 30) can work both as a meeting place for children and teachers. From a recreational point of view the site lacks values like places to be "alone", vegetation, and room for creativity. It does provide to some extent social and open PSD.

Lessons learned

- Sites like this one works well when to detain a lot of water from cloudbursts and still have a use when its not flooded.
- Shallow canals in different material can offer a variety in an otherwise uniform site.

4. Cultivation

One of the residential yards in Augustenborg have focused on cultivation (figure 30). Across the yard cultivation boxes are laid out where some have planted flowers and other have planted edible plants. When using the yard for cultivation, water is needed for irrigation which makes a great opportunity to collect the rainwater in rain barrels to use it during dry periods.

Additional values for people

The cultivation beds can provide a sense of context (Antonovski, 1991) and contributes to better human health. Furthermore, the positive health aspects lean on the PSD social and cultural and can be seen as an instorative activity (Hartig, 2007).

Lessons learned

- Since cultivation requires use of water, a suggestion could be to collect water from the roof and use as watering.
- Cultivation is an instorative activity and fulfil PSD connected to the social part in the color-wheel (Stoltz, 2019).
- Wooden chips protect soil getting to compact when the ground is getting trampled.

Figure 32. (Lewin, 2021).

5. Swales

The swale runs through a large lawn / park between a detention area and a retention pond (figure 33-34). The swale would have been hard to see if it weren't for the concrete squares that are placed in each turn of the swale.

Figure 33. (Lewin, 2021).

Additional values for people

The swale is visualized by the concrete squares which also slow down the water and protects the swale from erosion. The squares shows that it is possible to incorporate design to a swale making it more visually appealing and at the same time serving a purpose. If the squares were to be removed the lawn should instead have different values where the swale could be almost" invisible". This swale doesn't have any strong PSD that can be demonstrated at site. Natural elements and shapes (biophilic pattern 1 and 8) such as grass and trees can be seen as valueble (Browning et al., 2014).

Lessons learned

- Art and constructions can be incorporated to a swale to slow down water flow and at the same time give the swale an identity or aesthetic value (if its more developed).
- If a swale is left undesigned with a slight slope it can instead be used as a regular lawn.

Figure 34. (Lewin, 2021).

Bioretention

The stormwater canal in the residential area along the walking path open up to a bioretention facility. The runoff in the canal has the possibility to overflow from the canal into the bioretention facility. (figure 35-36).

Figure 35. (Lewin, 2021).

Additional values for people

The construction has an aesthetic value (biophilic pattern 1 and 8) and can divert and infiltrate large amounts of water. One issue is that it collects leaves and rubbish which decreases the aesthetic value. Moreover, it doesn't provide much value when there´s no flow of water. Therefore, information about the function is important to present in a sign for instance. Apart from the aesthetic value there is no strong PSD connected to this stormwater canal.

Lessons learned

- Information about the function is important to present so people understand why the channel most of the time is dry.
- Can be used to create water contact (even if its limited) and create lines for spaciousness.

Figure 36. (Lewin, 2021).

Rotterdam

Rotterdam is the second largest city in the Netherlands. Most of the city is built under the sea level making the city tremendously vulnerable to flooding. Large barriers protect the country from storm surges from the sea while dikes and canals redirect the inland water to give room for agriculture and cities. With extensive flood protection systems and a water management systems Rotterdam is one of the leading cities in the world. Even though most of the facilites in Rotterdam is made to counter floodings from storm surges and rising sea level, they have a well developed system to protect from rainfall as well. Here we present the sites in Rotterdam that could act as inspiration for implementation of open stormwater management and added well-being for humans.

Benthemplein

Figure 37. (Lewin, 2021).

Figure 38. The large basin with sports activities. Filled with leaves and the concrete is discoloured (Lewin, 2021).

Benthemplein is a *water square* located in central Rotterdam and was created, among other things, to show the public the stormwater management openly and on the same time have other functions when it's not flooded (figure 37-39). Benthemplein is a square built with an open collection area for rainwater. The square is made up of three different detention basins, of which the two smaller parts collect water from the nearby surroundings, while the third only fills up during persistent rain and then collects water from a larger collection area. To create additional awareness for water management, gutters have been built that lead the water to the stainless-steel basins, which creates a clear material change. After the two smaller basins are filled up, the water is filtered into the ground to naturally replenish the groundwater levels, which benefits the vegetation on the site. The large basin, on the other hand, is slowly emptied into the open water system in the city (e.g., the canals). The idea is that the pools will be emptied again after 36 hours

to be ready to receive a downpour again. In addition to the pools being efficient from a stormwater perspective, the idea has been to create a place for social activity and culture. In consultation with schools, universities, the church, and the gym located around the square, a place has been created according to what the users have requested. The elongated pool is the idea to function as a place to skate in. The other of the smaller pools has a stage where performances are held, for example dance. The last and largest pool is a sports field. There is room for various sports such as basketball and floorball with stands to be able to receive spectators. The vegetation on the site has been saved since the site was rebuilt and creates a good chance for shade and other ecosystem services.

Additional values for people

Benthemplein is a good example of how stormwater solutions can be multifunctional and offer extra values for people. The purpose of the place has been to create a place for social activities, which is clearly noticeable and goes in line with PSD like social, cultural and prospect (Grahn and Stigsdotter, 2010). There are clear venue areas and rooms for activities. There is a good overview of the place almost no matter where you stand or sit. There are also biophilic elements on the site such as the blue-painted pattern in the pools that indicate water (biophilic pattern 5, simulated value) (Browning et al., 2014). In addition, it helps to create further awareness of the site's water management purpose. The square is surrounded on one side by plant beds with older deciduous trees with grass and evergreen shrubs underneath. Also, around the pools, there are plant beds with elements of evergreen plants that add values to the site even during the winter months.

Figure 39. (Lewin, 2021).

During the visit, the place was perceived as abandoned. This is probably partly since outdoor activities are conducted mainly during the summer months, and partly due to the feeling of neglect in the management of the place. The surfaces were relatively dirty and gutters and collecting surfaces were filled with leaves which had a negative effect on how the place was perceived. In addition, there is also a risk of infiltration surfaces being clogged if too much rubbish enters the infiltration system and must then be cleaned more often. There is also no filter strip that could collect sediment before the runoff reaches the site and thus extend the life of the infiltration systems further. It is suggested that the plant beds around the site could have functioned as some type of filter strip. By replacing all the vegetation on the site with evergreen plants, they would have limited littering

through leaves and maintained the plants' positive effects on people all year round, which also would have created conditions for the site to feel more welcoming even during the darker months of the year (Blecken, 2021; Browning et al., 2014). Other improvements could be to use materials that’s more natural and comfortable to sit on, instead of only concrete.

Lessons learned

- A detention basin can be multifunctional and provide many different purposes apart from detaining stormwater.
- Deciduous trees can create a mess in stormwater facilities.
- Proper maintenance is required to keep the facility clean and functional.

Bellamyplein

Figure 40. (Lewin, 2021).

Figure 41. (Lewin, 2021).

Bellamyplein is another water square located in the Spangen district, Rotterdam (figure 40-41). This water square was implemented in order to improve the water management system in Spangen, which had relatively high degree of hardscaped surfaces. Bellamyplein is inspired by Benthemplein but is a simpler variant with only one detention basin. In addition to the detention basin, the park has other functions. The northern part has a playground with simple play equipment and a rubber turf as ground material. To the east of the playground there is a ball field. Next to the ball field is a small cultivation plot with a small greenhouse.
The entire southern part of the park is open without any programmed surfaces, which provides space for your own activities. A gutter runs around the entire park that collect stormwater from the surrounding area and leads it to the water square.

Additional values for people

Bellamyplein fits in to PSD like social, cultural and prospect (Grahn and Stigsdotter, 2010). There are areas that are created for social activities such as the playground and the ball field. The cultivation area is both social and cultural. The park is also quite diverse in terms of function and rooms. Spatially however, the park feels quite open.

The water square has seating opportunities on the stairs. Under normal conditions there are supposed to be benches in the basin as well, but since the basin was under maintenance during our visit, they were not present. The benches would have provided more sheltered seating with a wall and vegetation protecting the back. Something that was needed on the otherwise open site with little shelter. Apart from seating areas in the basin, the water management facilities weren't really incorporated with any functions in the park. A plausible reason could be economy, Spangen is socio-economically one of the poorest parts of Rotterdam so effective stormwater management have likely been prioritized over multifunctionality.

Lessons learned

- It's possible to build water squares that's not too advanced and more economic (compared to Benthemplain).
- Proper maintenance is required to keep the facility clean and functional.

Natuurspeeltuin de Speeldernis (Speeldernis nature playground)

This nature playground is located quite central in Rotterdam and are the oldest nature playground in the Netherlands. *Natuurspeeltuin de Speeldernis* have over 33.000 visitors every year. The water is lead on from a tap and runs through canals and ponds in the water playground and eventually ends up in a river nearby.

Figure 42. (Lewin, 2021).

The playground is divided into two parts, the first part is located by the entrance and is quite open with only little water that runs through in a stream (figure 42). This part is more suited for smaller children. When passing through the first part, the larger second part appears (figure 43). Here we found a campfire where the children could barbeque apples, sausages, etc. From there you could hear sounds of rippling water (biophilic pattern 2) that tempted you to walk further into the dense vegetation. There we found a small waterfall with a view line towards a smaller hut. When entering the hut, there was a staircase that led up to a roof with a view over the playground (figure 44). The nature playground had shallow pools with logs and stumps that made an obstacle course that you could try to pass without falling into the water (figure 42). Apart from the water there were hills, dense vegetation, a watchtower/hut and tunnels.

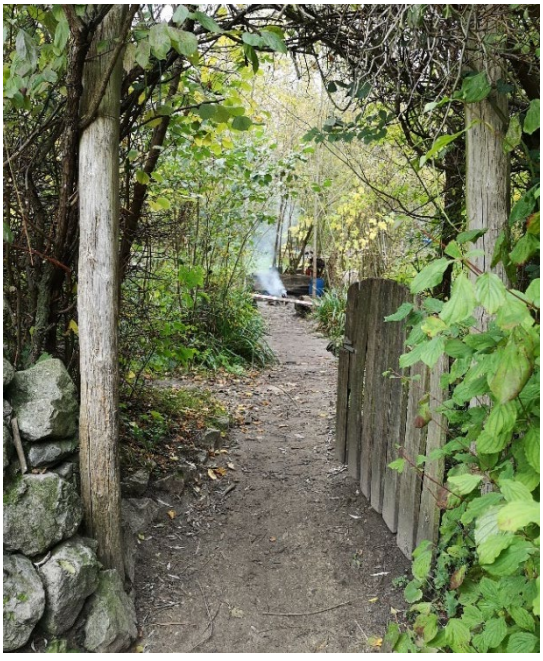

Figure 43. (Lewin, 2021)

Additional values for people

Since the playground is a nature playground, naturally it is classed as highly biophilic where almost every material on site is natural with natural forms, water elements and serene refuge areas (Biophilic pattern 1-2, 5, 8 and 12) (Browning et. al., 2014). However, even though the playground appears to just be a piece of nature it has been carefully designed. Just as you enter the second part, you can hear a rippling waterfall up on a hill to the left which can be seen as restorative (Cerwén et al., 2016, biophilic pattern 2) and a good criterion for physical exploration (Jansson, 2013). The ground material is different around the playground to provide different sounds and experience to walk on. Some parts have bark, other parts have shells, pebbles, and dirt.

Figure 44. (Lewin, 2021)

Figure 45. (Lewin, 2021)

Lessons learned

- To work with different materials that creates different sounds and sense. These techniques contribute to a better curiosity among children and can tempt and led them to different parts in the playground.
- Water can work as an element that physically challenge children in a healthy way.

- The construction/design of the water playground might be suitable to use as an area for detention of stormwater during extreme rainfall.

4. Summary of Site visits and Literature retrieval

Environments for human health

It is suggested that people have different needs from their outdoor environment, ranging from a place to recover and heal to a place to grow and get challenged. Age, mood, and situation all affect what environment that is preferred. Children need a challenging environment to evolve, natural environments where they can affect the surroundings with their creativity seems to be preferred. People that are exhausted, stressed, or sad seem to prefer environments where they can exclude themselves from their environment and let their soft fascination take over. Sports and social activities do not have the same requirements for calm and secluded sites.

Biophilic patterns could be used in the design phase to introduce elements that are preferred by humans and can induce different feelings like calm and excitement. Bo01 showed different ways of using biophilic patterns to create sites. Patterns that we found were prominent were Visual connection with nature (pattern 1), non-visual connection with nature (pattern 2), presence of water (pattern 5), biomorphic forms (pattern 8) and refuge (pattern 12) (Browning et al., 2014). Augustenborg also had some biophilic values even if they were not as prominent.

Stormwater management

The main purpose of the stormwater management is to prevent flooding, however, treating the water is just as important to protect the environment from pollution.
There are different stormwater facilities that provide different values and are suitable for different situations, table (2). For example, a detention magazine could be preferable if there are areas nearby to flood during a cloudburst. However, if there are a park nearby that are suitable to convey the runoff towards and flooding it, that could be preferable since the park provide value during dry periods and extra facilities do not have to be constructed. If a detention magazine must be constructed, extra values could be given to it like in Benthemplein.

Stormwater facility	**Purpose**	**Potential added values**
Swale	Infiltration, conveyens.	Can have a slight slope and therefore function as a multifunctional lawn area or have a higher slope and provide visual aesthetics.
Detention basin	Detaining runoff	Can be multifunctional, sport arenas, amphitheatres or other social activities can be placed in a detention basin.
Retention pond	Detaining runoff, however less effetive than detention basin since the retention pond is already filled. Also have a water treating quality.	Introducing water to a site which provide biophilic values.
Treatment island	Water treatment, biodiversity	Extra biodiversity values which can have a positive effect on humans
Raingarden	Infiltration, detention, treatment and aesthetic	Adding vegetation and have the potential to build secluded rooms within a raingarden.
Permable surface	Provides infiltration where there is no infiltration normally	
Green roofs	Detention, aesthetics and some treatment	If placed on lower buildings, people with view over the roof will have an improved view.

Table 2.

5. Case study with design proposal in Kristianstad – Nya Udden

Kristianstad is located in Skåne, Sweden (figure 46) and is the largest municipality in Skåne in terms of area with 125 101 hectares. The municipality consists of 6 cities and about 20 smaller urban areas. In 2020 Kristianstad had about 86 271 inhabitants where 46 072 lived in Kristianstad city (Kristianstad, 2022).

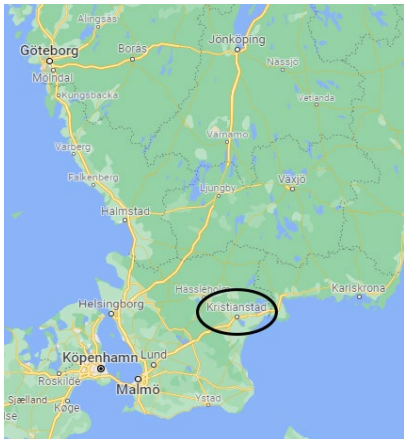

Figure 46. (Härstedt, 2021)

Kristianstad has a history of flooding due to its altitude. Parts of the city are located below sea level and much of the city is right above sea level making it vulnerable to flooding. Both from the lake Hammarsjön and the river Helge Å that lies next to Kristianstad but also from cloudburst. The summer of 2021 Kristianstad suffered heavy material damages due to cloudburst. There is a water barrier planned to be built in order to protect Kristianstad from future flooding from the river. However, our design proposal in Nya Udden will not include the design of this barrier since there are incomplete plans on how to build it.

Green plan - Kristianstad

The green plan is one of several documents for the general planning in Kristianstad municipality. The explanation of this green strategy was adopted by the City Council on the 20th September 2019. The green plan is a strategic document that shows the goals and plans for the green land of Kristianstad municipality. The green land covers a broad area of activities and aspects like recreation, biodiversity, blue infrastructure, cultural heritage, ecosystem services etc. Furthermore, the green plan proposes strategies with analysis and guidelines for how to implement and

improve these activities and aspects and is based on previous positions taken internationally, nationally, regionally, and locally. Some of the challenges presented in the green strategic plan are presented below (Kristianstad, 2019):

Public health - Social community and green areas with multiple values are seen as important factors in order to improve the public health in Kristianstad.

Densification and increased population – There is a challenge in how to densify the city and at the same time keep/create valuable and multifunctional green areas.

Attractive residential areas and accessibility to green areas – In order to create attractive residential areas, proximity to green areas with valuable qualities that meet different interests are important.

Climate change – Due to the climate change there are consequences like increased temperature and cloudburst which becomes problematic in urban areas like flooding's, high heat waves and disturbances in the ecosystem.

Water quality – Nutrient load, pollution and brownification of watercourses, lakes and sea areas are challenges that require action. Natural cleansing through the ecosystem is often the cheapest and most effective way to purify water but requires surfaces and investment for establishment.

The decision process – Investigation in green areas often finds it difficult to assert itself against other interests in the decision processes of the municipality. Therefore, improved decision material that shows the long-term values of the green structure are central.

Urban cultivation – Interests in cultivation has increased in recent years. Many people want to be able to contribute to less environmental impact and enrich their immediate environment with plants and get the satisfaction of harvesting their own vegetables. However, creating space for urban cultivation is a challenge as well.

Management – It is a challenge to improve green values and at the same time minimize the costs of management.

In order to move forward with these challenges, the green plan of Kristianstad municipality has decided on 4 goals. To reach the goals, 11 strategies have been created.

1. **Long-term sustainable housing and living environments**

Strategy 1 – To ensure good access to parks and natural areas with different character, functions and experience qualities through planning, design and management.
Strategy 2 - To link green environments into a functional unit for residents, preschools and schools. To see the whole and work across sectors.
Strategy 3 - To work strategically with green-blue structures in one climate adaptation perspective
Strategy 4 - To increase knowledge of what is long-term sustainable living and living environments and analyse ecosystem services in existing buildings and at new exploitation.

2. **A rich nature and strengthened ecosystem services**

Strategy 5 - To preserve and develop a rich plant and animal life and the green cultural heritage as well as linking the green structure in a functioning whole for it the biological diversity.
Strategy 6 – To protect nature values where it is necessary, avoid, prevent and reduce adverse effects and ultimately compensate for lost values in park, nature as well as forest or agricultural land.
Strategy 7 - To create and manage multifunctional parks and natural areas that provide many ecosystem services and resilience for future change.

3. **A good and equal health**

Strategy 8 - To be close to soothing and relaxing green environments for everyone and offer exercise opportunities in green environments.
Strategy 9 - To create conditions for local cultivation and healthy food.
Strategy 10 - To increase citizens' participation in planning and management and develop collaboration between different actors to strengthen and further develop the greens values.

4. **Attractive environments for work, leisure and tourism**

Strategy 11 - To develop the experience qualities in and the service at existing green areas for work, leisure and tourism.

Nya Udden

Nya Udden is located adjacent to open water bodies and close to the highway. Kristianstad (2015) suggests that the area is in need of ecosystem services like water treatment, flood protection and noise reducing elements. The area is also suited for implementation of health promoting areas (Kristianstad, 2017b). There are limited

green areas in Nya Udden today and most of the green areas are classified as "difficult to access". There are many private gardens in the southern part which increases the amount of green structure in the area. However, those are not publicly available. The municipality judge the potential for recreation as inadequate at the site today, this is something they wish to improve. They do state that there are good natural areas close by which have a good connection to the site (Kristianstad, 2015). In the same analysis Kristianstad (2015) presented a study that investigate what qualities their parks possess, and in contrary, what qualities that are missing. The result showed that Nya Udden primary lack cultural, social and openness as values in the green areas located in or nearby Nya Udden.

Planning guidelines

According to the general planning for Kristianstad municipality (2021) Nya Udden should contain:

- New bicycle paths and parks should connect the old and new areas of Nya Udden with Kristianstad inner city.
- A park should bridge over the railway by the arena square, breaking the barrier it creates.
- Ecological values should be kept and enhanced, and ecosystem services should be created.
- The water accumulation on site should be regulated. This should be done by treatment, detaining in open water systems before it is released into Helge å/Hammarsjön.
- Flooding areas for 100-year rains should be created. This could be done by multifunctional development of green areas.
- Park areas should be considered to change to areas for school/pre-school's needs. The designer must have a general knowledge in children's needs and what interventions that can be done for the children's best.

Apart from these desires from Kristianstad they also want to connect Nya Udden to the existing and planned green infrastructure, especially since Nya Udden today lack green environments.

Risk areas for flooding

Nya Udden is prone to flood during cloudbursts. According to Kristianstad's cloudburst map, a large part of the southwestern part will be flooded (3-10 dm water depth) and there could be standing water outside the arena and also on the railway (figure 47). The cloudburst map simulates a 100-year rain. The dark-blue color represent a a standing water of up to 1 meter.

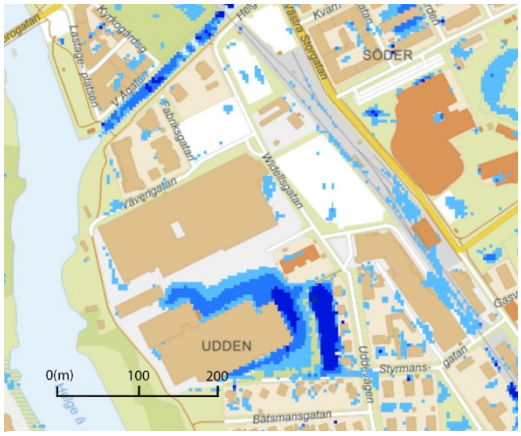

Figure 47. Kristianstad's cloudburst map (Kristianstad, 2021).

Utopia architects

Utopia architects (2020) have presented a first version of the new structure in Nya Udden where buildings and partly outdoor areas are presented based on consultation with Kristianstad municipality. The main ideas for Nya Udden are to:

- Connect the area to the rest of Kristianstad
- Turn the area towards the water (Helga å)
- Create a green district
- Prioritize cyclists and pedestrians over traffic
- Improve the cultural character
- Create venues for people in all ages
- Mixed building types
- Organic and small-scaled district structure
- Sustainable development ecologically, socially and economically.

Utopia Architects (2020) have made a design proposal for the structure and buildings in Nya Udden (figure 48-49). They do however not present a full plan for the green areas in Nya Udden. Some general thoughts have been suggested like development of green areas along the old train tracks and Yllefabriken and that the cultural values

Figure 48. Utopia architects master plan (Utopia, 2020)

are raised. The area is according to to Tyréns (2021) cloudburst analysis designed to handle a 20-year rain. Even then most roads will have a maximum depth of 20cm water.

The structure plan (figure 46) presents seven new apartment blocks whereas another zoomed in structure plan (figure 47) from a later updated document presents six buildings. Moreover, buildings are planned along the railroad which by Kristianstad municipality (2015) want to be converted into a park with increased ecological values.

Figure 49. Utopia architects (Utopia, 2020).

Design proposal

Nya Udden

Introduction

Utopia Architects have provided the structure of the buildings in Nya Udden where we have continued to design the outdoor areas between the buildings. The goal with the design, as mentioned earlier, showcase how stormwater management facilities can be used in a way that provide added values for the locals, with human well-being in focus. Since the area is in high risk of flooding, we decided that stormwater management has to be the start point of the design.

Runoff

To decide how to handle the stormwater on site we had to locate the waters runoff pattern, this was provided by Tyréns (2020). The low point is located in the most southern part of the work area, where the new area are planned to be built (figure 48 and 49). The new area will get a raised ground level at 1.5 meters which creates a new low point south of the buildings (B at figure 50). Excessive stormwater is planned to be collected at A and B in figure 50.

Another low point is located at the square by the arenas entrances where water is currently led.

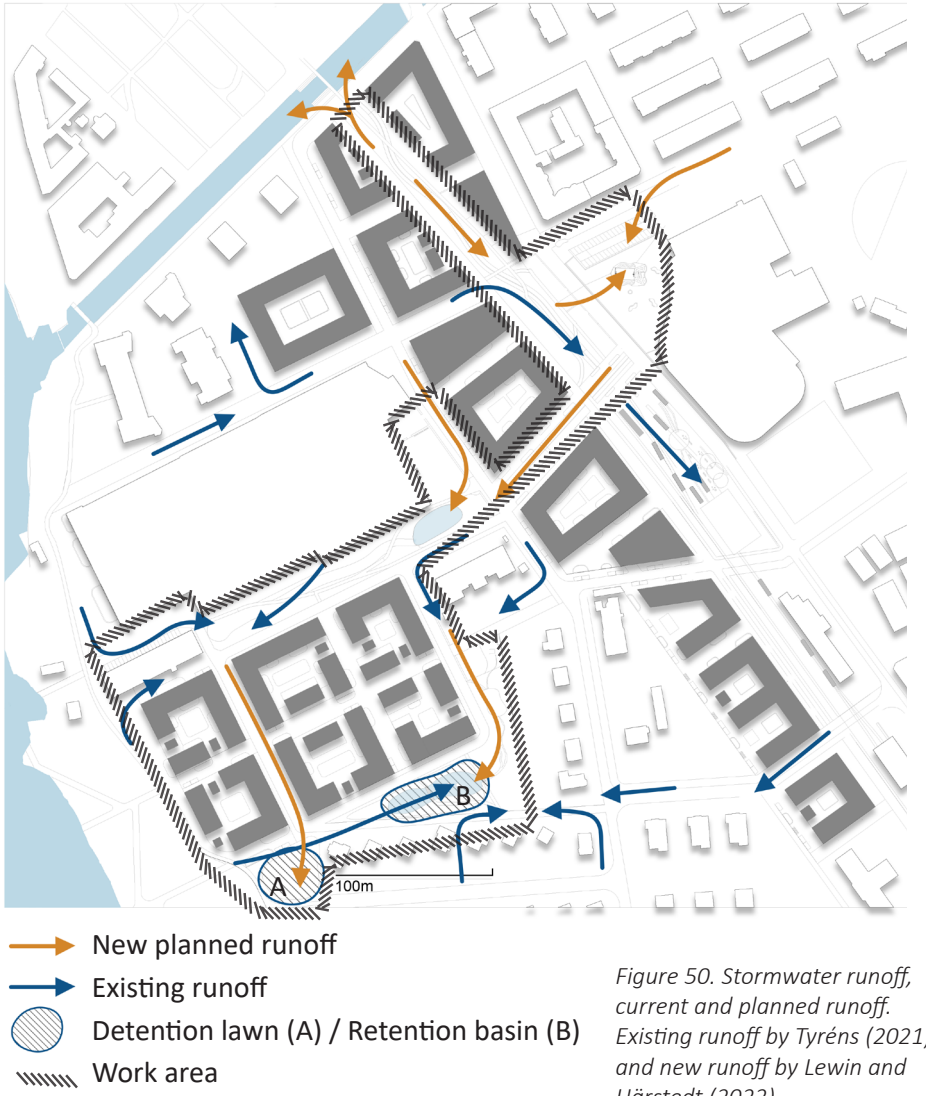

Figure 50. Stormwater runoff, current and planned runoff. Existing runoff by Tyréns (2021) and new runoff by Lewin and Härstedt (2022)

Stormwater management

Tyréns (2021) states that area A and B in figure 50 is not large enough to retain big cloudbursts. Therefore, we suggest that the runoff should be detained along the way before reaching the final retention pond (B at figure 50).

Swales are a cost-effective stormwater facility (Blecken, 2021) and are therefore planned to be laid out along the runoff's path within the workarea. The swales provide good infiltration which reduce the total runoff volume that reaches the retention pond and can also be filled up to detain smaller amounts of water. The swales lead the water into three different detention areas along the way to the final retention pond (B at figure 50), whereas one of the detention basins is a water square (figure 51 at number 4).

The swale-system starts in the north, by the canal, and lead the water south towards the arena. From here, the water can, during extreme cloudbursts overflow to the water square/detention basin in front of the arena (4 in fig. 51). Underground pipes will transfer the runoff under the roads. The retention pond (5 at fig. 51) next to Yllefabriken has to overflow before the runoff is lead further into the swale (2 at fig 51)., that lies along the façade of Yllefabriken. From the swale and retention pond the water is led through small canals (figure 51). The western canal lead the water to a detention lawn. The eastern canal leads the water through a vegetation area before it reaches the retention basin.

With this solution the water has time to infiltrate along the way to the retention pond and also be detained which could prevent heavy flooding on site, purifies the water and lets it percolate down to refill the ground water.

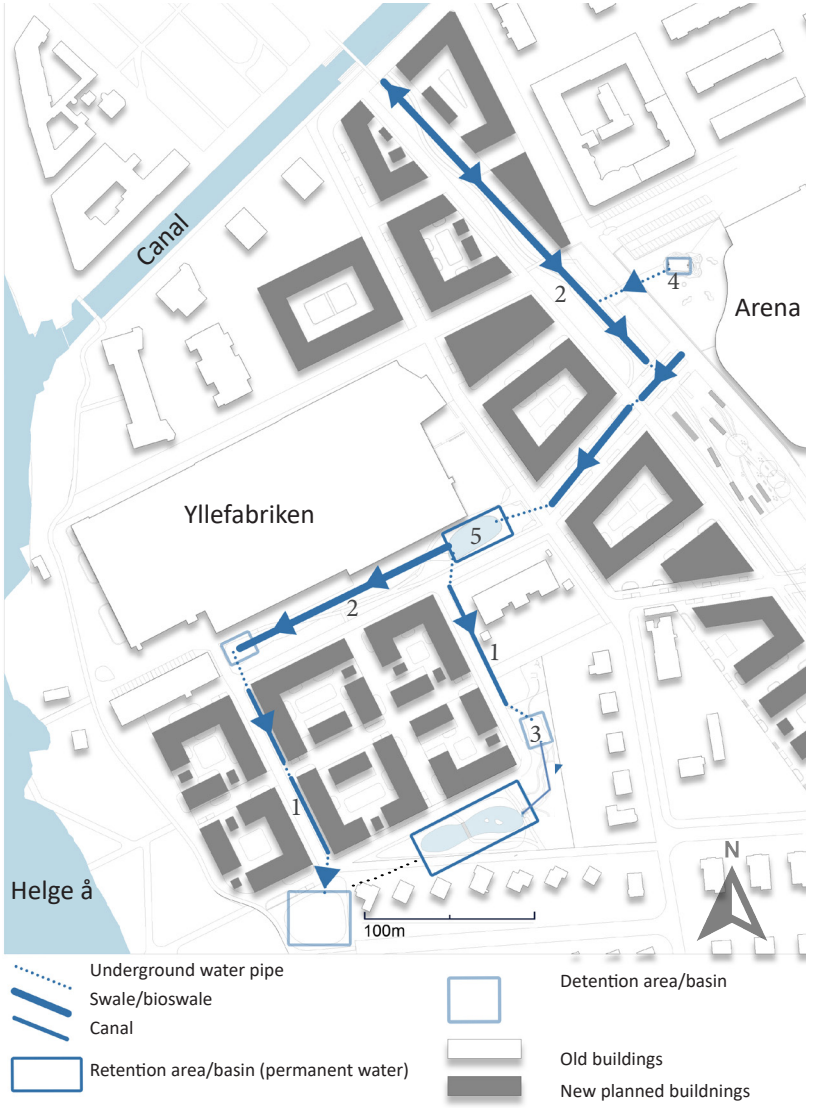

Figure 51. The planned stormwater management facilities and course in Nya Udden. (Härstedt and Lewin, 2021)

Inspiration facilities

1

Canal in Augustenborg
Figure 52

2

Bioswale in Kronsberg, Hannover, Germany
Photo by: Atelier Dreiseitl Figure 53

3

Natuurspeeltuin de Speeldernis Rotterdam. *Figure 54*

4

Water square, Benthemplain in Rotterdam
Figure 55

5

Retention pond in Augustenborg
Figure 56

Design thoughts

The presented open stormwater management (figure 51) also aims to bring added values for people's well-being. We have therefore, in this design proposal decided to divide the outdoor environment along the open stormwater course into different characters that supports different needs and values in residential areas with guidelines from EBD and the site visits. The design proposal will focus on four sub-areas that is named (figure 56);

1. *Eco park* and *Water square*
2. *Bioswale* and *Pocket park*
3. *Residential yard*
4. *Water playground*

Swales along the greenway

By adding aesthetics to the swales, such as ornate rocks and drought/ flood-tolerant vegetation, the swale can be perceived as a tasteful planting along the green way in the Eco park and Bioswale park (figure 51 and 57). This provide the value of a view and can be seen as a quality with naturalistic elements (Browning et al., 2014). The swale is also a way to guide the user along the green way towards the water, Helge Å. Another added value to the sites is the increased biodiversity. The vegetation and occasional water provide habitats for birds, insects and critter. This is also highly biophilic and contains PSD like rich in species and nature which provides an increased chance of restoration (Browning, 2014; Stigsdotter et al., 2017).

Function and use

The Eco park and Water square is affected by surrounding traffic, bicycles and pedestrians and is located next to Kristianstad arena where intention of practicing and watching sport takes place. The area also contains other activities nearby like bowling, taekwondo and a gym. The Eco park and the Water square can therefore naturally be seen as an area where implementation of outdoors activities and a place to gather could benefit the surrounding. The Bioswale park however, is more tucked away from the city life and can instead provide values that otherwise could be hard to achieve in an environment with high activity level. Here a more restorative environment can be found.

The Water playground in south focus fully on children's play and their best way of reaching personal and physical development (Jansson, 2013). The area can also be used for flooding during cloudburst and leads the water down to the detention basin. Here treatment islands can be installed to further purify the water before it percolates into the groundwater. This also brings added values like biodiversity and aesthetics.

One residental yard have also been designed in relation to the local green areas.

Figure 57. Green infrastructure. (Lewin and Härstedt, 2021)

Figure 58. Points of interests in Nya Udden. (Lewin and Härstedt, 2021)

Water square and Eco park

Inspiration

The water square is mainly inspired by Benthemplain in Rotterdam regarding design and use. Techincally it´s inspired by Bellamyplain (see chapter Site visits).

Eco park

The Eco park is designed in order to offer activities and a social context in the area that resonates with PSD like social and contributes to the feeling of a context (Adevi, 2012; Antonovsky, 1991). In the Eco park an outdoor gym, ping pong table, twister, chess and other activities that brings instorative values can be found embedded in vegetation next to the swale. The swale aims to present aesthetic values and leans on PSD like cultural, prospect and partially rich in species.

Situation

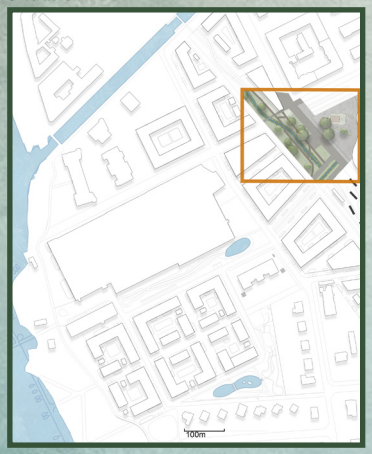

Figure 60. (Lewin och Härstedt, 2022)

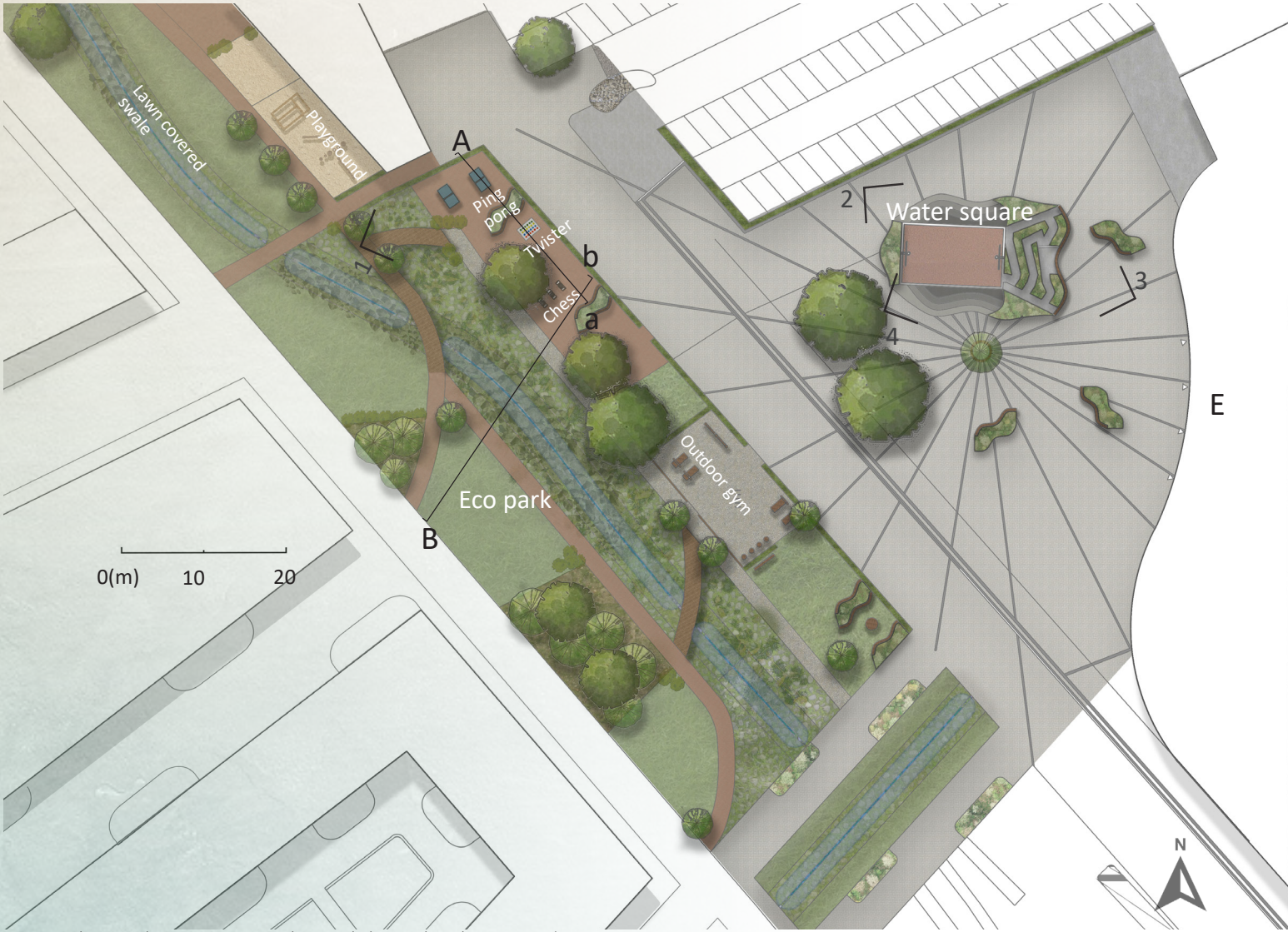

Figure 61. Plan over the Water Square and Eco park. (Härstedt and Lewin, 2021)

Wooden bridges cross the bioswale which gives a closer feeling of walking within the vegetation (See Bo01, intimate canal for reference). Parts of the swale is covered with a lawn to provide a larger coherent area. Here unprogrammed activities can be exercised and break the barrier that the bioswale otherwise could create. Furthermore, the Eco park and the Water square can be explained to be PSD that are drawn to the social part in the color-wheel (Stoltz, 2019) (figure 65).

Water square

The Water square lies next to the entrance to Kristianstad arena and can be seen as a natural site to gather. The Water square is dressed with a sports court which reflect the arena and creates a bond with the building and square outside. Next to the sports court a maze is placed that children can explore and investigate (figure 66). The maze aims to arouse curiosity which can be seen as a type of fascination (Kaplan, 1995; Jansson, 2013). The whole Water square can be filled with water during extreme cloudbursts and is placed in a low point at the square where the runoff is currently led today (figure 68).

Regular maintenance is required to keep the Water square from clogging and miscolour from the water. Most of the water square is built in concrete so it can stand against high wear and water. Elements of wood are found at seating areas and an organic shape are constructed in order to give a naturalistic feeling

Figure 62. Perspective 1. (Härstedt and Lewin, 2021)

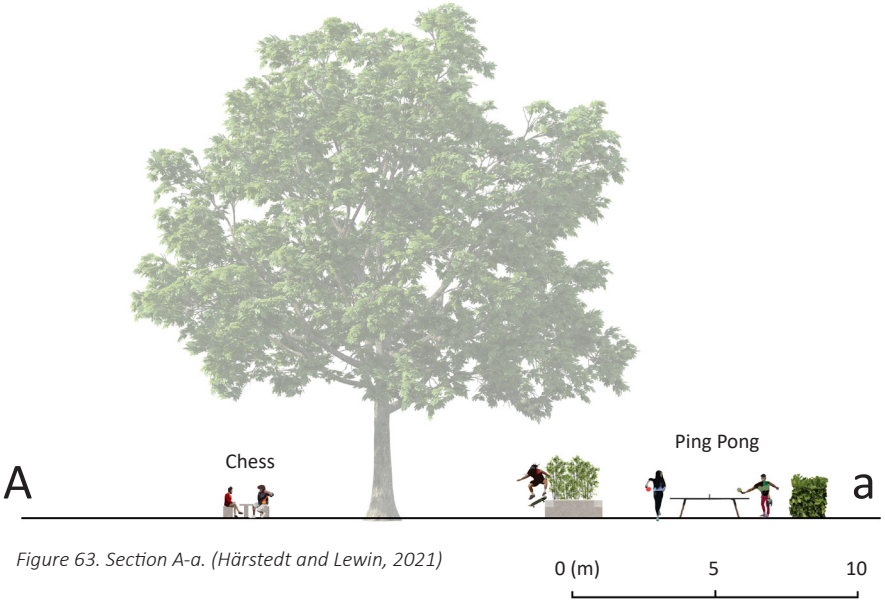

Figure 63. Section A-a. (Härstedt and Lewin, 2021)

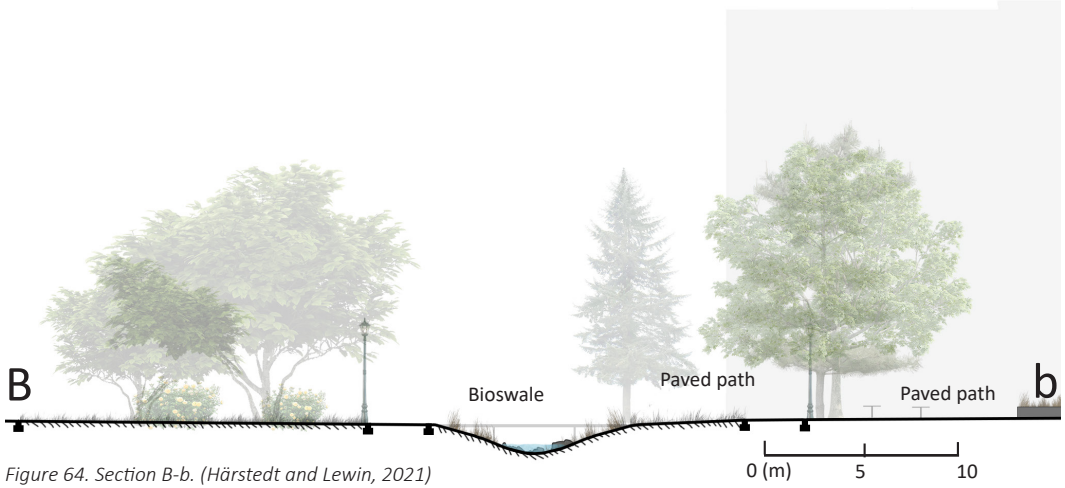

Figure 64. Section B-b. (Härstedt and Lewin, 2021)

(pattern 1) (Browning et al., 2014). We found that the choice of material at Benthemplein gave an impression that felt very urban. Therefore, we wanted to use elements of natural materials at the water square in front of the arena that could contribute to a more natural feeling.

Only evergreen plants has been chosen in the plantbeds (figure 64-66) to diminish maintenance and clogging. Evergreen plants also give a green impression all year around.

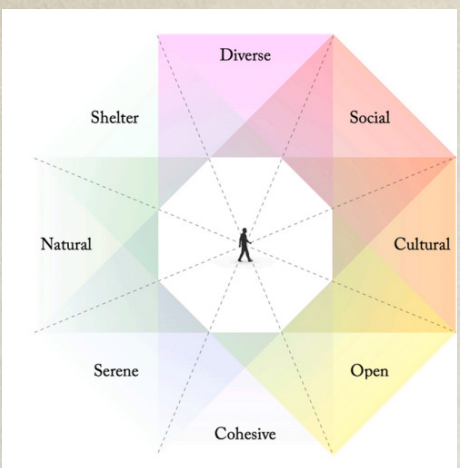

Figure 65. The PSD-wheel lean towards the instorative side. (Stoltz, 2019)

Figure 66. Perspective 3. (Lewin and Härstedt, 2021)

Figure 67. Perspective 2, Kids playing basketball in the water square. (Lewin and Härstedt, 2021)

Figure 68. Perspective 4, The water square is flooded and filled with water. (Härstedt and Lewin, 2022)

Bioswale and Pocket park

Inspiration

The swale is partly inspired by some of the water points in Bo01 that showcase how a site with focus on the details can provide a site that appears to be tended and that gives a sense of relaxation. The waterpoints also use a biophilic design together with water to give a “pseudo-naturalistic” feeling.

The retention pond on site is inspired by Augustenborg’s use of retention ponds in residential areas that provides both restorative values as well as an effective way of detaining water on site.

Situation

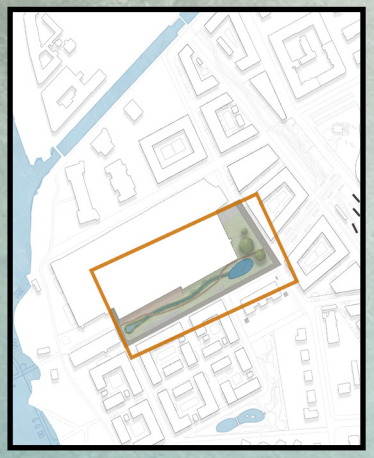

Figure 69. (Lewin and Härstedt, 2021)

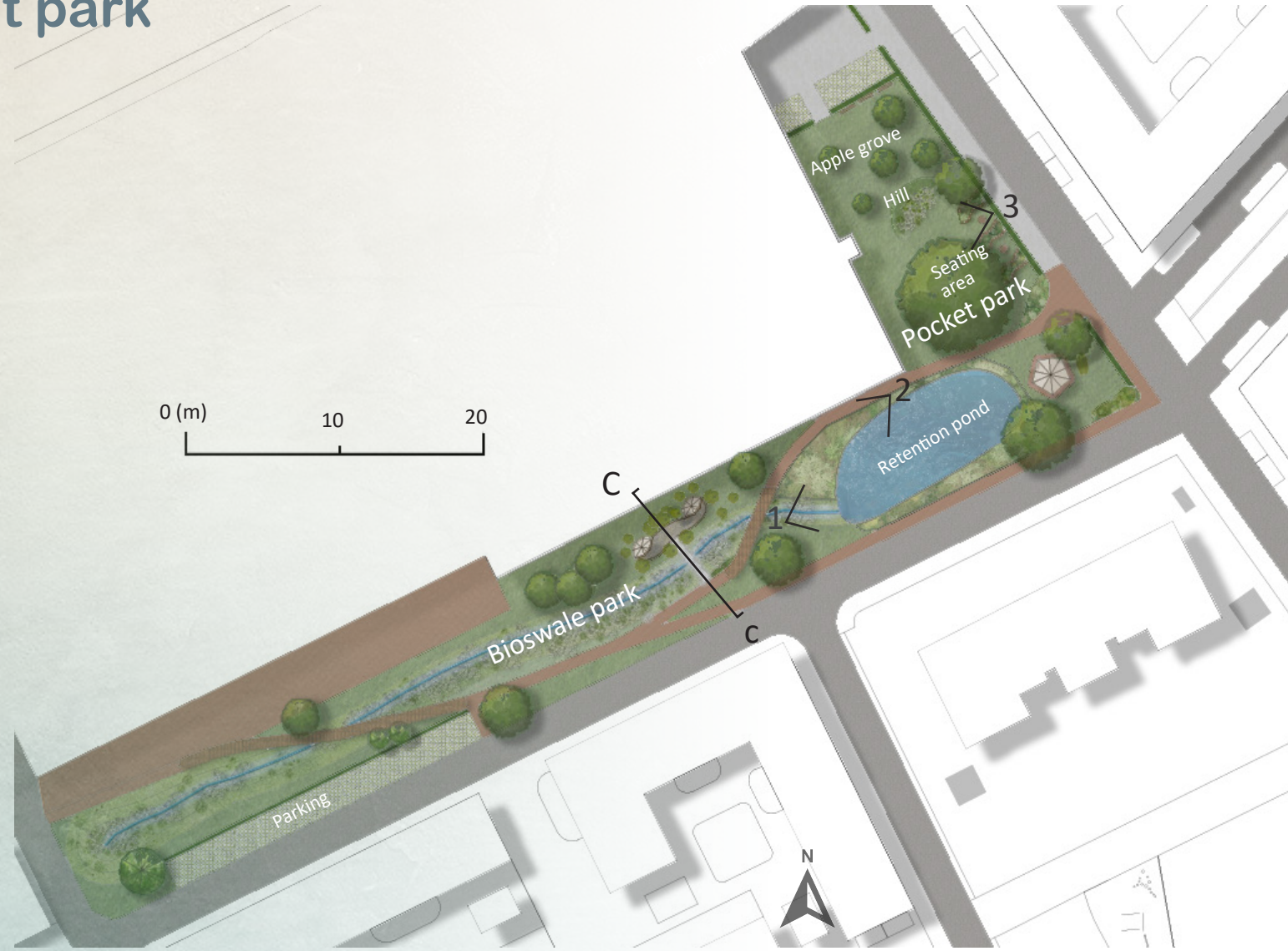

Figure 70. Plan over the Bioswale park and Pocket park. (Lewin and Härstedt, 2021)

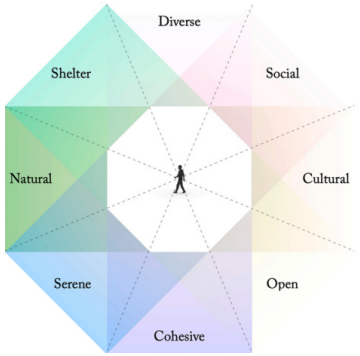

Figure 71. The PSD-wheel lean towards the restorative side (Stoltz, 2019).

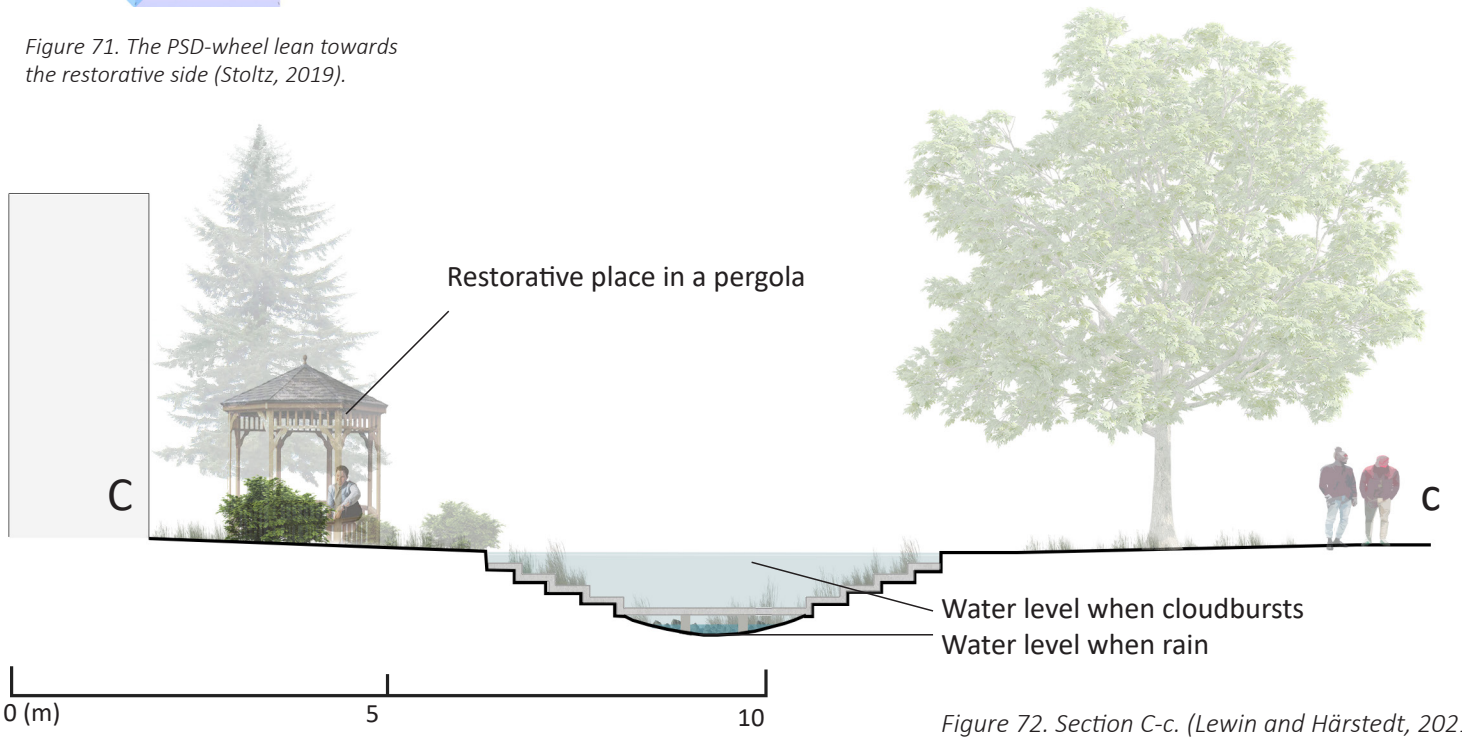

Figure 72. Section C-c. (Lewin and Härstedt, 2021)

Bioswale

Along the Bioswale ornate plants and rocks are added to provide aesthetic and ecological values. It also purifies and reduce the runoff's velocity. Next to the building of Yllefabriken, two resting sites in a pergola are built hidden with vegetation but with a view towards the bioswale. Higher level of details can be used to create a site that feels tidy and taken care of. Here the use of the stormwater can enhance the resting sites biophilic value (pattern 5) even more, like in the waterpoints at Bo01. Overall, the PSD are drawn to the serene part in the color-wheel (Stoltz, 2019)(figure 72). PSD like serene, refuge, prospect and partially culture and rich in species are in focus in the design at site (Grahn and Stigsdotter, 2010). Even though the resting sites in the bioswale and by the retention pond have the goal to provide restorative values it is worth noting that this site is still in an urban context. Therefore, the area cannot fully replace "real" nature in terms of restorative values.

The path is of tile that matches the buildings in the area which contributes to the cultural character at site. The bioswale is crossed with a bridge in wood material in order to give a closer connection to the bioswale and a naturalistic feeling. The ground in the resting areas consists of gravel

Figure 73. Perspective 1. (Härstedt and Lewin, 2022)

Figure 74. Perspective 2. (Härstedt and Lewin, 2022)

which also gives a naturalistic feeling and a sound that indicate when people enter the place.

Pocket Park

The park east of Yllefabriken is dedicated to an apple grove. Here different fruit trees are planted and hidden behind a hedge from the road and a small hill from the south. The hill creates an eye-catcher and blocks the view line, creating an urge of exploration (figure 75).

Retention pond

Figure 75. Perspective 3. (Härstedt and Lewin, 2022)

The retention pond on the eastern side of the site is accompanied by a seating area with a view towards the pond and further out over the bioswale. The seating area is protected in the back by one of the saved trees (Laburnum aplinum) and new added vegetation. The design aims to go in line with the representation of a restorative site (Stigsdottter et al., 2017) where a place with a view and protection from behind along with the PSD serene, refuge, rich in species and nature are the most important ones. High grass has been chosen close to the seating area in order to mask traffic sounds from the road.

Residential yard

Stormwater management

The Residential yard has been designed to detain the stormwater from the roofs and water collected on site. One important strategy for stormwater management in Nya Udden, is to manage stormwater as locally as possible. The downspouts from the roof leads directly to the plant beds around the Residential yard. In extreme cases, the lowered centre part of the yard can be flooded to protect the buildings and has therefore been lowered in the design proposal. Some of the downspouts lead to water collecting barrels that can be used for irrigation.

Situation

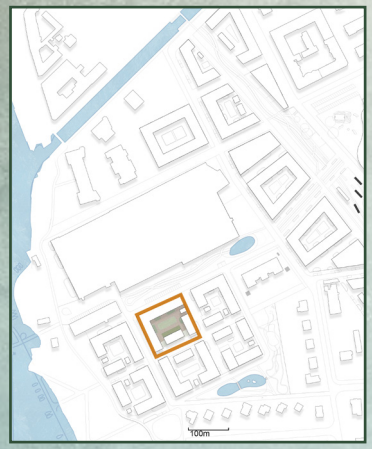

Figure 76. (Lewin and Härstedt, 2021)

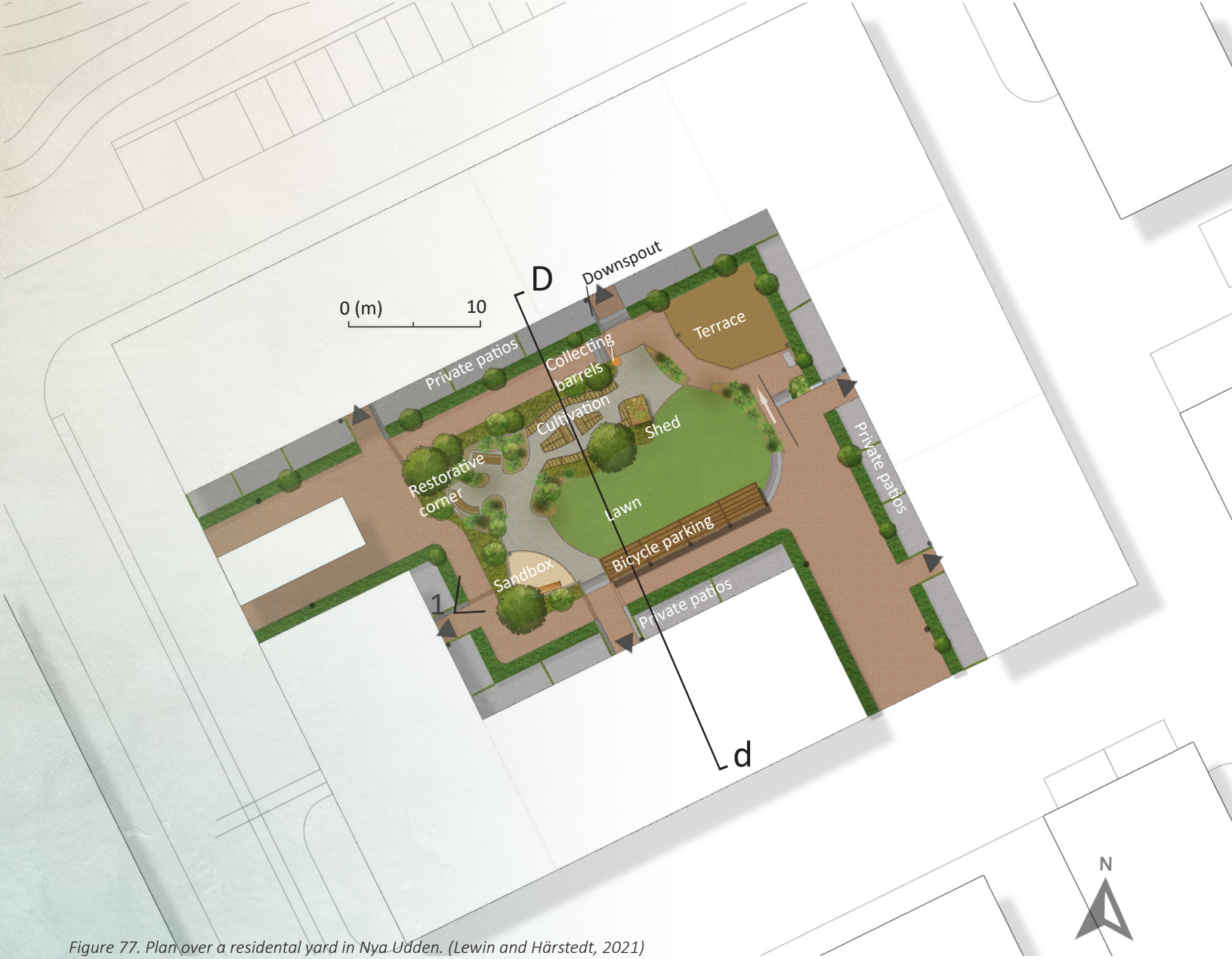

Figure 77. Plan over a residental yard in Nya Udden. (Lewin and Härstedt, 2021)

The four rooms

In this thesis the Residential yard is partly explained and planned to be designed with guidelines from Kristensson's (2007) four rooms. However, it is also argued in this thesis that if there is a lack of space in the residential yard, other local green areas could be used to complete the functions of these rooms and needs. The residential yard presented here, is not large enough to bring all the rooms and with fully PSD-values. Choices and prioritizes had to be made considering different aspects.

Playground

Children's need vary a lot in different ages. In this residential yard, children's play has been focused on the youngest children. A sandbox is placed in the southern part where the vegetation and buildings bring shade to protect the children from the sun. The sandbox is large enough to add small play equipments in. The lawn can also provide for unorganized play and games. Overall, we judge that this residential yard is too small to provide play for older children. Therefore, other play opportunities (water playground) in the approximate area have been implemented as a complement. The cultivation area could however be used for both older and younger children and bring positive effects on their health (Bergemalm, 2019).

Cultivation

There's a dedicated area for cultivation in the residential yard. Cultivation could also be a place to gather and meet your neighbours and built meaningful connections that contributes to the feeling of a context (Kristensson, 2007; Adevi, 2012). It is also suggested that cultivation has a somewhat healing effect on people (Grahn & Stigsdotter, 2002).

Venue

A place for venue is located in the north-eastern part of the yard with a barbeque site, tables and seating. This could be a place to gather and enjoy company in the common backyard.

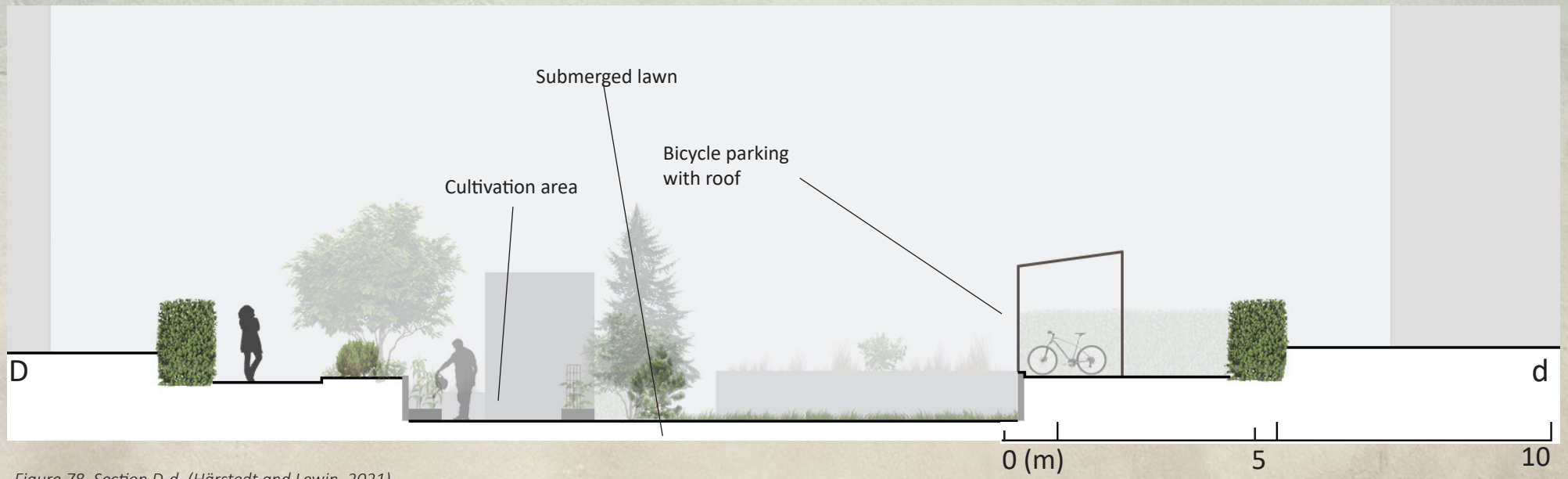

Figure 78. Section D-d. (Härstedt and Lewin, 2021)

Figure 79. Perspective in residental yard. (Lewin and Härstedt, 2022)

Lawn

Even though a lawn is simple, it provides values to a residential yard. It gives room for unorganized activities such as play, sunbathing or taking your dog out for a quick evening rest. It is also an area where water can infiltrate.

Restorative corner

A place for rest and restoration occupies the top left corner of the residential yard. This place is partly hidden to create a feeling of “see but not seen”. With the gravel path leading to it, you cannot be sneaked up upon without hearing the footsteps in gravel. Restorative places can be hard to create in public environments since there almost always are people nearby which can “disturb” the serenity and peaceful feeling. The residential yard can therefore to a greater extent provide restorative qualities since it’s semiprivate. But if the yard lack space, a fully restorative effect could be hard to achive (Stoltz, 2019).

Light plan

The light in the Residential yard aims to orientate and give use for play and venue during the winter season (Fuxén & Fagrell, 2015). Areas that are not useful during winter, like the cultivation area, is not lit in order to avoid disturbing lights for the residents.

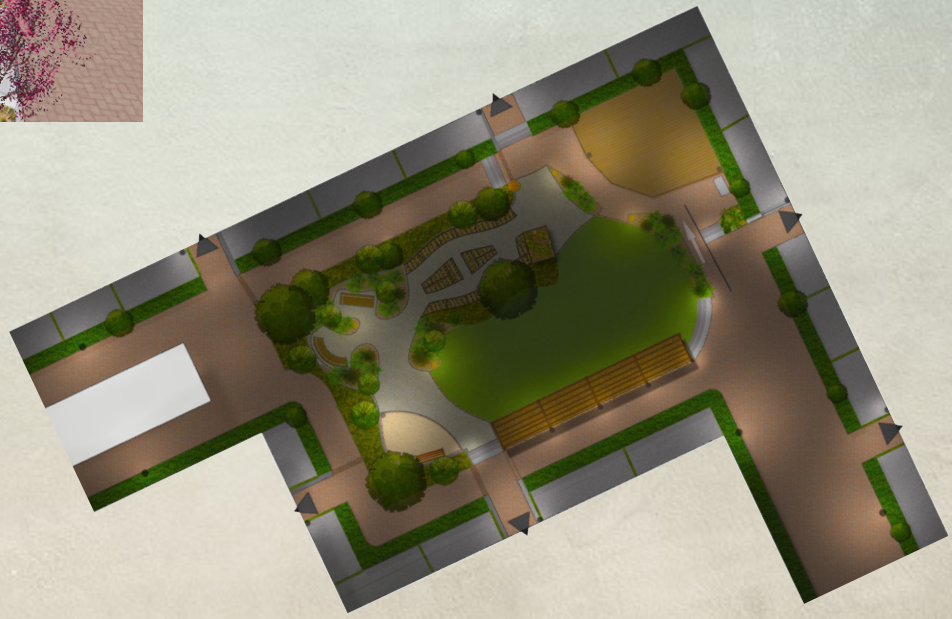

Figure 80. The residental yard’s lightmap. (Lewin and Härstedt, 2021)

Water playground

Inspiration

This site is heavily inspired by Natuurspeeltuin de Speeldernis in Rotterdam. The carefully designed natural landscape promotes exploration, creativity and physical activity. The water in Natuurspeeluin is from the nearby stream, here the water has to be pumped up. This provides clean water which eliminates the hazard of children consuming contaminated water.

North part

The northern part of the current grove is proposed in accordance with Kristianstad's general plan (2019) wishes to become an area for children where they can develop and meet their needs. The site has been divided into two parts. Closest to the preschool in north, the first part will represent a more intimate area for venue and play suitable

Situation

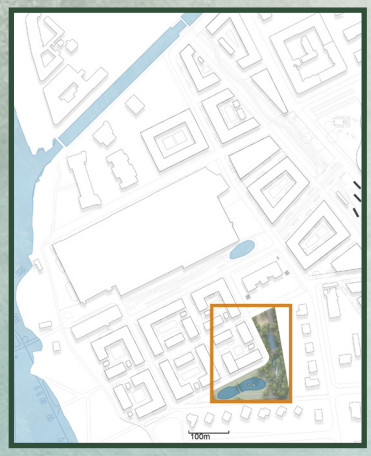

Figure 81. (Lewin and Härstedt, 2022)

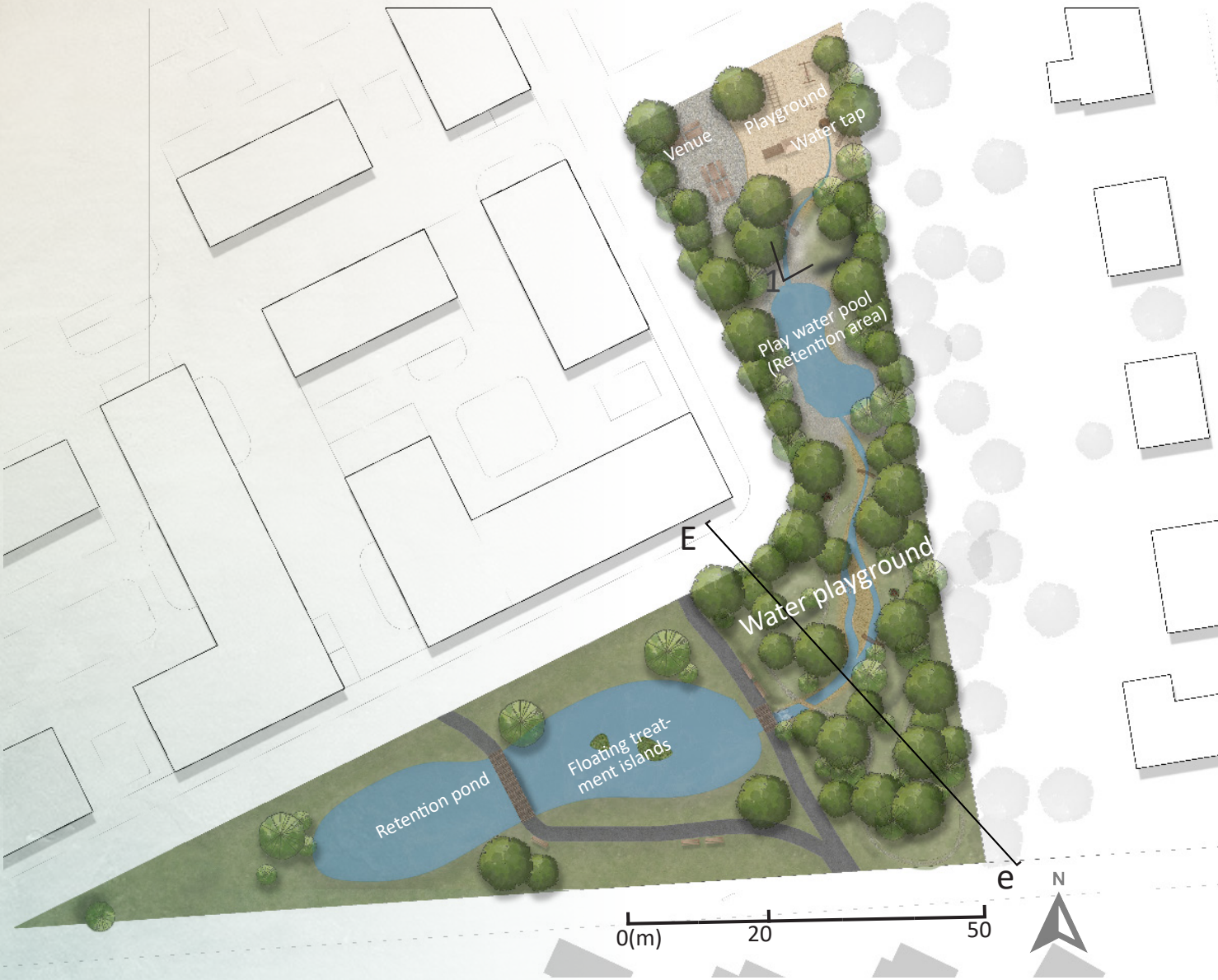

Figure 82. Plan over Waterplay and retention basin. (Härstedt and Lewin, 2021)

for younger children. The venue aims to be enjoyable for parents and teachers. If grownups like the playground, it's more likely that the playground are visited more often and improves the children's play opportunities (Jansson, 2013). Furthermore, this part is safer and more controlled compared to the southern part.

South part

In the south part of the playground, as much as possible of the current vegetation is saved to maintain a naturalistic feeling. This gives the children an opportunity to explore, create their own places and be creative, which is good for their personal development (Jansson, 2013). It´s important to preserve the curiosity and creativity for the children, therefore, we judge that this water playground shouldn´t be too much programmed. Children are given the opportunity to take calculated risks, however, safety is central in the construction of a playground, and we belief that this playground are balanced between safety and risks that supports the children's development.

Water play

In the play area there is a water source that creates an opportunity for children to explore play together with water in the sand or with the help of other play equipment. Here the children can create an impact, for example digging smaller canals in the sand through which the water can be led. Trunks and stumps can be placed over shallow waterways to invite physical challenges.

The water is led from the playground into the nature play where it forms a shallow stream and ponds on the way before it finally flows out into the final retention pond. There is a fence between the water canal and the retention pond for safety reasons.

Water is an important element in nature play as it contributes to physical challenges (Jansson, 2013) and is an important element when working with biophilic design (Browning, 2014). Moreover, water attracts insects and other small creatures that gives the children a better understanding for nature (Wennerström, 2019).

Figure 83. Section E-e. (Härstedt and Lewin, 2021)

Vegetation and stormwater function

The fact that the vegetation is saved on site not only benefits the children's play and development but is also an important part of the local area's water management. The area also allows to be flooded in the event of a cloudburst. When this happens, there is a risk of pollution at the area. But since the surface is not hardened, it has a good infiltration ability. The trees also slow down the runoff's velocity, which further increases the infiltration rate and allows the water to release sediment particles (Strom et al., 2013). In addition, the vegetation also purifies the water of contaminants and helps to transport water away from the soil by storing it in its body and evaporating it through transpiration (Blecken, 2021). Finally, the trees that are preserved in the southern part also shade the place, which protects children from both heat and overexposure to UV radiation.

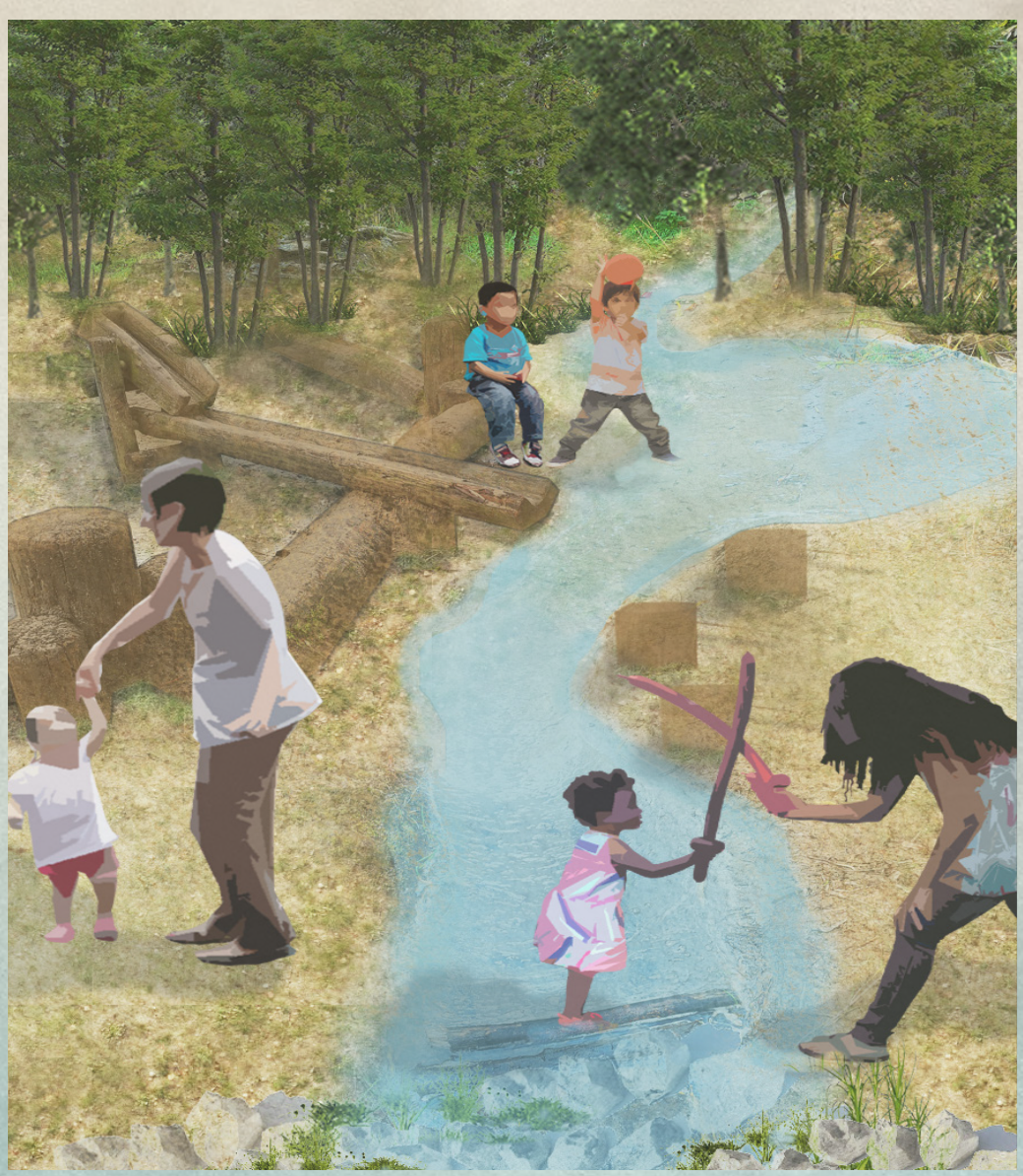

Figure 84. Children playing in the waterplayground (Lewin and Härstedt, 2022)

Stormwater calculations

As the thesis' purpose is not to plan the stormwater capacity of the site but rather how to design with stormwater management the calculations, are only a rough estimate to conclude if there are a potential to handle a 100-year rain. A rough estimate of the stormwater runoff can retention capacity is presented below.

First, the watershed area of Nya Udden is required to know how much precipitation that falls into the area. This is calculated in ArcMap's watershed function. See figure 83. This watershed boundary is calculated using the current digital elevation model (DEM) without any new development. The DEM is also a raster with 2x2m cells which is inaccurate in this scale. However, we do get a rough estimate of the boundaries. In ArcMap the watershed boundary's area is exported.

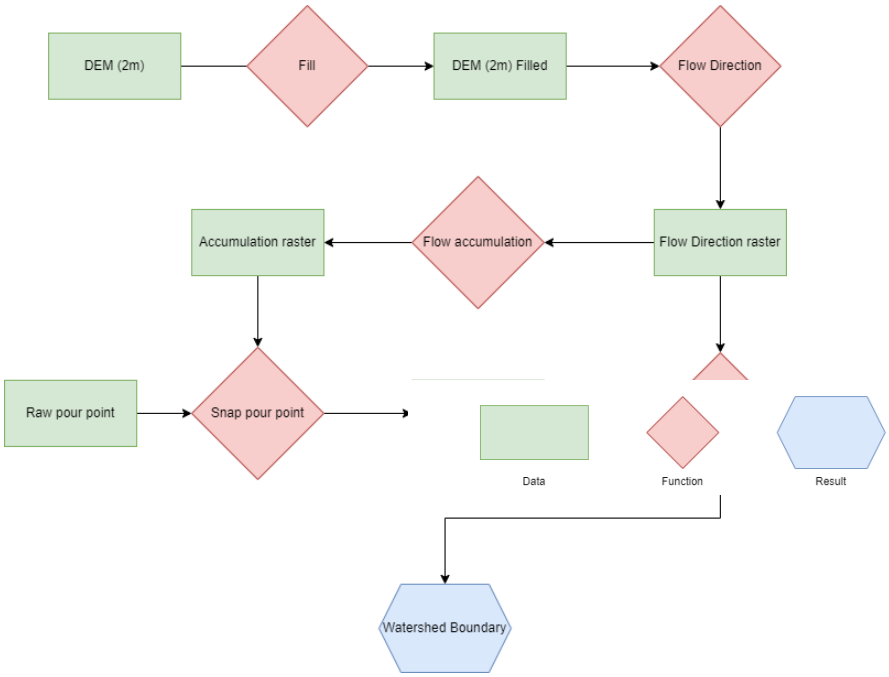

Figure 83. Flowchart of workprocess in ArcMap. (Härstedt, 2022)

The result gave a total area of the watershed: 120 141m^2

Comparing this to Tyrén's (2021) calculated watershed area of 150 000m^2 we calculated an area that's 20% smaller than Tyréns. This should be considered when calculating the total runoff on the site after interventions.

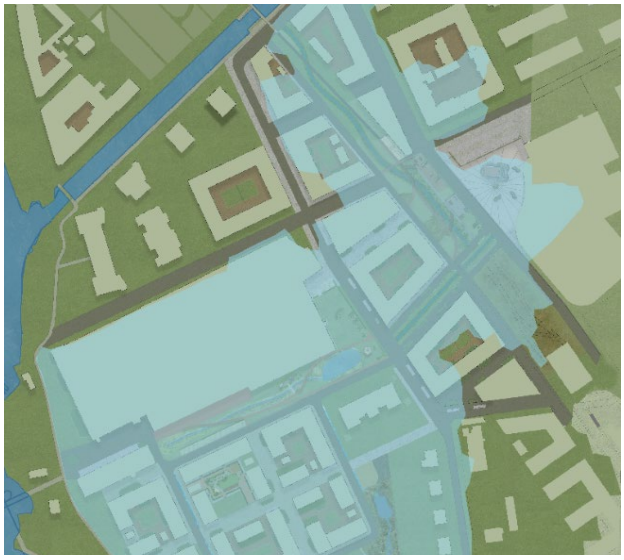

Figure 84 Watershed, produced in ArcMap (Härstedt, 2022)

To calculate the expected runoff on site we need the runoff coefficient on each ground material on site. The different materials runoff coefficient is presented in the table below.

The design proposal was added to ArcMap to receive the surface area of each material.
Since all the residential buildings that contains a residential yard are proposed to handle all precipitation that falls on their land, all of those areas were excluded from the mapping of surface areas.

Surface type	ϕ	Area (m^2)
Roof	0,9	28161
Road (Asphalt)	0,8	17317
Hardscaped	0,8	14597
Permeable	0,2	838
Vegetation	0,1	25270
Water	1	952
Weighted runoff ϕ		**Total Area**
0,63		87135

Table 3.

The ground materials are given a runoff coefficient according to table (3). This is a simplified version of runoff coefficient, but it does give a general idea of the runoff on site. (Tegelberg & Svensson, 2013). 20% will be added to the total area to match Tyrén's (2021) watershed area. This is done after all the buildings are excluded. These 20% will receive the weighted runoff coefficient since it is unknown where Tyréns watershed area is located and thus which surfaces our calculation missed. The added 20% surface area will give us a higher runoff amount.

At last, the detention detention/retention capacity of the site is needed. All stormwater facilities that can retain water are mapped out in GIS and their area is calculated. In this table we suggest that the larger swales are 1.5m in depth and 10m wide. The "connecting swales" than connects the bioswale and activity swale are suggested to be 0.5 deep and 8m wide.
The bioswale pond are suggested to be filled with 0.8m water apart from the water it is already containing. The detention lawn should be flooded with a 0.5m depth and the retention pond can be

filled up 1 meter from the current water level (or 0.5m in mean value when considering the slopes). Other surfaces that can be flooded but like the water playground and lawns in the parks have been excluded since their main purpose is not detaining water, but rather treating and infiltration. The total of 4462m^3 is the volume of water that can be detained on site.

Swale	Volume (m3)
Activity park	1763
Bioswale park	1043
"Connecting swale"	214
Basins	
Water square	270
Bioswale Pond	333
Detention Lawn	455
Retention Pond	386
Total	4462

Table 4 Stormwater facility volumes

To calculate the accumulated volume from the runoff the rational method is used. The equation is presented below:

$$V = A * \phi * i * t$$

As the area (A) and runoff coefficient (Φ) is known, the rain intensity (i) and time (t) is required to calculate the total runoff volume. The rain data is provided by Svenskt Vatten (2022). All coefficients are presented in table (3)

100 year rain, 60min	
A (m^2)	104 562
Φ	0,63
i (l/s m^2)	0,01515
t (s)	3600
V (m^3)	3593

Table 5.

The total runoff volume on site from a 60 minute 100-year rain is ≈3600m^3 while our site can detain ≈4400m^3.

This is a rough estimation of both the detention capacity and runoff volume, but it indicates that there is a potential for our design to handle a 100-year rain.

Delimitations:

- The DEM raster is not accurate (2x2m)
- Sewer drainage is not considered.
- Slopes are not considered.
- Rational method is a rough calculation method.
- Detention capacities are a rough estimate.
- The site is located on loamy soil with low infiltration capacity.

Final discussion and conclusions

Good design means that the site meets the requested needs and can function for many purposes, which often collide in urban situations due to lack of space. Therefore, the importance of a site's context and how it relates to the surroundings has to be looked at in order to prioritize needs and function that shapes the base for the design, which in our case has been to some extent neglected since focus mainly been on stormwater management design and EBD that support human well-being. The given design proposal, Nya Udden, are designed in a way that aims to support human well-being needs in residential areas and handle the stormwater runoff aspect due to the flood exposed location. These needs are mainly based on literature research and wishes from Kristianstad's general plan (2017) and green plan (2019). One note is that to get an even better understanding for the needs (people in focus), conversations with the locals would have improved the understanding. Unfortunately, we hadn´t the opportunity to have these conversations.

The design argues for how to implement different kinds of functions that support humans' well-being and at the same time contribute to multifunctional stormwater solutions. One strategy has been to implement different well-being values on different spots to bring the best function out of it. Lack of space seems to be the biggest obstacle when to constructing a well functional green area (Kristensson, 2007; Stoltz, 2019). In this design proposal a large contiguous green space has not been possible to design. There is thus a risk for a loss of context if green areas with different functions are to spread out. Even though our design proposal with implementations for different well-being values are placed in different subareas, there is still a connection between them through a green-way, swales, and paths.

Most of the time the research present theories and models you can use, however, they can be hard to implement if you don't know how to use them or don't understand them. This thesis is therefore an example on how to implement the research. We found that the use of EBD is beneficial in many aspects when it comes to the design choices. It facilitates the work because guidelines are given. The question can be asked whether a whole essay is required to understand the use of EBD. Some claim that it´s time-consuming when you don't know how it´s used (Brown & Corry, 2020), other that it instead saves time (Phiri, 2015). It's important to demonstrate that the definition of EBD isn´t clear. In this thesis, we define that EBD could be any design based on research. Sometimes the guidelines are clearer, and sometimes they are vague. However, what matters is that you understand the principles and use them in a creative way that fits the site. Our perception is that if

knowledge about EBD could in a greater extent be taught during the education for landscape architects, it wouldn't be too much of a problem to understand the use of it. Sometimes it can be argued that the creativity goes lost when models and tools within EBD are too "hard" stencilled that it will be at the expense of a designer's creativity (Bengtsson, 2018). But since EBD could be vaguely expressed there are plenty of room to be creative. The guidelines just work as tools, and it's up to the designer to use them. For instance, the eight PSD and the Color-wheel, have in our perception well explained basics for a humans need in an outdoor area and can be used to divide sites for different needs and understand the importance of space. Moreover, Kristensson (2007) gives an explanation for the different needs in the residential yard (venue, playground, living room and view). Since the site Nya Udden is a residential area, Kristensson's (2007) research (the four rooms) can therefore be applicable in the division of the design proposal. To understand children's play better, research from Jansson (2013) is valuable. In the more detailed level, biophilic design (Browning et. al., 2014) also gives tools for choice of materials, vegetation, elements and much more. The way you as a landscape architect guide yourself through the research and make decisions for its use, is creativity.

Site visits can also be seen as a kind of EBD (Brown & Corry, 2020). The role of the conducted site visits in this thesis has been crucial for leading inspiration and choice of design, especially when it comes to the stormwater solutions. Inspiration of other projects is often used when designers are about to make design decisions. So, the use of EBD in that matter can be seen as already frequently used in the design process. The choice of inspiration sites are often places that are seen as successful projects. Knowledge and inspiration from those sites are in many cases useful when to designing a new site. But we judge that there could be a risk that the inspiration site sometimes takes too much of a role in the design which could put the design out of its context or blow tight budgets. For instance, the implementation of the water square in our design proposal is a creative and functional stormwater solution with multifunctional values. But the construction is costly and requires frequent maintenance which might stand against the economic resources in Kristianstad municipality. However, in Kristianstad's general planning document (2017), it is suggested that long term goals and sustainability facilities in the green sector should be enhanced. Cloudburst will become a problem in the future so implementation for multifunctional stormwater solutions should at least be considered. When it comes to costs, swales are often a more economical investment and has a good stormwater management ability (Blecken, 2021). Bioswales can also contribute to aesthetic and appreciated green environments. A disadvantage may be that they require larger areas and create barriers in the landscape. In the given design

proposals, the implementation of the swales/bioswales has been appropriate as the green surfaces have been narrow but long.

The actual function of the presented design proposal may have shortcomings due to lack of knowledge in the construction since our focus mostly has been on the architectural part and promotion of human well-being. This also highlights the importance of co-operation with other competencies in subjects such as hydrology, engineers, and ecologists. Moreover, choice of materials could have been more analysed in detail since water has a high wear and therefore requires well-adapted materials. It is also important to have enough steep, correct elevation and construction to make the water flow in-between the stormwater facilities. This isn´t presented at a detailed level even though it´s mentioned. The design could also have been more detailed on some sites. This is however a decision we made to keep it general and not work on details as it's not within the scope of the research question.

Shortcomings in the use of EBD considering environmental psychology could sometimes be hard to adapt since research within the subject usually are for certain target groups and in more private areas (health gardens for instance). As argued in the literature, this research could still be applicable in more public areas, such as residential areas. But the actual function for restorative and instorative effects at the given sites, Bioswale park and Eco park, is still unknown. Research for implementation of EBD (especially the PSD) in more public areas are required in order to demonstrate factors that effects the human well-being. The way design for health promoted areas co-operates with stormwater facilities is still also mostly unknown. This thesis only suggest how it can be combined, but with no result for the actual function.

Our use of EBD did not provide any new unique values that hadn't been seen before e.g. Augustenborg and Bo01. The strength of the use of EBD is, in our point of view, a way to argue for the design choices that we have made, and effectively and confidently take design decisions that are proven to work. We judge that the use of EBD in this thesis has been to some extent time-effective since it provides a base and guidelines for design decisions.

If we suppose the stormwater calculations are accurate, the site seems to function as proposed, at least in the sense of stormwater management. In fact, the site's stormwater management is over dimensioned and therefore some of the more expensive solutions like the water square could have been cut and still function during a 100-year rain. In the future, the stormwater calculations can be produced at an earlier stage before detailed design (like the water square) are produced. It

would save time to not designs stormwater facilities that are not needed on site. This can also be a part of the EDB-toolkit.

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