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Water gardens and roofs;

*a research into their potential for contributing to water problems in modern cities*

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**Introduction**

Due to climate change, West Europe experiences more and heavier rainfalls in a shorter time span. Next to it, as a result of the increase of hard, sealed surfaces in particular in urban areas, storm water enters the sewage system so rapidly that it is likely to cause flooding. Apart from the run-off system, being in or on the ground there is little space in cities to store water.

Since the most populated area of the Netherlands is laying below sea level the problem is even more complicated, as rainwater cannot find its way out into rivers and sea. In the entire polder landscape, which occupies one third of the country hundreds of pumps are needed to discharge the water. In the last seventy years the most practised strategy has been to discharge water as quickly as possible out of the lowlands. The discharge system, either the polder-‘boezem’ system\(^1\) or the sewage system must therefore be able to hold increasing volumes of water during periods of heavy rainfall. Therefore water experts came up with a *three-stage sustainable strategy*.\(^2\) Preferably water should infiltrate into the ground, but if this is not possible or if the ground is saturated, the rainwater then should be collected and stored. The stored water could be used to water plants in the dry season or to keep fish in water basins. Only as a last resort should the water be discharged. The method of the three-stage strategy sounds so logical one wonders why everybody, even house owners don’t apply it in their gardens! Instead of it, nowadays gardens are transformed into an appendix of the living room and kitchen all with sealed clean floors and cannot take in any water at all.

In this paper we investigate the possibilities of solving water problems with the help of sustainable water design in private gardens and roofs in the city of Rotterdam. The theme of solving water problems in cities is widely discussed. Studies like Urban Green-Blue grids give a good overview of possible design solutions (Pötz & Bleuze 2012). To enrich the discussion we will look into the relation of context, the specific aspects of the place (ground type, garden size and orientation – roof slope etc)\(^\text{cetera}\) based on the *three-stage strategy* and the understanding of the genius *loci*.\(^3\)

Our aim is to argue; that water gardens and roofs can contribute to the water management in the city, to a more sustainable environment and at the same time can enrich the spatial quality and the joy of the garden itself.

**2. Water control and sustainable measures**

At least half of the precipitation could be processed on roofs by transforming the impermeable surface into a green surface (Geiger et al. 2009). The storage capacity varies according to the type and depth of the roof, the selected substrate and plants. There are two main green roof approaches; intensive and extensive. Intensive green

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\(^1\) The ‘boezem’ system, consisting of peat-rivers and canals, is the discharge system of the polder landscape. It connects polder water (on a lower level) and out- water (on a higher level) with the help of pumps.

\(^2\) *Commissie Waterbeheer in de 21e eeuw* (WB21, 2000) in its advisory report

\(^3\) The Genius Loci is an assembled concept that both, the ideas of topos (the consecrated ground) and locus (the rational basis) embed.
roofs are similar to having a garden, where the soil depth is at least 15 cm in order to create a condition for trees and shrubs to grow. The capacity of water absorption is high (80% in summer due to evaporation and 40 to 50% in winter). Retention can differ according to the type of soil, the vegetation and the weather itself. They impose a large additional load on the existing roof (290 and 970 kg/m2). Extensive green roofs don’t require much effort. These roofs are mostly not accessible, the substrate depth is thin, approximately between 2 and 15 cm. Plants like sedum, moss and dry meadows are used in this case. The water absorption is even higher than on the intensive green roofs (90% in summer and 75% in winter). They impose a small additional load on the roof (between 70 to 170 kg/m²) (Dunnet 2008). Besides the fact that green roofs slow down the run-off of heavy rainfall (peak rain), improve the air quality by filtering dust and cool the building they provide a habitat for birds and insects (Kadas 2006). Extensive green roofs are, therefore stimulated by municipalities.

Private gardens and outdoor spaces are nowadays not self-evidently ‘green’ (planted areas) and ‘blue’ (including water surfaces) anymore. In many cases large parts of the garden are covered by buildings like garages, greenhouses and sheds or sealed by paving stones. In order to give the garden its role back in managing the water, owners need to be informed and educated about the role their garden can play in reducing the run-off of rainwater to a possible zero. Next to this information, knowledge and design tools are needed in order to start the transformation of the garden.

In many countries house owners have to pay extra money, if they want to bring rainwater falling on their plot into the sewage system. This administrative practice helps to keep the water within their domain of house and garden

Infiltration
According to Pötz a large part of the problem is solved by opening-up half of the plot in order to make infiltration possible (Pötz & Bleuze 2012). Besides one could think of adding materials like gravel, bark flakes, plants and water surfaces. This part of the garden can take in water of the other sealed half of the plot, including the roof. But of course within the urban condition one should consider that most of the gardens are too small to follow this principle.

Storage
Next to infiltration water can be stored. The storage element should be as large as it can to catch the water amount of a peak storm. Within dry moments the water can be used in the garden, in order to water plants or slowly infiltrate into the ground. The storage elements can take on many forms (round, orthogonal, cylindrical etc.), sizes (small, large etc.) and positions (in, half-in and on the ground etc.) in the garden or even on the roof.

Discharge
By discharge we don not refer to discharging the rainwater into the sewage system but we will discuss the possibility of connecting the city rainwater to the polder water system.

Soil conditions and context
In the Dutch condition as in the case of Rotterdam we are dealing with three main soil types: peat, clay and sand. Some soil types, for example peat have a very low absorption coefficient and moreover the water table of peat-polders is too high to let water infiltrate into the ground. In clay polders, which have established a lower water table the soil type itself causes the problem because water can hardly infiltrate. Sand was introduced on large scale into the polder landscape from the 1960’s onwards. Not only the houses were built on it but many gardens as well. Here infiltration is possible. According to ‘Water duurzaam in het ontwerp’, absorption measured in meters in a day, vary due to the soil type: sand 1-50 m/day, clay and peat less than
0,01 m/day (Teeuw 2005). By adding more plants in gardens and roofs absorption increases. It is possible to mimic natural infiltration into the clay and peat soil by building wadis. A wadi is a low-lying wet zone, whereby the ground is prepared in a way that the water slowly infiltrates into it. This element increases the biodiversity in the garden, but needs quite some space.

**Design and composition**

Water has been one of the main components in garden design throughout different periods in history. Water elements next to its pragmatic use of irrigation and drainage have been used to determine the geometry of a place, to give meaning to it and to stimulate the senses. Studying these gardens (for example: Villa d’Este, Chatsworth house and Vaux le Vicomte) one becomes inspired by the variety of water elements employed in the design.

Three main themes, which evoke different atmospheres and experiences in the garden can be distinguished: the edge of the infiltration, storage or discharge element: hard or soft, the movement of the water: flowing or still-standing and the passage point between the element: inflow and outflow of water.

_The edge: hard and soft_

The edge, between water and land determines the form of the water, its flow and quality and the variety of flora and fauna. Bounds made with hard materials, like wood and stone make a sharp, straight, formal division between water and land. Waterbassins with hard edges can be classified as architectonic elements. Soft borders have a more natural appearance, water and land blend into each other, the shores are less steep and allow plants to grow and animals to move between water and land. Habitats of plants can be allocated to different zones according to their respective ideal distance to the water. Like there are: Moist zones, the capillary effect keeps the ground constantly wet with flora shrubbery and marsh plants; the littoral zones with 60 cm water with floating plants, rooted in the soil and leaves floating and the aquatic zones which host floating plants and underwater plants.

_Flowing and still-standing water_

In order to keep the water quality up to standard, water needs to circulate. Water can flow, fast or slow, fall from one level to another and jet, by introducing fountains, which at the same time can help to oxygenate the water. The movement of water introduces a sense of time and can be directive in a composition. In the garden, especially within the Dutch condition, a landscape without significant height differences one needs to design and build these water dynamics artificially. Flowing water is associated with dynamic activities like playing, refreshing and entertaining and can stimulate all senses. Still standing water is, typical for the Dutch lowland landscape. These surfaces work as a mirror upon which light and colours are reflected. Still standing water is associated with contemplative activities.

_Inflow and outflow of water_

One of the main themes of solving today’s water problems in gardens and roofs is to regulate the in- and outflow of the water into the garden and between the water elements inside the garden. Within the composition of the water design the in- and outflow mechanism deserves special attention, since they are stirring the water system. Managing the storm water, storing it during peak moments and letting it go after the peak helps to reduce the water problem. Elements, which regulate the water flow, can be formal or informal. Formal elements like gutters or cascades are fit to visualise the management of water.

**Housing districts in Rotterdam**

The city of Rotterdam is struggling with severe water problems due to the fact that the mixed sewage system cannot cope with the amount of rain anymore. More storage is needed. So far the municipality is aware of the problem and is
investigating many different strategies (Waterplan - Waterstad 2035), all focused on the public domain. This research likes to open up the discussion of private participation towards today’s water problem by offering knowledge and design tools to house owners. As an example three neighbourhoods are selected, differing in building age, housing type, roof type, the size of the garden, soil types and the height of the water table. They are Oude Westen (end of 19th century), Hillegersberg (1920-‘40) and Blijdorp (1930-‘40).

**Oude Westen**
The neighbourhood is situated near the riverbanks on clay near the city centre. The building blocks are four to five storeys high and are topped by flat or pitched roofs. The houses of the perimeter blocks border directly the street. The houses are only 4-5 meters wide and owned by two or four households. The private back garden is connected to the ground floor apartment. Parking lots or sheds occupy some courtyards. To find water management solutions for this dense area is very difficult. Space is sparse and plots are small. Furthermore, since the roofs have different forms using roofs for water absorption or storage is not so easy. Each individual house needs to check its roof and the possibilities of keeping water on it, in a basin or by greening it. Due to the fact that water doesn’t infiltrate in the ground and the small size of the garden one has to look for more architectonic elements, meaning more built solutions in the gardens.

**Hillegersberg**
The neighbourhood used to be a little village, which was founded around an old church on top of a river ‘donk’ (sandy hill). The housing area itself is built directly on peat with only the streets being raised by 2 meters of sand, like the front gardens. The back gardens remain on polder level and most of them are connected to ditches, which are linked to a lake. This lake is a leftover from peat digging. All surface water in the neighbourhood is connected to it. From the lake the water is pumped into the ‘Rotte’, the peat river, which gave Rotterdam its name. Lake and peat-river function as a water storage for the entire neighbourhood. From the ‘Rotte’ the water is discharged with the help of a pump into the river Maas. Most houses have a pitched roof and consist out of single or two households. Since the water table is kept very high the gardens are very wet and demand special plants. The roofs cannot hold the water and need to be directed into the ditch (right through the garden) or to be stored in the garden. A very interesting way of doing so would be to implement a pool in the garden, which changes size due to the amount of water. In summer time it could even serve as a swimming pool. Working with soft edges seems to be quite obvious in peat ground.

**Blijdorp**
The neighbourhood is situated close to the inner city. The former peat polder was entirely covered by 2 meters of sand. Streets and gardens are situated on almost the same height level. The housing block contains four levels of individual apartments. Most roofs are flat and are collectively owned. The backyards are, in general, small and directly connected to the apartments on the ground floor. Flat roofs and the sand layer offer a lot of possibilities for the arrangement of sustainable water gardens and roofs. The flat roofs can quite easily be transformed into roofs that can absorb half of the storm water. More water can infiltrate into the ground. Still small basins or water barrels can be placed in the garden in order to store water, which can be used during dry periods for watering plants. Thinking about solutions for peak water and playing with the seasonal changes can enrich the garden design.

**Conclusions and recommendation**
In this paper we have discussed the circumstances of three different 20th century neighbourhoods and their potential for contributing to water problems in modern cities. As said, infiltration measures in the Rotterdam area will fulfil the demand. The
main problem solving measures on Rotterdam's private plots are the implementation of water storage, the adding of roof vegetation and their mutual connection. The storage itself is an instrument, which can regulate the amount of water within the plot, is the most visible element in the garden design.

Besides solving the water problem on the plot itself, it is very effective to connect the plot's water directly to the surface water of the polder. By doing so the 'private rain water' is linked to a much larger scale of water management, which makes its regulation more flexible. Next to this advantage the connection supports the understanding of the water system as a whole. In many new neighbourhoods built in the 21st century these principles are better understood and water management is integrated in the urban plan.

More research on the 20th century neighbourhoods forming the largest part of the city is needed. All neighbourhoods need to be scanned by soil type, water table, sizes and form of gardens and roofs. From out this starting point the neighbourhoods could be categorized into general models, assigned by facts and figures of the current situation. The municipality should provide all data. As a second step water problem-solving elements could be listed and categorized according to context and function. Examples of usable water elements could work as a 'tool-box', which might even include water elements offered by the market. From here owners with or without the help of designers could start to assemble a specific, 'waterproofed' design for their garden and roof. We think that if owners become more aware of their possible contribution to solving water problems in the city and if then they start to understand the specific context of the house, they could become engaged in garden and roof designs, which are more sustainable. Last but not least, water and roof gardens offer unexpected atmospheres and experiences.

**Literature**


