

# USING WATER TO IMPROVE THE COMFORT AND EXPERIENCE OF A SPACE

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## **ABSTRACT**

Formerly, water contributed to innovation taking place on The Marineterrein in Amsterdam. However, currently its main use is for boats to sail on or people to swim in. Simultaneously, Bureau Marineterrein, the organisation involved in the development of the area, aims to create a future-proof city district featuring open innovation. Therefore, this paper will give an insight into how water can be used in an innovative way to contribute to the sustainability of a building but also help boost the image of water and the experience of the location or building that the solution is applied to. It does so, firstly, by examining three types of buildings or built elements that incorporate water into their design: the bathhouse, the fountain and technological water works. Secondly, it gives a brief overview of the history of evaporative cooling. Lastly, it analyses four reference projects. The research indicates that water has given the built environment a boost in two primary ways. Firstly, by being aesthetically pleasing and by providing comfort and refreshment, a calming feeling or opportunities for recreation, summarised as creating an "urban oasis" either inside or outside. Secondly, by solving a problem or by being a problem, that is solved using new technologies or existing ones in new ways, thus innovating, fascinating and impressing people. The identified design principles can be applied to developments on the Marineterrein or elsewhere.

**KEYWORDS:** water, fountain, bathhouse, water works, evaporative cooling, urban oasis

## 1 Introduction

The Marineterrein is an area in Amsterdam that recently opened up to the public. Previously, the Dutch Navy used the area, now they use a part of it. Water was always vital for the functioning and success of the terrain. First, it was a shipyard, where workers tested and improved many innovations. Craftsmen, plumbers and mast makers built modern war ships and helped the Netherlands become the powerful nation that they were during the 17<sup>th</sup> century.

Now, the area has once again become a place of innovation. As Bureau Marineterrein, the organisation involved in its development, states: "The Marineterrein will be developed into a future-proof city district featuring open innovation, accessible and flexible living and working spaces, unique housing, sports, recreation, and greenery."

Water used to be an important part of the terrain's innovative character and actually of the Netherlands in general. Currently, water still surrounds the site but its function has not changed significantly in a long time. The water is crowded with boats and in summer, people dive in for a refreshing swim. However, of what other use could it be? The main questions regarding water that Bureau Marineterrein asks are: "How do we maintain clean swimming water in the Marineterrein harbour and how do we develop an optimum water management system that helps cities cope with rainfall, cool their buildings, and create green roofs?" (Amsterdam, 2018b).

These questions are mainly looking for straightforward solutions to problems. This paper aims to focus on additional effects that water can have while solving these problems, for instance, with the technology of evaporative cooling. That could not only be useful for the Marineterrein, but also in many other places dealing with similar problems. Therefore, this paper will answer the following question:

*"How can water be used in an innovative way to contribute to the sustainability of a building but also help boost the image of water and the experience of the location or building that the solution is applied to?"*

## 2 Method

This study aims to gain insight into the use of water to make a building more sustainable, in an innovative way, while also adding value for the users or to the location, making this a 'place'. The following sub questions will help answer the main research question:

- What different types of water are there in the built environment? How do they affect their surroundings and how do people use them?
- How does evaporative cooling work?
- How was evaporative cooling used before and how is it used now?
- What design principles regarding water do several reference projects apply?

Two main methods serve to answer the sub questions and divide the paper in two. The first part is a literature study on the history of water as a place maker and on evaporative cooling. Studying how water structures in the built environment with different functions and applying various technologies create diverse places for people to use and experience or to gather at, will help develop guidelines for how to create such a place in the future. The examination of the history of evaporative cooling intends to provide insight in how to benefit from this method and in what different ways it can be employed.

The second part consists of case studies of four instances of water in the built environment. They will consider the functional use of water, the technologies involved, the degree of innovation at their time of realisation, their aesthetic value and their social function. These case studies should help find design principles that can be applied presently with the innovations of the current time. A schematic overview of the design guidelines is included in the appendix.

## 3 Different applications of water

Water is omnipresent in nature as well as in daily life. People need water to stay alive, use it for hygiene, swim in it for refreshment and pleasure or for sports, and they visit seas, oceans and lakes during holidays. Water is present in houses as drinking water from the tap, and in the built environment in the form of fountains, rivers, canals and ponds (Symmes, Breisch, & Cooper-Hewitt, 1998, pp. 9-14). Especially in the Netherlands, water has had a distinct presence in the country's history and landscape.

On one hand, there is the ongoing battle with water, which is the result of about 25% of the country being situated below sea level. The counter measures that the people had to take because of it, have shaped the country's landscape with its polders and dikes (Ham, 2009, p. 7; Reh, Steenberg, Aten, & Messchaert, 2005, p. 11; Rijn, Polderman, & Wammes, 2010, p. 11).

On the other hand, there is the importance of water for the country's wealth throughout history. The Dutch trade flourished in the 17<sup>th</sup> century. Trading happened mostly over water and its success was partially due to the country's strategic position in regards to rivers and seas (Stuijvenberg & Nederlandsche Maatschappij voor Nijverheid en, 1977, p. 105). The building of war ships also led to many innovations in shipping and ways of dealing with water, such as improved locks (Amsterdam, 2018a).

Throughout history, water has been present in many shapes and forms and with varying functions. This chapter discusses several instances of water that were of functional value, but additionally also had a social function. They are the bathhouse, the fountain and the technological waterworks.

### 3.1 The bathhouse

The bathhouse goes as far back as the ancient Greek and Roman times. Among the Greeks, the purpose of bathing developed over time. It changed from maintaining hygiene to being considered as beneficial for one's health and as a possible remedy against diseases. A common combination was that of a bathhouse with sports. Thus, athletes were able to take a bath after their physical exercise.

The Romans frequently built their baths at thermal or mineral springs and near military encampments. This intensified their use as a medical treatment for wounded soldiers. Aside from that, bathhouses were a place to rest and relax, to maintain hygiene, and a place of recreation, of religion, but also of socialising (van Tubergen & van der Linden, 2002, p. 273). As such, it was part of the culture of the Romans. It was common to go to the public baths daily. Whereas the Greeks would often combine their baths with a gymnasium, the Romans would also add lecture halls or libraries to challenge the visitors intellectually. They created a combination of health, education and recreation that was accessible to the masses, influencing the welfare of both the community and the individual. Scattered throughout the city, they almost functioned as community centres (Yegül, 1992, p. 30).

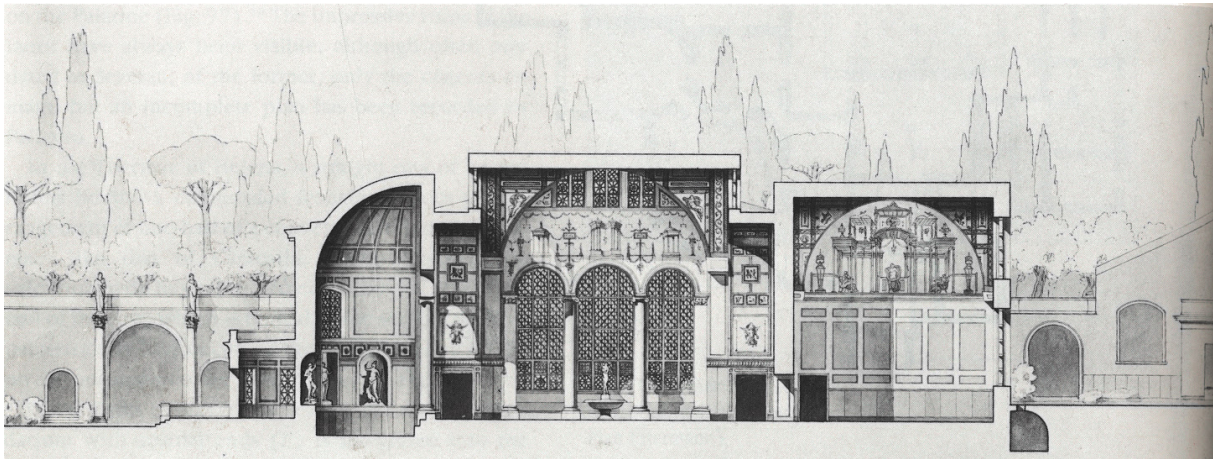
Two main aspects can account for the popularity of bathing among the Romans: the social aspect and the experience of the space and ritual. Bathing was a daily habit. Generally, the people would work during the morning, followed by light exercise and then a bath before having dinner. It was a moment for social interaction, from generic chitchat to business negotiations to making dinner plans with others. In addition,

the most important part of the Roman day, dinner, followed it. That expectation increased the enjoyment of the activity.

There was also the experience of the water, the smells, and the actions that were part of the bathing ritual (Yegül, 1992, pp. 4-5):

*"Bathing was a physically and psychologically satisfying experience. The experience of the bath - the warm, clear water, the shiny, marble surfaces, the steamy atmosphere, the aroma of the perfumed ointments, the intimacy of massage and public nudity - involved the awakening of all the senses. Thermal sensibility alone was an extremely powerful stimulant for the creation of a feeling of relaxation, comfort, well-being and happiness."*

Water was present in different ways and forms. Various types of baths and spaces were normally available: the caldarium, a hot bath, the tepidarium, a warm, central space with radiant heat and the frigidarium, a cold bath. Fountains (Figure 3.1), large pools and nymphaea, fountain like features dedicated to nymphs, were employed to activate the senses (Yegül, 1992, pp. 39, 395).



**Figure 3.1.** Baths with fountain and frigidarium at Hadrian's Villa, Tivoli.

Thus, water was evidently the central feature and main necessity of the Roman bathhouses. However, its availability was only made possible through the advanced water-supply system that the Romans invented. Aqueducts supplied many of the larger thermae with water. The cascades and fountains showed wealth and luxury but also the success of this technologically advanced system (Yegül, 1992, pp. 390-393).

### 3.2 The fountain

Just as bathhouses, fountains have existed since antiquity. While a "fountain" was initially a natural spring or source with the meaning deriving from the Latin word *fons* meaning well or spring, it now means "an artificial structure designed to contain and move water" (Symmes et al., 1998, p. 13). From the change in definition, the change in use also becomes apparent. At first, the main function of a fountain was to provide drinking water, water to bathe in and to clean with (Juuti et al., 2015). Later on, other functions emerged or became more important.

Thus, until water became available in homes, fountains were the place where people got their water. As such, they were also places where people would meet, and talk to and interact with each other, creating a feeling of community (Symmes et al., 1998, p. 31).

Not only did fountains serve the functional purpose of providing drinking water, they also served an aesthetic purpose as decoration or as a celebration of their builders (Juuti et al., 2015, p. 2315). Both the structure containing the water, sculptures inside it and the way they all guided water and light contributed to this quality. The design and hydraulics could together create different appearances of water: a flow, a jet, a pool, a spray, a mist, steam, droplets, a torrent, a cascade or a frothy mass and sometimes even ice. These forms of water came with different sounds, all influencing the experience of the visitor. (Symmes et al., 1998, pp. 9-10). As decorations, there are two distinguishable types of fountains: those where the structural or sculptural and architectural elements are the main feature and those where water is most important. Additionally, there are two main options for the location of a fountain: either in the middle of a space, or at the side of it, situated against a wall or a building (Symmes et al., 1998, pp. 14-15). Whereas a fountain at the edge of a space resembles more a scene from a painting, or a still of a play to be viewed, a central one becomes a focus point of the space, where movement and interaction revolve around.

Aside from these primary purposes of fulfilling basic needs and being decorative, fountains were sources of refreshment. There are instances of fountains intended for providing drinking water that people used to



**Figure 3.2.** People bathing in the fountain of the Acqua Paolo in Rome.

bathe in. The Fountain of the Acqua Paola, or Il Fontanone, in Rome is such an example (Figure 3.2). It was so popular for bathing that this was eventually prohibited (Symmes et al., 1998, p. 37).

Furthermore, in summer it is common to see people dipping their feet into a fountain, splash themselves (or others) with its water to cool down or see young kids playing around in one. Thus, they offer refreshment through the sensation of cold water on one's skin. They also refresh by causing a slight decrease of the temperature of their immediate surroundings, which occurs through evaporation (Bulut & Atabeyoğlu, 2007, p. 2438). The following chapter will explain this principle in more detail.

The use of fountains for refreshment partially coincides with that for recreation. While the water has a cooling effect, the action of splashing and playing with or avoiding water provides pleasure. When new technologies became available, new types of fountains emerged. One was that of water jets emerging from the pavement (Figure 3.3). The jets often varied in height and appeared in seemingly random patterns. These fountains challenged and encouraged people, perhaps mostly children, to try to run through them while keeping dry or on hot days with the exact opposite goal: getting wet. The mayor of West Palm Beach in Florida even converted the classification of one such fountains from fountain to pool and added a life guard and public bathrooms due to its incredible popularity (Symmes et al., 1998, pp. 146-147, 181).

In the sixteenth century, joke fountains became popular. With them, designers aimed to surprise, entertain and fascinate visitors, as they were made with new technological features. There were less pleasant examples,



**Figure 3.3.** Children playing in the Centennial Fountain in West Palm Beach.

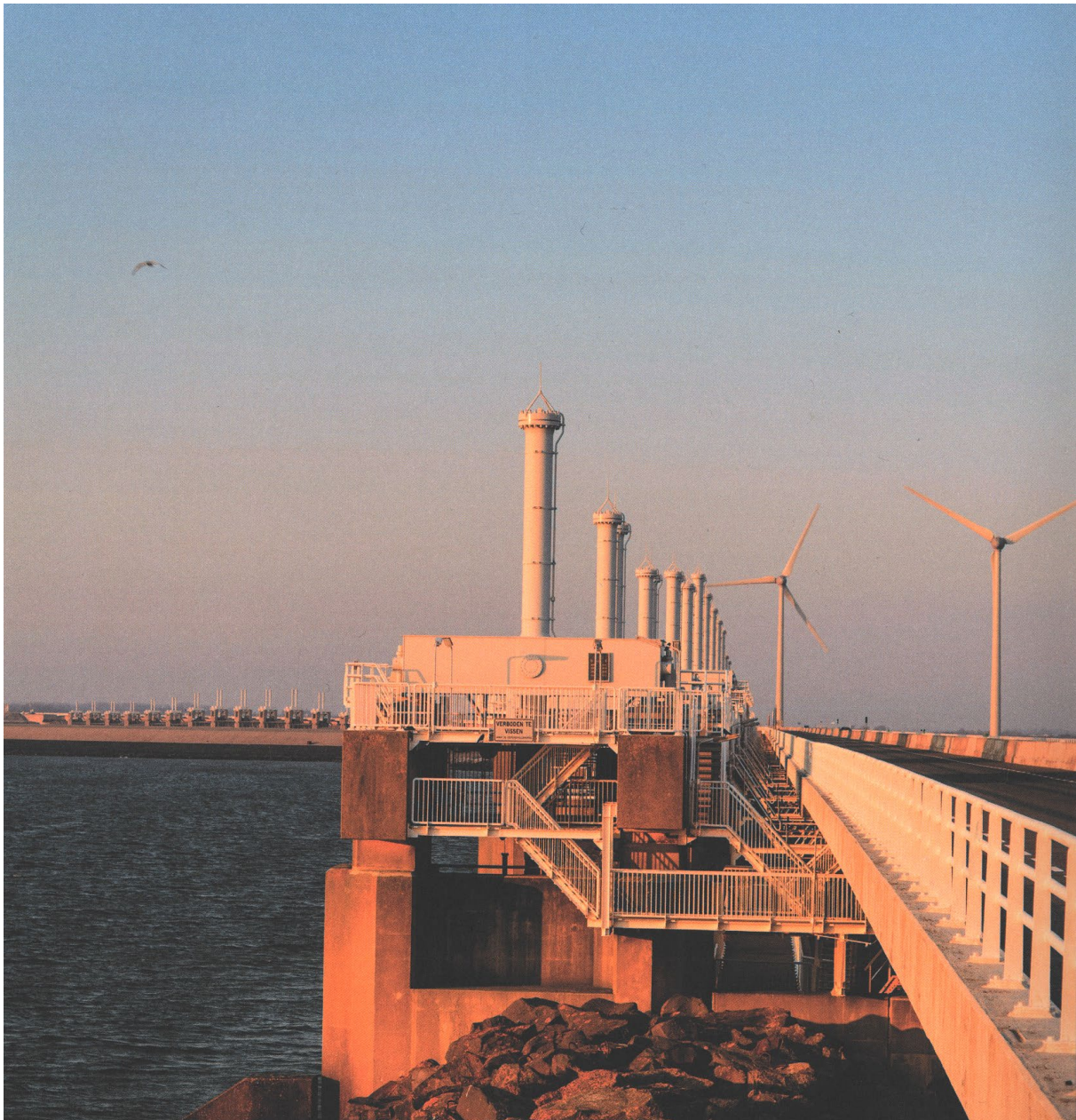


**Figure 3.4.** Tourists gathering at and looking at the Trevi Fountain in Rome.

of water flooding benches that users were sitting on, and more pleasant ones, of water flowing over a handrail as one placed their hand on it. (Symmes et al., 1998, pp. 137, 139-140).

Presently, people also go to fountains, especially in summer, just to watch the flow and play of the water, the sculptures the water flows over, to listen to its sounds and enjoy its cooling spray. Plenty of fountains have even become popular tourist attractions, such as the Trevi Fountain in Rome (Figure 3.4) or the fountain on Trafalgar Square in London (Juuti et al., 2015, pp. 2340-2341; Symmes et al., 1998, p. 137).

Combining all the aforementioned purposes of fountains, it is fitting to describe them as an “urban oasis”, a public space that is of value to the neighbourhood and its users in multiple ways. Fountains offer a visual experience but also appeal to the other senses. The different forms of water attract people and especially children. Thus, fountains add life and scale to the place they are in (Symmes et al., 1998, pp. 162-163, 167).



**Figure 3.5.** The technical structures of the Oosterscheldekering have a sculptural quality to them.

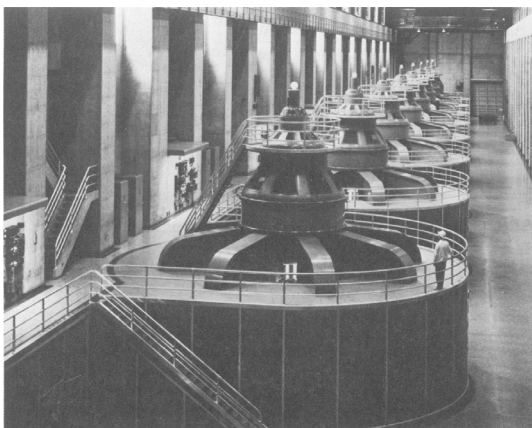
### 3.3 Technological water works

Water has not only been part of the built environment in buildings or as urban elements. It has been part of the landscape too. Both in natural ways such as rivers, streams, lakes, seas, oceans and waterfalls, and in combination with works of technology, such as dams, storm surge barriers, sluices, or mills. As such, technology has served worldwide to provide defence against flooding, to harvest water’s power, to transport water and more.

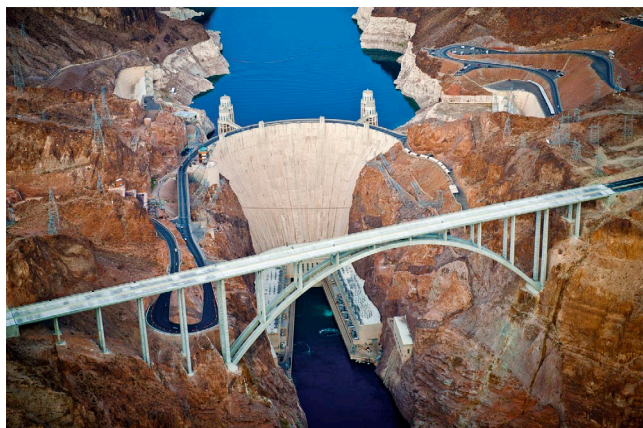
In the Netherlands especially, technology has provided a means to protect the country and its people from the sea and rivers (Bijker, 2002, p. 570). The measures against the water were necessary to survive and therefore demanded the Dutch to continuously come up with new and advanced techniques to assure their safety (Will & Berg, 2002, p. 9). The Oosterscheldestormkering (Figure 3.5), opened in 1986, was an example of a completely innovative use of technology and hydrological sciences (Bijker, 2002, p. 584). It was a representation of the Netherlands as a modern country and together with the other Dutch water works received much admiration worldwide (Ham & Toussaint, 2018, pp. 374, 391). Kramer, Oeffelt & Heeringa call the Dutch water works “innovative, impressive and iconic” (2017, p. 21). They refer to them not only as the equipment to control the water, but also as works of art. Although the main purpose of the water works was functional, they did have an architectural style or architectural elements to them (Kramer et al., 2017, p. 23). This was not only the case the past decades, but already around the 17<sup>th</sup> century. Public water works were monumental and representative. Dams were the most symbolic, “combining the functions of central instrument of regulating water levels and currents, transshipment of cargo and demonstration of the independence and self-governance of the city” (Meyer, 2009, p. 435). The technologies set in place by the Dutch, changed the way the Netherlands looked. Dikes and windmills started to dominate the landscape. Inhabitants considered dikes an appealing place to live, high and dry (Meyer, 2009, p. 434; Reuss, 2002, p. 466). Thus, the Dutch water works were made out of necessity, but also represented modernity and innovation, and yielded new types of landscape and buildings or built elements.

In the United States, dams were common examples of technology applied to restrain and utilise water. There were over 50 dams that together regulated the waters of the Colorado River, which was repurposed to serve the needs of human civilisation (Gibbs, 2002, p. 88). The dams provided water for agricultural and municipal purposes, such as irrigation and drinking water, produced electricity for the states California, Nevada, and Arizona and created new water transportation routes (Rogers & Schutten, 2004, pp. 260-261; Wilson, 1985, p. 463). The Hoover Dam was one of the largest ones. Completed in 1936, its creation resulted in the great reservoir and water park called Lake Mead. As a(n) (artificial) lake amidst hot and arid country, it provided opportunities for refreshment and water sports and turned into a popular tourist destination (Rogers & Schutten, 2004, p. 260).

The dam itself became a symbol of modernity, of technological progress and of the ability of man to control and overpower nature (Rogers & Schutten, 2004, p. 261; Wilson, 1985, p. 465). As such, it also attracted numerous tourists, both during its construction and after. An elevator took those who entered the dam down about 154 meters. Visitors then arrived at a tunnel of volcanic rock, with water from natural springs dripping down the walls. The tunnel guided them to the generator room, where the tops of nine 21 meter high generators, calmly humming, were visible (Figure 3.6). If the timing was right, an alarm would sound from one of the generator gates opening, resulting in the building starting to tremble. In the visitors centre, an explanation of how the dam functioned and how it was built was available. Outside, tourists could walk across the top of the dam and look down to see the water emerge from the dam some 220 meters below (Figure 3.7). Visitors could also reach the intake towers of the dam, in the lake, where the water entered through huge pipes (Gibbs, 2002). Although functionality, not aesthetic quality, was the prime goal in constructing the Hoover Dam, the work of architectural advisor, Gordon B. Kaufmann did contribute to the dam’s appearance and symbolism. His architectural decisions aimed to emphasise the engineering and the machinery. Kaufmann placed the transformers outside in full view. He lit up the dam at night and added light globes on top of the towers on the crest that “conveyed an almost supernatural effect as if some hidden dynamo was pulsating energy.” (Wilson, 1985, pp. 476, 479, 485-486). Thus, built with a functional purpose, the Hoover Dam became a symbol of technological progress and control over the landscape, through its size and design.



**Figure 3.7.** The generator room of the Hoover Dam.



**Figure 3.6.** The impressive size of the Hoover Dam from above.

## 4 How evaporative cooling works

One of the qualities of fountains that the previous chapter mentioned was the cooling effect they offered through evaporation. It is a principle or technology that could also be applied on a larger scale, to cool buildings sustainably. Therefore, it is worth examining how the technique works and how it was present in the built environment before.

Evaporative cooling is a way of cooling that depends on the evaporation of water. When a person is sweating, tiny bits of water will form on their skin. The water droplets need energy to evaporate and extract this energy from the environment. Thus, the temperature of the surrounding air decreases (temporarily) and feels colder. The same principle can be applied to a building. There are two common types of evaporative cooling: direct and indirect cooling.

With direct cooling, the simpler alternative, hot (outside) air is sucked into an enclosed space with an evaporative pad. This pad is a porous structure made of, for instance, cellulose, wood or paper. A pump keeps it continuously moist. As the hot air passes through the pad, part of the water evaporates. This process cools the air and moistens it (Figure 4.1). A fan proceeds to blow the cooled air into the spaces that need it. The already present hot air should be able to escape. It is best to solve this at a high level, using natural ventilation (Colt, 2014; Lazzarin, 2015).

With indirect cooling, the evaporatively cooled air does not enter the space, but passes through a heat exchanger and transfers its cold to another airflow, generally outside air, which is then blown into the space. Consequently, the air temperature decreases slightly less than with direct cooling. However, the humidity does not increase (Colt; Lazzarin, 2015).

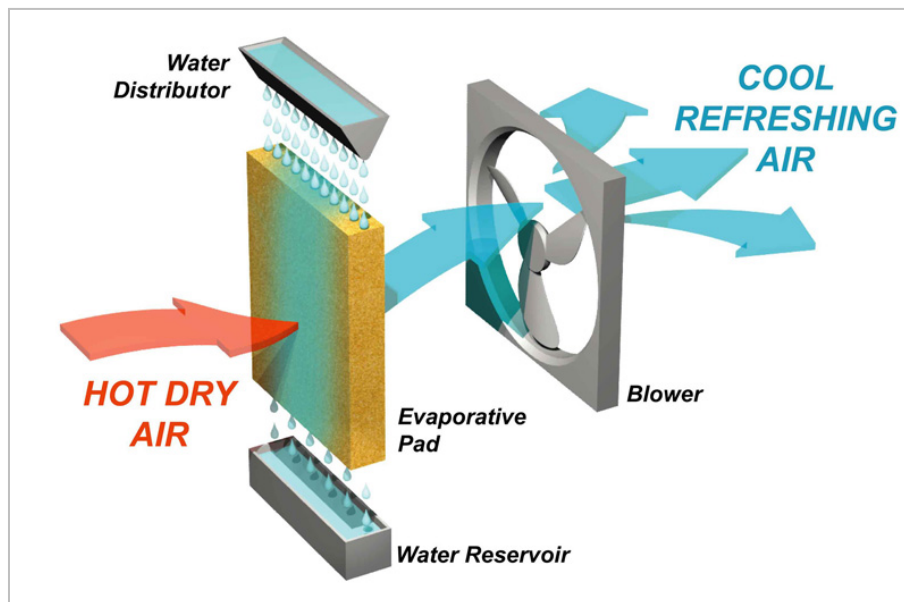


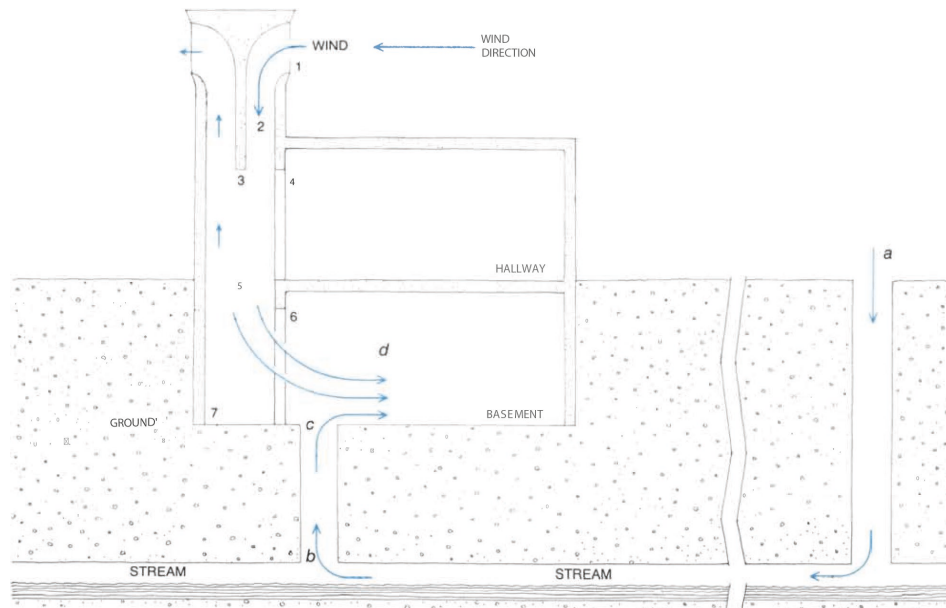
Figure 4.1. Schematic workings of an evaporative cooler

## 5 A brief history of evaporative cooling

Although evaporative cooling is not as common as the better-known air conditioner as a means to cool a building, it has been around for a considerably longer amount of time. Traditional Middle-Eastern architecture already applied the principle, originating sometime between 3000 and 900 B.C. The hot and arid climate in most Middle-Eastern countries demanded a way to keep cool. As their only energy sources were the sun and wind, they used the passive principle of evaporative cooling to successfully keep temperatures low and even circulate and humidify air (Bahadori, 1978, p. 144). Iranian architecture offers some examples of the early application of evaporative cooling in different ways. It often occurred in combination with a wind tower. A wind tower had one end that rose higher than the building that it cooled and one end that connected to the basement. Depending on weather conditions, the exact functioning of the tower varied. However, the main result was that it created a draft, which the opening and closing of doors directed through the building. By itself, it did not lower the temperature as such but provided a cooling effect through the movement of air (Bahadori, 1978, p. 146). Evaporative cooling was added in various ways to lower the temperature.

One method was groundwater seeping through the basement walls of the tower. When the air flowed past it, the air would cool evaporatively.

Then there were generally two options of placement for the wind tower: attached to the building, as part of it, or a certain distance away from the building, separated by for example a garden. The first option could

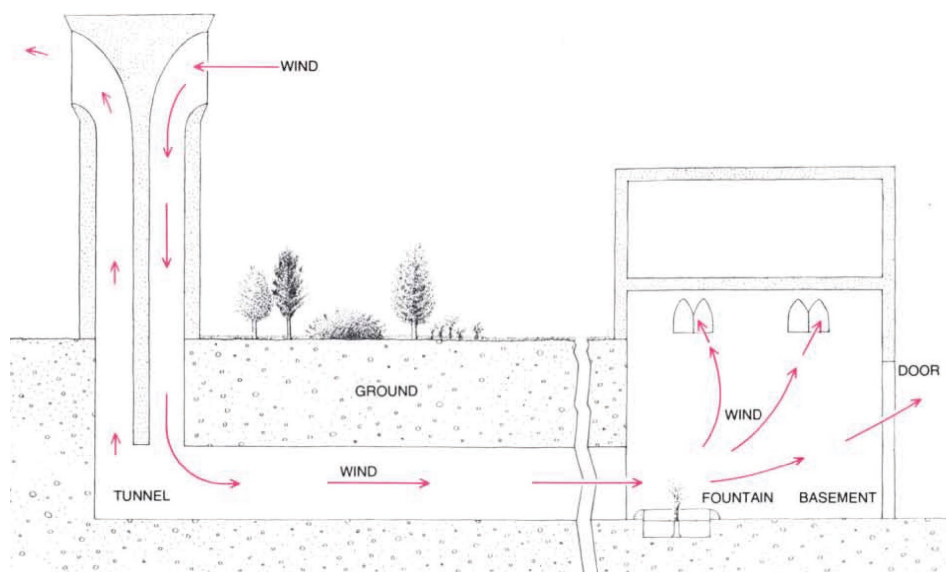


**Figure 5.1.** Evaporative cooling with a wind tower attached to the building.

result in the system shown in Figure 5.1. There, a shaft connected an underground stream with the basement that the wind tower served too. Another shaft adjacent to the building connected the stream to the surface and let in fresh air that the underground stream consequently cooled evaporatively. As the wind tower was next to the building, the wind entered the basement directly. When it did, it passed over the shaft from the stream and mixed with the cooled air coming from it. This system was so effective, that the point where the cold air entered became a popular place to store food. An alternative to the underground stream with the same effect was the placement of a fountain or water basin where the air of the wind tower entered (Bahadori, 1978, pp. 148-149).

Figure 5.2 shows an example of the second option, where the wind tower is not directly adjacent to the building. A tunnel connects them. In between tower and building sits a garden. When the plants are watered, the water seeps down through the ground and moistens the ceiling and walls of the tunnel. As the air from the wind tower passes through, the evaporation of these water droplets once more lowers the temperature of the air and humidifies it (Bahadori, 1978, p. 147).

The visible parts of the aforementioned evaporative cooling systems were the wind tower and in some of the options the fountain or water basin in the basement (Figure 5.3). All of these are architectural elements. The tower was either part of the building and could share the same architectural appearance and characteristics as the rest of the building (Figure 5.4). Otherwise, it was a standalone building that could still be similar in appearance. The placement of the tower also had an effect on the space around the building. By choosing to separate it from the main construction a space in between could be created. This could be a garden or a square with the tower as a central focus point. Thus, the tower had the potential to add value to the overall



**Figure 5.2.** Evaporative cooling with a wind tower separated from the building by a garden.

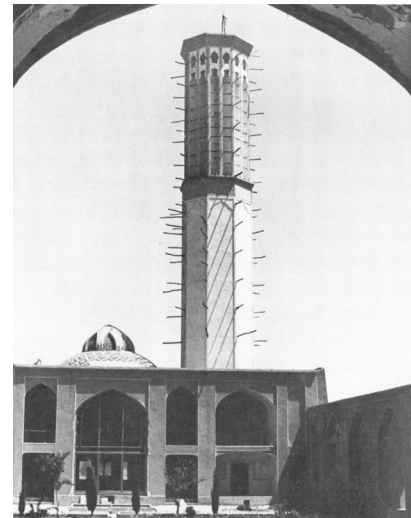


design or at least did not diminish it. The same applied to the bodies of water that were part of the cooling system. They simultaneously provided cooling, had an aesthetic value and could make pleasant sounds.

Between these first forms of evaporative cooling and the current application with mechanical units, evaporative cooling mainly occurred as fountains, pools, or other bodies of water on squares, patios or in parks. In hot periods, the evaporation of a fountain's waters would cool the direct environment and make public spaces more comfortable (Symmes et al., 1998, pp. 173-174). Thus, they were not as much part of buildings, but they were part of the built environment. As Symmes said: "Throughout history, fountains have refreshed, cleansed, satisfied, spiritually nourished, soothed, inspired, impressed and entertained people while enhancing places." (Symmes et al., 1998, p. 28).



**Figure 5.3.** The opening of a wind tower ending above a fountain to increase the evaporative cooling.



**Figure 5.4.** A windtower integrated into a building in Yazd, Iran.

Evidently, simpler, often outdoor forms of evaporative cooling have been around for centuries. As a mechanical system, it has a much shorter history though. In the USA, direct evaporative coolers appeared around the 1930s (Reichmuth, Turner, Higgins, Pierce, & Lau, 2006, p. 1). Recently, evaporative cooling has resurfaced on a larger scale, although still widely underutilised. Because it is an energy efficient method, does not use a chlorofluorocarbon refrigerant or other ozone-depleting substances, and, depending on the climate, can increase comfort, it fits the need for sustainable solutions (Colt, 2014, p. 2; Foster, 1998, p. 1).

Evaporative cooling is the most effective in arid climates. This could explain why for the past decades, or ages even, it has not been applied largely in other climates: because it would be less efficient there.

Although in an arid climate it can lower the energy consumption by up to ten times compared to a conventional system with the same cooling ability, in other climates energy consumption can still become, on average, up to four times lower. Additionally, the cost of a much more commonly used vapour compression system can be roughly twenty times higher. Lastly, the use of only outside air for cooling improves the quality of the indoor air. These positive facts raise the question why in the built environment evaporative cooling is not more present. In arid climates, a possible disadvantage could be water consumption. The quality of the water has to be good enough too. (Lazzarin, 2015, p. 4; Reichmuth et al., 2006, p. 1). In climates that are more humid a disadvantage could be the fact that the (direct) system raises the humidity of a space.

Currently evaporative cooling's main use is the air-conditioning of buildings. It lowers the air temperature and humidifies the air when necessary. When evaporative cooling is not sufficient on its own, it can serve as a way of pre-cooling. As such, it can reduce the energy consumption of the conventional system that provides the cooling demand. Evaporative cooling can also cool a liquid, via a heat exchanger, which can then discharge the heat of for instance an industrial process (Lazzarin, 2015, p. 5). Since evaporative cooling is particularly suitable for large or high spaces, buildings in the metal, plastics and food industry, warehouses, and spaces that have the purpose of preserving fresh fruits and vegetables commonly use it. Data centres, which create heat and therefore consume quite some energy needed for cooling, already regularly use evaporative cooling as well (Colt, 2014, p. 3). However, evaporative cooling is also applicable in homes and perhaps even in public transport. Countries such as the USA, Australia and India already employ it for residential use. Even there this could happen more, but in some parts of the world, the system remains entirely unknown (Foster, 1998, pp. 1, 9).



**Figure 5.5.** A modern evaporative cooling unit on the roof of a building.



**Figure 5.6.** Modern evaporative cooling units on the facade of a building.

Whereas the aforementioned wind towers and fountains were often part of the architecture or at least had some aesthetic qualities to them, that is less true of the modern, mechanical evaporative coolers. These consist of units that suck the air in and pull it through a water-saturated membrane. In practice, these can be found on roofs or attached to the side of a building (Figure 5.5 and Figure 5.6). They are generally made of metal. As they come as prefabricated, installable units, they are rarely integrated into the architecture of a building. A variation to the metal units is that of the water-saturated membrane covering almost entire walls. This is, when used, commonly seen in a brownish colour in for instance greenhouses (Figure 5.7). Thus, the modernised way of evaporative cooling, with mechanical units, currently remains a mere solution to a problem rather than becoming part of the building and its design.



**Figure 5.7.** Evaporative cooling pads applied to the side of a green house.

## 6 Examples to learn from

The four reference projects that this chapter investigates each apply water in a different way to make a space. They create a different experience. The four projects to be discussed are the Alhambra and Generalife in Granada in Spain, the Salinenbad in Salzuflen in Germany, the Lovejoy and Keller fountain in Portland in the USA and finally the Delta Works in Zeeland in the Netherlands.

## 6.1 The Alhambra and Generalife

The Alhambra is a collection of palaces that consists of both Arab and Renaissance architecture, located in the southern city of Granada in Spain. It was built in the thirteenth and fourteenth century and later expanded in the sixteenth century, by king Charles V. Nearby, slightly uphill, the gardens of the Generalife can be found (Nevins, 1988, p. 693; Willmert, 2010, p. 157).

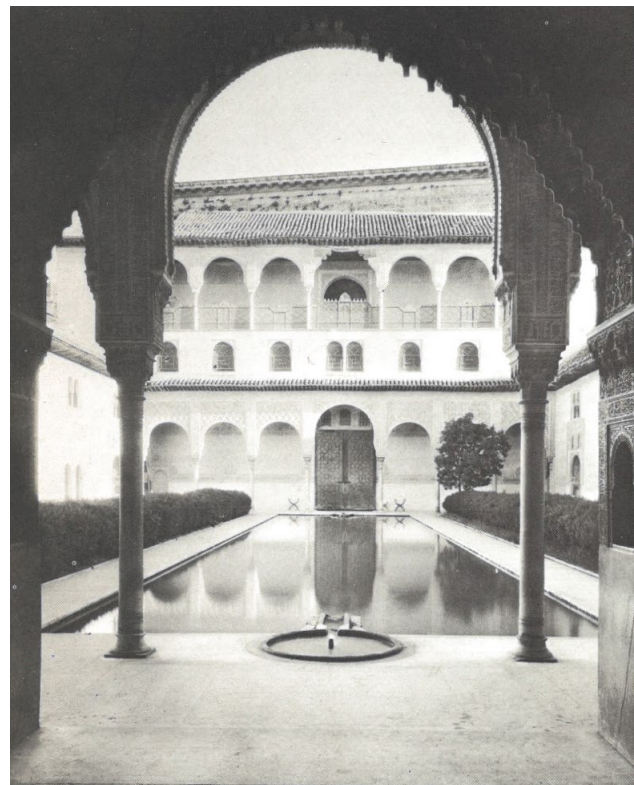
The buildings contain various courtyards, which are centred around water and together with the gardens are the main focus of this case study (Nevins, 1988, p. 694). Water played an important part in the Spanish-Arabic architecture. Islamic religion pictured paradise as a garden that was full of rivers and earthly gardens often tried to mimic this. In Islam, a cross with a circle at its intersection was a way of representing earth divided by the four rivers of paradise. Therefore, it frequently shows up as a motive in gardens, particularly as water channels. Sometimes a fountain was present in the middle, representing the source of the Paradise Rivers. The generally simple and geometric fountain shapes also originated from the fact that according to Islam the depiction of living beings is prohibited (Juuti et al., 2015, p. 2339; Nevins, 1988, p. 698).

An additional characteristic of the water in these gardens and courtyards was that the channels were narrow, the water shallow and the jets modest (Figure 6.1). In the hot and arid climate, water was valuable and therefore used sparsely (Nevins, 1988, p. 698). However, despite water's relatively scarcity, water features were still abundantly present. That was due to the positive effect they had on the climate through evaporative cooling. They moderated the temperature and increased the humidity. The courtyard of the Comares Palace, for instance, featured a 250 square meter pool of about 1.3 meters deep to utilise this effect (Figure 6.2). Furthermore, with its sizable volume, it had quite some thermal mass and was able to absorb a fair amount of solar energy. The water of the Lions Palace had the same purpose of cooling. However, the method differed. Instead of a large, static surface, the water here flowed and bubbled or was sprayed through the air. Thus, the exposed surface of water increased and more of it could evaporate (Willmert, 2010, p. 170). Details such as a gutter-like handrail on stairs with water flowing through offered additional refreshment. This was a practical solution for getting the water where it needed to be, as the water came from the mountains and moved only by the force of gravity, but it added functional value too (Nevins, 1988, p. 698). Sound was also an aspect in which the fountains differed from the typical Western ones. With their multitude of small jets, the fountains created tinkling, peaceful and musical sounds, relaxing for those who visited (Nevins, 1988, p. 701).

Thus, the fountains in combination with the architecture and gardens were visually pleasing, but also contributed to creating a comfortable climate and pleasant sensory experience.



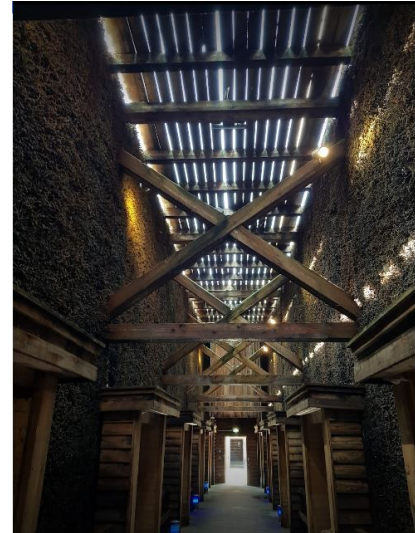
**Figure 6.1.** One of the cross-shaped fountains in the Generalife in Granada.



**Figure 6.2.** The pool in the Court of the Myrtles in the Alhambra in Granada.



**Figure 6.3.** People sitting and inhaling the salt air under the covered part of the Gradierwerk in Bad Salzflen.



**Figure 6.4.** The inside of one of the Gardierwerken in Bad Salzflen.

## 6.2 Gradierwerk Bad Salzflen

In Germany there is a multitude of towns with the prefix *Bad*, meaning they are or once were a spa town. Bad Salzflen is one of them. Originally, though, it was a salt extraction site ("Geschichte Bad Salzflens," 2018). At what is now a public square, salt works were located. There, workers would heat saline, a solution of salt in water, until the water evaporated and the salt crystallised ("Zoutziederij," 2018). The salt industry made Salzflen prosper and it became a wealthy city. In the eighteenth century, the new landlord had the salt works modernised. Then, "Gradierwerke" or graduation houses came into existence. They ensured a highly (energy-)efficient production process by increasing the salinity of the saline solution (the brine) from six to twenty percent. The graduation houses did so with a timber structure that was filled with wooden branches from blackthorn shrub, through which the brine slowly seeped. The water on the brushwood evaporated and a more concentrated solution ended up at the bottom of the construction. A side effect of this process was the creation of slightly salty air, similar to seaside air ("Geschichte Bad Salzflens," 2018; "Graduation Houses," 2018; Rendle, 2016).

While Salzflen's importance in the salt industry decreased, the rise of Salzflen as a spa city started in the early nineteenth century. Doctor Heinrich Hasse advised to build a bathhouse as it would have positive medical effects ("Geschichte Bad Salzflens," 2018). The graduation houses ceased to be useful for the salt production around 1945. Although they use 600.000 litres of water a day and the brushwood needs replacement regularly, the city kept them. As they attracted many visitors, especially in summer, and were valuable elements for the public space and its liveliness, the houses were important for the town. They began to function as an enormous outdoor inhalation facility. The sea air had a positive effect on the respiratory system and reminded visitors of the sea despite not being near it ("Graduation Houses," 2018).



**Figure 6.5.** People sitting in front of and walking along one of the Gradierwerken in Bad Salzflen.

Three graduation houses remain and they all offer a different experience. Rose bushes, adding their scent to that of the salty air, surround one of them. Visitors can go up to the top of another one and walk over the entire wooden wall or sit there with a view of the city. It also features a covered walk for when it rains (Figure 6.3) and a basin with salt water for a Kneipp arm-bath. This bath is also said to have a positive effect on the users' health.

Of the third one, the inside and top are both accessible. This graduation house replaced the oldest one in 2007 and was completely rebuilt. Tourists and inhabitants can experience the even stronger salty air inside and see how the house was built and the brushwood stacked (Figure 6.4). Benches inside the structure provide sitting opportunity, and calming music and a ceiling resembling a starry night sky add to the experience ("Erlebnis Gradierwerk Graduation House," 2018; "Graduation Houses," 2018). Along all the graduation houses, there are benches for people to sit on too (Figure 6.5). While sitting, they can inhale the healthy air, following the instructions provided on information boards. Thus, combined with several ways to walk through, over or alongside the timber construction, the graduation houses create different experiences. Simultaneously, they show part of the history of the town and give insight into a technology that also positively influenced its surroundings.

### 6.3 Lovejoy and Keller Fountain

The Lovejoy Fountain and Keller Fountain, designed by Lawrence Halprin and Charles Moore, are located in Portland, Oregon. Dating from 1966 they are quite recent, realised as part of Portland's urban redevelopment. The fountains distinguished themselves from others through the fact that they combined two urban elements: the fountain and the plaza (Symmes et al., 1998, pp. 168-169). They were places where all kinds of people gathered. As Alison Hirsch describes it (Hirsch, 2006, p. 2):

*"On a sunny day at the Ira Keller Fountain, one will see families with enthusiastic children cannonballing themselves into the pools, people watching from the grass sidelines or dangling their feet over the concrete ledges, a gathering of peaceful homeless youth, and perhaps a dog or two wading in the lower pools."*

Several aspects explain what made these water playgrounds such a success. They created an experience, making use of water as an attraction for playfulness. Halprin studied human behaviour to uncover other elements that encouraged interaction with a space or an object (Ward Thompson, 2013, pp. 88-89). He said: "What I want is to design events, which occur - which have no necessary or recognizable form but which generate qualities of experience." (Halprin, 1972, p. 43). To accomplish this he let the High Sierra Mountains in California inspire him. Halprin made an abstract representation of elements of its landscape in the fountains. He believed the natural landscape had certain qualities that could also feature in an urban design, mentioning the "unpredictable rhythms, relatedness of things, small counter rhythms, quiet but persistent sounds, edges softened by natural process, evolution by addition or subtraction, non-completion of spaces, variability of light, and a context conducive to participation." (Symmes et al., 1998, p. 169). The abstract landscape of stepped terraces around the Lovejoy fountain (Figure 6.6) provided opportunity to sit or lie down and to walk or climb (Beesly & Khan, 2009, p. 13). Water flowed from a higher pool onto a cascading waterfall, which invited adventurous exploration by climbing on its steps or walking through it (Figure 6.7). The upper pool was relatively quiet, with water bubbling up in the middle and wide edges around it to sit on. The lower pool, with water about ankle deep, was perfect to wade through. It too featured a wide edge



**Figure 6.6.** The stepped slopes of and people bathing in the Lovejoy Fountain in Portland.



**Figure 6.7.** Children climbing the stepped waterfall of the Lovejoy Fountain in Portland.



**Figure 6.8.** The Lovejoy Fountain in full use.



**Figure 6.9.** People jumping into the water at the inauguration of the Keller Fountain in Portland.

to sit on and from which one could dip their feet in the water or from which parents could watch their playing children (Figure 6.8). Large stepping-stones formed a route from one side to the other side of the lower pool, encouraging a first, easy, interaction with the water or fountain. With the waterfall and the still pools there are multiple types of water, calm and frothy, both creating different sounds (Symmes et al., 1998, p. 170). The Keller fountain featured a larger and higher waterfall, with water that cascaded over tall concrete blocks at the higher level and then dropped steeply down. Stepping slabs provided a route through the lower pool here too. However, in this case they varied in height. They created a more adventurous route by allowing people to climb on or walk over them and to jump from slab to slab. The upper pool was again a shallow, tranquil one. Elderly people would be seen there, sitting and talking, while babies played in the shallow water and the more adventurous people explored through the knee-deep water to the edge of the falls (Figure 6.9).

Thus, the success of the Lovejoy Fountain and Keller Fountain seems to depend on their functioning as urban space or elements that offer both visual pleasure and an (interactive) experience, with water adding an extra dimension of adventure, refreshment and sound (Symmes et al., 1998, p. 171).

#### 6.4 The Dutch Delta Works

The Dutch Delta Works are a famous example of how the Dutch have protected themselves from the water surrounding them. In 1953, a huge flood killed eighteen hundred people. At the time, the Rijkswaterstaat was the main party in control of the water management in the Netherlands and instantly started with the Delta Plans (Lintsen, 2002, p. 565). The Oosterscheldestormkering or Oosterschelde storm surge barrier, was created as part of this plan. Queen Beatrix opened it in 1986. The barrier was a dam across the Oosterschelde, consisting of rows of caissons that closed when a storm was expected, but were otherwise open (Figure 6.10). Then, this barrier and the other dams of the Delta Works were hugely innovative pieces of hydrological engineering (Bijker, 2002, pp. 580, 582). Consequently, they brought the Netherlands global fame and a reputation of having defeated the sea (Lintsen, 2002, p. 565). The Delta Works also became a national pride and, due to the advanced technologies used, a symbol of modernity (Ham & Toussaint, 2018, pp. 374-375).



**Figure 6.10.** The Oosterscheldekering in Zeeland in open situation.



**Figure 6.11.** The watchtower on the Philipsdam, providing a wide view of the surroundings.

The Delta Works did not bring merely safety and fame, they also enabled the realisation of new roads on top of them. This contributed to the connectivity of Zeeland to the rest of the Netherlands and of its own different islands (Meyer, 2009, p. 440).

Aside from new roads, the Works also brought forth new landscapes. Examples were beaches on top of dams, beautifully staged routes over the series of dams, and new nature reserves. The road near the Philipsdam was consciously put next to the dike instead of on top of it. Only near the dam it gradually rose to its level, thus creating a feeling of leaving the polder and going onto the dam. Other roads on dams were specifically designed to offer a wide view of the surroundings.

Although first meant to all have the same height, the pillars of the Oosterscheldestormkering eventually had cylinders and valves with a variable height. The deeper the water, the higher they would be positioned. Thus, their height showed visitors the depth of the water. The barrier became a defining element in the landscape. On the Philipsdam, a watchtower was added to offer a view of the Krammersluices, and the vastness of the surrounding landscape (Figure 6.11). The Works themselves stood as sleek, technical elements in the vastness of the water, with the effect of the tides made apparent as much as possible (Ham & Toussaint, 2018, pp. 362-364; Steenhuis, Voerman, Swart, Emmerik, & Uitgevers, 2016, pp. 30, 138, 157).

The Works attracted many visitors. They were a place where civil engineering, landscape, and nature coincided and one could experience sun, sea, and technology simultaneously. On Neeltje Jans, an island near the Oosterscheldestormkering, a small amusement park was realised (Figure 6.12). From there, tourists could take boat trips, watch the barrier or swim with sharks and it educated its visitors about water (protection). The closing of several estuaries created lakes and areas for water sports, fishing and beach recreation (Ham & Toussaint, 2018, pp. 318, 326, 329). Thus, the innovative technology of the Delta Works themselves, the new landscapes that they had generated, and the opportunities for recreation that they offered all contributed to their popularity.



**Figure 6.12.** Children playing in and with water in attraction park Neeltje Jans in Zeeland.

## 7 Conclusion

The aim of this paper was to find an answer to the following research question:

*"How can water be used in an innovative way to contribute to the sustainability of a building but also help boost the image of water and the experience of the location or building that the solution is applied to?"*

Examining various types of buildings or built elements that use water, briefly reviewing the history of evaporative cooling and studying several reference projects, lead to the discovery of certain common characteristics. These properties can serve as an answer to the question and as guidelines or input for a design project.

The success of Roman bathhouses was threefold. Firstly, there was the combination of a regular habit and a social aspect. Visitors came to fulfil a daily need and while doing so could meet and interact with other people and possibly make plans with them for the night. Secondly, there was the sensory experience: the warmth of the water and the steam, inducing a feeling of comfort and relaxation, the smells of perfumes, the cold freshness of the water, smooth and shiny surfaces with water running over them, the sound of water in fountains and their visually pleasing effect, together with the calmness of large pools of water. Thirdly, the bathhouses represented wealth, luxury, and a successful, technologically advanced, water supply system.

Fountains similarly combined a daily need, getting water, with social activity and sensory pleasures. The sculptures of fountains aimed to have aesthetic qualities, together with different ways of displaying water: as a flow, a jet, a pool, a spray, a mist, steam, droplets, a torrent, a cascade or a frothy mass. Aside from that, they offered refreshment by evaporative cooling or the sensation of cold water on one's skin. The sound of the water could be enjoyable to listen to. Some fountains offered a recreational aspect too, allowing or encouraging people and children to interact with the water or fountain, or showcasing new technological features for manipulating water.

The more technological water works, such as those in the Netherlands or the dams in the United States, gained popularity from their representation of modernity. The innovative technologies applied fascinated their visitors. They were something they had not seen before. Their novelty, often combined with their size, was impressive. Visitors centres informed people about the history and operation of the particular structure. Evaporative cooling as a method to cool buildings or spaces has fluctuated in use throughout history. Currently, mostly industrial buildings use it and these do not integrate it architecturally. The system units are simply placed on top of a building or attached to its side, whereas in Middle-Eastern architecture the cooling system was integrated into the architecture with wind towers outside, and fountains and pools inside the buildings.

The reference projects apply many of the aforementioned characteristics. Additionally, the Alhambra makes the water part of the architecture, by giving fountains a symbolic (religious) shape or running it through, for instance, a railing. Water helped to cool either through large surfaces/volumes or moving water and resulting spray.

The Gradierwerk in Bad Salzuflen adds the element of smell, creating an experience reminiscent of walking along the sea. Aside from cooling, it provides a positive effect on one's health. Visitors can also go inside to discover how the system works and learn about its history. On top of the Gradierwerk, they have a view of their surroundings. Benches allow people to sit down and prolong their stay, while covering part of the installation ensures that rain does not prevent its use. Finally, the length and the differences between each of the three works, create a route with changing experiences for people to follow.

The Lovejoy and Keller fountains encourage interaction. They do so by having routes through the fountains. There are dry routes, across stepping slabs, and more adventurous wet routes, where people have to climb up and down blocks or up through a fall. The depth of the basins enables children to play in them. Height differences of parts of the fountains encourage movement and exploration.

Finally, the Dutch Delta Works offer an experience on a much larger scale. Visitors can drive on top of them, with the height and placement of roads influencing the way they see the landscape. A watchtower offers a view from a new perspective and shows the vastness of the project. The Works promote technology and use it to impress.

To conclude, water has given the built environment a boost in two primary ways. Firstly, by being aesthetically pleasing and by providing comfort and refreshment, a calming feeling or opportunities for recreation, summarised as creating an "urban oasis" either inside or outside. Secondly, by solving a problem or by being a problem, that is solved using new technologies or existing ones in new ways, thus innovating, fascinating and impressing people.



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## functions



**(daily) need:** adding a facility that fulfills a basic need intensifies the use of the facility

## senses



**evaporative cooling:** the evaporation of water can provide a cooling effect

## aesthetics



**display of water:** displaying water in various ways can be fascinating to look at

## interaction



**route:** creating a route through or over water can encourage interaction with it



**refreshment:** immersing oneself directly into water can provide a cold or refreshing feeling



**nature:** a(n abstract) representation of nature, such as a waterfall or slope can be experienced as pleasant by users



**depth:** the depth of the water can influence the interaction with it. a shallow pool can encourage playing or dipping ones feet in it



**showers:** people that are exercising outdoors can be tempted to go inside a building if the building contains accessible showers



**sound:** the sound that water makes can be experienced as calming. different 'types' of water make different sounds



**size:** a large size can be perceived as impressive



**water type:** the way water is displayed affects the way people interact with it. jets can be more playful and a pool more calming



**drinking water:** a drinking fountain can attract people that are exercising outdoors to a building it is close to



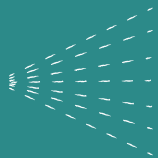
**varied display of water:** different ways of displaying water have a different effect on the experience of people



**innovation:** the fact that something is new, that it was previously unknown can be attractive to people



**flow:** water flowing through a containing element



**spray:** water dispersed as small droplets



**droplets:** small bits of water, dripping



**cascade:** water falling in steps from a high to a low level



**steam:** mist that forms from hot water



**waterfall:** water dropping from a high to a low level



**pool:** large surface of water



**mist:** very fine collection of water particles



**torrent:** a wild stream of water



**frothy mass:** a foam of white bubbling water



**jet:** a stream of water forced out under pressure

## displays of water