Chapter 13: Urban wetlands and storm water management

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Introduction

Increasing risks of flood damage to life and property combined with wider health and socioeconomic and environmental issues are perceived as a major threat in both developed and developing societies. Many global cities have built grey infrastructure to provide efficient urban services (e.g. road infrastructure, drainage), which has marginalised natural hydrological systems and concealed them underground. A high proportion of grey infrastructure and techno-sols in urban areas results in a huge amount of polluted urban storm water following significant rainfall events and has been acknowledged as a so-called “wicked problem” with widespread public health implications. Due to increases in urban land sealing, impervious surfaces and the interruption of natural infiltration of runoff coupled with urban activities (e.g. ground water extraction and domestic, commercial, agricultural and industrial wastewater discharge), high volumes of peak runoff discharge can be produced, which alters the natural hydrological pattern and cycle and causes localised flooding. An excessive runoff load event puts pressure on the existing and conventional storm water drainage infrastructure that forces storm water to mix with sewage and disgorge into natural stream and river systems. In response to the growing prevalence of urban flooding and storm water-induced socioeconomic and health issues, urban planners have shifted their focus towards adopting nature-based solutions (NBS) (see Chapter 2) and low-impact development (LID), water-sensitive urban design (WSUD) and integrated storm water management (ISWM) approaches and practices (Fletcher et al., 2015). Cities have been re-inventing, reinstating and liberating forgotten and modified natural hydrological systems, such as rivers (see Chapter 11), natural drains and wetlands, for environmental and societal benefits.

Historical accounts of ancient civilisations (e.g. Indus and Minoan) show how they developed sophisticated systems to collect rainwater, prevent nuisance flooding and convey waste, based on many trial-and-error modifications (Burian and Edwards, 2015). In mediaeval Europe, urban drainage practices were non-existent, and urban storm water runoff and industrial wastewater were discharged into local streams and rivers – a practice that continued until relatively recently. Over the last century, there has been an evolution in management of urban storm water. Especially in the United States, the establishment of local and federal regulations requiring storm water control measures (SCMs) explains the early developments of single-service engineering solutions, such as sediment traps or drywells, which proved efficient and effective SCMs to detain or retain storm water (McPhillips and Matsler, 2018).

The inclusion of ecological components that changed the paradigm of storm water management can be traced back to Boston’s renowned “Emerald Necklace” park system. Designed by landscape architect Frederick Law Olmsted in 1895, the park demonstrates a well-established concept of blue-green infrastructure (Marks et al., 2015). It encompasses a hydrological network that resolves the functional issues of urban storm water management and contributes to providing aesthetic, functional and cultural values as Boston’s largest public park (Figure 13.1). The

Figure 13.1

A late plan of the Boston Park System by Olmsted in 1894, which shows an integrated network of blue-green infrastructure

(Source: Wikipedia Creative Commons)

Clean Water Act (CWA), established, reorganised and expanded in 1972, formed the basic legal structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. Also in the United States, the low-impact development concept emerged from the approach of “design with nature” (a term coined by Ian McHarg in 1969) and aimed to minimise the cost of storm water management and its adverse impact on nature.

The integrated urban water management concept in the 1980s broadened the practices of urban drainage and combined with water supply, ground water, wastewater and storm water (Fletcher et al., 2015). Similarly, in the 1980s, the sustainable urban drainage system (SUDS) was developed in the United Kingdom and defined the scope for controlling urban runoff. The concept of water-sensitive urban design began to be applied in the 1990s in Australia, with the objectives of managing the water balance to enhance water quality, encourage water conservation and maintain aquatic environments.

The concept of green infrastructure emerged in the United States in the 1990s to promote storm water management practices by using a network of green spaces (Benedict and McMahon, 2006). However, this goes beyond storm water and encompasses the role of vegetated systems in enhancing urban amenity and human health (Tzoulas et al., 2007). The European Union Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council) establishes a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater. It aims to prevent and reduce pollution, promote sustainable water use, protect and improve the aquatic environment and mitigate the effects of floods and droughts.

Urban green storm water infrastructures (UGSWIs) can help to mitigate urban flooding by introducing a sustainable and resilient water cycle in the city. Innovative storm water management approaches have been widely accepted and used compared to conventional grey infrastructures (Li et al., 2019). These systems operate at different spatial scales, and, especially at the city scale, they deal with domestic and conventional water flow

and the local atmospheric water cycle. Most cities adopt combined sewer and storm water discharge systems, which have shown many flaws over time in managing and treating wastewater, especially during wet weather conditions.

Storm water infrastructure can be directly connected to the landscape either through landscape application of ecological principles, landscape features supporting ecological principles or both. These spatial structures formed of natural or semi-natural areas are claimed to accomplish three main objectives: water quantity, water quality and amenity and biodiversity (Perales-Momparler et al., 2015). Moreover, they can contribute to Sustainable Development Goals (SDGs) by providing flood resilience (e.g. flood mitigation), natural resources management (e.g. protected water quality, quantity and biodiversity), increasing liveability for people (e.g. improved microclimate and enhanced social cohesion, etc.) and transition and innovation (e.g. stakeholder participation, improved economy, built knowledge, etc.) (Sørup et al., 2019).

The term 'storm water management system' refers to the ability to control the quantity (e.g. reduction of runoff and velocity) and improve the quality (e.g. reduction of pollutants) of urban storm water. To elaborate further, the function of an effective storm water management system depends on the environmental processes it involves and bio-physical features it uses to support various functions and services (Dover, 2015) and to promote human health and well-being. For example, the Active Beautiful Clean (ABC) water programme in Singapore demonstrates the popularity of using storm water management projects for outdoor recreation and nature experience (Lim and Lu, 2016).

Green storm water management infrastructure projects utilise natural processes to infiltrate, retain, transport and treat storm water using different biophysical elements. There are different kinds of sustainable drainage system techniques available for different functions. For runoff reduction at the source, landscape structures such as rain gardens, rainwater harvesting, vegetated roofs, bio-retention cells and infiltration structures such as permeable paving are proven effective. For the purpose of reducing peak flow of storm water, vegetated detention basins or dry and wet ponds are designed to hold temporarily and pre-treat the first flush of storm water before regulating discharge to a receiving water body, from where the water is slowly released over 24–72 hours into the stream or river system. For sediment removal and water quality improvement, bio-swales, filter strips and wetlands are effective measures. Besides cleaning and filtering water, a large number of urban wetland projects support citizens' needs for cultural, social and recreational activities. Thus they have emerged as popular places for obtaining nature experiences and have been found to be frequented by large numbers of visitors annually. The important design aspects that promote the health and well-being potential provided by green storm water management systems are an increase in accessibility that facilitates activities and minimises the risks (since the water in these parks may be rather polluted).

Semi-natural and constructed wetlands are flood plains inundated or saturated by shallow water, seasonally or annually, sufficient to support plant and animal growth and reproduction. They are formed of and connect with lakes, ponds, rivers or streams and create a transition between dry land and open water. Due to rapid urbanisation of rural land, uncoordinated urban management and infrastructure development, agriculture and so on, many natural wetlands have been destroyed and degraded. However, in recent years, cities around the world have recognised and begun to understand the importance of ecosystem services provided by wetlands and the benefits of restoring and, wherever necessary, creating new wetlands (McInnes, 2014; Jia et al., 2011). Wetland functions and benefits depend on the hydrological regime, soil conditions, local vegetation types and the size and location of the wetland in the landscape. Wetlands, irrespective of whether they are natural, semi-natural or constructed, provide benefits and contribute to wildlife habitat, flood control, pollutant filtration, storm and wind protection, agricultural land fertility, recreation and tourism, carbon storage, education and jobs and enhance property prices, climate change mitigation and so on. Wetlands, depending on their size, shape and location, adjust the urban

micro-climate by increasing urban cooling, an effect found to be important in mitigating the urban heat island effect (Sun and Chen, 2017). Wetlands purify water naturally by trapping, removing and settling or detoxifying pollutants such as chemicals (nitrates, ammonium, phosphorus); sediment loads or soil particles; fertilisers; pesticides; and grease and oil from vehicles, roads or parking areas. Despite the fact that they provide conventional water treatment replacement cost benefits, recent research and design has focused on their additional recreational values and economic benefits.

Urban wetlands may attract large numbers of people to perform a range of outdoor activities such as bird watching, recreation and sightseeing and, when close to settlements, they promote nature connectedness. With the increasing risk of destroying or degrading wetlands as a result of ill-thought-out urban growth, we may permanently lose these important recreational, health and well-being and economic benefits. Therefore, when planning the design and management of wetlands in and around urban areas, it is important to maintain the complex socioeconomic and natural ecosystem to help create liveable cities. While urban wetland planning processes set out tasks for the determination of wetland function, type of wetland, spatial distribution and water requirements for the maintenance of ecological function (Jia et al., 2011), there is a need to explore the social, cultural and experiential paradigm of wetlands as landscape settings, and research on this aspect has been lagging. There has been an increase in wetland creation and restoration projects, and many of these have been monitored to see how the different benefits accrue and to demonstrate their role as scenic, recreational and cultural hotspots. Modern public and institutional campuses also incorporate wetland landscapes and, with careful site planning, integrate them with everyday site functions and recreation.

Why the cases were chosen

For the selection of cases, this chapter covers categories of blue space projects based on their success at combining storm and other water treatment measures and solutions with recreational aspects in green storm water management infrastructures, wetland and urban parks and open space demands and functions. We selected a range of projects that were successful in restoring existing natural waterways which fell victim to urban development and the processes of controlling water environments within urban environments. We also looked for examples that are multifunctional public urban spaces that function within the urban context and offer extended ecosystem services. We consider that these engineered blue spaces have the potential to serve communities in a similar way to conventional parks and plazas yet also offer more possibilities for interacting with the natural environment in different ways. Thus, we present cases with a combination of development themes and an array of unique solutions pertaining to the particular problem and a specific context. We have four categories of projects: restoration of natural streams as green infrastructure, public space and urban waterfront green spaces, green infrastructure and storm water management and natural and semi-natural wetland parks.

Restoration of natural water bodies as blue-green infrastructure

Projects that completely restructure the urban fabric are unconventional and require strong motivation, justification and budgetary requirements. They are large-scale projects involving either the reinvention of lost blue and green natural environments or re-establishing natural processes within an urban environment. They represent the concept of adapting to the forces of nature and making urban living more resilient to those forces as opposed to trying to control or tame the environment for societal purposes. They may serve urban communities at different scales through the adoption of different nature-based solutions. Therefore, the access to and use of such environments created within societies are fundamental to human activities that connect social systems and the ecosystem. The projects included in this section are as follows:

- Bishan-Ang Mo Kio Park, Singapore
- Mill River Park and Greenway, Connecticut, United States
- West Seoul Lake Park: Seoul Urban Renewal, Seoul, South Korea

Blue infrastructure as public space

The next set of projects focus on public spaces at different scales that are predominantly built environments and designed spaces for urban functions and also provide unique ways to experience blue space. They have predominantly evolved as architecturally inspired spaces juxtaposed with engineering functions. However, they indirectly engage users with an environment that retains, infiltrates and treats storm water. They are valuable projects that respect the urban context, whether historical, sociocultural or economic, as well as urban planning and construction practices. The projects included in this section are as follows:

- City Park, Bradford, United Kingdom
- Sherbourne Commons, Toronto, Canada
- Witangi Park, Wellington, New Zealand

Blue infrastructure and storm water management creating community spaces

These projects demonstrate the current trends of sustainable environmental practices with urban developments that produce low-management and resilient localised solutions for storm water management that combine with the requirements of community blue-green spaces. The projects included in this section are as follows:

- Welland Canal Park & Civic Square, Welland, Canada
- Anchor Park, Malmo, Sweden
- Nansen Park, Oslo, Norway

Wetland parks

The last category of projects represents recent attempts to restore natural wetlands or create constructed wetlands as recreation destinations. They are very useful biotopes to support a deteriorating urban ecology and support innumerable urban ecosystem services yet depend on their size, location and carrying capacity. Despite being nature-based solutions specific to water detention, retention and treatment, they also create safe and enjoyable environments with very high cultural ecosystem services. They are multifunctional environments that provide both urban and rural experiences; however, they also require large areas and a longer time to be realised and conceivable. Wetlands are found to be very popular destinations for outdoor recreation, as they provide spectacular opportunities to interact and be immersed in the natural setting, which promotes a high sense of being-away.

- Tianjin Qiaoyuan Wetland Park, Tianjin, China
- Magnuson Park, Seattle, United States
- Sydney Park Water Reuse Project, Sydney, Australia

Each project is briefly described (based on information from a range of sources, often the designer or articles, as well as what the authors have seen). It is then illustrated with a photograph of a typical view, assessed for project quality based on the factors presented in Chapter 10 and illustrated using a set of sketches designed to bring out the key aspects which make the project special and inspirational. These are presented as annotated images, and they aim to complement the text visually, so there is no additional description in the text, only the captions.

Restoration of natural water bodies as blue-green infrastructure: Bishan-Ang Mo Kio Park, Singapore

Bishan-Ang Mo Kio Park was developed as one of the largest urban parks in central Singapore that was realised under the Public Utility Board's Active, Beautiful and Clean Waters scheme. The project was initiated in 2009 and designed by Ramboll Studio Dreiseitl for the Public Utilities Board/National Parks Board, Singapore. The project transformed an old concrete canal into a 3-km-long meandering river with natural banks offering different types of blue and green infrastructure and public spaces for different recreational and social activities. The project is located between two housing estates and first opened in 1988 (and is thus an early example of such a project) on a 62-hectare site. It attracts millions of visitors annually and hosts many organised events. The aim was to create cleansing biotopes using bio-remediation, which provides many benefits through creating inclusive playgrounds, diverse habitats, community allotment gardens and places for nature play and recreation. Dealing with the wicked problem of urban hydrology by applying principles of landscape ecology, the project helps to break away from civil-engineering solutions to a more nature-based bio-engineering approach that increases the carrying capacity of the river. Coupled with re-engineering of the cross-section of the river using a nature-based approach, the project transformed community perceptions towards water in the city and promotes close interaction with nature and biodiversity.

The design of the park with the river offered a balanced functional, ecological and sociocultural space. The park, to date, is home to a growing number of species of wildflowers, birds and dragonflies enriching the biodiversity. The site features which promote active and passive interaction with water include bridges, terraced riverside galleries, river platforms, stepping stone paths and a water playground (Figure 13.2). The project incorporates a comprehensive river monitoring and a warning system, signal lights, sirens and audio announcements to provide early warning to the park users in the event of heavy rain or a possible flood.

Figure 13.2
Stepping stones at Bishan-Ang Mo Kio Park used for interaction with water and nature play
 (Source: Ramboll Studio Dreiseitl Singapore)

Project quality rating assessment

The project demonstrates excellent performance in all aspects of accessibility to the site from the surrounding community and the city. The site is very visible and provides good and sufficient car parking. It was found to have good design quality, though it does not feature conservation or protection of cultural heritage, as there are no elements to take into account; however, it is successful at restoration of the natural heritage within the area. The site is very well provisioned for public amenities and facilities. The site offers good potential for health and well-being benefits through its safe and secure condition, opportunities for relaxation and contemplation, sensory affordances and some sense of being away. The aspect of contact with nature is limited to certain activities and limited compared with other aspects. Water accessibility and connectedness in terms of direct tactile experience is limited to a few areas. The site provides very good opportunities for nature play, different recreational activities and places to organise events and informal sports. The site is less suitable for water sports, as swimming and other immersive water activities are prohibited due to temporal changes of water level and water quality, though people like to paddle in it. The design is unique and an exemplar of a multi-functional nature-based solution that is iconic and a popular destination for recreation. Figure 13.3 presents the sketch analysis of the park.

Mill River Park and Greenway, Connecticut, United States

Mill River Park and Greenway in Stamford, Connecticut, is a long greenway design; the 11.33-hectare (28-acre) park is spread over 4.8 kilometres (3 miles). It was initiated in 2007 by OLIN for the Mill River Collaborative that is located along the Rippowam River in downtown Stamford, Connecticut, United States. This river landscape project, finished in 2013, was conceived to revitalise aquatic and terrestrial habitats, reduce flooding, restore the canalised river's edge and promote native planting. The project involved extensive community participation and was funded by a community collaborative of the city, state and federal government, along with local corporations and private citizens.

The riverbank within the project area has dramatically evolved over the years from its intense industrial past of mill and manufacturing activities. In the 20th century, it fell into disrepair, becoming an abandoned and unused green space; the river with the imposing concrete walls turned into an eyesore and a barrier between communities. The derelict and polluted riverfront had accumulated decades of debris, and an unmanaged riparian edge choked the river, leading to flooding. In 2005, a master plan was developed to remove the concrete dam and restore the meandering river and to offer the community a maintainable and implementable public space for recreation, with a rich natural habitat of native flora and fauna.

Besides regulatory ecosystem services such as flood management, the renewed riverbank offered places for active and passive recreation and active interaction with river's edge. The large flexible green space is suitable for events, which makes the place popular for waterfront entertainment. There is also the opportunity for contemplation and relaxation, and using native planting in the landscape design promotes regionalism.

The project revitalised the aquatic and terrestrial habitat and reduced flooding by introducing native plants and restoring the natural meandering form of the river (Figure 13.4). By implementing green infrastructure principles, the project provided habitat rehabilitation and community public green space. It also accomplished an ecological

Figure 13.3a and b

a) A simplified water flow scheme at Bishan-Ang Mo Kio Park, explaining how the water enters the park, flows along the restored meanders through different vegetation types criss-crossed by paths and bridges and then exits as clean water; b) a cross-section showing the water channel with the vegetated flood terraces to hold and filter water during heavy rain events, with a bridge at its widest point so that people can cross over it even during a flood (Source: Anna Wilczyńska and Jekaterina Balicka)

Figure 13.4

The restored meandering profile of Rippowam River within an upgraded park setting that provides opportunity for activity and water connection

(Source: OLIN)

revitalisation by bringing together a natural, protective flood plain, preventing flooding and managing the peak flow of water during a heavy storm event. The project was envisioned and developed in phases.

Project quality rating assessment

The project is rated very well for aspects of accessibility, design and facilities. In terms of health and well-being, the site can be perceived as highly restorative, except for the sense of being away. As the site is highly accessible and frequented by visitors, it is perceived to be safe and secure. Water connectedness and water safety are limited, however. Except for water sports, the project supports physical activities for formal, informal sports and children's play. Figure 13.5 presents sketches analysing the site.

Figure 13.5a and b

a) Schematic overview of the Rippowam River describing the essential character of the project – the restored meander with stone weirs to break the flow and to manage the level changes, the vegetated slopes and the parallel path along the edge of the restored valley; b) longitudinal section showing a typical part where the stone weirs break and slow down the flow

(Source: Anna Wilczyńska and Jekaterina Balicka)

West Seoul Lake Park: Seoul urban renewal, Seoul, South Korea

West Seoul Lake Park is an urban renewal project that was developed in an old and abandoned water treatment plant and industrial facility and reclaimed as a zone for public recreation and community park. The park design was initiated with collaboration between landscape architecture firm CTOPOS Design and architecture firm JIAN Architects for the Seoul Metropolitan City and was opened to the public in 2009.

The project adopted the concept of an ecological park because the place was considered inappropriate for residential development due to the constant noise coming from the nearby international airport. The design embraces the old and dilapidated industrial fragments, and its core design concepts are regeneration, ecology and communication. The function of the new park is an “open cultural art space” that fosters community interaction and diversifies areas of identity and urban culture. It integrates nature, culture and urbanity and promotes education about urban nature and urban ecology.

The park embodies environmental sensitivity and sustainability and is also welcoming and environmentally friendly. As the central theme of the park is water purification, the spatial organisation considered the horizontal and vertical arrangement of old water pipes that dominated the space. The design highlights water by retaining the natural appearance of the old water treatment plant, lake views and recreational spaces and facilities located between the lake and the old water treatment building (Figure 13.6). Demolition of high walls opened up lake views, and water jets reduce overhead aircraft noise, making the place popular. A central plaza was created by opening up old structures (with a few left in place to reflect the heritage); a square garden introduces a variety of scales and produces a harmonious effect. The new water circulation and purification system replaces the existing one by creating a constant loop that feeds water into the series of landscape features and biotopes, for example, a water purification

Figure 13.6

A view of the West Seoul Lake Park showing the pattern of paving and planting, the pools and the old industrial structures retained in the design

(Source: Hana Shin)

Figure 13.7

Schematic section of the West Seoul Lake Park water purification system using the different basins, some with aeration features (waterfall); the water purification garden; and then provision for user activities such as ecological play or a botanical garden, with higher-level paved areas among it. There is also re-circulation of the water to increase the purification process

(Source: Jekaterina Balicka)

garden, ecological waterway, aqua botanic garden and ecological water playground. A large fountain illuminated by LED lights using renewable energy makes the place enjoyable at night. This project is a good example of restoration of old city infrastructure as well as use of water and nature to successfully create public space to improve community health and well-being. Its contribution to integration of urban renewal and landscaping is an exemplar.

Project quality rating assessment

The project is highly accessible and displays excellent design quality. Cultural heritage value is included, and the place has been designed as a cultural melting pot. This ecological park offers flexible spaces for different activities and facilities, performing well for quality of nature, amount of seating, arrangement and accessibility of facilities compared to other aspects. The project also has potential for health and well-being and is safe and secure. The water connectedness in terms of water visibility, access to water and land-water connectivity is all positive. The water safety issue is of less importance, as the water body is shallow. It is good for informal sport activities and possibilities for children to play with water. However, the project also offers formal play facilities nearby. The site divides the space very well in terms of zoning. Figure 13.7 shows sketches analysing the site.

Figure 13.8
A view of City Park Bradford showing the flooding and fountains in action
(Source: City of Bradford)

Blue infrastructure as public space: City Park, Bradford, United Kingdom

City Park, Bradford, was opened in 2012, designed by Gillespies Landscape Architects, United Kingdom, for the Bradford city council. In the masterplan for the city centre drawn up in 2003, a signature project as a focal point in the city was envisaged through regeneration and the creation of a public space. The resulting project created a destination for informal recreation, altered public perception of the area and supported the local economy and businesses by drawing people to it and increasing foot traffic. The project involves water features, planting and public amenities. The water feature is the central, unique element consisting of a 4000-m² mirror pool and 100 fountains with a complete drain-down provision so that water can appear or disappear (Figure 13.8). This multi-functional 2.4-ha public space is capable of holding large-scale events, as sections function as causeways when the water level is lower. Crucially for the purposes of this chapter, it also acts as a rainwater retention pond, collecting storm water from the immediate area while maintaining the overall visual quality of the place. The tailor-made lighting design is an innovative feature of the place that provides a playful, night-time setting, making the place unique and attractive. The public realm design offers flexible space to be adapted over the years and offers longevity of the life cost of material in use.

Project quality rating assessment

The space is highly accessible, except for car access and parking (which is controlled to ensure the area is pedestrianised). The design quality of the place is unique, providing a perfect juxtaposition of functionality and aesthetics. However, the cost-effectiveness of maintenance is an issue due to the expensive lighting design and technology for storm water treatment, as well as floor surface treatment – although high-quality materials and construction are essential here. The park offers flexible spaces for different activities and facilities, performing well for lighting and seating facilities. It also provides an excellent sense of place and sensory experiences. It is also very safe and secure. The water

Figure 13.9a and b

a) Overview of the Sherbourne Commons sketch of the City Park circular basin, which, when full, becomes a mirror pool and otherwise has a slightly higher centre and several lower sections with fountains; wooden decking for walking and seating is placed around two sides; b) cross-section showing the gradual variation in levels for holding and draining the water and associated fountains, lights and decks

(Source: Anna Wilczyńska and Jekaterina Balicka)

connectedness within the place is excellent for water visibility and direct access to water. Water safety is of less importance, as the water body is shallow or has no water present during dry periods. It is also a good place for informal sport activities and children's play possibilities with water. Figure 13.9 demonstrates how the site works through sketches.

Sherbourne Commons, Toronto, Canada

The Sherbourne Commons is a brownfield regeneration project located on 1.47 hectares (3.63 acres) of land along a neglected area of Toronto's waterfront with a post-industrial heritage. The project was designed by landscape architects PFS Studio and Associates for the Waterfront Toronto and made open to the public in 2010 before completion

Figure 13.10

View of the Sherbourne Commons storm water treatment and purification facilities that provide space for water interaction and water showers improve the aesthetics of the place – here seen illuminated at night

(Source: Tom Arban)

in 2011. The public space has been created by developing a connecting park equipped with storm water treatment facilities. The park presents a concept interweaving landscape design, architecture, engineering and public art. The place caters to a large, mixed-use waterfront community and has become a popular flexible waterfront park, with the essential facilities for a diverse community. The park offers places for tranquillity and for recreation and active socialising. For children, the park provides many opportunities for play, information gathering and relaxation that also includes children's playgrounds.

The main landscape and sculptural features installed in the park form a composition of storm water collection and purification before discharge into Lake Ontario. The water treatment system consists of a UV treatment unit, a water cascade with a series of light showers and a bio-filtration plant bed and aquatic grass beds. The civic amenities, green space, lawn, splash, plaza and pavilions complement and are integrated with the nature-based solutions (Figure 13.10). The park provides an opportunity for activities in all seasons and different times of the day. The water treatment units, especially the water showers, create visual interest as well as active water interaction opportunities. It is a good example of reconnecting and re-engaging people with the old and forgotten waterfront.

The park exemplifies landscape design for public engagement with nature, community integration and increased opportunities for socialisation, sustainability and innovation. The sustainability features incorporated in the park include easy access to public transport, bicycle storage and reduction of light pollution, as well as water efficient planting. The project saves a huge amount of potable water by treating and reusing storm water. Overall, the park offers a destination for recreation and relaxation in a dense and busy urban environment while preserving the *genius loci*.

Figure 13.11a and b

a) Overview of the Sherbourne Commons showing the water movement between the different elements – inflow, ultraviolet purification, use of water showers and flow of water through the area to the channel from where it is discharged; b) cross-section focusing on the water movement from the water showers, through the vegetated strip and into the channel from where it flows out

(Source: Anna Wilczyńska and Jekaterina Balicka)

Project quality rating assessment

This project is highly accessible. Design quality and site planning and circulation perform very well, although the project is considered expensive to maintain because of all the pumps and other technical equipment. In terms of facilities and amenities, the site has good lighting and a wide range of facilities which are very accessible. It is rather wind exposed. The site provides plenty of seating and a good quality of nature experience. In terms of health and well-being, the project is very good for safety and sense of place, especially the opportunity for sensory stimulation. Water connectivity is also good, promoting water visibility and access. For physical activities, children's play has the greatest potential, followed by informal sports opportunities. The site design divides it very well into zones for different activities. Water sports do not, of course, feature here, nor does access from the water, and so water safety equipment is not needed. Figure 13.11 sketches present the site analysis.

Waitangi Park, Wellington, New Zealand

Waitangi Park is a brownfield regeneration in Wellington. This multifunctional park integrates an urban park and waterfront destination with a water treatment landscape that also supports public amenities and many diverse activities. The waterfront park was designed by Wraight Athfield landscape architecture and built in 2006 on a total area of 5.8 hectares (39.04 acres) for the Wellington Waterfront Limited. It features an environmentally sustainable design

Figure 13.12

A view of Waitangi Park, Wellington, showing access paths and some of the planting used as part of the water treatment system

(Source: Bruno Marques)

that implements water-sensitive urban design for treating and harvesting storm water, interwoven with recreational uses for a diverse range of users (Figure 13.12). The park is divided into five zones: a promenade, informal sports and recreation area, spaces with cultural and ecological promotion, the field and blue-green infrastructure. The operational blue-green infrastructure contributes to improved water quality and enhances the aesthetic quality. The storm water filtration system designed at Waitangi Park includes the main elements of filtration of storm water road runoff, bio-retention along the Waitangi Stream, recycling of the harvested water for irrigation of plants and use of ecologically sourced native plants from the Wellington region.

Project quality rating assessment

The project appears to perform poorly for water connectivity when compared to other aspects. The site accessibility is good, except for inclusive access. The overall design quality is very good, except for cost-effective maintenance (always a feature of such parks where this is especially important) and cultural heritage values (none to be taken into account). The facilities and amenities perform well, except for measures for protection from sun and wind, this being in part due to the design strategy of providing open views to the water wherever possible. The health and well-being aspect has high potential, except for the sense of being away, this being partly due to the high popularity of the place and to its being predominantly an urban setting. Water connections are limited due to the past industrial use of the place, although the storm water system provides ample opportunities to view and experience passive water-related activities such as spending time in and around the re-created wetland designed to filter and cleanse the Waitangi Stream. The site supports many physical activities, except for water sports – not being relevant given the context. Figure 13.13 presents the sketched analysis of the site.

Blue infrastructure and storm water management create public spaces: Welland Canal Park and Civic Square, Welland, Canada

Welland Canal Park is a civic square in front of the city hall building designed by Janet Rosenberg & Studio and constructed in 2005 on a 0.6-hectare (1.5-acre) site. The project comprises a series of gardens, ramps, bridges and viewing platforms that also retain the former historic walls of the canal. The space was built into the existing recreation network of the city and enhances the experience of using the existing scenic and historic canal walk. The place is perceived as a very welcoming destination for obtaining an outdoor nature experience and relaxation and provides all the necessary civic amenities such lighting, signage, walkways, seating, artworks and planting (Figure 13.14). The project also aimed to reinforce Welland's urban core. The project is very accessible to local transport and also provides car access and parking. It is also well connected to pedestrian and cycle paths and provides opportunities for walking, running, sitting and relaxing, together with spaces to organise small concerts and events. The design has improved the aesthetic quality by adding viewing points, selecting a unified palette of vegetation, introducing the plaza and tree planting. The water treatment aspect of the park comprises a series of pockets of artificially created biotopes, and the plaza itself helps to infiltrate storm water before its release into the canal.

Project quality rating assessment

The project appears to perform well or very well for almost all aspects, except for possible physical activities. It has high accessibility. The design quality is good, especially for views and landmarks and cultural heritage values. In terms of facilities and amenities, it performs well for lighting and quality of nature. Health and well-being potential is also very high for safety and security, opportunities for contemplation and sensory experiences. The site has good water visibility and water safety equipment but no real direct access (although the canal is next to the site). The Figure 13.15 sketches analyse the site.

Figure 13.13a-c

a) Layout of the main elements of Waitangi Park and scheme of the water flow using the storm water run-off onto the planted area for irrigation and filtration; b) scheme showing how the water moves across the site; c) section from parking across the planted areas, showing how the storm water is pumped from the sealed surfaces (roads and parking) into the gravelled and planted filtration beds, which also incorporate paths for pedestrian access

(Source: Anna Wilczyńska and Jekaterina Balicka)

Figure 13.14

View of Welland Canal Park wooden decks within series of filter strips increase the provision of access to view water and provide a place for relaxing and contemplation

(Source: Landscape Architecture by Janet Rosenberg & Studio, photography by Jeff McNeill)

Anchor Park, Malmö, Sweden

The site under review was designed by Stig L. Andersson (SLA) in 2000–2001 as a central open space within the new urban development at the Västra Hamnen, or Western Harbour, in Malmö. This was an area of docklands on land artificially reclaimed from the sea in the period between 1948 and 1987 when the economic downturn led to it being abandoned as a harbour. After a period lying unused, a new set of economic opportunities emerged following the opening of the Öresund Bridge in 2000. The Västra Hamnen then became the site for the development of a new urban residential quarter, whose iconic symbol is the tower block known as the Turning Torso (which stands overlooking the park). The area is divided into different architectural zones with a range of styles and models. The focus is on safe and pedestrian-friendly streets, with vehicular traffic limited in its entry and a human scale. The seafront retains the harbour walls and features an esplanade park. In the centre of the district lies the Anchor Park, which forms the main public space for the district and is well connected to the rest of the residential areas and to the esplanade via a number of paths. It follows the line of an original channel through the area, now a shallower linear lake, with one side having a straight edge formed of concrete and a promenade next to residential buildings. On the opposite side, the channel takes a more serpentine form, still formed from concrete but backed by extensive grassy areas and groups

Figure 13.15a and b

a) Overview of the Welland Canal Park site showing the different site components and the vegetated areas used for filtration; b) section depicting the level changes across the site and the location of the vegetated filter strip

(Source: Anna Wilczyńska and Jekaterina Balicka)

Figure 13.16

A view of Anchor Park showing the different water edges and the wetland vegetation, overlooked by the Turning Torso

(Source: Lisa Rizell)

of trees surrounding some wetlands to help deal with storm water (Figure 13.16). The site is furnished with wooden decks and bridges, and the water area connects with the rest of the water system by canals leading to and from it, acting as water retention.

Project quality rating assessment

This project rates highly for accessibility – although not so much for cars, since these are deliberately designed out of the project, while little reference to cultural heritage can be found in the park itself owing to the complete redevelopment of the original site. The facilities lack shade and shelter, and there is a low degree of lighting within the park. The health and well-being aspects are good, although there can be no sense of being away, given the fact it is overlooked by housing, and the lack of lighting may lower the sense of safety and security in places (although it is overlooked). The water body is not designed for recreation, nor is it equipped for formal sports, although other physical activities can be pursued. Figure 3.17 shows the site analysis through sketches.

Nansen Park, Oslo, Norway

Nansen Park and the new community in Oslo, Norway, is one of the largest industrial wasteland reclamation projects and serves as an active and attractive meeting place for the community. It also reflects a strong identity, simplicity

Figure 13.17a–c

a) Overview sketch of Anchor Park showing the main features – the contrast between the straight section with paving and the meandering water’s edge; the patches of planting each function as filtration beds, and the sloping site allows water to flow into the water body; b) a general section across the site showing the location of the water body between buildings, part paved and part park; c) the different sections – water edge, grass and tree thickets

(Source: Anna Wilczyńska and Jekaterina Balicka)

Figure 13.18

View of Nansen Park, Oslo, showing one of the water collector swales with the parallel path and vegetation elements

(Source: Blørbeek and Lindheim)

and endurance. The park was designed on 20 hectares of land by Bjørbeek & Lindheim landscape architects and was completed in 2008. The design of the new community and the park, which transformed the central part of the old airfield, maintained its original linearity and dynamism and fragments of the original cultural landscape. The public space consists of an open plaza for holding festivals and events and has made artistic use of stone and water. The place offers different types and scales of recreational possibilities. The master plan of the area conceptualised the space as a bowl-shaped landscape with a centrally located park and seven green arms reaching out towards the sea in all directions. The water feature forms the central landscape element and is constantly changing, with playful variation between geometric and organic forms for the pool, stream, falling water and so on (Figure 13.18). The central lake collects all the water, which is cleaned using biological and mechanical filters to ensure good water quality. The surplus water is allowed to overflow into an infiltration area before it is released into the fjord. The storm water management system also efficiently caters to the drainage from the nearby housing areas and roads. Most of the water is recycled and used in the park for park activities and aesthetics. The project thus presents a strong ecological profile that supports the whole transformation process. Polluted grounds and materials have been cleaned, retrieved and reused in a landscape of different spatial qualities.

Project quality rating assessment

The project is very accessible. It has very high design quality, with a good range of facilities and amenities, as well as health and well-being aspects. The water connection is limited to some degree, and some of the aspects are less well provided for, such as water safety equipment and water activities (to be expected, as the site is not designed for this). The site also provides many physical activity opportunities. The sketches in Figure 13.19 present the site analysis.

Figure 13.19a–c

a) Overview of Nansen Park showing the radiating arms lying between the developed area collecting storm water, which flows down to the central lake, being cleaned as it does; b) schematic plan showing how water is allowed to run down the swales with water features and planting which follows all the paths down towards the centre, where the water collects in the detention/retention pond from which it infiltrates, is recycled or allowed to flow into the fjord; c) section showing how the water can flow over the ground surface to the water features, through vegetation and into the swales edged by the paths and by rocks

(Source: Anna Wilczyńska and Jekaterina Balicka)

Wetland parks: Tianjin Qiaoyuan Wetland Park, Tianjin, China

The Qiaoyuan Wetland Park project in the Chinese city of Tianjin was designed by Turenscape and completed in 2008. The wetland park was built on a 22-hectare site based on an adaptive strategy to deal with storm water by creating a series of biologically diverse ecosystems that also help decontaminate the soil. Once a polluted and contaminated industrial and landfill site, it has been transformed into a place rich in habitat diversity and a destination for recreation and nature experience. The design reclaimed the brownfield site by integrating regenerative ecological functions and provided a high-quality public space for the surrounding dense residential community. This regenerative process involved changing the landform to create a series of pools, promoting the natural process of plant adaptation and community evolution to create a low-maintenance urban park that contains and purifies storm water, improved soil chemistry (reducing alkalinity) and a rich aesthetic experience.

The project was initiated with the aim of resolving issues related to storm water management, including minor flooding within the area and to create a multi-functional public space to meet community needs. The wetland park has been designed as a series of wet and dry ponds with local materials and plants, creating a framework for nature

Figure 13.20

View of the water retention ponds at Qiaoyuan wetland park and the different wetland habitats that provide opportunities to connect with nature and recreation

(Source: Yu Kongjian)

to rejuvenate ecological processes. The ponds are laid out like a series of cells within a structure of recreational spaces and a network of footpaths and linkages (Figure 13.20). The layout thus created rainwater catchment facilities with both retention and detention functions. Platforms and bridges provide different visitor experiences and park views. The key objectives of the project include the creation of habitats, selection and design of plant communities and provision of cultural services. The overlapping and intertwined concepts that supported the wetland park design objectives have resulted in a powerful and successful landscape that is resilient and regenerative and provides a myriad of ecological services. The project has become a major destination park and attracts large number of visitors each year, as well as providing educational opportunities for children from nearby schools.

Project quality rating assessment

This project has excellent accessibility, although it is not so visible from outside, which could be due to the large site area and dense vegetation that occupies much of the land area. The design quality is excellent but lacks cultural heritage references (no relevant here) and views and landmarks (as an enclosed and large site). The facilities and amenities are somewhat limited – partly due to its function as a wetland park, although it does well for quality of nature and lighting conditions. The health and well-being potential for all aspects suggests the site can be perceived as being highly restorative. Despite good health-promoting qualities, the water connection aspects are limited (except for access to water and water visibility) – to be expected for a water-purifying park when some of the water bodies are still polluted. Except for zoning of activities, the site has limited opportunities for physical activity – again, it is not designed for this, so it would not be expected. Figure 13.21 shows how the site has been analysed by sketching.

Magnuson Park, Seattle, United States

Magnuson Park in Seattle, United States, is located along the shore of Lake Washington. It has rejuvenated an old wetland that was converted into industrial land and which changed dramatically under the land ownership of the US Navy. The park was designed by the Berger Partnership PS and was built in three phases. The park was partly completed and open to use in 2006, and the development then continued until 2012. As the second-largest park in the city of Seattle, the park covers an area of 62.32 hectares (154 acres) and has a 1.6-kilometre-long stretch of shoreline. The park offers a variety of recreational uses, social events, play opportunities, nature experiences, wildlife interaction and wetland habitats.

The park design established a hydrological regime formed by a grid of ponds on a slope to create a cascading effect as the storm water fills the upper ponds and overflows to the lower ponds and so on. The wetland system collects water running off the playing fields and parking lots. The ecological function of the wetland concept is manifested through leaky berms, log weirs, rice paddies, willow-wattles and peaty sponges as water flows through the system of 63 connected ponds which vary in depth (Figure 13.22). The site layout provides a framework that allows nature to reclaim the land and provide an abundance of wildlife in the wetlands. Native species were planted on the berms, in the ponds and in the forest to provide shelter for insects, amphibians and birds. The wetland also provides clean water for amphibian habitats and a freshwater lagoon. The constructed wetland treats storm water runoff by reducing suspended solid particles and bacteria and increasing dissolved oxygen. The project has successfully and substantially increased biodiversity and reduced carbon dioxide emission by recycling old techno-sol from the site. The park attracts a large volume of visitors and local school and university students, while local communities are engaged in activities such as tree planting, nature experience, research, invasive species removal and establishing native planting.

Project quality rating assessment

The project is very accessible, although access via public transport is limited and site visibility is not so good due to it being a large area with high forest cover that screens views. Design quality is moderate overall, although the site

Figure 13.21a-d

a) Broad overview of the entire Qiaoyuan park in its wider setting, with the pattern of pools (wet for retention to dry for detention) which treat the water; b) detail of the pattern of paths and wet retention ponds; c) some of the movement of the water across the site from detention ponds which fill during storm events; d) a typical section showing the transition across the site from the upper dry detention to the lower retention ponds and on to the larger lake

(Source: Anna Wilczyńska and Jekaterina Balicka)

Figure 13.22

View of Magnuson Park, Seattle, showing the series of descending ponds with access paths between them and the natural vegetation

(Source: Seattle Parks)

circulation, the cost effectiveness and the design of furniture to the context are highly rated design attributes. Other facilities and amenities are limited, although quality of nature, range of and accessibility to facilities perform well. The health and well-being potential is moderate, but within this, there are good possibilities for contemplation, a sense of being away, sensory stimulation and contact with nature. Similarly, the water connection is supported by conditions that provide opportunities for access to and viewing water, less so for the opportunity for water activities or for the availability and condition of safety and security equipment. The site provides good opportunities for formal and informal activities. Figure 3.23 presents the sketches of the site analysis.

Figure 13.23a and b

a) Overview sketch of Magnuson Park showing the relationship of the natural wetland areas lying between the car parking and the rest of the restored wetland, providing a rich biodiversity area; b) section through the park showing the typical level changes and the way the water passes gradually from level to level through each set of ponds

(Source: Anna Wilczyńska and Jekaterina Balicka)

Sydney park water reuse project, Sydney, Australia

The Sydney park water re-use project was designed by Turf Design Studio, together with Environmental Partnership, Alluvium, Turpin+Crawford, Dragonfly and Partridge and was completed in 2015 on a 44-hectare area with 1.6 hectares dedicated to water reuse facilities. The project implemented a green infrastructure strategy and upgraded an industrial and landfill site to a public park in an inner city suburb of Sydney. It incorporates storm water treatment infrastructure, thereby creating a vital asset for the growing communities of southeast Sydney. The project demonstrates an overlapping of art, design and science and highlights the intrinsic relationship between water and urban life, topography, people, flora and fauna. The story about water within the project is carefully narrated through the functions and processes involved from collecting/harvesting water through to cleaning and reusing it within the park.

The project in part rejuvenated an existing park wetland and transformed it into a sustainable park that reuses its own water with little need for precious water from external sources. The project enhanced the circulation of water through ponds and wetlands and renewed the ecosystem into a greener and more functioning public amenity space. The system of blue infrastructure harvests a large amount of water annually and uses it for maintaining park functions and the ecological health of the ponds and wetlands. The water treatment within the park is carried out through water pollutant traps, bio-retention systems, vegetated swales, aeration devices and a series of wetlands (Figure 13.24). The park, while offering a thriving wildlife habitat, also improved the cultural use of the site by promoting increased nature connectedness and connecting people to the concepts of blue infrastructure in terms of capturing, circulating and

Figure 13.24
The view of water harvesting in Sydney park water reuse project
(Source: Turf Design, Sydney/Ethan Rohloff Photography)

Figure 13.25a and b

a) Diagrammatic overview of the Sydney park water reuse project system showing how the water enters and passes from lake to lake; b) section showing the terraces and cascade from which water flows into the pond and aerates it at the same time

(Source: Anna Wilczyńska and Jekaterina Balicka)

cleaning water. The wetlands have been attracting new wildlife to the park and recorded a high population of native bird species in the local area. The park offers numerous opportunities for activities and relaxation for the local Sydney community. The cascading wetland system and stepping stones especially offer play opportunities for children.

Project quality rating assessment

In this wetland restoration project, all variables of accessibility perform very well. The design took a very balanced approach dealing with important design criteria and does very well in all sections. In terms of facilities and amenities, it performs very well for lighting, the range of facilities present, accessibility to these facilities and the amount of seating and quality of nature it offers to the users, although it is rather wind exposed and not especially well shaded. The site offers very good access to water and has high water visibility that promotes water-related activities, although not for formal or water-based sports. The site can be considered highly restorative, as it is rated very well for health and well-being potential. The site offers an excellent opportunity for nature contact and experience. Figure 13.25 presents the analytical sketches of the site.

Comparison of projects in terms of different aspects

General design aspects

The projects presented in this chapter were chosen for their diversity and creativity in dealing with storm water using different nature-based solutions in different built environments. Each project displays many interesting and exceptional design qualities and demonstrates multi-functional landscapes that integrate technical concepts and detailing for storm water management. They also demonstrate how projects can create a sense of place along with high-quality, aesthetically attractive places for recreation and relaxation. Many of the projects selected in this chapter are highly acclaimed, demonstrating how imitative and technical solutions to deal with the wicked problems of storm water are possible within more traditional landscape design approaches. All these projects that adopted different nature-based solutions which have demonstrated high-quality design solutions both in the organisation of space and detailing they contain. All projects have given consideration to an efficient site circulation of water along with designs

of furniture that fit the context. Cost effectiveness of projects may vary, considering that they belong to different socioeconomic conditions and planning practices and in many cases they are technically complicated. The variation in cost effectiveness also depends on the objective of the project and whether the built structures or vegetation material used for it fit the context and improve aesthetic quality of the space. All projects have created new landmarks as design elements to attract more users and to improve the sense of legibility with the site.

Potential for enhancing health and well-being

Almost all projects display many opportunities to improve health and well-being. All projects have considered safety and security as one of the common and important attributes to ensure health and well-being of visitors (and to reduce risks – especially if the parks include access to actual or potentially polluted water). Most projects also either maintained the existing or created a new sense of place by using water creatively. The sense of being away can only be felt prominently in large-scale projects rather than small ones rooted within an urban setting. The selection of design elements and construction materials can play a role here. For example, wetland projects have shown a higher sense of being away compared to the public spaces which are blue infrastructure projects. Despite all projects representing different environmental qualities, features and characteristics, they promote high mental health through opportunities for contemplation, sensory stimulation and, especially, contact with nature. These health benefits were found to be higher for large-scale, more natural projects within an urban environment, such as the West Seoul Lake Park, Nansen Park or Tianjin Qiaoyuan Wetland Park restoration project.

Accessibility

All the sites evaluated are very accessible for most. Variability in access conditions is observed mainly due to varying disabled access provisions (although this is sometimes hard to determine exactly) and car access and parking provisions – where car access was restricted in favour of better pedestrian or cycle access. The extent of visibility of these sites is less important due to most of the sites being large in size and visually disconnected by dense vegetation in and around the perimeter. However, this contrasts with public plaza-type environments, which are designed as open, connected and legible systems that are meant to support urban functions and need to be visible.

Interaction with water

Water has been the key feature in all projects evaluated, contributing to ecosystem services and sustainable water management in an urban environment. Interaction with water as a tactile experience is a key predictor of nature connectedness, and the success of each project depends on the degree to which it supports the concept of human ecology. All the projects assessed successfully promote physical and mental accessibility to water, although to varying degrees. It is important to understand that nature-based solutions create opportunities for nature play and active interaction with water and associated natural biotopes, as well as providing knowledge about biodiversity that promotes pro-environmental behaviour. Efforts to restore natural settings (e.g. urban stream and wetland restoration projects) within highly built environments could benefit inhabitants and users the most. These projects have dealt with the challenge of reusing polluted storm water for recreational purposes through creating adaptive, sustainable and resilient systems of blue infrastructure that benefit both people and the environment.

Physical activities and opportunities for socialising

Physical activity and opportunities for socialising depend on the space organisation, zoning, design and availability of recreational facilities and seating as well as good accessibility to spaces and facilities. Most of the projects provide space and opportunity for children's play, although playing in water greatly depends on the quality of water available for reuse. In this context, natural stream or river restoration projects, such as Bishan-Ang Mo Kio Park and large-scale

community park projects, such as Nansen Park, Oslo; West Seoul Lake Park, Seoul; and wetland park projects have demonstrated higher-quality water environments that are safer for nature play. Most of the projects provide plenty of opportunities for informal sport activities, primarily due to the design of multifunctional, flexible and adaptive spaces. Almost all sites demonstrate good zoning of activities, despite the fact that these landscapes are primarily designed to harvest, retain, contain and purify water. After completion, all have become popular destinations for communities and attract large numbers of visitors annually and encourage recreation, nature contact and social cohesion.

Microclimate amelioration

Almost all projects contribute to local climate amelioration and improve microclimate within the area of intervention, although it depends on the size, scale and type of project. Water as the most common and prominent landscape feature produces a cooling effect, so river or stream restoration and wetland projects that retain large areas of water with vegetation improve the cooling effect, such as the Sydney Park water reuse project. Similarly, reduction of noise coming from the nearby airport operation has been successfully accomplished in West Seoul Lake Park. Moreover, creation of urban plazas and use of water features always provides microclimatic benefits in hot weather. The presence of both still and moving water in highly built urban environments, such as Bradford City Park and Toronto's Sherbourne Commons, provide numerous health benefits to users through microclimate improvement and high-quality sensory experiences.

Use of water, vegetation and ecological aspects

All the projects have used water to create functional and aesthetic landscapes that support different ecosystems and provide many ecosystem services. Most used native plants and restored natural forms and functions of water bodies either through mimicking nature or providing support frameworks for nature to reclaim and restore the poor health of an existing natural ecosystem. River, stream and wetland restoration projects also strongly demonstrate the role of landscape ecology and bio-engineering in solutions that substantially improve the environmental quality and increase biodiversity within the projects. The biotopes created within the projects to deal with storm water management and cleansing also support other functions such as an increase in aesthetic value, providing places for activities and increased opportunities for biodiversity interaction.

Sustainable storm water management

The main focus of this chapter is of course storm water management, systems for which the blue infrastructure components are manifested in both static and dynamic hydrological structures. These structures are embedded within landscapes that promote ecosystem functions and services, as demonstrated for the most of the projects. When we recognise the multifunctional role of storm water management systems, using similar projects becomes vital to urban areas where both a lack of nature and continuing or increasing storm water problems are prevalent.

The idea of integrating engineering solutions to improve environmental quality, to create social functions and to regulate storm water efficiently are unique aspects of these projects. Incorporation of sustainable urban drainage systems to manage storm water is technically complex and takes up street space. While mostly working in the everyday landscape, landscape architects and designers should be able to work freely and innovatively with SUDS so as to improve the overall quality, character and identity of the neighbourhood. Moreover, the symbiotic relationship between green and blue allows wildlife habitats to thrive, protects water quality, recharges groundwater, provides soil stability, enhances water supply and improves quality of life, health and well-being. Sustainability and energy efficiency is the main focus among landscape architects and engineers involved in such practices for creating flexible, beautiful, functional and regenerative projects. Most of the reviewed projects adopted tools and techniques to reduce water demand, filter and reduce storm water runoff, promote and protect wildlife habitats, improve environmental quality and human health and increase opportunities for outdoor recreation. These have demonstrated different

ways of adopting storm water management tools and techniques within different levels starting from master planning down to the details of landscape design and construction.

Conclusions and implications for practice

This chapter has reviewed the history and importance of stream and wetland restoration projects, urban plaza projects that used water as prominent features, large- to medium-scale community projects that demonstrate the application of landscape ecology concepts and bio-engineering techniques to create multi-functional landscapes. These places have become successful recreational spaces to visit and engage with nature, which was not otherwise possible. They promote high educational benefits for children, students, researchers and local residents alike. These projects demonstrated ways of dealing with storm water as a wicked problem within urban areas. Some projects involve low cost and simple interventions, while some demanded high investment and complex, overlapping concepts and methods of landscape architecture, landscape ecology and engineering. However, all projects have demonstrated high levels of public participation and community involvement, thus proving that projects of such a complex nature can be successfully implemented using an active integration of the community through the process of place-making. The selections presented here all have their strengths and weaknesses according to a number of factors such as the setting, terrain, history or climate. Despite the fact that these projects are primarily designed to deal with harvesting and cleaning storm water, they often also have had significant impacts on the local economy and aided the process of regeneration of places where they are located.

There are a few specific aspects of the projects we wish to draw attention to:

- The projects used and respected the local environmental setting and context of the development; they adopted sustainable and innovative approaches to co-create spaces both for the environment and the community to co-exist and flourish;
- They used the terrain and intelligently blended the presence, quality, flow and importance of water in landscape design;
- They efficiently used the static and dynamic values of water;
- They encouraged native planting and native biodiversity;
- They involved communities in the project development process and used community knowledge to create multi-functional landscapes;
- They applied landscape architecture and landscape ecology concepts combined with bio-engineering techniques; and
- They promoted high health and well-being values through creating high-quality landscapes, flexible spaces that promote a myriad of opportunities to become active and relax within these blue spaces.

Finally, we can observe that the selection of parks here represents a very important category of blue space design. It is not always certain how effective they are at treating water, and combining public access and recreation may also pose threats or risks of water-borne diseases, perhaps at certain times of year or in certain climatic regions, which need to be monitored. Nevertheless, in terms of combining functions of water treatment, storm water management, ecological restoration and public recreation, they are truly inspirational as multi-purpose landscapes.

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