STORMWATER MANAGEMENT IN CITIES AS A CLIMATE CHANGE ADAPTATION STRATEGY: CASE OF HALKAPINAR DISTRICT (IZMIR, TURKEY)

A Thesis Submitted to
the Graduate School of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in City Planning

by
Zeynep BALLAR

October 2019
İZMİR

We approve the thesis of **Zeynep BALLAR**

Examining Committee Members:

Nicel Saygin

Asst. Prof. Dr. Nicel SAYGIN
Department of City and Regional Planning, İzmir Institute of Technology

Assoc. Prof. Dr. Koray VELİBEYOĞLU
Department of City and Regional Planning, İzmir Institute of Technology

Assoc. Prof. Dr. Hilmi Evren ERDİN
Department of City and Regional Planning, Dokuz Eylül University

17 October 2019

Nicel Saygin

Asst. Prof. Dr. Nicel SAYGIN
Supervisor, Department of City and Regional Planning,
İzmir Institute of Technology

Alicandemirkeseniş

Prof. Dr. Ali Can DEMİRKESEN
Head of the Department of
City and Regional Planning

Prof. Dr. Mehtap EANES
Dean of the Graduate School of
Engineering and Sciences

ACKNOWLEDGMENTS

Firstly, I would like to extend my sincerest gratitude to my supervisor Assist. Prof. Dr. Nicel SAYGIN for her support, guidance and encouragement.

I would like to thank my family who has always shown their support during this process. I would especially like to thank my brother Efe BALLAR for his support and love.

I would like to thank my friends and teachers whom I met during my undergraduate and graduate studies. What I have learned in my education has brought me to this point and I continue to learn. Especially, I would like to thank my friends who have been with me in this stressful process recently and I embrace them.

Writing a thesis was a long and not always easy process for me. Finally, I am hugging and thanking myself for successfully completing this process.

ABSTRACT

STORMWATER MANAGEMENT IN CITIES AS A CLIMATE CHANGE ADAPTATION STRATEGY: CASE OF HALKAPINAR DISTRICT (IZMIR, TURKEY)

Water scarcity, one of the effects of climate change, has started to affect the world. Stormwater acting a main role in how the world mitigates and adapts to the effects of climate change. Cities need strategies to manage the influx of stormwater. One of these strategies is the capture and re-use of stormwater instead of run off.

This thesis deals with the studies that can be carried out in urban areas within the framework of stormwater management as a climate change adaptation strategy. In this context, this study treats stormwater as an asset. Thus, preventing stormwater from producing runoff or causing floods, shows what can be done in the city to capture and even re-use again. This thesis focuses on the use of green infrastructure to increase urban resiliency to climate change and natural hazards.

In this study, firstly, the theoretical literature about climate change and stormwater management are examined. Then several different projects implemented throughout the world and Turkey are investigated. It has been shown that how these examples can be used as inspiration in Halkapınar District of İzmir. Subsequently, the stormwater infrastructure of İzmir from the antiquity to the present has been researched within the scope of water management. As a result of this study, what can be done for Halkapınar district is proposed. For this purpose, regional analyzes were examined first. As a result of the analyzes, the studies that can be done for stormwater are explained. This study is intended to be a guide for future studies stormwater management in cities.

ÖZET

İKLİM DEĞİŞİKLİĞİ ADAPTASYON STRATEJİSİ OLARAK ŞEHİRLERDE YAĞMUR SUYU YÖNETİMİ: HALKAPINAR ÖRNEĞİ (İZMİR, TÜRKİYE)

İklim değişikliğinin etkilerinden olan su kıtlığı dünyayı etkilemeye başlamıştır. Yağmursuyu, dünyanın iklim değişikliğinin etkilerine nasıl uyum sağladığı ve adapte olduğu konusunda ana rol oynamaktadır. Şehirlerin yağmur suyu akışını yönetmek için yeni stratejilere ihtiyacı var. Bunlardan biri de yağmur suyunun akıp gitmesi yerine yeniden kullanılmasını öneren stratejilerdir.

Bu tez, bir iklim değişikliğine uyum stratejisi olarak yağmur suyu yönetimi çerçevesinde kentsel alanlarda gerçekleştirilebilecek çalışmaları ele almaktadır. Bu kapsamda çalışma yağmur suyunu bir araç olarak kullanıp yağmur suyunun akıp gitmesini veya taşkınlara sebep olmasını önleyerek, yeniden kullanılabilmesi için kentte neler yapılabileceğini göstermektedir. Böylece, yağmur suyunun akıntı oluşturmasını veya taşmalara yol açmasını engellemek, şehirde tekrar kullanmak için ne yapılabileceğini göstermektedir. Bu tez, iklim değişikliğine ve doğal tehlikelere karşı kentsel dirençliliği artırmak için yeşil altyapının kullanımına odaklanmaktadır.

Çalışmada, ilk olarak, iklim değişikliği ve yağmur suyu yönetimi hakkında teorik literatür incelenmiştir. Daha sonra, dünyada ve Türkiye'de uygulanan birçok farklı proje incelenmiştir. Bu örneklerin İzmir Halkapınar Bölgesi'nde nasıl ilham kaynağı olabileceği gösterilmiştir. Daha sonra, geçmişten günümüze İzmir'in yağmur suyu altyapısı su yönetimi kapsamında araştırılmıştır. Bu çalışma sonucunda Halkapınar bölgesi için yapılabilecekler önerilmiştir. Bunun için önce bölge analizleri incelenmiştir. Analizler sonucu yağmursuyu için yapılabilecek çalışmalar anlatılmıştır. Bu çalışmanın şehirlerde yağmur suyu yönetimi hakkında bundan sonraki çalışmalar için yol gösterici olması amaçlanmıştır.

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, global warming and climate change are most significant problems caused by human. There are many reasons for global warming, and the release of carbon dioxide as well as the emission of methane gas plays an important role. Human behavior plays a very important role here, because our consumption habits cause us to consume excessive resources. Water is coming at the top of this list, and if we continue to spend at this speed, a water crisis is expected in 2040. Water scarcity is not only caused by the amount of water we use in homes. Water is also used in agriculture, farming and industry which takes up much larger space. We need to re-use our resources while reviewing our consumption habits.

Many countries around the world are working on sustainability and resilient cities, and making their cities more resilient. This thesis focuses on the use of green infrastructure to increase urban resiliency to climate change and natural hazards. One of these working areas is stormwater management. Stormwater management is very important because it has a significant value for our lives and is a resource that can be consumed in the future. However instead of reusing the stormwater, in our country we leave it back to the seas to prevent floods. Water will be a big problem in the world and we should do something for a liveable environment before it is too late. Within the content of this study, the history of İzmir about water resources has been investigated and its connection with the past has been established. The study area was previously referred to as Halkapınar district. Today, it consists of Halkapınar and Mersinli neighborhoods. The elements in determining the Halkapınar district will be explained in the study. If we talk about them briefly;

Halkapınar is a historical water source. It still holds groundwater today. It is located in one of the lower basins of the Meles Stream. Halkapınar is in a position of risk with climate change.

1.2. Problem Definition

In most countries of the world, city strategies and city plans have been started to reduce the effects of climate change. Reusable of water is an important issue for global warming and water scarcity issues. Our groundwater is running low and the access to fresh water is expected to be very difficult after a few decades. Although many countries are working to prevent it from getting worse. Turkey still has not been able to proceed on this issue. Recently the sewage and stormwater have been separated by separate pipes in İzmir. The aim of the system is to remove the stormwater and thus discharge it into the sea. Rainfall areas such as İzmir need stormwater collection areas. These areas can create a solution to future water drought. It can also be used to prevent urban floods caused by stormwater.

This study first examines İzmir's relationship with water and how it evolved from the past to the present. Afterwards, it examines the present situation of Halkapınar district which has an important place in relation to water in the past and includes studies on what the future role can be.

1.3. Study Objectives

The aim of this study was to examine how urban stormwater management can be used in cities by contributing to the environment.

The main question of the study is: "How should we create areas to collect and reuse stormwater in cities?"

The work also answers the following questions:

What is climate change and what are the effects?

What are the examples of nature based stormwater management in the world?

Which stormwater management methods should be applied in Halkapınar district?

Therefore, the study aims to create a district that includes stormwater systems despite the lack of existing conditions.

1.4. Methodology

The methods used in this study have been established to observe and evaluate stormwater management initiatives on urban scale through the use of literature, internet applications across the world and academic publications. A case study approach has been conducted through site survey, secondary data gathering and by examining the change of the region with its surroundings from past to present.

First, a detailed literature review on climate change and adaptation concepts and efficient stormwater infrastructure was conducted. In the literature review, books, articles, academic research, theses and websites are used. After studying the theoretical part, exemplary the most successful examples in the world have been examined to see how the theoretical framework is created in the city. Following the example of the world stormwater management in Turkey was investigated. Since there are no examples like world examples in our country, field work is gaining importance at this stage. Finally, the studies that can be done in Halkapınar region on the collection and reuse of stormwater are described.

Halkapınar district is a very important area for İzmir from past to present. Halkapınar has been described with Meles Stream in many history sources. Two sources from the past to the present region provide a great potential. However, now that potential is not used. It is important to have a regional service with the new city center. For this reason, the historical and future functions of Halkapınar district have been examined in this thesis and the district is designated as the study area.

1.5. Structure of Thesis

This thesis consists of five parts. The first chapter consists of a short introduction and a theoretical framework describing the expression of the problem, study objectives and methodology. The second chapter starts with the climate change and its effects. Also includes climate change adaptation. In the third chapter, the concept of storm flood resilience is examined. Also applied in the world and Turkey, stormwater management practices were examined. The third section describes the case study of the research. For this, it starts with İzmir and shows data with Halkapınar region. Then, strategies for the district in the future are expressed in detail. Finally, in the fifth section, all findings obtained from the research are reviewed.

CHAPTER 2

CLIMATE CHANGE & ADAPTATION

2.1. Climate Change

Climate change or global warming apparently that was something humans had created by our way of living. Climate change encompasses rising average temperatures, extreme weather events, shifting wildlife populations and habitats, rising seas, less stable ground conditions and a range of other impacts. All of these changes are emerging as humans continue to add heat-trapping greenhouse gases to the atmosphere. Many of the climatic changes forecast for the next 30–40 years are 'locked in'– the result of past greenhouse gas emissions. Even if we make significant reductions in emissions, the lag in the climate system means that emissions we have already put into the atmosphere will continue to affect the climate for several decades to come.

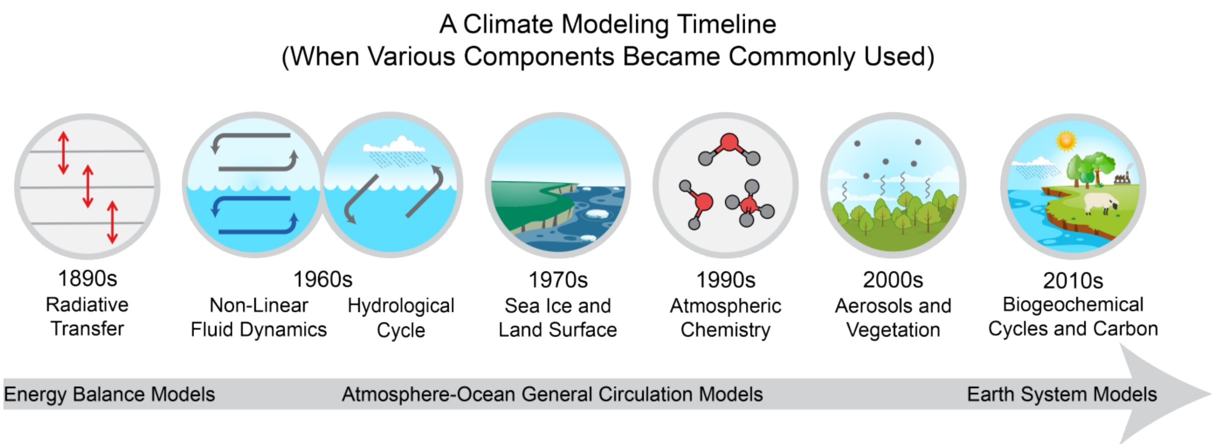


Figure 2.1. A climate modeling timeline
(Source: https://science2017.globalchange.gov/chapter/4/)

Emissions of carbon dioxide (CO2), methane (CH4), and other greenhouse gases emitted by humans are emphasizing the impact of natural drivers on the external forcing of the Earth's climate. Climate change and ocean acidification are already occurring due to the accumulation of atmospheric CO2 from emissions released by humans in the industrial era.

The complexity of climate models has grown over time, as they incorporate additional components of Earth's climate system (Figure 2.1). Today, global climate models simulate many more aspects of the climate system: atmospheric chemistry and aerosols, land surface interactions including soil and vegetation, land and sea ice, and increasingly even an interactive carbon cycle and/or biogeochemistry.

Causes and Effects of Climate Change

Scientists have documented the following climate change impacts:

- Ice is melting worldwide, especially at the Earth's poles.
- Rising temperatures are affecting wildlife and their habitats.
- As temperatures change, many species are on the move. Some animals have migrated farther north or to higher, cooler areas.
- Precipitation (rain and snowfall) has increased across the globe, on average.
- Also some regions are experiencing more severe drought, increasing the risk of wildfires and drinking water shortages.
- Some species are thriving (National Geographic).

If this global warming continues, other effects will occur. These:

- An increase in hunger and water crises, especially in developing countries
- Sea levels are expected to rise to 82 centimeters by the end of the century.
- Hurricanes and other storms will grow stronger.
- Floods and droughts will become more common.
- Glaciers will have less fresh water since they store three-quarters of the world's fresh water.
- Some diseases such as mosquito-borne malaria will spread.
- Ecosystems will continue to change: some species will move away from the north and some species will be extinct (National Geographic).

2.2. Climate Change Adaptation

It is important to be clear that climate change cannot be avoided however we can mitigate its effects and adapt to its consequences. These actions are known as climate change mitigation and adaptation measures (Acciona, Climate change).

Mitigation addresses the root causes, by reducing greenhouse gas emissions, while adaptation seeks to lower the risks posed by the consequences of climatic changes. Mitigation will take too long to achieve results; therefore, adaptation to climate change is indispensable and urgent (Fisher, S. The Guardian).

Mitigation consists of launching actions to reduce and limit greenhouse gas emissions with the aim of preventing the global temperature of the planet from continuing to increase. These actions consist of greater investment in renewable energies, transition to a low-carbon economy, promoting energy efficiency, electrification of industrial processes, and the implementation of efficient transport means (electric public transport, cycling, car sharing, etc.)(Acciona, Climate change).

Adaptation focuses on actions to decrease vulnerability in the face of the effects of climate change, such as improving infrastructure and making facilities safer and more resilient, reforesting and landscape restoration, water treatment and purification, varied farming to be prepared for natural catastrophes. The environment provides critical 'natural infrastructure' for climate change adaptation (Acciona, Climate change).

Influential adaptation in the built environment wants to be supported by powerful policy and a range of incentives to supply delivery on the ground. Policymakers must think of the full variety of infrastructure options - whether engineered or natural and they need to determine which are most cost-effective in terms of short-term benefits and long-term resilience.

Both approaches will be necessary, because even if emissions are dramatically decreased in the next decade, adaptation will still be needed to deal with the global changes that have already been set in motion (Fisher, S. The Guardian).

UNEP (United Nations Environment Program) categorized policy issues for adaptation and mitigation in a total of 12 areas. Mitigation issues;

• Increasing energy efficiency and energy saving,
• Improving land use management practices,
• Increasing the share of low carbon energy sources in the fuel mixture and
• Encouraging carbon dioxide capture and storage.

Adaptation issues;

• Improving coastal zone management,
• Reducing human health impacts and risks,
• Reducing agricultural production losses,

• Increasing infrastructure resistance,

• Improving water resource management,

• Increasing the resistance of terrestrial ecosystems,

• Increasing the resistance of marine ecosystems and

• Reducing the effects of extreme weather events.

According to EPA (Environmental Protection Agency) climate change adaptation strategies can be grouped under 4 headings: air, water, waste and public health (EPA, Climate Change Adaptation Resource Center).

The future effects of climate change on the water resources of the world will depend on trends in both climatic and non-climatic factors. Evaluating these impacts is challenging because water availability, quality and streamflow are sensitive to changes in temperature and precipitation. Other important factors include increased demand for water caused by population growth, urbanization, changes in the economy, development of new technologies, changes in watershed characteristics including degradation and water management decisions. According to Global Risks 2015 Report from World Economic Forum, figure shows global trends connected to global risks. Climate change is in direct relation with water crises, loss of biodiversity, extreme weather events and ecosystem collapse (Figure2.2).

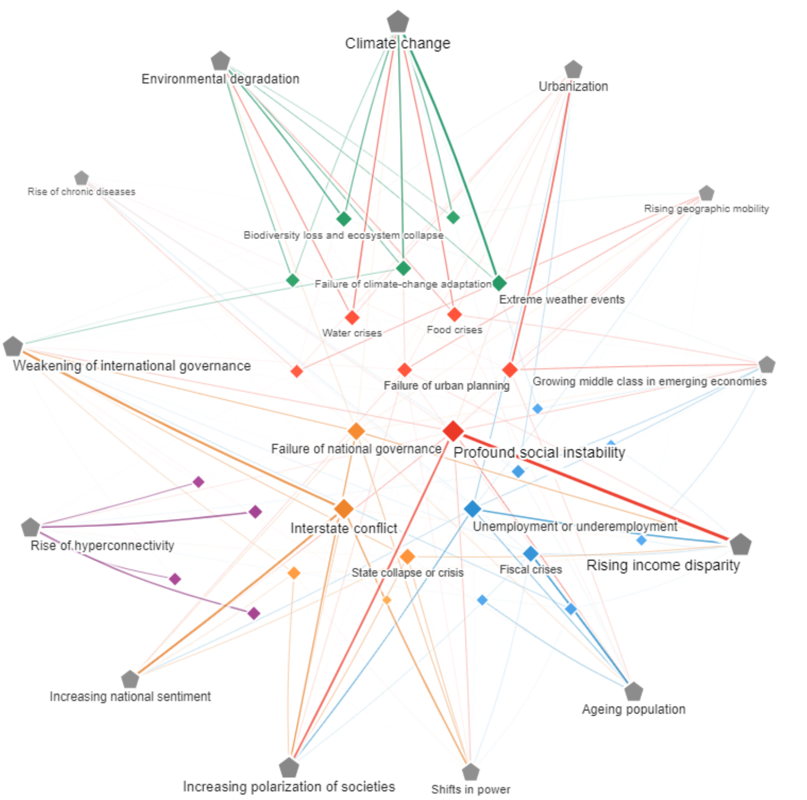


Figure 2.2 Global trends connected to global risks (Source: Global Risks 2015 Report)

Water is the primary medium through which we will feel the effects of climate change. Water availability is becoming less predictable in many places, and increased incidences of flooding threaten to destroy water points and sanitation facilities and contaminate water sources (Unwater, water and climate change).

Water acting a main role in how the world mitigates and adapts to the effects of climate change. An integrated view on water, the biosphere and environmental flows is needed to devise systems that will allow us to decelerate climate change effects, preserve us from extremes and to adapt to the unavoidable at the same time (Unwater, water and climate change).

2.2.1. Climate Change Adaptation in Turkey

According to the IPCC (Intergovernmental Panel on Climate Change) based on the climatic conditions in 1990, the amount of water per capita per year in in Turkey are now 3,070 cubic meters. But most of this water is not available in places where water is needed. Simply because of the population increase the amount of water per capita per year in Turkey in 2050 will be 1,240 cubic meters. Our population is increasing along with global climate change as a result of the falling amount of water per person a year in Turkey in 2050 will be between 700 and 1,910 cubic meters. Considering that the rainfall is irregular, water is limited in big cities and agricultural production; the quality of drinking, using and irrigation water decreases as a result of increasing industrial and other environmental pollution, and global warming is considered, our country will feel the drought severity more recently than today (Kadıoğlu, M. 2012: 52).

Prof. Dr. Mikdat Kadıoğlu summarized the possible adverse effects of global climate change on water resources in our country as follows:

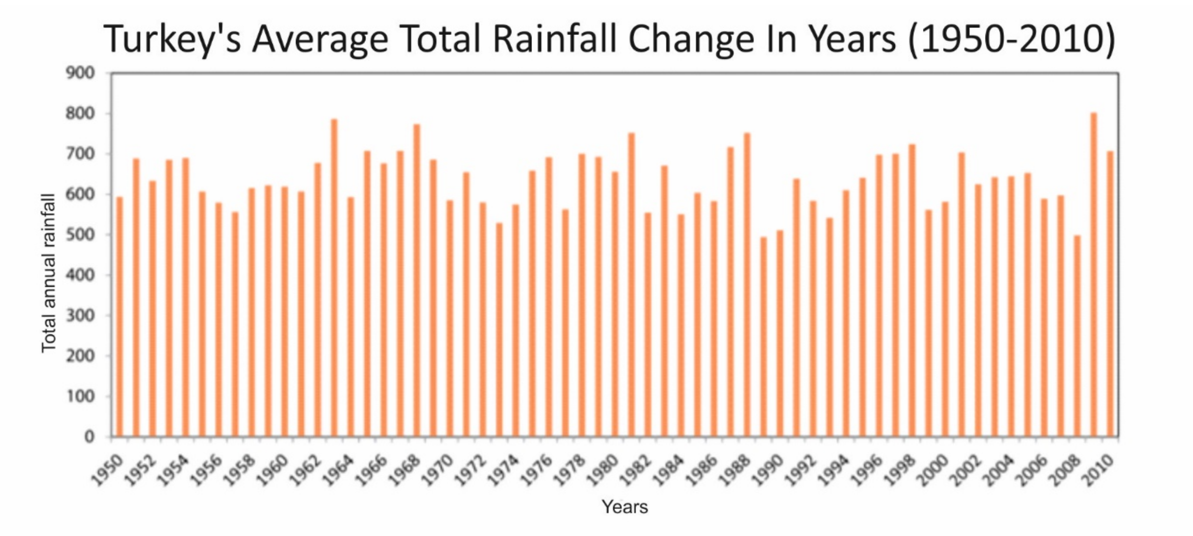
- There will be a big decrease in precipitation in summer but evaporation may increase.
- Seasonal distribution and intensity of precipitation will change.
- Sudden floods are expected to increase.
- Snow cover, which has already been below average since 1987, may be further reduced.
- The currents will not only decrease in quantity but also peak times will change.
- Drought frequency and severity may increase.

- Water stress will increase
- Problems may arise in the sharing of many international, national and local water resources.
- “Kuş Cenneti” and similar national parks will be destroyed and the migration routes and accommodation places of the birds will change (Kadıoğlu, M. 2012: 53).

Climate change is an important condition for Turkey. Instead of seeing this as just a problem, we need to improve this picture that we created as a result of our actions. We should try to improve the situation because it is not possible to correct or restore. For this, we must look at which deal with Turkey's problems. At the beginning of these, there are floods caused by inadequate infrastructure.

Table 2.1 shows that the rains of the last 60 years, we see that there is a steadily increasing and decreasing rainfall. Rainfall showed the lowest time in 1990 and the highest time was in 2009.

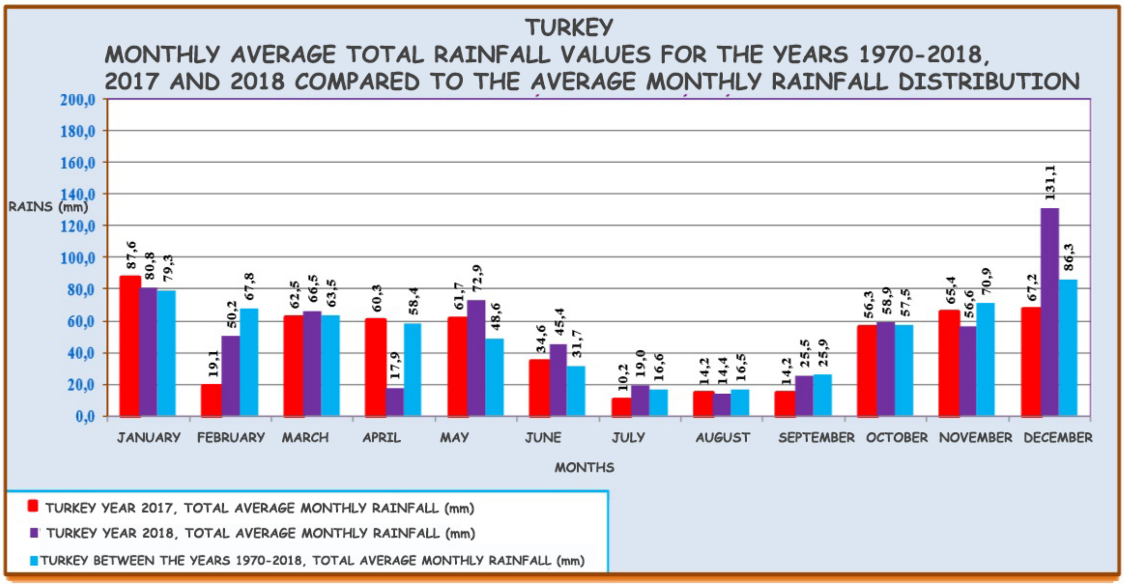
Table 2.1 Turkey’s average total rainfall change in years (Source : Kadıoğlu, M. 2012)



There is no balance between the years seen in the Table 2.2 and we see that they differ from each other. This indicates irregular rainfall. When we look at the comparison of the distribution of average total rainfall values in the months of 1970-2018 with the average rainfall values in the months of in 2017 and 2018; we see that 2018 monthly total rainfall results increase in December and February, decrease in April.

When the same 2018 data of these months are compared with Turkey's Total Average Monthly Rainfall between the years 1970-2018; it is observed low in February and April, observed high in December (Table 2.2).

Table 2.2. Turkey overall annual rainfall (Source: Turkish State Meteorological Service)



We can also see the imbalance in precipitation in Table 2.3. While the rainfall in September 2018 was below the seasonal norms, the rainfall in 2019 was much lower. Rainfall norms and differences between years are very evident in 7 regions. The rainfall observed in the Ege region in 2018 and the rainfall observed in 2019 is about 2 times. When we look at the overall picture, it is seen that regional rainfall is more or less than normal. This can be associated with extreme rainfall and drought from climate change impacts.

Turkey's many cities are being flooded due to excessive rainfall and insufficient infrastructure system. Rapid population growth, unplanned urbanization and lack of permeable surfaces in cities have reached serious results especially in Turkey's most populated three cities. Table 2.4 shows the news for İzmir, Istanbul and Ankara.

Table 2.3: The normal of areal precipitation in September 2019 and comparison with 2018 (Source: https://www.mgm.gov.tr/veridegerlendirme/yagis-raporu.aspx?b=a#sfB)

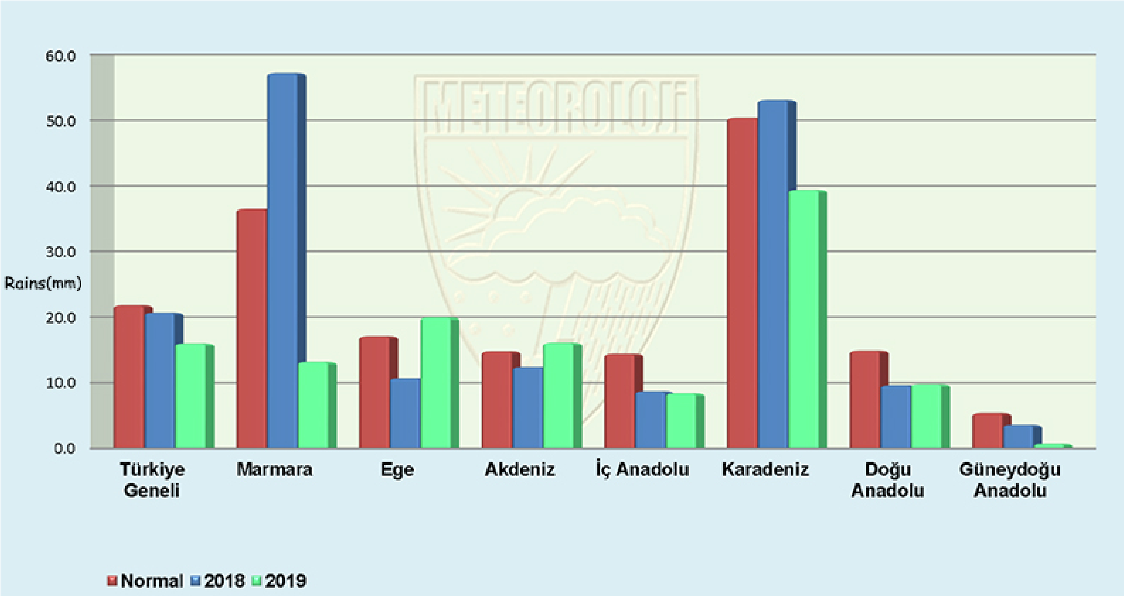


Table 2.4. News for İzmir, İstanbul and Ankara in last ten years

Year/ City	**Content of the News**	**Source**
2009 İstanbul	31 people died in floods in İstanbul. As a result of heavy rainfall, Ayamama stream overflowed. Flood waters left all the factories and roads under water.	http://www.hurriyet.com.tr/gundem/istanbulda-sel-felaketi-31-olu-12441217
2017 İzmir	The flood, which was effective in İzmir, led to the demolition of the walls of some houses, the flooding of vehicles and the burial of a Gültepe neighborhood.	https://kazete.com.tr/haber/izmirde-sel-felaketi-53013
2018 İzmir	In İzmir, the sea rose with the effect of severe lodos. Alsancak was flooded. Sea waters rising 50 cm caused great damage.	https://indigodergisi.com/2018/01/izmir-sel-alsancak/
2018 İstanbul	Cendere Stream flooded in Kağıthane due to rainfall. About 3 meters rising flood waters flooded the surrounding houses and businesses. The retaining wall collapsed with great noise.	https://www.dha.com.tr/yurt/istanbulu-siddetli-yagis-araclar-mahsur-kaldi-ev-ve-is-yerlerini-su-basti/haber-1615842
2018 İzmir	In Bornava, Ege University Faculty of Medicine was flooded due to downpour. In Karşıyaka, due to heavy rain, part of the ceiling of Bostanlı Ferry Port collapsed.	https://www.karar.com/guncel-haberler/izmirde-sel-hastaneyi-su-basti-iskele-coktu-985381?p=3#
2019 Ankara	In Ankara Kizilcahamam, flood caused an hour of precipitation.The overflowing riverbed dragged everything in front of it. Many houses and stables were flooded.	https://www.cnnturk.com/yerel haberler/ankara/kizilcahamam/kizilcahamamda-bir-saatlik-yagis-sele-neden-oldu-1011479

Of the total water consumption in Turkey, from 2004 to 2030 it is projected to increase almost three-fold. Considering the number of adverse effects, such as climate change effects, reduced rainfall, increases in irrigated areas and inhomogeneous distribution of water resources, it is likely to experience significant water stress. By the European Environment Agency, 2030 year in Turkey and in EU countries was estimated water stress levels. Accordingly, in 2030, Turkey's central and western regions are expected to experience water stress at a rate exceeding 40%. In the southeast and eastern regions, this rate will be between 20-40% (Bursa Enerji ve İklim Değişikliği Uyum Planı: 8).

Water is used in many areas in cities. At the beginning of these; drinking water, water for animals and natural life, agricultural irrigation water, water for energy and industry, tourism and fishing. For this reason, water stress that is expected to be experienced will affect people in many areas (Figure 2.3).

Figure 2.3 Distribution of Water Use by Sector World and Turkey In 2015
(Source: https://sutema.org/kirilgan-dongu/suyun-sektorlere-gore-kullanim oranlari.9.aspx#_ftnref2)

Countries take various policies to mitigate and adapt to climate change. In our country, there are climate plans in various cities for climate change. In this study of these plans, Turkey Climate Change Action Plan (2011-223), Energy and Climate Change Adaptation Plan of Bursa, Istanbul Climate Change Action Plan and Green Re-Opinion for İzmir City: A Framework Project for Flexible Cities was examined. The targets planned in the Istanbul Climate Change Action Plan are planned to be achieved by 2022.

Turkey Climate Adaptation Strategy, focused primarily on five areas of vulnerability as follows:

1. Water Resources Management
2. Agriculture and Food Security
3. Ecosystem Services, Biodiversity and Forestry
4. Natural Disaster Risk Management
5. Human Health.

Stormwater has an important place in order to reuse water, to fight floods and excessive drought. In our country, stormwater is included in the above mentioned plans. Stormwater related parts of the plans examined are given in the table below.

Common decisions of the plans made shown in table 2.5 include:

• To increase the permeable surfaces for the absorption of rainwater in the city,

• To give examples to the citizens with rain water collection practices in public buildings and

• Aims to make the stream improvement works more ecological.

Table 2.5. Turkey Climate Change Action Plan (2011-223), Energy and Climate Change Adaptation Plan of Bursa, Istanbul Climate Change Action Plan

Turkey	**Bursa**	**Istanbul**
• To determine the amount of carbon held in residential areas in 2012 and to increase this value by 3% with green tissue until 2020.	• Preparing integrated plans with inter-institutional cooperation which is one of the important deficiencies seen in Bursa. • Establishment of urban green belts by constructing river / stream sides as green areas.	• Permeable surfaces to prevent rainwater accumulation in open parking areas • Separation and extension of rain drainage system from sewerage network.

(cont. on next page)

Table 2.5 (cont.)

• Making the necessary legislative arrangements to ensure the inclusion of ecological elements in the river rehabilitation works carried out by the municipalities. (2011–2015) • Preventing canalization in order to improve water quality in streams where flood risk is not high and supporting practices encouraging restoration of creeks with plant elements. (2011-2015) • Encouraging the construction of rain water recovery systems such as roof gardens and permeable pavements and rain water infiltration. (2011-2013)	• Selecting permeable materials in urban surface coatings, avoiding ground coverings that prevent groundwater feeding. • Carrying out studies for the use of stormwater within the site area. • Establishment of hobby gardens through urban expropriations. • Providing water management trainings on disasters. Creation of simulation rooms for floods. • Demonstrating good practice examples to the citizens in the practices to be made in the fields of public institutions (rainwater collection, increasing green / permeable areas).	• Reducing the risk of sudden flooding by increasing the use of permeable coating materials that will ensure the absorption of rain water in large urban areas • Pilot project for storing stormwater and gray water in cisterns (water harvesting) in IBB buildings. • Facilitation of transfer of stormwater to sea and creeks

Recommendations have been developed for the creation of a climate-resilience urban area based on the potential of green infrastructure for the city of İzmir. These recommendations are discussed in the Green Re-vision: A Framework for the Resilient Cities Project.

The aim of the Green Re-vision: A Framework for Resilient Cities Project is to create a resilient urban space in the context of climate change by using, developing and supporting the potential of green infrastructure.

The activities planned for the project are listed below:

- Creation of climate models for the middle optimistic and pessimistic climate scenarios belonging to the period between 2050 and 2100 in and around İzmir province,
- Mapping the urban green infrastructure system and creating land use models for the Balçova district of İzmir, selected as the pilot region,
- Calculation and mapping of regulatory urban ecosystem services for Balçova district,
- Preparing recommendations for adaptation of İzmir to climate change as a result of mapping,
- Organizing seminars on the effects of climate change, adaptation to climate change and urban green infrastructure (Dirençli Kentler İçin Bir Çerçeve, 2019)

2.3. Evaluation

Climate change is a problem that is caused by human effect and affects the world. Many effects of climate change are already being observed in the world. If the necessary measures are not taken, more will be observed in the future. One of the most important impacts of climate change is water. Recently climate change adaptation policies have been prepared in Turkey. Especially in Turkey Climate Change Action Plan to stream rehabilitation work is intended to ensure the inclusion of ecological aspects. The dates targeted in the action plan indicate the years 2011-2015. However, it was observed that the decisions taken were inadequate in practice. For example, in the IZSU activity reports examined, it was observed that even the stream improvements made in 2018 were made by pouring only concrete. Instead of fighting water, we should take advantage of it. The implementation of the plans made in our country is very important in terms of preventing future water stress.

CHAPTER 3

STORMWATER MANAGEMENT PRINCIPLES and CASES ACROSS THE WORLD

3.1. Resilience & Stormwater Management

In recent years “resilience” has become a popular concept to address increasing risks. It has been applied in various fields linked to sustainable development, climate change adaptation, disaster risk management, and reduction and environmental science.

Resilience strategies for flood risk management can be defined as strategies that allow floods, but aim at minimizing the flood impacts (K.M. de Bruijn :60).

Resilience strategies focus more on living with floods instead of preventing them. Such strategies rely on a flexible response to floods and a rapid recovery from them. Resilient water systems are believed to be able to cope more easily with disturbances such as pollution and extreme events.

There are multitudes of ways in which we can enhance flood resilience. Developed assessment and communications of the hazard would help people make better choice and take mitigating actions. Better preparation and community planning reduces costs in human life. Investments in infrastructure can help dissipate flood waters. Warning systems can help keep people safe (World Economic Forum).

Unlike conventional gray infrastructure that consists of concrete and metal systems that carry stormwater away, green infrastructure minimizes impervious areas to hold and treat stormwater.

Stormwater flooding, on the rise due to climate change, can destroy urban areas and result in drawn-out, costly repairs. Cities need new strategies to manage the influx of stormwater. Stormwater flooding in cities is exacerbated by urban infrastructure, as many of the natural ecosystems that would absorb rainfall have been replaced with pavement, which greatly limits an area’s infiltration capacity. This holds stormwater on the surface, where it picks up all kinds of pollutants that are finally carried into nearby bodies of water, often including the regional water supply. Natural stormwater management systems are becoming more popular options for cities, in part because of their suitability.

Stormwater occurs from the excessive surface flow. When the rainfall intersection rate and the leakage of precipitation are reduced and the volume and surface flow rate increase. In this case, the amount of stormwater passing to the surface flow increases and the stormwater transition time is shortened. Clearance of vegetation covers and flattens of landform and developed into impervious covers such as buildings, roads, parking lots, solid pavements and storm sewers caused a massive discharge of stormwater with high frequencies especially during heavy precipitation (Musa, Zen ve Tukiman, 2013: 45).

The primary method for stormwater drainage was the construction of stormwater sewers where stormwater was be directed to adjacent receivers. As a result of the impermeable increase in urban areas and the decrease of green areas, stormwater after rainfall cannot sufficiently infiltrate the soil. The growth in impervious areas has shifted the hydrological cycle in urban areas to increase the runoff and decrease the evapotranspiration and soil infiltration. It is expected that there will be an increase in urban stormwater with the change of rainfall types due to climate change. Thus, urban floods will increase due to the overloading of existing sewage systems (Berglund, 2018: 4).

Blue-green infrastructure (BGI) is a way of sustainable and local stormwater treatment. BGI has been mentioned in the literature with many different names; Sustainable Urban Drainage Systems (SUDS), Nature-Based Solutions (NBS) and Low Impact Developments (LID) take into account the implementation of sustainable stormwater management (Berglund, 2018: 5).

In recent years, in the scope of urban stormwater management, besides the traditional stormwater analysis, sustainable urban stormwater management models have emerged. Australian-based Water Sensitive Urban Design (WSUD), UK-based Sustainable Urban Drainage Systems (SUDS) and US-based Low Impact Development (LID) are the most preferred models (Müftüoğlu ve Perçin, 2015: 28).

The WSUD approach as proposed by Brown et al. (2008), is defined as " *an approach to urban planning and design that integrates land and water planning and management into urban design*". WSUD believes that urban development and improvement can be combined with the sustainability of water (Engineers Australia, 2006).

Water Sensitive Urban Design (WSUD) combines urban water cycle management with urban planning, simulating natural systems to minimize the harmful effects of the natural water cycle (South Eastern Council, 2013: 5). The fundamental principles of WSUD as stated in the Urban Stormwater: Best Practice Environmental Management Guidelines (BPEMG) (Victorian Stormwater Committee, 1999) are:

- To protect and develop natural water systems in cities.
- To integrate stormwater operations on the land and create recreation areas appealing to the eye.
- To increase the water quality transferred from cities to the environment.
- Minimize impermeable areas to reduce the flow rate of water.
- Minimizing the costs of developing drainage infrastructure.

Bio-retention systems are one of the most commonly used Water Sensitive Urban Design (WSUD) technologies in Australia. Bio-retention systems are a kind of stormwater treatment method designed to control stormwater flow. In this system, water is filtered from a vegetative soil layer before entering the garden bed. The filtered stormwater is then gathered in the spongy pipes at the bottom of the garden bed and is directed to the place where it is planned to go (WSUD Information page No: 4, 2016: 1).

Green infrastructure is a component of an approach to land development or re-development called Low Impact Development (LID) which incorporates ways to handle stormwater on site into project designs.

Low Impact Development (LID) is an environmentally sensitive approach to stormwater management. By applying LID principles, water can be managed to reduce the effects of built-up areas and to ensure the natural flow of water in the ecosystem. If the LID is widely applied, it can preserve the hydrological and ecological functions of a basin and can provide benefits in many different areas. In order to better protect water resources and the environment, efforts should be made to protect natural resource areas and minimize impermeable surfaces (Figure 3.1.) (EPA, 2009).

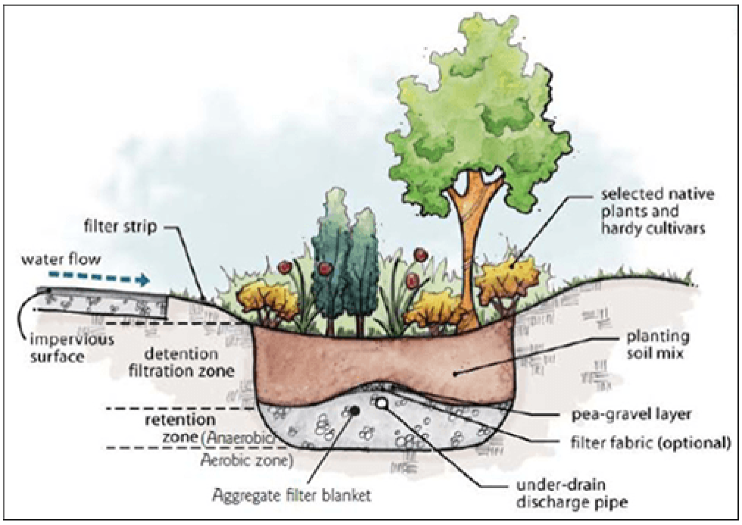


Figure 3.1. Low Impact Development Project
(Source: https://www.yakimacounty.us/1737/Low-Impact-Development)

LID practices use natural processes to manage the stormwater runoff from the neighborhood. However, because they are utilized as a stormwater management facility, and therefore minimize downstream pollution and flooding, it is significant to continually inspect these systems to ensure that they are functioning correctly. The maintenance needs of the individual LID practices vary and may require the assistance of a trained professional, which should be determined up-front to assure the appropriate maintenance of these practices (DNR, 2009: 1).

3.2. Efficient Stormwater Infrastructure

The problem of stormwater can be solved using Sustainable Urban Drainage Systems, namely green infrastructure systems. Sustainable Urban Drainage Systems allow more leakage of precipitation into the underground. At the same time, the passage of rain prevents less contamination on the surfaces. With the help of coating materials such as vegetation on the ground, it slows down the surface flow rate and purifies the water (Ünal ve Akyüz, 2017: 16).

Green infrastructure design is an engineering design that takes a "design with nature" approach or engineered green infrastructure is human-designed devices that mimic nature in function or strive to reduce their impact on ecological systems and capacity. Same techniques are called Sustainable Urban Drainage Systems (SUD) in the United

Kingdom. Some call high-performance landscapes-infrastructure. Green Infrastructure is defined by the US Environmental Planning Agency (EPA) Office of Wastewater Management as "*a flexible term used to describe an array of products, technologies, and practices that use natural systems to enhance overall environmental quality and provide utility services. As a general principle, Green Infrastructure techniques use soils and vegetation to infiltrate and recycle stormwater runoff.*" (Saygın ve Ulusoy, 2011: 225).

Green infrastructure techniques for stormwater management include the following designs; Green roof, separation of rainwater downpipe from wastewater channel, rain water collection and reuse systems, natural rain water drainage systems (rain ditches) , rain water flowerpots and infiltration gardens, rain water basins (retention and catchment basins, ponds), effective landscaping and irrigation (dry landscaping, local planting) and reduce areas of impermeable surfaces. The methods used in this project are further examined. The applications of this system are described in Appendix A with detailed examples.

3.2.1. Raingardens

Rain gardens are landscaped areas that collect rainwater using biological aprons. Biological treatment systems collect and filter rainwater through the soil and plant root systems, where water pollutants such as bacteria, nitrogen, phosphorus, heavy metals are retained, disintegrated and absorbed. Treated rainwater is then given to ground as groundwater. If not, the rainwater is transferred to the drainage system. Rain gardens may look like traditional landscapes but differ in design and function (Figure3.2.). Perennial plants, shrubs, small trees and local plants can be preferred in rain gardens (CRWA, 2008: 1).

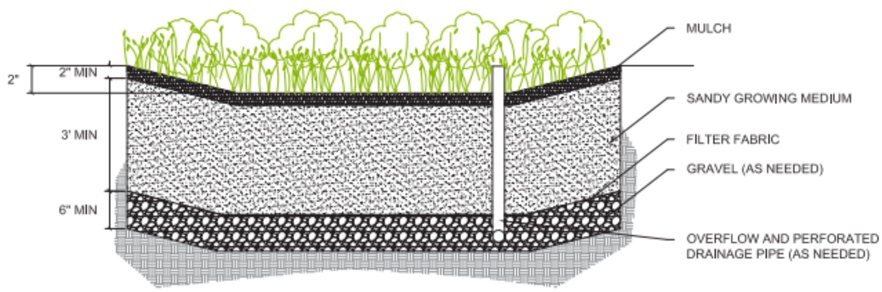


Figure 3.2 Rain garden example (Source: CRWA, 2008: 2)

3.2.2. Constructed Wetlands

Constructed wetlands (CWs) are ‘‘engineered systems, designed and constructed to utilize the natural functions of wetland vegetation, soils and their microbial populations to treat contaminants in surface water, groundwater or waste streams" (ITRC 2003).

Constructed wetlands are classified in two ways according to the water flow regime. These are free water surface flow or subsurface flow CWs. These are able to treat different urban and rural wastewater flows.

Constructed filter beds provide the place for biological treatment of effluent. Filter beds generally include one of two different types of filtering material, usually sand or gravel. Constructed wetlands are commonly defined according to their flow regime in the filter bed (WECF, 2001: 4).

A surface flow (SF) wetland is formed of a shallow basin, soil or other medium to support the roots of vegetation. It is also a water control structure that maintains a shallow depth of water. The water surface is above the substrate. SF wetlands look much like natural marshes. It can provide wildlife habitat and aesthetic benefits as well as water treatment. Stormwater wetlands and wetlands built to treat mine drainage and agricultural runoff are usually SF wetlands (EPA, 2015: 13).

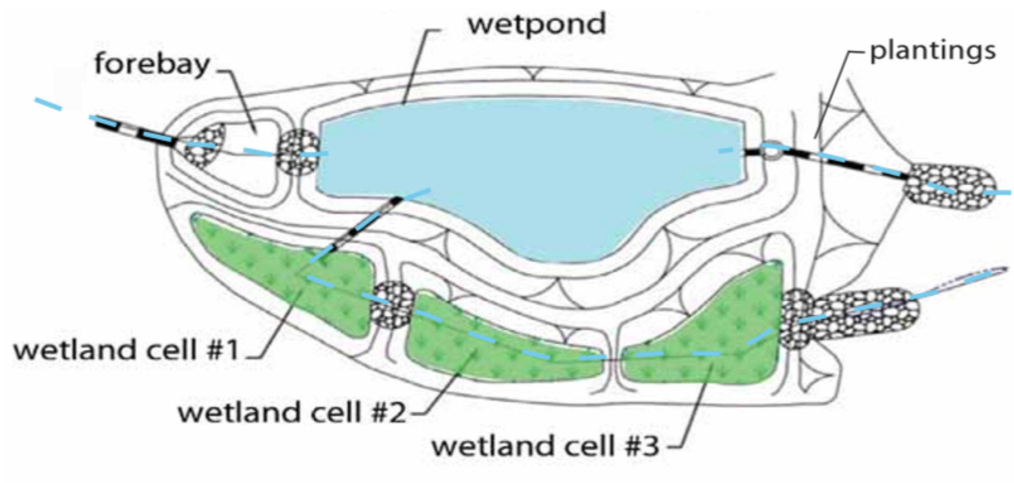


Figure 3.3 Wetlands sample plan view (Source: https://www.vermont.gov/)

3.2.3 Water Reservoirs

The reservoirs are water bodies created by human activities for specific purposes to provide a reliable and controllable resource. Reservoirs are often used in areas with water shortages or excess water. Reservoirs can be made in various types (Figure 3.4). Where there is little water, the reservoirs protect existing water so that it is comfortable to use for irrigation or drinking water at the times when it is most needed. When there is an over-water problem, a reservoir can be used for flood control to prevent the sample from precipitating further rainfall areas or areas that prevent water flow during snow melting (WHO, 1996:1).

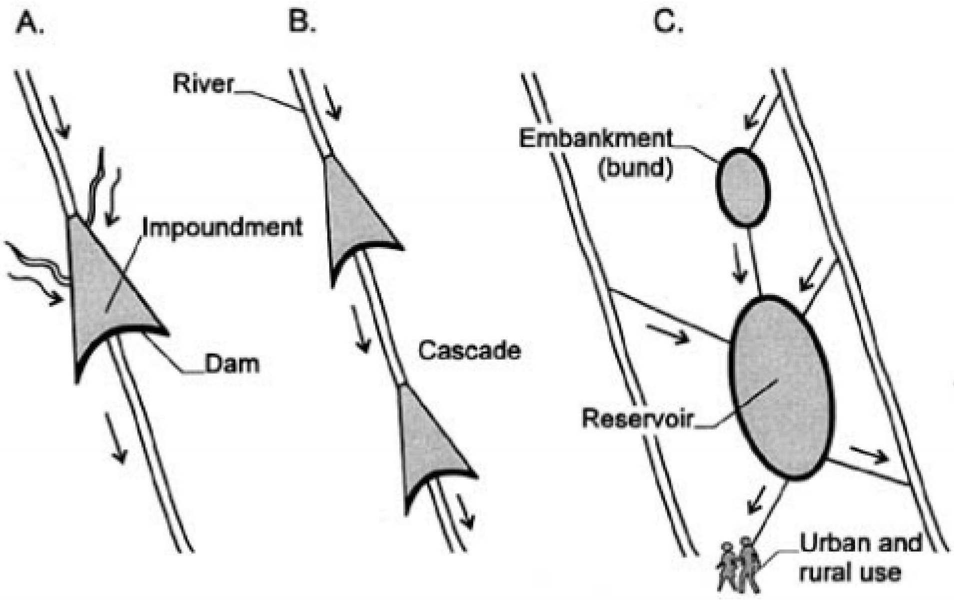


Figure 3.4. Various types of reservoirs: A. Reservoir created by damming a river; B. A cascade formed from a series of river impoundments; C. Bunded reservoirs with controlled inflows and outflows to and from one or more rivers.

A reservoir serves the storage of water, and the size of the tank is subjected to the volume of water to be stored. Reservoirs are of two main categories: (a) Impounding reservoirs into which a river flows naturally, and (b) Service or balancing reservoirs receiving supplies that are pumped or channeled into them artificially. In general, service or balancing reservoirs are required to balance supply with demand. The second type of reservoirs is relatively small in volume because the storage required is short-term. Impounding or storage reservoirs are intended to accumulate a part of the flow of the river for use during the non-flood months (Kharagpur, 2008:1).

3.2.4 Green Streets

"A green street is a stormwater management approach that incorporates vegetation (perennials, shrubs, trees), soil, and engineered systems (e.g., permeable pavements) to slow, filter, and cleanse stormwater runoff from impervious surfaces (e.g., streets, sidewalks). Green streets are designed to capture rainwater at its source, where rain falls. Whereas, a traditional street is designed to direct stormwater runoff from impervious surfaces into storm sewer systems (gutters, drains, pipes) that discharge directly into surface waters, rivers, and streams."(URL 10).

Green streets incorporate depressed planted areas, typically located between the roadway pavement and the sidewalk, into the overall design of the street (Figure 3.5). Green streets reduce and control the flow of stormwater directly at the source, from the nearby roadway, by collecting runoff in the intentionally designed planted areas so that it can be slowed down and absorbed before it is transmitted to the larger stormwater management system. Planting should be able to tolerate drying conditions under summer and occasional flooding. Preferably, the plants will be evergreen and be low-growing plants as well as plants which do not have deep roots (Naturally resilient communities).

A green street planter is a small rain garden that collects stormwater runoff from streets.

- Green streets are important parts of the city's green infrastructure and help protect and improve the efficiency of the city's grey, or pipe, infrastructure.
- Green streets increase urban green space, improve air quality, replenish groundwater, and reduce air temperature (The City of Portland Oregon).

Green Street features include vegetated curb extensions, sidewalk planters, landscaped medians, vegetated swales, permeable paving, and street trees. They are detailed in the Appendix B.

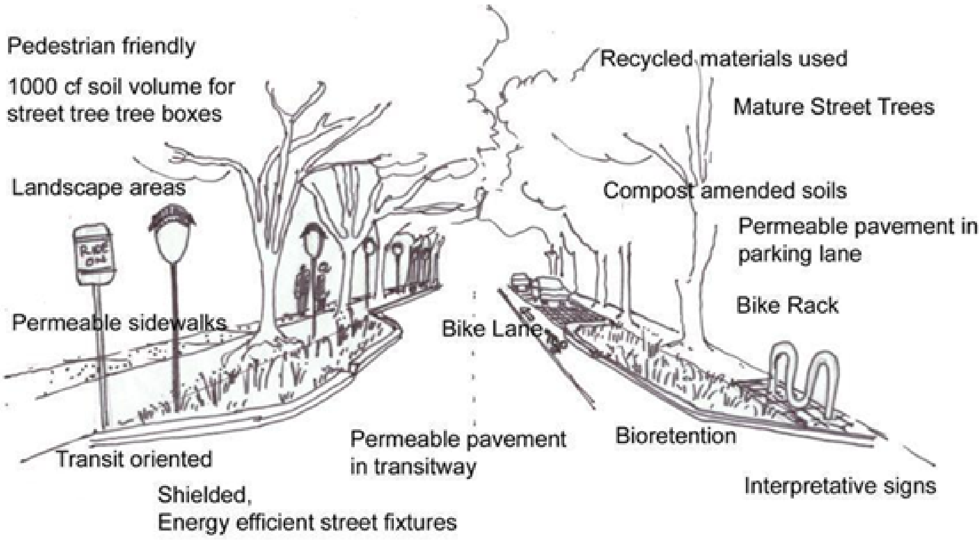


Figure 3.5. Green street example
(Source: https://www.epa.gov/G3/learn-about-green-streets)

3.2.5 Ecological Water Resource Center

There are many kinds of Ecological Water Resource Center. They can be constructed in different sizes, in different functions, in different capacities and in different areas. Ecological water resource centers educational programs encourage life-long learning about the environment—and people's relationship to the environment. The multitude of activities offered, including recreational opportunities, connect children and their families to nature and water.

One of them is The Center for Urban Waters (Figure 3.6). It's located in Washington. The Center for Urban Waters is the result of nearly a decade of work by civic leaders and organizations who dreamed of a premier research center dedicated to developing solutions to the problems facing urban bay communities. In 2007, the old industrial property was purchased at Thea Foss Waterway and in 2010 the building was completed. The Center for Urban Waters brings together environmental scientists, analysts, engineers and policymakers. It provides a living laboratory for researchers to investigate water systems and natural resource issues (URL 13).

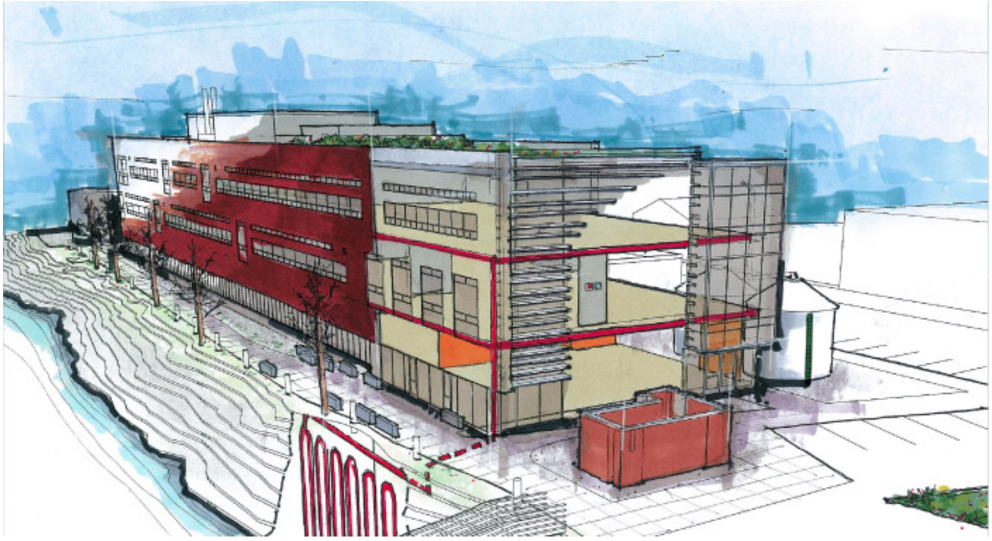


Figure 3.6. Tacoma’s Center for Urban Waters (Source: https://www.urbanwaters.org/the-building/leed-platinum/resources/)

The Center for Urban Waters was certified in 2012 as a LEED (Leadership in Energy and Environmental Design) Platinum® project (the highest rating possible).

The Center was designed with the following environmental categories in mind:

- The building's entire roof, with the exception of mechanical areas, is a green roof. It is covered with soil and plants over a waterproofing membrane. It absorbs rainfall and reduces stormwater runoff.
- In addition, rain garden was built in the parking lots of the building. Rain gardens provide habitat for beneficial birds and insects and reduce flooding problems.
- Water storage tanks collect runoff from the roof and water rejected by the laboratory’s pure water system. The Center for Urban Waters uses 46% less water than a conventional facility because of the combination of water reuse and efficient plumbing (Figure3.7).
- Daylighting reduces energy consumption by using windows and reflective surfaces to light the facility. Open areas are equipped with daylight sensors that automatically adjust light levels based on the amount of natural light.
- This facility has fixed sunshades on the south building facade and motorized shades on the west. Solar shades are designed to prevent sunlight from directly landing on the windows and heating the building interior.

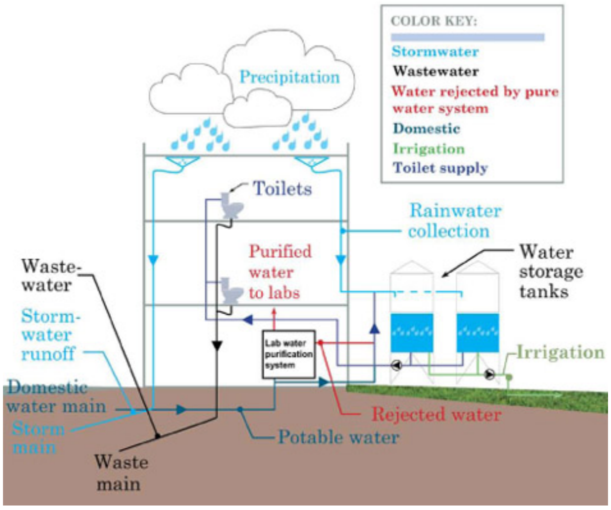


Figure 3.7 Building water flow diagram
(Source: https://www.urbanwaters.org/the-building/leed-platinum/saving-water/)

3.3 Best Practices Across the World

3.3.1. China

China's urban drainage systems have long failed to keep pace with population growth and urban expansion. Rainwater management facilities are not sufficient for the infrastructure. Unsustainable urban development is unable to cope with the challenges of climate change and urbanization. For these reasons, China is increasing the risk of urban floods, and in recent years, China's cities are experiencing many floods (Figure 3.8) (Jiang, 2018).

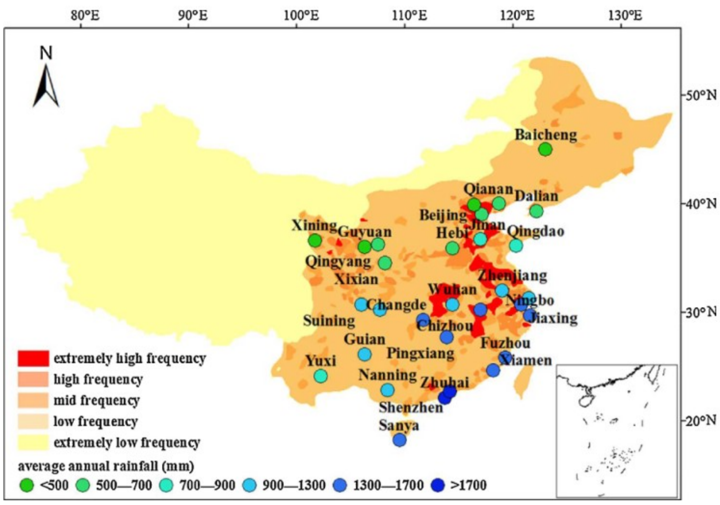


Figure 3.8. Spatial distribution of selected pilot cities for sponge city development as compared to annual rainfall and water disaster frequency in China (Source: Jiang, 2018)

To rising pluvial flooding events in urban areas, the Chinese government has adopted a group of policies and programs to speed up and strengthen the development of drainage systems across. Most significantly, in 2014, the government officially announced a national attempt termed "Sponge Cities" as a holistic strategy to handle urban pluvial flooding while improving the environment (MHURD, 2014a,b).

The Sponge City signifies a type of city that absorbs the stormwater, which is then naturally filtered by the soil and let to reach into the urban aquifers. This allows for the drawing of water from the ground through urban or peri-urban wells. Drawn water can be easily treated and used for the city water supply (World future council).

There are many parks designed to create sponge city. One of is the "Deep Forms of Nature-based Solutions: Meishe River Greenway and Fengxiang Park, Haikou, China" project. Haikou is a tourist city in South China's tropical area with a monsoon climate. The project includes a significant park, the Fengxiang Park, 80 hectares in size and a linear river corridor 13 kilometers long that runs through the densely built area. Based on land use and hydrological process, a stormwater drainage-centered green system (green sponge), was planned to separate the stormwater from the sewage, to integrate the river and all built and potential green spaces. The concrete flood walls replaced with an eco-friendly river bank. The blocked waterway is reconnected to the ocean to allow tides to enter the city again; wetlands and shallow shores along the river were reconstructed (Turenscape, 2019).

Through the transformation of this wetland, stormwater that constantly causes a flood in the city to become a positive environmental amenity for the town. The areas that were previously very bad in the region have gained a completely new look and function (Figure 3.9). The stormwater park now has been listed as a national urban wetland park (Figure 3.10).

This project demonstrates an ecosystem service oriented to urban park design and a water urbanism approach (Turenscape, 2017).

Figure 3.9. Before and after of the region
(Source: Turenscape, 2019)

Figure 3.10. Part of the region after the project is completed
(Source: Turenscape, 2019)

Another Sponge City parks examples is "Qunli Stormwater Park". Beginning in 2006, a new urban district, Qunli New Town was planned to be developed on North China. More than one third of a million populations are expected to live new town. While only about 16.4% of the developable land was zoned as permeable green space, the majority of the former flat plain will be covered with impermeable concrete. Flood was frequent in history for this area. Turenscape was commissioned to design a park of 34.2 hectares. Water sources for this former wetland has been cut, and the wetland is under the threat of disappear. Turenscape's strategy is to transform the dying wetland into an urban stormwater park (Turenscape, 2019).

The design solutions include the use of simple cut-and-fill technique to create a necklace of ponds-and-mounds surrounding the former wetland. Stormwater from the newly built urban area is collected into a pipe around the circumference of the wetland, and after that is distributed into the wetland after being filtrated and deposited through the ponds. The pond and mound ring have formed a road network with platforms and display towers to give visitors a hiking experience in the forest (Figure 3.11). Skywalk allows residents surrounding scattered mounds to have a wetland and canopy experience (Turenscape, 2019).

Figure 3.11. An example of a platform through the Qunli Stormwater Park
(Source: Turenscape, 2019)

The stormwater park now has been listed as a national urban wetland park. This project demonstrates a water urbanism approach. Figure 3.12 shows the change between 2011 and 2014.

Year 2011 one year after the stormwater park was built

Year 2014, 4 years after the wetland park was built; residential development was catlized by the stormwater park

Figure 3.12. 2011 and 2014 images of the Qunli Stormwater Park
(Source: Turenscape, 2019)

3.3.2. Denmark

In the future, it will be challenging to protect the city against storm surges and rising sea levels. The climate adaptation plan has shown that the water level in Copenhagen harbor should be regulated. The rising water level and the risk of rainwater fluctuations lead to a closer examination of the first step in resolving the problem of a long-term increase in sea level and therefore the risk of a storm surge wave and others (Copenhagen, 2014: 44).

In the past, when the gutters were replaced by actual surface drainages in Copenhagen, a combined system was installed to deal with both stormwater and wastewater. In Copenhagen, the vast majority of the sewage system is still the same system. This sewer network under the city is the only drainage system Copenhagen can use for surface flow from roads and buildings. The sewage system is a problem in extreme fats and cannot be handled when there is a heavy downpour. As a result, floods occur (Copenhagen, 2012: 7).

Initially, the Climate Change Plan advised that stormwater from excessive rainfall should be evacuated to open areas, such as parks, where flooding would lead to minimum degradation. The goal was to store rainwater in these buffer areas until the drainage system capacity increased. The heavy rainfall in 2011 showed that this method was insufficient to prevent plural flooding in large parts of the city. The estimates show that the storage method can only cover a small part of the need for draining the rainwater. New research shows that water should be transferred to the sea, urban waterways and underground tunnels by sea measures. Therefore, the preferred action will drain into the sea with new flow paths (Copenhagen, 2012: 8).

The area of storage of surface flow in buffer areas during slow rainfall are the determining factors for initiating flexibility measures. Such measures may be actual emergency flood ducts or tunnels for rainwater, which will increase drainage capacity. These measures will reduce damage in the city. Therefore, the scope has been investigated to drain rainwater into areas where it can be stored temporarily. However, the amount of water coming from intensive dams will not be as large as any storage capacity in Copenhagen. The suitability of open urban areas for stormwater storage is quite different and the choice of territory should be combined with detailed city planning in various parts of the city (Copenhagen, 2012: 8).

Reducing the risk of floods in Copenhagen will make a significant contribution to the blue and green infrastructure if the measures are implemented or if the ground-level excess water is drained. Attempts may include reopening flows, building new channels and creating more green areas, and using roads with high paving stones to guide the resulting flood waters into them. However, the amount of water is so enormous that it will be impossible to transport all flood waters at ground level in the most densely populated area in central Copenhagen. As a suggestion, water can be directed to the port with large pipes. For this reason, the Cloudburst Management Plan has provided measures to make the city more green and blue by emptying rainwater with tunnels in the non-drainable areas of the ground level (Copenhagen, 2012:8).

The square known as "**Tåsinge Plads**" doesn't look much different from other parks in Copenhagen. The area was previously dominated by parked vehicles. It is now the cornerstone of the plan to make the world's first "climate-resilient neighborhood" area.

There are many different items in the park. During heavy rains, flower beds are filled with water and wait for the storm to subside. The upside-down umbrellas collect water and then are used to nourish the plantings. Landscaping elements direct rainwater to large groundwater storage tanks. These tanks have bouncy floor panels that are what children like to jump. As the children jump on these panels, the energy that comes out of their feet pumps water from the pipes below (Figure 3.13).

More parks like it are being built to turn into small ponds during heavy rains. Thus allowing them to capture water on site until the drainage system has capacity to handle it. A solution was chosen where the space still has value when it does not rain. During the worst flood, certain streets with raised sidewalks will become "cloudburst boulevards". It creating water channeled safely through the city until it can empty into the harbor.

Copenhagen has recently been hit by two so-called "100-year flood" events, first in 2011 and then again in 2014. The Intergovernmental Panel on Climate Change predicts that this sort of extreme weather will become increasingly frequent in Denmark, with heavier downpours. Planning for this future, Copenhagen had to make a choice between two very different paths the first option was to expand the city's existing subterranean sewer and drainage system—its "gray" infrastructure. The second option was more of a "green and blue" system. So Copenhagen chose the second approach. Instead of collecting all rainwater through underground pipes, this option envisioned dealing with water at street level through a park network, cloudburst boulevards and retention zones.

In the initial phase of this project, the locals who lived there were listened to and the space was designed to meet their tastes and needs. This project offers a holistic approach by caring about citizens and ecology. These projects will ensure that the local people have a public space, improve their quality of life and protect them with projects that will reduce the effects of climate change for city residents (Cathcart A. 2016).

Figure 3.13. Tåsinge Plads, Copenhagen (Source:https://www.citylab.com/design/2016/01/copenhagen-parks-ponds-climate-change-community-engagement/426618/?utm_source=SFFB)

3.3.3. Netherlands

The Netherlands is the low-lying triangle of North-West Europe. Over the past 1000 years, rivers have been used among higher and stronger trenches. However, river discharges have been increased due to climate change, and excessively high water levels are expected to occur more frequently. Following the river water in 1995, a national River Chamber program was launched to give more space to the rivers to reduce the risk of flooding. The purpose of the Dutch River Program is to provide more space to streams, to cope with higher water levels. In more than 30 locations, measures are taken to accommodate the river to reduce flood risks. These measures are designed to improve the environmental quality of the immediate environment. This is the most complex project in the River program for the Room. A bypass canal is built and a long island is formed between the historic center and the northern shore of the Waal River. Several new bridges improve the connection of the region (Figure 3.14). Together, the island and the bypass channel reduce the risk of flooding and create a recreational and ecological river park (WLA, 2017).

The river park highlights the new flood protection of Nijmegen towards the Waal River. The design is based on river water dynamics, erosion and sedimentation process and tides. The Urban River Park is accessible, and the archaeological and historical elements have combined the past and present in the design. Activities and exhibitions are organized using different ways to design innovative parks. The plan consists of three components: creation, cultivation and water movement. The elder Creation element layer represents the physical elements built during the construction phase. The ‘growing’ which is second layer shows how the landscape may develop in the future. The third layer, ' water movement’ shows the fluctuation of water levels during the season (WLA, 2017).

Figure 3.14. River programme before and after (Source: WLA, 2017)

Experiencing river view and combining river dynamics was one of the main goals of our design. Some roads are flooded by high water levels but are only accessible by stepping stones. Also, the accessibility of the river was also considered and improved. Also, the conditions for sedimentation and erosion processes are carefully incorporated into the design, which is specific to the river landscape and will gradually create various ecotypes.

3.3.4. Rotterdam

Rotterdam's sewer and surface water can deal with peak storms until the late 2000s. Groundwater flooding caused by a mixture of stormwater and wastewater became more common today. Meanwhile, the ground level in large parts of Rotterdam is decreasing gradually. To avoid further threats, a large number of experts in the 2005 International Architecture Biennale discussed how to overcome the water problem at the Rotterdam "Diamond" (Hooimeijer and Vrijthoof, 2007).

The Water Action Programme, which is a package of measures for a sustainable water system, is added in the 2000-2005 Water Plan. Main necessary steps were about construction, management and maintenance of the sewer system and regulating the groundwater level. The purpose of the sewer is to take the wastewater and remove excess water in case of a flood. Sewerage capacity is not increased to carry out these functions. To achieve this, through flow into waste treatment plants will be improved (Hooimeijer and Vrijthoof, 2007).

There are two urgent problems for the center of Rotterdam; these are space for parking and rainwater depots. While solving these issues, they benefited from a multi-story car park with an underground water storage facility (Hooimeijer and Vrijthoof, 2007).

The Museumpark 3-story underground car park accommodates 1,150 cars and also houses one of the largest underground water reservoirs in the Netherlands (Figure 3.15). With a capacity of 10 million liters of water, this storage ensures that in the case of heavy rainfall flooding is kept to a minimum in the city center (Atlas, Museum car park).

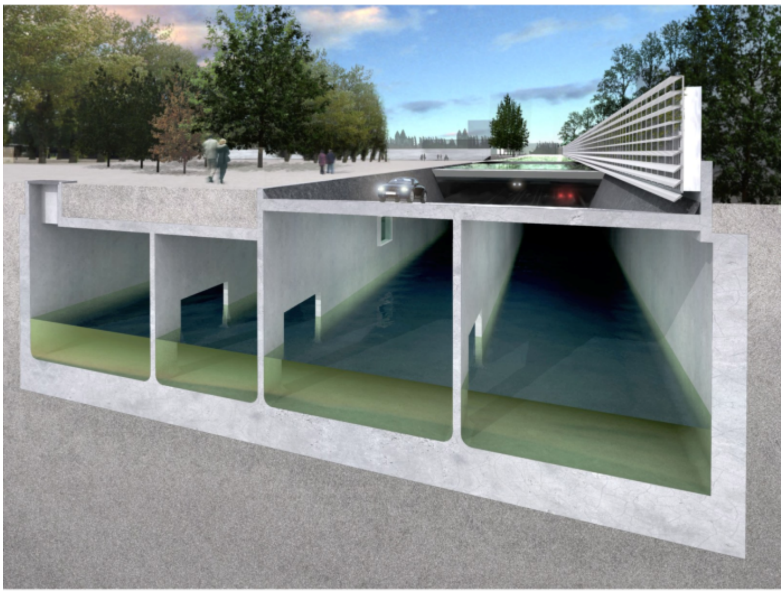


Figure 3.15. The Museumpark underground car park
(Source: https://the-atlas.com/projects/museumpark-car-park-flood-defense)

Another recent issue in Rotterdam is the contamination of singles due to overflow in the existing combined sewer system during heavy rainfall. The underground reservoir becomes an extension of the sewage system, resulting in a combined function, thereby preventing overflow and improving the water quality (Hooimeijer and Vrijthoof, 2007).

This is an important concern for Rotterdam's City Council, as part of the city is flooded every year. The municipality, which has been building underground tanks to collect and hold the rainwater for several years, has adopted a strategy with new water storage systems placed on the surface to make them open and even contribute to the environmental quality of the urban area, as well as to strengthen neighborhood identities and provide entertainment areas.

Thus, the field is made functional. In a previously empty square, it now has three large rainwater collection pools that can be used as amphitheater, basketball and volleyball courts or skateboard tracks when the weather dries (Figure 3.16).

Figure 3.16. Water Square
(Source: https://www.publicspace.org/works/-/project/h034-water-square-in-benthemplein)

3.3.5. England

England is not a stressful region of water as a whole. However, it is a fact that the local and regional areas of England are experiencing more water management problems. Various applications have been developed for these problems on a property scale.

A BedZED residences created with zero waste principle is another application in the UK. The stormwater coming from the roofs is collected in the stormwater tank and used in the toilet reservoir, landscape irrigation. In these houses, it is aimed to reduce carbon consumption with renewable energy in areas such as energy, transportation, waste as well as water. The stormwater coming from the roofs is collected in the storage tanks in each block (Figure 3.17). Rainwater passes through the self-cleaning filter down the pipe before entering the tank. It is then delivered by submersible pumps and is used in toilet cleaning, irrigation and garden watering points (Figure 3.18) (Lazarus, 2003: 25).

Figure 3.17. Rainwater harvesting terraces (Source: Lazarus, 2003: 25)

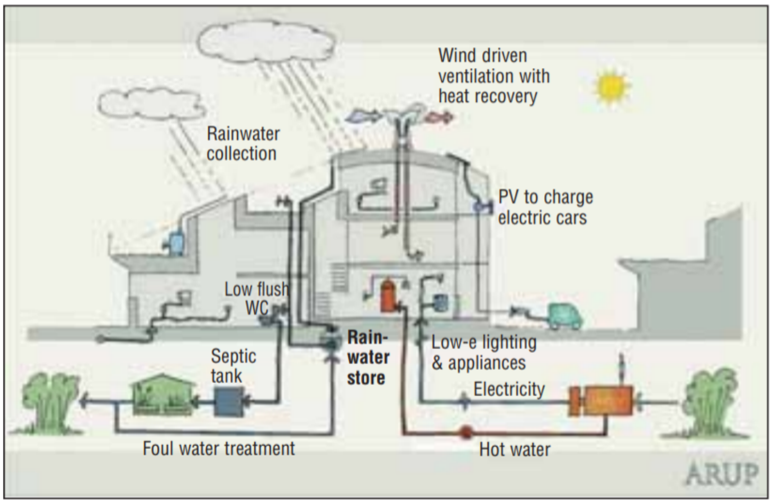


Figure 3.18. BedZED Systems (Source: Lazarus, 2003: 25)

3.3.6. United States of America

Tanner Springs Park is located in Pearly District, Portland. This park, which is 1 acre, was completed in 2010 (Figure 3.19). Tanner Springs Park's current status is due to its connection with its history. In the late 1800s, the Pearly District was a wetland, but in the 1890s the wetlands were evacuated and the natural areas were wiped out to ensure industrial and railway development.

The 19th century train tracks are used in the field arrangement to show the connection between Tanner Springs Park's and its past. A lot of material from the past, such as train tracks, has been used inside the park. Tanner Springs Park connects people living in the district to ecology and explains the local history of the region.

The park is a mix of active and passive spaces. These spaces layered on top of the functional rainwater infiltration and detention wetlands. Some of the park roads are covered with stones on wetlands. Grass areas are designed for activities. The rainwater pavilion placed at street level is an example of catching stormwater (Figure 3.20). When rain falls on the leaf-shaped roof of the pavilion it is channeled into multiple runnels and spouts. Finally rainwater trickling down the steps and into Tanner Springs Park. At the same time, park also receives rainwater from the street (Figure 3.21) (Kruse R. 2015).

According to the Green Values National Stormwater Calculator; "*This project is able to The Green Stormwater BMP(s) applied in this scenario decrease the site impermeable area by 169.7% and capture 100% of the runoff volume required. Compared to conventional approaches, the green practices in this scenario will increase the total life-cycle construction and maintenance costs by 154% (Urban ecology).*

Figure 3.19 Tanner Springs Park
(Source:http://www.landezine.com/index.php/2013/03/tanner-springs-park-by-atelier-dreiseitl/)

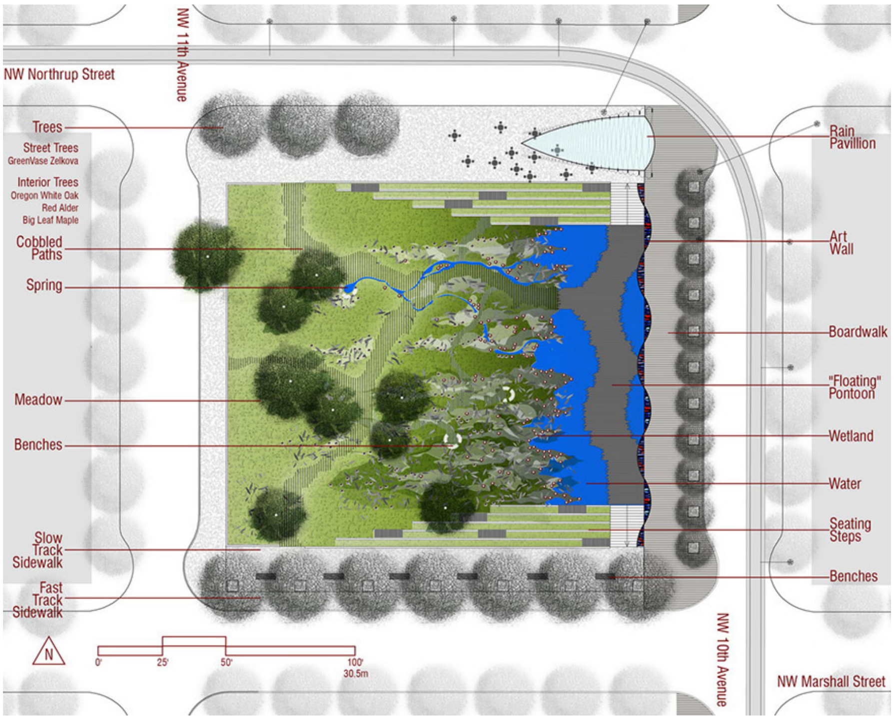


Figure 3.20 Tanner Springs Park Plan
(Source: http://www.landezine.com/index.php/2013/03/tanner-springs-park-by-atelier-dreiseitl/)

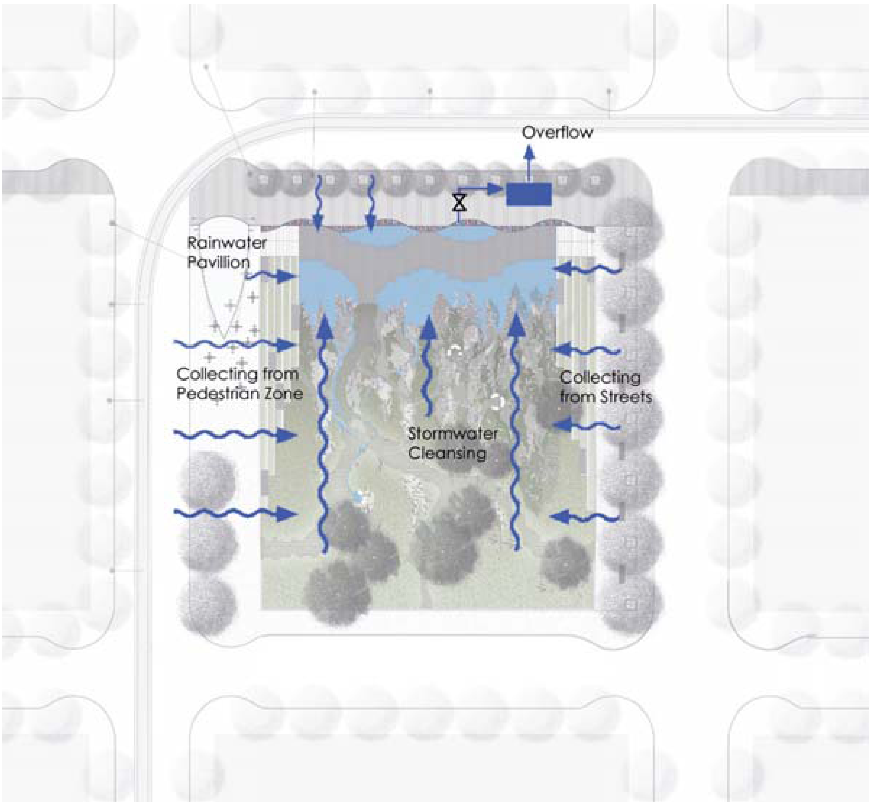


Figure 3.21. Tanner Springs Park rainwater flow (Source: http://www.landezine.com/index.php/2013/03/tanner-springs-park-by-atelier-dreiseitl/)

3.4. Stormwater Management in Turkey

The vast majority of Turkey is under the influence of semi-arid climatic conditions. Arid and semi-arid areas in Turkey amount is 51 million hectares. So, 37.3% of Turkey's semi-arid climate prevails. Therefore, changes in the amount and distribution of precipitation due to both water resources and dry agriculture, which are dependent on rainfall, can have a serious impact (Kadıoğlu, M. 2012: 51).

Gray stormwater management is used in Turkey. In Turkey, stormwater has been viewed as something that needs to be carried away from inhabited areas as quickly as possible to prevent potential hazards such as flooding. Groundwater cannot be fed by this method. They also cause pollution because they flow directly into the sea and rivers without cleaning.

The recovery and reuse of treated waters have become a more critical issue in recent years. The recovery and reuse of rainwater, especially with separate collection and treatment, is vital for the management of urban, regional and national water resources. Although climate change causes an increase in heavy rainfall and floods, it also causes drought. This situation causes pressure on stormwater drainage systems. On the other hand, it also creates difficulties in the water supply. With the rapidly growing urbanization, the land becomes impermeable. These impermeable surfaces, which are the result of urbanization, prevent the leakage of underground water in the natural cycle. The superficial flows generated by rainwater are also increasing dangerously. This situation leaves the residential areas inadequate in the management of heavy rainfall (Avdan, Yıldız and Çabuk, 2015: 735).

Stormwater system in Turkey is an application that is still made in small scale. Recently one of the methods used for stormwater management system in Turkey is a ditch. It is carried out to support vegetation that holds soil and prevents erosion (Figure 3.22). It is the method of forming the hill and pit by digging the existing soil to collect the surface flow formed by rainwater and leaking underground. It is applied in areas with a slope of 32.5%. Not applicable in flat areas. In the heavy rainfall, a weir is applied so that the trench is not disturbed and the water is drained. There are two types of ditches. Boomerang trenches aim to hold the soil by directing the water to the plant that is present or planned to be planted. The contour level ditch is a trench that surrounds the top of the hill along the curve of the arc (PAD, 2017: 22).

Figure 3.22. Ditch example (Source: Tanık, 2017: 32)

Water need of town and villages are provided from precipitation, surface and groundwater. Rainwater is stored in warehouses called cistern. Cisterns are historical buildings. Cisterns are generally built as graven to the ground and waterproof. The water which is collected from roofs and terraces stored in this cistern (Şahin and Manioğlu, 2011: 23).

Cisterns are usually built in a manner that is buried on the ground and does not leak water. Water collected from roofs, terraces and clean concrete courtyards are supplied to the cistern. Cistern applications are offered as the ideal solution especially for places where there is limited ground and surface water resources, but there is sufficient rainfall and there is no central water supply infrastructure.

A typical cistern system consists of four components. These;

- Collecting rainwater from roofs or floors of buildings,
- Ensuring the transmission through the gutter system,
- Accumulation in rain water tank,
- It is conveyed into the building by purification (Su Tema).

Green Building Certification Systems in the world is an example of the developments and the importance given to this issue. With the developing technologies on reducing water consumption, each country has established guidelines for the use of these technologies with guidelines, standard or scientific guidelines and has ensured its widespread use. There is no Green Building Evaluation System in our country yet.

However, it is in the process of preparation. Therefore, the use of stormwater in buildings from water conservation technologies is not yet widespread (Tanık, 2017: 32).

Figure 3.23. Siemens Gebze Facility (Source: Yaman, 2009: 1094)

A Siemens Gebze facility in Turkey is the first factory with the LEED green building rating certificate (Figure 3.23). Stormwater is collected by the system on the roof of the factory. These waters are used in fire irrigation systems and landscape irrigation. In order to protect the groundwater resources and quality, perforated stones and green area were used in the parking lot to ensure that the rainwater coming from the field to the ground and be absorbed by the soil. Again for the same purpose, it is foreseen to use it again within the building after storing rainwater. To protect and increase the water quality, the rainwater coming from the asphalt areas is directed to the soil instead of the rain channels and it is provided to be filtered here (Yaman, 2009: 1094).

Solar house in Diyarbakir, a research center that has benefited from the rain system in Turkey (Figure3.24). In the center located in Summer Park, studies are carried out in the field of awareness and clean energy. Stormwater collected from the roofs and accumulated in the water tank with water from domestic wastewater treatment, used in garden irrigation and toilet reservoirs by the carbon filter. The gravel-like filter material and drainage channels placed under 50-60 cm of the soil recycle the excess of rainwater wetting the roots of the garden soil and surface plants (Şahin, 2010: 86).

Figure 3.24. Solar house in Diyarbakır (Source: Şahin, 2010: 86)

3.5 Evaluation

In our country, in addition to the effects of global climate change, river bed concretization, rapid urbanization, rapid population growth, inadequate infrastructure system, increase of impermeable surfaces cause urban floods.

As a result of heavy rainfall with the effect of climate change, combined with the hard ground rates and infrastructure problems that increase with intensive urbanization, it causes serious material damage and leads to a decrease in the soil yield in the fertile agricultural areas. In addition to increased pollution with rainwater, there is more water inlet to the sewage system. This significantly increases the load of the system.

To use water resources sustainably and to ensure water saving, the use of rainwater in cities is essential. Developing and supporting technologies for collecting and using rainwater in cities makes it possible to take an important step towards the conservation of ecological balance, the sustainable development of human communities and the more efficient use of water resources.

Urbanization and inadequate responses to urban stormwater have contributed to the problem of water quality, flooding, and altered stream dynamics. As society continues to urbanize, it is important to develop stormwater management systems that do not contribute to more significant environmental problems. Green site design strategies that focus on environmentally friendly stormwater management have the potential to alter the current direction of increasing impervious surfaces. Also, as existing systems antiquate, opportunities to retrofit to mimic the functions of nature and create green infrastructure exist.

When rainwater systems in developed countries are evaluated, it is seen that especially recycling systems are given importance. Thanks to the methods developed within the scope of sustainability, pollution of water resources are prevented. Especially with the collection of rainwater collecting systems installed in the buildings, the collected waters are used for various purposes. However, stormwater control systems in Turkey are not developed enough. Usually, simpler systems such as terraces or cistern systems are used.

It is not possible to prevent flood disasters only with the measures and works to be taken by some public institutions. All members of society and institutions, especially local administrations, have great responsibilities. Therefore, citizens, institutions and local authorities should be continuously and periodically informed about the causes and consequences of floods.

CHAPTER 4

CASE STUDY: HALKAPINAR DISTRICT (IZMIR, TURKEY)

4.1. Izmir's History of Water Resources

In this section, the water management in İzmir was examined as ancient ages, the Ottoman era and the republic era.

4.1.1 Ancient Ages

The place of the Meles Stream in İzmir has been a subject of debate for centuries. These discussions are carried out over three streams. The first one is called "Yeşildere." It starts near Gaziemir and flows into the İzmir Bay from the intersection of Konak and Bayraklı districts (IBŞB, 2017: 35).

Another stream, which is said to be the Meles is "Halkapınar Stream". Aristides, who lived in the Roman period, about Meles has said: “Summer and winter are at the same level. Neither dries nor roars. Meles is not a bum; it does not leave its bed. “This is a remarkable detail. Because Yeşildere has an irregular regime but Halkapınar stream has a regular water regime that stays at the same level in all seasons (IBŞB, 2017: 37).

The last claim is that Meles is Bornova Stream. However, in all these possibilities, it is most likely to accept Halkapınar Tea as "Meles Stream". It is justified by the fact that the three streams are spill almost to the same place and the delta formed by the alluviums brought by these streams is called "Meles Delta" (IBŞB, 2017: 38).

The water source called Halkapınar is invaluable in contributing to İzmir's vital need for water supply and its cultural accumulation. About 50 years before the antique ages, it has been a source that resolves the thirst of İzmir. Although it is not as old as it is, it continues to provide water supply to the people of İzmir (IBŞB, 2017: 39).

In ancient time’s people have many sacred places. One example of this in İzmir is Diana Temple. People living in the Ancient Age of İzmir have blessed Halkapınar, the largest water source of that period. They named it “Diana’s Baths" and based it on various mythological legends (IBŞB, 2017: 39).

Although there is no concrete information from the antique period until today, the stone fragments around the Halkapınar source and which belong to the Roman period were blended with the information from the 13th century and it was believed to be a bath dedicated to Diana.

There is a myth that adds mystical air to Halkapınar in the " Seyahatname " of Evliya Çelebi. Unlike mythological myths, Evliya Çelebi, in his famous book, said about Halkapınar: "*This is sweet water from Halkalı Pınar. Get out of a rock. The four sides of the greenery and the sound of the nightingale are full of shady trees and a resting place for recreation*" (IBŞB, 2017: 40).

In the period when İzmir was established, Halkapınar and Kızıllçullu stream watering the Bornova plain became the most important water resources of the city. Again in these ages other waterways in İzmir; Pergamon (Bergama) waterway, Phokaia (Foça) waterway, metropolis (Torbalı) waterway, Ephesus (Efes) aqueducts and Aigai (Aliağa) water accumulation system.

In the period they lived, people saved water with the structures they built to meet their water needs. Especially in many parts of Mount Yamanlar, artificial ponds have been formed to give water to animals or to prevent water from disappearing. They have met the water needs of people for centuries. In doing so, it also provided soil fertility (IBŞB, 2017: 58).

Although Meles is considered to be the most important source of water, there are other sources of water. Apart from Meles, the waterways that give life to İzmir in Antiquity are (Figure 4.1):

- Karapinar Waterway
- Akpinar Waterway
- Kapancıoğlu Waterway
- Buca Waterway

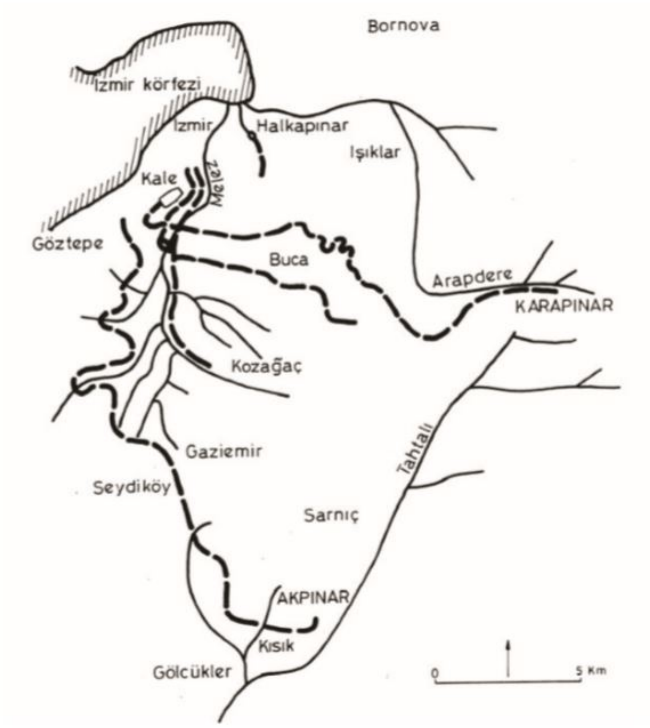


Figure 4.1. The routes of the main water ways that carry water to İzmir
(Source: IBŞB, 2017:45)

4.1.2. Ottoman Era

During the Ottoman period, substantial works were carried out on the distribution of water, and many buildings were built during this period. Until the 17th century, İzmir continued to feed with the same resources. In the 17th century, with the development of trade, the population had increased and new searches have been made to meet these needs. Water supply is at the beginning of the requirements (IZSU, 2017:6).

İzmir was damaged by a major earthquake in 1664 and faced with the danger of thirst. When İzmir was damaged by the earthquake, the Ottomans built many fountains, baths and bridges to the city. The most significant benefit to İzmir was the construction of the "Vezir Waterway," which had spread the boiling water near Şirinyer in 1674 by opening the Meles Stream with a long aqueduct. The 17th-century waterway has an important place in the supply of water in İzmir for more than 150 years (IZSU, 2017:6).

Figure 4.2. Vezir Waterway (Source: IZSU, 2017:6)

Figure 4.3 The Kızılçullu aqueducts that were used to carry the water
(Source: IBŞB, İzmir'de Suyun Serüveni, 2017:8)

Another water source of İzmir during the Ottoman Period is the water path called "Osman Ağa." With this waterway, as in ancient times, the water brought from Kızılçullu Aqueducts, which were important in the Ottoman era, were delivered to the city (IBŞB, 2017: 64).

Halkapınar, Hasib Efendi Water and Damlacık Pınarları, which served as an important source of water in the present-day Konak region, were used for the water demand of the city center (IZSU, 2017:6).

İzmir continued to grow in the 19th century by taking over the railways and using the İzmir port. The drinking water brought to this growing city by the waterways was insufficient and the water supply started to look for new sources in İzmir when it became a public health hazard (IBŞB, 2017: 76).

The solution was the first water concession in İzmir and this concession was granted to İbrahim Niyazi Bey. In 1895 a new company was established under the name of "İzmir Ottoman Water Company" and all members were formed by Belgians and İbrahim Niyazi Bey has transferred all its concessions to this company (IBŞB, 2017: 83).

The company decided to buy the waters to be watered to İzmir from Halkapınar, also known as the Diana Baths. In 1895, seven wells were drilled in Halkapınar as the first work. In 1896, the construction of Halkapınar Water Factory was started right next to Diana's Baths. The bottom of the structure carried by eight columns right next to the factory was made of a fountain at the bottom of the 3 meters deep well. Şadırvan, which succeeded to reach today, is an important work in terms of art history (IBŞB, 2017: 87).

4.1.3. Republic Era

In the Ottoman Era, Vezir Water, Osman Ağa water, Halkapınar water and the water supplied from the wells other than these sources continued to be used in the Republic Era.

In 1945, the management of the water in İzmir was taken from the private company and established in the municipality of İzmir, electricity, water, gas, bus and trolleybus (e.s.h.o.t) was given (IZSU, 2017: 8).

The first activities of ESHOT have been strengthening the equipment of Halkapınar water factory, increasing the amount of water produced and then expanding the network and giving water to all parts of the city.

As a result of the rapidly growing urban population and industrial enterprises, the bay was increasingly polluted due to untreated domestic and industrial wastewater discharged directly into the İzmir Bay (IZSU, 2017:10).

Figure 3.5 shows the streams of İzmir. The total amount of water discharged by these streams into the Gulf of İzmir is 182 million m3 annually. The largest stream in terms of water potential is Manda Stream which has a share of 16.8%. After Manda Stream, Meles Stream has a water potential of 16.5%. The next largest river basin is Arap Stream with a share of 10% water potential.

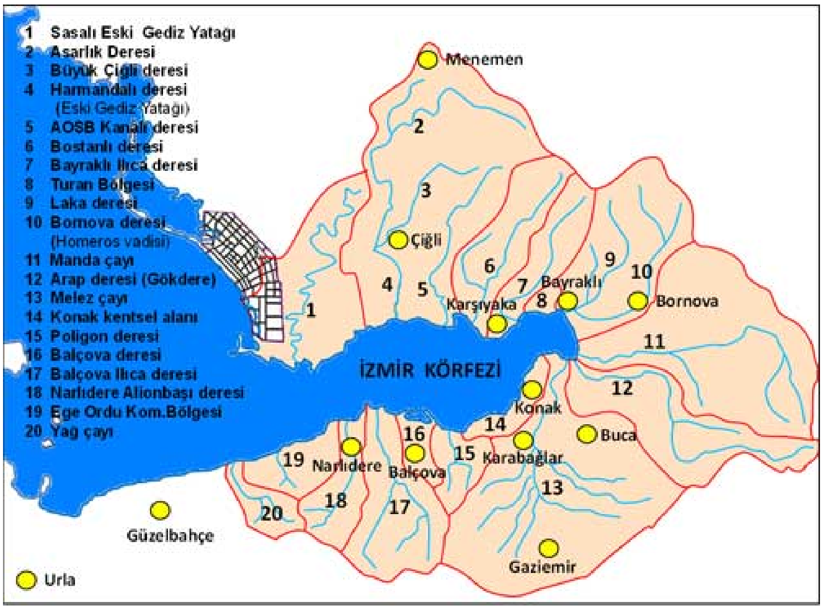
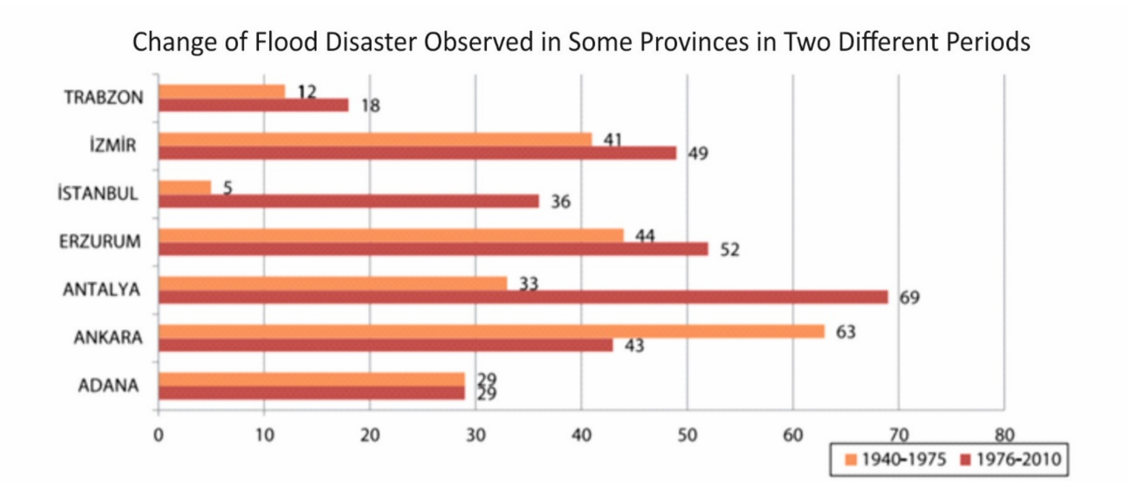


Figure 4.4. Large streams in İzmir city center (Source: IZSU, 2019)

4.2. Stormwater Management in Izmir

Flood disasters observed for İzmir between the years 1940-1975 are compared with the years 1976-2010 and seen that the risk between the year 1976-2010 are rising up (Table 4.1.)

Table 4.1 Comparison of the number of floods registered in 7 provinces between 1940-1975 and 1976-2010 according to MGM and AFAD records (Source: Kadıoğlu, M. 2012: 81)



In general, stormwater problem in İzmir can be grouped under three main headings.

- Covered creek and lake beds,

- Rainfall and seawater flooding as a result of ground elevations falling to sea level and below sea level due to spatial collapses,
- Due to the fact that wastewater and stormwater canals are submerged into the sea, floods occur as a result of inability to discharge water (Yarıcı, A.: 347).

The studies carried out in İzmir with the aim of preventing floods can be gathered under the following headings:

- İzmir Grand Canal Project and stormwater outfall project
- Stream rehabilitation and prevention of flooding
- Combating erosion
- Maintenance and operation plan of sewerage system and stream beds
- Stream basins in the expanding metropolitan municipality (Yarıcı, A.; 351).

The idea of the Grand Canal Project, which is of great importance for İzmir, was formed in these years. The first studies on the Grand Canal Project were initiated in 1969. In the plan completed in 1971, after the collection of domestic and industrial wastewater, which is the main cause of the environmental pollution in the inner and central part of the İzmir Gulf, was gathered with a canal, it was envisaged that the Çiğli Wastewater Treatment Plant will be increased in the area where it is located and emptied with the deep sea discharge structure in the middle bay (IZSU, 2017:10) (Figure 4.5).

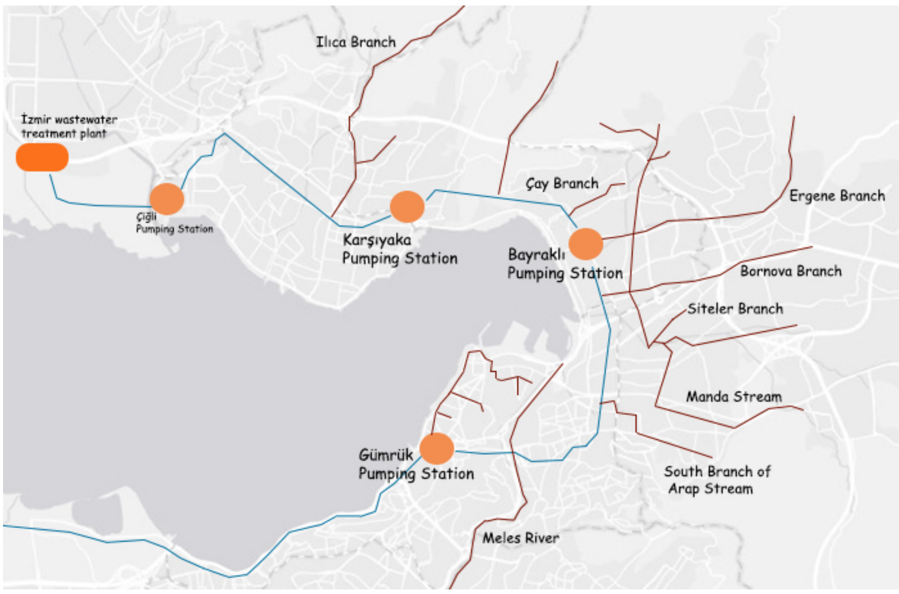


Figure 4.5. The Grand Canal Project

ESHOT and İzmir Municipality continued drinking water and sewerage works until the foundation of İzmir Water and Sewerage Administration (IZSU) in 1987. Izsu General Directorate established in 1987 took over the project and Çiğli Wastewater Treatment Plant, which is the last steps of the project, was completed in 2000 and the southwest wastewater treatment plant was completed in 2002 and the wastewater flow to İzmir Bay was discontinued entirely.

In this study, the Annual Reports of IZSU from 2007 to 2018 were examined. For the first time, the rain water that has been discharged into the sea without being separated in İzmir has been included in IZSU's 2007 Annual Report. In the report, the performance program of 2008 aims to separate 30 km of Stormwater and Sewerage Network.

When IZSU's 2008 Annual Report is examined, we see that since 2008, separate channels for stormwater collection have been started (Table 4.2). According to reports the purpose of these channels is to collect rainwater and not to use it again, but to ensure that it is thrown into the environment such as lakes and sea in the fastest way.

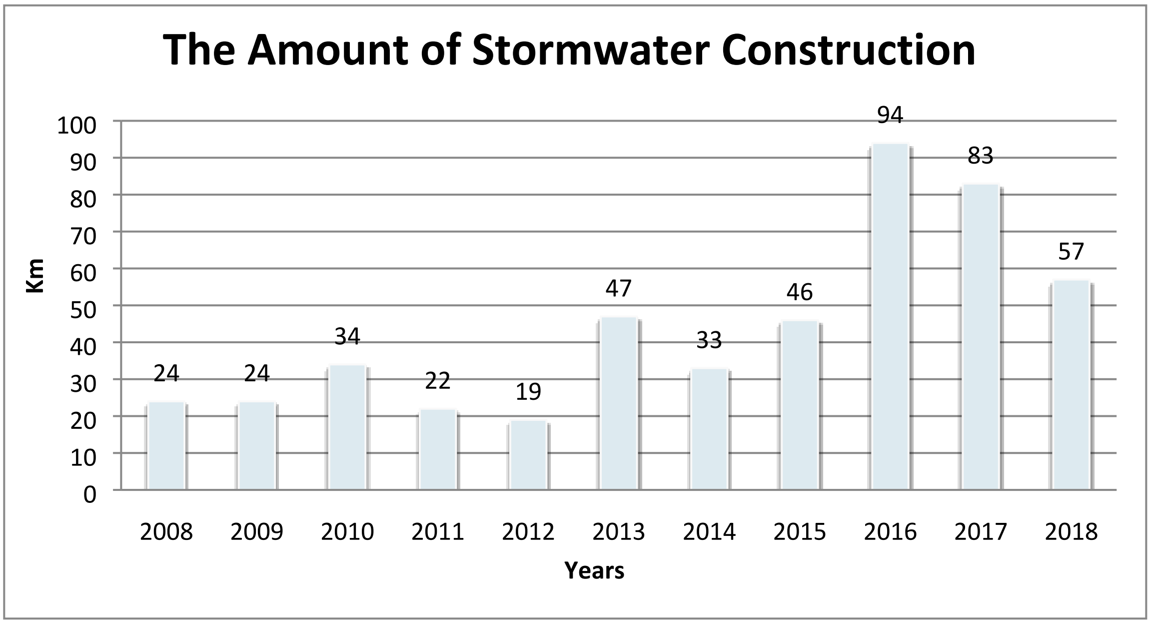
According to the IZSU Annual Report written between 2012-2018, the purpose of stormwater work projects is to transport rainwater to receiving environments (streams or seas) without damaging the environment. Rain water is separated from the sewerage system. These studies are also aimed at eliminating problems in flood areas.

For nearly 10 years, IZSU has always seen stormwater as a problem and the water has been transferred to the sea without treatment. Instead of this approach, it could create stormwater paths and purify the water to make it reusable. So the groundwater was also fed. Since it has never changed its approach, it has continued to be floods in İzmir for years.

The slogan "water is life, not let it go "written in the 2014 IZSU Annual Report should be said not only for tap water, but also for rain water. Therefore, this study presents some studies that can be done for collecting, filtering, cleaning and feeding groundwater rather than pouring rainwater into the seas.

In 2017, IZSU conducted an important study in the Gültepe region. Due to unplanned development for many years, natural streambeds have been transformed into roads. In the Gültepe region, a stream bed of 19 km in length was rebuilt two meters under the roads and rain water was provided to reach Meles with this line. Thus, with this study carried out in the Gültepe region, the floods to be experienced in the future were prevented (IZSU, 2017).

Table 4.2. The amount of separated stormwater construction in İzmir between 2008 and 2018.



As one of the new projects, İzmir Metropolitan Municipality is creating a project with the European Union. In this project, İzmir's Green Infrastructure Strategy will be established. It is planned to reconstruct a green network system in relation to the Central Green Belt (Figure 4.6). In which the points where the inner stream systems flowing to İzmir Bay meet with the gulf within the central city. The Green Infrastructure Strategy and its applications will contribute in this direction.

What is Green Infrastructure?" It is an approach that provides and manages biodiversity in a wide ecosystem in both rural and urban environments, enhances the nature's ability to deliver ecosystem products and services, such as clean air and water, as well as strategically plans the link between high quality natural, semi-natural and urban areas (İzmir Yeşil Altyapı Stratejisi, 10)."

The project was divided into subheadings 'Planning and Governance', 'Water Areas', 'Green Areas', 'Corridors and Connections and Structures' and 'Dormant and Repaired Areas '. The project divides the water areas under the headings of water systems, groundwater, stream / river and coastal areas. Some of the decisions taken under these headings are shown in Table 4.3.

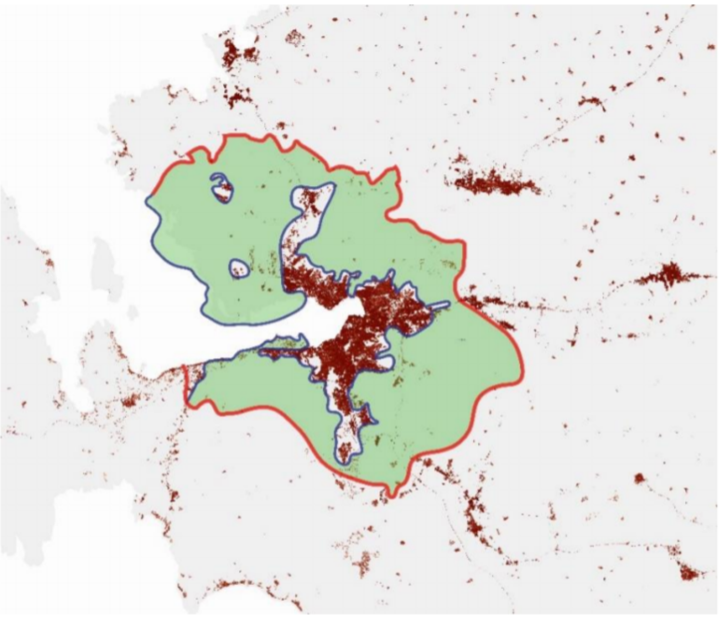


Figure 4.6. The Central Green Belt (Source: İzmir Yeşil Altyapı Stratejisi; 10)

Table 4.3. The green infrastructure strategy decisions (Source: İzmir Yeşil Altyapı Stratejisi)

Water Systems	• Regional solutions for water resources. • Creating artificial wetlands and rain gardens in the city. • Evaluating the connection and integration of blue and green systems with the city (eg, more intense recreational use of creek edges) • Selection of drought-resistant plant species with low water consumption and testing in the Central Green Belt area.
Groundwater	• Determination of groundwater strategy and creation of groundwater resources map (flow directions, risky areas, feeding areas etc.) • Seeking solutions to the nutritional problem caused by reinforced concrete reclamation structures in the stream beds of groundwater.
River / Stream	• Creation of protection zones in urban streams such as dam protection zones. • Determination of settlement problems in urban floodplain (flood maps) and investigation of green infrastructure solutions.
Coastal Areas	• Conduct a state assessment of the interaction of existing coastal structures with green infrastructure. • Consider a water level rise of approximately 1.5 m to prevent flooding.

4.3. Characteristics of the Study Area

4.3.1. Location

İzmir, which coordinates 38° north and 27° east, is one of Turkey's largest city. İzmir is Turkey's 3rd populous city. The population is about four million three hundred thousand people. The study area, Halkapınar districts, is located in the center of İzmir (Figure 4.7).

Figure 4.7. Location of Halkapınar District in İzmir, Turkey

İzmir Port Region is one of the most important and strategic places near the city center. The International Urban Design Project Competition was held in 2001 for this region. It was envisaged that the competition area would implement urban scale strategies for the port area and its vicinity. The data obtained from the projects that received degrees in the international urban design idea competition were evaluated by the İzmir Metropolitan Municipality and in 2003 a 1/5000 scale master plan was produced for the region. In this plan, they have created a New City Center Plan.

The study area is located between the old city center and the new business center, which can be indicated by a circle since there is no possibility to allocate certain boundaries (Figure 4.8).

Figure 4.9 is a satellite image of the region shown in the map above. There are Atatürk Football Stadium, old Halkapınar Lake, Meles Delta, Meles Stream and transportation center.

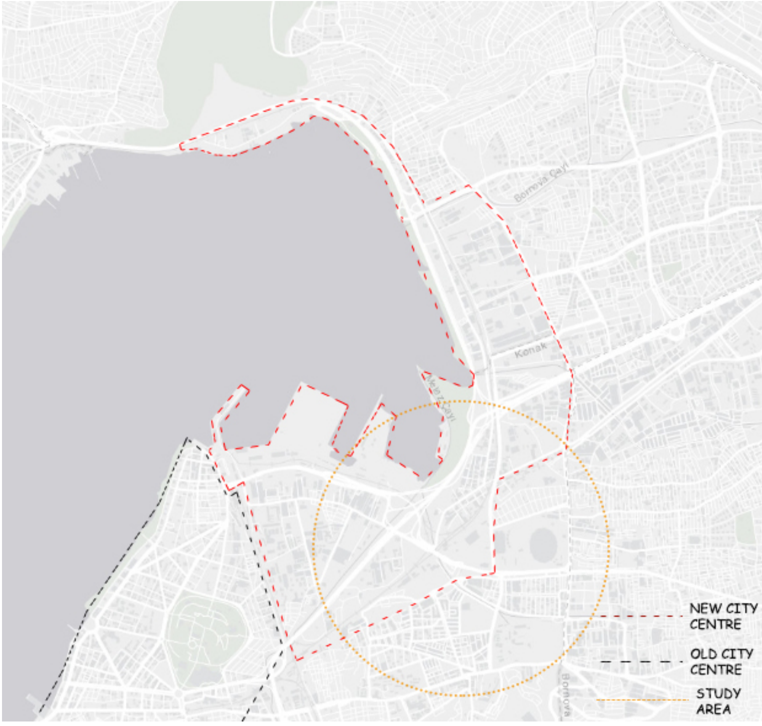


Figure 4.8. Old city center, New city center and Study area

Figure 4.9. Satellite image

4.3.2. History

Halkapınar district is one of the most important districts of İzmir. The Meles Stream passing through the region and the Halkapınar Lake in the region have been the water resources of the region for many years. Today, the Meles Stream flows into İzmir Bay (Figure 4.10).

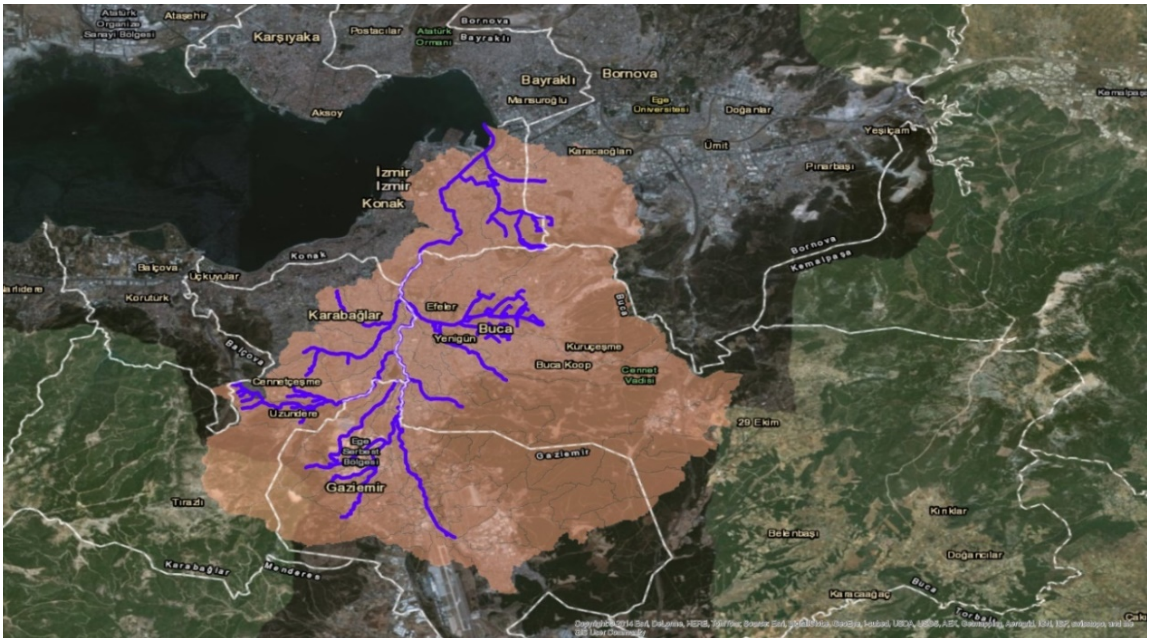


Figure 4.10 Meles Stream and basins

Since ancient times, Halkapınar has been a source of water for İzmir. The people, who lived in ancient times, sanctified the Halkapınar and called Diana Baths because it was the biggest water source of that period. The famous historian Herodotus described the region as year the place where the goddess of fertility, the beautiful Artemis (Diana), came along with the fairies and washed every day (IZSU web).

In the map of 1922, we see that Halkapınar Lake is called Diana baths (Figure 4.11). Diana's baths [Halkapınar] were a recreation spot of Smyrna stretching back to antiquity (Figure 4.12). People would go there to spend their time by the water (Levantine Heritage).

As shown in Figure 4.13. In these times, there were some structures made of marble around the lake, its still exist in the property of IZSU (İzmir's Water and Sewerage Agency) which are not used for recreational purposes.

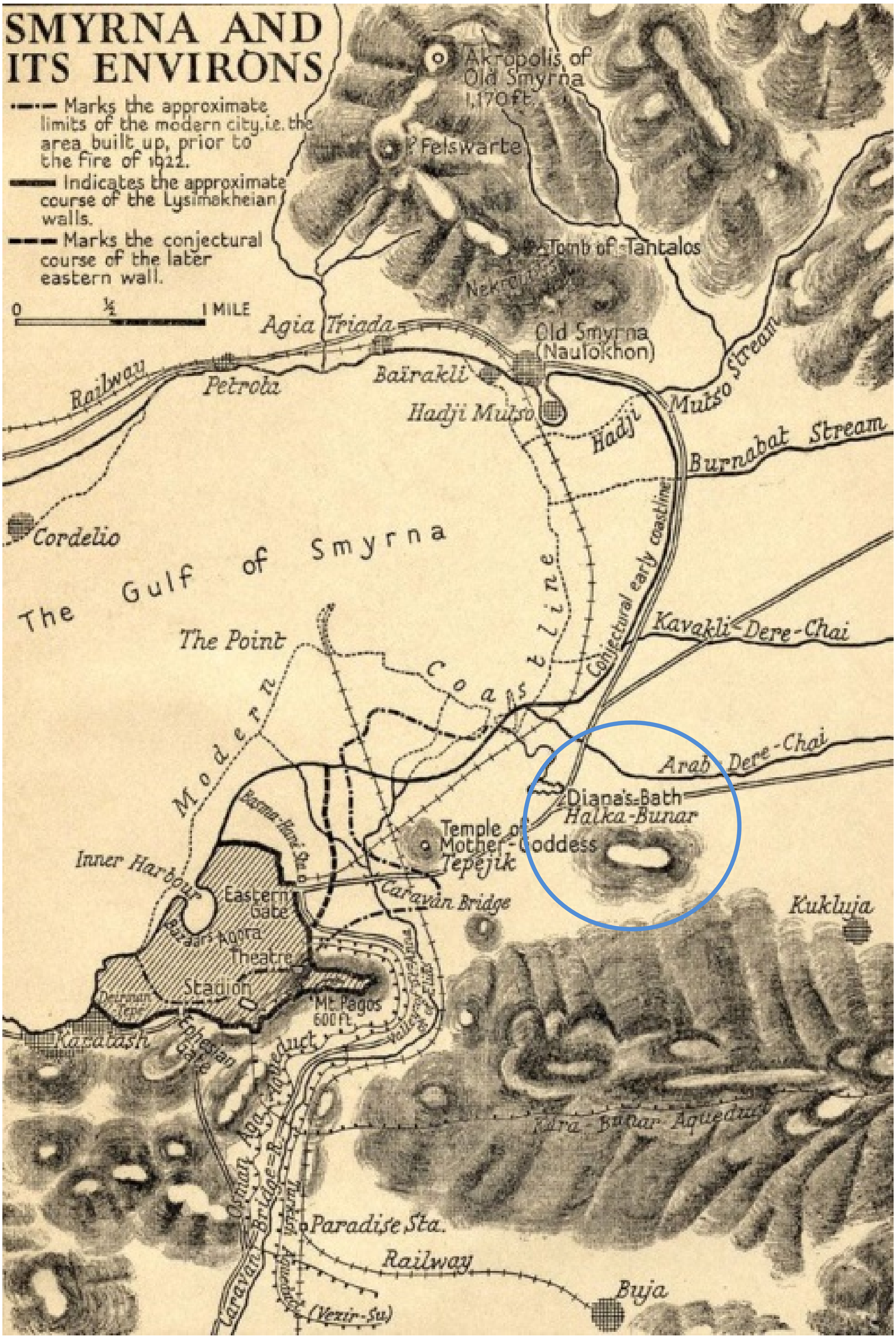


Figure 4.11 Map of İzmir year 1922

(Source: http://www.levantineheritage.com/book10.htm)

Figure 4.12 Map of İzmir year 1878 (Source: Beyru R.2011;85)

Figure 4.13. Picture of Lake Halkapınar in 19th Century
(Source: http://www.levantineheritage.com/waterworks.htm)

Towards the end of the nineteenth century, when a severe water scarcity was a problem for the city of İzmir, a Belgian company was brought in to investigate new water resources. At the end of the research, it was proposed that Halkapınar resources should be developed and İzmir city water should be taken from here and a system was planned to be established here. The Belgian company completed the construction of the main cistern, distribution pumping station, water tank, connection ducts and pipes in 1897. Halkapınar facilities were used for 76 years until 1973. After this date, Halkapınar Lake, which has existed thanks to new wells and springs, has disappeared and new pumps and water facilities have been put into operation. The cistern and water pumping station still exist in the study area. Halkapınar Lake, which was used during periods of high water demand, had an average surface area of 14 000 m² in 1970. As shown in figure 4.14, the historical water collection structure is now inactive and the restoration project is being carried out by IZSU (IZSU, Halkapınar Kaynakları).

Figure 4.14. A remaining structure on site: A cistern
(Source: https://www.izsu.gov.tr/tr/halkapinarkaynaklari/17/124)

Fifty-six percent of the drinking water of İzmir city is provided from groundwater resources. Halkapınar (located on Bornova Plain) is one of the important groundwater resources area. This region is providing 14 % of İzmir drinking resources (Figure 4.15). The water withdraws from the Halkapınar wells is about 30 million m3 in recent years (Baba A., Yazdani H. 7)

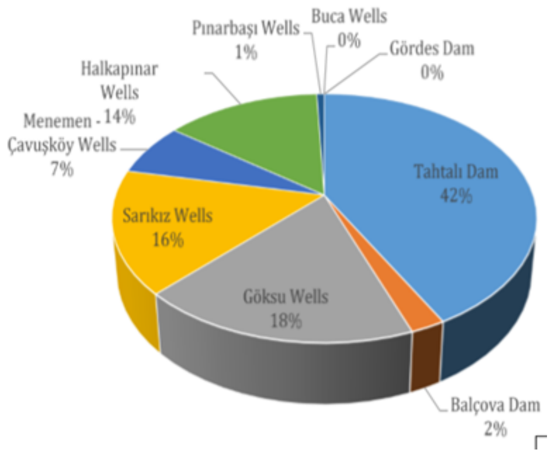


Figure 4.15. Distribution of water resources of İzmir in 2016
(Source: Baba A., Yazdani H. 7)

Halkapınar district is next to İzmir's small scale industrial zone (auto related) and because of this zone, air and water flowing into streams are dirty (Figure 4.16 and Figure 4.17). We can also explain the pollution status of the region from the amount of garbage accumulated in the stream beds. According to IZSU news; the teams working in Meles and Arap Streams in May and June collected 44 thousand 100 tons of waste. These wastes accumulate in the mouths of streams pouring into the sea and prevent undesired smells and water from entering the sea (IZSU Haber, 2017).

Figure 4.16. The water pumping station providing potable water for the city from 1897 to 1988 (Source: Aksoy S. 96)

Figure 4.17. Existing land use around the Former Halkapınar Lake

Previous floods in the district of Halkapınar caused serious hazards to life (Figure 4.18). When heavy rainfall continued nonstop for 36 hours in 1930, not only did 117 people drown but more than 2000 people were left homeless and much trade stock, including sacks of dried fruit, was ruined and washed to the sea. Also, a repeat flood occurred in November 1995, and that resulted in the death of 60 people in İzmir (Levantine Heritage Foundation, 2011).

The Halkapınar region, which includes Halkapınar Lake from the past to the present, is not in the Halkapınar neighborhood with its current neighborhood borders. It is now located in the borders of Mersinli (Figure 4.19).

Figure 4.18. The 1930 İzmir Flood
(Source: http://www.levantineheritage.com/flood.htm)

Figure 4.19. Neighborhood borders

4.3.3 Geology

The settlement located in Halkapınar district is situated on the alluvial plain of Bornova. It has changed the geomorphology of the delta because organic materials have been transported to the coast with the streams in the region. Bornova Plain is one of the important region for groundwater resources where have been used many years. Many well were done in this region for irrigation and domestic purpose (Figure 4.20).

Bornova Plain is formed by the alluvial brought by the short, seasonal flowing streams reaching the plain from the high masses in the surrounding area and filling this collapse. Bornova Plain does not reach a large stream from the surrounding area. The plain is shaped by alluvial carried by flood regimen streams (Karadaş, A., 2014: 38).

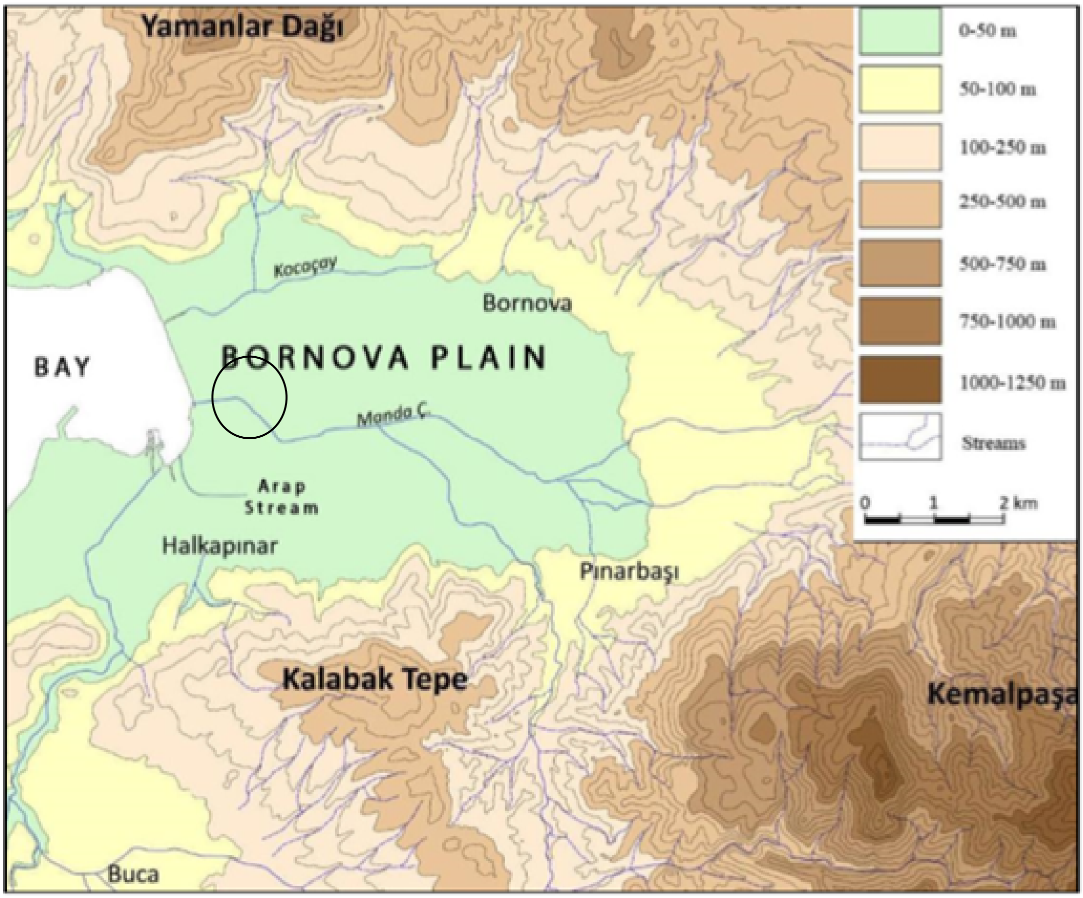


Figure 4.20. Hypsometric map of Halkapınar and its surroundings
(Source: Karadaş, A., 2014: 39)

Moreover, a topographic map of İzmir was made in Figure 4.21. There is a very large height difference in the studied area. The region is located at sea level. Therefore, one of the issues to be considered is the sea floods.

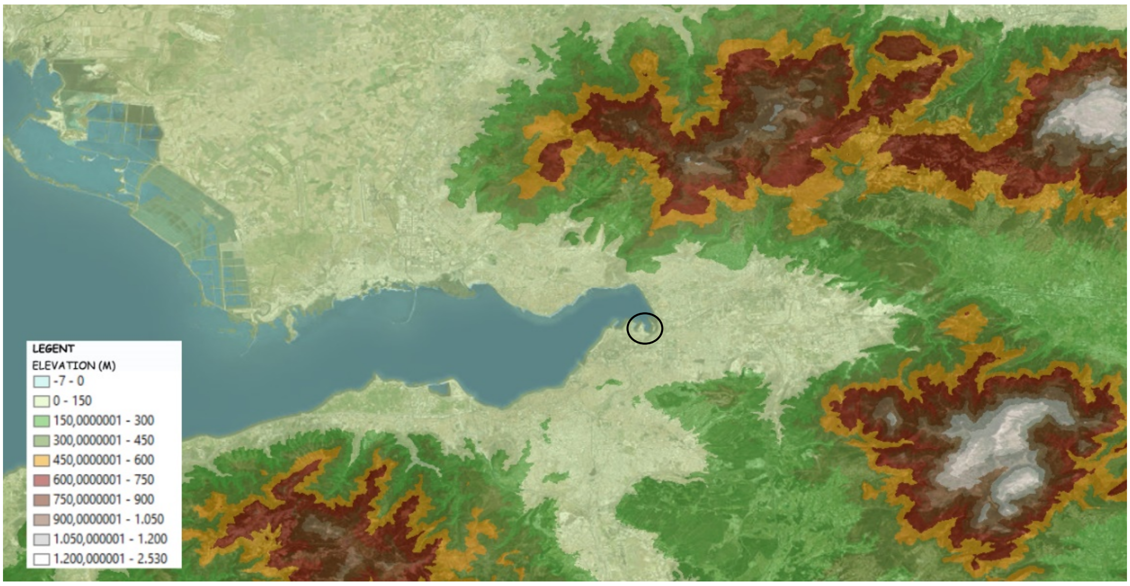


Figure 4.21. Topography of İzmir

One factor in the selection of the study region is that it has become a risk-bearing region together with climate change. According to the study of "Determination of Areas Vulnerable to Climate Change Due to Spatial Structure Characteristics, İzmir ".

Excessive rainfall leading to floods and sea level rise threatening floods were considered as two major disasters to be exposed to the central city of İzmir. For the geographic region where İzmir is located, climate change threatens the settlement in two contexts: extreme rainfall and elevation of sea level (Aydın, M. B. S., Erdin, H. E., Kahraman, E. D., 2017:278).

İzmir has high and very high-risk zones along the coast. Despite the outskirts of the coast, the urban areas on the lowland area are high-risk areas. Stream beds have a significant role in the emergence of hazardous areas in the inner parts of the city. When the relationship between risky urban areas and urban land use is examined, it is seen that Halkapınar District are located at high and very high-risk areas (Figure 4.22) (Aydın, M. B. S., Erdin, H. E., Kahraman, E. D., 2017:283).

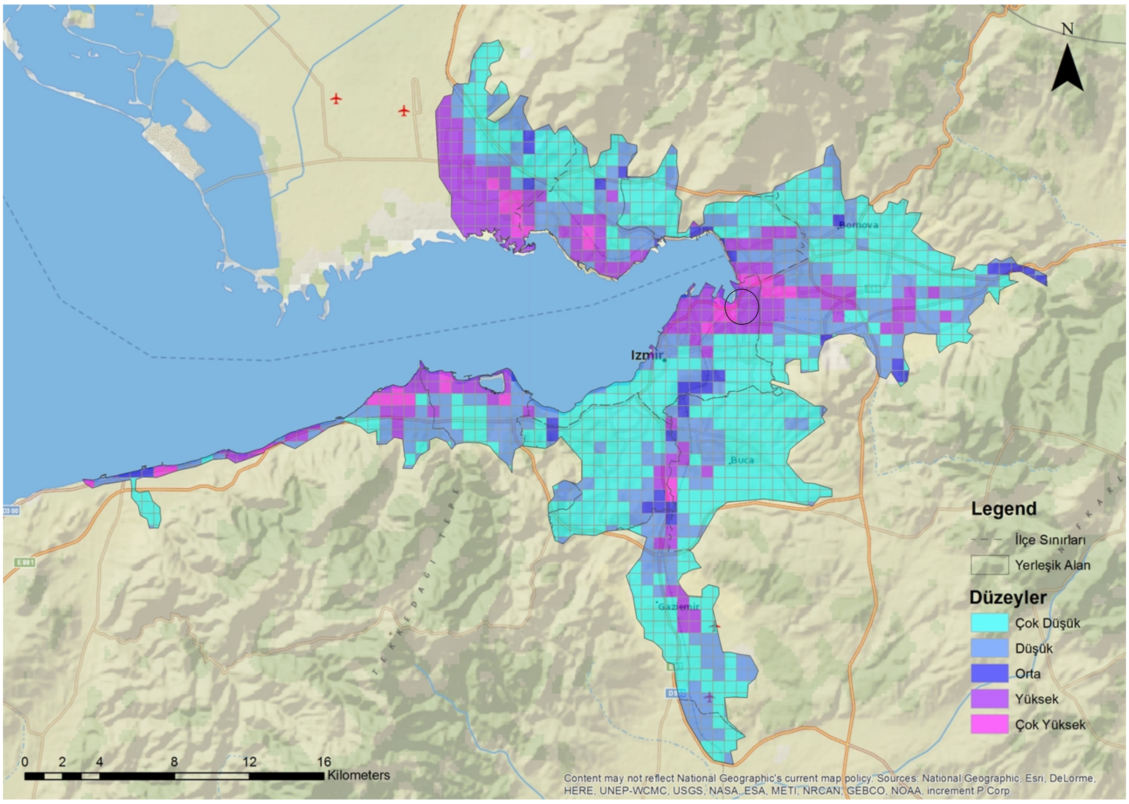


Figure 4.22. Areas of risk and risk levels in terms of physical characteristics
(Source: Aydın, M. B. S., Erdin, H. E., Kahraman, E. D., 2017:283)

4.3.4 Built Environment

Since the study area is located in the city center, the built-up area is very large and the permeable surfaces are very limited. The closest and largest green area to the Halkapınar region is the Park of Culture (Kültürpark), known as the International Fair Center. Additionally, the Meles Delta is one of the important ecological areas in the region fallowing the Kültürpark. The Delta forms the place where the Meles Stream, Manda Stream and Arap Stream intersect before discharging into the bay (Figure 4.23).

Figure 4.24 shows schematically the green areas in the region according to their width. The scarcity of green areas and the density of the built environment is a problem for the region.

We can include green areas such as parks, refuges, football fields and sports fields in the permeable areas. The following map shows only the park and the green areas are very few. In the calculation for permeable surfaces, all permeable surfaces were taken into account and the working area indicated by round is approximately **3.78km2** (3.780.000m2) and the total permeable surfaces is **0.5km2** (510.538m2) (Figure 4.24).

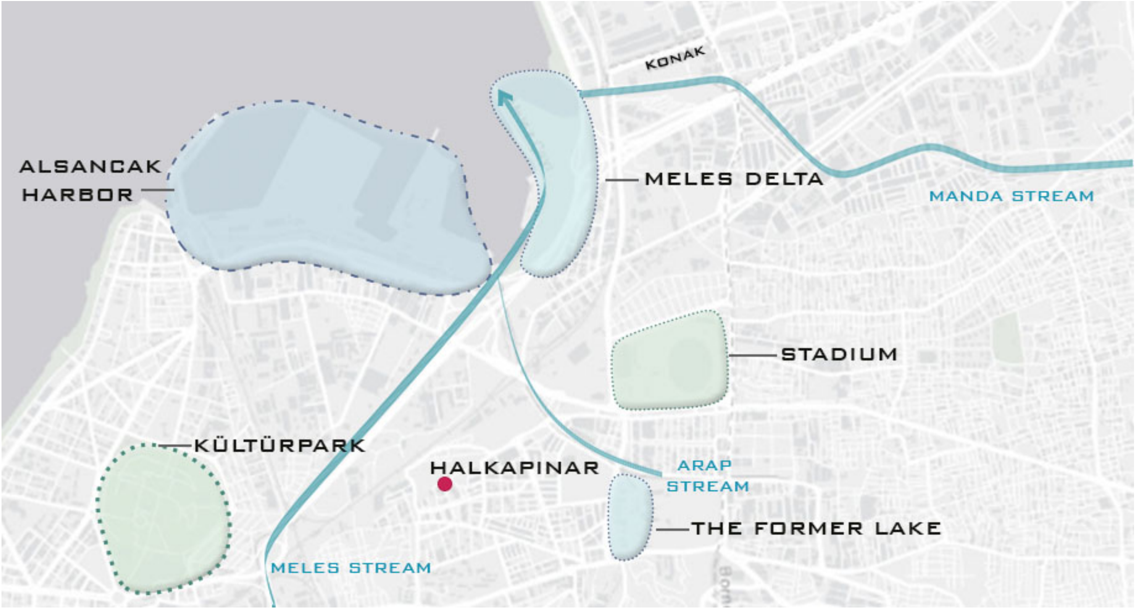


Figure 4.23. Highlights in the city center

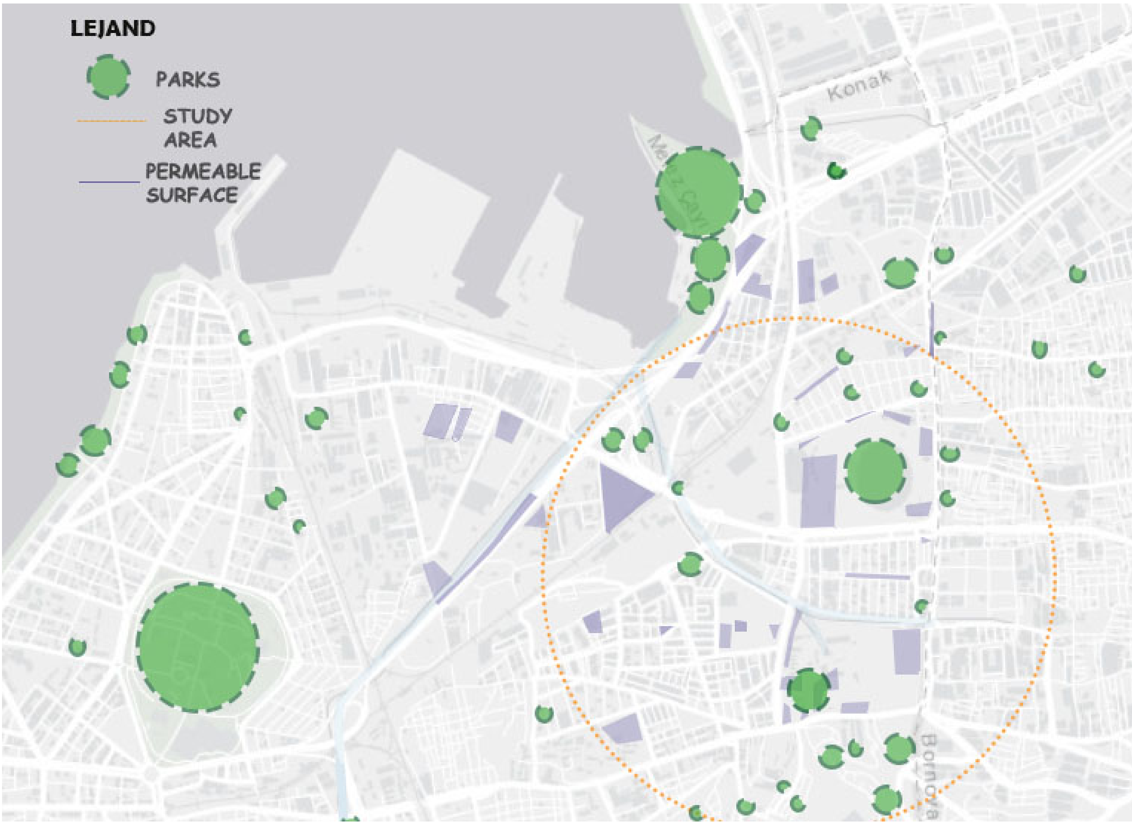


Figure 4.24. Study area and surrounding green areas

Since the study area is in the center, it is suitable for public transportation. In particular, the Halkapınar Transport Hub is located within the working area. The transfer center makes it easy to switch between public buses, metro and tram and is one of the most important centers of İzmir in terms of public transportation. The study area is at the center of the transportation lines, so people from İzmir can also come to the region. It is also a potential for permeable surfaces formed by the tram line (Figure 4.25).

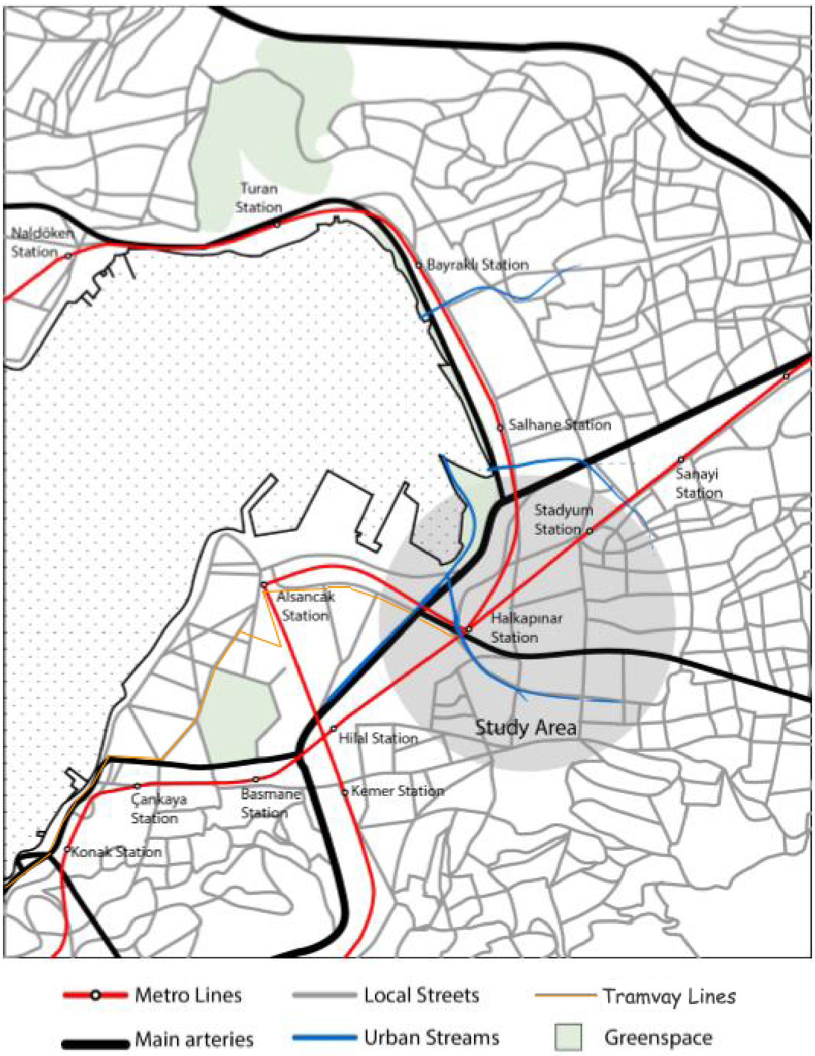


Figure 4.25. Transportation network around study area (Source: Aksoy S. 119)

With regard to the existing land use, the study area mainly consists of mixing uses and industrial uses (Figure 4.26). Halkapınar Metro Station (transportation hubs), Stadium, riverside area and İzmir’s Water and Sewerage Agency (IZSU) are major public areas in the study area.

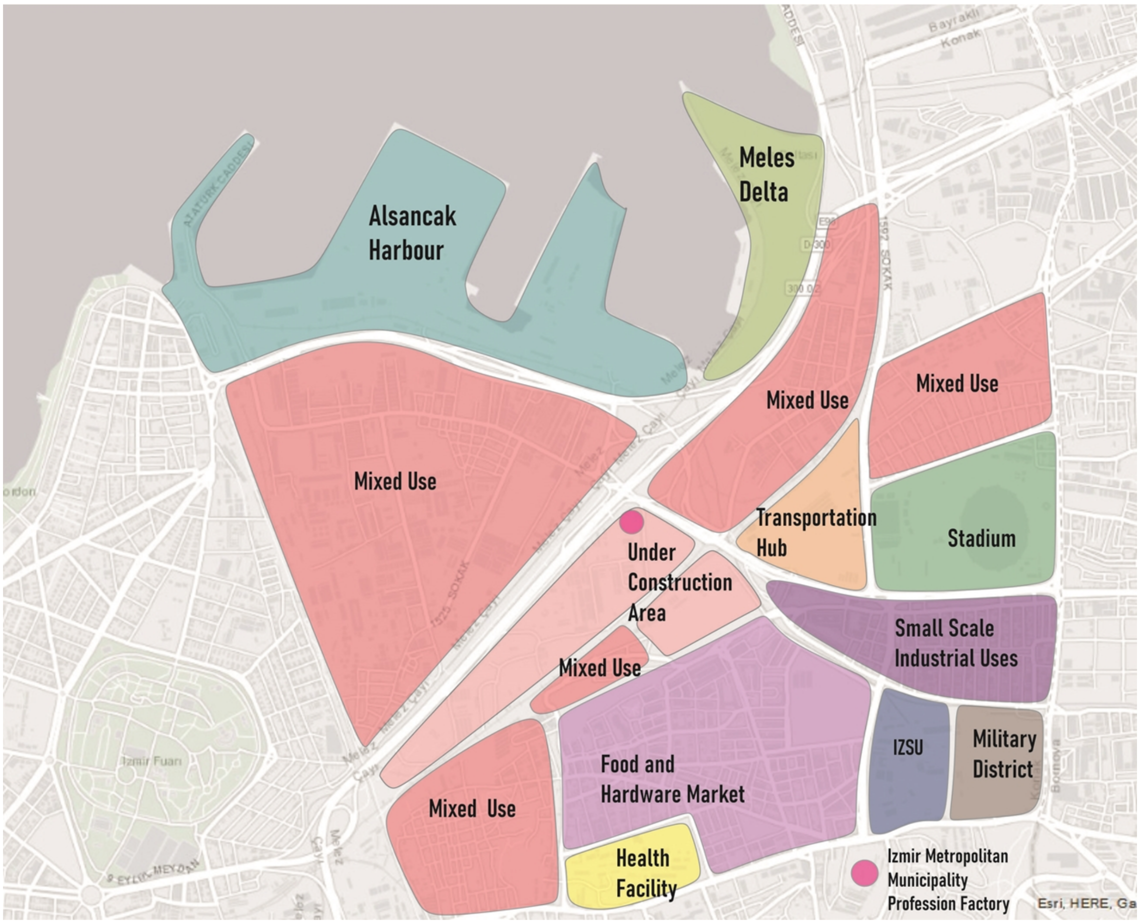


Figure 4.26. Existing land use analysis

4.3.5. Planning Works

After looking at the the Structure Plan (scale 1/25000), the study area was examined in this plan (Figure 4.27 and Figure 4.28).

The basic decisions of the Structure Plan (scale 1/25000) about the study area; central business district, industrial zone, regional park, military zone, central trade zone indicate land use. According to the plan, only military areas and public utilities can be located in the area where Halkapınar Lake once existed. The small industrial area in the center of the city has also been left in place (Figure 4.27).

The use of municipal land in the region is insufficient to show the historical character of the district. The land uses of the district do not reflect the historical and ecological aspects of that place. For a better environment, the infrastructure of the region is to develop stormwater to keep and reuse. So, this study presents ecological sustainability in terms of stormwater sustainability and provides a new perspective to the environment.

İzmir New City Center Master Plan offers a new central business district for foreigners and local investors, 2030, also known as a high-density skyscraper area and commerce area (Figure 4.29).

In the two plans examined, no decision was made for the Meles Stream. The riparian zone around the river is not considered. In İzmir New City Center Master Plan, only a part of the Meles Stream was greened but not enough for a high density residential area.

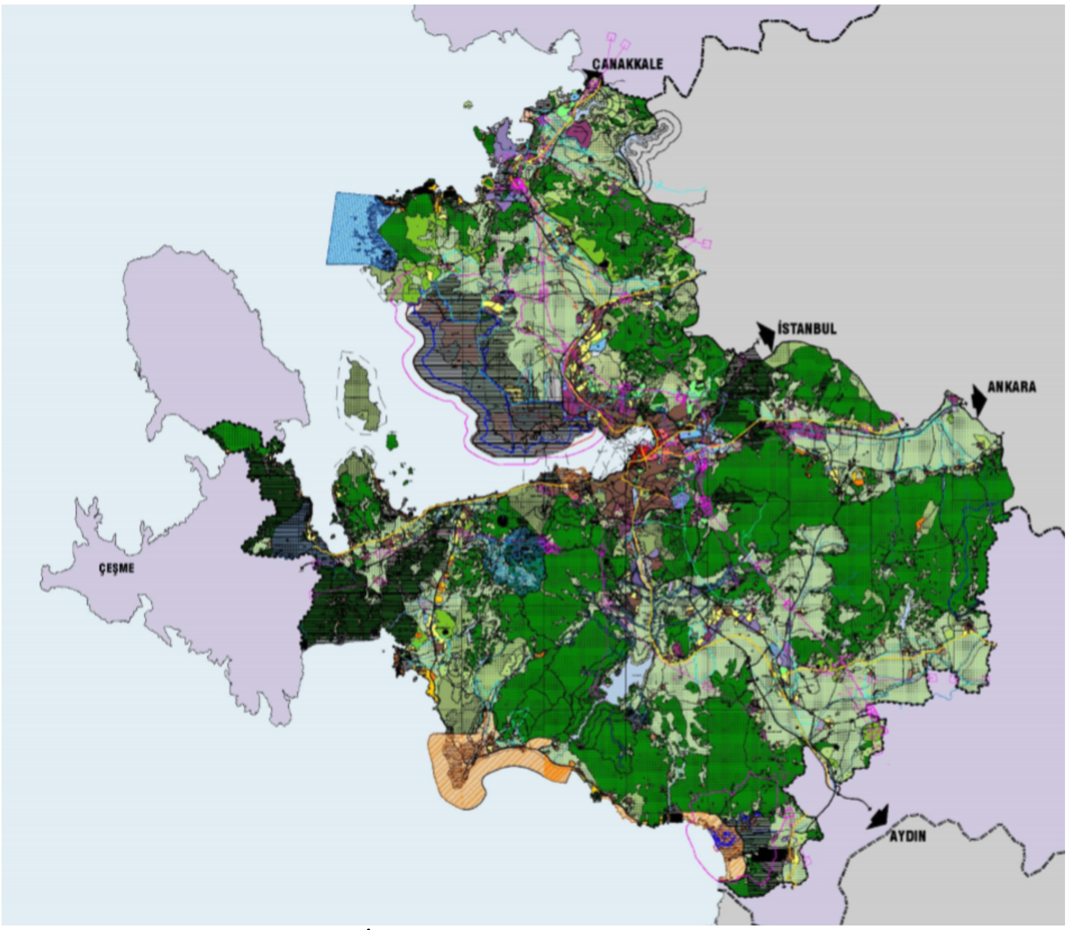


Figure 4.27. 1 / 25.000 scaled İzmir metropolitan area master plan
(Source: 1/25000 Ölçekli İzmir Büyükşehir Bütünü Çevre Düzeni Planı Açıklama Raporu, 2012)

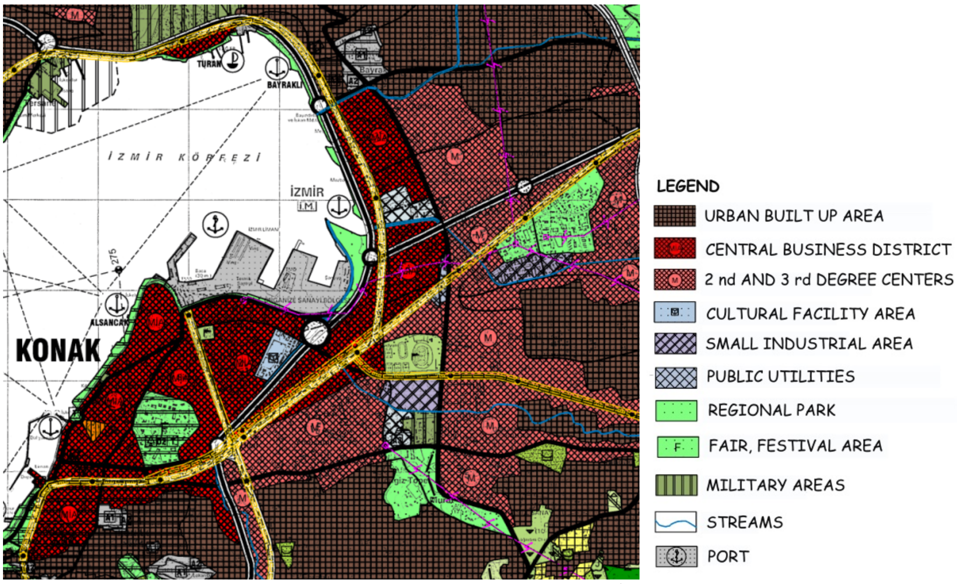


Figure 4.28. Halkapınar region in 1 / 25.000 scale İzmir metropolitan master plan
(Source: İzmir City Planners Room)

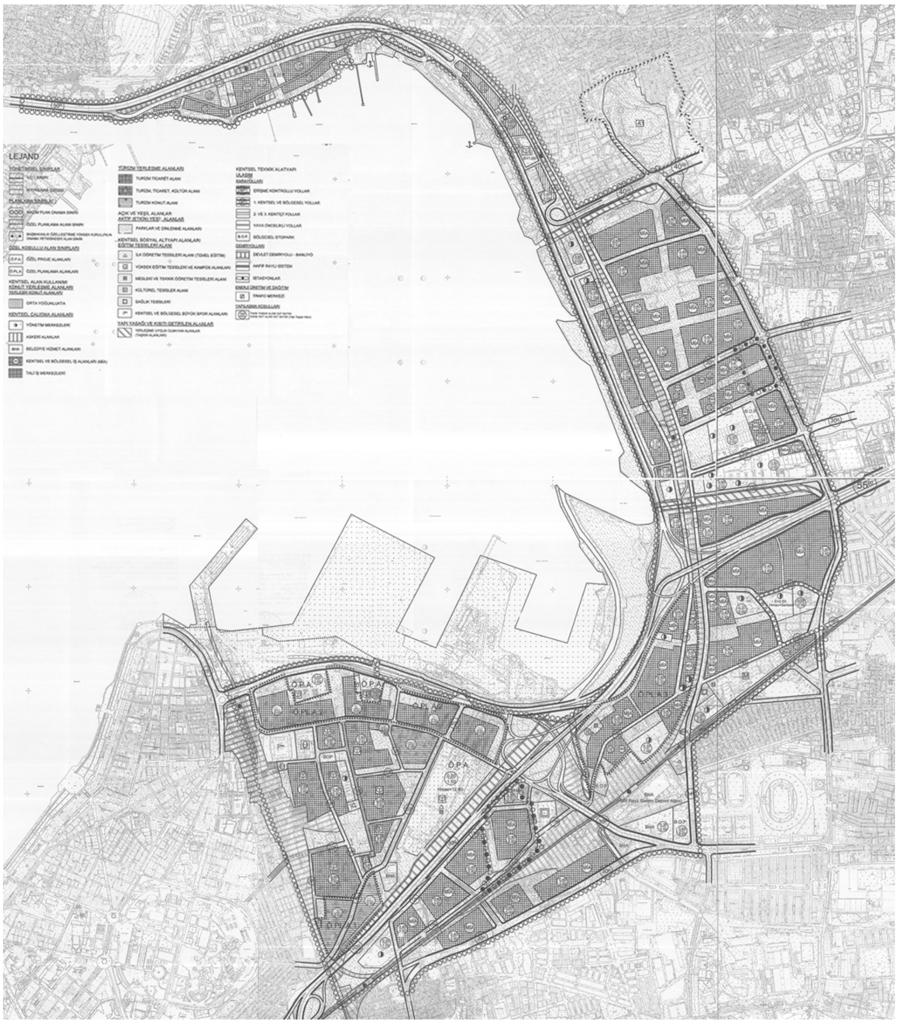


Figure 4.29. İzmir New City Center Master Plan
(Source: İzmir Metropolitan Municipality)

4.4. An Alternative Vision of Halkapınar District

Within the scope of this study, the history of İzmir on water resources has been investigated and its connection with the past has been established. The study area was identified as Halkapınar and Mersinli neighborhoods.

In determining the region, Halkapinar:

- Being a historical water source,
- Although the old Halkapınar pond was covered, it still contains groundwater,
- The Halkapınar region is located in one of the lower basins formed by the tributaries of the Meles River,
- Being located between the old city center and the new city center and open to transformation,
- Being centrally located in terms of transportation resources,
- As stated in the studies carried out in a risky area due to climate change.

In the light of the above information, the vision of Resilient Stormwater Management as a Climate Adaptation Strategy for Halkapınar District was determined.

SWOT (Strengths, Weaknesses, Opportunities, and Threats) Analysis

SWOT (strengths - weaknesses - opportunities - threats) analysis was performed in order to understand the problems and potentials of the district and to develop stormwater management strategies.

As shown in Table 4.4, a SWOT analysis shows the strengths, weaknesses, threats and opportunities of the Halkapınar region. This analysis will give an idea of the changes to be made in the district.

Table 4.4. SWOT analysis for Halkapınar District

	Strengths	**Weaknesses**	**Opportunities**	**Threats**
Historical	*There's a historical and natural water resources. *Historic water structures are public amenity such as water factory and cistern.	*The district experiencing many flood events.		* There is a new city center plan where the historical importance of the district is not considered.
Environmental	*Presence of groundwater. *There are still streams flowing with in the district. *There are green areas around like parks and stadiums. Since it is also permeable surface, it is important for the district. *There are potential areas available for change. *There is mixed use in the area, so it is a vibrant region.	*Surrounded by highways, this also increases air pollution. *Existence of industrial use in the district. *Very low permeable surfaces. *Insufficient stormwater infrastructure system. *The district is one of the places that carry risk in the future.	*İzmir has adapted a Green Infrastructure approach. * Sewerage and stormwater infrastructure systems has been started to be separated.	* Changes in the rain regime due to climate change.
Accessibility	* There is a public transport center in the district, making it easy to reach the district. * In the city center, where access is easy.	*There are no reliable roads with pedestrian focus.		
Policies	*The district is located between the old city center and the new city center; available to transformation.		* Projects in İzmir has started to be environment-oriented. * Turkey's recent climate change adaptation plans	*Lack of sustainable and ecologic land-use decisions. *Low environmental awareness of society.

Halkapınar district needs to be re-constructed due to its historical and environmental importance. The district where it can best do this renewal is to create a more livable environment by blending the water infrastructure from antiquity with today's needs in a modern way.

After examining the inputs of the SWOT analysis, it can be seen that the re-construction of Halkapınar district calls for different types of strategies, which are property scale decisions, neighborhood scale decisions and district scale decisions (Table 4.5). Since these scales are different, some of them will be completed in a short term and some will be completed in a long term.

Table 4.5. Proposed resilient stormwater management across different scales

Property Scale
• Attach roof water downspouts to rainbarrells or a storage tank and use the water for in door to flush toilets and wash cloths or outdoor uses. • Use collector roof water to water grass and gardens. • Minimize impervious surfaces use pervious pavement. • Plant and maintain trees a property for stormwater generation reduction and carbon credit. • Native and drought-tolerant plants can be planed on green areas on roads. • Grey water recycling to use waste water from plumbing systems for toilet flushing and irrigation
Neighborhood Scale
• At the neighborhood scale, efforts should focus on understanding and managing flood pathways and protecting areas at risk. • Build stormwater detention ponds and wetlands for large storms to detain runoff and reduce pollutant loads that enter streams. • Use of green open space and green roofs to reduce runoff and improve pressure on drainage systems during heavy rainfall. • Built Raingardens. • Build parking lots with pervious pavement materials. • Minimize the width of roads, lift curbs and gutters and direct runoff into roadside infiltration swales use pervious pavement.

(cont. on next page)

Table 4.5 (cont.)

<u>District Scale</u>
• Create wide riparian buffer zones and constructed wetlands within the zones to store and filter to stormwater. A main goals is minimize all stormwater outfalls discharching directly into streams. • Maintaining natural stream channels to allow lateral flow and storage of stormwater within the riparian zone. • Watershed areas need to be planned as low-density development • A riparian zone should be established for the Meles Stream and the Arap Stream. • Impervious surfaces in the district should be reduced to control stormwater runoff, and also to decrease the urban heat island effect. For this reason, the streets should be covered with permeable surfaces. • The infrastructure system should be separated and a holistic stormwater infrastructure should be established in the district.

The district has been handled in a holistic way with the aim of combining different techniques. Therefore, different scales were planned together. There are ruptures between urbanization and interventions and above ground and ground water, and methods to improve rainwater to feed groundwater and to collect rainwater have been determined.

It is important to emphasize that before explaining the studies on a regional scale: Among the most important studies to be done in the region are separated infrastructures and increasing permeable surfaces. Decomposition of the infrastructure system is not only to decompose the stormwater and sewage system. Stormwater infrastructure of the region should be a robust system for stormwater projects to work effectively in this area. Thus, when there are suggestions such as permeable surfaces or water tanks, water flow should be ensured regularly from underground. In this way, the work done does not become property-scale and forms a working network.

The purpose of creating water collection areas is not to drain the stormwater in the surrounding impermeable areas into the streams, but first to collect them around here. After this water is cleaned by filtration, it feeds the groundwater.

Formerly the place where Halkapınar Lake is located is currently used as IZSU area. However, this use is insufficient for the nature of the area. In order not to break the past connection of the region and use its existing infrastructure, a constructed wetland is proposed in the area. The Halkapınar area was an area that included a series of recreational activities and the Halkapınar Lake until the middle of the 20th century, but after significant changes in the district, it lost its characteristics and identity. For this reason, the city's past needs to be reorganized in order to reconnect to its present place by reconstruction of wetlands and collective memories.

In order to tell the history of the region and that it is a very important resource for İzmir, an ecological water resource center was planned where the water factory used to be. Thus, the natural values of the region can be brought together with the citizens in a more meaningful way with an area to be built in its natural resource. It can benefit the community, provide an experience-based learning environment, and serve multiple purposes such as research laboratories and classrooms. In this center, as in the world examples: the representation of the natural purification of water is an area where children and adults can travel, consisting of both open and closed areas. Thus, the region from the past can be connected with the future.

While ecology awareness is applied at the urban scale, this information should be supported with seminars and educational activities. Thus, not only professionals or local authorities, but also the public become conscious. In the studies to be made, as in the overseas examples I have examined before, the studies in which people living in that region also play a role in designing the area may emerge.

Riparian zones are the transitional areas between land and water, including the margins of streams. They are rich in biodiversity and play a significant role in protecting water quality and stream ecosystem health. For this reason, we can combine the ecological cycle with the land by creating transition areas around the streams. Riparian zones should include a pedestrian and bicycle path. Only permeable pavements such as porous concrete, pervious asphalt, and porous interlocking paving should be used in the surroundings of Meles Stream and Arap Stream.

The stadium grounds nearby is a permeable area because it is a green space. Although it is a permeable surface, it needs to be transformed with suitable studies to feed groundwater. It is therefore proposed as a water reservoir area. As a second alternative, the stadium can be used as a sports field by stormwater tanks under the area. The examples of the stadiums are described in Appendix D with detailed examples.

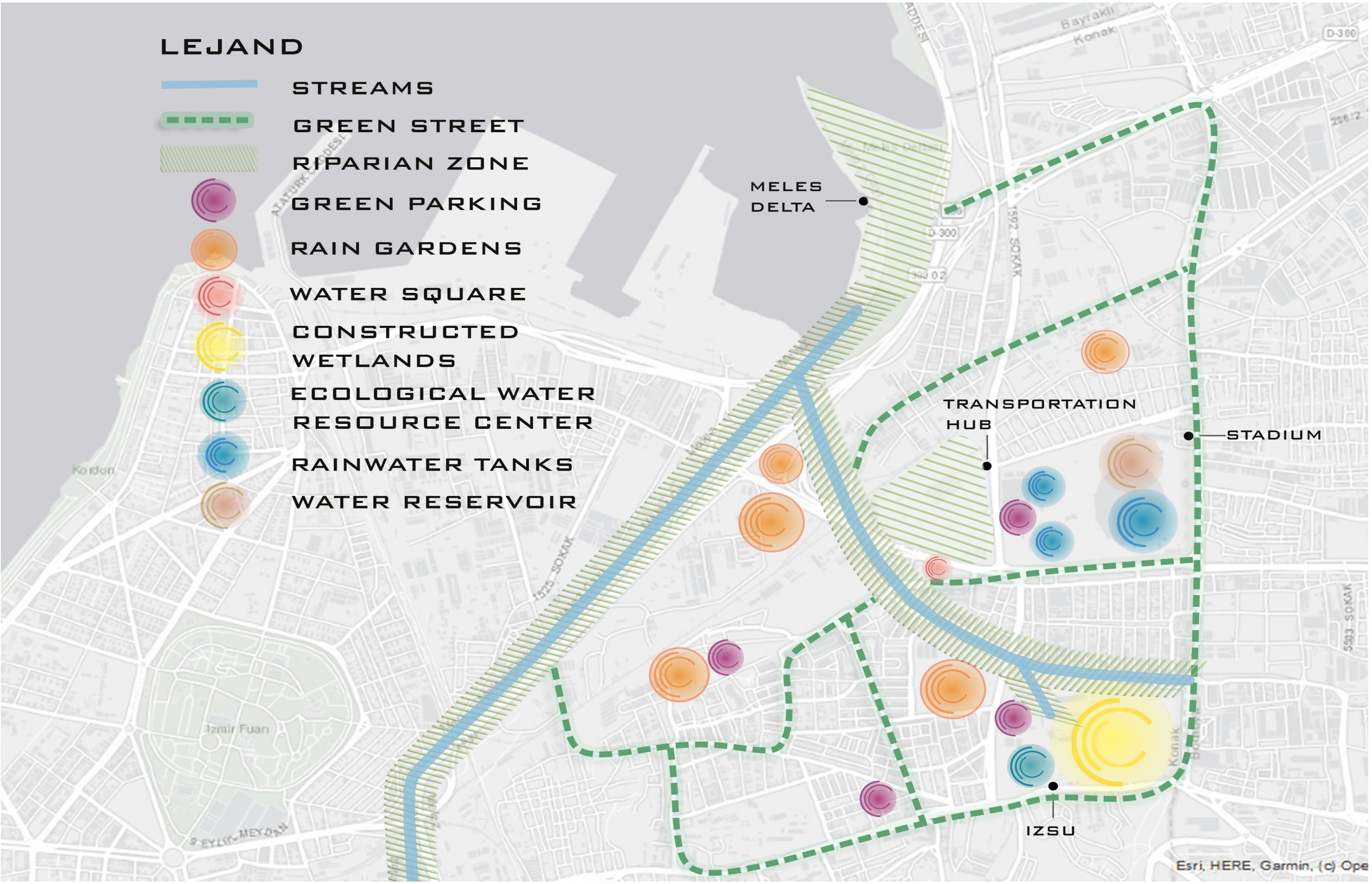


Figure 4.30. Conceptual Scheme of Resilient Stormwater Management as a Climate Adaptation Strategy for Halkapınar District

As the priority pilot region, the land of the General Management of IZSU Halkapınar Water Plant and the military zone next to it were selected. One of the impacts on the selection of the area is the public land. It is important to transform public spaces with priority as shown in the previous world examples and climate adaptation plans. Thus, it is an example of what can be done for the public. In addition, the relationship of the region with history has been influential in the fact that the traces of groundwater are still visible today and that it is in a central position to bring people together with water.

As observed during the trip to the region in April 2019, there is still an underground water source there. During the talks, it is said that there is more groundwater in the military area than IZSU land. This water in the military area is drawn from the underground with large pipes.

The construction of the IZSU head office building with a width of approximately 6,400 m2 has started within the area and it is planned to be completed in 2022. There are many buildings in the area that have remained empty. There are buildings that have preserved their old historical texture but have broken windows. The area includes parking, old pumping station, old cistern, izsu buildings and wooded areas. The tree-lined areas within the area provide an isolated environment from the city. When the region is examined, it is observed that more effective transformation can be realized depending on its history.

First of all, the plan of the region was drawn by comparing the existing maps and satellite images. The places left with white in the plan are impermeable surfaces. The single permeable surfaces in the area are the areas indicated in green (Figure 4.31).

Permeable surfaces, building areas, parking lots and total area are calculated separately for both IZSU and military land (Table 4.6 and Table 4.7).

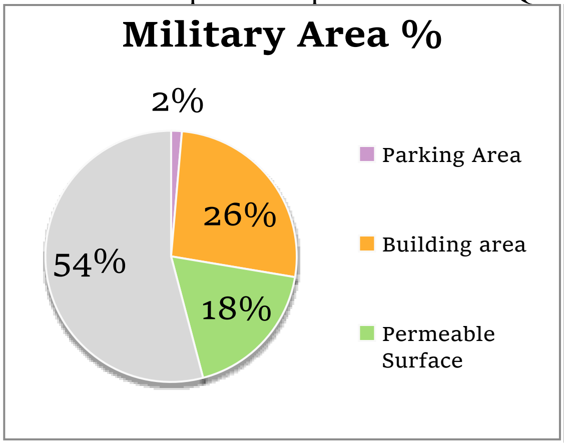
According to the analyzes, permeable surfaces in Izsu region cover only 14% of the area and 18% in the military area. The built environment constitutes 14% of the IZSU region. A built environment constitutes 26% of the military region. All remaining areas are impermeable surfaces.

Figure 4.31. Pilot zone plan

Table 4.6. Study Area Quantitative Data

	Military Area m2	Military Area %	IZSU m2	IZSU %
Parking Area	1.266	1,38	5.806	5,26
Permeable Surface	16.801	18,25	15.596	14,15
Building area	24.178	26,27	14.893	13,52
Other impermeable surface (concrete)	49.809	54,1	73.877	67,05
Total Area	**92.054**	**100**	**110.172**	**100**

Table 4.7. Graphical Representation of Quantitative Data



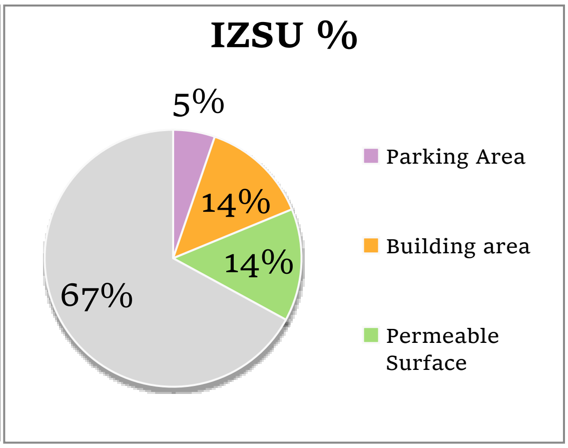


Table 4.8. Study Area Proposal Quantitative Data

	Military Area m2	Military Area %	IZSU m2	IZSU %
Parking Area	13.000	14,12	11.000	9,98
Wetland area	40.000	43,45	40.000	36,30
Building area	-	-	7.400	6,72
Total Area	92.054	100	110.172	100

The area determined in the schematic plan (Figure 4.30) is examined in more detail in Figure 4.32. Contrary to the present use of the field, a use is provided in which impermeable surfaces are reduced to almost zero. Constructed wetland and green parking are enhanced with permeable areas. Consructed wetland will collect stormwater from the street, as in the case of Tanner Springs Park. As in the example of ecological water resource center, which was examined in Chapter 3, a nature-based building region is suggested. Green roof, permeable pavements, stormwater collection areas and permeable surfaces in these regions will be increased.

The depths of the Wetland areas in the studied samples are approximately 3 m, so the estimated water retention capacity in this project was calculated as 3m. In the proposed project, wetland diameters are approximately 180 m. Calculated volumes of Wetlands for stormwater retention are 810 m3.

Figure 4.32. Pilot zone, schematic proposal

Examplary plans and sections of proposed green infrastructure techniques in Halkapinar District are provided in detail in Appendix A, B, and C.

CHAPTER 5

CONCLUSION

The research aimed to examine how urban stormwater management can be used in cities by contributing to the environment. This study focuses on stormwater management in cities with green infrastructure techniques and nature-based solutions to commute future climate change impacts. The main question of the study is: " How should we create areas to collect and reuse stormwater to ensure resilience in cities?"

This study has been examined under 3 main headings. These are theoretical literature findings, best practices findings and the case study findings. To understand climate change and its effects, firstly the literature infrastructure of the subject has been formed. Methods for stormwater resilience were investigated. After the literature research, best practices across the world have been examined, because after understanding the theory, it is important to see how it is put into practice. Finally, the case study was studied.

Understanding climate change is important for the progress of the topic. We need to understand that we cannot completely eliminate their effects, but we can reduce their impact with the practices we will make in cities. We need to understand current concepts such as resilience caused by climate change. Stormwater management, which is one of the sub-headings of the concept of resilience, is the main subject of this thesis. Stormwater is a highly valuable resource that can enhance the liveability, sustainability and resilience of cities. There are a lot of stormwater management methods that are built and not built to protect water quality, prevent urban floods and collect water. These methods can be composed of many elements such as green roofs, ponds, rain gardens, water reservoir, and wetlands. The common features of these methods are to make a potential water source. These techniques are also essential for environmental improvement because they are nature-based approaches.

The examples examined in this study include studies of different scales, different countries, different climates and different sample types. These projects have made significant contributions to communities and ecology. Since they are natural solution approaches, they contribute to the environment. They generate a reduction in air pollution and water pollution and creation of a clean environment and livable urban areas. They are also more economical than other approaches, because once a sustainable stormwater infrastructure is implemented, districts can store, clean and reuse their water. They add value to empty spaces so that it is beneficial to the ecosystem when it rains, and provide places where people can spend time on non-rainy days. There are also times when the locals are involved in designing these spaces. Thus, they have areas to fulfill their needs and desires, and the public is involved in the design process. When the world samples are analyzed, Turkey is not in a very good position in stormwater infrastructure. Studies in Turkey based on building work are ongoing. It is also not in good shape in terms of infrastructure. This situation needs to be improved as soon as possible because increasing floods are devastating cities.

Buildings constitute the majority of the current use of the pilot area. However, it is also possible to design the district as suggested in this study. In our country, there is no area examples designed in this way. As a reason, planning decisions taken in our country can be referred. The planning decisions should be revised according to the needs of today's cities and citizens. For this, cooperation between sectors and stakeholders should be increased. Existing policies and practices should be analyzed to promote nature-based solutions in urban areas. And partnerships should be established between policy-makers, the private sector and civil society.

Halkapınar District has changed due to rapid urbanization, population growth and human interventions. This study presents an alternative vision for the Halkapınar District by using the results obtained from the literature, best practices and analyses conducted in the field study. For this reason, property-scale, neighborhood and district-scale studies were determined.

Following the study, the Halkapınar district was investigated. Location, history, geology, built environment and planning work for that region have been put forward. After examining the area, SWOT analysis was performed on the district, thus determining the needs and possible natural interventions. In this study, it is important to make the existing resources sustainable by linking the past and the future.

Halkapınar District is historical heritage. However, today it has been ignored. The district has come from ancient times as a water district. The former Halkapınar Lake was a popular place in the history of İzmir, from mythology to real life. Also, İzmir's first water factory was established there. In spite of this, the district has been changed with human intervention. Therefore, it is crucial to consider the past and the future together. Halkapınar district is a region that has experienced floods in its history. Also, the area is located between the old city center and the new city center. The location of the district is within the borders of the new city center, but it is also connected to the old center. It is at the intersection of transport links and it is open to transformation. However, these changes will not change all at once, but as a process and holistic transformation.

The district should not lose its natural characteristics while being reclaimed to İzmir. Therefore, it is important to study the region as a whole. This integrity must take place both underground and above ground.

The district accommodates many mixed uses such as residential areas, commercial areas, stadiums, and small-scale industrial space. For this reason, each scale is mentioned in the project. As it is a region that is open to change and that everyone is interested in today, this study shows what can be done ecologically in the region. For this, indigenous people and the state should be able to work together. Adding locals people to the project will ensure their ownership of the space.

This study shows what can be done for stormwater management in cities. For example, a pilot region was studied in order to examine it more clearly. The land of the IZSU and the military zone next to it were selected. The total area of the two regions is 202.226 m2. In total, 32.397 m2 areas consists of permeable surface. This is 16% of the area. With the proposed constructed wetland area, it is planned that at least 104.000 m2 area of the area may consist of permeable surface. It constitutes 51% of this area. It was calculated that the formed wetlands could hold approximately 810 m3 of water. The pilot region study showed that stormwater management is possible in cities. A region from the public sphere was studied. The study could not find the flood data of the district. Therefore, how much of the flood rate in the area can be prevented is not solved in part. Subsequent studies may be complementary in this sense.

These projects in Turkey will take time. But İzmir is a little ahead because there are green-focused projects had already begun. For this reason, Halkapınar is in a leading position. Therefore, the studies there should be considered as holistic.

REFERENCES

Acar, A., 2008. Yeni Bir Doğal Kaynak Olarak; Yağmur Suyu. Birlik, 2: 28-31.

Acciona, Climate change, Retrieved from https://www.acciona.com/climate-change/

Aksor, S., 2016. Reclaiming Ecological Sustainability Of Urban Streams By Use Of Green Infrastructure Techniques

Atlas , Museum car park, Retrieved from https://the-atlas.com/projects/museumpark-car-park-flood-defense

Avdan, Z.Y., Yıldız, D. Y. and Çabuk, A., 2015. Evaluation Of Green Infrastructure In Management of Stormwater. 2nd International Sustainable Buildings Symposium.

Aydın, M. B. S., Erdin, H. E., Kahraman, E. D., 2017. Mekansal Yapı Özellikleri Açısından İklim Değişikliğine Karşı Risk Taşıyan Bölgelerin Saptanması, İzmir

Baba A. , Yazdani H. Effect Of Urbanization On Groundwater Resources Of Izmir City :7

Berglung, P., 2018. Cost-benefit analysis for sustainable stormwater management - A case study for Masthuggskajen, Gothenburg, Uppsala Universitet.carbon neutral developments, BioRegional Development Group.

Beyru R., 2011. 19.yy'da İzmir Kenti

Cathcart A. 2016, Retrieved from https://www.citylab.com/design/2016/01/copenhagen-parks-ponds-climate-change-community-engagement/426618/?utm_source=SFFB

Constructed Wetlands , 2011. Virginia DCR Stormwater Design Specification No. 13:5

Cook, E. A., 2007. Green Site Design: Strategies For Storm Water Management, Journal of Green Building, 2 (4): 46-56.

Copenhagen, The City of Copenhagen, 2012, Cloudburst Management Plan.

Copenhagen, The City of Copenhagen, 2014, The Coherent City, Municipal Planning Strategy 2014 For The City of Copenhagen.

CRWA, 2008. Rain Garden, Charles River Watershed Association.

Dirençli Kentler İçin Bir Çerçeve, 2019 , Retrieved from https://direnclikent2019.izmir.bel.tr/tr/AmacKapsam/18/10

DNR, 2009. Maintenance of Low Impact Development (LID) Stormwater Practices, Guidance for Homeowners Associations Based on Oak Terrace Preserve in North Charleston, SC.

EPA, 2004. The Use of Best Management Practices (BMPs) in Urban Watersheds, United States Environmental Protection Agency New England.

EPA, 2009. Incorporating Low Impact Development into Municipal Stormwater Programs, United States Environmental Protection Agency New England.

EPA, 2015. A Handbook Of Constructed Wetlands. United States Environmental Protection Agency.

EPA, Climate Change Adaptation Resource Center, Retrieved from https://www.epa.gov/arc-x/strategies-climate-change-adaptation

EPA, Green streets ; 4-6 , Retrieved from https://www.scribd.com/document/34622032/Green-Streets-A-Conceptual-Guide-to-Effective-Green-Streets-Design-Solutions

Fisher, S. The Guardian, Retrieved from https://www.theguardian.com/environment/2012/feb/27/climate-change-adaptation

Hooimeijer, F., Vrijthoof, V.D.T, 2007. More Urban Water: Design and Management of Dutch Water Cities, Urban Water Series,Taylor & Francise-Library, 133-142.

IZSU. 2017, Retrieved from https://www.izsu.gov.tr/tr/HaberDetay/14151

IZSU Faaliyet Raporu, 2017 , Retrieved from http://www.izsu.gov.tr/YuklenenDosyalar/Dokumanlar/2017YiliFaaliyetRaporu.pdf

IZSU Haber, 2017, Retrieved from https://www.izsu.gov.tr/tr/HaberDetay/14181

IZSU, Halkapınar Kaynakları, Retrieved from https://www.izsu.gov.tr/tr/halkapinarkaynaklari/17/124

IZSU web, Retrieved from https://www.izsu.gov.tr/tr/izmirtarihisuyapirestorasyonu/59/135

Izmir Büyükşehir Belediyesi (IBŞB) , Izmir'de Suyun Serüveni, 2017

İzmir Yeşil Altyapı Stratejisi, Retrieved from http://izmirdoga.izmir.bel.tr/tr/suAlanlari/4/14

Jiang, Y., Zevenbergen, C., Ma, Y., 2018. Urban Pluvial Flooding and Stormwater Management: A Contemporary Review of China's Challenges and "Sponge Cities" Strategy, Enviromental Science and Policy, 80, 132-143.

Kadıoğlu, M. 2012 . Türkiye'de iklim değişikliği risk yönetimi: 51

Karadaş, A., 2014. Bornova Ovası (Izmir) Holosen Paleocoğrafyası Ve Kıyı Çizgisi Değişmeleri , Ege Coğrafya Dergisi

Kharagpur, 2008. Water Resources Engineering, India.

K.M. de Bruijn , Resilience and flood risk management: 60

Kruse R. 2015, Retrieved from https://land8.com/tanner-springs-park-an-oasis-in-the-middle-of-the-city/

Lahde, E. and Ariluoma, M., 2017. Sustainable Stormwater Management Solutions, iWater Toolsheets.

Lazarus, N., 2003. BedZED: Toolkit Part II, A practical guide to producing affordable carbon neutral developments

Levantine Heritage, Retrieved from http://www.levantineheritage.com/lost.htm

Musa, M. F., Zen, I. H. and Tukiman, I., 2013. Reconstituting The Concepts Of Sustainable Stormwater Management, Journal Of Architcture, Planning & Construction Management, 3(2): 45-72.

Müftüoğlu, V. and Perçin, H., 2015. Sürdürülebilir Kentsel Yağmur Suyu Yönetimi Kapsamında Yağmur Bahçesi, İnönü Üniversitesi Sanat ve Tasarım Dergisi, 5(11): 27-37.

National Geographic , Retrieved from https://www.nationalgeographic.com/environment/global-warming/global-warming-effects/

Naturally resilient communities, Retrieved from http://nrcsolutions.org/green-streets/

New York State Stormwater Management Design Manual, 2015; 6/ 23-26

PAD, Peyzaj Araştırmaları Derneği, 2017. Yağmur Hasadı Uygulamalarına Giriş Rehberi: İklim Değişikliğine Uyum Kapsamında Bir Çözüm Önerisi, AB-Türkiye

Sivil Toplum Diyaloğu Programı.

Saygın, N. and Ulusoy, P., 2011. Stormwater Management and Green Infrastructure Techniques for Sustainable Campus Design, Journal of Polytechnic, 14 (3): 223-231.

Sert, E., 2013. Enerji Etkin Kentsel Peyzaj Tasarımında Yağmur Suyu, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.

South Eastern Councils, 2013. Water Sensitive Urban Design Guidelines. Melbourne Water.

Su Tema, Retrieved from https://sutema.org/gelecegin-suyu/yagmur-hasadi.20.aspx

Şahin, N. İ., 2010. Binalarda Su Korunumu, İstanbul Teknik Üniversitesi, Fen Bilimleri Entitüsü, İstanbul.

Şahin, N. İ. and Manioğlu, G., 2011. Binalarda Yağmur Suyunun Kullanılması, Tesisat Mühendisliği, 125: 21-32.

The City of Portland Oregon, Retrieved from https://www.portlandoregon.gov/bes/article/414873

Timmeren, A., Bacchin, T. K. and Aires,, C., 2015. Green Blue Infrastructures Overvıew Of Smart Spatial Strategie Simplications for Future Innovation in Design Processes, Delft University of Technology.

Turenscape, 2017. Minghu Wetland Park, Retrieved from https://www.turenscape.com/en/project/detail/4645.html

Turenscape, 2019. Deep Forms of Nature-based Solutions: Meishe River Greenway and Fengxiang Park, Haikou, China, Retrieved from https://www.turenscape.com/en/project/detail/4656.html

Unwater, water and climate change, Retrieved from https://www.unwater.org/water-facts/climate-change/

Urban ecology, Retrieved from https://urbanecologycmu.wordpress.com/2015/10/22/water-case-study-tanner-springs-park/

Ünal, U. and Akyüz, D.E. 2017. Sürdürülebilir Kentsel Drenaj Sistemlerinde Yağmur Hendeklerinin Değerlendirilmesi. Uluslararası Sürdürülebilir Mühendislik ve Teknoloji Dergisi, 1(1): 15-24.

Yakima County, Retrieved from https://www.yakimacounty.us/1737/Low-Impact-Development

Yarıcı, A. Kentimizde Su Taşkınlarının Meydana Geliş Sebepleri ve Çözümleri:347-351 http://www.tmmobizmir.org/wp-content/uploads/2014/05/200832.pdf

WECF, 2011. Constructed Wetlands Sustainable Wastewater Treatment for Rural and Peri-Urban Communities in Bulgaria, Women in Europe for a Common Future.

WHO, 1996. Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition.

WLA, 2017. Room for the River | Nijmegen, The Netherlands | H+N+S Landscape Architects, Retrieved from https://worldlandscapearchitect.com/room-for-the-river-nijmegen-the netherlands-hns-landscape-architects/#.XNwX5Y4zbIV

World Economic Forum, Retrieved from

https://www.weforum.org/agenda/2015/07/how-to-improve-flood-resilience

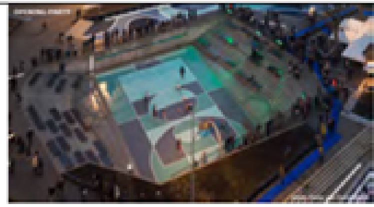
World future coulcil, Retrieved from

https://www.worldfuturecouncil.org/sponge-cities-what-is-it-all-about/

WSUD Information Sheet No: 4, 2016. Water Sensitive Urban Design.

APPENDIX A

Table A.1 Green blue spatial strategies list (Source: Timmeren, Kuzniecow BacchinandAires,106-113)

Spatial Strategy					Urban Patterns
Object	**Harmony**	**Design**	**Management**	**Samples / Case**	**Open space type**
Flood hazard and drough preventation					
Buffering rainwater	-Public space -Suitable design -Flexibility	Parks, sport faclities and outdoor theater	Implement sapareted stormwater systems	 Watersquare Benthemplein	square, plaza , parks, playground
		Bioswales	The buffering systems are designed to be 85% dry, to avoid excess water soil and mosquito density	 Bioswales Ruwenbos District	playing field square, plaza, courtyard, parking lot, parks

(cont. on next page)

Table A.1 (cont.)

		Public spaces in different altitude to accommodate changing water levels		 HafenCity	meadow, riverside parks, playground, green areas
		Urban ponds		 Potsdamer Platz	square, plaza, courtyard, parks, playground
Riparian buffers	-Sanitation, biodiversiy -Flexibilit	The pool serves as a buffer for the river by preventing heavy pollutants		 Manassas, VA USA	Riverside parks, Green areas

(cont. on next page)

Table A.1 (cont.)

		Drainage gutters: reroute water from paved surfaces to the sediment basin			playing field, square, plaza, parking lot, parks
		Canals with land form depressions forming public space		 Copenhagen Strategy Flood Masterplan,	water bodies, meadow, parks
Buffering rainwater in water robust streets	-Mobility infrastruct ure	Gutters over the streets		 Bioswales Ruwenbos District,	

(cont. on next page)

Table A.1 (cont.)

		Curbside rain garden		 Portland	
		Urban creek		 Copenhagen Strategy Flood Masterplan,	
Buffering rainwater in the building scale	-Building	Green roofs		 Rotterdam Adaptation Strategy	

(cont. on next page)

Table A.1 (cont.)

		Rooftop gardens		 Rotterdam Adaptation Strategy	
Recharging the groundwater and buffering water	subsurface	Infiltratio planters that buffers rain water		 Zollhallen Platz	playing field outdoor theaters, square, plaza, parks, playground, green, churchyard/ cemetery
		Trenches		 SuDS Wales	playing field, square, plaza, courtyard, parking lot, atrium, private garden, communal garden, allotments,

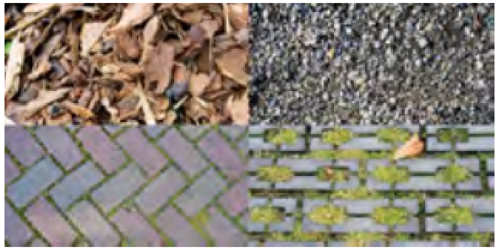
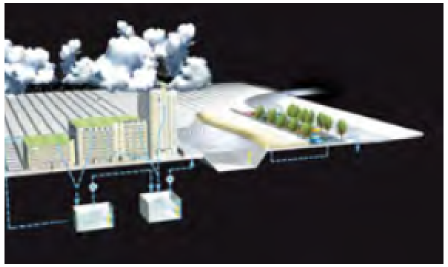
(cont. on next page)

Table A.1 (cont.)

		Artificial and natural ponds		 EVA Lanxmeer Project Living Lab,	square, plaza, green, parks
		Rain gardens		 Portland	playing field, square, plaza, courtyard, parking lot, atrium, private garden, comm unal garden, allotments, parks
		Ditches			playing field, square, plaza, courtyard, parking lot, private garden, communal garden, allotments, parks

(cont. on next page)

Table A.1 (cont.)

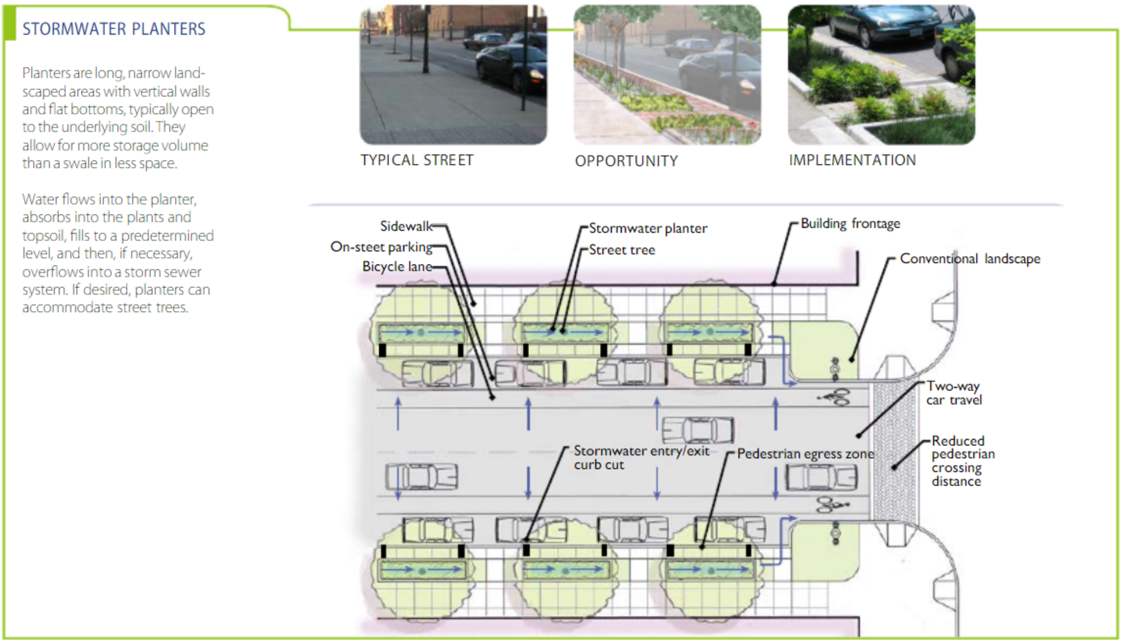
		Porous paving materials			playing field, square, plaza, green, courtyard, parking lot, private garden, communal garden, allotments, parks
Retention of rainwater	-Building -Public space -Social integrati on and cohesion	Underground cistern, tanks and pools to store water during longer periods		 Potsdamer Platz	underground playing field square, plaza, green, courtyard, parking lot, privat garden, communal garden, parks

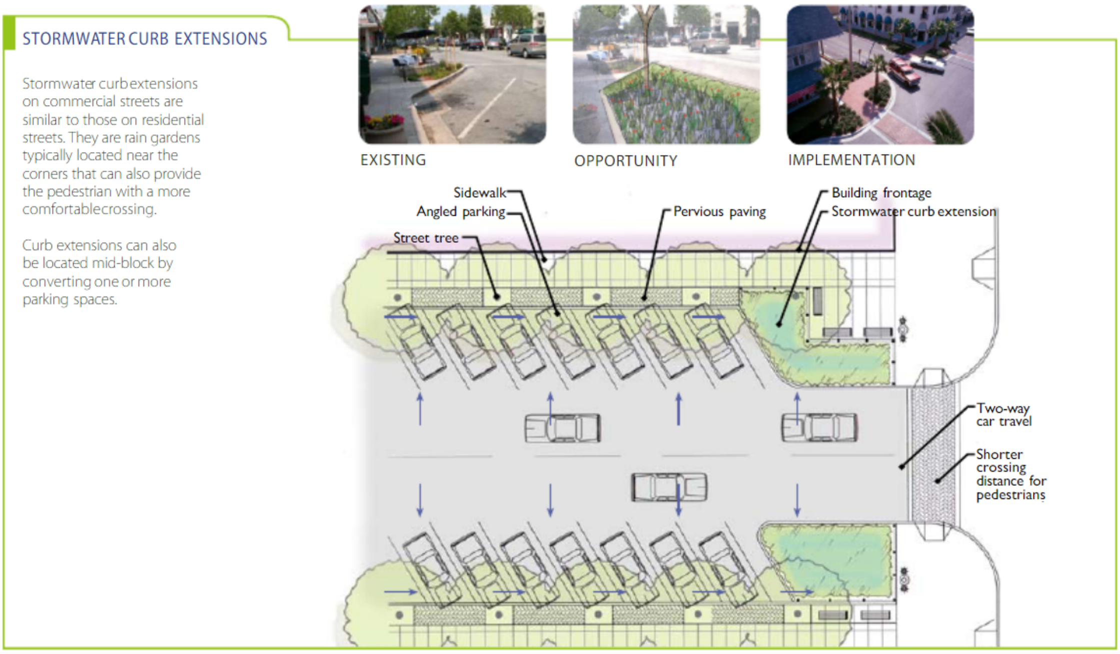
(cont. on next page)

APPENDIX B

A Conceptual Guide to Effective Green Streets Design Solution

(Source: EPA, Green streets ; 4-6)





PERMEABLE PAVING

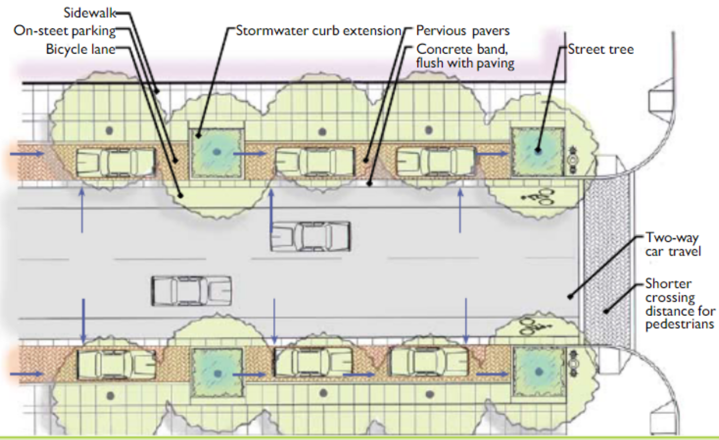
Permeable paving on commercial streets can be incorporated into sidewalks and parking lanes.

Recent advances in permeable paving technologies now make many appropriate for higher speeds or where large, heavy vehicles are expected to be parked—areas such as loading zones and bus stops.


EXISTING


OPPORTUNITY


IMPLEMENTATION



VEGETATED SWALES

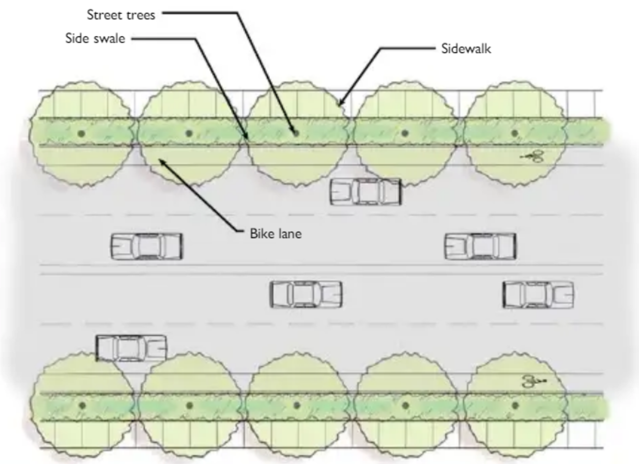
Like residential streets, arterial roadways are good street types for swales because they typically have long, linear stretches of uninterrupted space that can be used to manage stormwater.

Some arterials may not have landscape space in place but do have travel lanes or paved shoulders that can be narrowed to create space for swales.


TYPICAL STREET


OPPORTUNITY


IMPLEMENTATION



APPENDIX C

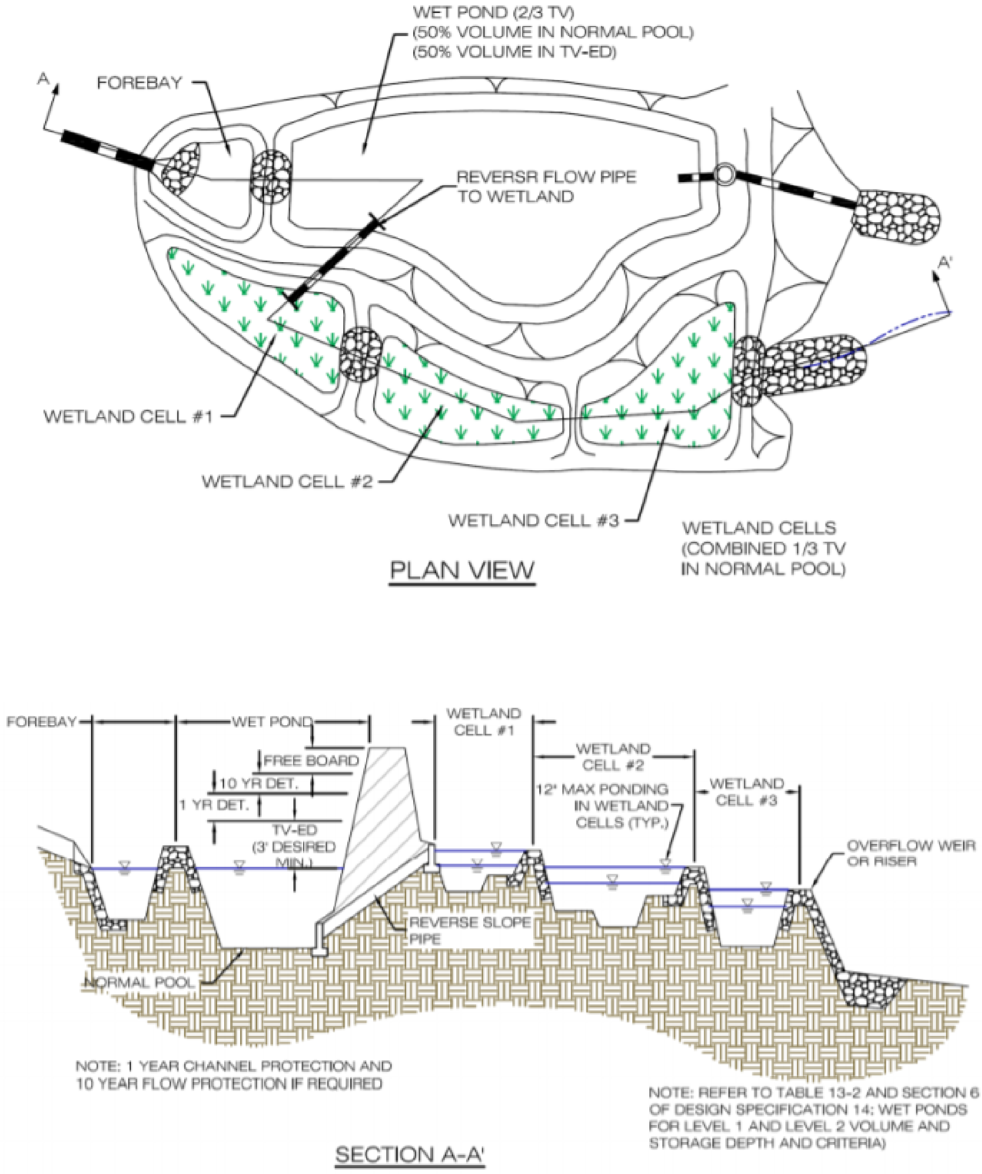
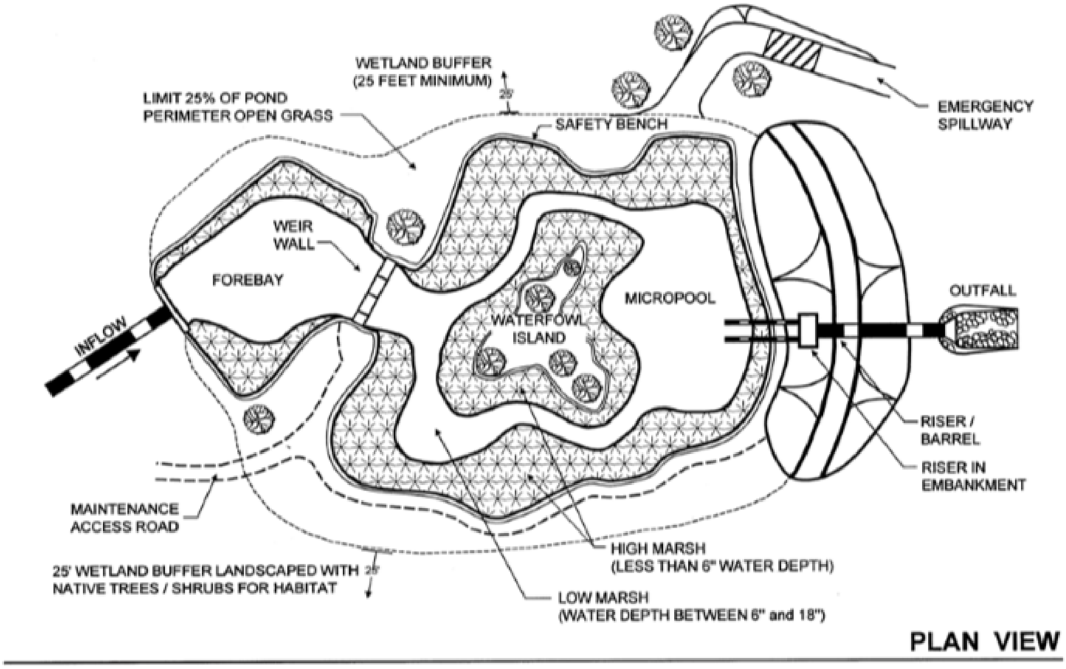


Figure C.1. Wetland Plan and Section (Source: Constructed Wetlands , 2011; 5)



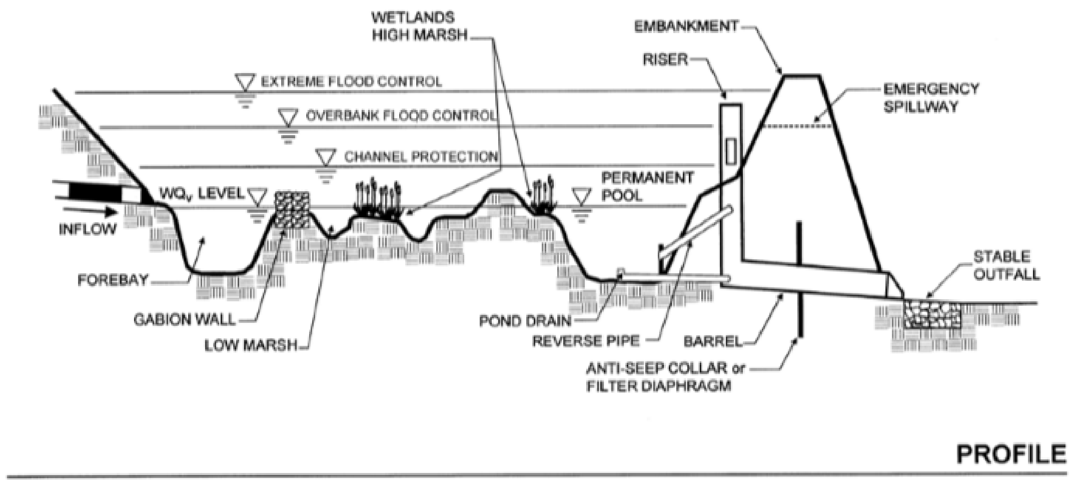


Figure C.2. Shallow wetland plan and profile (Source: New York State Stormwater Management Design Manual, 2015; 6-23)

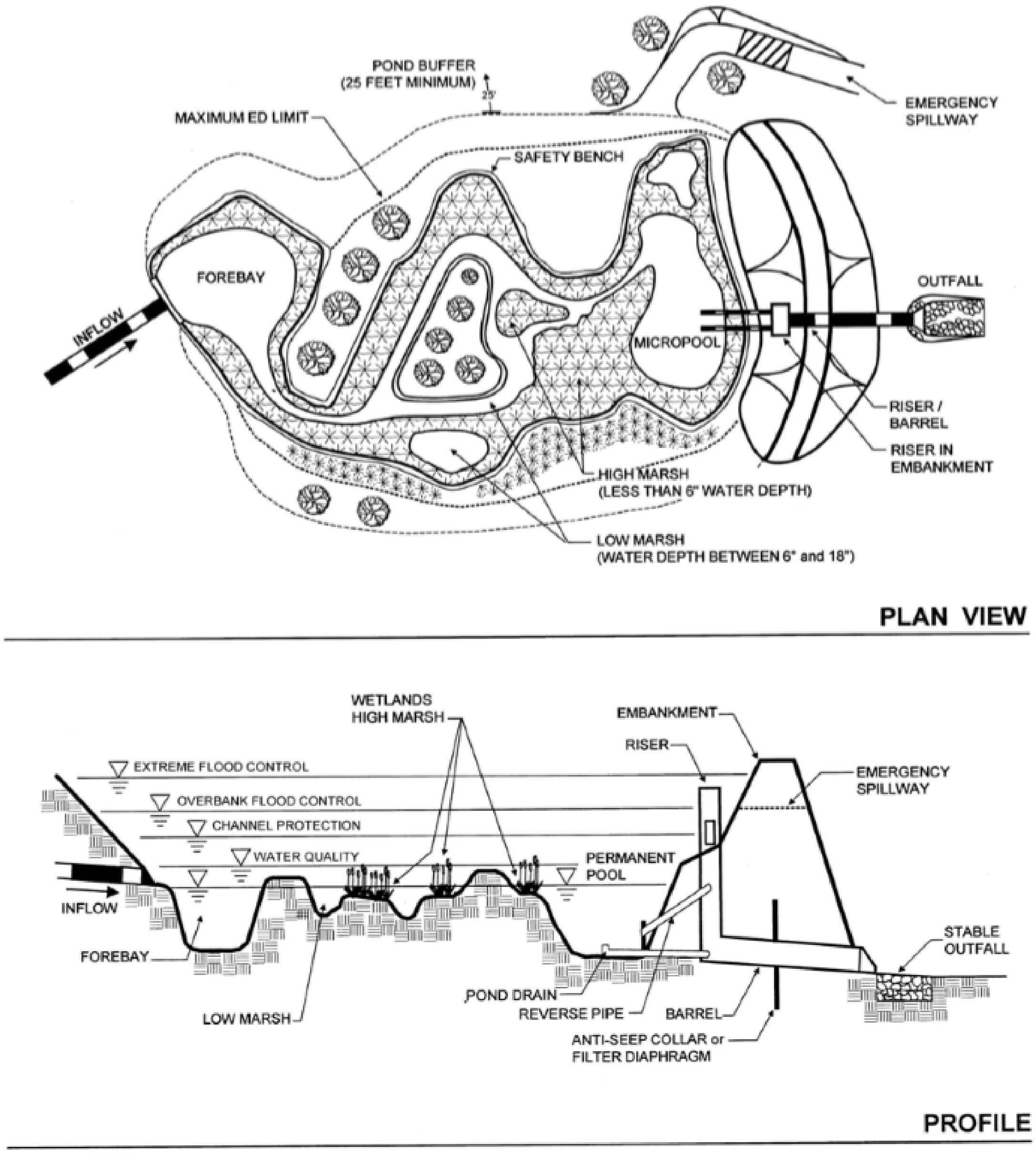


Figure C.3. Extended detention shallow wetland plan and profile
(Source: New York State Stormwater Management Design Manual, 2015; 6-24)

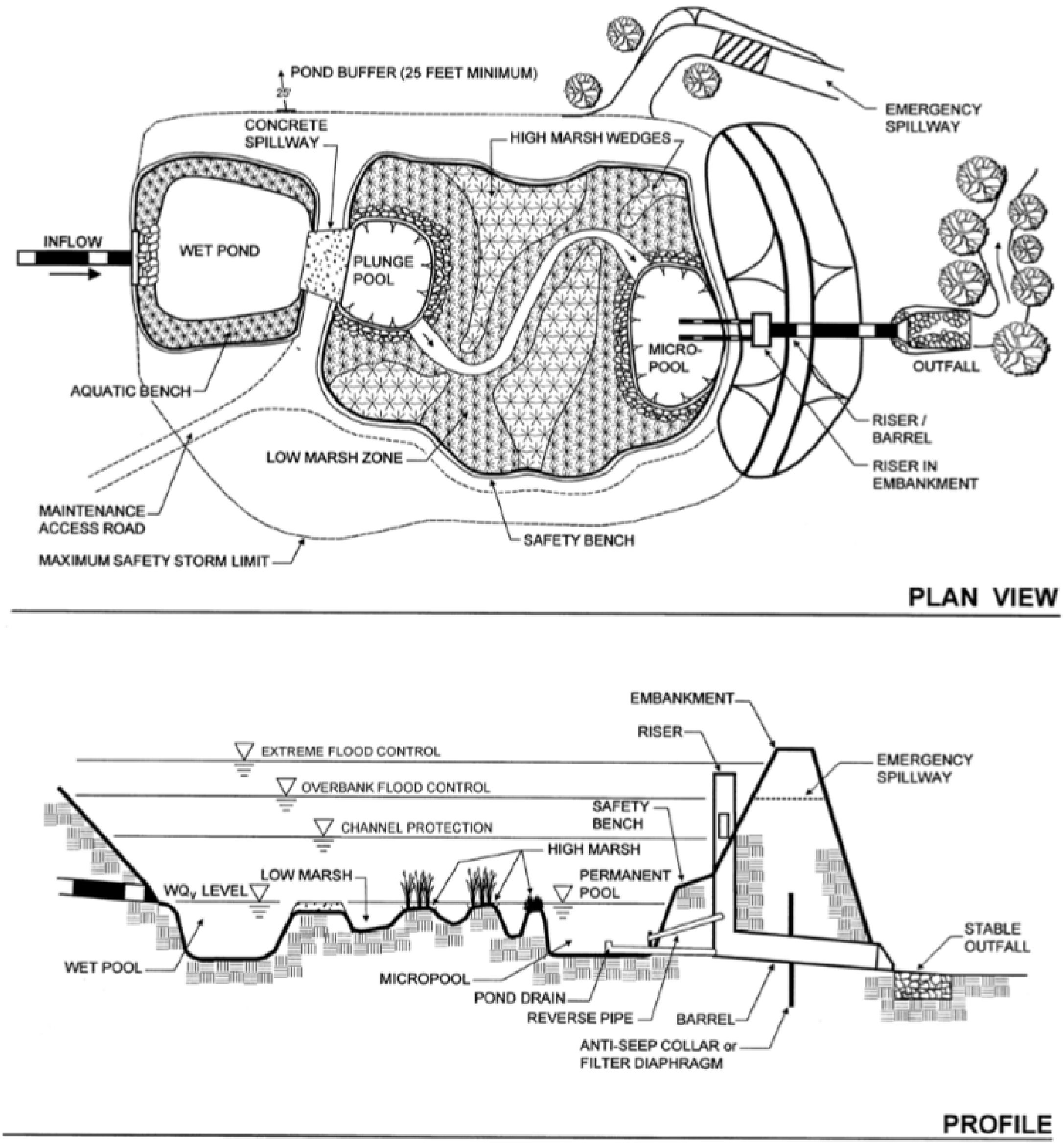
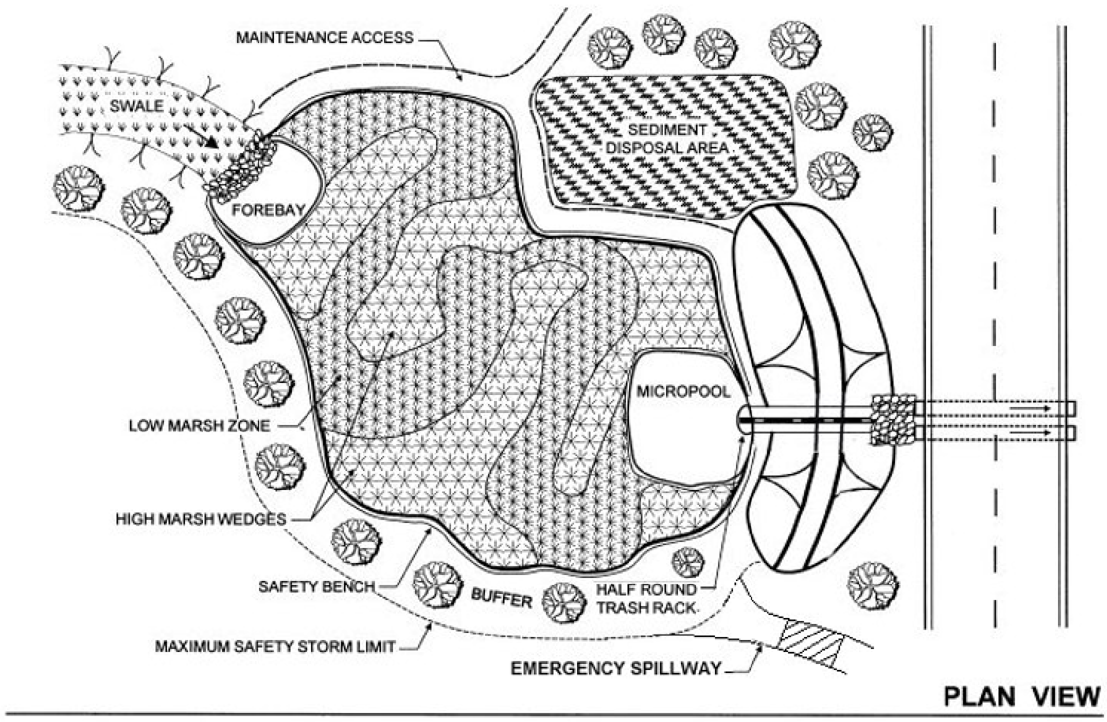


Figure C.4. Pond/Wetland system plan and profile
(Source: New York State Stormwater Management Design Manual, 2015; 6-25)



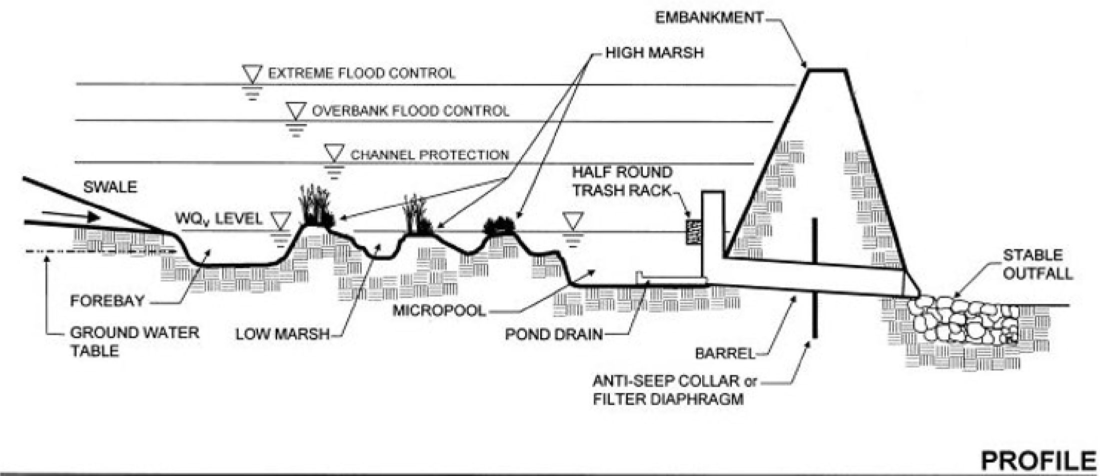


Figure C.5. Pocket wetland plan and profile
(Source: New York State Stormwater Management Design Manual, 2015; 6-26)

APPENDIX D

Table D.1. Stadiums that are successful in stormwater collection

Name	Country	Stadium feature	Source
Maracana Sports Stadium	**Brazil**	*The stormwater tanks are fed from the roof, which have been engineered to collect large amounts of stormwater for use in the stadium's water systems, reducing its reliance on externally supplied water by 40%. *The modular stormwater tanks supply water to irrigate the pitch, as well as for use in the 292 toilets and restrooms.	https://rainharvesting.co.uk/portfolio/maracana-sports-stadium/
The New Lawn Stadium	**England**	*The world's first organic pitch its power from over 100 solar panels, *The grass is cut with a solar-powered robotic mower. *The stromwater is recycled.	https://www.redbull.com/za-en/8-football-stadiums-designed-to-save-the-world
Morro da Mineira	**Brazil**	*World's first ever people-powered football pitch using over 200 underground kinetic tiles, the turf converts players' movements into energy to power the bulbs.	https://www.redbull.com/za-en/8-football-stadiums-designed-to-save-the-world
Princes Park	**England**	*Has a 'living roof'. *Featuring a sedum roof blanket which provides a natural air filtration system. *Solar panels to serve the community areas. *A stromwater recycling system to keep the clear stuff flowing.	https://www.redbull.com/za-en/8-football-stadiums-designed-to-save-the-world
Amsterdam Arena	**The Netherlands**	*4,200 solar panels in the roof. *Re-using stromwater. *The Arena is chilled using cold water from a nearby lake. *Wind turbines positioned strategically around the stadium. *The world's first to feature 100 percent renewable seating from sugarcane.	https://www.redbull.com/za-en/8-football-stadiums-designed-to-save-the-world
Zorrilla Football Stadium	**Spain**	*Collection, treatment, infiltration and reuse of stromwater. *Aquifer storage.	https://fieldfactors.com/blog/indexphp/a-rainwater-harvesting-system-for-zorrilla-football-stadium-valladolid