INTEGRATION OF INHERITED WATER MANAGEMENT SYSTEMS WITH CONTEMPORARY NATURE-BASED SOLUTIONS: THE CASE OF BODRUM, TURKEY

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ABSTRACT

INTEGRATION OF INHERITED WATER MANAGEMENT SYSTEMS WITH CONTEMPORARY NATURE-BASED SOLUTIONS: THE CASE OF BODRUM, TURKEY

Water, as an indispensable source of life, is considered as a scarce resource due to excessive consumption, pollution, climate change, and poor management practices. As water scarcity is being felt more and more every day around the world, innovative and creative solutions have gained an emergency for cities. Instead of conventional solutions, city managements are searching for sensitive solutions to nature and local. Turkey is already facing the problems of water scarcity due to its semi-arid climate susceptive to climate change; however, the conventional approach dominates water management. Bodrum is chosen as the case study area because it has its own water collection methods used for centuries by local population and have been emerged as a cultural heritage.

The aim of the thesis is to propose environmentally sensitive and effective solutions to the water scarcity of the peninsula by combining the local water heritage methods and contemporary nature-based water supply techniques. In the study, water management methods of different historical cities are examined. Later, the current water problems and different management techniques from around the world are discussed. Additionally, approaches of countries are discussed to understand concepts and implementations. In the case study, the water problems and management history of the Bodrum Peninsula are investigated. The current situation analyses and a survey are conducted. With the obtained data, a guide which presents integrated strategies to combine the local water heritage methods and innovative nature-based techniques have been developed for the Bodrum Peninsula.

Keywords: Water Heritage, Integrated Water Management, Nature-Based Solutions, Blue-Green Infrastructure, Freshwater Scarcity in Bodrum.

ÖZET

MİRAS SU YÖNETİMİ SİSTEMLERİ İLE ÇAĞDAŞ DOĞA-TEMELLİ ÇÖZÜMLERİN ENTEGRASYONU: BODRUM (TÜRKİYE) ÖRNEĞİ

Hayatın vazgeçilemez bir kaynağı olarak su, aşırı tüketim, kirlilik, iklim değişikliği, ve kötü yönetim pratikleri gibi nedenlerden dolayı günümüzde kıt bir kaynak olarak değerlendirilmektedir. Dünya'da su kıtlığı her geçen gün daha fazla hissedilmeye başladıkça, kentlerde su yönetimine yeni ve yaratıcı çözüm arayışları ortaya çıkmıştır. Bilinçli kent yönetimleri, beton ve boru çözümlerin yerine, doğa ve yerel ile uyumlu ve hassat çözüm arayışlarını sürdürmekte ve farklı şekillerde uygulamaktadırlar. Yarı-kurak iklimi nedeni ile halihazırda su kıtlığı problemleri ile yüzleşen ve iklim değişikliğine hassas Türkiye'de, su yönetimine beton çözümlerin oluşturduğu geleneksel bir yaklaşım hakimdir. Bodrum, Anadolu'da, kendi kültüründe barındırmış olduğu ve geçmişte yüzyıllarca kullanılmış etkili su toplama yöntemleri olan önemli bir yerleşim örneği olup çalışma alanı olarak belirlenmiştir

Tezin amacı yerel yöntemleri gün yüzüne çıkararak, tekrardan, doğa temelli tekniklerle birleştirip kentin su sıkıntısına kendi geçmişinden gelen doğası ve yereli ile uyumlu, çevresel olarak hassas ve etkili çözüm önerileri sunmaktır. Çalışmada, ilk olarak farklı tarihi kentlerin su yönetim methodları incelenmiştir. Daha sonra dünyada ve Türkiye'de su problemleri ve farklı yönetim şekilleri tartışılmıştır. Bunlara örnek olarak farklı ülkelerin uyguladığı yenilikçi ve hassas su yönetimi konseptleri ve uygulama biçimleri ile yeni bir bakış açısı olan mavi-yeşil altyapı sistemleri doğa-temelli çözüm önerilerinin bir aracı olarak ele alınmıştır. Daha sonra Bodrum Yarımadası su problemleri ve yönetimi araştırılmış, mevcut durum analizleri yapılmış ve yore halkından 51 kişi ile bir anket gerçekleştirilmiştir. Analizler ve anket sonucu elde edilen verilerle Bodrum Yarımadası için yerel su mirasını, yenilikçi doğa-temelli çözümler ile entegre edici stratejiler sunan bir rehber hazırlanmıştır.

Anahtar Kelimeler: Su Mirası, Entegre Su Yönetimi, Doğa-Temelli Çözümler, Mavi-Yeşil Altyapı, Bodrum'da Tatlı Su Kıtlığı

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CHAPTER 1

INTRODUCTION

"Too much, too little, too polluted: these are three water risks facing many urban areas. By 2050, worldwide water demand will increase by 55%. This situation will mean fierce competition across different water users–farmers, industries, households, etc. Whether containing flooding in Paris, drought in San Francisco, or groundwater contamination in Mexico City, cities everywhere are asking how to anticipate, avoid, and overcome future water crises." (OECD, 2016)

1.1. Background of The Study

The genesis of life has started with water. Living without water is impossible for every creature. Scarcity of water will affect the continuity of life irrespective of our ideology, belief, nationality, or gender. From the beginning of the civilizations until today, managing water has always been an issue for humanity. Human being all the time have been searching for water sources for settlements, food, health, sanitary, agriculture, and industry, etc. Although communities and authorities have always understood the importance of water, not many of them have been successful in sustainable water management. Accordingly, many cities face issues related to water such as contamination of groundwater or lack of freshwater resources.

With the Industrial Revolution and then globalization, human effects became more destructive for nature. When human-being have started to be capable of using machine power, constructions have started to become at massive scales. Standard management approaches such as dams, concrete channels, pipe systems in the ground which are called conventional water management techniques (also called grey infrastructure), were adopted all around the world with no respect for neither nature nor local water knowledge. The consequences of this growth to humanity such as a considerable degradation of the natural reserves and vulnerability of life. With this progress, our relationship with the nature has changed. Nature became a system that can be dominated by human-made technology instead of adapted or cohabited to it. But also, there has been a positive aspect of the modernization where with the development of digital tools like remote sensing and geographic information system (GIS), it has become easier to analyze the problems and plan the solutions for future development which contemporary nature-based solutions (NBS) are receiving help from them. **Contemporary NBS** are the techniques which mimics the natural processes like infiltration, purification, and storing the water in urban areas.

In the earlier times, city planning and design was primarily based on the natural topography and sharing the natural resources within the community. Water ethically was a common good, and everyone has had the right to use it. However, nowadays, water has become a commodity that people have to pay for. According to the Water Footprint Network, by 2050, nearly 52 percent of the world's population will be living in water stress areas (the world population projected as 9.7 billion people for 2050) (Water Footprint Network 2014). A similar emphasis for the current situation has been made by the United Nations where already more than two billion people are living in countries with water stress. Therefore, there are different institutions and organizations that are looking for innovative and sensitive approaches for city managements.

In 2015, the United Nations published “the 2030 Agenda for Sustainable Development” which provides a blueprint sustainable development goals for peace and prosperity of people and the planet (UN - Water 2019). Sustainable Development Goals (SDGs) describes 17 objectives need to be achieved by 2030 and three of them cover water related issues which are Clean Water and Sanitation (Goal 6), Climate Action (Goal 13) and Life Below Water (Goal 14). Management and operation of these sustainable development goals need understanding of the importance of human-water interaction with dynamic operations especially in urban areas like blue-green infrastructure network under contemporary nature-based solutions.

Climate change is the current global issue being discussed across the world. As an advanced community, the European Union has already implemented measures for the societies to adapt to the climate change. Human development in the last century has caused irremediable damage to the world ecosystem. Therefore, future steps should be taken adaptively and sustainably. As of today, the world still has a chance to be resilient but, in a few decades, we will lose this chance if the right steps are not taken urgently. Otherwise, the human society will end in violence. Adaptation to climate change requires a comprehensive approach focused not only on urban areas but also rural areas. The good news is that there is a global awareness all around the world and the actions are already being implemented in some places. Water, as one of the most concerning issue, requires an urgent consideration within the context of water heritage (Burkett 2020). For example, ICOMOS Netherlands has been researching on water-related roots of various cultures and their relationship with nature since 2012 (Icomos Netherland 2012).

Historic waterworks in old settlements are a civil engineering achievement that today we need to learn from. Today, most of them are under protection or officially designated as a heritage monument or structure for tourism but they do not spread any awareness or knowledge about how they were designed with respect to the local conditions and requirements (Burkett 2020). That is why, in this thesis, **inherited water management techniques of locals** are considered as the main source of adaptive water management for future developments of cities. The importance of water supply systems is clearly understood by the meticulous collection structures constructed by people in the settlements that have been formed for centuries across the world such as the sewage system of ancient Rome, *the Mamanteo* canals of pre-Columbians' water harvesting system and the earliest drainage system of Indus Valley Civilizations. In order to understand the importance of such historical collection structures, their site-specific design should also be studied. Thus, for an accurate identification of these design characteristics, an appropriate, feasible, and reliable approach and a conscious decision-making mechanism that promotes long-term management are required (Burkett 2020).

Especially for the water resources management and water-related problems, the idea of today's water management considerably has a conventional approach. However, there are several lessons that we can learn from our ancestors who used indigenous water management solutions to solve local problems like drought or flood. Moreover, we can integrate this inherited water knowledge with contemporary nature-based solutions for better design of the future cities. We should not forget that the future solutions are hidden in the past experiences itself. Hence, the experience is a key that can be learned from the past, be shared today, and be considered for the future. In the report of Water Governance of Cities, prepared by OECD in 2016, the general secretary of OECD Angel Gurria summaries the purpose of the report as a "3Ps" co-ordination framework with People, Policies, and Places. Different cities face different water problems, but with reliable information and experience sharing systems between institutions and people, it is possible to help improve the city's infrastructure and creation of better and sustainable future cities.

Likewise, it is known that through the history of human settlements, there have been investigations done to find, provide and protect water. All around the world, water has had been a pervasive problem of societies, and the scope of solutions that are against the issues created by cultures mostly depended on the local conditions and this respect to the local conditions created their own specific ways to deal with water issues. Therefore, when proposing solutions for any problems, along with the new sustainable technologies, one should consider city history and culture which are very essential.

1.2. Aim of The Thesis

For this thesis, inherited water management knowledge, and contemporary environmentally sensitive water management techniques are examined within an integrated framework which can ease the human effect on urban ecosystems and create unique solutions for local water stresses. In this thesis, inherited water management techniques are considered as water management knowledge that contains nature-based solutions for water management of historical and rural towns and produced by the locals. In this sense, the thesis focuses explicitly on cities inherited with the traditional knowledge of water, and contemporary cities that are using contemporary nature-based solutions for water management. With the findings, a guideline is proposed by re-integrating the inherited water management knowledge with innovative and sensitive water management techniques so-called contemporary nature-based solutions for Bodrum Peninsula in Turkey. With the aim of this, the main question in this dissertation mainly asks: "How can water heritages enlighten urban water management with the integration of contemporary nature-based solutions with a sensitive approach to the ecosystems?" To answer this question, the research presents other sub-questions of the study. These questions are listed as follows;

- How water heritage knowledge of a place paves the way for an innovative and unique solution?
- What are the innovative water management techniques with a sensitive approach to the ecosystems?

- How can an inherited water management knowledge and contemporary nature-based solutions be integrated?

1.3. Methodology

The method of the study contains three main phases: reviewing of traditional water knowledge of historical communities; evaluation of the theoretical literature of water management and analyzing the best practical approaches to water management; and the case study analysis. Depending on the findings of these steps, the study generates a guideline with integrated strategies of Blue-Green Infrastructure (BGI) components and inherited water heritage knowledge for the case study of the research, Bodrum City and the Peninsula.

The first phase of this study explores the inherited water management techniques, used and created by historical communities. This phase is to investigate a collection of inspirations from our ancestors to learn and adapt to future water management plans. For the purpose of this, book chapters, journal articles, research reports, and electronic documents were reviewed.

In the second phase, an extensive theoretical literature review of water management was carried on. Interrelatedly, water problems, water resources protection and management, and innovative nature-based solutions as a sensitive management method are described in this phase. Also, water challenges that the world and specifically Turkey has facing today are discussed under the water management title. For this phase, besides book chapters, journal articles, research report, and electronic documents, dissertations, city plans, and maps were researched. Additionally, various academics from İzmir in Turkey, and Prague in the Czech Republic, who specialize in protection of water resources, were interviewed. Furthermore, in order to understand the contemporary water management approaches and integration of water heritages with contemporary NBS, six different NBS approaches and two different good management practices from various countries have been examined.

Anatolia has a vast historical background, and even today, there are communities still using the past and indigenous knowledge. Bodrum is one of the places in Anatolia which has hidden and respectful solutions that people used for decades as water collection techniques to provide safe and clean water for themselves and their animals. Moreover, for this fishery town, water was a source of work and connection to the world. On the other hand, today, it is one of the most populous small-scale town which settles drastic summer house population and mass tourism investments. With whole this growth, in the development of the city, Bodrum has forgotten its inherited water knowledge and adapted the conventional technological solutions, which have created problems for the city instead of providing a solution. For example, traditional streets of Bodrum which turns into flowing creeks during rain are called “Irme streets” by the locals, today are covered by asphalt surfaces that are unable to infiltrate the rainwater anymore. These changes do not only damage ecologic life but also traditional local methods and people spiritually and materially.

In the case study, a guideline is proposed which explains how inherited techniques can be integrated with contemporary solutions for adapting sensitive and sustainable water management. The case study area is chosen as Bodrum Peninsula in Turkey due to its vast inherited water supply techniques adapted by the inhabitants till the near past.

1.4. Structure of the Thesis

The thesis consists of five main chapters, each with a different focus. In the first chapter, the establishment of theoretical frameworks, including the statement of the problem, study objectives and methodology. In the second chapter, an extensive literature review of the traditional way of water management investigated from historical cities and searched for what remains till today. The third chapter introduces current problems related to the urban water cycle, also contains a comprehensive literature review about evolution of city water management systems and water problems of the World and Turkey. Finally, the chapter introduce innovative nature-based solutions and compare different approaches of contemporary cities for sensitive water management and try to evaluate some good examples of integration water heritage with current water management. Chapter 4 gives information about the case study of the research: Bodrum Peninsula and the city center. As a result of this chapter, a guideline proposed for combining inherited water management methods with contemporary nature-based solution techniques. Lastly, the final chapter includes the main conclusions.

CHAPTER 2

INHERITED WATER MANAGEMENT METHODS

This chapter presents a general overview of the different historical periods related to their traditional water structures and knowledge and how those structures survived until today. It envelops extensive examples of localized water management methods from different cultures around the world. Later, water scarcity and general water problems are investigated, which caused failures of the communities, and the solutions that old communities had used to fight with water issues, are discussed. After presenting the general outline, inherited water management methods, their implementations, and importance are examined for present and future problems. Finally, in order to evaluate the chapter, the main elements of water management tools that had been used, are discussed to have a contribution to long-term sustainability.

2.1. History of Water Structures and Management Methods

Transition to a settled life for communities has been started by a search for freshwater for their existence. Civilizations and societies settled their cultures and traditions through the water. They learned how to deal with water. They respected the water and protected it carefully. Throughout the history of humanity, the rise of communities took place thanks to water management of the settlement, and again the collapse of the societies manifested due to drought or deficiency of water. Thus, how scarcity or excess of water affected the decline of civilizations and stimulate social conflicts or complexities, are tried to be examined by traditions through history. By this means, in this part, reasons for the creation of water structures by civilizations and their purpose of usage are discussed to interiorize and adapt them for the future.

Ongoing relations of water and societies during centuries could show us essential facts which can enlighten the future of current cities. Mays et al. (2013), in their research, make a comparison of the water technological developments for several civilizations and claim that these technologies can be a directive for modern achievements in water engineering and summarize as "*the past is the key for the future*." From pre-Columbians to Anatolia, from Mesopotamia to Indus Valley, Civilizations had figured out their own indigenous solutions for water collection and use it back for utilities. Sulas and Pikirayi (2018) say in the book Water and Society that tradition together with history as a unique archive provides us with different examples of how scarcity and excess of water have caused to happen the decline of ancient civilizations as well as a driver for developing social complexity. Surviving human life always have been in connection with the adaptation of the natural environment (Ertsen and Spek 2009). In the book Water and Society, Sulas and Pikirayi (2018) underline three critical aspects for the availability, management, and conservation of water heritage in the discussion of global challenges, resilience, and sustainable development are significantly recognized as fundamentals for understanding and mitigating water, people, and environment dynamics. Firstly, the consensus believes increasingly that historical knowledge can provide essential information to address present water challenges and resilience. The second key aspect is that history offers unique opportunities to appreciate the pattern of solutions and mechanisms of societies that have developed over time to deal with water in all its forms from rainfall to groundwater and soil moisture. Lastly, the traditional rural-urban divide has begun to diminish as the results of the notions of life-supporting systems, and blue-green infrastructure enables a recognition that conditions in the countryside and local ecological knowledge have a direct impact on urban dynamics as much as these shape the needs of, and demand for, water and food.

The importance of local and indigenous knowledge now is under discussion for adaptive management of cities with the growing concerns about climate change. Understanding old systems for reusing, adapting and redesigning may be partly responsible for the life of the communities and the sense of place and self-identification (Hein, et al. 2020). Using technological solutions have always been a way to adapt to the natural environment for humanity. However, nature-based solutions and blue-green infrastructures are currently found new technical solutions with sensitiveness of locality and nature for densely urbanized concrete cities, which cause more CO_2 emission, more heat islands, and less precipitation. Water has been used for various purposes throughout human history. Freshwater resources have always been a priority for civilizations but together with supply of freshwater, irrigation systems are also one of the essential technological improvements that have been invented by civilizations and used for the purpose of food production (Ertsen and Spek 2009). In the figure 2.1, the locations of historical city examples are shown which had special water management methods for providing and protection of water.

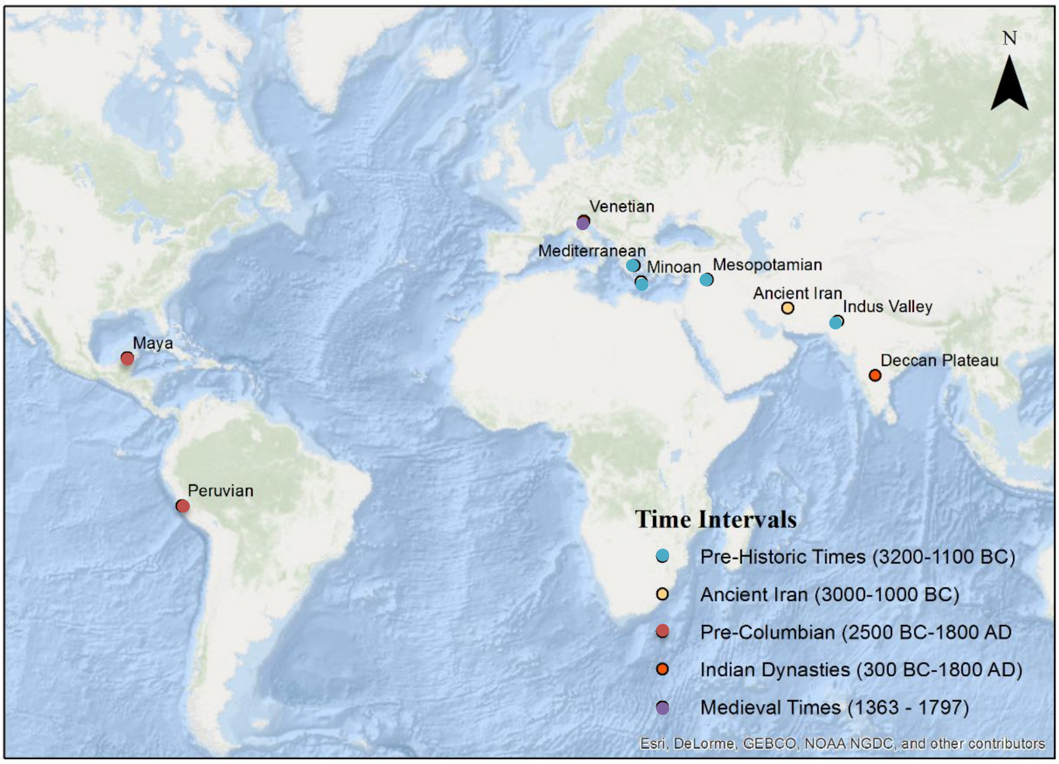


Figure 2.1. Water Management Examples of Civilizations
(Source: prepared by the author)

Freshwater supply systems have been played an important role for development of cities with the purposes of carrying, catching and harvesting the water from rain and runoff. Thus, water cisterns are known as an essential element of ancient cities, especially in arid and semi-arid regions. For instance, during Roman era, because of the growing population, water cisterns were the main infrastructures of the cities. Today, these structures are still in use in some part of the world and part of a sensitive design approach.

2.1.1. The Minoan Rainwater Cisterns and Dams

Ancient Crete, as an island in the middle of the Mediterranean Sea, was the place urban water management of ancient Greece appeared. Especially, Minoan civilization (ca. 3200 – 1100 BC) which was the largest Neolithic settlement in the Aegean Sea, is famous with their water structures and sewage systems. Their cistern type was cylindrical shape, constructed with stones under the soil surface with diameter ranging from 1.5 to 7.0 meter and depths ranging from 2.5 to 5.0 meter (Figure 2.2). The prevention of water loose from the surface and walls was provided by a hydraulic plaster (Mays et al., 2013).

Figure 2.2. Minoan Cistern at the Ancient Town of Tylissos, Crete
(Source: Angelakis & Spyridakis, 2010)

On the other hand, Minoans were impressive with their complex water management systems. Those systems which were included check-dams for the purpose of slowing runoff, dams made by stone and soil to catch water in big reservoirs and retention walls for prevention of erosion, were built to conserve and to control water (Baba, et al. 2018).

2.1.2. Indus Valley Water Reservoirs

Civilizations of Indus Valley are very well-known communities by their water management from freshwater supply to sewage systems. One of the best known Harappan city, Dholavira has various developed techniques to conserve, harvest, and store water for usage of the citizens (Baba, et al. 2018). Because of the semi-arid region conditions, there were no available water sources for each season. These natural conditions made Dholavira create a series of 16 reservoirs system to collect the monsoon runoff with the help of existing slope (Figure 2.3).

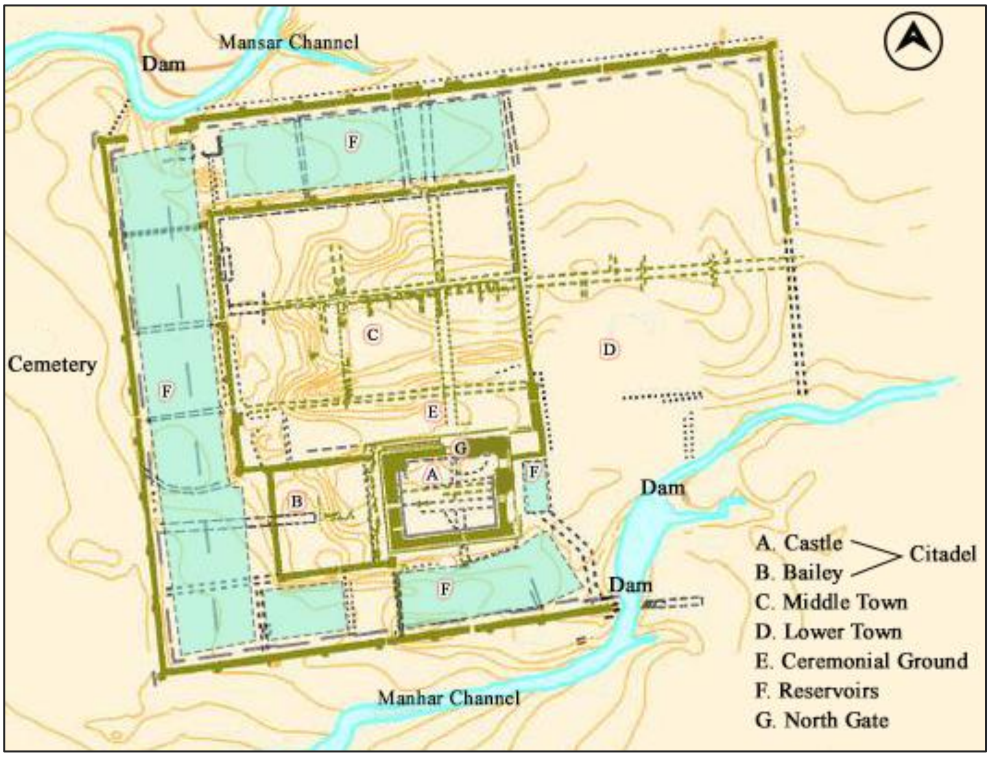


Figure 2.3. The Water System of Dholavira
(Source: Url1 and modified by the author)

2.1.3. The Mayan Cistern System

On the other side of the world, another civilization created its water collection and protection way. Maya lowlands cover about 250,000 km^2 today in southeastern Mexico, Guatemala, Belize, and Honduras. Inscriptions and iconography of pre-Columbians show how fundamental water was for the Maya, and how rainfall was vital as the major part of water dependency. According to seasonal expectancy, Mayas dealt with excessive or insufficiency of water by controlling or distributing it. Freshwater security was addressed by two leading hydro-technological solutions: large open still-water reservoirs and small underground water cisterns. Both captured and stored rainwater for multiple purposes like household consumption, garden and field pot irrigation and in ritual and ceremonial activities. Household cisterns were constructed by excavating a chamber in the soft marl layer of the bedrock, typically in the center of the residentiary patio group. Rainwater filled the cistern through a narrow, circular, vertical tunnel, and cistern walls were lime plastered to prevent seepage. Isendahl et al. (2018) mentions about freshwater security and community wealth of Maya lowlands. For instance, the cisterns were the primary source of water for domestic use in each residential unit and, to construct and provide maintenance on cistern was common knowledge or required skilled artisans. Cistern construction may have organized by the responsibility of household heads, assisted by household dwellers and neighbors, and with some element of consulting with an experienced and skilled cistern-builder in a system of obligations within the urban neighborhood level of social organization (Isendahl, Lucero ve Heckbert 2018).

As an outstanding example, the Chultun (Figure 2.4), which is underground rainwater storage, shows the success of the management of rainwater of the Maya civilization. Thanks to the Chultun cistern system, Mayans provided potable water to their large population in the region of Yucatan Peninsula where there are not any natural water sources.

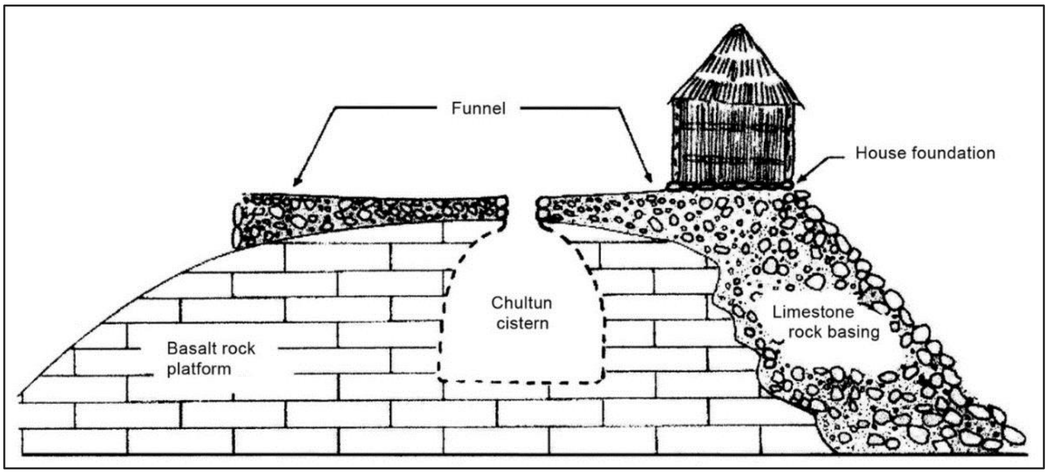


Figure 2.4. Maya Chultun Cistern
(Source: Url 2)

2.1.4. The Venetian Well-Filtered Cisterns

Another type of cistern technique was used during the Venetian period called a well-filtered cistern (Figure 2.5). Approximately between the years 1204 and 1668, the kind of Venice cisterns spread around some parts of Europe (Mays, et al. 2013). This high technology of the era was collecting the surface runoff from the drains located on the surface and was filtering the water to inside the cistern. As being a water city Venice had generated the technique to supply freshwater which is another good example of local solutions.

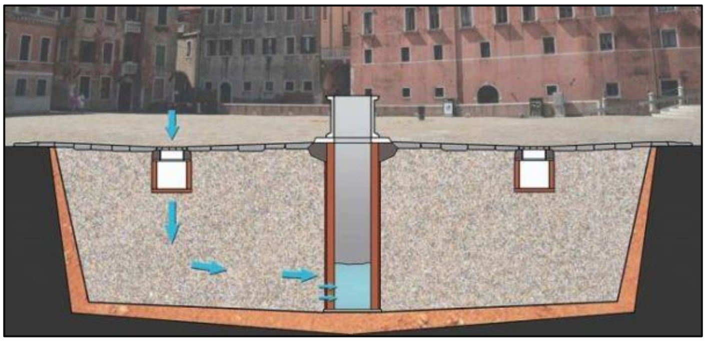


Figure 2.5. Section of a Venice well-filtered cistern
(Source: Url 3)

2.1.5. Early Mesopotamian Irrigation Systems

According to the current evidences, the oldest irrigated agriculture was made in Egypt near Nile River around 5000 BC which was using the peak of flood (Angelakis, et al. 2020). A similar system was adopted in Mesopotamia near the Tigris and Euphrates Rivers which consists of connection of canal systems through the ancient Semitic city-state, Mari.

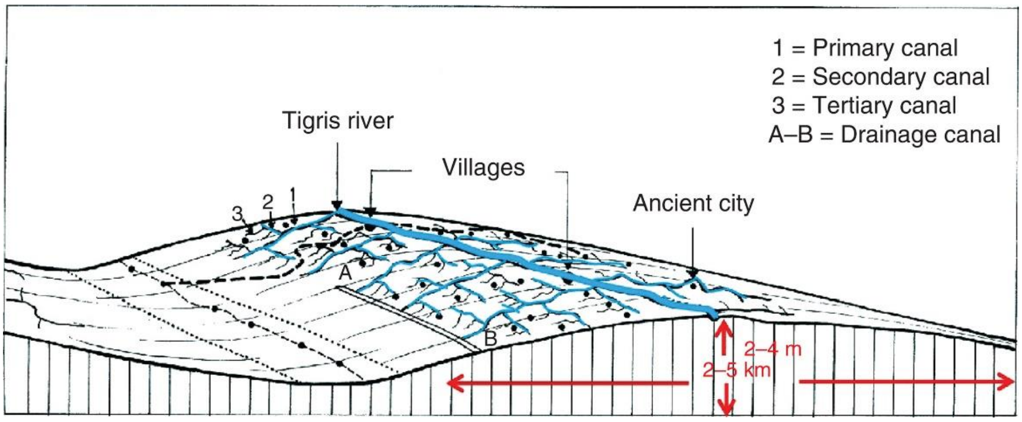


Figure 2.6. Ancient Mesopotamian Irrigation System
(Source: Url 4)

2.1.6. The Irrigation Systems of Mediterranean

From the beginning of early settlements, city structures always designed according to water conditions. Due to the climate conditions of the Mediterranean Region, some of the techniques such as drainage systems, horizontal wells like qanat system, simple irrigation systems, dams, weirs, dikes outwards, etc. are adopted and/or created in Mediterranean empires. The most known water supply structures of the region date back to the primeval era in history. However, historical irrigation systems of the Mediterranean are not well known. Civantos (2018) investigates these historical irrigation systems and highlights that these systems are still in practices thanks to the local population which conserve the traditional ecological knowledge. However, these systems are under threat of senseless modern techniques or abandoned because of urbanization (Civantos 2018).

In the Greek settlements, irrigation and reclamation techniques were used. The climatic conditions were few major rivers and scant moisture in summer, so irrigation and economy of water use were considered carefully. Small dams built up, and water-wise plants were used. Moreover, the success was because of restricted irrigation and good drainage, no accumulation of salts and alkalizes in soils.

However, even in those advanced empire cities because of the growth of population created demand for food. Excessive usage soil and water caused saltiness, alluvial lost, and as a result, fertility of soil became vulnerable. Soil depletion led to stronger competition for remaining resources. Consequently, over-irrigation brought the end of the city-states.

2.1.7. The Deccan Plateau Irrigation Systems

Very fragile agriculture of India is depended on its summer monsoon and with the changing climate, the drought is affecting the India severely. On the other hand, through the history of Indian civilizations, there are many water management and conservation systems that should be a lesson for today's management.

As a different irrigation technology that had been used for several millennia in the agricultural field of Indian Plateau, "tanks" were an important part of the local method. On the other hand, water systems of the Deccan Plateau have various names changing according to the localization and usage like the Ramtek model of water harvesting structures locates in the town of Ramtek, Maharashtra, Phad community-managed irrigation systems locates around the northwestern Maharastra, Kere tanks locate in the central Karnataka Plateau, and Kohli tanks locate in the district of Bahandara, Maharastra (Chaturvedi 2018). A "tank" can be explained as a "receptacle" for rainwater and constructed by embankment or bund across a valley for the drainage of the valley; however another essential function of the tanks was feeding the groundwater (Ramesh 2018). In the plateau, more than 150,000 irrigation tanks located in hydrologically suitable areas, are known as useful to capture rainfall and are incredibly vital for irrigation. However, such fragile but straightforward systems during British occupation were suffered due to dilapidate. Then during post-independent India, the tradition was continued to be ignored by governmental decisions and instead continued constructing a dam or digging tube-wells, which caused a permanent failure of irrigation. As a result, the Deccan Plateau's new water supply network has failed due to the governmental decisions that ignore the traditional water harvesting system (Sulas and Pikirayi 2018). Currently, there are still remaining tradition of water in India which should be seen as living examples of sustainable technologies (India Water Portal 2016).

Figure 2.7. The Tank named as Karez in Bljapur, India
(Source: Url 5)

To sum up, the Deccan Plateau, as a geographical zone has various types of traditional and historical water systems. It is important to underline that all these different types of water system traditions are not only architectural and engineering success but also, being a remarkable resource for sustainable and resilience development plans of the area (Chaturvedi 2018).

2.1.8. The Qanat System

The qanat system is a method of irrigation developed in Ancient Iran by the Persians. The pressure of urbanization, growing population, and the new world demands made them be forgotten and use modern techniques instead, which was not dealing with the local conditions and realities. Bensi (2020) in the paper criticizes the current situation of the system with a more in-depth look and claims that even though the system seems an out-of-date solution for growing demands of the new world, actually it is more than a technical solution to the purpose of access to water in case of irrigation and urbanization. During World War II, the system changed with deep wells because of the possibility of providing faster and more water than qanats, and there was no need to consider topography and soil conditions. However, eventually, it causes taxation on the water source, capitalize the source and empty aquifers. So, basically, the condition shifted from collective legal action to exploitation (Bensi 2020).

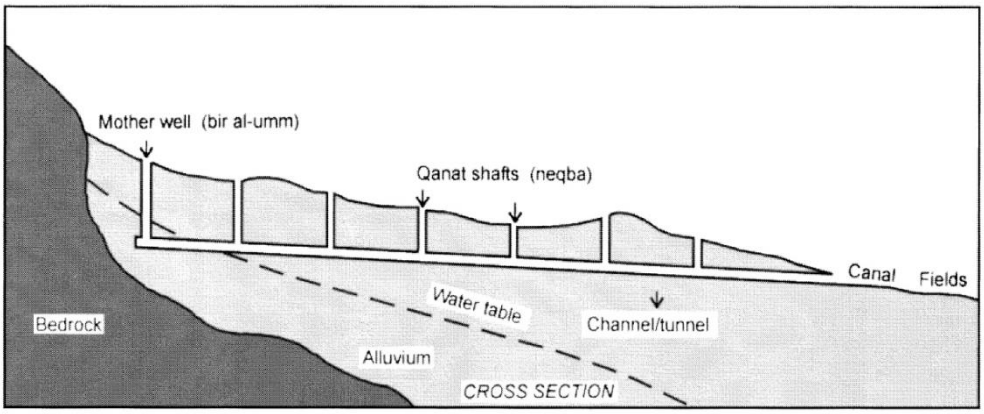


Figure 2.8. A Typical Cross-Section of a Qanat
(Source: Url 6)

There are various local names of the qanat system from around the world such as *livas* in Gaziantep Turkey, *kehriz* by Uyghurs, *galerias* in Spain.

Figure 2.9. A kehriz is using by Uyghur Women for washing dishes
(Source: Url 7)

Today there are some villages where the qanat system still in use in Iran and also in different part of the world (Figure 2.9). The rest abandoned or used for tourist attraction. However, Bensi (2020) focuses on understanding the logic and complexity of the system rather than functionalization of the existing structure for alternative usages.

2.2. Water Structures of Anatolia

Anatolia represents a wide range of water and society relations. In the history, various societies inhabited in Anatolia at different time scopes and all of them had dealt with water scarcity or deficiency by different water infrastructures like aqueducts, cisterns, wells, irrigation canals and dams. (Arikan 2018)

During the first half of the 1st Millennium BC, there are similar waterworks with the "qanat" system constructed by Urartian civilization in the eastern part of Anatolia. The considerable period of water structures of Western and Southern Anatolia had happened between the second half of the 1st Millennium BC and the first half of the 1st Millennium AD during Hellenistic, Roman, and Byzantine periods. During this period, on the behalf of water supply and conveyance structures, aqueducts, lead-pipe inverted siphon, dams, and cisterns were constructed. (Öziş 2015)

2.2.1. Ancient Irrigation Systems of Anatolia

The oldest water structures of Anatolia dates to 2nd Millennium BC, constructed by the Hittite civilization. The water structures of Hittite's were varied according to the needs of settlements like dams, spring-water collection canals, and irrigation systems. In 2002, by Aykut Çınaroğlu and his crew, a Hittite dam was discovered within the borders of Çorum province which is considered as the oldest water structure in Anatolia (Kuşlu and Şahin 2009).

As understood from the cuneiform writings of the Hittites, they were aware of the value of rainwater in the arid land of central Anatolia (İnal 2009). In order to catch the flood and use the water for irrigation, they built several dams, some of the most knowns are Karakuyu dam in Uzunyayla, Güneykale dam near Boğazkale and Gölpınar dam near Alacahöyük (Öziş 2015). According to the excavations in Gölpınar dam, Hittites were using different size of stones for embankment and lower part of the dam. The stones on the lower part of the dam are bigger and reinforced with hardpan to minimize the permeability (Baba, et al. 2018).

Another irrigation system example, dams, water reservoirs and irrigation canals of Urartian period were made with a great understanding of the local conditions which makes some of them still in use like the dams at Keşiş, Doni and Süphan lakes (Baba, et al. 2018). Another water structure of Urartu period which is still in use and one of the oldest is the Şamram canal. It is 56 km long and irrigates 2000 ha today (Öziş 2015).

2.2.2. Hellenistic – Roman – Byzantine Freshwater Systems

Anatolia has an abundance of water works of ancient civilization and especially cities of Hellenistic, Roman and Byzantine periods have a special importance such as Priene, Miletus, Ephesus, Pergamon, Hierapolis, and İstanbul (Öziş, Alkan and Özdemir 2020). Cisterns are important freshwater collection structures of these periods;

particularly, they were used to keep pluvial water in cities on the western side of the Anatolia for dry seasons.

One of the outstanding examples of cistern system is in the Termessos ancient city on the northwest of Antalya. According to the Kürkçü's Survey Report (2010) 14 different cistern forms were discovered and the biggest cistern was found in the agora which has a capacity of more than 1500 m^3 (Figure 2.10) (Kürkçü 2010). On the other hand, cisterns of İstanbul are great examples of their times (4^{th} -6^{th} century AD).Especially, during Byzantine period, hundreds of cisterns were constructed to support the city population (Güngör 2017).

Most of the ancient settlements that discovered from Hellenistic, Roman and Byzantine periods have their water supply systems. These systems consist of spring-water collection chambers, rock-cut and masonry canals, tunnels, inverted siphons and aqueduct-bridges (Öziş, Alkan and Özdemir 2020).

Figure 2.10. Cistern in the agora of Termessos which has tree cylindrical room covered by domes. (Source: Kürkçü, 2010)

2.2.3. The Ottoman Period Freshwater Systems

Ottomans were careful about supply and fair distribution of water. During the Ottoman Period, major hydraulic works developed and cisterns, especially in İstanbul were changed their role with centralized water systems. However, specifically during this period, circular type of cisterns emerged in rural areas, mostly in southwest Anatolia

(Mays, Antoniou and Angelakis 2013). The general water policy of the Ottoman was based on the right of use rather than the right of property (Uçar 2017).

Muğla has many examples of water cisterns in its urban and rural areas. Some of these cisterns are still in use for local people or animals but most of them were abandoned to their fate. Cisterns were constructed on settlement, on roads between settlements, and open areas and the location choice of cisterns was made mostly based on topography, waterways, underground water resources and precipitation of the region (Öter 2008).

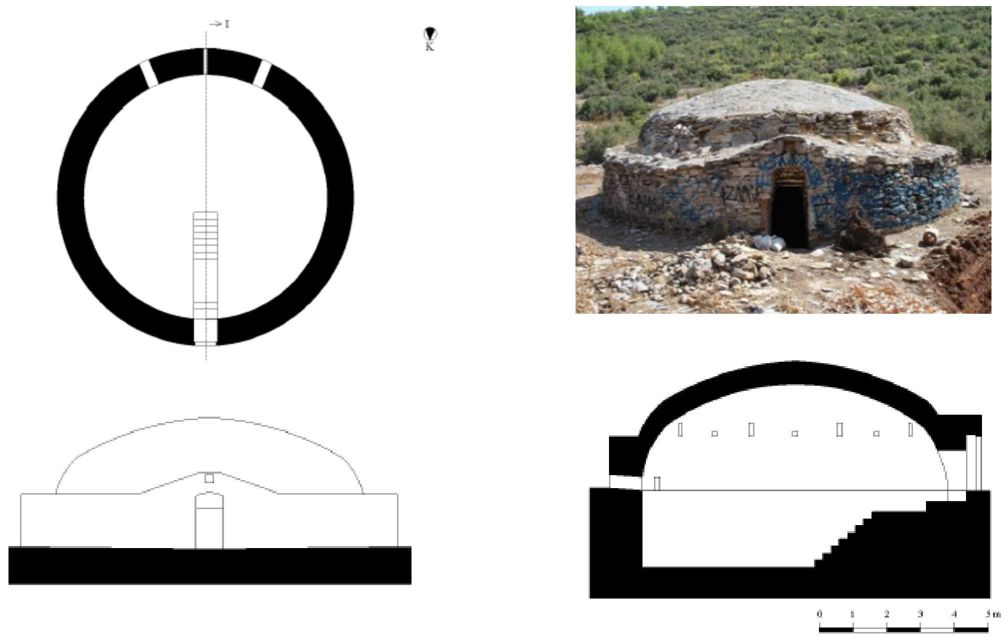


Figure 2.11. A cistern in Muğla located near a road with its top view, side view and section (Source: Öter, 2008)

Unfortunately, there is not enough studies about these cisterns yet. According to some of their tablets, the earliest examples are dating back to 16th century (Mays, Antoniou and Angelakis 2013). Most of them were built by philanthropists of the region and even today cisterns are known by their name (Öter 2008).

Another interesting example is historical water management system of Gaziantep. Current findings show that there is a complex underground water supply network which can protect the water from hot and dry climate of the region. The main purpose of these underground canals to carry water from a source located outside of the city to the city center. These canal systems called “livas” in local dialect are similar to the qanats.

Figure 2.12. A "Livas" Canal Link
(Source: Uçar, 2017)

2.3. Evaluation

This chapter shows the similarities and uniqueness of the behaviors and responsibilities of different communities from different places of the world towards the same problem. Every day, researches about water management of old communities are growing. This topic is not only essential for our past illumination but also, inspiration for our future. Apparently, the decisions and measures taken by neighborhood communities have played an essential role in the continuity and resilience of these societies. Although there is a vast-time difference between some of the management systems, societies found eventually the best solution to the problems with collective mind and solidarity.

These locale-specific systems developed by hundreds of civilizations have been forgotten mostly due to external interventions (like colonization) or extreme climate changes. However, these systems show us the importance of integrating with local resources, recognizing natural possibilities and acting accordingly, as well as the responsibility of the citizens. Even though the purpose of humanity aims the same, creativity, originality and compatibility brought by possibilities should be an example for today's uniform management systems. Accordingly, the greatest value of this section adds to this thesis is how important it is for local governments to evaluate the originality and knowledge of the local.

In this context, with the awareness of the locality framework, this research emphasizes the importance of local knowledge for a comprehensive urban management plan. Therefore, to reach and learn from the local water knowledge of the case study area is taken as a first step for the guideline proposal of BGI network development plan.

CHAPTER 3

WATER RESOURCES MANAGEMENT AND CONTEMPORARY NATURE-BASED SOLUTIONS

Chapter three presents an overview of the basic water-related concepts to find out which components are necessary for better water management systems in urban areas. Water management has different concerns, mainly environmental, social, and economical. For this purpose, firstly, the problems of water around the world, and Turkey are discussed to understand the importance of water and the dangerous effects on environmental, and social health. Then, water management and protection of water sources are indicated as theoretically and nature-based solutions (NbS) as a new approach to urban water management is explained. Moreover, importance of stormwater and its management in urban areas are specified and blue-green infrastructure (BGI) is introduced. After presenting the theoretical literature, a practical literature review of good water management examples around the world is shown.

3.1. Water Problems

75% of a human body consists of water and similarly, 71% of the earth's surface is covered by oceans, glaciers and ice caps, rivers, lakes, and pond, in-ground aquifers and vapor in the air. Scientifically, water described as a common chemical substance and essential for all known forms of life to survive. As the most essential natural source, water exposes to various natural and anthropogenic impacts which makes the water inaccessible and insufficient for all. By the UN-Water, current issues of water stated as climate change, disasters (floods, landslides, storms, heat waves, drought, etc.), ecosystems (forests, wetlands, grasslands) which mitigate the effects of disasters and organize the water cycle, human rights, scarcity, transboundary water bodies, urbanization, quality and wastewater, and food and energy.

3.1.1. Climate Change

The effects of humans on the climate system have been discussed by the United Nations from the end of the 1980's. the United Nations Climate Change Environmental Agreement was established in 1992 for the purpose of reducing the negative impacts on the climate. Following this, in 1997, the Kyoto Protocol (KP) was signed at the third session of the Conference of Parties (COP3) in Kyoto, Japan. The target of the KP is an agreement on reducing greenhouse gases all around the world, which is necessary for climate change mitigations and accordingly, differentiation the responsibilities due to the possibilities of each country. Later, in 2016, the Paris Agreement was signed within the United Nations Framework Convention on Climate Change to recognize need of an effective and progressive action to the threat of climate change with the guidance of the best possible scientific knowledge. The long-term agreed achievements of the Paris Agreement are to keep global average temperature up to 1.5 ^{o}C above than its pre-industrial value (COP21 2015). Today, the temperature of the world has increased almost 2^{o}C, which means each country, organization, and community must immediately act both individually and collaboratively. UN-Water is underlining that active countermeasure of climate change mediates significant benefits like coordination and sustainable measures in levels of countries and international river basins. Water is an integral part of mitigation and adaptation procedures for climate change. There is no other way to think that global climate crisis is directly linked to water. The effects of the climate change on water cycle are more extreme weather events, incorrect predictions of water availability, reducing water quality and threatening sustainable development, biodiversity and human right to access water and sanitation worldwide (UN - Water 2019).

Another considerable part is finance for water resources management and sanitation for a better climate change mitigation measure. Mostly, the main barriers are lack of capacity and lack of institutional coordination. However, to overcome these obstacles, support is needed for local level job opportunities through green works and improvement of sustainable development outcomes. Also, innovative finance solutions which can bond green and blue climates, can influence the economy.

3.1.2. Water Pollution

Water as the most abundant molecule on Earth's surface cannot be considered as a renewable resource because of the pollution. Water quality are classified under 4 different quality parameters; physical and chemical parameters, organic parameters, inorganic parameters and bacteriological parameters. According to these parameters, the water quality degree is classed from I as good quality to IV as bad quality (Uslu 2020). Basic physio-chemical parameters of water quality are conductivity (mS/m), oxygen reduction potential (ORP) which states the condition of water as anaerobic, aerobic or anoxic; sensorial parameters can be described by human sense like temperature, color, odor, taste, transparency and turbidity, and pH. Water pollution can be caused by natural causes from the atmosphere or soil and bedrock, or by anthropogenic causes such as untreated wastewater (industrial, municipal) or air pollution.

Conventional stormwater drainage systems are able to collect and carry gross pollutants like large amount of rubbish, leaf litter and other refuse into receiving waters (Walsh, et al. 2004).

3.1.3. Water Scarcity

Water scarcity is a term used to express the lack of freshwater supplies for every user and habitats. Figure 3.1 shows the places of the world where there is less availability of water than 1700 m^3 per capita per year. 1700 m^3 per person is determined value for water scarcity annual threshold and availability of water less than this value indicates water stress (Uslu 2020). If the amount of renewable water is below 1000 m^3, it is indicating water scarcity and below 500 m^3 is an absolute scarcity (Altınbilek and Hatipoğlu 2020). According to the UN-Water, water scarcity can be lack of availability due to physical shortage, lack of accessibility because of wrong management or inadequate infrastructure. As a related term water stress describes the total demand for freshwater in a certain period that is more than a region can supply. Also, poor quality of water can affect the supply availability (Greenfacts 2020). While the demand for freshwater is growing rapidly and the supply is not, there are already almost 1.5 billion human lives in a water stress area and it is not clear how many animals (Kallen 2015).

With the consideration of water as finite resource, international and national organizations and initiatives are in discuss for global sustainability achievements such as in 2015, the United Nations agreed on the 2030 Agenda for Sustainable Development. Out of decided 17 goals, the 6th goal is “water and sanitation” which targets ensuring availability and sustainable management of water and sanitation for all. In 2020, almost all over the world, freshwater scarcity is a fact that people are experiencing, or it is a threat that people will be experiencing. The estimations of the United Nations show that if the trend goes similarly like today, then between 4.8 and 5.7 billion people could be suffering from water scarcity heavily at least one month in a year by 2050 (UN - Water 2019).

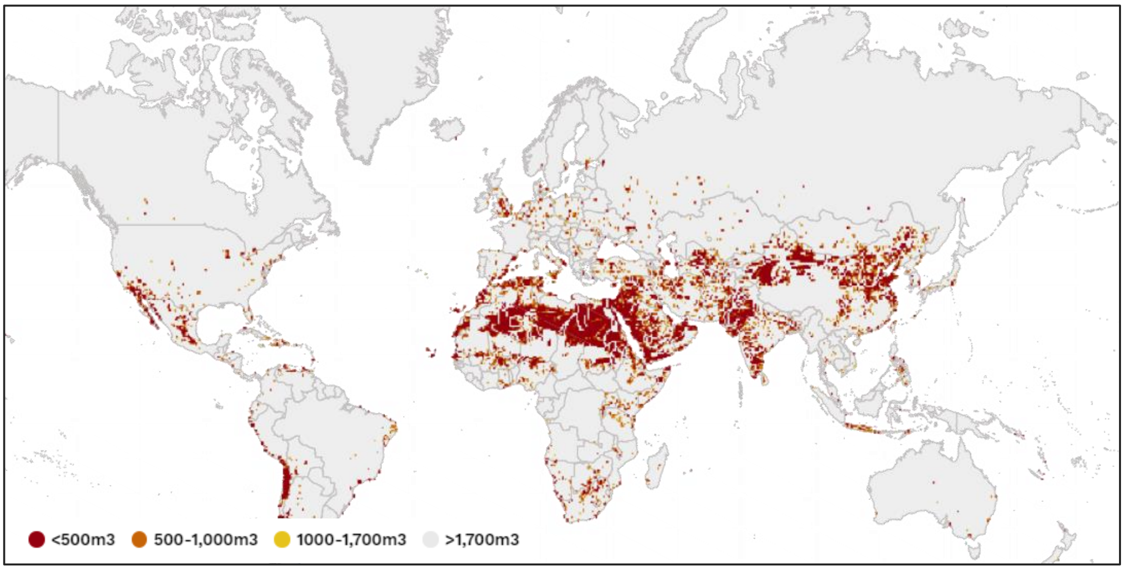


Figure 3.1. Average Water Availability Per Person for 2020
(Source: Url 8)

Today water issues take a gain of importance that being discussed in every meeting for climate change. However, water scarcity is not a new term that we are discussing today only because of climate change. Because of the rapid growth of population, even we can say that scarcity is a term close relatedly with population growth and as a result of population growth, rapid and uncontrolled urbanization. A given description of water scarcity is that water scarcity "is a decrease in the volume of water available per capita over time" (Turton and Ohlsson 1999) In another article of Turton (2002), description is stated as "is the condition that exists when the demographically-induced demand for water exceeds the prevailing level of local supply". Beyond that, water scarcity is a public health concern that can cause sanitation, hygiene, and disease prevention problems. According to the World Health Organization's estimation, the need for clean, freshwater is changing from fifty to one hundred liters per person per day for basic needs and health care. So, the deficiency of freshwater can have a severe impact on public health. While assessing the problems, water scarcity can be experienced as physical or economic assets. Physical poverty mostly derived from natural situations like drought or inadequate groundwater, whereas economic scarcity can be concerned with insufficient infrastructure systems for the distribution of water to people or lack of equal access to water services (Céleste Codington-Lacerte 2020).

On the other hand, Turton (1999), in his hypothesis, claims that water scarcity can cause social instability. In order, he is describing two transition phases. The first transition phase is occurred by the transition from water abundance to water scarcity, which then creates an alienation to the nature of people. The second transition is the transition from water scarcity to water deficit and generates a social response and conscience. So finally, with this process, some specific interest groups start to control support and begin to question and criticize governments' interpretation of the hydro-social contract. As mentioned by Turton & Meissner (2002), the hydro-social deal is an unwritten contract between the public and the government. It appears when the individual is not able to have any more enough water for their own personal survival, and thus, inevitably, the government takes place and deal with this responsibility. In the meantime, the process naturally provides a basis for institutional development and also, determines what the public presumes on to be a fair and validated practice, such as the desire for ecological sustainability, to which politicians react accordingly (Turton and Meissner 2002). Therefore, within this fact, each administration and culture should protect and support their local water cycle for future threat of water deficiency and scarcity to sustain social stability and justice.

3.2. Water Resources Management and Protection

With the development of the population, the usage of water has been increased significantly. Today, like electricity, industrial production, agricultural production, recreation, etc. every living part of cities needed freshwater resources. Furthermore, these developments have been fragmented and cut off the landscape matrix and its natural cycle. With all these growing cities and city needs especially after 1980's in accordance with the neoliberal politics, constructing, financing, and management of water supply infrastructure significantly has been increased, and between 1987 and 2000 just in developing countries, 183 water and sewerage projects were set up with private and state cooperation (Bakker 2003). All behind these evolvements, humans forgot about the natural cycle and turned towards only technological solutions. Besides of inherent value of water, it also has socio-political dynamics that have described under the “hydro-social contract” concept. The existing unwritten contract between governments and society seeks a safe and sustainable source of water. Thus, this vital and urgent need for clean water creates central authorities for supplying clean water and sanitary services. However, since then, water has become a commodity instead of being a source of life (Turton and Meissner 2002). In brief, the conventional approach of water services, besides providing clean water to society, also created a market value for water that people need to pay taxes, utility bills, or bottled drinking water.

Today, in most cities, water resources managements rely on human-built (grey) infrastructures. The report of the UN-Water (2018) underlines, instead of being only dependent on grey infrastructure or replacing them totally with nature-based solutions, a balance should be caught by identifying the appropriate, cost-effective, and sustainable way. As P. Gleick (2003) undermines that besides of remarkable benefits of "hard path" solutions such as solutions for sanitary problems in big cities, decreasing the problems caused by floods and droughts, hydropower energy, irrigated agriculture, etc. which dominated the 20th century they have been caused significant degradation of nature, replacement of billions of people, unexpected social and economic problems and more importantly, it is realized that they are not the solution for the basic human needs for all. On the other hand, P. Gleick adds that the new approach to water has been changed to "soft path" solutions, which means briefly decentralized and integrated water management (Gleick 2003).

On the other hand, with the help of technology and science, while approaching the millennium, the world has started to recognize the damage on the earth and how fast this damage is returning to humans. With the environmental movement of the 1970s, a new approach to water resources management had become a current issue, and large-scale water projects has begun to be criticized. The first major international conference which were concerned about protection and improvement of environment, was the United Nations Conference on the Human Environment (UNCHE) held in Stockholm, Sweden, on 16 June 1972. The Stockholm Conference created an awakening against environmental issues among the countries.

The evolutionary start of more holistic urban drainage terms was dating back to the 1970s. It started with the term of low impact development (LID), which first appeared in the report of Barlow et al. (1977) for land use planning in Vermont, USA. It was considering “design with nature” approach for minimizing the cost of stormwater management. The most persuasive early use of the term was in the early 1990s in Maryland, USA. It was used to indicate the distinction between the site-design and catchment-wide approach and the common stormwater management approach. Later on, the term as an approach seen in different places, particularly in New Zealand. Similarly, in the UK, new approaches to stormwater management had started to be discussed during the 1980s and the first implemented example of sustainable drainage system (SuDS) was constructed in Wheatley, Oxfordshire in 1997 (Susdrain 2014) . Water Sensitive Urban Design as a term was first used by Mouritz (1992) and then in 1994, a report was prepared for the Department of Planning and Urban Development and the Water Authority of Western Australia by Whelans et al. (1994) which describes the objectives of WSUD as managing the water balance, improving the water quality, support water conservation through harvesting, recycling, and improving water-related environmental and recreational life. Another concept Integrated Urban Water Management (IUWM) was first emerged during the 1990s and widely discussed as a new approach to urban water management. Integrated approach considers all part of the water cycle, demand of water for anthropogenic and ecologic consumption, and the balance for environmental, social and economic needs. Although the definition of the best management practices (BMPs) were universally explained as a prevention of pollution in the Pollution Prevention Act of USA in 1990, the term now refers more broadly to different scopes such as in agriculture or water management. The BMPs for stormwater was first appeared in 1987 under the EPA’s Clean Water Act (CWA) (Fletcher, et al. 2015).

Today, thanks to the growing awareness to single-mind conventional solutions for cities, the discussion and conception on alternative infrastructure solutions have been gained speed. A fair and deep connection between human and nature are the main elements of the alternative approaches for a city infrastructure all for healthy nature, bodies, and minds which will be the significant support for resiliency and sustainability. The urban water management transition framework (Figure 3.4) shows the historical evolvement through the sustainable urban water management goal which is provided by the research of Brown, Keath and Wong (2008) based on Australian cities. So, according to the research, while cities are evolving through the water sensitive city concept, both environmental sustainability and the hydro-social contract stability should be provided. The evolving trend of the water management concepts show that how social effect and service function complete each other and how much the concepts contain these elements.

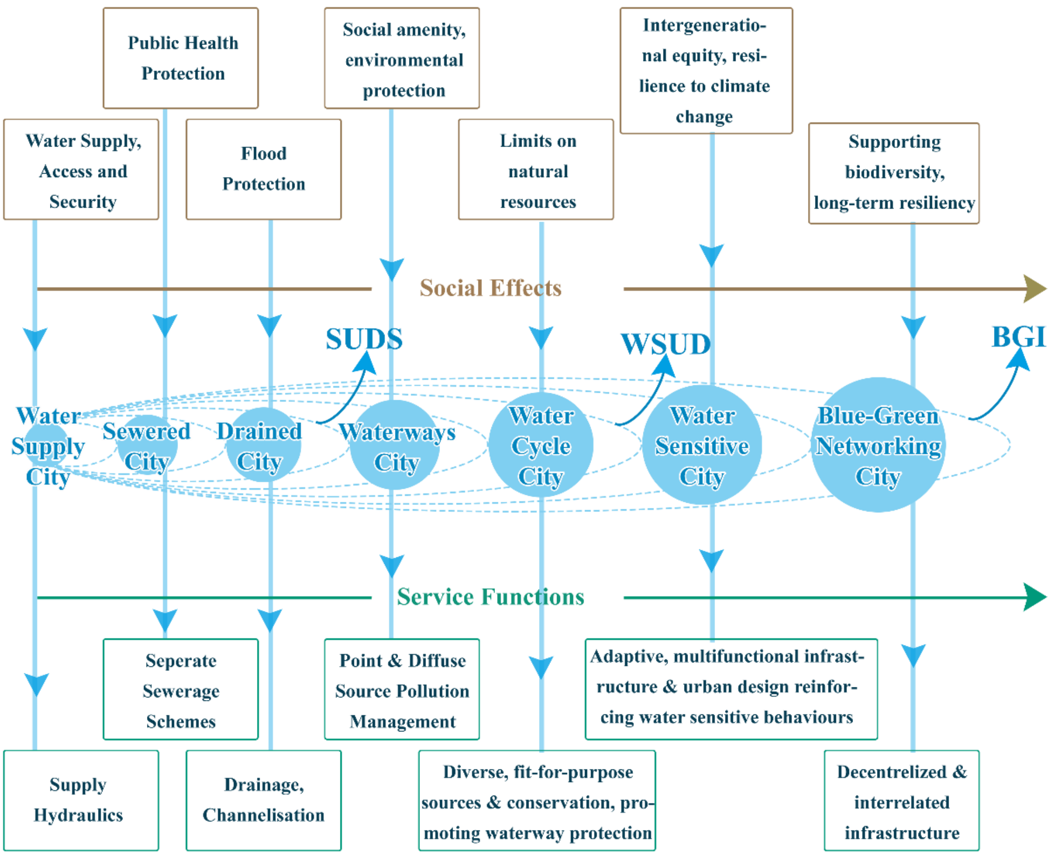


Figure 3.2. Urban Water Management Transition Framework
(Source: modified from Brown et al., 2008 and Bozovic et al., 2017)

On the other hand, there are also other studies which tries to define sustainable water management future for cities. Transitions to the Urban Water Services of Tomorrow (TRUST) as the European Union project identifies a roadmap guideline which explain transition planning of Urban Water Cycle System (UWCS) (Schwesig, et al. 2015). As another innovative solution, the Blue Green (BG) Systems brings an approach promotes a synergy between urban components and ecosystem services (Bozovic, et al. 2017).

Although the principal structure of the hydrologic cycle stays unchanged in urban areas, the needs of the urban population including water supply, drainage and sewage systems, and beneficial uses of receiving waters modified the hydrological cycle extremely which make the process very complex; thus urban water cycle (UWC) concept has occurred (Marsalek, et al. 2006). This concept gives a satisfying basis to study urban water balance and management. For an integrated urban water management, it is essential to know about the UWC main components and pathways as showed on Figure 3.5.

The UWC has two primary water resources municipal water supply and precipitation. Municipal water supply often is a source of water from outside the urban area, sometimes even from another catchment area. The municipal water is distributed to urban area for the usage of population and then by the collectors (drainage and sewage systems) taken to the wastewater treatment and eventually, after treatment back to the receiving surface water.

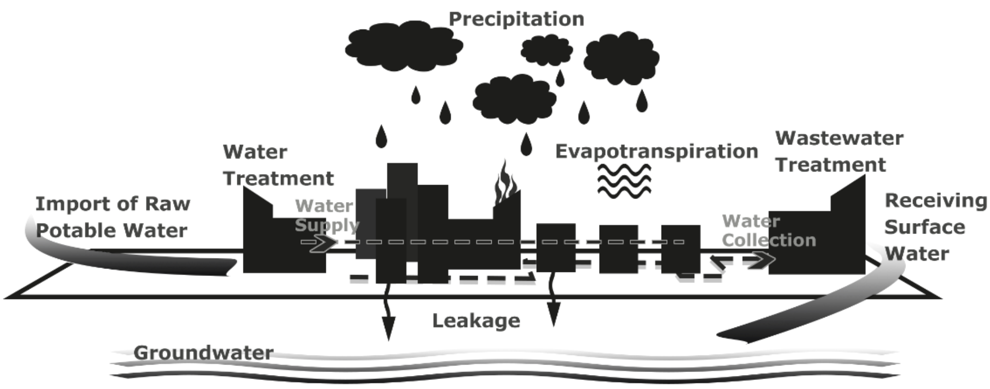


Figure 3.3. Urban Water Cycle - Main Components
(Source: Prepared by the author, 06/04/2020)

The main changes in the urban water cycle structure because of urbanization in a long-term period can cause the removal of natural vegetation from drainage patterns and loss of natural basins which store surface water. Native vegetation can help either prevent precipitation quickly from flow away or provide evapotranspiration by infiltration to the ground and then back into the atmosphere (New Jersey Department of Environmental Protection 2004).

The study of the OECD (2016) puts effort into identifying the different features and capacities of cities in OECD for providing a functional approach to achieving sustainable and sensitive water management. For example, urban sprawl puts enormous pressure on the environment more than compact cities. However, these negatives may create an opportunity for rainwater drainage, groundwater recharge, and flood and scarcity management within the different dynamics of the cities. The management of the water scale is depended on the function. For example; for potable water and sanitary services, management could be at a plot, local or metropolitan level; for water resources management, it could be at sub-basin or basin level; or flood protection could be considered at an interconnected higher level. However, anyhow multiple scales should be integrated in a basin governance system for the purpose of more efficiency usage of water resources, information sharing, and cost-saving (OECD 2016).

For these challenges mentioned above, the "3Ps" framework can guide;

- Policies: Interdependent policy mechanism, vertical and horizontal co-ordination for active management.
- People: Engagement of stakeholders like public, private, non-profit or individuals that can play a role in water management.
- Places: Collaboration of urban-rural areas which interconnected with water basins

This triple frame points out the key subjects that need to be identified for cities and sustainable management transition. With these multi-level interactions, the sustainable water management framework can be determined for each city (OECD 2016).

3.3. Contemporary Nature-based Solutions for Water Management and Protection

Contemporary nature-based solutions (NbS) can be seen as an alternative approach for urban water management like a supplemental of ‘grey’ infrastructure. They are solutions which are inspired or supported by nature and use or resembling natural processes (WWAP /UN-Water 2018). According to IUCN (2016) definition, nature-based solutions are an action to protect, sustainably manage and restore natural or modified ecosystems that focus on social challenges effectively and adaptively, and at the same time providing human well-being and biodiversity benefits (Cohen-Shacham, Walters and Maginnis 2016). The other description considers nature-based solutions as living solutions that have their inspiration and support from nature and also, use nature in design to address societal challenges within a resource-efficient and adaptive manner (Kabisch N. 2017). Diverse explanations more or less meet in a universal view, which agrees that nature-based solutions can help the living spaces to be more livable and greener while being a useful infrastructure for city needs.

Water and air pollution, mitigation of flood risk and heat islands, improvement of resource efficiency, and supply for recreation/amenity and urban agriculture can be listed as the proven benefits of nature-based solutions (Bozovic, et al. 2017). There are several types of nature-based solutions where can be implemented from an individual level to city or even regional level, which are alternative ways of water management. Specifically, on the urban scale, nature-based solutions can reduce the impacts of urbanization and climate change. The NbS are supportive of a circular economy that points out designing as restorative and regenerative and promoting higher resource productivity, which aims reducing waste, avoiding pollution. The co-benefits of the NbS can be listed as social, environmental, and economical, like improving livelihood quality and human health, rehabilitation, and maintenance of the ecosystem, protection, and enhancement of biodiversity and sustainable economic growth (WWAP /UN-Water 2018)

An essential feature of the nature-based solutions is that despite the only one target by intervention, they tend to deliver groups of ecosystem services together. Nature-based solutions generally provide numerous water-related benefits and, at the same time, focus on water quantity, quality, and risks. Moreover, they can be beneficial for the ecosystem like constructed wetlands, which ones purifying the wastewater, simultaneously can be an ecosystem that creating biomass for energy production. So, the significant advantage of nature-based solutions is the help for building a long-term resilient system (WWAP /UN-Water 2018).

Realization of the role of ecosystems and the concept and application of nature-based solutions reach out to a few decades before in modern hydrological science. However, the ecosystem’s essential role already had been discovered by our ancestors, which is visible on their belief systems and traditional knowledge systems for centuries.

(Cohen-Shacham, Walters and Maginnis 2016). With the development of modern technologies and techniques, those local-cultural systems left their place to concrete and pipe solutions (conventional or grey) which do not have the sensitiveness of traditional ways for nature system. With the understanding of that conventional methods are not fair enough for environment and social benefits, as an “umbrella concept” NbS have different implementation approaches related with ecosystems such as ecosystem restoration approach or issue-specific ecosystem approach like climate change or infrastructure-related approach like green infrastructure and blue-green infrastructure which considers also aquatic ecosystems (Cohen-Shacham, Walters and Maginnis 2016).

However, since urban areas are the most affected areas by human and affecting areas to ecosystems, there are various management tools of NbS which promise to balance the urban water cycle. As an application of NbS, green infrastructure creates an alternative perspective to grey infrastructure. Still there are different discussions which claim one of them as a better solution, however, the right step would be an action which consider both option on the right place. For instance, potable water supply to households relies on grey infrastructure (Cohen-Shacham, Walters and Maginnis 2016, WWAP /UN-Water 2018).

On the Figure 3.6, green infrastructure solutions are given with their equivalent grey infrastructure solutions where they can be replaced. Also, their primary service of water management issue is provided with their application scale. Even though the scope of application can be very extensive under the NbS umbrella concept, urban scale applications were elaborated within the scope of this thesis (showed with darker blue on the Figure 3.4). Stormwater as an alternative but perhaps the most reliable water source of urban areas is an essential part of the infrastructure-related strategy for nature-based water management. That is why in this thesis the infrastructure-related approach was taken as the main discussion.

Stormwater management of NbS consists of wetland restoration/conservation and constructed wetlands for riverine flood control and green roofs, green spaces (bioretention and infiltration), water harvesting and permeable surfaces for urban stormwater runoff control. Moreover, at the same time, these solutions provide different water management services like quality regulations as shown on the Figure 3.4.

According to the policy, practice and scientific researches, the application of green infrastructures tend to consider urban areas (Cohen-Shacham, Walters and Maginnis 2016). The general service of green infrastructures in urban areas is management of stormwater for water supply, and water quality. Tools of green infrastructure for urban areas are green roofs, bioretention and infiltration spaces, tree planting, water harvesting, and permeable pavements.

Water Management Issue (Primary Service to be provided)		Green Infrastructure Solutions	Location: Watershed	Location: Floodplain	Location: Urban	Location: Coastal	Corresponding Grey Infrastructure Solutions (at primary service level)
Water Supply Regulation		Re-afforestation and forest conservation	■				Dams and groundwater pumping Water distribution systems
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Water Harvesting*	■	■	■		
		Green spaces (bioretention and infiltration)			■		
		Permeable pavements*			■		
Water Quality Regulation	Water Purification	Re-afforestation and forest conservation	■				Water treatment plant
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Green spaces (bioretention and infiltration)			■		
		Permeable pavements*			■		
	Erosion Control	Re-afforestation and forest conservation	■				Reinforcement of slopes
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
	Biological Control	Re-afforestation and forest conservation	■				Water treatment plant
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
	Water Temperature Control	Re-afforestation and forest conservation	■				Dams
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Green spaces (shading of water ways)			■		
Moderation of Extreme Events (floods)	**Riverine Flood Control**	Re-afforestation and forest conservation	■				Dams and levees
		Riparian buffers		■			
		Reconnecting rivers to floodplains		■			
		Wetlands restoration/conservation	■	■	■		
		Constructing wetlands	■	■	■		
		Establishing flood bypasses		■			
	Urban Stormwater Runoff	**Green roofs**			■		Urban stormwater infrastructure
		Green spaces (bioretention and infiltration)			■		
		Water Harvesting*	■	■	■		
		Permeable pavements*			■		
	Coastal Flood (storm) Control	Protecting/restoring mongroves, coastal marshes and dunes				■	Sea walls
		Protecting/restoring reefs (coral/oyster)				■	

Figure 3.4. Green Infrastructure Solutions with their Equivalent Grey Infrastructure Solutions
*Built elements that interact with natural features to enhance water-related ecosystem services.
(Source: WWAP / UN-Water, 2018)

All in all, besides of many advantages of Nature-based Solutions (NbS), there are some concerns and criticisms. Living vegetation inside urban areas introduce a wide range of animal species, although they have limitation due to urban surroundings. Another concern about increased vegetation in urban areas is allergens, especially pollen.

Increased vegetation density may cause feel insecure for some people, and also high moisture with watering may cause local pest population increment (Pearlmutter, et al. 2020).

3.3.1. Stormwater Management Practices of Contemporary NbS in Urban Areas

Heavy rains as the result of changing climate will cause an increase in the amount of water needed to be treated. Ultimately, urban environments and as indirectly rainwater are polluted by nutrients, hydrocarbons, heavy metals, pesticides, and animal wastes. As a result of urbanization, which is not allowing natural retention of stormwater, stormwater management is getting more and more critical for urban environments. Furthermore, a significant change can be possible by public areas in an urban area from traditional to innovative approach. Thus, in this sense, the design of the public area's effect is very considerable for urban-scapes.

There are two types of approaches to urban drainage system; conventional urban drainage and integrated urban drainage systems. Conventional urban drainage can be applied as combined sewer system or separated sewer system. The difference between these two sewer systems is that the combined sewer system carries wastewater and stormwater in the same pipe, however separated sewer system has a different canal or pipe for stormwater. On the other hand, the common idea of these systems is to try to carry all water (waste and storm) to a treatment plant or a receiving waterbody. The problems related to the conventional system are that besides there is no social benefits, also there are quality and quantity problems. Quantity problems are high possibility of flooding (when heavy rain occur, the system can easily collapse), erosion of channels and banks and low flow during dry seasons. Quality problems are pollution of water bodies by surface runoff, overload of wastewater treatment plants (WWTP) during rain and consequently decreasing efficiency of treatment and pollution of receiving body.

The other approach is an integrated urban drainage system (IUDS), which is considering quantity, quality, and amenity at the same level. Under this approach, there are different applications in different parts of the world. In the USA and Canada, it is called Best Management Practices (BMPs) and Low-Impact Development (LID), Sustainable Urban Drainages (SUDs) in England, Water Sensitive Urban Design (WSUD) in Australia. The common idea of these practices is to mimic the natural processes of the area and try to get closer to the ecological balance such as before the urbanization for better water management. In this approach, the benefits are an ecologically friendly drainage system with sustainable development, to capture the rainwater in the place and minimize the adverse effects on aquatic biota. However, there are questions also related to the application of these sensitive urban drainage practices. Hydrological and hydrogeological conditions of the locality must be analyzed carefully, and then a comparison of costs and benefits of a sympathetic drainage system and traditional drainage system should be considered. However, within the awareness of these considerations, a new approach of urban drainage should be accepted by countries.

Every urban area has different characteristics and dynamics. With the guidance of this transition frameworks, different local urban mobilities should be taken into consideration. Nevertheless, without proper information sharing system which can define standards and support inventions for the development of long-term policies, a clear vision and goal for a sustainable urban water has a significant barrier despite these alternative water management approaches such as integrated urban water management and water sensitive management (Brown, Keath and Wong 2008).

"Total imperviousness" (TI) is a measure of urban density, which is the proportion of impervious surfaces of a catchment area such as roofs and pavements that are impermeable to water. On the other side, "effective imperviousness" (EI) which means calculation of imperviousness using only those impervious surfaces that are straight connected to recipients by pipes drains, might identify more correct predictions of stream degradation since it considers the only direct impact on the stream (Walsh, et al. 2004). Also, Walsh, et al. (2004) suggests that EI values are influential explanatory variables which can show alternative drainage systems can provide more effective stormwater management than stormwater drainage pipes.

For effective stormwater management in an urban area, prevention of runoff can start from each plot. Walsh, et al. (2004) explains different drainage scenarios with the calculation of effective imperviousness (EI) (Figure 3.5). According to their studies, "drainage connection" has an impact directly on EI. The equation of EI is multiply of total imperviousness (TI) and drainage connection. If an impervious surface is connected to a receiving water body by a stormwater pipe or a sealed drain, the accepted connection value is 1, which means the effective impervious area is equal to the total impervious area. On the other hand, if an impervious surface drains to a pervious surface or a vegetated swale and then to a receiving body, the accepted connection value is 0, which means effective imperviousness is also 0. The range of connection index between 0 and 1, depends on daily rainfall that can be retained in the area.

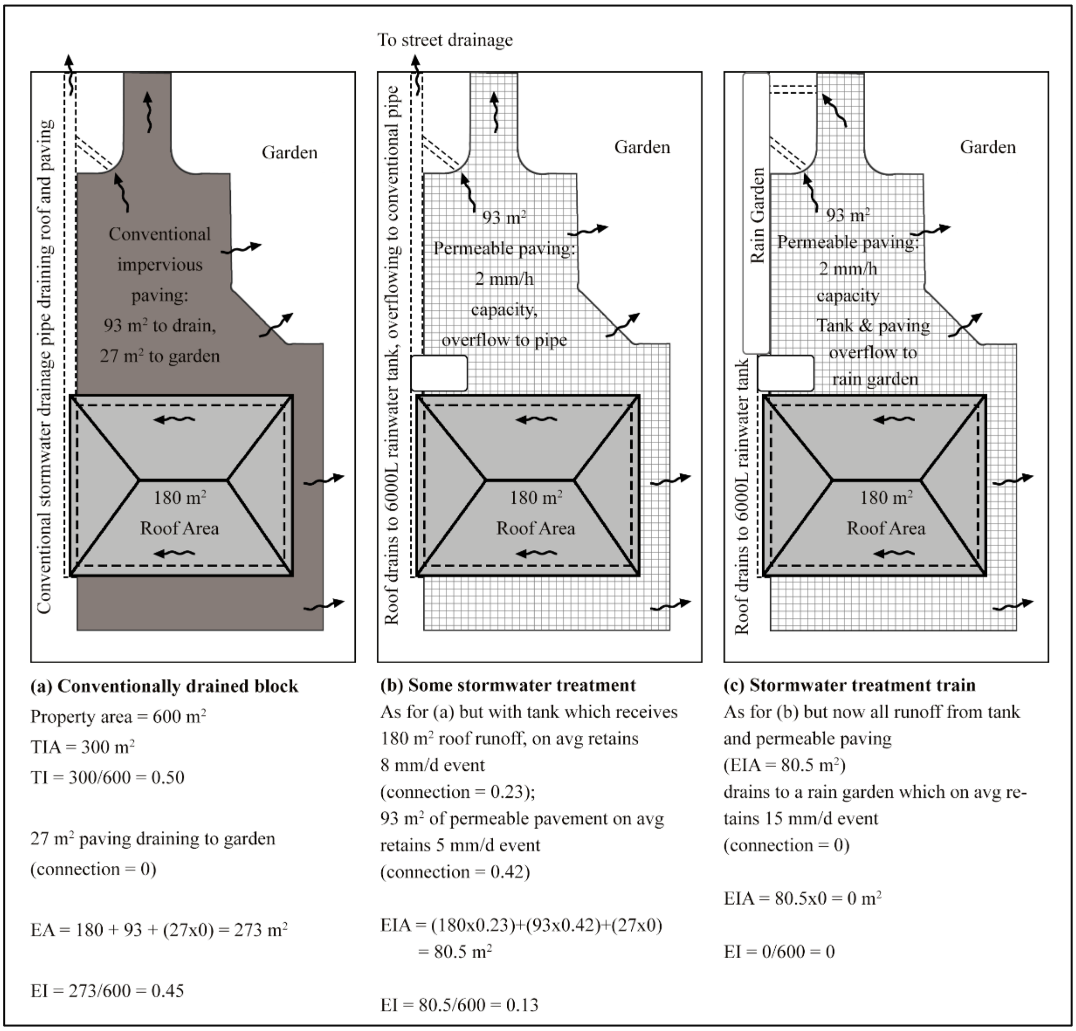


Figure 3.5. Three drainage scenarios for a typical housing plot, illustrating the calculations of effective impervious area (EIA) and effective imperviousness (EI) in each case. Arrows indicate the direction of flow. (Source: adapted from Walsh, et al. 2004)

In this regard, it is essential to adopt a comprehensive stormwater management system in an urban area. Parcels as the smallest scales of urban areas can reduce urban runoff, decrease flood risk, save and improve urban water, and create a better urban environment. Countries and international organizations are in a stage of changing their approaches. In the IPR Praha Public Space Design Manual, for the part of stormwater management, it is emphasized that the conventional drainage method that takes surface water quickly to canals are necessary to be replaced with decentralized drainage system for the purpose of increasing infiltration at the site of precipitation (IPR Praha, 2014).

Surface water management can apply at different levels with different techniques in an area such as prevention by education and increasing awareness of housekeeping and re-use, source control by infiltration methods swales, filter drains, porous materials and bio-retention areas, site control by storage and detention pools, regional control by end-of-pipe treatment, retention ponds, constructed stormwater wetlands, and reed beds. However, although all these tools are parts of stormwater management, Blue-Green Infrastructure can offer a systematic and synergetic combination of all these tools for prosperity of environment and public.

3.3.1.1. Wetland Restoration

Wetland restoration can be described as regeneration of a lost (because of human activities) or drained wetlands. These areas have primary importance as providers of ecosystem with a significant biodiversity which makes them necessary to conserve (Kisser, et al. 2020).

3.3.1.2. Constructing Wetlands

Constructing wetlands (CW) are wetlands created artificially. They mimic the natural process of wetlands and can be beneficial for improving the water quality, regulation of flood and drought and creating habitats. Also, they can store stormwater runoff and release it slowly, so they help for regulation of velocity (UNEP-DHI, IUCN and TNC 2014). CW are the most efficient nature-based solution for nutrient recovery and urban wastewater carry significant amount of nutrients. So, this nutrient rich content can be adapted to the crop fertilization requirements.

3.3.1.3. Green Roofs

Green roofs are building roofs are building roofs with partially or totally covered with vegetation. The choice of vegetation usually depends on local climatic conditions and ability of plant to grow on soil, gravel or sand. Green roof can help to decrease water quantity and therefore, reduce stormwater and prevent floods. Additionally, their aesthetic value, improving air quality in cities, noise pollution reduction, improvement of biodiversity can be seen as their co-benefits.

Green roofs can be classified as extensive and intensive. Extensive style requires low maintenance, low capital cost and 30-150 mm built-up height. Intensive style can have built-up height between 300-1000 mm depending on plant selection. It has higher benefits for urban climate and biodiversity but requires more complex system with higher cost and maintenance (EFB 2015).

Figure 3.6. Green Roof of a House in the Czech Republic
(Source: Url 9)

3.3.1.4. Tree Planting and Xeriscaping

Tree planting provides ecological, economic and social services to urban areas. Trees can intercept the rainwater and help infiltration and water storage in soil. Also, reducing energy, improving air quality and reducing atmospheric CO_2 can be seen as their co-benefits (CNT and American Rivers 2010).

Xeriscaping is an approach to vegetation of landscape that should be chosen by native plants of the region or with similar climatic resistance plants. This approach can help plants to overcome water stress or avoid it (BGI 2011).

3.3.1.5. Rain Gardens

Rain gardens are elements of urban landscape designed for infiltration and filtration of stormwater runoff. They minimize the rainwater that enter drainage system and utilize it for environment or possible other usages. They take the stormwater from impermeable surfaces around them with the help of arranged slope (UNEP-DHI, IUCN and TNC 2014).

Vegetation type can affect their perform. In order to increase their performance, long-rooted plants can be the best like native grasses. They possible to install parking lots, along roadways, sidewalks or private/public gardens (Figure 3.7). One of the most significant advantages of rain gardens for urban areas is that provides filtration and infiltration of urban surface runoff which can consist of harmful pesticides, oil, gas, etc., rather than sending it to surface water or sewage system (Aksoy 2016).

3.3.1.6. Bioswales

Bioswales (also bioretention) are also landscape elements designed to transport water from a place to other and this is their main difference from rain gardens. Their vegetation choice is usually high tolerance plants to wet conditions. Their often-linear structure makes them suitable for near residential roads or highways, parking lots and pavements. Besides of stormwater runoff control, their primary benefit is pollutant filtering.

Figure 3.7. Street Rain Gardens and Illustrative Section of the Rain Garden (on the right) Courtenay, Canada (Source: Url 10)

3.3.1.7. Permeable Pavements

Permeable pavements are impervious surfaces which can allow water infiltration and therefore, recharge the groundwater. Permeable pavement material types are pervious concrete and asphalt, permeable interlocking concrete pavers (PICPs) concrete grid pavers, and plastic reinforced grass pavements. Even though concrete and asphalt block pavers are not permeable materials, they can help to reduce impermeable surface area by providing gaps between them (Figure 3.8).

In order to prevent soil and groundwater contamination, permeable pavements are advised to use in places where there are low traffic and low possibility to potential contaminants such as residential roads, parking lots, walkways, patios, etc. Permeable pavements can require maintenance regularly for any clogging and, monitoring for any pollutant.

Figure 3.8. Concrete Block Pavers for Purpose of Parking Place in a Garden in Prague, Czech Republic
(Source: taken by the author on 24/03/2020)

3.3.1.8. Water Harvesting

Water harvesting refers rainwater or stormwater runoff redirecting and storage for re-use purposes (like irrigation, gardening or drinking water for humans and animals). Rainwater harvesting (cisterns) are discovered in early times of human history. The thing that makes cisterns unique and useful is the source of water. They do not use groundwater; instead, they collect and store rainwater for later usage. This feature of water harvesting creates various benefits for urban areas such as reducing water consumption, reducing the water quantity that enter the sewage system and thus, provides energy saving. Also, it is found that rainwater is more helpful for the health of plants thanks to its substance of nutrients like nitrogen and phosphorus (CNT and American Rivers 2010). On the other hand, the other type of water harvesting which is trapping and storing the rainwater in a desired place, aims to increase the amount of water that captured in the soil.

Figure 3.9. Rain Barrel and Stormwater Planter
(Source: Vysoky, 2017)

In the Figure 3.10, there is an illustrative summary of BGI practices that described above. The practices are matched with their combination of benefits.

Benefits	Reduces Stormwater Runoff											Improves Community Liveability						
	Reduces Water Treatmentts Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increase Available Water Supply	Increase Groundwater Recharge	Reduces Salt Use	Reduce Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Rain Gardens	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes Maybe No

Figure 3.10. Stormwater Management Practices and Benefits
(Source: modified from CNT and American Rivers, 2010)

All these separated practical solutions became a systematic solution under different programmes and concepts such as sustainable urban drainage systems in the UK, water sensitive urban design from Australia, and the new approach to stormwater management blue-green infrastructure network system.

3.4. Different Approaches of Contemporary Nature-Based Solutions

In this part, chosen good innovative and integrated water management approaches from around the world are described for a better understanding of the nature-based solution implementations. Thus, some selected international experiences of nature-based solutions and as new and widely accepted approach blue-green infrastructure (BGI) are defined according to the concepts of different countries. Although these approaches are slightly different from each other as management and implementations, the concept of being a blue-green city is a common purpose for better control of urban water cycle while delivering numerous benefits to the environment, society, and economy.

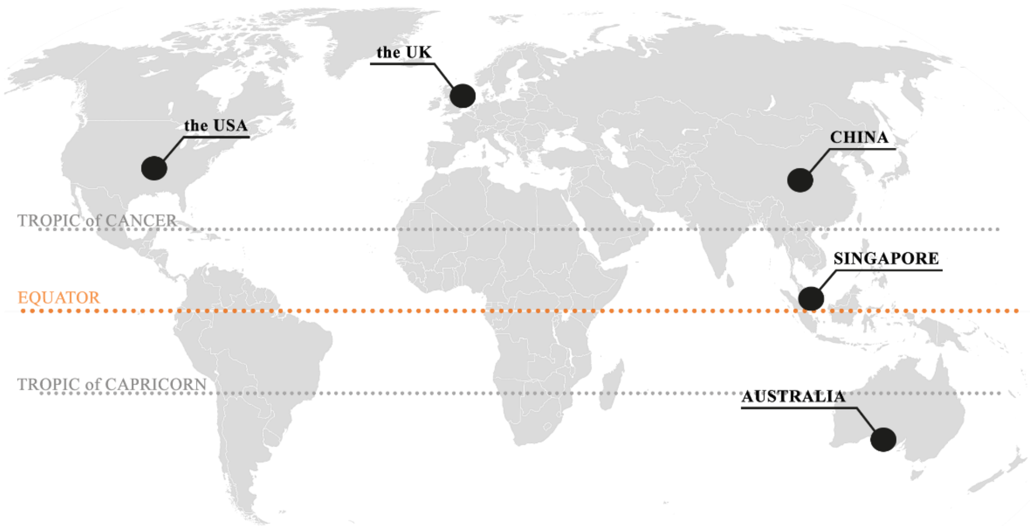


Figure 3.11. Location of the Countries which has NbS Concept
(Source: prepared by the author)

3.4.1. Low Impact Development (LID) / Green Infrastructure (GI) – the United States

The term of Low Impact Development first have been used in Vermont, USA in a research report on developing a community level natural resource inventory system in 1977 (Fletcher, et al. 2015). It is described as "systems and practices that perform natural processes of infiltration, evapotranspiration and precipitation for the protection of water quality and water habitats" by the Environmental Protection Agency of USA (EPA). In 1972, for regulating discharge of pollutants into the waters and quality standards of surface waters of the USA, the Clean, Water Act (CWA) was established (the EPA 2019).

In the USA, Portland is an outstanding example with their stormwater management practices. The stormwater program of Portland began early in the 1990s. After that, they started to examine new techniques under the Best Management Practices (BMP) feasibility and effectiveness and according to the results, they started to create a matrix which has regulatory information, current practices' failure and successes. Also, Portland followed a collaborative approach with other departments. Together with this approach in order to be sure that private property owners using the BMP techniques, the city created a Stormwater Policy Advisory Committee (SPAC) in 1996. The committee consisted of different stakeholders like architectures, landscape architectures, engineers, institutional organizations and the stormwater treatment industry (WERF 2009).

Figure 3.12. Eco-roofs of Portland, OR
(Source: Url 11)

3.4.2. Water Sensitive Urban Design (WSUD) – Australia

The term of Water Sensitive Urban Design (WSUD) first appeared to be used in the 1990s (Fletcher, et al. 2015). In 2004, the Council of Australian Governments approved a water reform with a national approach which supports the creation of Water Sensitive Australian Cities. The main objectives of WSUD were listed water conservation, runoff quality, runoff quantity, and integrated design (Department of Environment, Water and Natural Resources of South Australia 2013).

Water Sensitive Urban Design (WSUD) is a concept developed in Australia for the purpose of creating a comprehensive water management system. The aim of the concept is an optimization of total urban water cycle management and integration of urban design and planning with water, wastewater, and stormwater in different scales from a city-wide perspective to the site (Akinyemi 2009).

Figure 3.13. On the left, bioswales near carparks to collect stormwater. On the right side, constructed wetlands treats stormwater runoff from local streets before it enters to the creek (Source: Sydney WATER, 2018)

3.4.3. Sustainable Urban Drainage Systems (SUDS) – United Kingdom

The Sustainable Urban Drainage Systems (SUDS) in UK refers to a method for reducing surface runoff, collect it from hard surfaces to storages and feed the groundwater via infiltration. The regulation of SUDS is under the Water Environment (Scotland)

Regulations from 2011. It is a general requirement says that new developments' discharge will pass through SUDS before enters surface water drainage system (Susdrain 2014).

Currently, Sustainable Urban Drainage concept of the UK produced a guidance which has different manuals including sustainable drainage manual, surface water management manual, general water management manual and green infrastructure. Additionally, in order to encourage people, good management practices and components of SUDS are explained within another manual. On the other hand, the approach is divided into two for delivering SUDS as adopting and retrofitting. Adoption is aiming more new developing projects while retrofitting aims on existing developed areas to change conventional systems with sustainable solutions.

One of the first private projects of SUDS constructed by Barry Business Service Center as a sideway rain garden system at the parking area in 2012. The system applied by dividing the area into 3 sub-catchments due to lack of enough space and design the raingardens serve individually according to sub-catchments (Susdrain 2012).

Figure 3.14. Biofilter unit with drain inlet, Barry Business Center
(Source: Url 12)

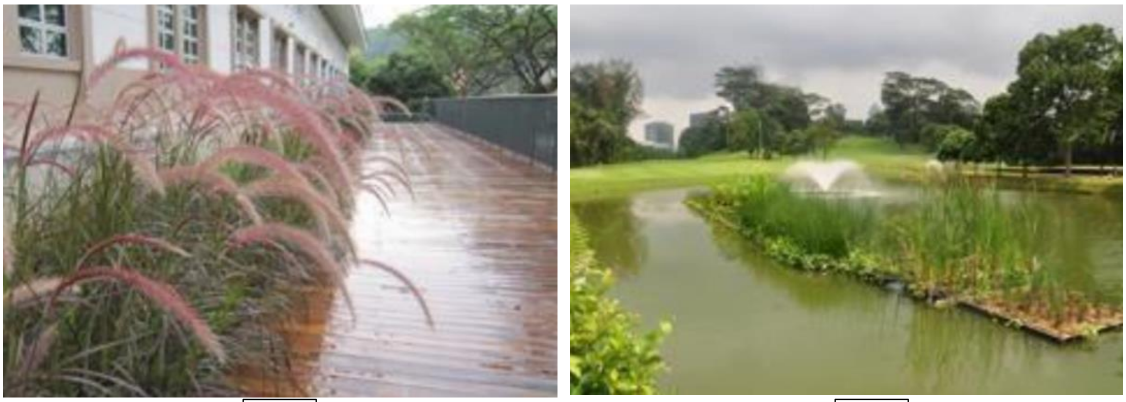
3.4.4. The ABC Waters Programme of PUB - Singapore

Singapore is a city-state and an island with a big population density and limited water resources and land availability. The Active, Beautiful, Clean Waters (ABC Waters) Programme has launched by the Public Utility Board (PUB), the National Water Agency of Singapore in 2006 as a city-wide BGI strategy. The aim of the ABC Waters is to create beautiful and clean streams, rivers and lakes for all by integrating the drains, canals and reservoirs with their environment in a holistic way (PUB the National Water Agency of Singapore 2018).

The actualization of the ABC program headed up with an evolution of Singapore's institutional capacity possibilities for implementation way of water sensitive approach. For this purpose, the regulatory and administration, technical development, and implementation and building industry capacity were the main focuses to evaluate. The program achieved by considering different level implementations such as an education program for architects, planners, engineers, and landscape architects, technical guidance for design and maintenance of WSUD systems, and a certification program which is given through the "ABC Water Practitioners" and is a legal requirement for finalization of projects (Brown, Rogers and Werbeloff 2016).

Also, Singapore's achievements of an efficient blue-green infrastructure (BGI) systems rely on their educational programs like the ABC Waters Guidelines. The aim of this effort is to improve local knowledge of local planners for adapting BGI approach and just between 2011 and 2016, almost 200 professionals were attended these programs (Dreiseitl and Wanschura 2016).

Between 2010 and 2018, 75 projects are certified by the ABC Waters Programme. Some good examples are Assumption Pathway School certified in 2010 and Keppel Club certified in 2011. Assumption Pathway School aims to integrate a rain garden with a boardwalk which the rain garden will detain and treat the rainwater from school area and also, serve as an open class for children to learn more about ABC Water Programme. Keppel Club is a golf club. Six retention ponds with wetland plantings and a floating wetland are constructed to treat rainwater runoff of more than 35% of the area and reuse the water for irrigation of the site area. Additionally, these wetlands creates habitats for different species and the Club nature group provides nature walks to share the benefits of wetland for nature (ABC Waters Programme 2018).



a **b**

Figure 3.15. a) Assumption Pathway School Boardwalk with Raingarden. b) Keppel Club Wetlands. (Source: Url 13)

3.4.5. Sponge City Concept (SPC) – China

China's central government presented the 'sponge city' project for the purpose of improving water availability in urban settlements and prevention of urban flood in 2014. The concept has the idea of a combination of nature-based solutions and green infrastructure instruments to absorb urban runoff and keep it for possible reuse. Another goal of the 'sponge city' concept is to mitigate the negative impacts of urban construction on natural ecosystems. There are six basics purposes of Sponge City concept; infiltrate, detention, store, clean, utilize, and discharge.

On the implementation stage, by 2020, 16 pilot cities are chosen by the government including Wuhan and Jinan. For the pilot cities, the government provided subsidies and some extra awards according to their success like good performance on public-private partnership (PPP) arrangement. The pilot cities have different conditions and problems. For instance Jinan city has a major water shortage problems, that is why, rain is considered as a new water source by harvesting and surface runoff control (Li, et al. 2016).

3.4.6. Blue-Green Infrastructure (BGI) for Stormwater Management

Blue-green infrastructures (BGI) are functions of nature-based solutions and sometimes equivalently ecological or natural infrastructure are used. BGI is a representation of a strategically and synergetic planned network which covers natural and semi-natural areas. Also, other environmental features are designed and managed to deliver a wide range of ecosystem services. It integrates green spaces ("green"), aquatic ecosystems ("blue"), and other terrestrial ("built"), coastal and marine areas (Figure 3.16). Together with these strategically planned networks of blue-green elements are able to present multiple advantages delivered like sustaining a green economy, improving quality of life, protecting biodiversity and increasing the ability of ecosystems for disaster risk reduction, water purification, and air quality, space for recreation and climate change mitigation and adaption (Dreiseitl and Wanschura 2016).

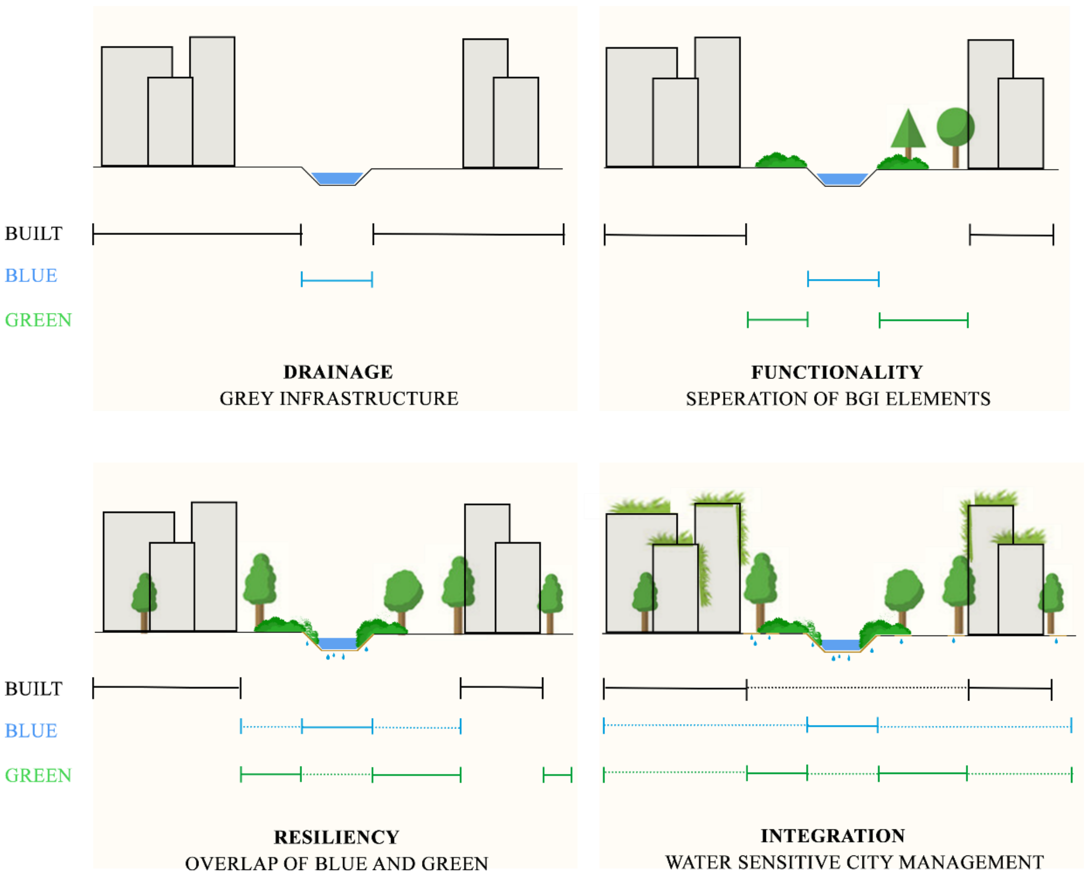


Figure 3.16. The Process of Stormwater Management from Drainage to Integration
(Source: modified from Dreiseitl and Wanschura, 2016)

As a relatively new term BGI has been improved and implemented under different programmes of different countries such as Best Management Practices (BMP of the US, Sustainable Urban Drainage System (SUDS) of the UK, Water Sensitive Urban Design (WSUD) of Australia, ABC Water Programme in Singapore and the Sponge City Concept of China (Liao, Deng and Tan 2017).

The primary functions of Blue-Green Infrastructure components are regulation of water quality and water quantity, creation of habitats, and social advantages in urban areas. Regulation of water quality consists of sedimentation, filtration, and phytoremediation. While sedimentation allows big particles to settle down of water, filtration allows pollutants to separate from water by soil as a natural process. Phytoremediation is a biological process done by plants and soil, and it is a cost-effective and publicly acceptable solution. Regulation of water quantity includes evaporation infiltration, retention, detention, conveyance, and storage. Socially, it can have various benefits; however, recreational facilities and the possibility of integration of nature and society are the major functions. Additionally, aesthetical value, dynamic use possibilities (such as a retention pond during rainy period can be a playground during dry period), traffic regulations can be said as their functions (Vysoky 2017). On the other hand, integration is important also for financial reasons.

3.5. Good Practices of Learning from Water Heritages

This part, within the aim of the thesis, tries to exhibit some selected good water management practices which consider integration of inherited water techniques with the sensitive water management tools like contemporary nature-based solutions. Unfortunately, even though almost all regions have their own traditional way to deal with water issues, it is not common that new studies are trying to combine them to contemporary urban water management systems. General tendency is to protect these inherited water management techniques and structures and consider them as cultural and touristic values. So, a recent growing awareness, realizing that the contemporary urban managements have techniques to learn from past experiences and apply them to the cities with contemporary nature-based solution.

3.5.1. Dutch Water Heritage Management

The Netherlands is one of the most aware country that its water heritage can help to build sustainable and sensitive future water systems. For example, polders and flood defense systems are well known water managements and heritages. ICOMOS Netherland is a pioneer organization which support researchers and researches on water heritages, launches publications and co-operate with international organizations and institutions like UNESCO World Heritage. Since 2012, ICOMOS Netherland is trying to raise an awareness of water-related heritages for a sustainable future.

Water heritages of Dutch cities date back to the Middle Ages which mostly relied on groundwater, surface water and harvested water for consumption. Rainwater and surface water were stored in large and small cisterns. Large cisterns were sometimes filled by carried water from rivers and small cisterns were commonly connected to a farm, dwelling, or buildings (Loen 2020).

Figure 3.17. Rainwater wells connected to a rainwater pipe
(Source: Loen, 2020)

The book, Adaptive Strategies of Water Heritages by Hein (2020) underlines that heritage is not just a historical object. It is crucial that education is the key for successfully applying water heritage knowledge to present and future issues of water management. So, the proposal is heritage management education which will be integrating water management, civil engineering, hydrology, and urban and spatial planning.

Recently, a new approach has been developed in the Netherlands for heritage management which is combining innovative technologies and historical preservation such as The Belvedere Memorandum policy document which was examining the relationships of heritages and spatial planning. A similar strategy is applied by the Dutch Heritage Department which puts attention on sustainable practices of classified heritages.

3.5.2. Ancient Water Management in Monte Alban - Mexico

Indigenous people of Mexico, Zapotecs were able to manage the rainwater through terraces, canals, dams, and wells in Monte Alban. Currently, *Parque Monte Alban* was a design project conducted by the cooperation of Mexico and the Netherlands between the years of 2015 and 2016. Monte Alban has been an UNESCO cultural site since 1987 but at the same time it is densely urbanized city. The project aimed to design an ecological park with the objects of protecting the archeological site of Monte Alban, improvement quality of life for the inhabitants and organizing an informal urban growth.

During the project, investigations on both traditional control way of water at the site and learning about effective and failing strategies were conducted. The current main problems of the site, flooding, and invasive urban growth were considered together with the community who lives there to generate the solutions. So, inhabitants of the area were accepted as allies, and rainwater considered as a fortune the same as how it was for the indigenous Zapotecs (Rojas and Davila 2020).

The approach of the project has relied on the integration of community and heritage. Therefore, different workshops were conducted with the residents of the area to create an understanding of heritages that can enlighten the future way of the city.

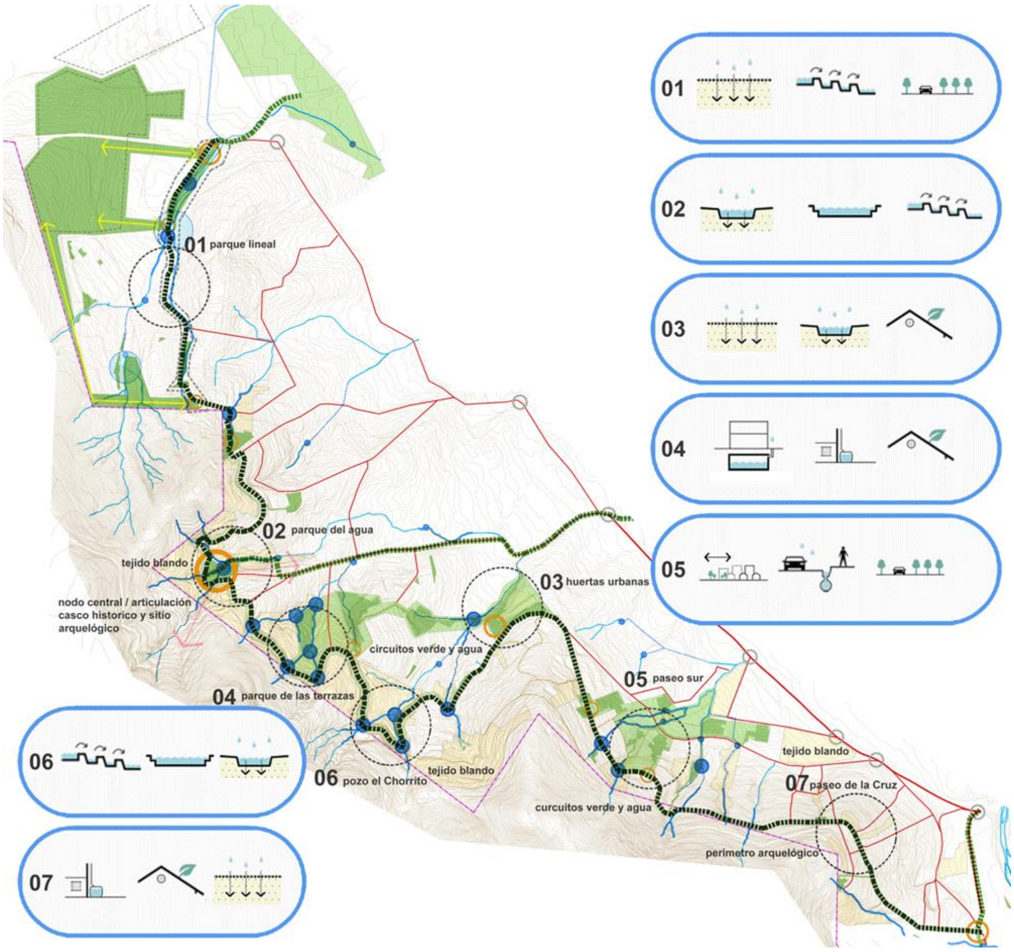


Figure 3.18. Proposed Urban-Hydrological Acupunctures for Improvement of the Park (Parque Monte Alban is on the second area) (Source: Url 14)

Figure 3.19. Site views of Parque Monte Alban, on the right is the current situation and on the left is the proposal (Source: the booklet of "Monte Alban Ecological Metropolitan Water Park Area")

3.6. Evaluation

This chapter introduced the water problems of the World and Turkey. As hot issues of water, climate change, drought, scarcity, pollution, all are pointing the same question that how we will sustain our future? In this sense, the study indicates that restoring water balance is a principal aim to achieve in urban areas and to do so, stormwater could help by being an alternative supply to reduce the consumption of mains inputs. And finally, this can create a water balance which closer to the predevelopment conditions of urban areas. In the case study area Bodrum, the typical block system is mostly similar to the conventional drained block example showed under urban water cycle. On the other hand, in the tradition of water structures of city development, individual cistern system, which still some houses have, can be seen similar to the parcel block which has some stormwater treatment facilities. However, accordingly, with the thesis purpose, the proper example should be a block with totally stormwater treatment facilities.

Later, the chapter points the water management evolvements and approaches around the world and Turkey. In the scope of the thesis, as an addition to the 3Ps framework, Perception can be included. Perception offers more about the sense of place, people, being local, and knowledge of areas from the past. This is important because it also considers experiences from previous generations and considers what has been gained and what has been lost. In the Oxford Dictionary, the description of "perception" is expressed as "an idea, a belief or an image you have as a result of how you see or understand something" and the other explanation also as "the ability to understand the true nature of something." These definitions are preparing an excellent base that the perception of a community can be a fundamental driver. In the case of Bodrum, there is a perception coming from the roots that rainwater is a valuable source to collect and reuse. Furthermore, this shows us how locals understand the actual needs and supplies of their nature.

The theoretical part of nature-based solutions helps understanding of the key principles and features of conventional nature-based solutions concept and blue-green infrastructure system. Using these techniques as a new approach in urban areas are not just giving a good water management of the area but also providing other benefits like more friendly and sensitive environment, social interaction areas, ecosystems for different species, and economical sustainability for long term plans. Additionally, searching different water management practices from around the world proved the additional benefits. Moreover, it was important to understand how they implement these techniques and adapt them to their community. As an good example, the certification program of Singapore for design projects by ABC accredited professionals can be adapted by metropolitans or municipalities in Turkey and modified with a suitable policy framework which can be possible to implement within their borders with the support of central government's basin governors.

As the main purpose of this thesis is to create an integration between inherited water management techniques and contemporary nature-based solution, also different good practices are evaluated which tries to investigate on water heritages and learn from them for sustainable future development. Even though there are not enough attention to re-integration of these techniques to contemporary city managements, it is understood that the importance of past experiences and knowledge have started to be realized by researchers and this can drive the future management approaches to be more sensitive.

As a conclusion, all these introduced concepts are aiming similar purposes such as saving water and utilize it when necessary and also, prevent water related problems. Instead of conventional systems that offer a one-way solution by focusing only on the problem, concepts of NBS or soft-path solutions address the problem in several stages such as social and environmental. On the other side, their implementation way changes according to countries' and cities' regulations, stakeholders and public. Among these concepts, the concept of WSUD which considers urban planning and design combined with water management, is more widely accepted around the world. However, as a relatively new approach BGI network system is gaining attraction day by day.

CHAPTER 4

THE CASE OF BODRUM PENINSULA

This chapter presents the Bodrum Peninsula and its socio-natural characteristics as the case study area of the thesis. The aim of the chapter is to apply the techniques represented in the previous chapters to create an ecologically and socially functioning environment and also historically and culturally combined techniques for Bodrum City Center. Accordingly, Bodrum Peninsula and City Center is studied to provide sustainability in the local context, improve and create multi-functional land uses inside the city (especially closed stream sites), to keep the collective memory of the community alive for Bodrum Peninsula's traditional water management and collection techniques, and transform the city center into its natural structure similar with its pre-urban times as much as possible.

In this manner, first, the Bodrum Peninsula is analyzed regarding its characteristics like historical, economic, climatic, topographic, geologic, and hydrologic. Secondly, the blue-green infrastructure practices as innovative nature-based solutions, together with considering its traditional practices for Türkkuyusu and Yokuşbaşı districts of Bodrum City Center, is developed with the aim of showing how closed streams (Gerence and Gökçebel Streams) can be ecologically rehabilitated within the blue-green infrastructure framework together with its inherited water management techniques. As the third step, a series of integration strategies based on Bodrum's social, historical, and traditional background with the help of conducted survey and investigations is developed across scales. Lastly, together with the combination of the knowledge of local culture and the techniques of nature-based solutions, a de-centralized and integrated water management system is proposed for the city.

In the conducted study, besides of legislative borders, natural borders are also taken into consideration as the study area of the Peninsula. Different scale analyses are concentrated on during the study. Firstly Peninsula, which almost half of the Bodrum-Milas Basin and then, inside the peninsula, each waterway is analyzed within their own watersheds. Lastly, the focus and analyses centralized on Bodrum city center watershed, which has the densest urbanized area. The field of design area for a blue-green infrastructure was chosen as the Bodrum city center according to the urbanization analysis, which shows the densest area and the survey's results.

4.1. Methodology

In the third phase, a case study approach is embraced as a research approach, and Bodrum is undertaken as the case study area within the scope of all mentioned above. In the case study, the research activities are combined under three main phases; identification of the problems, collecting and analyzing the data, and proposing the BGI guideline (Figure 4.1). The first phase consists of identifying the research questions that are based on the literature and then the data collecting for Bodrum.

For the collection of the data, two separated approaches were conducted. The first approach was to survey the residents of Bodrum who were using these indigenous methods for water supply or have heard from their close environment how people were using these methods. Also, according to the addressed points of the city which were obtained from the survey are investigated by observations. The data that have been collected within this method are called Social Data. The second approach for collecting the data that is called Spatial Data, combined the historical information, environmental factors including hydrology, geology, geomorphology, climate and vegetation and urbanization problems of the study area which affect water resources. For collecting the spatial data, journals, books, theses and local newspapers from governmental and non-governmental institutions, universities were searched and studied. Additionally, some interviews and data collection were done from MUSKI and Bodrum Municipality.

In the analysis phase, separately, these social and spatial data were analyzed. In order to analyze the social data, a survey was conducted as online and face to face. 51 people from Bodrum were answered the questions. All the answers to each question were grouped in an excel sheet and compared individually. According to the obtained information from the survey, observations were conducted in the city center. The physical data analysis aims to provide a strategic localization for the BGI network. For this purpose, the GIS Environment and Spatial Analyst tools were used to produce maps which include the development of imperviousness, slope, green areas, and delineation of waterways.

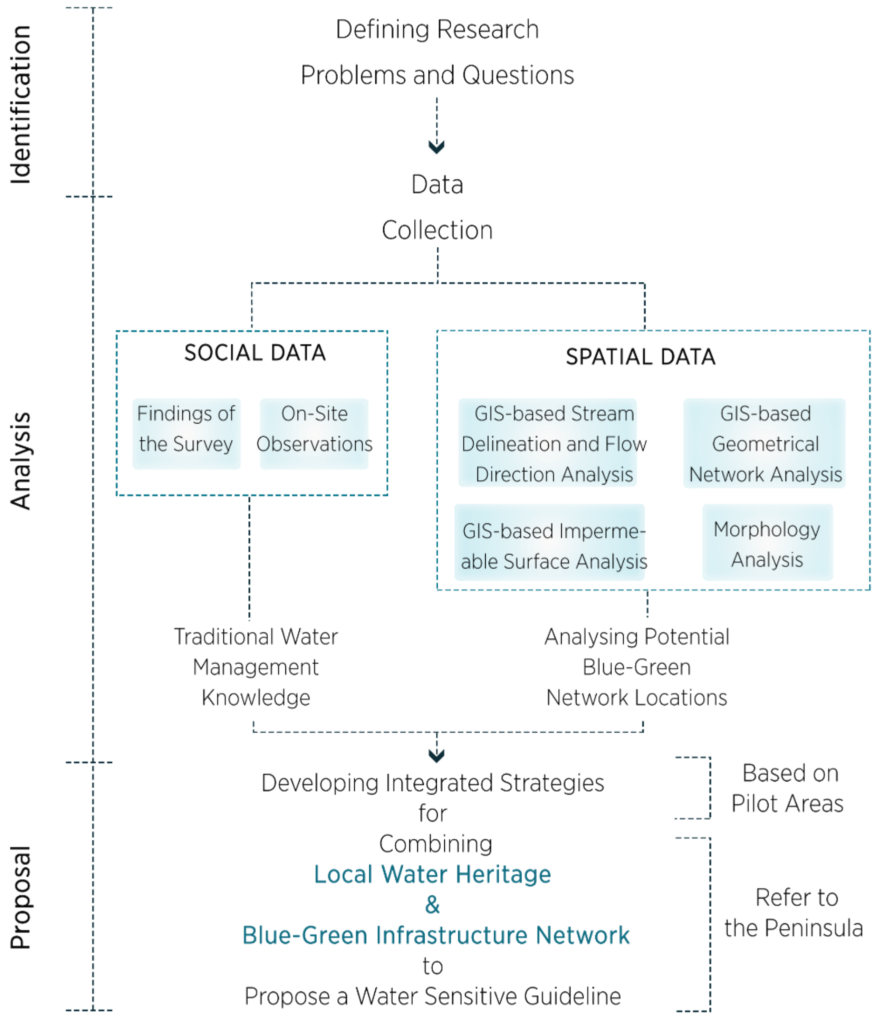


Figure 4.1. Flow Chart of the Methodology
(Source: Prepared by the author)

Lastly, for the proposal of a decentralized, comprehensive, and sustainable water management in the city and around the peninsula, a guideline of integrated strategies for combination of local water heritage and BGI network was prepared. In order to prepare the guideline, an inductive approach is adopted. At the beginning, a staging study is conducted to explain the stages for realization of the guideline. Then, as a first step, according to the pilot study areas, integrated strategies are prepared as manuals of different city elements such as streets, buildings, parking areas, and open areas. It is predicted that these manuals can be implemented in the other settlements of the peninsula and then, create a comprehensive water management approach to whole peninsula.

The study also confronted various limitations that need to be considered. First of all, there was no information gathered for rain data and flood risk assessment for Bodrum.

Additionally, the main limitation was data collection from related authorized institutions regarding the buried streams and cisterns of the Peninsula. For buried streams, limited information gathered from Bodrum Municipality as NetCAD file and Word file, but for cisterns, there was an ownership complexity between MUSKİ (Muğla Water and Sewage Works) and Bodrum Municipality. This bureaucratic relations and confusion of authority have obstructed having permission and reaching the data at some points. Another issue, on the base map which taken from Planning Department of Bodrum Municipality, there were not enough information about gardens of the buildings. So, this situation could cause some miscalculations about permeable-impermeable areas. However, the study was concluded within the limitations of individual work. For cisterns, addition to the data gathered from MUSKİ, a site investigation conducted, and some more new cistern locations were determined, and in the city center of Bodrum, some household cisterns are found thanks to the survey and observations.

4.2. General Characteristics of the Bodrum Peninsula

4.2.1. Location

Bodrum Peninsula is in the south-western part of Turkey, on co-ordinates 37.0344° North and 27.4305° East. Bodrum is one of the thirteen province of Muğla Metropolitan City and stays inside the West-Mediterranean Water Catchment and the Aegean Region (Figure 4.2). Muğla has the longest coastline of Turkey with 1480 km length. According to the water resources, besides of the Bafa and Köyceğiz Lakes, the Dalaman, and Eşen Streams are inside the city borders. Muğla can be divided into five different sub-basins as Eşen Stream Sub-basin, Köyceğiz-Dalaman Sub-basin, Milas-Bodrum Sub-basin, Muğla-Marmaris Sub-basin and Büyük Menderes Basin Part which stays in Muğla borders (Muğla Metropolitan Municipality 2015).

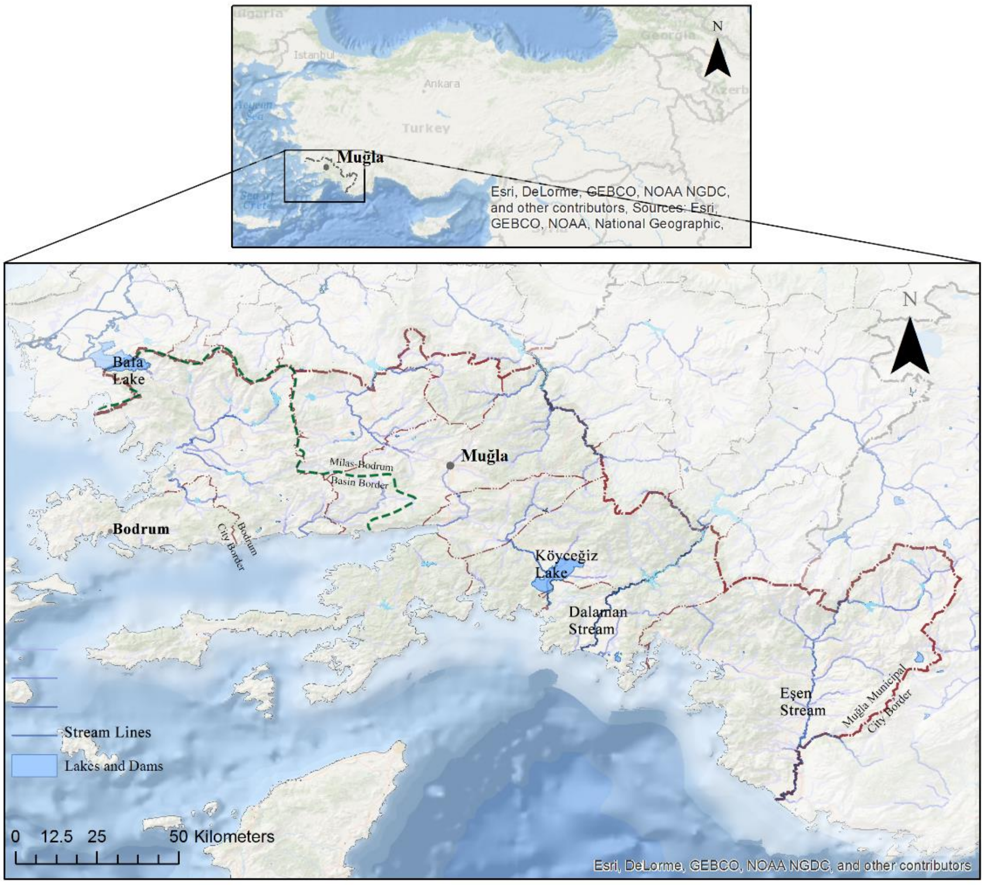


Figure 4.2. Location of Muğla in Tukey and Bodrum in Muğla
(Source: Prepared by the author in ArcGIS 10.7.1)

As natural borders, the peninsula embodies almost half of the Milas-Bodrum Basin. The Peninsula is one of the most known touristic destination within the country and also, it has a fame globally. The study area, Bodrum City Center is located on the south-center of the Peninsula. Around the Peninsula, besides of Bodrum city center, there are other main settlements like Turgutreis, Yalıkavak, Bitez and Mumcular (Figure 4.3). Totally, inside the city borders, there are 56 neighborhoods, 17 of them were rural areas and 41 were urban areas. However, in 2012, the law of Metropolitan Municipalities numbered 6360, Muğla became a metropolitan municipality and within this law, the rural areas count as urban areas. The total surface area of Bodrum which locates in a peninsula, is approximately 689 km^2.

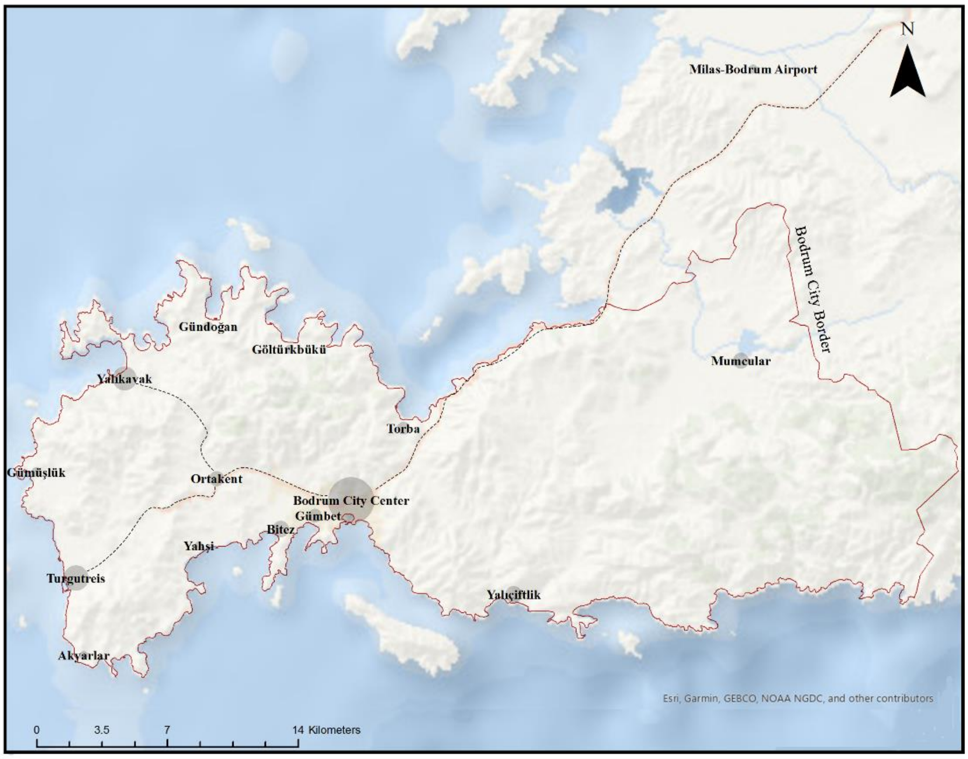


Figure 4.3. Location of Bodrum City Center in the Peninsula, Turkey
(Source: Prepared by the author based on Esri Oceans Online Map, 2020)

4.2.2. History

Bodrum contains an immeasurable historical value from past to present. Heredotus, one of the most important historical names in history and known as "the father of history." He was born in Halicarnassus (the former name of Bodrum in ancient times) in 484 B.C. According to Heredotus, Bodrum was first founded by Dorians. Later, Caria and Lelegians settled in the region. Bodrum had its bright times around 353 B.C. when became capital of Caria Region. Mausoleum, which is one of the Seven Wonders of the World, constructed in that time.

The city was conquered by the Knights of Rhodes in 1415 and was permanently brought to the Ottoman territory by Kanuni Sultan Süleyman in 1522. Bodrum's name is given after the foundation of the Republic of Turkey. In the book of Sir Charles Thomas Newton and Richard Popplewell Pullan (1862), while they were mentioning about the topography of Halicarnassus, underlines the importance of rainwater for the city. Their foundations for Budrum indicates that water reservoirs which constructed on rocks were abundant in ancient times and fed by subterraneous aqueducts (shown by a star on the right-down corner of the Figure 4.4) which carry the rainwater by earthen pipes and square shafts. Also, in the book, several waterways are mentioned as flowing only with winter torrent.

Also, Muammer Karadaş mentions in his book (1976) about the aqueducts as Caria's way to provide freshwater. So, these aqueducts were carved into smooth stones as cages. One of them is called Eskiçeşme-Kanlıdere (shown by a star on the left side in Figure 4.4) was still being used during 90s (Karadaş 1976). Besides of Eskiçeşme-Kanlıdere aqueduct, there were Kocataşdibi and Manastır aqueducts however, only Eskiçeşme is possible to use today (Baykara 2010).

Around the peninsula, there are different historic fountains. Salmakis Fountain in Bodrum city center (on the left-down corner of Figure 4.4) is taken the name from a beautiful fairy, is known also as Bardakçı. Another fountain is in Kadıkalesi coastal side which has an inscription says the fountain made by Süleyman Kaptan (Captain) around 1737-38 years (Baykara 2010).

In the early times of the Republic of Turkey, houses were mostly made by stone. They had separated each other by yards and fruit trees. Rooftops of the houses usually covered by a type of soil called in the region as "geren". It is kind of clay but harder than it, and thanks to its oily structure, it does not allow water permeability. It is a local soil which has purplish color (Baykara 2010). The streams of the city Gerence and Gökçebel were important water supplies for inhabitants of the city. To fulfill the fresh and clean water need of Peninsula, there is a local solution which is a special cistern (Figure 4.5).

These cisterns are located almost all around the settlements of the Peninsula and on the route between the settlements (Figure 4.6). Between Karatoprak (former name of Turgutreis) and Bodrum city center, approximately each 1 km there is a cistern located. According to Mustafa Ünlü's field researches (obtained by the survey), he claims there are almost 600 cisterns that exist all around the Peninsula. Though, according to the documents taken from the MUSKİ (Muğla Water and Sewerage Affairs Directorate), there are 87 cisterns inside Bodrum City Borders. However, together with the Bodrum Municipality data in the Peninsula there are almost 200 cisterns (Saraçbaşı and Doğan 2014). On the other hand, these special cisterns are not the only solution used by the locals. Most of the houses were having underground cisterns in their garden and collecting the water from their roofs.

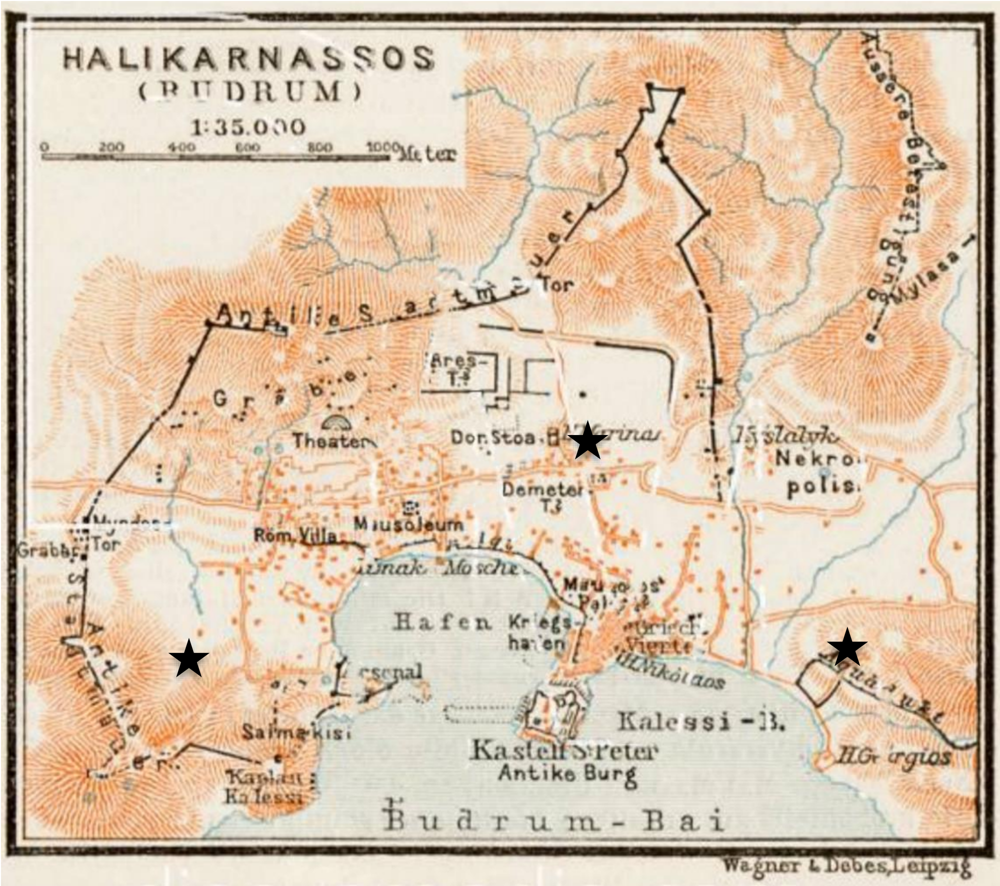


Figure 4.4. Map of the ancient site Halicarnassus drawn on the cartographic background of 1914 at the scale of 1:35,000 (Source: Url 15)

Individuals and each neighborhood were able to get their own water from cisterns and wells. Each cistern approximately able to capture 200 ton water (Baykara 2010).The culture of water was built up on a sharing system which is another benefit of these cistern systems as social. The neighborhood cisterns are no longer used in the city but in some mountain areas still in use for animals.

Even if the garden cisterns were private, people used to share their water with their neighbors. The household cistern system is still in use in the city. Basically, the water was a common good in the Peninsula. However, after mass tourism and eventually, urbanization, the quality, and quantity of water were not enough anymore to sustain itself. So, when the individual was no longer able to supply their own water needs, they have been seeking the city administration for solving this problem and asking the responsibility of providing clean water and sanitation service. Since these increasing needs, especially after the 70s, almost every house had mains water systems. But the quality of water has been never good enough for drinking. Around the region, Labranda Spring Water Establishment, which was found in 1978 in Milas, was the leader of the water market till 1991 (Milas Municipality web page). After that year, bottled water has started to increase its role in Turkey water market. Today, still for drinking water only bottled water is in use in Bodrum except for some household cistern owners.

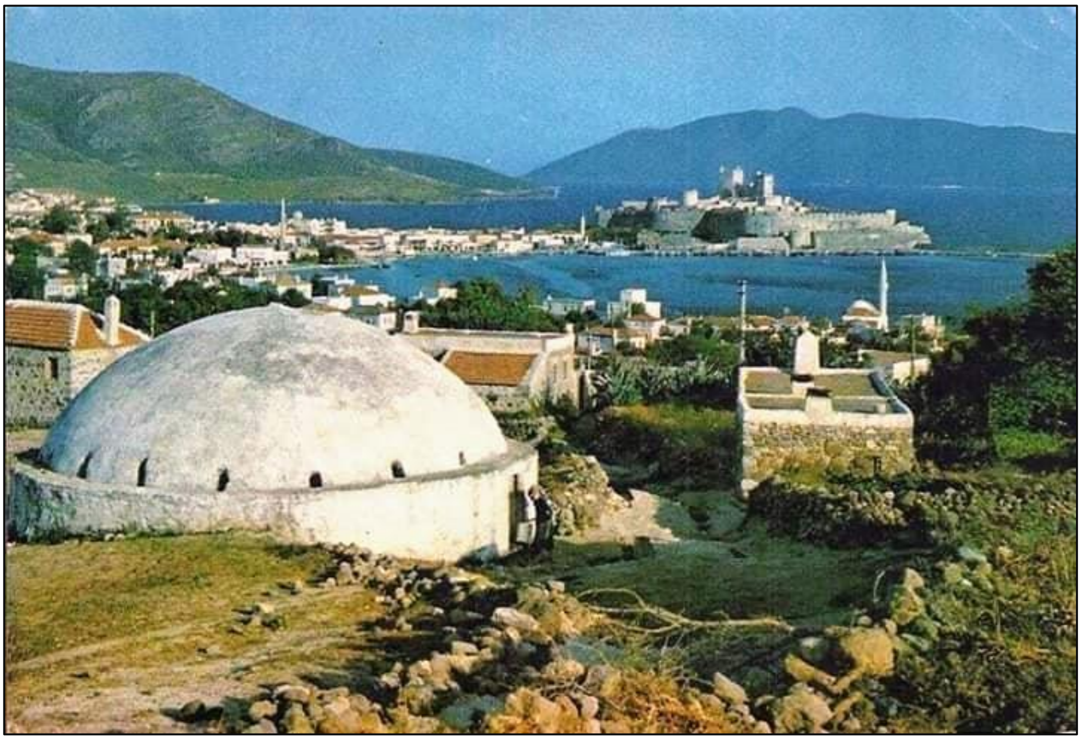


Figure 4.5. A cistern with a woman who is going to take water, approximately taken around 70s
(Source: Anonymous, "Eski Bodrum" Facebook Group, 06/03/2020)

Bodrum as a peninsula, till the beginning of the 1950s, was a small coastal town that had not got any proper highway. The most proper way of transportation had been provided by sea transport until the 1960s. Arbak (2005) is expressing Bodrum's untouchable mountainous geography until the 1970s as the reason for the protection of its local and urban character until today. The town's economy in those times was mostly based on fishery and sponge diving, and partly on agriculture, especially olives and citrus (Arbak 2005).

During these years, for the public awareness and cultural activities, the Bodrum's Youth and Sports Club was one of the leading communities. In those times, inside Bodrum, tourism only managed by locals who opened their houses for tourists. Even new houses were started to build according to this purpose with two separated bedrooms and toilets. Within the realization of tourism in Island Kos (Greece) where is located across Bodrum Peninsula, and how tourism brought the wealth and welfare to the small island, between 1955-56 years Association of Bodrum Discovery and Tourism was founded by Kemal Palaoğlu who was the district governor in that time.

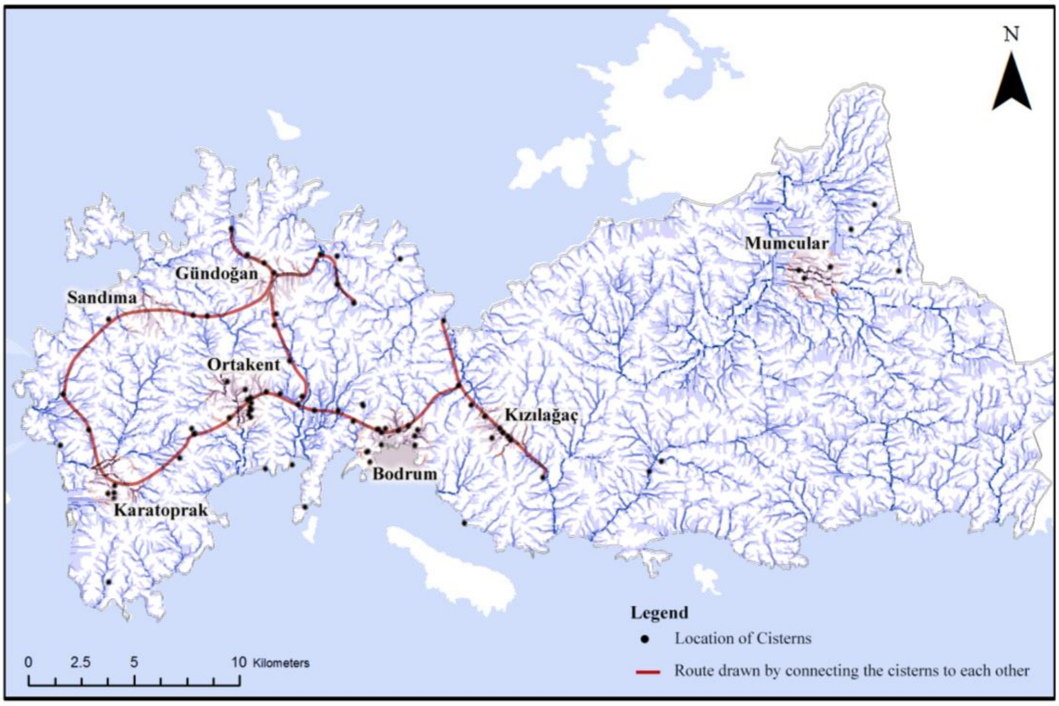


Figure 4.6. Location of cisterns and relation with the local conditions
(Source: Prepared by the author in ArcGIS 10.7 based on the data taken from MUSKİ and observations)

After the realization of the potential for the tourism sector in the town, touristic usage of local houses had to leave their places to the massive four-stars, five-stars hotels, institutionalization of accommodation, trade, and service (Akça, 2014). This massive growth of the tourism sector was the main effect of the transition of Bodrum from a coastal town to a tourism city (Bozyer 2008). According to the news on Melengiç Newspaper in 1972, motor and yacht travel increased multiply between İstanköy (Kos-Greek Island) and Bodrum. Again, in the same newspaper, for the advertisement of Bodrum, a slogan competition arranged, which should express Bodrum with all its good aspects and during 1971, due to highway counting 18,907 people and a totally 40,000 people had visited Bodrum Peninsula (Akduman 2018).

After being such an attractive place for tourism, Bodrum's population growth momentum has shown an increasing line until today, and the trend still goes in the same direction. In the population graph (Figure 4.7) the huge impact of the Airport to the population (opened in 1997) is also visible on the population growth between the years 1990 and 2000. Between these years, the population increased almost 40.000 people from 56.821 to 97.826. According to the TUİK, in 2019 the population of Bodrum County is 175,435. The estimations show that the population of the Peninsula will reach 259.825 people according to the existing growth till 2030 and secondary house population will reach 283.967 people (Bakış and Arı 2010). This rapid growth brought a different social structure to Bodrum.

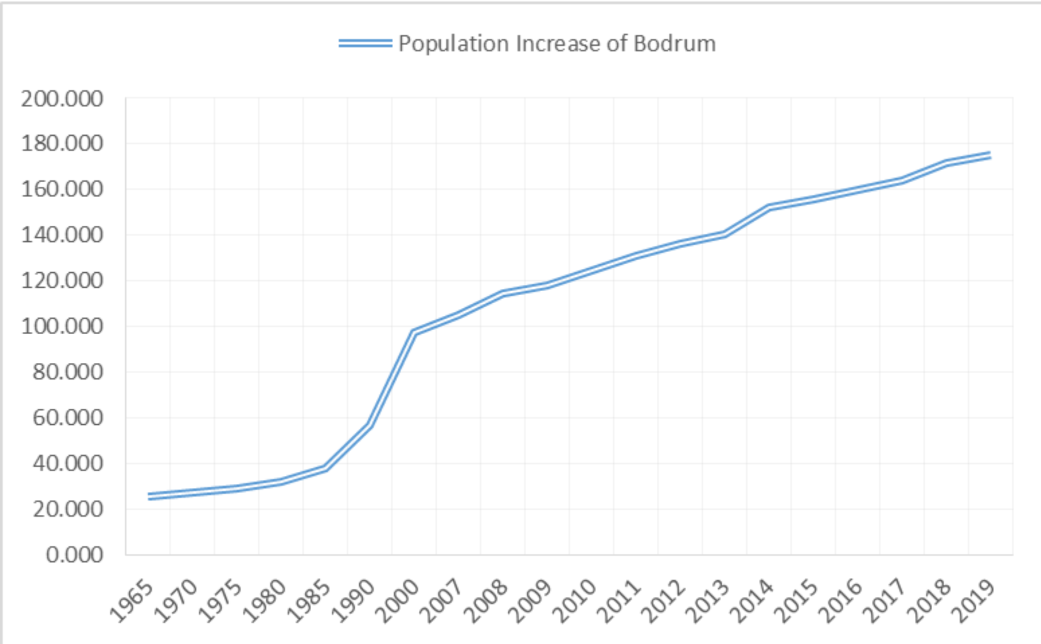


Figure 4.7. Population of Bodrum
(Source: Prepared by the author based on the information of TUİK)

4.2.3. Existing Conditions

In this part, environmental factors and vegetation of the Peninsula are analyzed. According to the findings, “What water problems occurred in the Peninsula?” which is one of the research questions, is aimed to be answered. Furthermore, the answers will create a basis for the design strategies of blue-green infrastructure that will be represented in the following section.

4.2.3.1. Climate

Understanding the dynamics of the Peninsula's streams and particularly Gerence and Gökçebel Streams, it is essential to be aware of the climatic conditions in the Peninsula and the region. The study area has a composed of the synthesis of Aegean and Mediterranean climates. However, the Mediterranean climate, characterized by hot, dry summers and mild, rainy winters, is effective in the Peninsula.

Precipitation consists mainly of rainfall and so rarely snow. Annual average rainfall in Bodrum is about 680 mm (Figure 4.8).

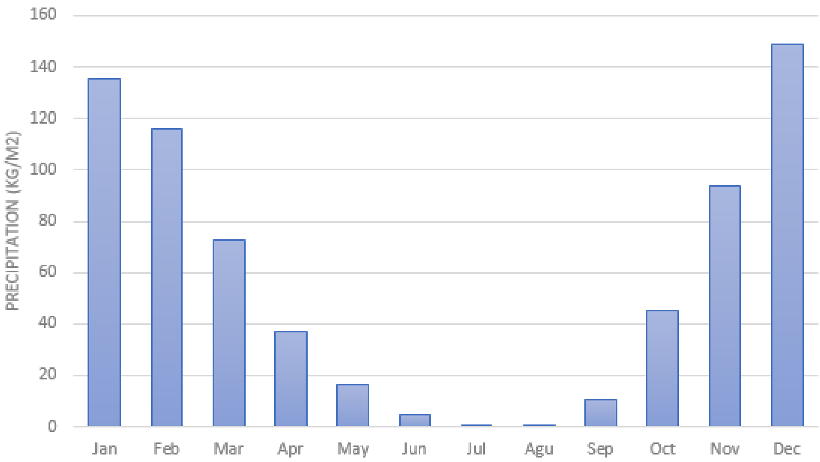


Figure 4.8. Average monthly precipitation between 1970 and 2011
(Source: Reported from General Directorate of Meteorology of Turkey, 2020)

The rainiest days are seen in Bodrum in December. On the other hand, Bodrum has an arid summer period, especially in July and August. On average, there are only a few rainy days during summer times, including September (Figure 4.9). Therefore, natural streams in Bodrum, most of the year, are dry. Due to this reason, the traditional solution of cistern structures is remarkable because they can keep the water even during these hot and dry summer season.

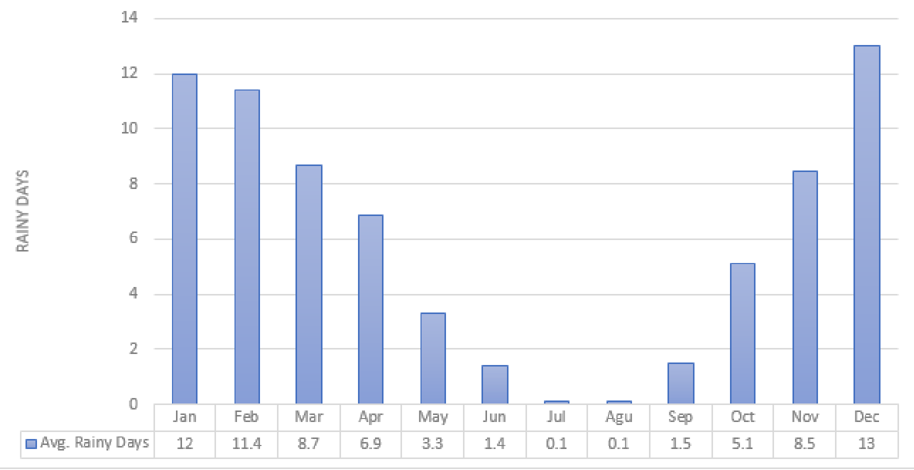


Figure 4.9. Average number of monthly rainy days between 1970 and 2011
(Source: Reported from General Directorate of Meteorology of Turkey, 2020)

According to the Meteorology Directorate information of provinces districts (2012), the average temperature during the summer range from 25.7 to 28 ^{o}C, while the winter months experience moderate temperatures, between 11.3 and 12.7 ^{o}C. The average annually maximum temperature is 23.9 ^{o}C between the years 1970 and 2011 and 34.2 ^{o}C during the summer times (Figure 4.10).

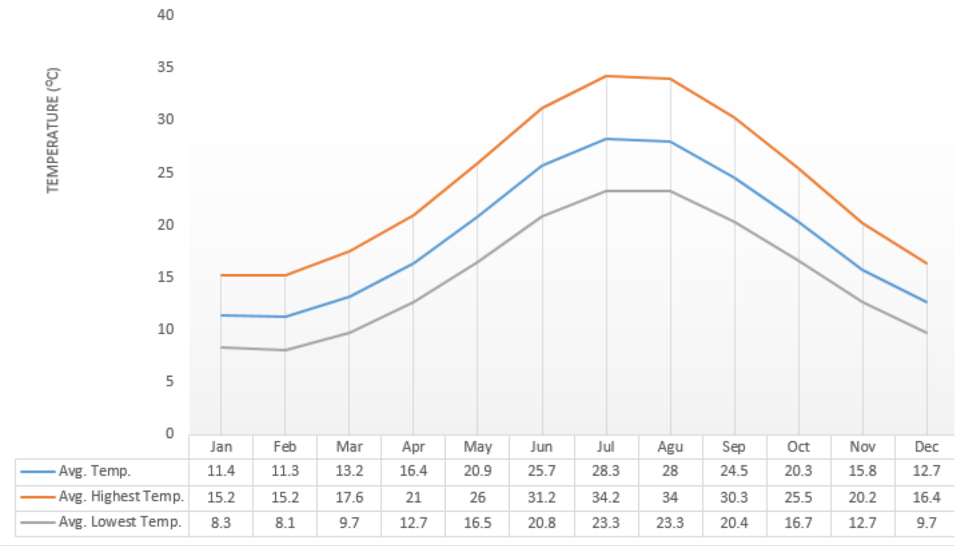


Figure 4.10. Temperature graph of Bodrum between 1970 and 2011
(Source: Reported from General Directorate of Meteorology of Turkey, 2020)

Thus, Bodrum has developed its unique freshwater management systems and collective water memory. Since the water is not available during dry seasons, with the existing population of the past times cisterns were enough for the locals. Today, the local solution should be improved by the new technological and natural solutions and implemented to the city life.

4.2.3.2. Geology

The peninsula can be divided in two parts as east and west sides. The east side of Torba is the eastern part and west side of Torba is the western part. On the western side, the highest point is 690 meters (Oyuklu Mountain) and extends in the east-west direction. On the eastern side, the highest point reaches 874 meters. The peninsula has a rough topography in general. While coastal areas show an indented-protruding structure because of the perpendicular direction of mountains to the sea, the Mumcular region structure is a plainer surface which is located at the north-east side of the peninsula and called Karaova (Figure 4.11). Karaova is the biggest plainer area in the peninsula.

On the coastline of the peninsula, there are depression areas and valleys that open directly to the sea and form small basins in the inner parts. On these depressions and valleys, there are alluvial plains which came by the streams (Figure 4.12). Limestone and andesite rock types have a permeable structure generally and these types cannot hold water. The peninsula is surrounded mostly with these types of rocks, especially on the western side. Because of this situation, surface and ground water resources are very scarce on the coastal areas of the peninsula. However, interior parts (Mumcular and surrounding area) have more water resources (Bakış and Arı 2010).

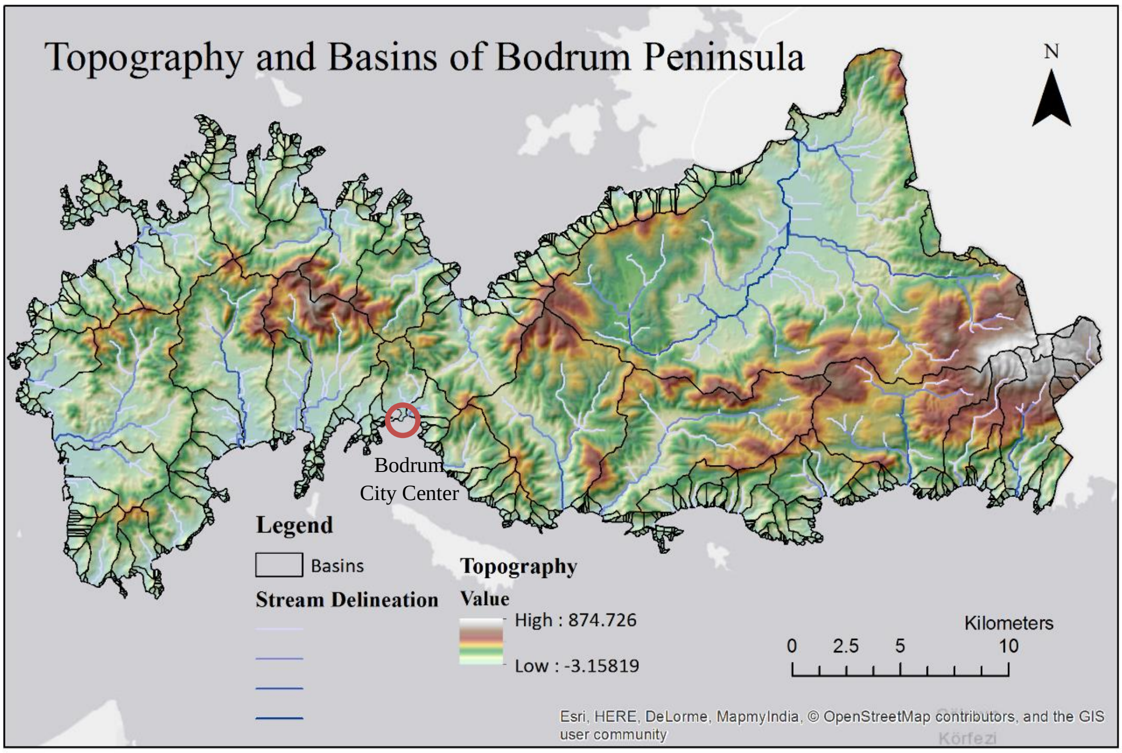


Figure 4.11. Topography and Basins of the Peninsula
(Source: Prepared by the author in ArcGIS 10.7.1)

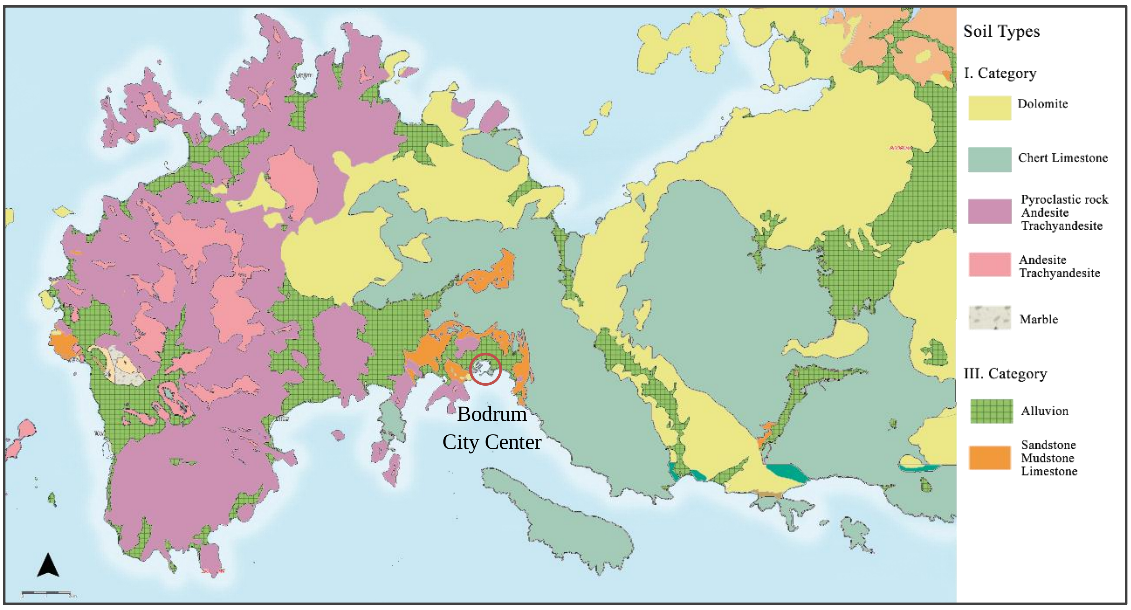


Figure 4.12. Soil Types of the Peninsula
(Source: Prepared by the author based on "https://muglacbs.mugla.bel.tr/TarimsalVerimlilik_app/", 2020)

4.2.3.3. Hydrography

The Bodrum Peninsula has seven streams that flow during the winter and the spring. Inside the Peninsula there are also one wetland (Akdeniz Lake and Wetland Area) and one dam (Mumcular), supplies the Peninsula's most of the usage and drinking water demand (Figure 4.13). Condition of these existing streams are remained as open stream concrete channels by the Turkey State Hydraulic Works (DSI).

In fact, because of the small valleys and coordination of mountains with coastline, almost every bay of the Peninsula has small streams that flow only with heavy rains (Figure 4.14). These stream pathways are called "irme" in the local dialect and the points where they meet with sea, are called "azmak" in the local dialect. The azmak has all year some small accumulation of water where ecosystem for different species especially fishes. Most of these stream pathways had rehabilitation which made them flow in a concrete bed by the Turkey State Hydraulic Works. Additionally, azmak areas are covered by sands or concrete to use as beaches by hotels.

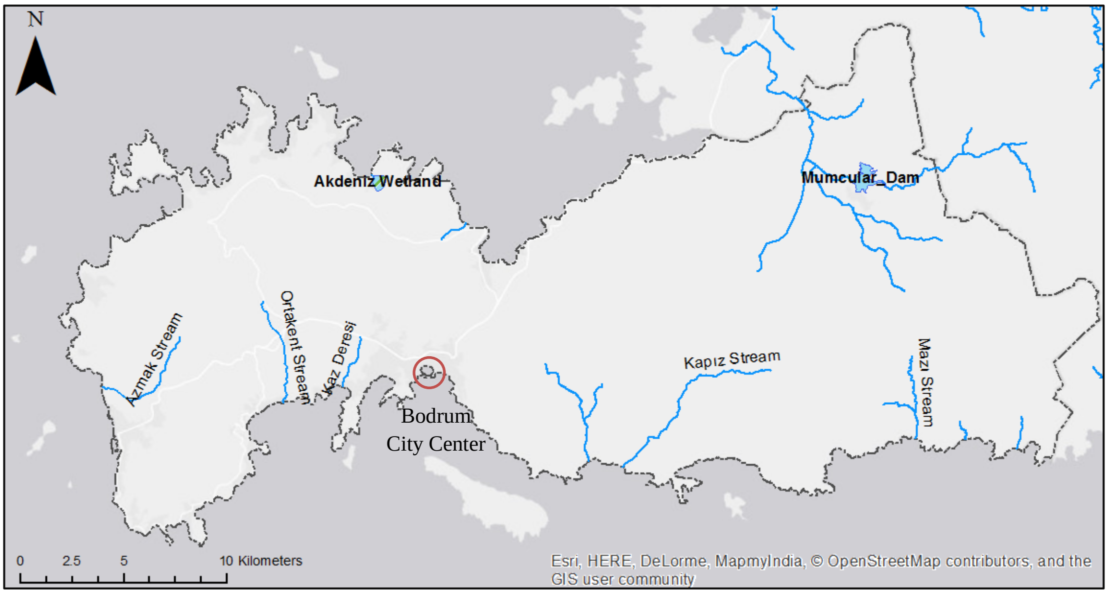


Figure 4.13. The Streams of the Peninsula
(Source: Prepared by the author)

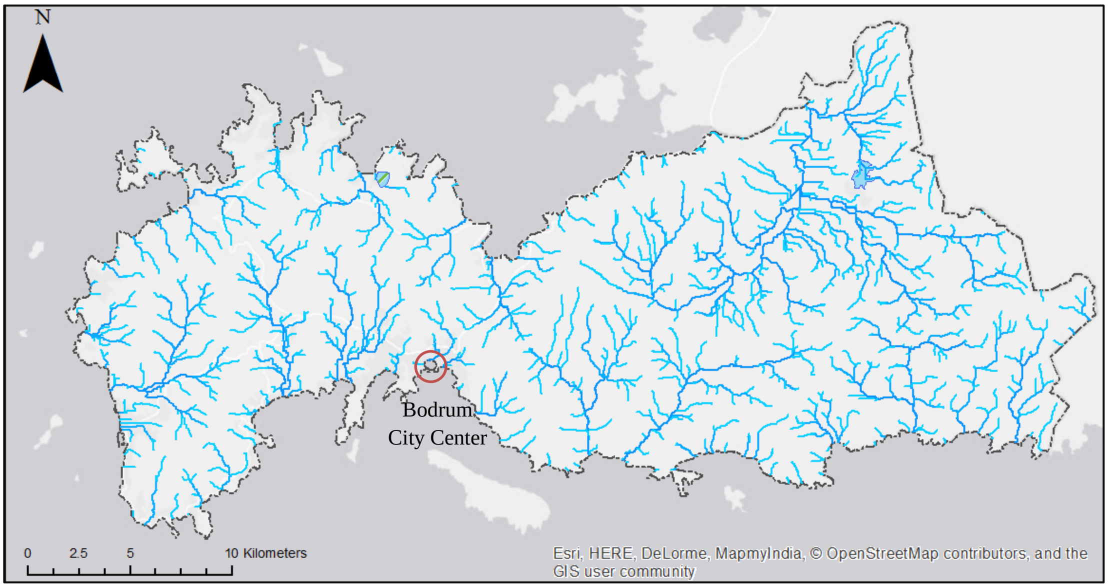


Figure 4.14. The Bodrum Peninsula's Stream Delineation, Main Streams, Small Streams and Tributaries. (Source: Prepared by the author based on Copernicus Turkey Hydrology Dataset and Bodrum Topography)

Due to the dense urbanization, most of the streams are today covered with concrete walls and buried underground for common purpose of making a road. In Bodrum city center, Gökçebel and Gerence Streams were channelized by the Turkey State Hydraulic Works (DSİ) like most of the other streams around the Peninsula. Unfortunately, these streams are no longer able to touch a permeable surface till reaching the sea after entered the urbanized area. These channels are taking the rainwater to sea with average rain, however with heavy rain, usually channels are not enough to flow the rainwater away, and flooding every year is inevitably happening in Bodrum. For preventing these floods inside the city center, according to the local media's news (KentTV, "*Bodrum'a Sel Kapanı Müjdesi*", 2019) a "Flood Detention Dam Project" for Gökçeler Stream, prepared by DSİ Aydın 21. District Office. However, the project is still in the tender stage.

The Figure 4.15 shows Gökçeler and Gerence Streams' buried pathway inside the city center with their surroundings, including football stadium, Halicarnassus Mausoleum, historical protected site, and bus terminal.

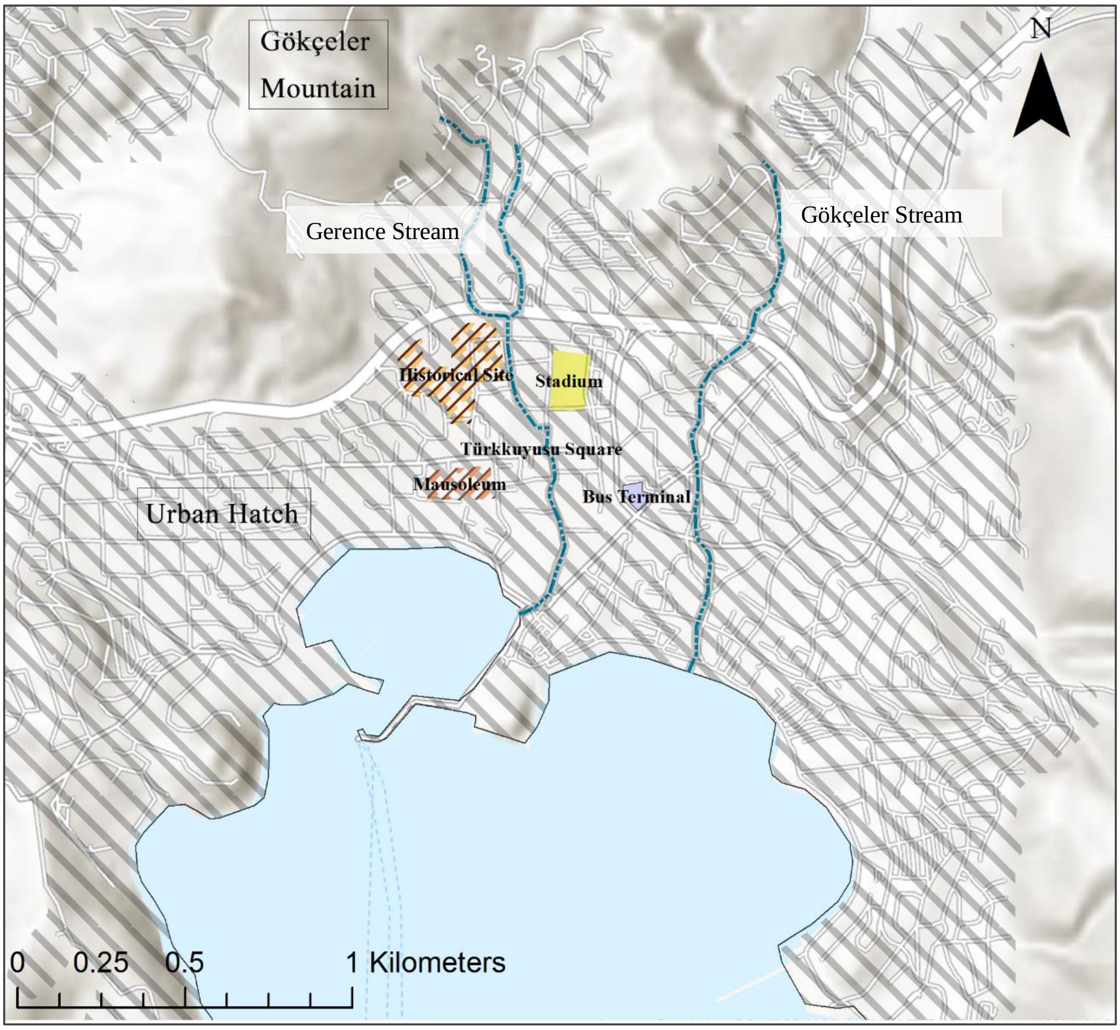


Figure 4.15. Gerence and Gökçeler Buried Stream Path inside the City
(Source: Prepared by the author based on DSİ AutoCAD drawings)

4.2.3.4. Vegetation

The flora of Bodrum Peninsula mainly consists of Mediterranean vegetation elements dominated by maquis shrubland. Eastern-south side of the Peninsula (Kızılağaç, Yalıçiftlik, Mumcular) covered by *Pinus brutia* (Turkish red pine), *Quercus* (Oak, Acorn), *Fragaria vesca* (Wild strawberry), *Myrtus* (Myrtle), *Ceratonia siliqua* (Carob), *Pistacia lentiscus* (Mastic), and *Santalum album* (Sandalwood tree). Also, Olea europaea (Olive) can grow in every part of the Peninsula.

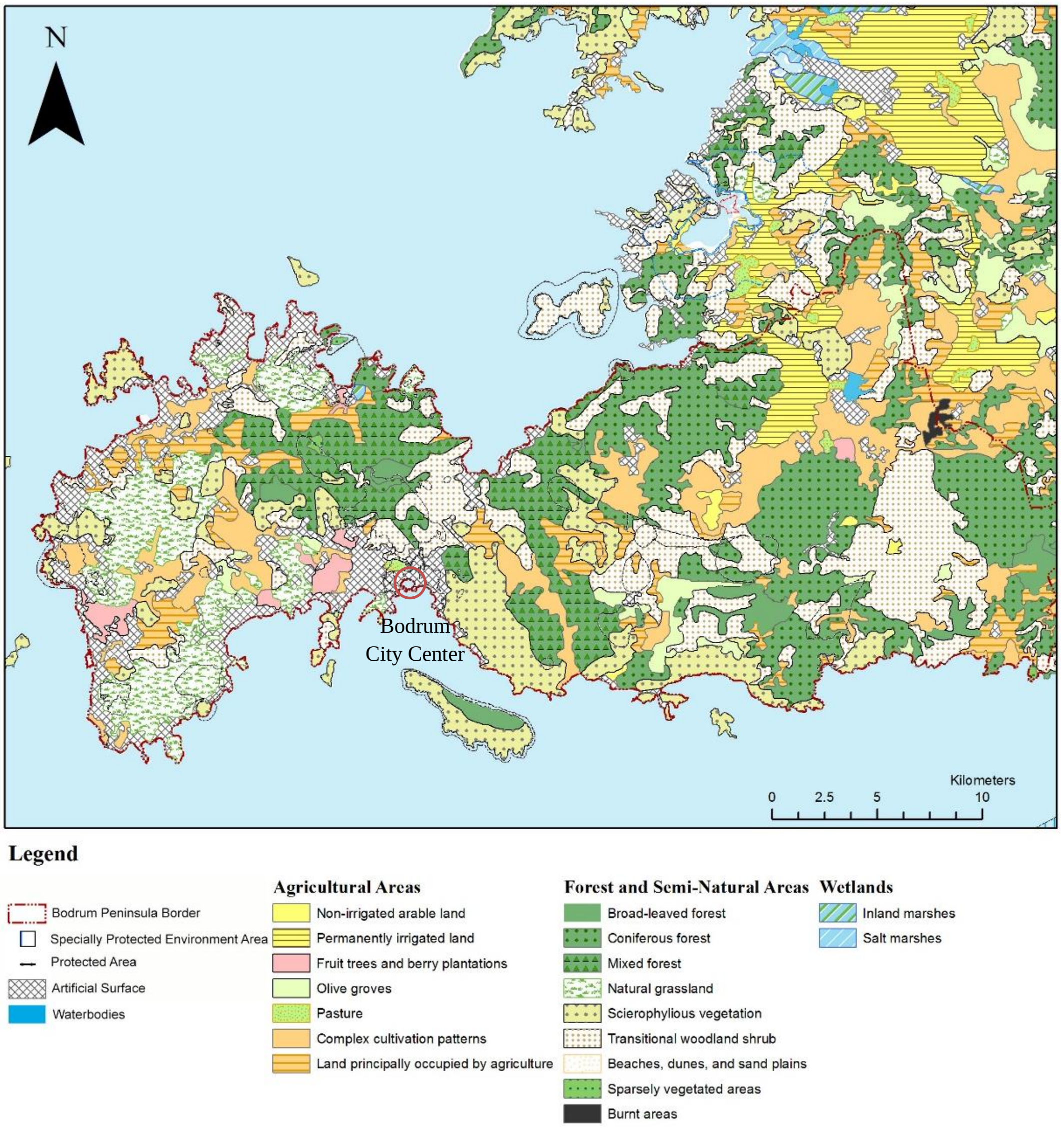


Figure 4.16. The Vegetation Distribution of the Peninsula
(Source: Prepared by the author based on the Corine Land Cover Classes 2018)

The vegetation type of the peninsula is divided as west and east sides. As can be seen from Figure 4.16, the eastern side is mostly covered by forests like broad-leaves forest which is summer-green, the Mediterranean vegetation, evergreen coniferous forests and mixed forests. The other common type of forest in the eastern side is sclerophyll vegetations which is shrubs but also woodland. The western side of the peninsula consists of more natural grasslands and heterogenous agricultural areas like fruit trees, olives and cultivated areas. Around the peninsula, all type of agriculture needs irrigation, there is only small area on the eastern side where non-irrigated agriculture exist. The areas shown as artificial surface includes urban fabric, industrial, commercial and transport units, mine, dump and construction sites, and artificial, non-agricultural and vegetated areas like green urban areas and sport facilities. Total artificial surface area is 155.65 km^2.

In the research of Ertuğ (2002) about medicinal plants in the Bodrum Peninsula, the plants that are found in Bodrum folk medicine are mostly the most common ones in the region, which indicates the locals have long-term compatibility with their natural environment. Bodrum is also famous with its various kinds of herbs which is used in cooking. Each year on March in the province there is “Bodrum Bitter Herb Festival” which exhibit local herbs, food cooked by this herbs, herbal oils and similar local products.

On the other hand, for a sufficient and successful blue-green system native vegetation use is essential. They are already adapted to the climatic conditions and maintenance cost can be minimize in this way. Also, it can create a good social recontact with the environment. In this part of chapter, some epidemic herbs identified for using landscape elements in proposal part.

Table 1. Some of the typical plants growing in the peninsula

Lavandula Stoechas (Cassidony/French Lavender) - It is an evergreen shrub - The flowers appear in late spring or early summer. - It likes hot, dry and sunny conditions in alkaline soil.	
Origanium Onites (Cretan Oregano) - It is drought tolerance. - It is good for bees and butterflies.	

(cont. on the next page)

Table 1 (cont.)

Coridothymus Capitatus (Thyme) - It likes rocky, arid places.	
Salvia Officinalis (Sage) - It is a perennial, evergreen subshrub. - It is native to the Mediterranean region.	

However, with the increasing population and pressure of urbanization, the proper living conditions for these species are fragmented and limit their spreading. Especially, intensive tourism activities along the coasts are creating high threat on vegetation and Bodrum is one of those places which lost its natural vegetation significantly (Avcı 2005).

4.3. Water Problems and Management in Turkey

The location of Turkey is between 26º – 45º eastern longitude and 36º – 42º northern latitudes of the Northern Hemisphere. Regarding the freshwater resources, Turkey is not an abundant country. Turkey is considered a semi-arid climatic region. In the central Anatolia, winters are cold but in the coastal regions, Mediterranean climate is dominant with warm winters. The average annual rainfall of the country is 574 mm and the highest average annual rainfall is in the north-east region with 1600mm. The most significant rivers of Turkey are the Euphrates and the Tigris Rivers, which are also known around the world. The rivers rise in the mountains of north-eastern Anatolia, flow down through Syria and Iraq and finally meet in the Shatt-al-Arab to flow into the Persian Gulf.

4.3.1. Climate Change in Turkey

The impacts of climate change in Turkey can be enumerable as increasing summer temperatures, decreasing winter precipitation in western provinces, loss of surface water, increased frequency of droughts, land degradation, coastal erosion, and floods. As can be expected, these conditions will have negative impacts on water and soil resources and, consequently, create a threat to food production and security (T.R. MoEU, 2011).

According to the existing climatic conditions, Turkey is already under mostly arid and semi-arid climate and environment which makes Turkey more and more vulnerable to the climate change impacts. Decreasing water holding capacity of soil due to heavy rains and increasing drought are the major problems which Turkey will face in the near future (Turkeş, et al. 2020). Aridity index projections for the period of 2021-2050, using the data from 1971 to 2000, which have done by Türkeş et al. (2020), show that semi-arid and dry sub-humid conditions will be severely influential over the Central Anatolia Region, the Southern Anatolia Region, and the Inner Aegean Region.

With the awareness of climate change ongoing and future effects on Turkey, under the coordination of the Ministry of Environment and Urbanization, The National Climate Change Adaptation Strategy and Action Plan (2011-2023) was developed in 2011. The Plan focuses on five different essential areas which are decided by considering the susceptibility to climate change. These are water resources management; agriculture sector and food security; ecosystem services, biological diversity, and forestry; natural disaster risk management; and public health. According to the Plan, the most significant impact of climate change considered as that it will be on the water cycle and water resources. Therefore, the first strategy, water resources management offers five priority targets which purpose to integrate adaptation strategies of climate change impacts to water resources management policies.

4.3.2. Water Pollution in Turkey

The main reasons of pollution in Turkey are summarized as overuse of natural resources; discharge of untreated industrial and domestic wastewaters into water resources and inadequacy of wastewater treatment facilities because of unplanned and rapid urbanization; and agricultural production (Uslu 2020).

In order to achieve the European Union Directives of water quality criteria both for ecological and chemical state, Ministry of Forestry and Water Works of Turkish Republic is preparing a Watershed Protection Action Plans which considers separately 25 hydrologic basins. For 25 hydrological basins, water quality monitoring activities have been implemented by the General Directorate of State Hydraulic Works (DSI) since 1970s (Uslu 2020).

4.3.3. Water Scarcity in Turkey

The population of Turkey is over 82 million people now in 2020 and population predictions show that it will reach 100 million people by 2040 (Uslu 2020). This growth of population is creating a significant pressure on water resources. According to the State Hydraulic Works (DSİ), water consumption for irrigation will be 72 billion m^3, household consumption will be 18 billion m^3 and industrial consumption will be 22 billion m^3 by 2023 (T.R. MoEU, 2011). The determined threshold for water scarcity is 1700 m^3 per capita per year, and lower value of the water availability means as the occurrence of water problems (Uslu 2020). So, according to these facts, when the Turkey population reach to 100 million, water availability will be 1000 m^3 per capita, which will indicate Turkey as a “water poor country” (T.C. MoEF & WB, 2010).

4.3.4. Water Resources Management in Turkey

With the foundation of the Turkish Republic in 1923, Water Directorates were established for the utilization of natural resources under the General Directorates of Public Works in 1925. With the understanding of the importance of water resources management, the Water Works General Directorate was established in 1939. Later on, more comprehensive water plans were increased after 1950’s with the establishment of the General Directorate of State Hydraulic Works (DSI). The DSI was established in 1954 by the means of the Law No.6200 and it is the main operational state institution in Turkey for planning, design, construction and operation of hydraulic structures (Altınbilek and Hatipoğlu 2020). The DSI is responsible for the long-term development and management of water and soil resources in Turkey such as dams, water and drinking water supply to settlements under municipal organization, hydroelectric power plants, and operation of water works including irrigation and flood control (T.C. MoEF & WB, 2010).

According to the Constitution of 1961, it is indicated that the right of search and operate natural resources belong to the state (the Article 130). However, with the Constitution of 1982, “the state may transfer this right to real or legal persons for a certain time” statement was added (the Article 168). Hereby, the ease of searching and operating natural resources was provided to private companies. Later, as part of the Electricity Market Law No. 4628, the construction of energy generation facilities was given to the private sector after the “Regulation on Procedures and Principles for Signing Water Usage Rights for Electricity Production Activities” came into force in 2003. DSI is the main organizer of the hydroelectric power plant projects to provide application for private sectors. However, the report of Water Working Group of Chamber of Civil Engineers (2009) indicates that the right of usage for all rivers in Turkey is transferred to the private sector of hydroelectric power plant and the application way of the projects are basically serving as the privatization of water resources. Additionally, public institutions responsibility for water management have been fragmented. Therefore, their budgets have been reduced and this situation made them unavailable to make investment for water utility services such as sewage systems. Unfortunately, indicating water resources as a commodity rather than a common good and adopting the “who pollutes, pays” principle, seem like the main problems of Turkey’s water resources management. Additionally, the general approach of the state can be summarized “As if water resources would never end” which is totally the opposite of the reality. These visions do not respect to the right of life for all and also, to the ecosystem.

Another important mission of the DSI is stated in article 2 of the Law No. 6200 as "Providing Preventive Structures Against Flood Water and Floods". Additionally, with the Law No.4373, detection of flood areas and potential flood areas, banning of urban development in these areas, and removal of constructions which may cause flooding were adjudicated. However, these generalized public mandates drove the institution to apply same conventional methods everywhere without consideration of the local possibilities and ecosystems. In addition to these, the vision of the DSI for stream improvement projects are still based on channel-conventional techniques which causes in a long-term period even more and irreversible problems for ecological, social and economic life. In 2018, the World Water Day 22 March was subjected as "Nature-based Solutions for Water" by United Nations and even though the DSI celebrated the day as "solutions are in the nature" concept, there is not any remarkable attempt to apply these mentioned contemporary nature-based solutions for water management.

For the accession process to the EU, two new water organizations were founded in 2012 in addition to the DSI: The General Directorate of Water Management and the Turkish Water Institute. The General Directorate of Water Management is mainly responsible for the implementation of the EU-Water Framework Directive and the Turkish Water Institute is responsible for studies about efficient water policies in Turkey and abroad. However, with the constitutional change in 2018 for the presidential system, water-related institutions are also being re-organized. Even though the new system claims that implementation procedures of the EU Water Framework Directive will proceed for the purpose of better conditions of Turkish waters and water-dependent ecosystems, this slow progress is not making significant changes (Yazıcıgil and Ekmekçi 2020).

For blue-green infrastructure integration with city management, a recent outstanding development from Turkey is İzmir. The project aims to integrate blue-green infrastructure solutions with the existing grey infrastructure and to combine green belt of İzmir with strategies of nature-based solutions inside the city. The project started in 2017 with a collaborative planning approach including universities, municipalities, non-governmental organizations, and local communities (İzmir Metropolitan Municipality 2017).

4.3.5. Development of Water Management in the Bodrum Peninsula

Starting from the 1950s, Turkey has been facing a high urbanization ratio. Urban areas with already inadequate infrastructures are also having the problems of unplanned development and growing population, which creates a significant pressure on the environment like pollution of water bodies (Burak and Mat 2020). On the other hand, especially the Aegean-Mediterranean coastal side of Turkey is created as an attraction area for tourism which makes another pressure on local resources and environment (with the law for encouragement of tourism numbered 2634 in 1982). Former mayor of

Gümüşlük Municipality Mehmet Ülküm criticizes the decisions of “development and protection of culture and tourism” with underlining that the decisions gave the right of decision-making for planning and infrastructure to central administration (the Ministry of Culture and Tourism); however, just after 2 months of declaration Bodrum as “development and protection of culture and tourism” area, a bylaw to “local administrative unions”, “tourism infrastructure service unions” were added which makes local authorities responsible for infrastructure but still unauthorized for tourism developments (Bakır 2007). This authority confusion and complexity have caused the decision-making process is far away from stakeholder integrity and comprehensive urban plans for the Bodrum Peninsula.

The population of Bodrum has being outgrown its drains and sewers. The Peninsula is an area with quite a limited volume of groundwater. Before the '70s, the peninsula has not had any sewage system. This was a small fishery town, which just started to take attention. Those years, the population of Bodrum was under 30.000 people and the distribution of urban-rural population was respectively around 20 percent and 80 percent. The toilets of the houses located in their gardens as a separate outbuilding, and the wastes were mixed into the soil, surface and underground water from there. These toilets were cleaned by people and even there were people who worked as cleaner. “Dalavera Mehmet” mentions about his cleaning work memories in the book “Dalavera Mehmet’in Bodrum Tarihi” (Oran and Görgün 2004). Also, in those years, there was no network system for drinking water. Each neighbor districts had their own cisterns and wells where residents could take water from, with bins and buckets. Since 1974, several studies have been carried on for a proper water system such as in 1937 the first attempt for a proper water supply network, then in 1946 and 1953 other attempts, however none of them were sufficiently successful (Baykara 2010). According to "Bodrum-Karatoprak Peninsula Hydrogeological Study Report" prepared by State Hydraulic Works (DSI) 11th Regional Directorate in 1974, in the Peninsula, underground water has accumulated at 13 small plains extending on the shoreline depending on topographic structure and formation mentioned in "Bodrum Sub-Province Sewerage Network Line Final Environmental and Social Management Plan Report" prepared by MUSKİ in 2018. Nature became a system that can be dominated by human-made technology instead of adapted or cohabited to it. Rare units carry some amount of good quality groundwater. In the aforementioned report made in 1974, it has been resolved that 9.74 hm^3 underground water could be safely withdrawn from the plain annually, and this value was revised as 11 hm^3 per year in 1998 by taking into consideration the observations and findings carried out during following years.

"Bodrum–Karaova Project," which was prepared for irrigation of 1,364 ha of land in Karaova in 1982, was revised in 1984 to provide drinking and utility water to the Bodrum Peninsula. In the revised planning report, it was envisaged to raise the dam by 2 meters and derive Gökpınar stream to the dam, and thus to give Bodrum Peninsula 2.7 hm^3/year and 5 hm^3/year drinking and potable water under constrained irrigation conditions. In the newspaper of Bodrum "Merhaba" dated January-February 1986, the news about the Karaova Water Project announced as "our water will reach the town 2 years later. According to the plans, the project will finish at the end of the 1987 and the cost will be 8 billion liras."

Currently, around the peninsula, there are places that still do not have a proper sewerage system. Only properly separated sewerage system exists in the city center of Bodrum which can separate stormwater runoff from wastewater. However, it is known that there are broken pipes that could cause a mixture of both water to each other. Bodrum Municipality's Office of Environmental Protection tries to evaluate and find the broken part and fix it. In the western side of the Peninsula, according to soil explorations, underground water depth ranges between 6.10 meters and 8.00 meters. In this area where contains Turgutreis, Akyarlar, Gümüşlük, İslamhaneleri, Dereköy, and Peksimet neighbors, within the scope of sustainable city concept idea of MUSKİ, new sewerage projects decided both for transmission of wastewater and treatment of wastewater. This project is still under development. According to separated proper sewerage system approach, around the peninsula, there is much work to do for an appropriate system of sewage as mostly the same all-around cities of Turkey.

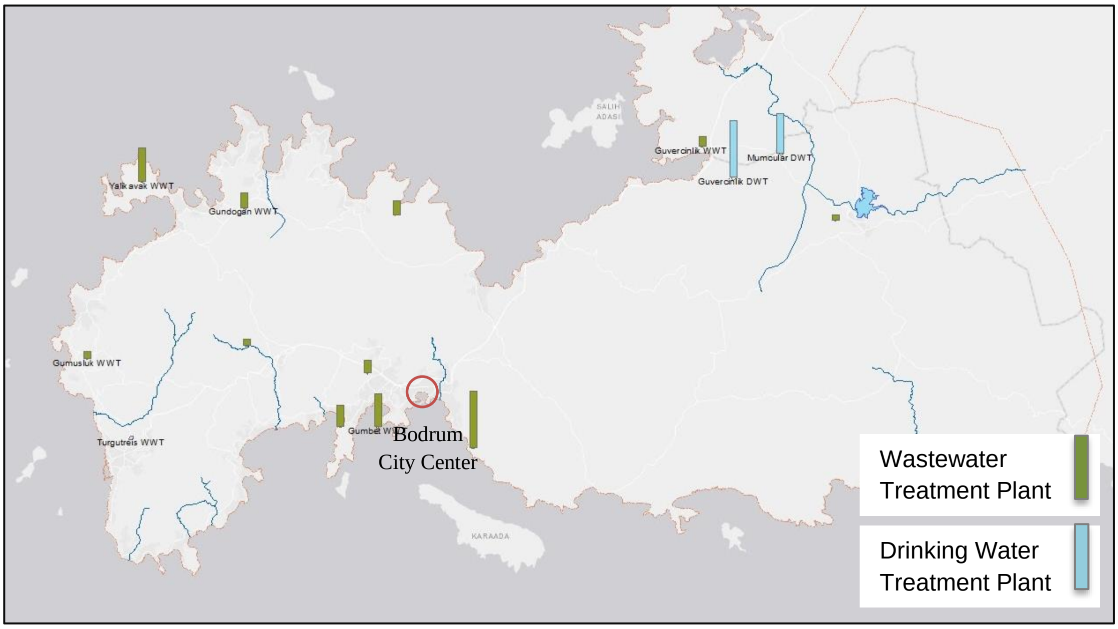


Figure 4.17. Comparison of yearly capacities of the treatment plants and their locations in the Peninsula (Source: Prepared by the author based on MUSKİ)

Within the Bodrum Peninsula, all other municipalities (before 2012, the Metropolitan Municipality status of Muğla Province, there were 11 municipalities across the Bodrum Peninsula), except Bodrum Municipality, have been supplying their water from the wells that they drilled in the peninsula and in their own districts until the last years. Within the scope of State Hydraulic Works Bodrum Peninsula "Urgent Water Supply Project", all the urgent needs of the peninsula are taken into consideration. With the project, Güvercinlik Drinking Water Treatment Plant (Figure 4.17), which was operated by MUSKİ after Law No: 6360, was put into operation in 2012. According to the project, the drinking water needs of 10 settlements (Bodrum, Turgutreis, Gümüşlük, Bitez, Ortakent, Konacık, Yalıkavak, Gündoğan, Göltürkbükü, and Yalıçiftlik) located on the Bodrum Peninsula will be supplied till 2040. Meantime, in order to benefit from the groundwater in the peninsula's water supply system, the settlement in the project area, especially Turgutreis Center, new wells were opened by MUSKİ for its units (Muğla Metropolitan Municipality 2015). In 2011, DSI provided 140 km long water conveyance lines from Geyik Dam in Milas to Bodrum for potable water. However, these pipelines are a constant problem of the peninsula that is broken and causing water cuts and loss. Even generally in Turkey, the new approaches to water supply, like the reuse of wastewater/rainwater or desalinated water, have not been accepted for large scale or city usage until the present time. The main reason behind this is mostly because of practical and social acceptance, but also, the approach of central administration mainly based on the use of existing water resources (Burak and Mat 2020).

Table 2. Wastewater Treatment Plants in the Peninsula
(Source: Prepared by the author based on the information from MUSKİ)

Name	Year	Attached Population	Capacity per day/m³	Capacity per year/m³	Treatment Type
İçmeler	1994	50000	10000	3504000	Physical, Biologic Deep Sea Discharge System
Bitez	1997	12500	2500	1342614	Physical and Biological
Gündoğan	2005	11500	3200	930750	Package Treatment
Ortakent - Yahşi	2008	5000	1000	419750	Package Treatment
Göltürkbükü	2008	15000	3000	854509	Physical and Biological
Gümbet	2009	48000	9600	2000306	Physical, Biologic Deep Sea Discharge System
Gümüşlük	2011	10000	2000	424234	Physical and Biological
Güvercinlik	2012	10000	2500	629400	Physical and Biological
Konacık	2013	15000	3000	790218	Advanced Biological Treatment
Yalıkavak	2014	30000	6000	2073200	Physical and Biological
Mumcular	2014	2000	500	307600	Physical and Biological
Turgutreis	2032		37000		Advanced Biological Treatment

Table 3. Drinking Water Treatment Plants in the Peninsula
(Source: Prepared by the author based on the information from MUSKİ)

Name	Year	Capacity per day/m³
Mumcular	1999	28000
Güvercinlik	2012	40000

However, around the Peninsula, especially during summer times, water shortage is usual part of the life. For this reason, almost each house has their own water tanks to be safe in such situation. Moreover, there are water truck companies in the Peninsula which carry the water from wells to people's water tanks.

Bakış (2010) in his article claims that after 2020, to eliminate the water scarcity in Bodrum, there will be need to obtain water from Dalaman-Akköprü dam, after the year 2025 Dereköy Stream and after the year 2040 Namnam Watercourse will be the destinations where Bodrum can provide water. These solutions may provide short-term water supply, however, in a long-term period will cause scarcity for both regions.

In the Report of Muğla Metropolitan Municipality (2015) urban water footprint comparisons are presented. Urban water footprint is divided as urban blue water footprint, which is obtained by summing amount of water (m^3) drawn in each settlement (amount of water drawn is sum of evaporation, distributed water and water loss and leakage), and urban grey water footprint is calculated by dividing urban pollution loads (units) by the difference between the quality standard (kg/m^3) and the natural concentration in the receiving water environment (kg/m^3) for each pollutant. According to the report, Bodrum is the second among the provinces of Muğla that creates urban water footprint pollution after Fethiye. One of the biggest reasons of this situation is given as that insufficient infrastructure of the peninsula for growing population. Insufficient treatment plants in the peninsula, especially during summer seasons creates more leaching untreated wastewater to the sea which increase the grey water footprint.

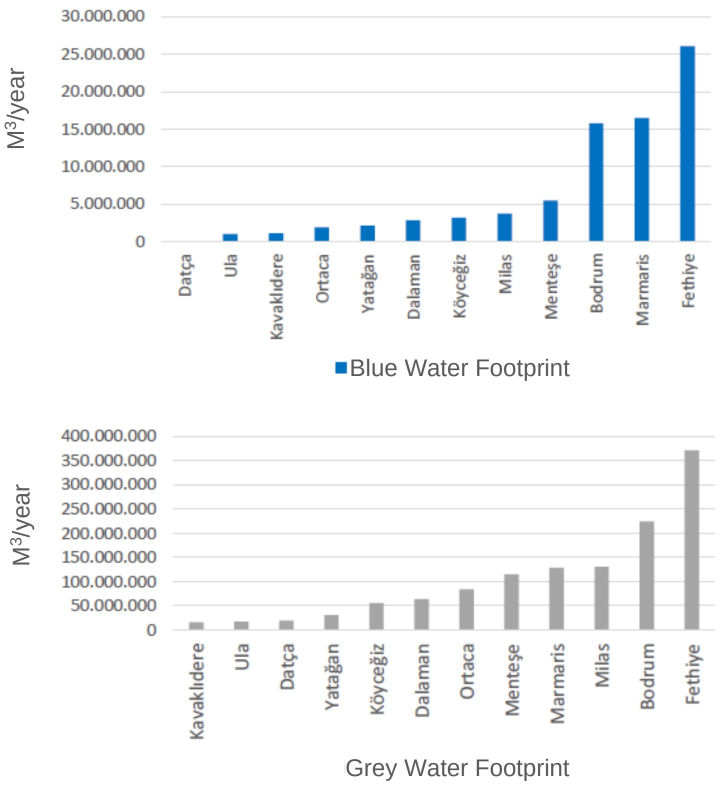


Figure 4.18. Urban Blue and Grey Water Footprints of Provinces in Muğla
(Source: the Report of Muğla Metropolitan Municipality, 2015)

Today dams and pipe systems are still perceived as the possible solution to solve water scarcity problems not only in Bodrum but also general in Turkey. These suggestions, instead of being a solution, are salvages for saving the day and they are not helpful to Bodrum which already has lost its water and healing process of water resources. Furthermore, these so-called conventional solutions will follow the same endless cycle, which will make other regions also dry in the future. However, this city has water inherence, which can sustain itself. So, this heritage knowledge should be carried to the future of our children's town and as their water inheritance. Today's world is struggling with climate change a lot, and one of the known facts is that it is because of the bad decisions taken by our ancestors and us. Now the question is: Are we going to continue in the same way, or do we have a plan to change the situation?

4.4. Freshwater Potentials and Problems in the Bodrum Peninsula

The freshwater problems of the peninsula can be grouped under five sub-topics: Urbanization, flash flooding, insufficient infrastructure, salinization of groundwater, and lastly, water scarcity. Bakış (2010) sort the problems directly or indirectly related with freshwater insufficiency in Bodrum as result of;

- the rapid increase of population;
- the existing watercourses both surface and undersurface cannot fulfill the needs;
- excessive usage of groundwater;
- increasing salinization;
- invasion of agricultural lands by tourism for constructing hotels, resorts, summer housing developments, etc.;
- deforestation and disturbance of habitats;
- seasonally population change and impact on life quality;
- destruction of historical sites;
- environmental pollution of the leakage of wastewater, and discharge to the sea and illegal construction wastes; and lastly,
- wastewater capacity of treatment plants arranged according to the peak times of tourism, thus inefficient treatment during the winter season.

From another perspective, there is a potential for freshwater supply in Bodrum, coming from its cultural history. Hence, to find the potentials, a public survey was conducted to analyze public opinion about the current water problems and traditional water supply techniques, and on-site observations were made for a better understanding of the case study area. Finally, to be able to propose planning strategies of BGI, pilot areas selection was made by synthesizing all the analysis.

4.4.1. Planning and Urbanization

In Bodrum, urbanization is not an old history. Municipality of Bodrum was founded in 1881. In 1944, the town became a province of Muğla, and the first master plan was prepared in 1948 by the İlbank (Bank of Municipalities). However, the plan had never been implemented. Till the 1970's, the settlement was a small fishery and agricultural town, where transportation provided mostly by sea transport. The first conservation plan which considers the local, cultural and natural values of Bodrum was prepared in 1971 by Tuğrul and Necva Akçura (Esmer 2012). Thanks to this plan, a common architectural style was determined for Bodrum Peninsula. However, due to the high tourism pressure, Bodrum was presented as a prior-degree tourism center at the beginning of the 1970s by the inter-ministerial tourism committee and right after, the first massive summer house production, Aktur Housing Development was constructed in 1972 (the second Bodrum Master Plan in 1974 gave the main importance to tourism for development of the city) (Arbak 2005). This decision also made the residents use their homes as touristic-rental houses. Moreover, in the following years, the significant changes appeared in the peninsula environment. For example, in 1979, the construction of Milas-Bodrum's main road, which provides a more comfortable connection with İzmir gave a significant impact on the growing attention of the tourist attraction of Bodrum. Towards the 1980's, Bodrum have become a second address for intellectuals who were trying to escape from crowded cities and political conflict (Esmer 2012). During this process, most of the registered heritages and assets of the city had been wiped out (Figure 4.19). In 1975, most part of the city center was declared as a third-degree archeological site and urban archeological site, and 773 civil architecture representatives and 112 monumental buildings were registered. However, in 1986, the decisions were decreased to 425 civil architecture representatives and 40 monumental buildings. Moreover, the decision of urban archeological site in the city center had pushed the urban development to the other parts of the peninsula.

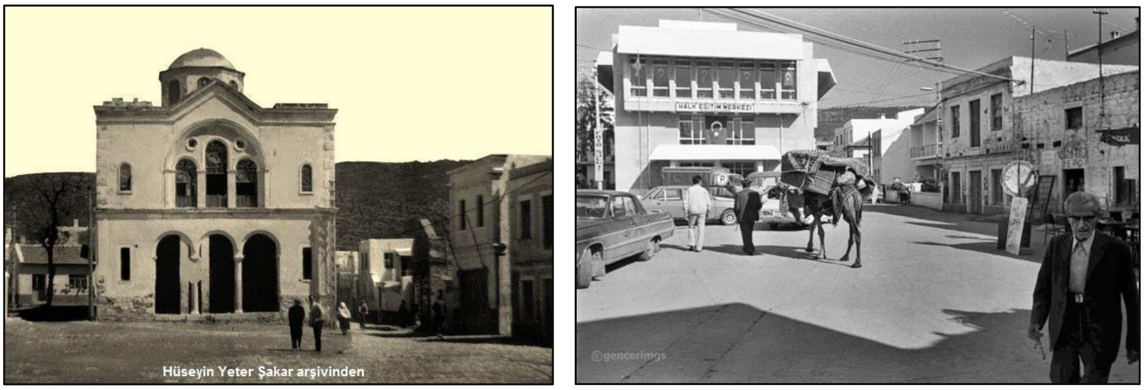


Figure 4.19. On the left picture, Church of Aya Nikola, located in the square of city center, was demolished and a public education center was constructed instead (on the right picture) during end of 1960's. (Source: the left picture is taken from Hüseyin Yeter Şakar Archive, the right picture is taken from Ali Şengül Archive)

After 1980's neoliberal policies and privatization have started to be implemented in Turkey and private entrepreneurship was encouraged. In 1982, the Tourism Encouragement Law have provided opportunities for tourism investments, especially in the coastal regions of Turkey. After all, in 1985 the bays of Bodrum Peninsula, Türkbükü, Yalıkavak and Yalıçiftlik have been allocated to tourism investments (Esmer 2012).

In 1982, Conservation Plan was prepared for Bodrum by the Ministry of Development and Housing. The plan included entire Bodrum urban settlements and development areas with archeological sites, 2nd and 3rd degree natural protected areas and new urban development areas. This plan revised in 2003 and 1/5000 and 1/1000 Scaled Bodrum Conservation Revision Plans have been accepted. The Plan Report indicates that streams cannot be covered except for the locations determined by the DSI, even if it is within a private property. For construction permission of property, it is essential that the ownership of the streams in private property to be passed to the public ownership. However, in reality, it is a subject to discussion if the water streams have been protected as it is decided in the plan.

1/25 000 scaled Master Plan for the Bodrum Peninsula Culture and Tourism Conservation and Development Regions have been prepared in 2007 by the Ministry of Culture and Tourism pursuant to 3rd article of 4957/2634 numbered Tourism Encouragement Law. However, the plan has been a subject of various discussions. The most essential problems of the plan were; coastal sites and untouched bays became threatened by tourism development pressure; without comprehensive plans, focusing on only tourism development and investments, the economy of the city became attached to tourism strictly, and this situation causes population differences between summer and winter seasons which also affects daily life of the city.

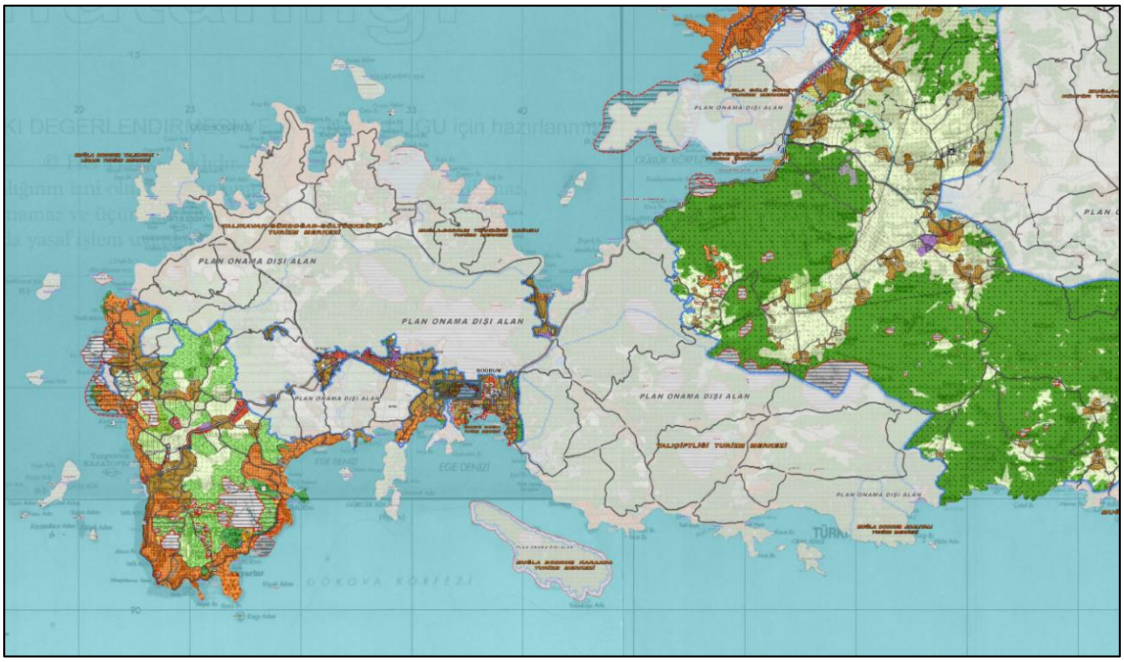


Figure 4.20. 1/25.000 scaled Master Plan
(Source: Url 16)

As can be seen from the Figure 4.20, a large part of the peninsula was decided as Culture and Tourism Conservation and Development Region by the Ministry of Culture and Tourism (shown as white and empty). By means of these regions, these areas are able to be divided to sub-regions such as Tourism Centers which means tourism is the most important activity in the area and has the biggest priority. In the peninsula, almost each region is decided as Tourism Center, only on the eastern side of the peninsula which includes Mumcular area is decided as Culture and Tourism Conservation and Development Region. These decisions are providing convenient environment for private investors which even attract more investment but without proper infrastructure and a huge pressure on natural structure.

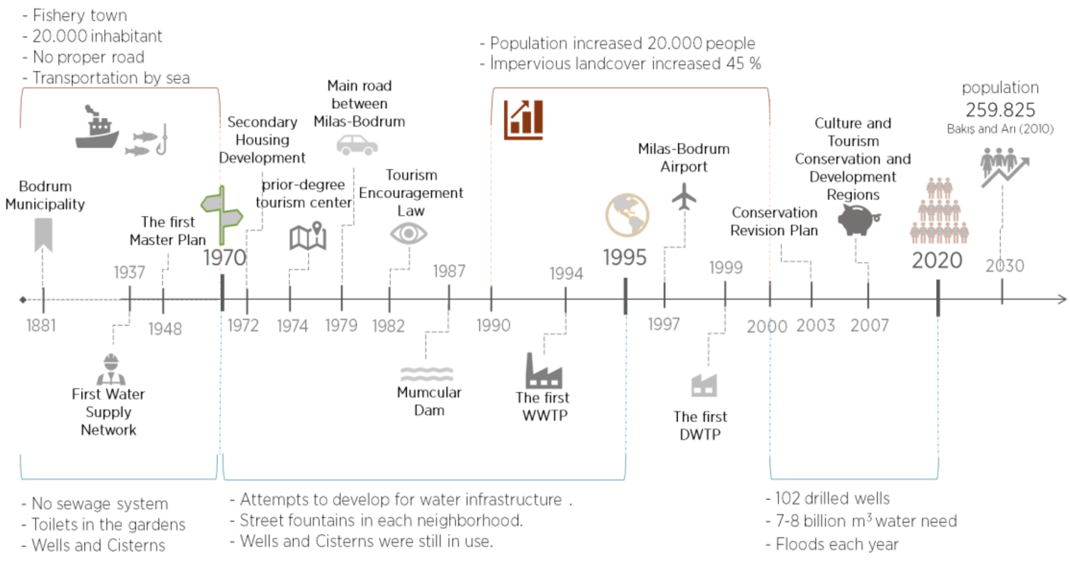


Figure 4.21. Urban and Water Management Developments in Bodrum Peninsula
(Source: Prepared by the author)

According to the Report of the 1/25 000 scaled Master Plan (2016) prepared by Semra Kutluay for Muğla Metropolitan Municipality, the population projections show that urban population of Bodrum will reach 176.351 in 2020 and 228.098 in 2025, and rural population will be 16.539 in 2020 and 15.432 in 2025. In the same report, secondary house population for Bodrum is given as 237.408 for 2025. All these excessive growth visions (which is already a massive problem) for the peninsula will bring the end of local culture and way of living. On the other hand, these visions are creating a huge pressure on nature, deforestation, and increase on impermeable surfaces (Figure 4.22).

As mentioned by Gürsoy Akça in the Report of the Third Symposium of Bodrum in 2013 with all aspects, tourism developments had made a significant effect on Bodrum's economic structure (Erdoğdu and Özgiray 2014). However, because of unplanned urbanization, it has also caused a devastating impact on the city's social and physical structure.

Figure 4.22. A 5-Star Hotel Construction after Deforestation
(Source: Url 17)

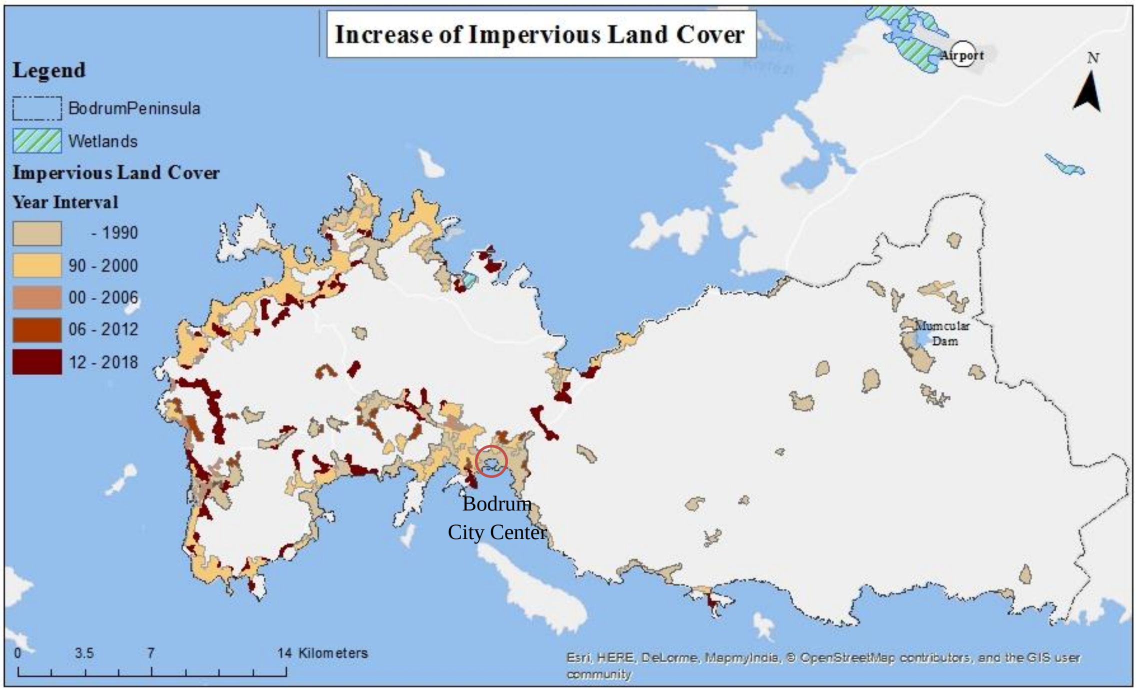


Figure 4.23. Impervious Land Cover Growth in the Peninsula
(Source: Prepared by the author based on the data from the Corine Land Cover Data Set with ArcGIS 10.7.1, 2020)

For understanding the historical development of urban structure and potential societal and environmental challenges, a peninsula-wide urbanization analysis was done by the author of the thesis (Figure 4.32). The aim of showing the loss of permeable surfaces and growing impermeable surfaces in the scale of the peninsula-wide to estimate the effects of urbanization on the natural environment and water surfaces. The urbanization morphology analysis based on historical maps and the Corine land-cover data set taken from the Copernicus Land Monitoring Services (CLMS) provided by European Environment Agency and the European Commission DG Joint Research Centre (JRC). According to the data, urban fabric of the peninsula, which is discontinuous urban fabric, is 48.63 km^2 which means 26 % of the total peninsula area.

As possible to see from Figure 4.24, till the 1990s, city centers were already exceeding the limits of its borders. According to Esmer (2012), almost half of the 700 different secondary housing development projects which were constructed till 1998, were built between the years of 1983 and 1988. More than that, 1299 hectares of agriculture areas were occupied by touristic investments between the years of 1975 and 1995 (Arbak 2005). The years between 1990 and 2000, have had the most effects on out-skirts and coastal lines of the peninsula. During these years, also the Milas-Bodrum Airport was started to construct, and in 1997, it was completed. Forty-four percent of this twenty-six percent area covered by impermeable urban structures between 1990 and 2000 (Figure 4.18). After the millennium, constructions were continuing in a way as filling the gaps which were stayed between urbanized areas as empty or green areas. In 2012, with the law numbered 6360, Muğla Municipality became a metropolitan municipality, and in the peninsula, 11 other municipalities are closed and attached to Bodrum Municipality. With the law, every rural area has accepted as urban area in Muğla City borders, and we can see from the Figure 4.19 that between the years 2012 and 2018, the impermeable surface cover increased 12%. It is possible to evaluate as how tourism decisions and declaration of Muğla as Metropolitan Municipality affected the increase of urbanization and directly development of impermeable surfaces in the Peninsula after 2012. Another interesting point is the difference between western and eastern sides of the Peninsula. On the western side, almost there is no more area left on the coastal line that is unaffected by the development. However, on the right side of the Peninsula, thanks to its vegetation structure which is mostly forest, and its rough topography, the area shown as protected area in the Aydın-Denizli-Muğla Environmental Plan (1/100.000).

The comparison pictures on Figure 4.25, clearly shows the urban development especially on the coastal areas. Secondary house production, hotels, resort hotels and café-bars are the main elements of this brutal development, however, the main problems are inadequate urban plans and control mechanisms.

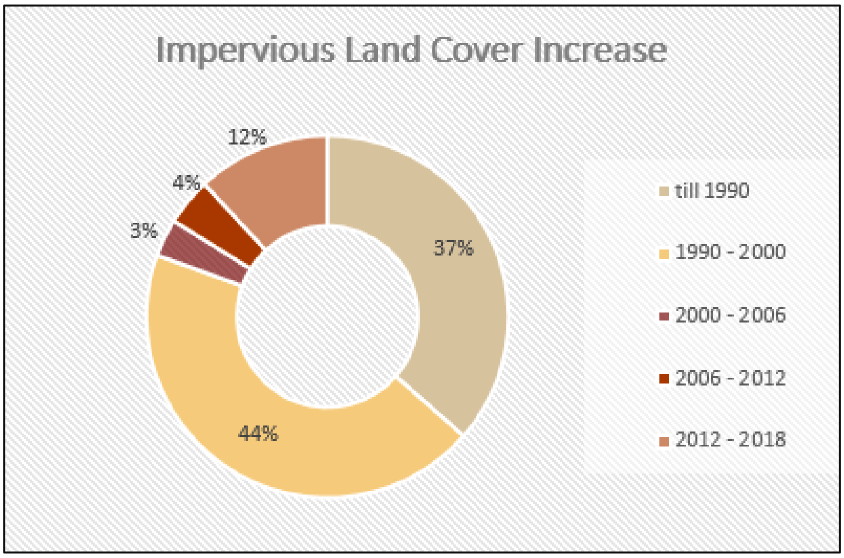


Figure 4.24. The impermeable land cover increases across the Peninsula as percentage (Source: Prepared by the author based on the Corine Land Cover data)

Figure 4.25. Comparison Pictures of same places in 1948, 1976 and 2018 (The left-side pictures, a general view of Bodrum City; above is from 1948 and below is from 2018. The right-side pictures, a view of Bodrum coast; above is from 1976 and below is from 2018). (Source: Photograph Collection of Ali DİZDAR)

4.4.2. Insufficient Infrastructure and Flash Flooding

Insufficient infrastructure has had always been a problem in Bodrum. Today this issue still preserving the top place of the problems. According to the results of the doctoral research made by Bozyer (2008) water problems are the most important issue in Bodrum. One of the most complex reason is tourism and simultaneously unplanned urbanization.

Today, the biggest problem caused by inadequate infrastructure is floods. At least once a year, there is a flood disaster that has caused substantial financial damage, and sometimes even causing loss of life. Unfortunately, among the vision and solution techniques of DSİ which is the responsible institution for water works in Turkey, flood plain management is totally depends on capture the runoff on upper basin and channelize the streamway to take the runoff away especially in urban areas. These standard solutions have been applied to all cities of Turkey with the same methods.

In Bodrum, one of the most devastating floods in recent years was occurred on November 18, 2018, affecting the entire Muğla region (Figure 4.26 a and c). According to the statement made by the Bodrum District Governorate, 120 kg per square meter of precipitation has fallen to Bodrum only between the hours 4 and 7 in the morning. It is pleasing that there is no injury or death. However, about 150 flooding reports and around 1000 vehicles were damaged around the Peninsula. The total amount of precipitation reached 150 kg per square meter during the day. The pictures in Figure 4.26 are taken from the Yokuşbaşı area, Gökçeler Stream which is buried under the road.

Currently, these problems are being considered deeply with the help of different organizations in Bodrum. One of the nearest discussions about the water was the Bodrum Water Panel organized by the cooperation of the Association of Bodrum Middle East Technical University Alumni (BODTUM) and Bodrum Municipality. The panelists were coming from different organizations and universities like State Hydraulic Works (DSİ), Muğla Metropolitan Municipality Water and Sewerage Administration (MUSKİ), and Muğla Sıtkı Koçman and Gazi University. The most remarkable evaluations, according to the result of the Panel, were made on flooding and broken water distribution lines. For flooding, the organizations negotiated on un-functional and insufficient inlets and canals and taking measures to slow the speed and direct the water from slopes before coming to the city center. Also, the statement “streams want their beds” made by the head of DSİ gives us signal of a different new approach is being formed around current water management discussions than the existing conventional approach. The other important topic about insufficient infrastructure was consistently broken water lines in the Peninsula. In the final of the Water Panel, important negation of water and wastewater distribution lines which have not got enough quality, are accepted as the facts of the current insufficient infrastructure.

On the other hand, in the second part of the Panel, Prof. Dr. Görer Tamer and Asst. Prof. Kübra Cihangir Çamur had presented sustainable management and planning evaluations for Bodrum and its future and indicated the fragmentation of natural integrity because of land-use change. Also, the importance of nature-based new approach solutions is emphasized by especially showing revitalizing of streams and increasing the permeability of urban areas.

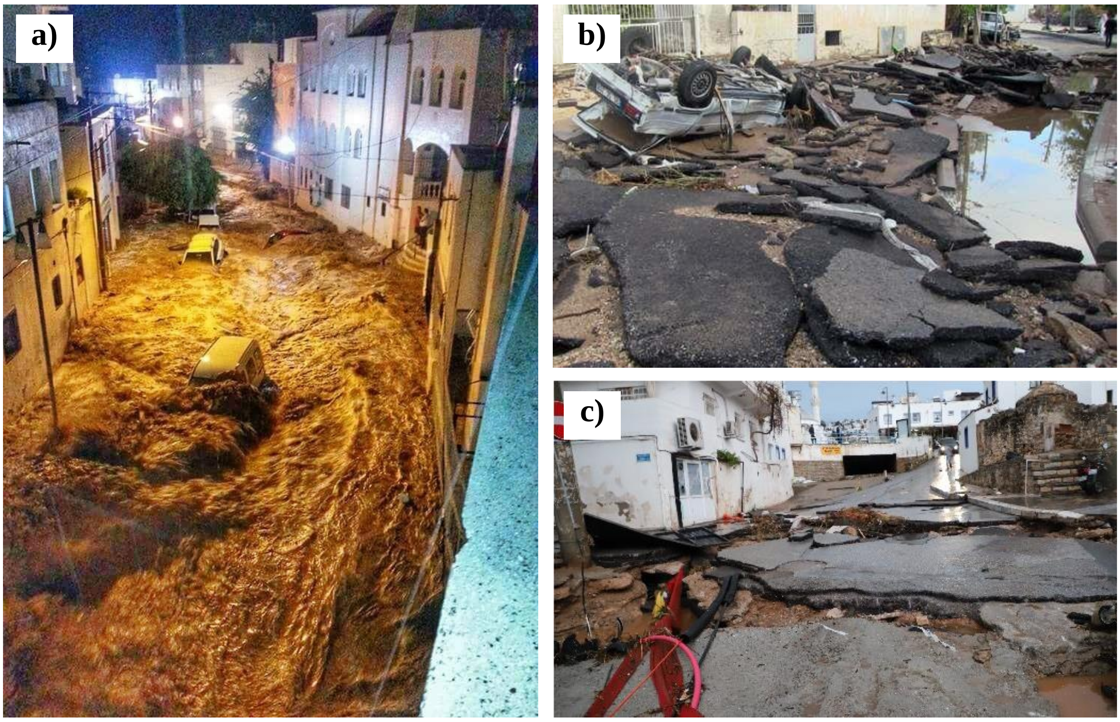


Figure 4.26. Different Flood Disasters in Bodrum (b) is from 23/09/2015, a, c) is from 5/11/2018)
(Sources: a) taken from “Eski Bodrum” Facebook Group. b) taken from Url 18
c) taken from Url 19)

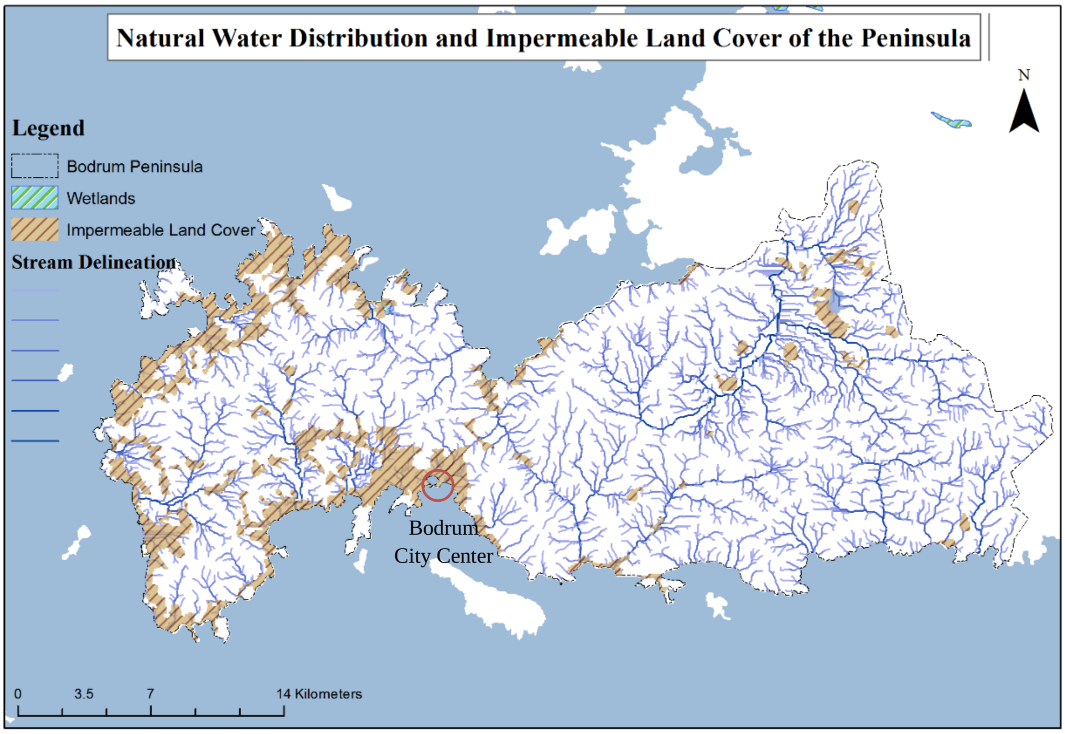


Figure 4.27. The Overlap of Natural Water Ways and Impermeable Land Cover of the Peninsula
(Source: Prepared by the author based on the Topography Raster Data with ArcGIS 10.7.1)

As emphasized in the Bodrum Water Panel, insufficient infrastructure with uncontrolled urbanization causes devastating impacts morally and materially to Bodrum. In Figure 4.27, natural waterways and the impermeable surface of the Peninsula are shown. For analyzing the natural waterways of the Peninsula, the hydrology tool of ArcGIS was used. The toolset provides an opportunity to identify the natural distribution of water networks, according to topography. The darkest blue color indicates streams of the Peninsula, and lighter colors are tributaries of these streams. Naturally, all these waterways are fed by mountains in the middle of the Peninsula and flow to the Aegean Sea. However, when the current impermeable surface (urban) layer was added to upon the waterway layer, the overlap is clearly showing how urban development is blocking the waterways. Therefore, flooding is an inevitable reality of the Peninsula.

On the Table 4, some of very damaging flood disaster news are collected from the news. As it is possible to see from the dates of the flooding disasters, almost each year, flooding damages to Bodrum and its districts. Even in some years, it happens more than once. Because the news was collected from web pages of news, before 2012 archives could not found. However, even in this eight-years period, at least eight times devastating floods have happened in Bodrum and its districts.

Table 4. Collection of some News from media about flooding in the Peninsula
(Source: Arranged by the author from different media websites)

Date	Location	Source	Title
15.02.2020	Bodrum	Sözcü	Tatil beldelerini sel vurdu (Flood hit the touristic towns)
	Yalıkavak	Kenttv	Dere Tıkandı, Ev ve İş Yerlerini Su Bastı (The stream stucked, houses and offices flooded)
23.12.2019	Bodrum	Kenttv	Yağış Günlük Hayatı Olumsuz Etkiledi (Precipitation negatively affected daily life)
	Main road		
8.10.2019	Bodrum	Kenttv	Sağanak Geceden Beri Etkili Oldu (Storm was effected whole evening)
	Main road	Ihlas News Agency	
	Gümbet		
	Mumcular		
	Konacık		
19.09.2019	Bodrum	Kenttv	Bodrum'a Sel Kapanı Müjdesi (Good news to Bodrum; flood detention dam)
29.11.2018	Bodrum	CNN Türk	Bodrum'u Sel Aldı (Flood hit Bodrum)
	Gümbet	Karar	
	Konacık	NTV	
18.11.2018	Bodrum (Türkkuyusu, Yokuşbaşı Nbh.)	Bodrum Gündem	Bodrum'da Yine Sel Felaketi (Another flood disaster in Bodrum)
	Konacık		
	Bitez	Bodrummuhabiri	
	Torba		
	Turgutreis	Ihlas News Agency	Bodrum'da Sel Felaketi! Asfaltlar Patladı, Araçlar Sürüklendi (Flood disaster in Bodrum; asphalts are broken, cars are washed away)
23.09.2015	Bodrum	Turksail	Bodrum, Bodrum olalı böyle afet görmedi (Bodrum has never experineced such a disaster)
29.12.2012	Turgutreis	Sabah	Bodrum'u Sel Vurdu (Flood hit Bodrum)

4.4.3. Water Scarcity and Salinization of Groundwater

As described in the theoretical part, water scarcity is as a term means insufficient water supply for everyone and every habitat. Bodrum Peninsula as a climatic condition is located on a semi-dry region. Therefore, generally the freshwater resources are not enough rich inside the region. Inside the Peninsula, there is not a big watercourse which has enough basic flow and with enough watershed. Small streams which drains to small lowlands during rainy time, dry during summer times almost totally and there is not any lake in the region. Water supply of the region mostly depends on groundwater supplies mainly from drilling wells in the city center, Ortakent, and Karaova (Mumcular) regions and from Mumcular Dam (Bakış 2010).

According to information taken from the MUSKİ (2019), there are 102 drilled wells around the Peninsula for drinking and usage water supply and annually total need of the Peninsula is approximately 7 – 8 billion m^3/y (Bahadır 2019). The potential of groundwater resources in Bodrum is fully used during winter seasons and during the summer season, with the almost 5 times more population, the water demand is supplied by these wells and Mumcular Dam. However, this overuse of groundwater resources brings also significant consequences like contamination of groundwater. One of the serious pollutants for groundwater is leakages from sewages and septic tanks (Öğüt 2011). On the other hand, this overuse of groundwater creates gaps in aquifers and especially coastal areas, the sea water enters the groundwater which creates salinity. Besides of the contamination of freshwater, salinity also creates a dangerous environment for vegetation growth. Another important issue of freshwater in the peninsula is hard water (limewater) (Baykara 2010).

All in all, all these factors which affects Bodrum's water scarcity directly are the local problems. However, as mentioned in the literature review part that we are facing more and more drought seasons (less frequency of rain but more amount) which called climate changes all around the world. So, anymore each settlement for their future plans has to consider these global effects, too.

4.4.4. Public Survey - Analyzing Local Memory on Water in Bodrum City

For understanding the local knowledge of the traditional water collection systems and memory of locals and assess the public view to nature-based solutions, a survey was carried out to support the socio-cultural inclusiveness of the thesis between 24th of January and 3rd of February 2020.

The survey has three elemental questions to get the profile of the participants and eleven questions about the public memory of traditional water management tools and general view of water problems of today. At the end of the survey, one free field was added for additional advice or story if participants would have more to say. The surveys were conducted as online and face-to-face. In total, the survey was answered by 51 residents of Bodrum. The age distribution is changing between 22 and 100, and thirty-three of the participants are over 50 years old. Participants are either residents of Bodrum Peninsula or living in Bodrum for a long time period. More than half of the participants (29 people) indicate their location in Bodrum city center and distribution is changing as Çarşı Neighborhood (5 people), Yokuşbaşı Neighborhood (8 people), Türkkuyusu Neighborhood (7 people), Eski Çeşme Neighborhood (2 people), Cevat Şakir Neighborhood (1 person), Tepecik Neighborhood (2 People) Yeniköy (former name is Kelerlik) Neighborhood (3 people), and Umurça Neighborhood (1 person). The rest of the participants are from Turgutreis (12 people), Bitez (3 people), Ortakent (former name is Müsgebi) (3 people), Kızılağaç-Yalıçiftlik (2 people), Gündoğan (1 person) and 1 is as unknown.

For the research, people's location of residence and age were necessary to know because of determining local's memory based on location and comparing the attitudes of people to traditional water collection method.

The fourth question, which is the beginning of the questionnaires (Appendix), asked participants for sharing their memories of approaches and methods that they were using in their lifetime in Bodrum. According to the answers, wells and communal cisterns are the most known and used methods of the local memory (Figure 4.28). The remarkable common answers (40 out of 50) were about how rainwater usage was common and normal among people in the past. People who used cisterns in their lifetime are underlining the importance of being together and enjoy doing things together. Also, another local method based on answers, "Çöplen" draws attentions to Bodrum houses. It is an uncomplicated water collection method from the roof of the houses; however, the water collected from roofs was vital and more reliable for them to satisfy primary needs. The roof cover of Bodrum houses traditionally is made of special clay soil belongs to the region. So, participants also underline the importance of this soil for houses and water collection. This clay soil is waterproof local material that every year after summer needs to be renewed. This clay soil is mixed with seagrasses, so this mixture keeps houses warm and dry during winter and cool during summer. When the answers and ages of participant are compared, it is possible to say that until 1970s, communal cisterns, wells, household cisterns are in vital position in the Peninsula. After 70s, municipality had started to construct public fountains in public places and streets. Another noticeable story is a retention pool constructed by local chief of Bitez. The pool helps to keep rainwater for longer time and absorb the water slowly into the soil and then feed the wells in Bitez mandarin gardens.

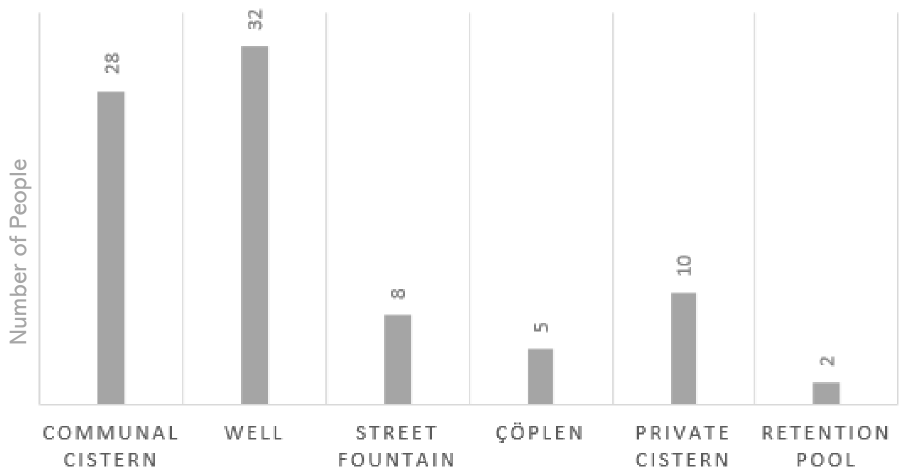


Figure 4.28. Number of People that Used Different Methods for Water Resource
(Source: Prepared by the author based on the survey results)

The next question was asked about the names of the common cisterns or wells which they were using in the past. This question displayed the common memory of the water collection points of the city. For example, Makuf Well, was located where the stadium is located today, was used or heard almost by all participants of survey who lives in the city center. To describe the location of the well, “under Gökçebel Mountain” is used. At the same point, it is understood that there are more wells called Kokoli, Kelerlik, Çatal, and Gerenkuyu. It is not exactly known how these names were given to these wells. On the other hand, they distinguish the wells’ water according to its saltiness. For example, Kelerlik and Makuf are known as the best quality of water that locals were using for drinking.

The sixth question was asked to understand the people’s opinion on the location of cisterns and wells. According to the answers, 44 of 51 people think that there is a reason for the location of cisterns and wells. 4 of them believe that it is randomly chosen and 3 of them have no idea. The descriptions of the participants, who think that there is a reason where cisterns and wells are located, differs. Majority thinks they are located on the main road routes where they can collect rainwater from surface. Additionally, people think when we consider all of them together, their location can show us an old route used for horses, donkeys and camels which were used as carrier in past around the region. However, on each settlement at least one, on a hillside, near a stream bed are other common opinions that they think of as a reason for location choice.

The purpose of the seventh question was asked to understand whether the local people think that the existing water structures creates a social and urban value. According to the answers, all participants think that they have an essential and constructive value for both social and urban. Especially the people who were using them in their lifetime, think that cisterns and wells were the vital utilities of the city. Water was not a product that can be sold; it was a common good for everyone, and all neighbors were sharing the water with each other. Additionally, it is obvious for the young generation that, cistern structures are giving a meaning to their city and they are thinking it is a value of their past that should be under protection today.

The eight question aims to see public opinion about the protection of water structures in the city. For this purpose, people's opinion was asked about the precautions to be taken for the protection of wells and cistern. People think that to recover and use them again as a city utility would be nice, but there are some concerns. For example, they are feeling uncomfortable about environmental pollution and its possible effects to the surface and underground water, and they believe that cisterns and wells can no longer be functional because of the dense urbanization. On the other hand, the majority think that they must be protected, renovated, and at least be used as cultural city monuments.

In the question of ninth, it was asked to find out any traditional method which was used by locals to protect the water structures. The common answer among the participants was whitewash (a traditional painting way with lime used in Bodrum also for houses). Whitewash was good as protection for any insect and vegetation on the structure. So, the life of the structure can be longer, and also it is a kind of traditional disinfector. This process had been done as a collective work in each neighborhood. After summer, when the water dried inside the structure, notables of the neighborhood were gathering and doing the maintenance and cleaning collectively.

In the tenth question, whether they know any person who is known as finding water with traditional methods, is asked. According to the answers, there is not explicitly known person for this purpose; however, generally, it was known that if a tree does not dry out during arid times without irrigation, it means there is a water source nearby. Additionally, there was a spring in Bardakçı Bay, and people who had boats were going there to bring water to sell in the city. Similarly, Kokoli well was used for some people to take its water and sell it to houses.

Supporting the tenth question, the eleventh question asks if there is any known water source or spring around. 27 of the total answers said no or do not have any idea. One respond says because of the artesian wells, existing water sources are dried out. In addition, today Karaada, Kızılağaç (Yalıçiftlik), Dereköy, Gölköy are known with their spring waters and also, one respond claims that there is a spring behind the Gökçeler Mountain. Additionally, two responds gave Mumcular Dam as water source.

The participants were asked in the twelfth question, whether they think of any water problems in Bodrum today. According to 50 answers of 51, 35 people think that there is a water problem in Bodrum. Over 35, a significant majority concerns about scarcity of freshwater especially during arid times. Two people perceive flooding as a serious water problem in Bodrum. The other water problems have been said are immigration, pipe burst, insufficient and old infrastructure, inadequate water resource, wrong vegetation choices, and unconscious consumption of water. Other 15 people mostly think that thanks to the constructed dams (Mumcular and Geyik Dams) there is no more water scarcity in Bodrum. Additionally, some people claim that there is occasionally water cut; however, they do not feel any interruption due to their private water tank.

According to the finding of the survey, the locations of the water structures are shown in Figure 4.29.

The last two questions were asked to discover public opinion on the future developments of traditional water structures and their functions. For this purpose, the thirteenth question asked: “What do you think about the use of cistern structures in the city today?” The question installed like a multiple-choice grid, and the choices were; protected as a local touristic image of the city should be used as a water source of the city and should be used for a cultural purpose by restoring (Figure 4.30). Each choice has “definitely”, “possible” and “never” responses, and participants were free to choose one or more alternatives. 50 people of 51 responded to the question. According to the response, 27 people think that “definitely” there should be cultural usage of the structures. It is understood that people were not accurately against any usage of the structures, but among “never” responds, touristic usage seems more unacceptable. To use of the structures again for water sources of the city seems acceptable for the participants, especially those who used them before in their lifetime, however, the concerns need to be addressed for complete trust.

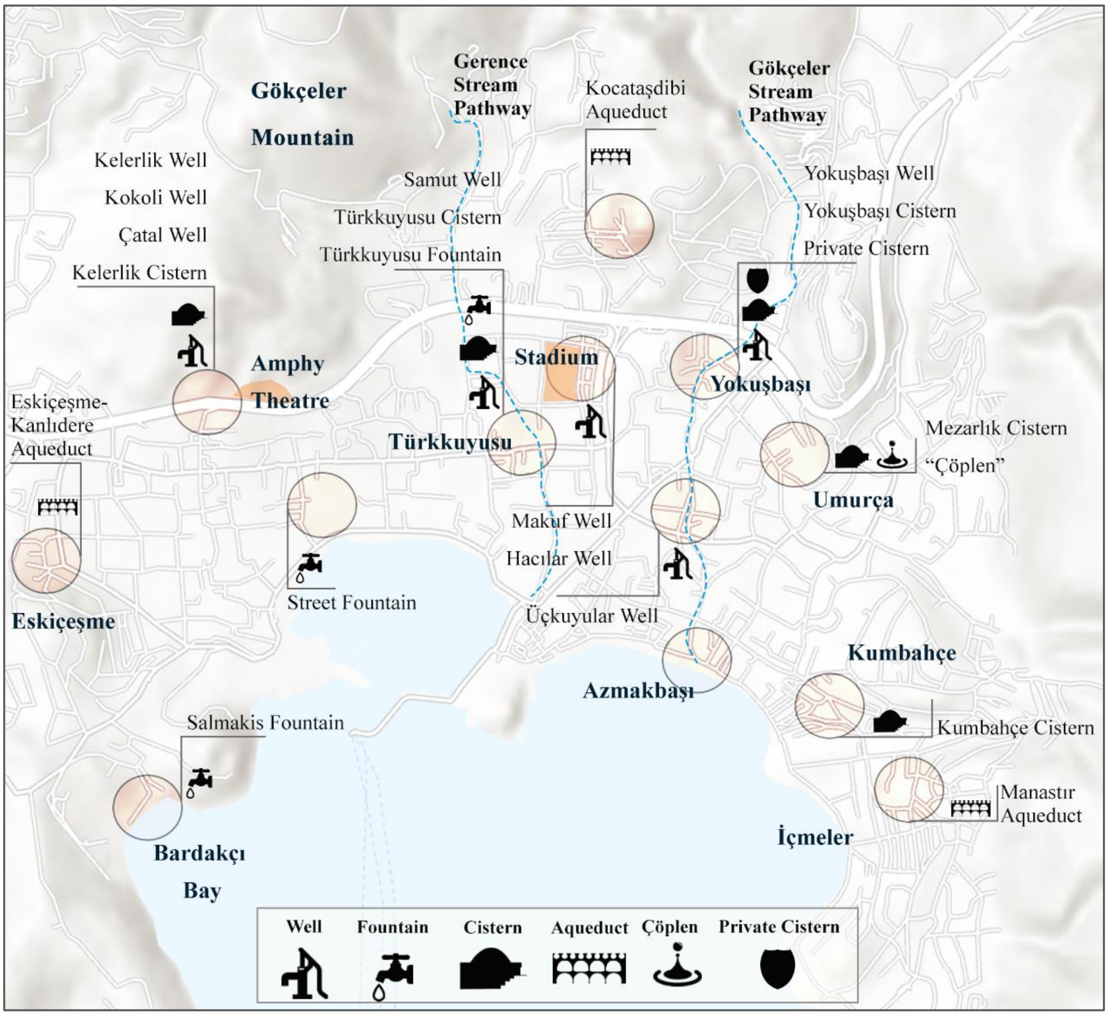


Figure 4.29. Symbolic Representation of the Location of Water Structures in Bodrum City Center
(Source: Prepared by the author based on the findings of the survey and Baykara, 2010)

The last question was asked to figure out the preferences of usage of the treated water from water structures. A multiple-choice grid structure installed with 5 choices. The choices were watering of traffic islands, irrigation of gardens, washing cars, as drinking water, and for environmental cleaning (Figure 4.31). Among the answers, most respond granted to definitely irrigation of gardens (25 responds). Responds following that were "definitely" for environmental cleaning (20 responds) and "definitely" for watering traffic islands (17 responds). It turns out that although people still think that it is "possible" to use this water as drinking water, there are 12 people out of 51 who believe that it will "never" happen.

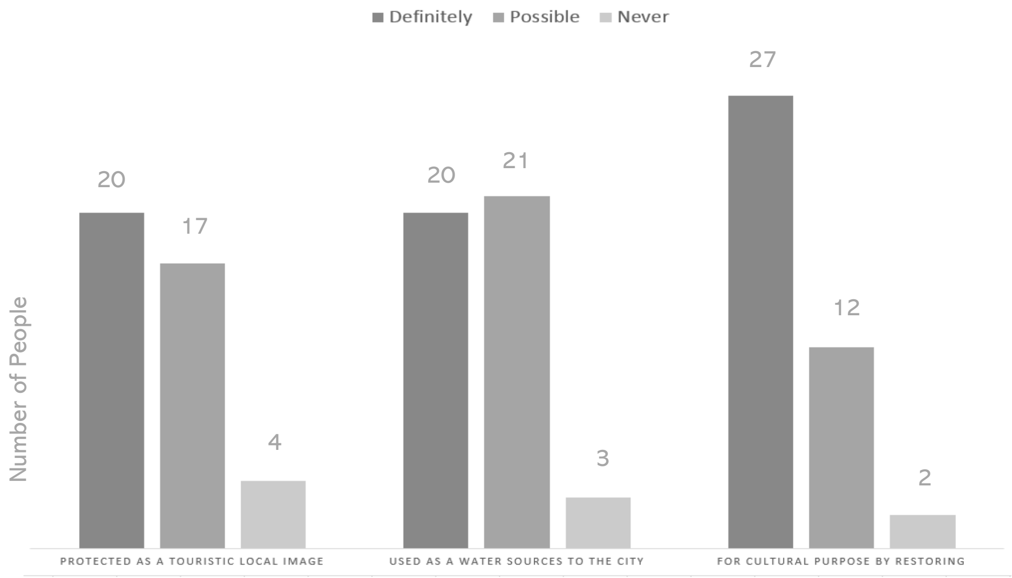


Figure 4.30. Comparison of the responds to the question of "What should be the use of water structures in the city today?" (Source: Prepared by the author based on the survey results)

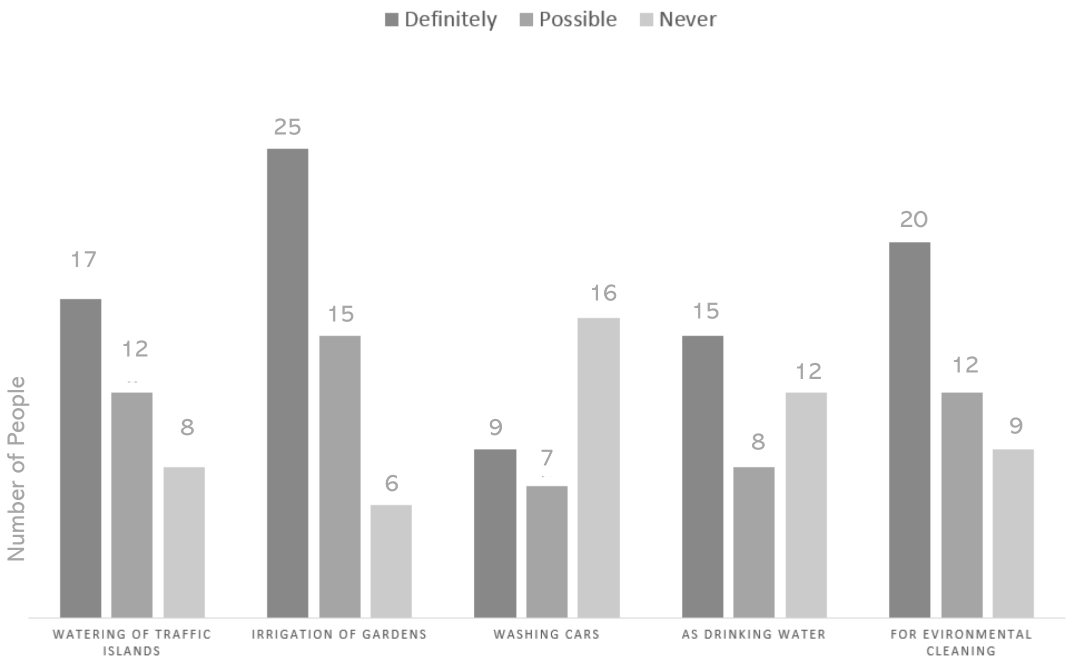


Figure 4.31. Comparison of the responds to the question of “If rainwater inside the cisterns is treated, for what purpose would you prefer to use it?” (Source: Prepared by the author based on the survey results)

For the additional part which separated for comments if participants want to add more, there was a comment from Mustafa Ünlü, who is an activist for Bodrum Cisterns. He claims some cisterns where locate on bushes or forest areas, are under use still for forest fires (Figure 4.32). So, they necessary to be protected for this purpose. Another comment was proposing that they can be useful for the drinking water of animals. Some other noticeable point that locals are still aware the value of rainwater for the city and requesting the utilization of it in the city before run out to the sea. Additionally, the major of the city Ahmet Aras underlines the value of rainwater and claims the necessity of new modern cistern structures for the peninsula.

Figure 4.32. A Cistern that was being used during a bush fire in Ortakent
(Source: the Photograph Archieve of Mustafa Ünlü)

4.4.5. Urban Morphology Analyses of Bodrum

For better understanding the form, distribution of the buildings and, more importantly, the relation of traditionally used water structures with the city, it is significant to know about the urban morphology in the city center. Bodrum had been used water cisterns for water supply till the 1960s. With the growing population, this water was not enough. Hence, street fountains were provided in each neighborhood area by the municipality. Also, after the 1970s, as concrete buildings began to increase, residentials added household cisterns to their houses. Today, some of them still are being used mostly for watering but even for drinking water.

Therefore, a site investigation was conducted by the author between the 24th January and the 3rd February 2020 in the city center. During the investigation, due to lack of information about household cisterns and traditional water structures of the city, these structures were tried to investigate by observations and on-site interviews.

The architectural typology of Bodrum is one of the most important features of the identity of the Peninsula. A typical Bodrum house which is with its white-washed facades, proportional dimensions and flat roof, is a symbol for Bodrum Peninsula. Bodrum has a defined design code for protecting the local architecture. Şebnem (2005) classify three main typical houses for the city; Mezzanine, Chios, and Tower Houses. Among those, the Mezzanine type is more commonly seen in the center. However, with the growing interest to city center, intensive commercial usages like restaurants, cafes, shops are changing the typical structure (Şebnem 2005). The typical construction way of roofs in traditional Bodrum houses are made by a clay type of soil which called “Geren” soil in the area. This geren soil was mixed with seaweed and was a efficient protection for heat and water (Tanrıöver 2011). Similarly, the observations revealed that except few of household cisterns which is currently under use, most of the water structure of the city are either restored and left for visual purposes or abandoned today. Some interviewed household cistern owners said that at least once a year, it is necessary to maintain the cistern. It usually happens at the end of the summer, when the water inside the tank is finished.

According to the observations, some of the investigated water structures (Figure 4.33), that have been used in city center, are presented and described in detail in the followings:

Figure 4.33. Urban Morphology of Bodrum and Investigated Water Infrastructure Locations showed by the red numbers. The locations of the cisterns in the city center. (Source: Prepared by the author based on Base Map prepared by Bodrum Municipality in 2017)

The first area is Kelerlik Mescit Street, known as Kelerlik among the locals. Formally, it is in Yeniköy Neighborhood. On the upper side of the street (northern), the Ancient Amphitheater, on the downside of the street (southern), the Mausoleum is located. On the other hand, this street has a place on the memories of locals as a meeting point for water. Two cisterns at the north beginning of the street were serving till very late of the 80s to the locals. Based on the on-site interviews, it was a daily habit to go to these cisterns for washing the clothes, dishes, and taking water to their home. It is said that there was a place for boiling the cistern water in big cauldrons near the cistern. Neighbors were washing the clothes with this water together. Also, for drinking water, there were wells known as "Kokoli and Kıdır" among the locals, located around this area. It is said that those wells were feed by Gökçeler Mountains, and it was delightful water for drinking because the current main road between mountain and city did not exist at that time.

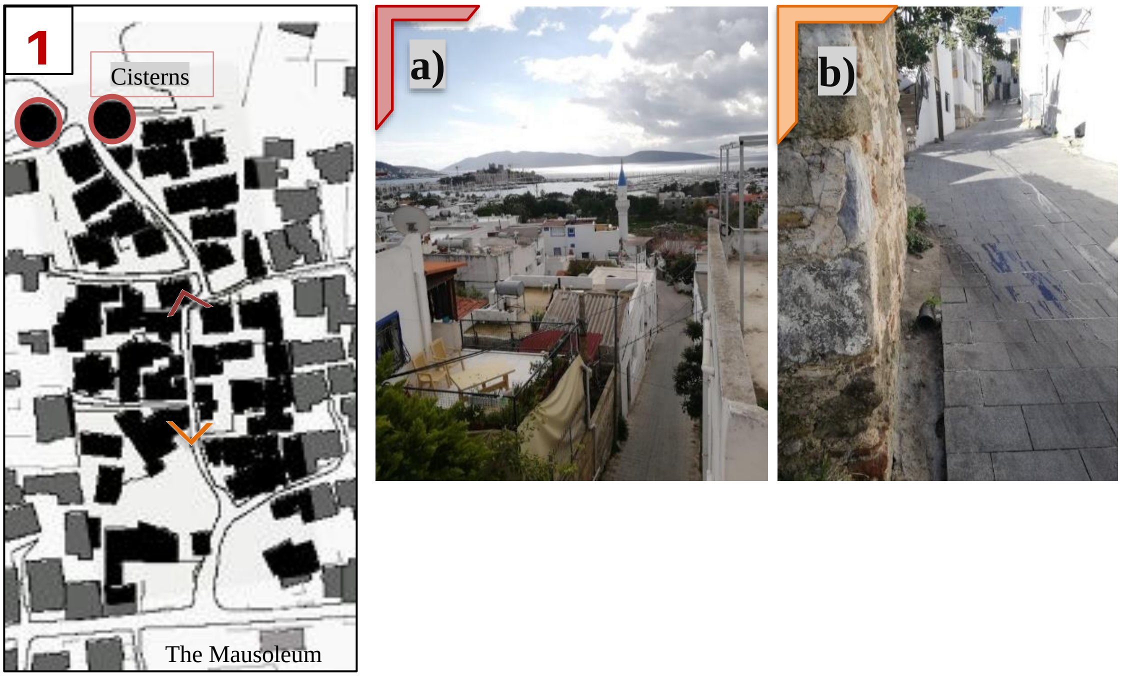


Figure 4.34. The First Area (Kelerlik). The view shows the flat roofs of Bodrum and the relation of the street and houses. b) The view of the street shows a stormwater outlet of a roof.

The second area is on the Turgutreis Street (shown by orange dashed line) which was used as a main road for Turgutreis and Bodrum before the new main road. Due to the elevation difference between the two parts of the road, flooding is very likely to occur for houses of downside. As water structure, on the road one household cistern and one street fountain observed.

The third area is a square called Türkkuyusu (Turk’s Well). This square is an abundant place regarding traditional water structures. On the square, today, there is located one cistern, one playground (inside the park there is two wells which is not under use), and one historical street fountain (also near the fountain there is one more well which is not under use). According to the obtained information from on-site interviews, during rainy times, the Türkkuyusu street (shown by an orange dashed line) was streaming as an "irme road". After the first rains, locals had been putting a set on the stream way and orient the water to the cistern. The first rain was for washing the streets. Today this street is covered by an impervious surface, and a channel under the road is taking stormwater to sea. Also, because of street paving works, the street is higher than usual which causes flooding during heavy rains.

Figure 4.35. The Second Area (Turgutreis Street). a) A household cistern. b) A municipal street fountains.

The fourth area is in Yokuşbaşı neighborhood where locates in the middle of the city. The houses are observed in this area mostly have gardens. Similarly, like Türkkuyusu street, the street (shown by orange dashed line) were an “irme” which was streaming during rainy times. Today, it has the same conditions with Türkkuyusu street. A channel under the street is taking the stormwater to sea. Because of the elevation difference between upper-side and downside, a bridge is located where Cevat Şakir Street cross the street, the channel is continuing under the bridge. Besides of unpleasant visual impact of this place, it is not also creating a proper solution for runoff (as shown in the flash flooding part). In this area, two household cisterns observed (showed by green shape). One of them is still under use for potable water and the other is under use for watering the garden. The owners of the cisterns are sharing the water with their neighbors.

The fifth are is in Umurça Neighborhood where locates on the eastern side of the city. According to the conducted observation in this area, the houses have mostly gardens. In the area two household cistern observed. One of them is inside the garden and the other is outside of the door. Their current usage is not known. Also, one typical Bodrum House is observed as a good example with its “Çöplen” on the roof (Figure 4.33, Picture C). In Bodrum, among the local people water outlets of roofs are called as “Çöplen”. Collecting the water coming from them is a traditional way of water harvesting. In front of the house, there is a place for water.

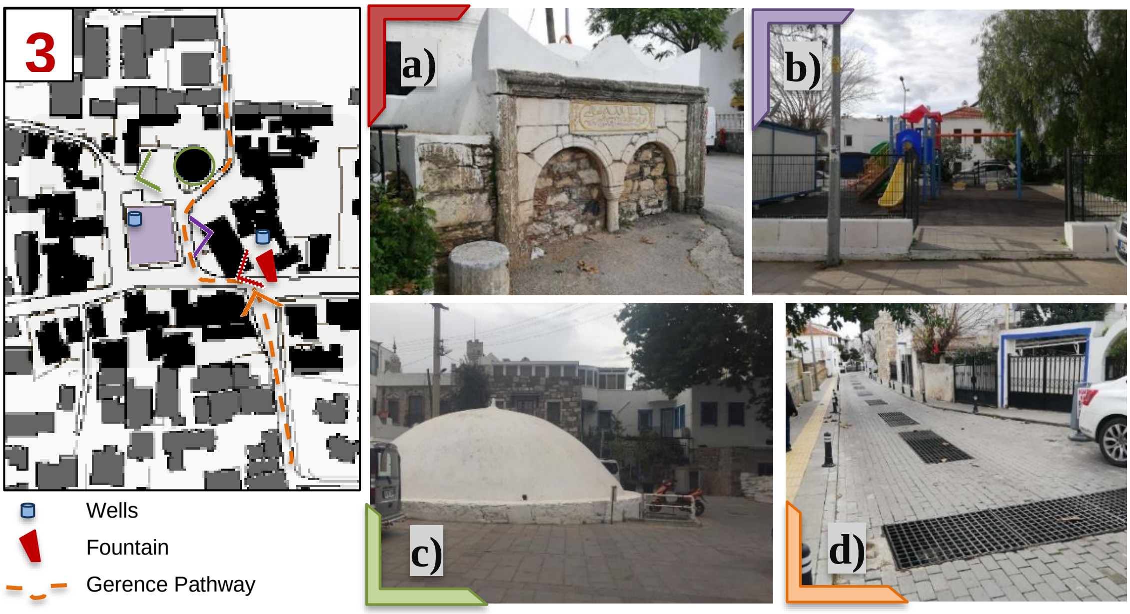


Figure 4.36. The Third Area (Türkkuyusu). a) The historical street fountain, some part of it stay under street due to paving works. b) Entrance of the playground, all ground is covered by impermeable paving. c) the cistern view with the parking lots around it. d) the Türkkuyusu Street view with the stormwater inlets.

The sixth area is in this middle of the city, on the Artemis Street. Before tourism, houses were with big gardens mostly for citrus trees. For watering the trees, gardens were having their own wells. Today, it is very dense commercial area of the city. Due to this reason, the gardens fragmented to small plots. During the site-views, one remained garden observed with a well and water wheel for taking the water from down to surface.

During the observations, the figure of Bodrum "Cistern" is investigated separately and detailly with their surroundings. As findings, the observations revealed that each cistern is located on the upper side of a slope which is a stream during rainy times.

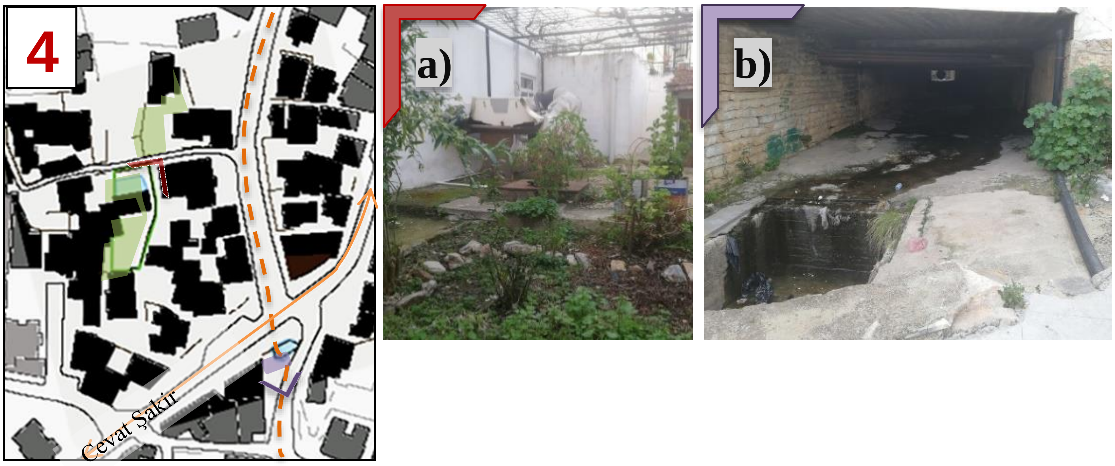


Figure 4.37. The Fourth Area (Yokuşbaşı). a) A household cistern using for watering the garden. b) The connection of the channel under bridge.

Figure 4.38. The Fifth Area (Umurça). a) A household cistern on the garden. b) A household cistern on the pavement. c) A typical Bodrum House with "Çöplen" on the roof and under it a place for water.

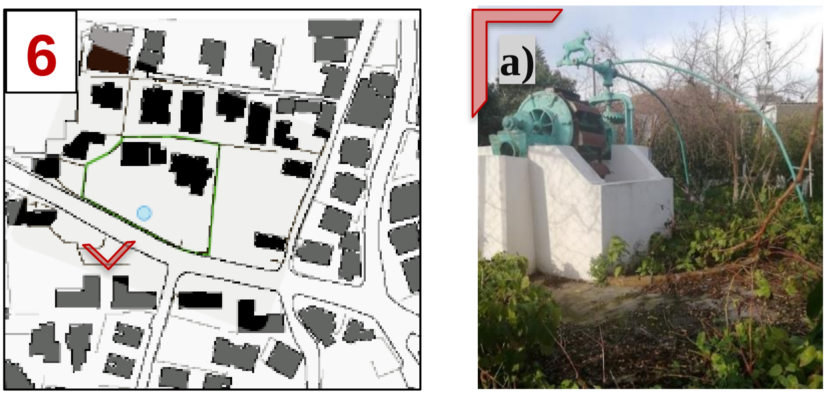


Figure 4.39. The Sixth Area. a) A well with water wheel in the garden.

4.4.6. Selection of Specific Pilot Areas

A proposal for the right strategies of the BGI network is a comprehensive mission. Thus, it is necessary to decide where to start first. As a result of all these evaluations, Bodrum City Center appears as the most affected district in the Peninsula by the freshwater problems and at the same time, the area has a precious heritage of freshwater supply systems. Therefore, two pilot areas are chosen in the city center which are problematic but also, has potentials. The evaluations for choosing the pilot areas, where more detailed analyses have done, are;

- the flood risk of buried streams,

According to the impermeable surface analyses and population growth of the Peninsula, Bodrum city center seems as the most affected place. Around the Peninsula, even though there are already a big urbanization pressure on each stream, Bodrum streams (Gökçeler and Gerence) are totally under urban structures (buildings, roads) without any buffer zone for flooding.

- local people who have used these traditional water methods and existing of these water structures,

According to the public survey, seven people from Türkkuyusu and eight people from Yokuşbaşı are interviewed. All of them are local people of Bodrum which had been used in their life at least one of the traditional water collection method and some of them still continue to use these methods or has belief that this methods can help to solve the current freshwater problems of the city. Additionally, these areas were used to known with their water supply structures like wells and cisterns.

- separated drainage system

Bodrum does not have separated sewage system in every part of the Peninsula. In the city center, because of the buried streams, there is separated drainage system. Therefore, it gives an opportunity to utilize the rainwater.

- Easier data finding in comparison with the other side of the peninsula

Thanks to the helps of Bodrum Municipality Urban Planning Department and the Bodrum City Memory Museum and Archive, the researches were conducted easier in the city center. In addition, previous researches have done by other researchers about Bodrum were helpful for analyzing these areas.

4.4.7. Analyzing Potential Blue-Green Network Locations for Pilot Areas

One of the fundamental requirements of spatial analysis is to visualize the data to be analyzed. Most data and measurements can be shown on a map because of integrated information of data such as location. So, using GIS analysis with such data can answer the question like; where are the most suitable places for a blue-green infrastructure network development in a specific area?

The ambition of this step was to determine possible options for a blue-green corridor with a base of nature-based solutions and intent to combine them with buried streams, the existing waterways, potential stormwater infrastructure locations, the existing green spaces, and the existing water heritage structures like cisterns. Thus, all these can act together to solve flood issues during heavy rains, to create greener cities for a better environment, and to re-adapt and re-function the existing water collection knowledge of the culture.

A GIS-based stream delineation model was used to discover the whole waterways of the peninsula and their sub-basins. The purpose of creating this model is to identify the hidden and buried streams that are missing under current urban development (e.g., buildings, streets, other impervious features). Furthermore, focus on those hidden or confined streams and propose a design which can help to make greener and sustainable urban environment for densely urbanized Bodrum City.

The conducted study’s scale is decided as specific streets inside the city center. Basically, these streets are created by burying old streams; Gerence and Gökçeler (Figure 4.40). These streets have memory in the local’s mind as meeting places for water and relatedly have old water structures like cisterns, wells and street fountains. These water structures were places where people were gathering for taking potable water, washing clothes or dishes. Even today, in local dialect, locals use Gerence for describing locations. Currently these two streets are the major problematic streets inside the city center regarding the flood risk. In this context, the two pilot streets are chosen as study areas to create a detailed analysis for proposing a correctly located blue-green infrastructure elements. These two stream pathways can be diveded to two different parts by the main road. The both parts of both stream pathways which shows on Figure 4.40, are buried streams. However, upper side of the road for both streams are wider than down side. Thus, for the analysis the parts which stays in the compact layout of urban, are taken consideration.

Figure 4.40. Location of the Two Pilot Streets for Analysis
(Source: Prepared by the author, on the Esri Imagery Map)

The necessary data were created by the author using the NetCAD Base Map, which was prepared by the Planning Department of Bodrum Municipality in 2017. In order to open the NetCAD drawing in ArcGIS, it was necessary to convert NetCAD to AutoCAD. After conversion, AutoCAD drawing is able to be imported to ArcGIS as polyline and point shapefiles. According to this base map, in the chosen areas, buildings, inlets, and open spaces were created as shapefiles named respectively “Buildings.shp”, “Inlets.shp” and “Open Areas.shp”. For the elevation of the roads, which were old “irme” and now have a stormwater channel underneath, a detailed elevation model is needed. For this purpose, elevation point shapefile created for both pilot areas. Inside the shapefiles, 648 elevation points for the first pilot area and 474 points for the second pilot area are obtained from the Planning Department of Bodrum Municipality. Resultant data which have elevation points are used to run IDW tool (inverse distance weighted technique).

IDW is an interpolation tool that creates a raster surface from points. These raster data have 0.5-meter resolution (determined cell size: 0.5) thanks to the detailed elevation data. Later, created buildings with their height were added and inlets of channeled stream were extracted from these elevation raster data. With these DEM (Digital Elevation Models) which include topographic data of the road, height of building and inlet holes, hydrology models in “spatial analyst tool” were created to figure out how the delineation of stormwater on surface is shaping for the two pilot areas.

4.4.7.1. Gerence Stream (Türkkuyusu)

The first pilot area is located in the middle of the city center. The area has been known as Turkish settlement in the city. The meaning of Türkkuyusu in Turkish is “Turkish Well,” which comes from the first settlers who were firstly searching for wells and then set up their homes. In Guffiers (1782)’s Bodrum Plan (Figure 4.41), the Türkkuyusu district appears as an area with small houses and gardens. The path of Gerence stream does not exist, however the road is quite visible. This kind of stream ways are special for the local culture. In local dialect, these streams are called “irme streams”. Because of the arid climate of the region, irme streams are flowing only during rain. Even during winter after rain, in few hours the water disappears due to the steep topographic structure of the peninsula. Other seasons, these stream beds function as dirt roads.

For Bodrum city, water have always been a problem, especially the scarcity of freshwater. Besides traditional water management systems, following the foundation of Turkish Republic, the city has tried to improve the quality and quantity of water systems in and around the city. A potable water project was transferred in the book of “Annex to Bodrum History” written by Avram Galanti Bodrumlu in 1946 regarding the Türkkuyusu neighborhood. In the book, he describes the main structure of the project: “Around Türkkuyusu district, there will be drilled wells with sufficient amount. The ground water acquired from these wells will be transported by motors to the tank with 200 cubic meter volume which will be constructed at the Hacıresil Hill (the place of the High School Today, Figure 4.43). The water will be distributed to the main streets and collectors by cast-iron pipes.” Also, he attaches the price of the project as approximately 75.000

Turkish Lira. About the location choice, he underlines that this area is the most suitable location for ground water with quite sufficient amount and good quality for drinkability.

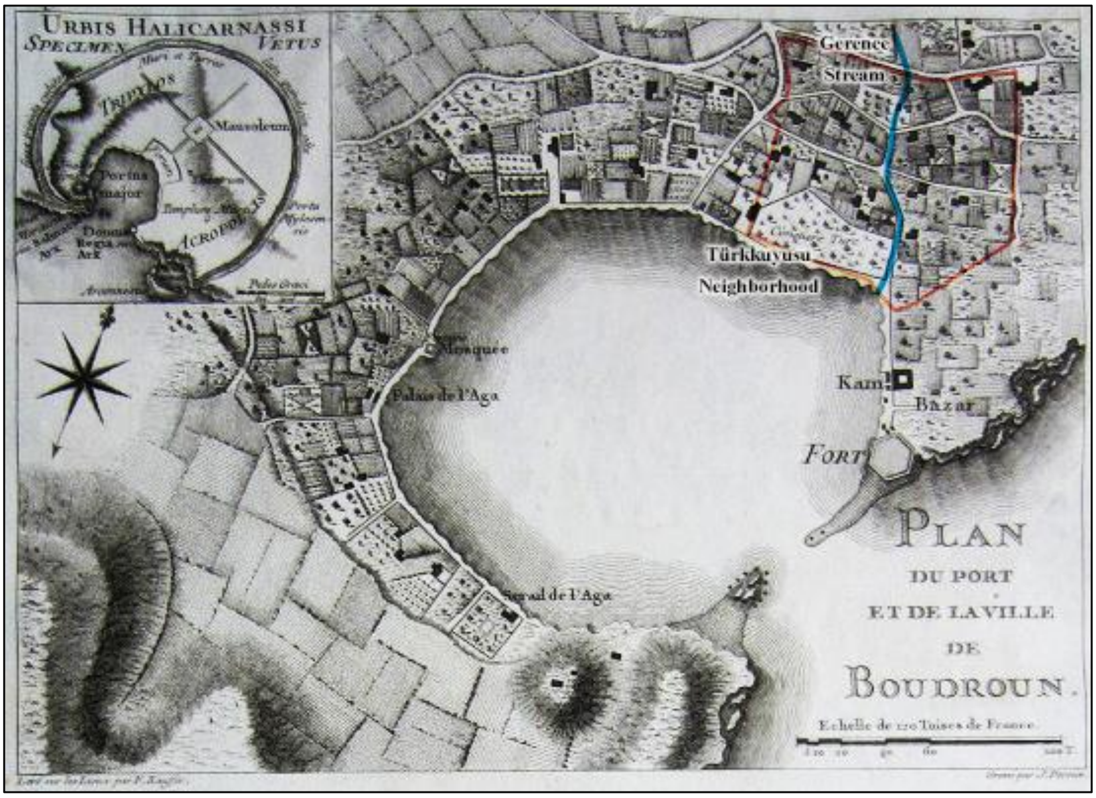


Figure 4.41. Türkkuyusu District and Gerence Stream on a plan of Bodrum City from 1782
(Source: Url 20)

Because of the rapid urbanization, growing rate of impervious surfaces and insufficient infrastructure inside the city, the Türkkuyusu Street (Gerence Stream) is subject to widely flooding area today. Besides insufficient conventional infrastructure techniques are not able to solve the problem in the district, they also cause an unhealthy and poor-quality living space like letting urban pollution drain to the sea. In the current condition, the surface of the square is almost totally impermeable surface and roads around the square are totally asphalt surface. Figure 4.42 shows the views of Turgutreis Street, which is passing through the front of the square, from different times.

Figure 4.42. Turgutreis Street View toward the square is from 1980's on the left and from 2019 on the right. (Source: “Eski Bodrum” Facebook Group)

In the area, open spaces are very limited. On the upper side of the area, Türkkuyusu square where a playground is located in the middle with few trees is almost one of the places that can be counted as a green area for public usage. However, the playground surface is covered by a material made by the rubber-mulch mixture. In addition, inside the park, a container office is placed for the mukhtar of the Türkkuyusu District. The rest of the space around the park is being used as parking lots. Thus, we can say all the square has an impermeable surface. Towards the middle of the pilot street, a large paid parking area is located. Although the area cannot be counted as a public space, it is still open space. Lastly, at the end of the study area, Bodrum Municipality’s building is located, and in front of the building, a small open space and a gathering place are located (Figure 4.43).

Based on these realities, this section tries to develop a blue-green network analysis for the Türkkuyusu Street on a micro-topographic urban scale by using ArcGIS 10.7.1. As a result of the analysis, the best possible locations are decided to place the different types of nature-based solutions. This analysis allows figuring out the water flow directions in the city according to the micro-topographic elements, so these accurate results are the main base of good design strategies for multi-functional greenery spaces.

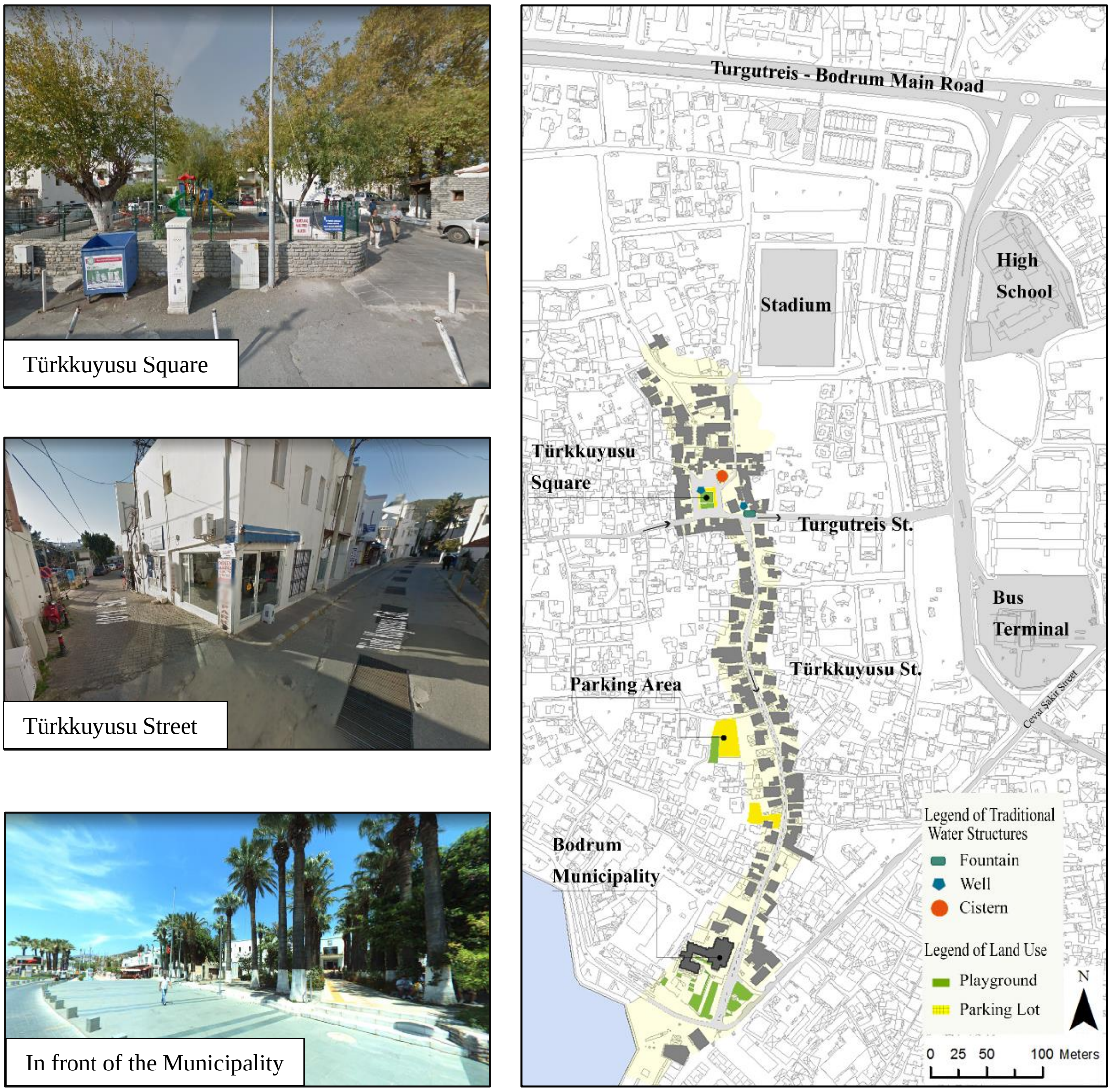


Figure 4.43. Pictures and plan of the case study area
(Source: Pictures from Google Maps Street View, taken 3/11/2020. Plan prepared by the author)

This workflow is inspired by the study “An Automated Method for Delineating Drainage Areas of Green Stormwater Infrastructure Using GIS” which is developed by the Philadelphia Water Development (PWD) and analyzed by Villanova University. The workflow integrates green and open spaces, and buildings by modifying the digital elevation model (DEM) to make these features part of the hydrologic landscape. Preparation of the micro-topographic DEM, after converting building shapefiles to raster data, separately, buildings added to the DEM by Plus tool. Then, all the raster data combined and created a Mosaic Raster by Mosaic to New Raster tool (Elevation Map). The new raster has 0.5 cell size which gives a fine resolution for the analysis (Figure 4.44 (a)).

For the flow analysis, the mosaicked DEM was used to analyze flow direction for each cell by the Flow Direction tool. Then, according to the flow direction, accumulation value assigned for each cell, which will be the base for deciding the magnitude for the delineation of waterways. The highest accumulation lines are shown by the line named as six (6), and the lowest lines named as one (1). These detailed flow lines obtained thanks to the high-resolution DEM, which includes the micro-topographic urban landscape, as mentioned above.

For examining the best locations, it is necessary to know about the sub-basins of the study area. According to the hydrology analysis and possible open spaces, the area can be divided into three parts (Figure 4.44 (b)) to propose a different and most suitable solution. Each part will be measured with its sub-basin areas. Inside each divided part, the area of impermeable surfaces, building areas, and green areas counted. Overall, this analysis assisted the study to identify the locations of flowing hidden streamlines where buried water stream's inlets could be connected through the existing urban fabric in order to manage stormwater runoff in a better way. Therefore, in each divided part, the Geometric Network Analysis operated by using delineated flow lines. By this analysis, identification of the possible open areas, where also the upstream sub-basins are draining, discovered. After the identification of sub-basins as raster, by the Conversion tool, they converted to shapefile, which allows calculating the area. Moreover, for a proper analyze results, each area calculated as meter square.

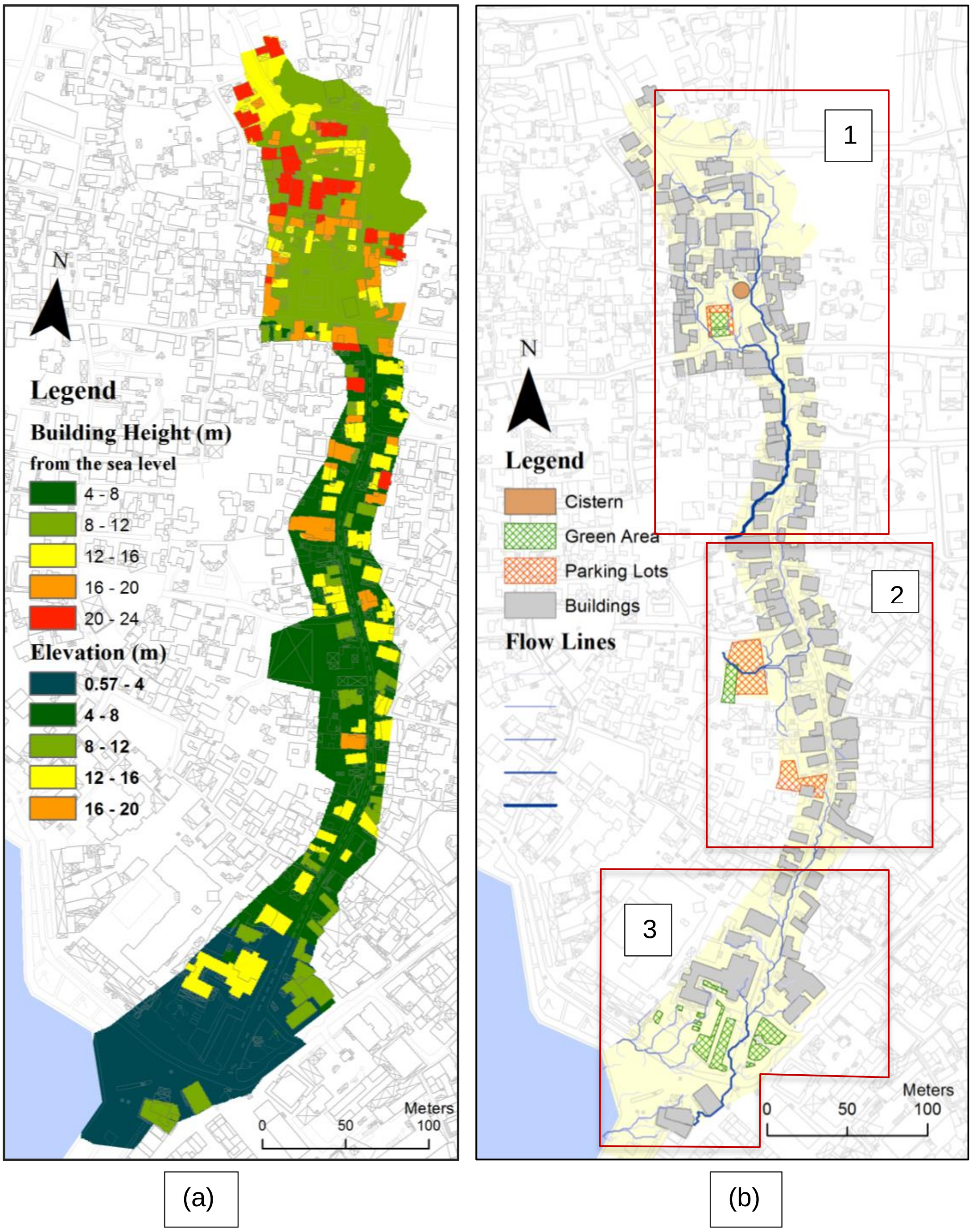


Figure 4.44. (a) The site with all the structures overlaid. (b) Flow accumulation of hidden streamlines of the site and the basins. (Source: Prepared by the author with ArcGIS 10.7)

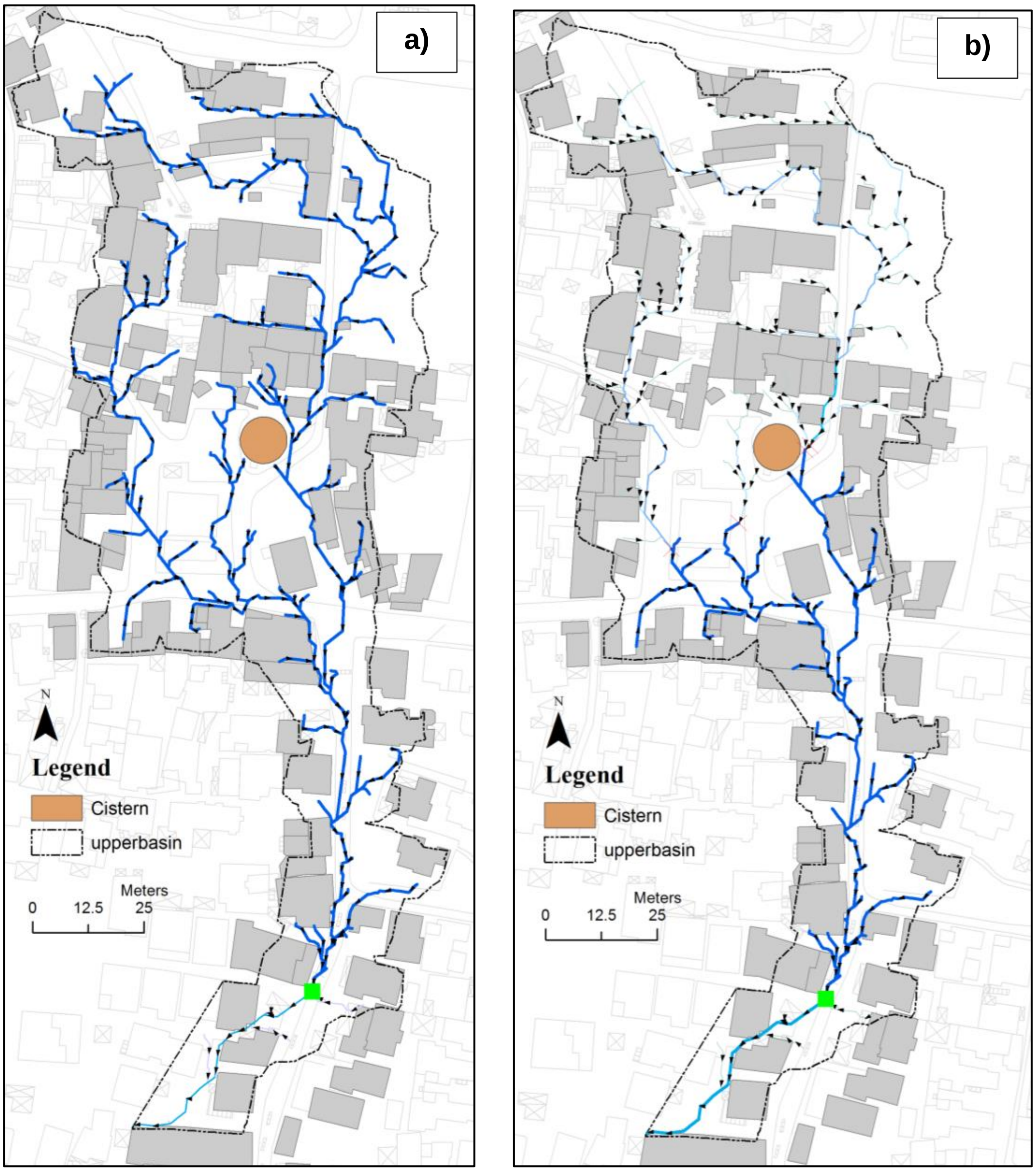


Figure 4.45. Upper basin, water flow tracing shows by the dark blue lines
(Source: Prepared by the author in ArcGIS 10.7.1)

On Figure 4.45 a, according to the water flow tracing, it is visible that how the surface runoff, which comes from upper basin, can accumulate on the Türkkuyusu Street. This analysis shows the current situation of the water flow. According to the analysis, the accumulation number is 607-line units in the first case. This street has a narrow section and the inlets are not enough deep. So, any heavy rain can cause easily flooding. However, the rainwater before entering the street, there are other points that water flow accumulates and creates small watersheds. For instance, the second case that showed in the Figure 4.45 b, when the surface runoff kept in the place where cistern is located and additionally where the playground is located, then the accumulation number decrease to 238-line units at where the green square located. This means that 60% of surface runoff can be saved in Türkkuyusu Square.

The current conditions within the upper basin, the land cover types and areas are calculated (Table 5). According to the calculations, it is evident that the basin has a lack of permeable surface, which can help infiltrate the water. 50% of the total upper basin area is covered only by buildings. When the asphalt surface also included, the percent is 87 of the total area. Furthermore, in the calculation of permeable cover, the only area taken as soil surface which is a plot and seems as urban development area in the current urban plan of the city. Thus, in the future, the percentage of the concrete surface has possibility to increase. Additionally, in the place of playground, there is construction of a building which planned to be used as mukhtar office. Therefore, besides of sidewalks and gardens of buildings, the area does not have any permeable surface. However, due to lack of data, how many buildings have garden and their soil surface ratio is not known.

Table 5. The upper sub-basin land cover types and measures
(Source: Prepared by the author based on the measurement in ArcGIS)

Upper Basin Land Cover Type (m^2)	First Watershed	Scond Watershed	Third Watershed	Total Upper Basin
Permeable Cover (Soil Surface)	873	non	non	873
Building Footprint	2350	323	1292	5968
Impermeable Paving (Asphalt Surface)	374	178	317	4490
TOTAL	4800	353	1820	11902

Geometric Network Analyze provides to display where exactly the flows are accumulating by the symbol of arrows. So, the junctions where density of lines, accumulation of flows and open public areas, can give good location choice for a BGI can be build. In the example of upper basin, location of Drain Points (shown in Figure 4.46 as triangles) shows the possible good location options for creating permeable surface and harvesting surface runoff from their watersheds. The important reason of choosing these points is that the possibility of proposing a water sensitive square as how it was in the previous times of Bodrum.

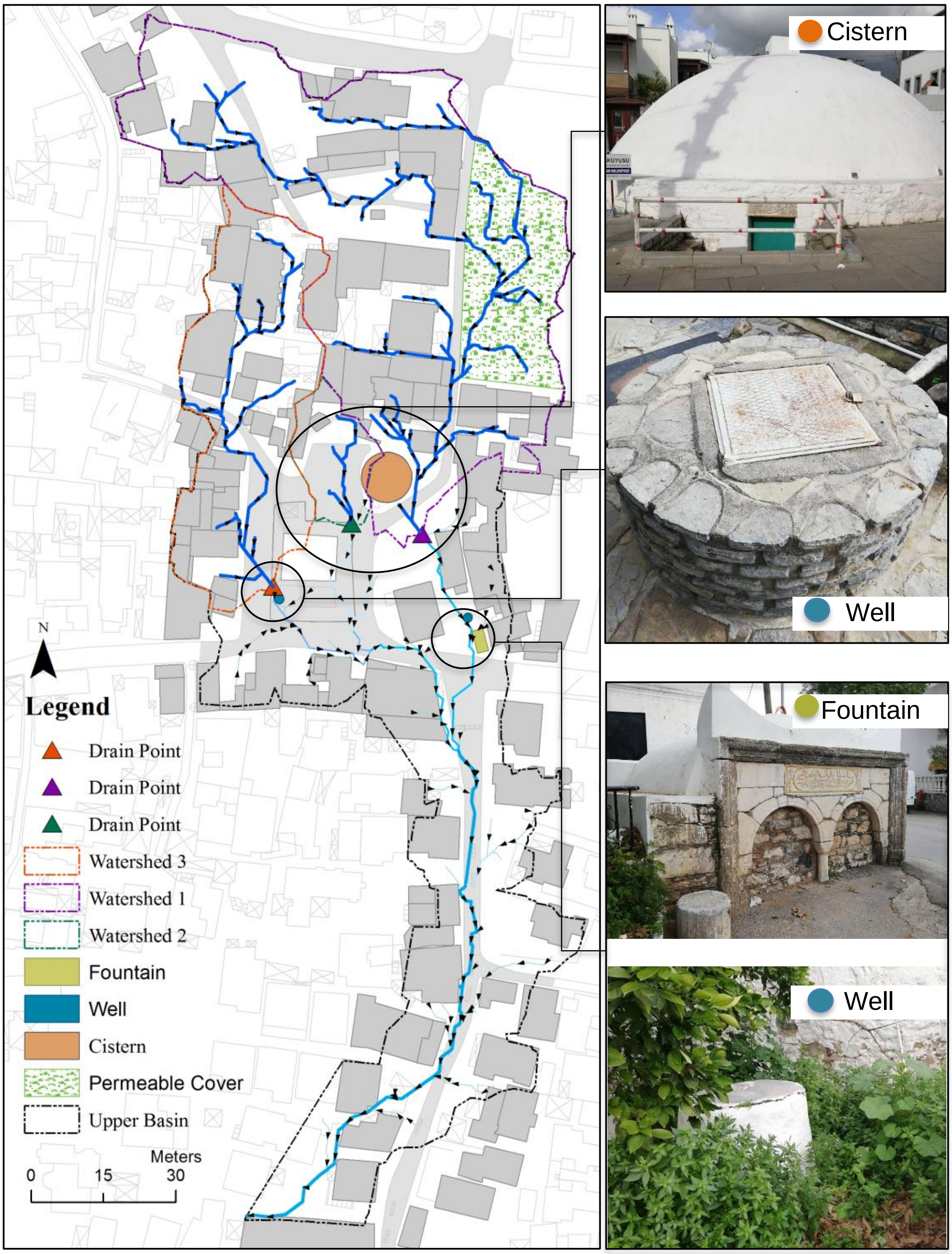


Figure 4.46. Watersheds of the Drain Points and Location of Traditional Water Structures (Source: Prepared by the author with ArcGIS 10.7.1)

Today, the main physical feature of the Türkkuyusu area is a very dense urban area. After development of the city, Gerence Stream pathway flows under stone and asphalt roads and kept in concrete walls same as many others. In the middle of the stream, Türkkuyusu Square is located including traditional cistern, one historic street fountain, three wells and a small playground (Figure 4.46). It is a very special square which include several traditional water structures of the region. Before massive urban development, the surface of the square was soil (Figure 4.47, the left) and according to the people who were surveyed, when it rain, Gerence Stream was running and after first two or three rain events (to let the first rains clean roads), locals were directing the stream flow to the cistern to collect the rainwater. Unfortunately, the water structures are not used today. There was an effort to use the cistern structure as a painting exhibition center. However, today it is locked down. Some of the houses around the area still have small gardens, and some of them are working as pensions or motels. The current condition of the square is mostly used as car parking area (Figure 4.47, the right), also there is construction in the playground area to change it as the muhktar building.

Figure 4.47. Views of Türkkuyusu Square from 1970s on the left and from 2020 on the right (Source: old picture taken from Facebook group "Eski Bodrum" and current picture taken by İpek Sarıer, 30/05/2020)

The analysis of flow lines, which showed in Figure 4.46, which also shows the locations of the water structures, may present an understanding of how water flow passing through close to the water structures. It is also possible to identify some other points for developing a plan of household cisterns in each or a group of houses because some buildings have their accumulation points that prove the integrity of the individual cistern idea which already exists in the local culture.

The possible infiltration areas where it is possible to rebuilt or implement blue-green infrastructures can be evaluated in two different type according to the ownership. Some of them are private areas which need to be thinking different than public areas. Public areas can allow to think broader options. In this example, public areas are in use as a playground and parking lots or as square for gathering place. In Bodrum, car parking is a big problem especially during summer. Even most of the street sides are in use for parking. So, their functionality should be protected as car parking however, the materials and vegetation choices can create multiple functional areas. On the other hand, the playground surfaces usually are covered with rubber-mulch materials in Bodrum. Although this material does not allow the water infiltration, it can be useful partially for the elements of playground for kids. However, different type of porous materials also can be proposed with the same sensitivity for kids and water also.

The same analysis is applied also to the middle sub-basin area and down sub-basin area to identify the best possible places for BGI network.

The middle sub-basin has not got so deep slope, so the surface runoff accumulates on the street which cause flooding easier. Additionally, the area does not have enough permeable surface cover. The biggest open area which also the rainwater accumulates according to the geometric network analysis, is a private area which is used for paid parking. In the proposals, strategies should be considered accordingly. The Integration between public and private ownership should be supported, and some benefits should be provided for such private places if they accept to be more water sensitive. Additionally, gardens of houses, hotels, restaurants can be very effective locations for proposing BGI solutions with multiple purposes such as harvesting runoff could help reducing water loss and pollution and also, re-using the harvested water in gardening or household (Figure 4.48).

The middle basin totally has 5400 m^2 area (Table 6). In the basin, houses have bigger gardens and only 22% of the area covered by buildings. However, there is no public permeable surface in the basin, so in such situations self-devotion of building or plot owners and support from local authorities to these people are being important step for achieving a water sensitive design.

Table 6. The Middle Sub-Basin Land Cover Type and Measures
(Source: Prepared by the author)

Middle Basin Land Cover Type (m^2)	**Sub-basin**
Permeable Cover (Soil Surface)	non
Building Footprint	1225
Impermeable Paving (Asphalt Surface)	590
TOTAL	5400

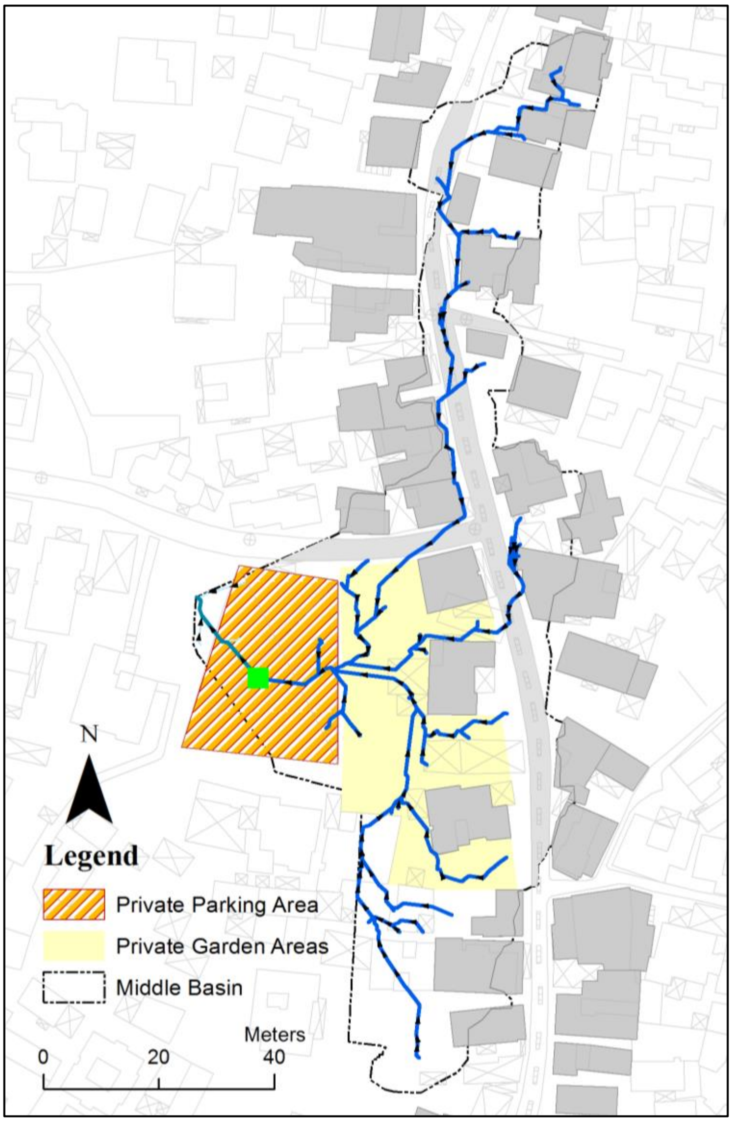


Figure 4.48. The Middle Sub-basin with the Possible Retention Areas
(Source: Prepared by the author in ArcGIS 10.7.1)

The down part of the area (Figure 4.49) is separated to tree sub-basins which consist Bodrum Municipality building and its front garden area, military police office area, and city square where people gather for ceremonies, celebrations, etc. Total building footprint of the area is 20% of the total down sub-basins areas. The area has big open spaces and public buildings which can be seen as a good opportunity to start BGI implementations as pilot examples.

Table 7. The Down Sub-Basin Land Cover Types and Measures
(Source: Prepared by the author)

Down Basin Land Cover Type (m^2)	Sub-basin
Permeable Cover (Soil Surface)	780
Building Footprint	2800
Impermeable Paving (Asphalt Surface)	1460
TOTAL	13630

The green areas in the basins are front gardens of the municipality which functions as shadowing and for aesthetic. Their total surface area is almost 780 m^2 which equal to only 5% of the total area of the basins (Table 7). With the interaction of open spaces and green areas by using BGI solutions, 70% of the surface runoff can be stored in the basins according to the network analysis.

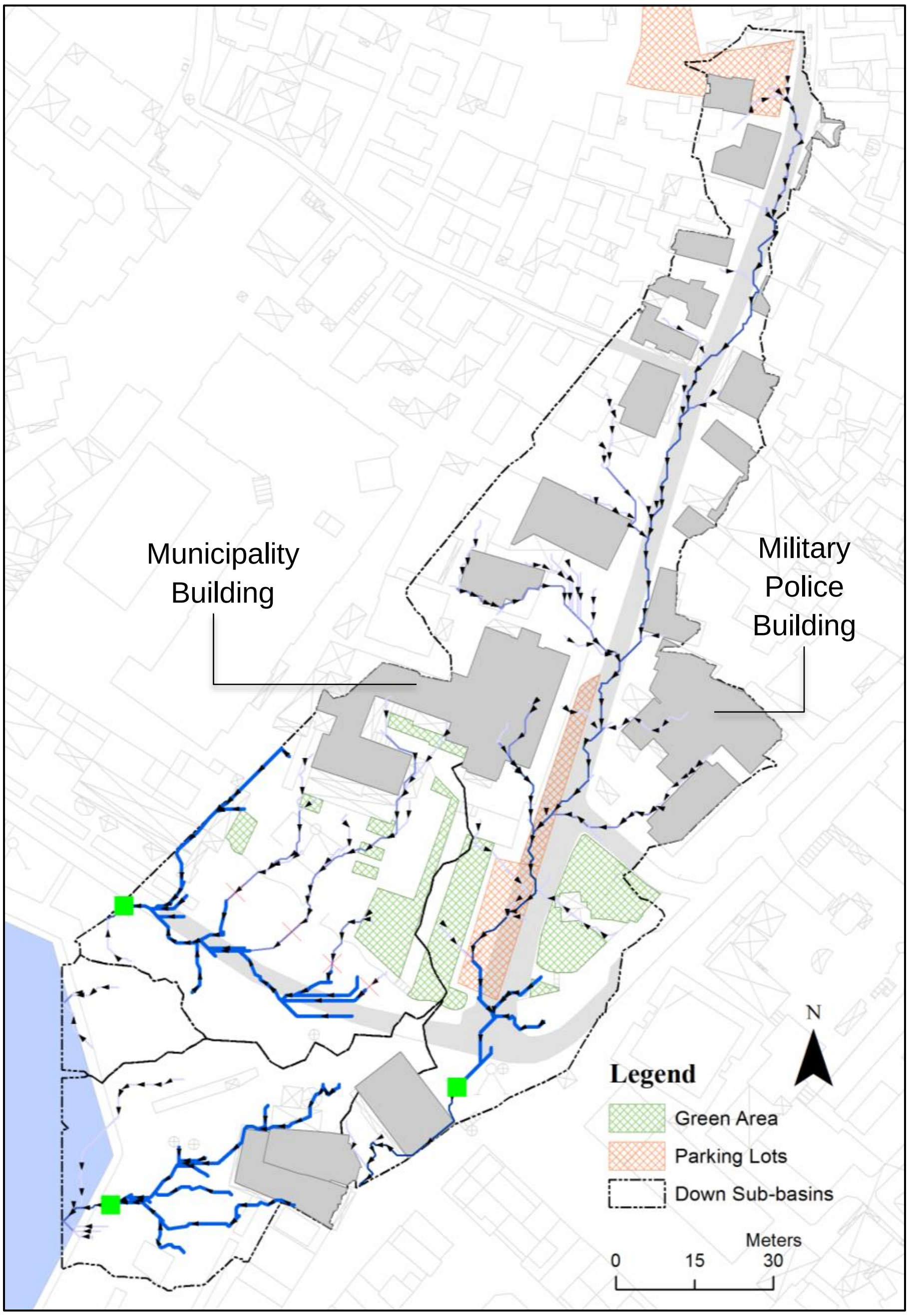


Figure 4. 49. The Down Sub-basin with the Possible Retention Areas
(Source: Prepared by the author in ArcGIS 10.7.1)

4.4.7.2. Gökçeler Stream (Yokuşbaşı)

The second pilot study area location is in the eastern side of the city center. The studied area cuts by the busiest main street (Cevat Şakir Street) of the city. This streamway called Gökçeler because of the mountain named Gökçeler where the stream takes its source. However, in colloquial language, it is called Yokuşbaşı stream, as well.

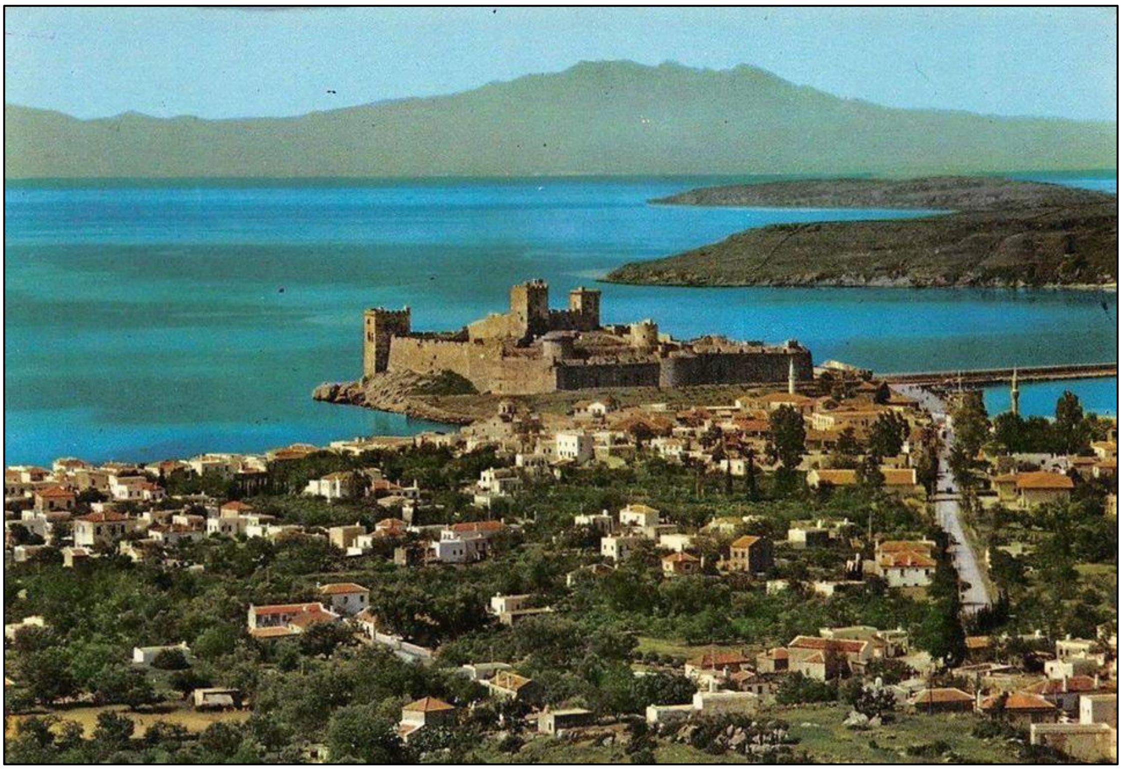


Figure 4.50. A picture shows the East Side of the City Center during 60's
(Source: Anonymous, "Eski Bodrum" Facebook Group)

Based on the survey with the locals, it is understood that this area is known as "üçkuyular mevkii" which means place of three-wells in English. The reason of this name is on the direction of this road, there are various wells located separately or in groups. Some of the wells are still exist but not in use, some of them already evanished under urban concrete. This area along the Gökçeler stream consisted of houses with large gardens, originally (Figure 4.50). Also, usually these houses had their own cistern or well.

Unfortunately, today, most of these gardens utilize as cafes, hotels, or restaurants for commercial purposes. The current situation in the chosen second pilot area is almost the same with the first pilot area regarding the open public spaces and green areas. Even though along the way, there are four playgrounds, their functionalities are very limited for both socially and environmentally (Figure 4.51).

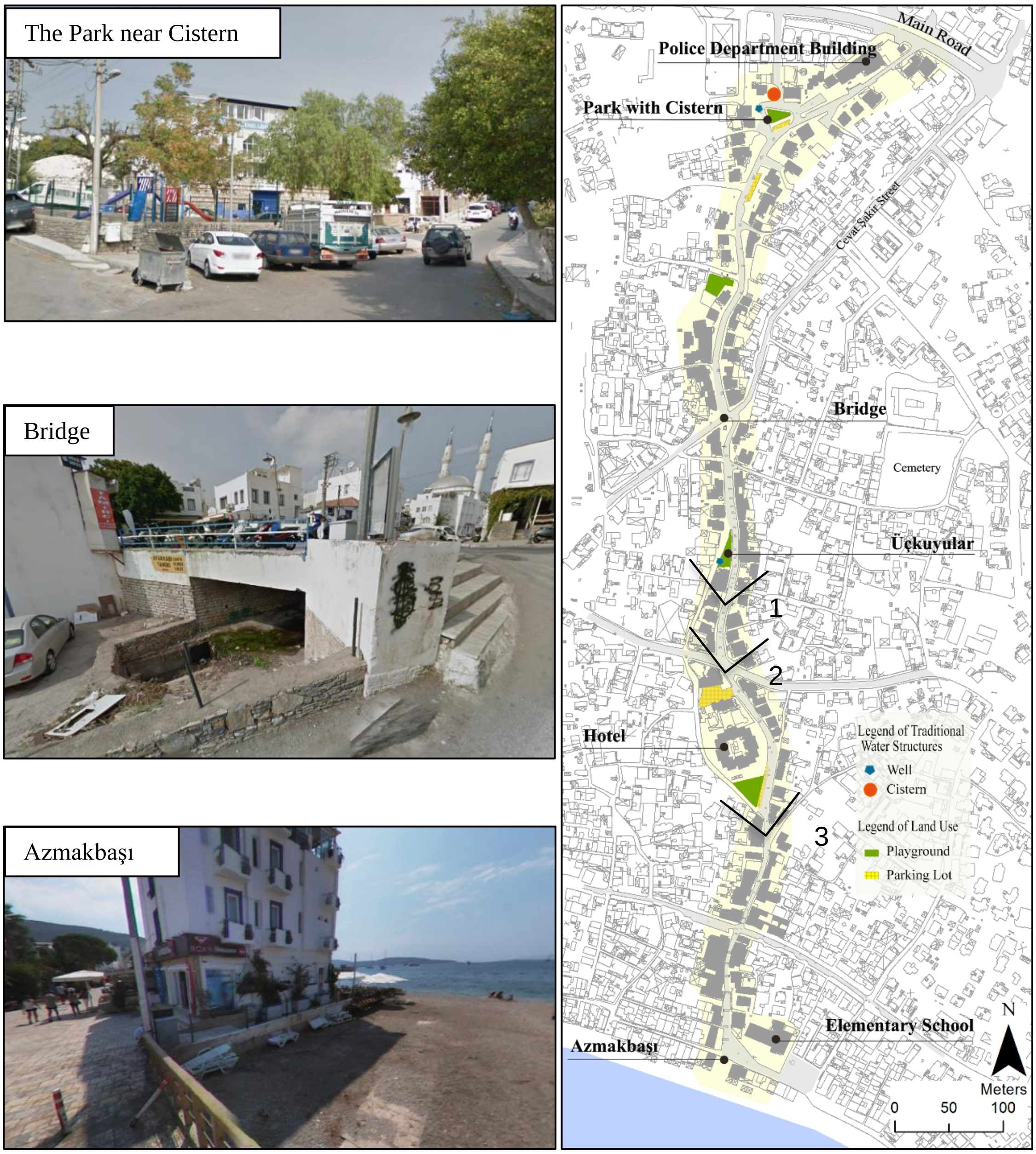


Figure 4.51. Gerence Stream Pathway and Land Use Around
(Source: Prepared by the author in ArcGIS 10.7.1 and pictures collected from Google Map Street Views)

Figure 4.52. The Street Views from the Locations Shown in the Figure 4.51
(Source: taken by Burcu Akalın, 10/06/2020)

In the second pilot area, width of the road changes between 6 meters and 8 meters in general. One side of the road is used as car parking and the road serves as one-way road (Figure 4.52). Buildings along the road are usually two-story buildings with terraces. In some buildings, terraces have half structure which called two and half-story buildings. So, the total height of buildings changes between 7 meters and 9 meters. According to the data taken from the Bodrum Municipality, dimensions of the drainage channel have taken as 4 meters for the width and 1.5 meters for the height (Figure 4.53). Additionally, the buffer zone for flooding is shown as 4 meters for the both sides. However, there is not sufficient space for flooding area and building along the street are staying within the flooding area.

The pilot area has a very sharp slope towards the road and from the road to the sea (Figure 4.56 a). Therefore, as shown on Figure 4.56 b, the flowlines accumulate on the road and take all the rainwater to the sea. The road in the middle of the area, which was a stream pathway before, today stays under the road as a drainage channel to carry the rainwater directly to the sea where called Azmakbaşı (Figure 4.54). “Azmak” is used to describe dry stream pathways where the dry stream pathways flow strongly with heavy rains, around the region. Today, as mentioned on the flooding problems part, during heavy rains, the drainage channel is not enough to carry all the water, and also sometimes due to the pollution, this channel can get congested which cause even more severe results regarding the flood. It is accepted also by the authority that the drainage channels are not sufficiently working in Bodrum. Additionally, they take away the rainwater during normal rainy day and this water is totally out of being a water resource to the city.

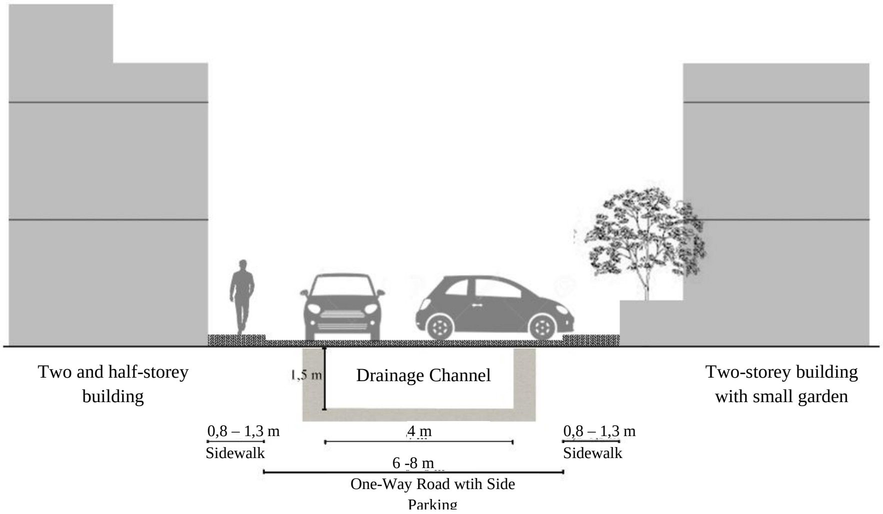


Figure 4.53. An Illustration of the Existing Street Scape from the Area
(Source: Prepared by the author)

Figure 4.54. Azmakbaşı, the Left View is from 90's and the Right View is from 2012
(Source: left picture is taken from "Eski Bodrum" Facebook Group, right picture is from Yandex Street View)

Regarding the permeability of the area, also, the playgrounds do not have any sufficient permeable spaces. Their surface covered with a material made by the rubber-mulch mixture same as in the first area (Figure 4.55). On the other hand, the houses and hotel around the area have gardens which should be considered as a part of BGI solutions. However, due to lack of data, these private gardens are not known exactly in terms of size and impermeability and that is why, for further studies, it should be investigated. As far as it is known based on the surveys, people who had big garden, also had a household cistern in their garden where they collect rainwater from their rooftops. Today, there are still people who use this method; however, majority already left this method after having potable water in their home.

Figure 4.55. a) Üçkuyular Playground and the Well inside the Park. b) the Playground near the Hotel (Source: a) taken by the author, 2020. b) taken from Google Map Street Views, 2018)

For all these reasons, in this part, flow line analyses have been conducted to provide a good understanding for the location choice of possible BGI solutions. Then, according to the flow lines, basins of the area were decided. There are two major basins in the second pilot area that were found as a result of the analyses.

Later, these two basins are separately analyzed to find out possible open spaces and gardens which could be a place for BGI solutions and also, thanks to the geometric network analyses, the flow accumulations were compared of the both basins.

The first basin area is totally 38, 675 m^2. The existing four playgrounds stay inside this basin. Their total area is 1,106 m^2. Separated areas as parking lots have 713 m^2 area. Additionally, along the road, one side is used as parking lots and there is one hotel. The length of the road that stays inside the basin is 783 meters. However, all these areas are not permeable areas. There are only some trees planted or left along the road and playgrounds, however, their health is controversial due to limited soil space. Regarding traditional water structures, one cistern and three wells stay also inside this basin.

In order to show the direction and accumulation of flow lines, the geometric network analysis tool is used. The figure 4.57 shows the results of the network analysis, the green point is the sink point of the basin and darker blue lines are heading ones toward the green point (black arrows show direction). According to the analysis, in the existing case which the flow has tendency to head toward the sea direction and collect all the rainwater from around, the accumulation number of flow lines is 2110 and the total length of the flow lines is 4425 meters (showed on Figure 4.57 a). The other scenario which shows the possibility that the playgrounds and parking plots considered as catchment areas, the accumulation of flow lines decrease to 331 meters and the total length of flow lines decrease to 703 meters (showed on Figure 4.57 b). With this scenario, if the water which drains through these lines successfully can be kept in those areas, 85% of the water can be saved inside this basin.

Figure 4.57 c shows a closer view of the proposal site which has the hotel and its parking lot, Üçkuyular Playground and the other playground. According to the existing topography, the flow lines do not tent to pass through the parking lot and Üçkuyular Playground. So, regarding such situations, there should be correction on the surface or the BGI solutions should be chosen considering this situation.

The second basin area is totally 7,080 m^2. In the area, there is not any green space or parking lot, however, there is one open area which serves as a junction, and one elementary school with a big garden. Additionally, sandy area of “Azmakbaşı” where the drainage channel effluent is going to the sea is in this basin (Figure 4.58). The square where serves today as a junction (Figure 4.59) has approximately 631 m^2 area. The garden of the school has around 740 m^2 area. The area of sandy part of Azmakbaşı is around 440 m^2.

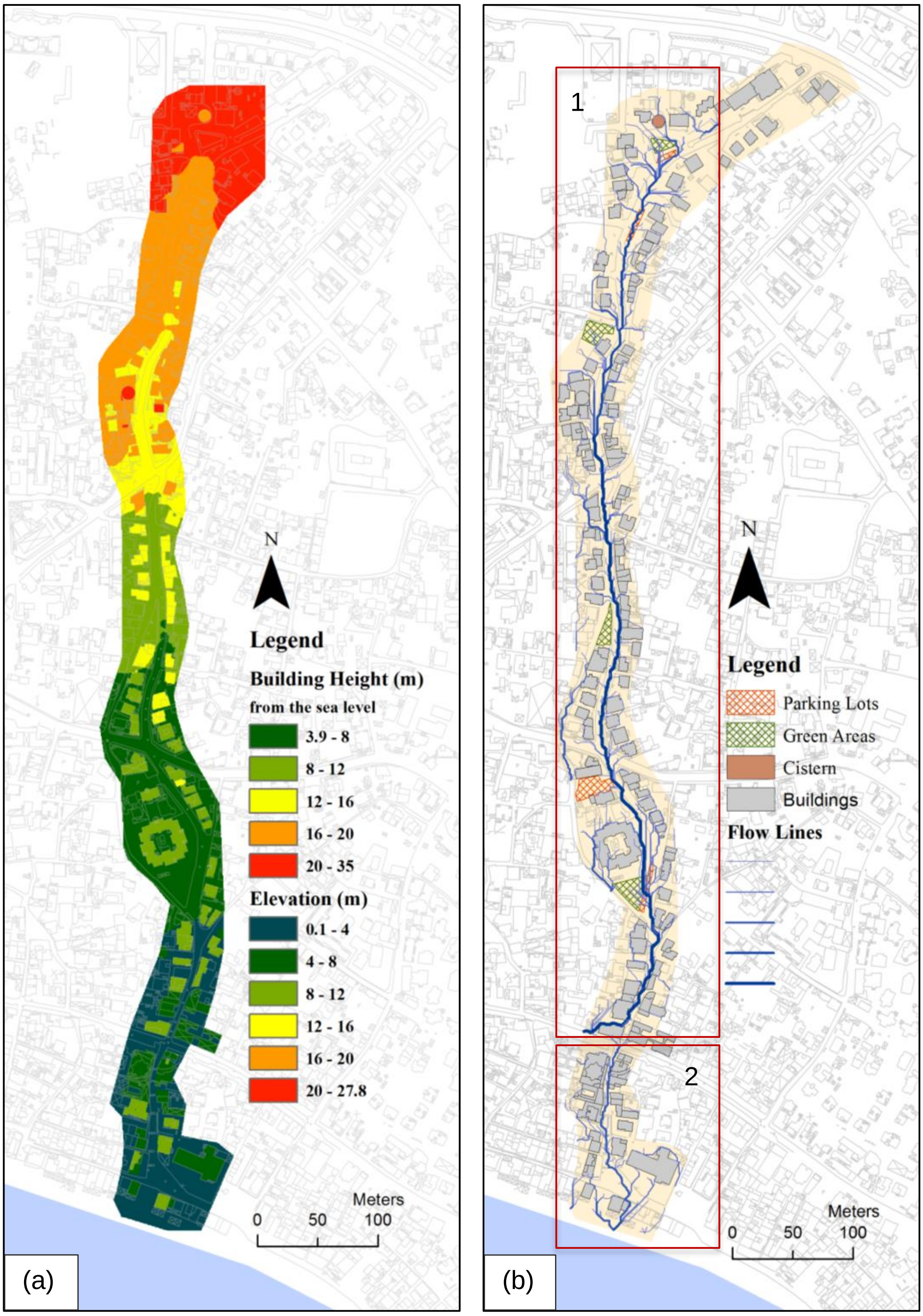


Figure 4.56. a) Elevation of the 2nd Pilot Area. b) Flow Lines of the Area and its Basin Areas. (Source: Prepared by the author using ArcMap 10.7.1.)

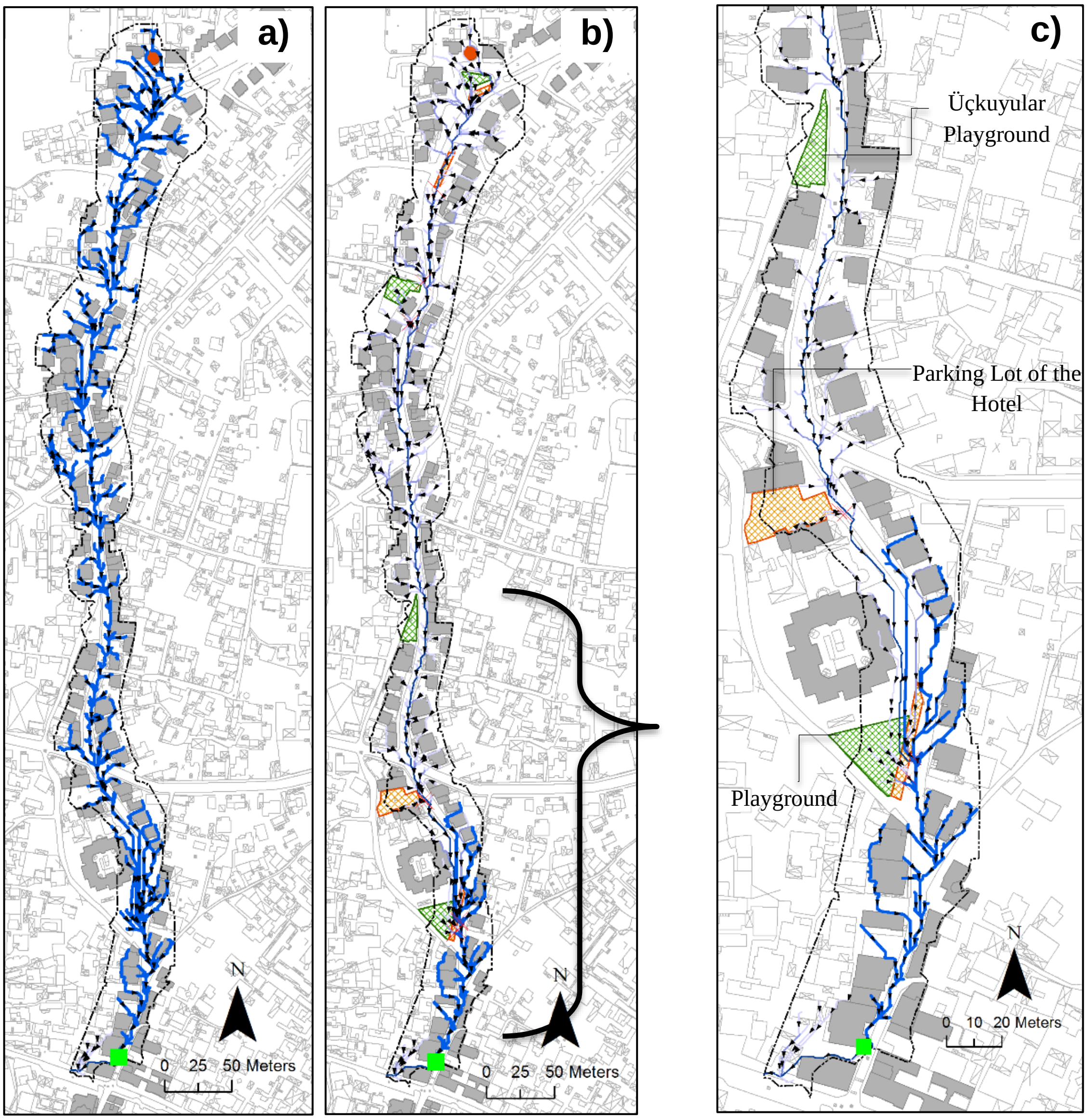


Figure 4.57. a) the Existing Case. b) Proposed Case. c) Closer View of the Proposed Case
(Source: Prepared by the author)

Figure 4.58. Sandy area of Azmakbaşı where the Drainage Channel's Outflow is Located (Source: taken from "Eski Bodrum" Facebook Group)

During summer, this area of Azmakbaşı is used for a place where the cafes and restaurants place their tables and sunbeds and during winter it is empty where the surface runoff and the drainage channel's effluent drain to the sea without any filtration process.

In order to provide a visual and numerical understanding, network analysis has been done. In the existing situation due to the topography of the area, surface runoff tends to flow to the sea. The accumulation of flow lines the first scenario is 391 line units however, the second scenario which use the signified areas (square, garden of school and Azmak) can decrease the accumulation to 36 line units which means 90% of surface flow can be kept in the basin.

All in all, the geometric network analysis has been done to give a better understanding for location choice of the BGI solutions. Today, specified places do not serve as catchment places which cause severe impacts to the city by flooding. On the other hand, seeing rainwater as something that needs to be taken away is creating other problems for the city and citizens like salinization of ground water due to lack of impermeability, unhealthy vegetation and water scarcity during summer. In order to that, as it is in the tradition of Bodrum, rainwater should be seen as the main resource of water and the tactics of collecting, storing and re-using of this water should be developed and implemented all around the Bodrum Peninsula.

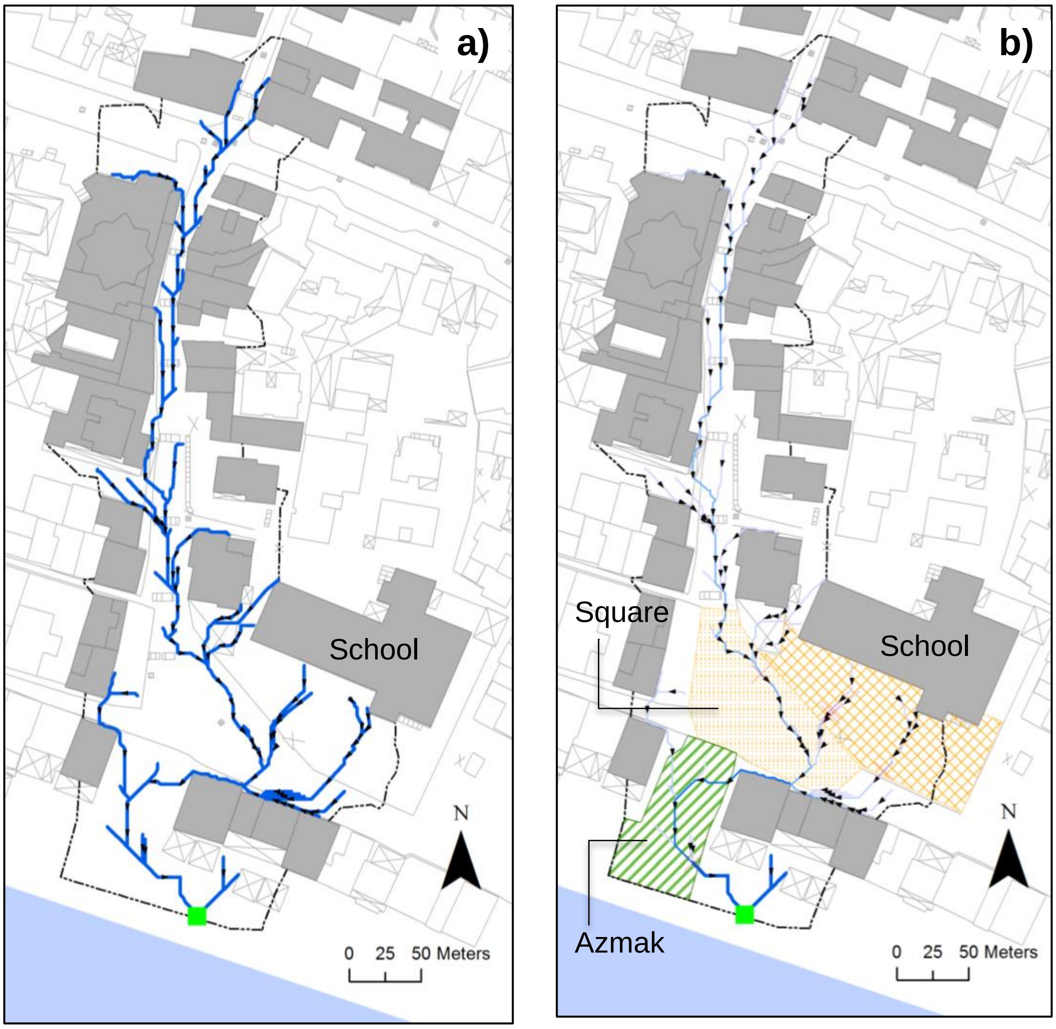


Figure 4.59. The Network Analysis of the Second Basin a) the Existing Situation b) the Proposed Situation. (Source: Prepared by the author)

4.5. Guideline of Integrated Strategies for Combined Local Water Heritage and BGI Network

Following all the analyses and examinations that have been carried out in the peninsula scale, Bodrum city scale, and street scales, a generalized "BGI Network Adaptive Strategy Guideline" is aimed to be proposed for the settlements of the peninsula with the respect to its traditional water management methods. However, analyzing of both pilot areas separately shows that an integrated BGI network for entire of the Peninsula needs different types of adaptive strategies, some of which can be on a plot scale while the other on a public park or in the scope of social measurements. Therefore, a staging study was prepared as first. For an integrated BGI development of all around the peninsula, the pilot areas are chosen as the first exemplary areas to create generalized manuals for different type of urban elements including streets, parks, playgrounds, parking lots and gardens. Therefore, the stages are decided in the order to considering natural basin borders that the first is the pilot areas which is sub-basins of the city center, the second is Bodrum city center, and the other settlement areas considering their natural basin borders and the third is the entire peninsula which is half of the Milas-Bodrum Basin for an integrated plan.

Table 8. Staging Table for Realization of the Strategies

Stage Priority	**Stage Scales**	**Activities**
First	**The Pilot Areas** (Gerence and Gökçeler Stream Pathways)	- Preparation of detailed analyses which includes different time period precipitation data for the peninsula. A determined ratio of precipitation should be accepted for design manuals to give an idea of how much an area can capture the rainwater without draining it to sewage system. Additionally, estimations of storage volumes for the sites should be done for proper design measures. - Generation of an office within the Bodrum Municipality with different professionals such as urban planners and designers, architects, hydraulic engineers, landscape planners, sociologists, archeologists, and ecologists which will be responsible for development and monitoring of the BGI strategies. - Recording the traditional water structures and methods including the information of their purpose of usage and current conditions of the structure. - Creating BGI design and material manuals for different urban elements like streets, parks and playgrounds, parking lots, passive areas, building gardens and roofs, hotels and summer houses. - Creating information centers about blue-green infrastructure and local cultural/traditional methods at the pilot areas for public awareness and interaction.

(Cont. on the next page)

Table 8 (cont.)

		- Starting implementation of blue-green infrastructure methods on street, parking lots and playground areas.
Second	**Bodrum City Area (City Basin)**	- Preparation of the citywide analyses for suitable locations BGI methods and traditionally used methods. - Continue the recording for the local and cultural methods of water management. - Introducing and implementing the manuals to citywide by the municipality chamber. - Creation of incentives, sanctions, and services to encourage the use of these methods in the gardens and roofs of hotels, restaurants, cafes and houses. - Creating cooperation between the municipality and different stakeholders of the city like schools, hospitals, hotels, restaurants, community centers and associations.
Second	**The Other Settlement Areas (City Basins)**	- Preparation of the analyses for each settlement separately for existing conditions and location proposals of the blue-green infrastructures with considering the natural basin borders. - Creation an inventory of traditional water structures and methods. - Creation information centers in each settlement for the community. - Introducing the blue-green infrastructure methods.
Third	**Entire Peninsula (Milas-Bodrum Basin)**	- Creation of an integrated water management design guideline for the peninsula with all information gathered including local and innovative methods. - Cooperation with the metropolitan municipality for the integrity of the design regulations among settlements. - Cooperation among institutions like municipalities, Western Mediterranean Development Agency and State Hydraulic Works of Turkey, also Ministries of Culture and Tourism, and Environment for better data creation and sharing, and application. - Increasing the permeable surfaces for the entire peninsula by increasing open public space and protecting the existing open spaces, increasing the afforestation areas.

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Table 8 (cont.)

		- Promote xeriscaping for landscape of the peninsula, together with private stakeholders like hotels, housing projects, gardens etc. - Organizing educational programs about rainwater protection and harvest for different age groups. - Organizing cultural-educational programs about traditional way of rainwater management in the peninsula for different age groups with cooperation of public education centers, schools and the municipality. - Providing certificate programs for different professions. - Providing education and awareness programs for farmers for dry agriculture and local methods. - Analyzing each natural streamways for protection and if buried or channelized, for ecological restoration. - Studies aiming for fully recycled water usage in the peninsula, including all rainwater, greywater, and blackwater. Additionally, creation of preventions for decreasing the water consumption.

The realization of the guideline of integrated BGI and local methods for the entire peninsula requires good first step parameters that are available for addressing designs and materials of manuals for the next stages. The manuals should consist of different urban elements like streets, parks, and playgrounds, parking lots, building gardens and roofs, hotels and summer houses, and traditional water structures, that can be implemented to the other parts of the peninsula later. In this sense, the urban elements of pilot areas are used as examples for creating the first strategies of these manuals.

4.5.1. Integrated Strategies for Combining Local Water Heritage and Nature-based Solutions

It is understood from the analyses and especially from the survey that traditional water management methods of Bodrum had played a big role on daily life of the locals in the past. The sharing and neighborhood culture improved thanks to water supply methods like going together to get water to cisterns or sharing the water in private wells with the neighbors and also, construction and cleaning of the structures as collective work. Additionally, those areas where people were used to going to take water, are still mentioned by their old names among the elderly locals, which shows the continuity of the water memory. For example, Kokoli, Kelerlik, Makuf are the names of the wells where people used to go to get freshwater, and even they have qualified the well's water as drinkable or usable according to the saltiness of the water. However, all these invaluable traditions are not a part of the daily life anymore and not known and unpracticed by the new generation. It is essential to keep these traditional water management knowledges for the memory of the city and furthermore for the value of the water for Bodrum. Therefore, it is urgent to act as soon as possible to collect and record these memories, methods and locations for future city plans and originality of the city.

4.5.1.1. Local Water Heritage Conservation

The public survey shows that there is a difference between the new generation who always have tap water at their home or bottled water for drinking and the old generation who used to practice the local methods to get fresh water. Among the old generation, there are still people who use these methods like keeping a cistern or a well in their garden, and they believe that "if the tap water stops, there is not any other way than to use cisterns again." However, the new generation thinks cisterns as the symbols of our past, and that is why they believe cisterns need to be protected. Therefore, changing public opinion to make people aware of water problems, making the community as highly water literate and revitalizing the usage of rainwater practices that already exist in the near past of the region, are the must for safe freshwater in the future.

- **Prepare a Water Heritage Inventory:** With the support of the City Memory Museum, an inventory of existing historic water structures by the stories of people about traditional water management methods and knowledge.

- **Enhance water knowledge and awareness among the community:** Educational Programmes will be promoted both for children and adults. To support the education, a collaboration between the Bodrum Municipality and schools should be ensured to make aware the new generation about the water scarcity and local water methods to maximize the water sensitive behaviors.

Figure 4.60. Water Cycle of a Watershed Education for Kids
(Source: “Blue Mountains City Council DRAFT Water Sensitive Blue Mountains Strategic Plan 2018”)

- **Make tangible and intangible water heritage elements apparent in the peninsula:** Traces of the water heritages coming from the city memory must be visible to remind and teach the public and tourists in the city by info graphs or urban furniture designs, so on. As an example, a project shown in Figure 4.61 from Australia in 2013. The project aims to remind pedestrians the old creek which was flowing in the past and covered with the street.

Figure 4.61. Pitt Street Mall, Sydney, Australia
(Source: Url 21)

4.5.1.2. Public Spaces

4.5.1.2.1. Open Spaces

Besides the value for social life, parks / playgrounds have a significant role as being only open spaces for urban area in Bodrum. However, unfortunately, growing urban service needs are slowly biting these areas for private usages such as waiting point for taxi drivers or locating "mukhtar" office. These usages can be seen as small changes; however, it creates a territory for the people who use those utilities and the park/playground loses its social interaction.

- **Analyze the Conditions of Parks and Playgrounds:** The typical park in the pilot areas contains a playground, small green spaces, and a small area for benches. However, the BGI strategies focus on the multi-functional utilization of these areas. Each of the parks in the city should be evaluated with it is own potentials. Sometimes the only possibility can be changing their surface material with permeable materials that make parks infiltrate the rainwater. Moreover, in some cases, these areas can harvest or purify the rainwater for irrigation of the park.
- **Integrate Cisterns/Wells and Open Spaces as a Unit:** In the pilot areas, both neighbor cisterns have a park near them. Additionally, in some of the parks, some old wells still exist. So, in such cases, parks and cisterns/wells can work together. The BGI techniques like sand filtered cisterns to the park area will help regulating the quality and quantity of the rainwater by storing and filtrating the water.
- **Retrofit the Existing Traditional Cisterns:** All the existing traditional cisterns must be analyzed to consider the possibilities of reutilization. The methods will be applied are changing the surface of surrounding to permeable surface with filtration gravel and sand elements, creating vegetation to purify the water during infiltration which can combine with raingardens, and maintaining regularly. This is also a good example of how the integration of water heritages and contemporary nature-based solutions can work together.

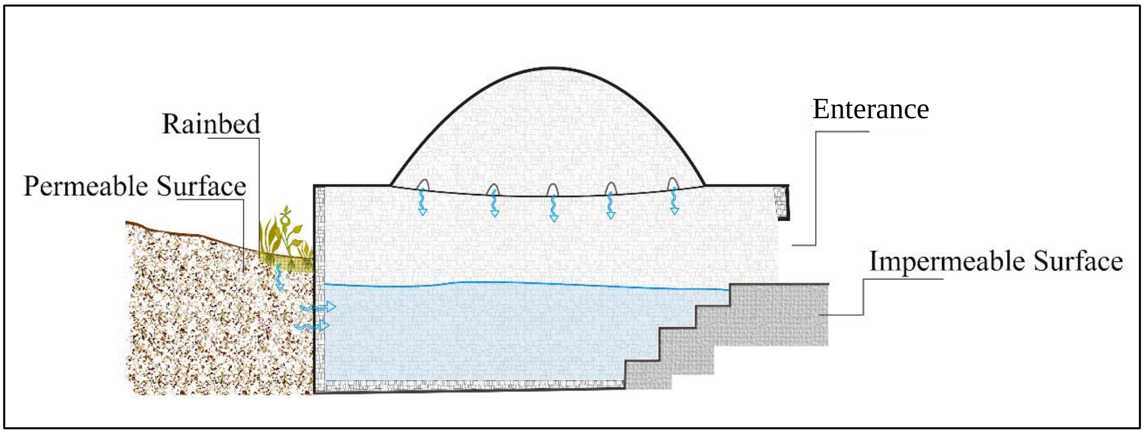

Figure 4.62. Traditional Cistern Structure and Rain Garden around It for Purification of Rainwater
(Source: Prepared by the author)

- **Create New Cisterns:** If there is a suitable area within or around the park/playground, new cisterns can be built to harvest rainwater and irrigate the vegetation of the area. Besides cisterns; raingardens, retention pools, swales, and constructed wetlands can be the other methods of BGI that are possible to implement.

- **Xeriscaping:** The manual must include xeriscaping as a local unique technique. Lavender, Sage, Oregano, Thyme are some of the possible species can survive through the summer period of the region and also these are the vegetation that the locals use for food and medicine. So, combining them in playground can teach to kids about the native species and their usages, as well.

4.5.1.2.2. Streets

- **Permeable Pavement for "Irme" Streets:** The concept of "irme streets" that comes from the local dialect should be restored to the settlements of the peninsula. According to the surveys and interviews with the locals, irme streets allows rainwater flow when it is raining, and their surface are covered by soil also allow infiltration of rainwater. So, instead of covering the surface of streets with impermeable materials like asphalt, covering them with permeable materials like cobblestone pavement.

- **Ecological Restoration of "Azmak":** The other term that is used in the local dialect is "azmak" for the confluence areas of streams which flows only during rains, with the sea. These areas have always small accumulation of water with sea connection and creates nesting and breeding area for fishes and other species in natural conditions. In the peninsula, there are azmak areas in almost each settlement. These areas need more special care because today again most of them are covered by urban utilities like roads, bridges, stormwater infrastructure or sandy areas to make beaches. Moreover, these interactions to those areas are one of the reasons of flooding in the peninsula. For example, the second pilot area which is Gökçeler Stream Pathway and today buried under the road with concrete channels, is meeting with sea on the area called "Azmakbaşı". Therefore, In these areas, it is important to identify the suitable areas to capture the water, in order to let the stormwater infiltrate and meet with sea by ecological restoration methods but also, at the same time it is essential to provide permeable pavements around as much as possible to reduce the impact of urbanization.

- **True Localization of BGI Elements:** In Bodrum city center, the general street structure does not have sufficient width for creating green spaces along the streets. Therefore, blue-green infrastructure tactics and the possibility of each street should be considered separately according to the street conditions. For the analyzed two streets, the proposed BGI elements consist of rain beds and bioswales which sizes and shapes should be designed specifically for the location where surface runoff accumulates according to the flow analyses. These methods, additionally, can provide traffic regulation, safeness for pedestrians, and greenery environment in the neighborhood besides dealing with rainwater filtration.

- **Reduce Amount of Stormwater Drains to City Sewage:** Ensuring the absorption of water by turning the place where roof drainpipes flow to the street, to a permeable surface for allowing the infiltration of water. These areas could be bioswales or just gravel surfaces or tank, barrels and cisterns to harvest the rainwater.

4.5.1.2.3. Parking Lots and On-Street Parking

These areas can be sideways of streets where the car parking is allowed or also, can be bus stops, bus terminals, parking areas of buildings and private car parking places.

- **Promote Permeable Pavement:** Pavements of all parking lots and on-street parking must be changed to permeable surfaces which supported with soil and gravel filtration techniques.

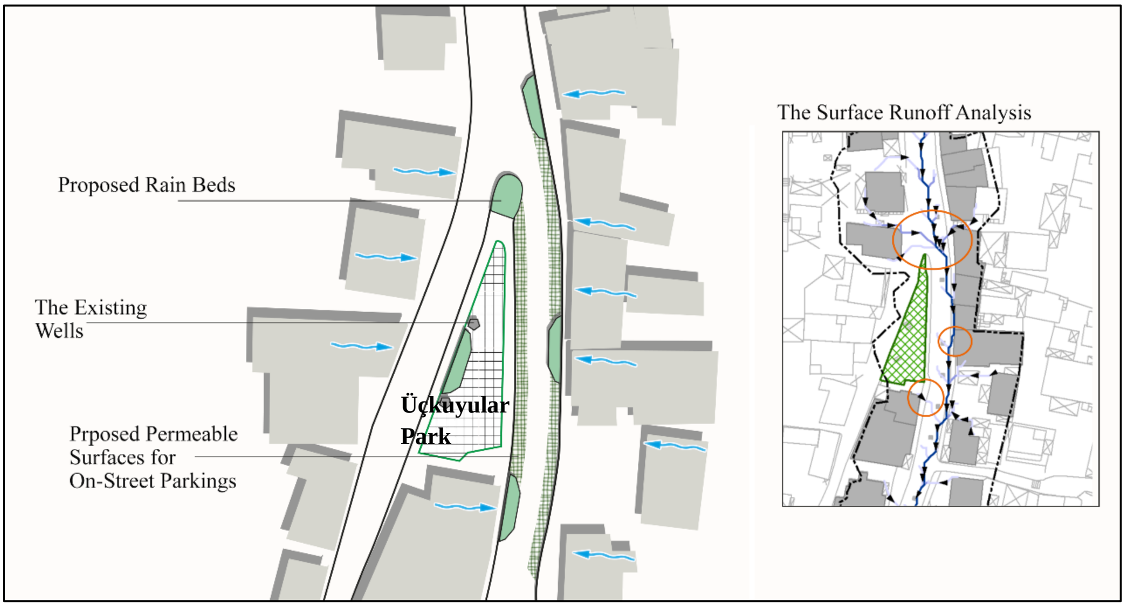

Figure 4.63. A Site-View from Yokuşbaşı Pilot Area Showing Proposed BGI Elements for Streets (Source: Prepared by the author)

- **Regulate as Multi-Functional Areas:** Parking lots must be designed as retention areas that can keep the rainwater to the determined ratio of precipitation divided by the total area(m^2).

4.5.1.3. Buildings and its Surrounding

As possible to see from analyses of the pilot areas, public areas are not abundant in the city. Therefore, private and public building plots have a significant role in the BGI strategies for Bodrum. Usually, private areas have got considerable green spaces in the city center and together these spaces present important opportunities for the city's blue-green infrastructure system.

In order to provide an encouraging and supportive conditions which can provide the opportunity to the residents, businesses, hospitals and schools, Bodrum Municipality and its Reconstruction and Urban Planning Directorate, Parks and Recreation Directorate and Bodrum City Council can play an assembling role. First attempt should consider informing people about the effects of climate change, instructing and informing them about what individuals can do and how much it can be affective. Tool from Municipality can be directive and financial supports.

4.5.1.3.1. Houses and its Gardens

Because of the narrow streets and inadequate open areas, roofs and gardens of buildings can play a significant role for planning a BGI network.

- **Create Incentives for Household Cisterns:** According to the observations and the survey, some of the houses still use cistern in their garden where they collect the rainwater from their roof. However, especially the new generation are not aware of these methods and the owners of these cistern says cleaning the cisterns are getting harder each year due to old age. Therefore, it is important to protect this existing method and it is essential to make it again popular among people. Municipality and MUSKİ can create an incentive program where people can apply and get some benefits and services like cleaning or discount on water bills. Additionally, creating a manual to explain how people can build a cistern in their garden and what benefits they can have from it must be prepared by the municipality to encourage the owners.

- **Revitalize "Çöplen":** Another traditional method that have been used by the locals in their houses was "çöplen". Revitalizing this method among the residents of Bodrum must be promoted. This method should be expressed by the water harvesting tanks and their possible usage in the manual.

- **Promote a Characteristic "Geren" Roof Concept:** The traditional roof cover material, clay soil – seaweed mixture must be promoted for new constructions at least for the half of the roof area. For existing buildings, retrofitting projects must be implemented.

- **Include EI Calculations in Planning Permissions:** Effective Imperviousness (EI) calculation must be in regulation (explained in detail in the part of theoretical literature; Stormwater management practices of contemporary NBS) – EI is a useful tool of stormwater management measures. Parcel types of Bodrum can be distinguished and different drainage scenarios can apply to different typologies.

- **Xeriscaping:** The choice of vegetation for gardens must be promoted as xeriscaping that will survive with drought and do not need everyday watering. Therefore, the manual has to propose suitable vegetations for gardens and also, for swales, rain gardens, and constructed wetlands.

4.5.1.3.2. Summer Houses and Hotels

In the peninsula, summer houses are built as groups of the same structure buildings. They usually have one pool and bigger green areas. Therefore; besides of the tools explained for houses in general some specific strategies are developed for summer houses and hotels.

- **Reduce Water Consumption:** There must be a prepared regulation to reduce their water consumption and drained surface water ratio to the sewage system of the city. Additionally, there must be requirements in planning permission for constructions like compulsory of building a cistern in their garden.

- **Require Ecologic Stormwater Treatment:** For the treatment of the stormwater, summer house sites and hotels must have constructed wetlands or rain gardens if they have enough space. The parameters of treated water should be decided and controlled by the MUSKİ.

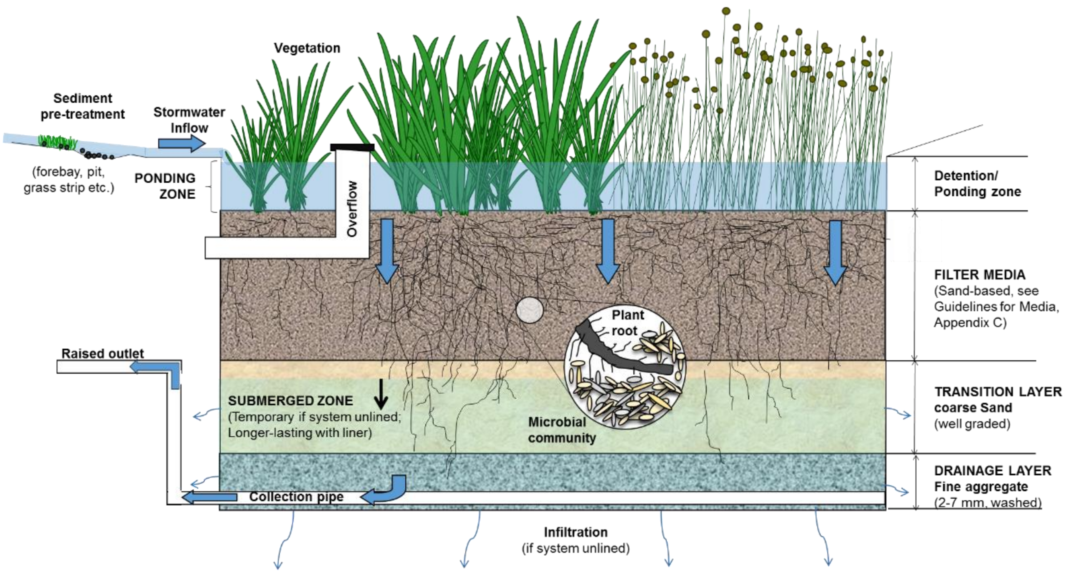

Figure 4.64. Stormwater Biofiltration Systems with Constructed Wetlands or Rain Gardens (Source: Url 22)

- **Create Regulations for Pools:** In the new constructions, constructing pool is not allowed unless they are filled with treated wastewater like greywater or rainwater. Ecologically treated pools must be promoted. In existing constructions, pools must have retrofitting projects which transform them to ecologically treated pools or pools used treated stormwater.

- **Promote Private Cisterns:** Every hotel is required to have cistern to collect rainwater from their roof. It could design as buried cistern.

- **Apply Water Sensitive Certificates:** A certification program is useful tool applied for hotels and group of summer houses for their design projects to support implementation of the BGI tools by providing incentives such as tax exemptions or reductions, so on.

Figure 4.65. An Ecological Pool Which is using Stormwater and Surface Water for Water Supply and Plants for Purifying the Water. (Source: taken by the author in Prague)

4.5.1.3.3. Public Buildings

Public buildings must be seen as representatives for the implementation of these integrated new approach water management system. In this sense;

- **Implement Retrofit Projects:** Every public building existing in the area must be retrofitted to have explained blue-green infrastructure elements both for buildings and gardens.

- **Implement BGI Systems to New Projects:** For the new projects, implementation of blue-green infrastructure (BGI) systems must be among the requirements.

All in all, creating a networking system for being integrated and decentralized is essential to have a good working water management system. Obtaining such a network is important even for the pilot areas stage, which shows the importance for holistic urban scale and then the peninsula scale.

CHAPTER 5

CONCLUSION

Nature-based solutions are innovative and environmental approaches to the development of cities. On the other hand, at the beginning of the settled human history, settlement development followed the natural patterns of the locality. For example, in arid regions, people settled according to the slope where they can collect the rainwater or used cisterns in their garden to keep rainwater longer. Growing population, sanitary concerns and technological development pushed humanity to use conventional water management techniques (grey infrastructure) which provided various advantages to the urban areas like providing safe drinking water and healthy environment, but on the other hand, it has created severe problems to nature and finally to humans. Thousands of people and animals had to move their living place and thousands of cultural heritages left under dam water as nearly happened in Hasankeyf, Turkey. Additionally, buried streams in urban areas for making roads or channelized streams for taking the rainwater away caused irregularities in the urban water cycle, loss in native vegetations or decrease in biodiversity. The blue-green infrastructure method, as a part of nature-based solutions, offers an integrated framework for water sensitive design together with conventional systems in urban areas that identifies rainwater as one of the main water resources for a city. Moreover, water sensitivity should consider the local possibilities and solutions, also together with the existing traditional water management methods. Therefore, the scope of the study aims to find the best possible integration between the traditional water management techniques of Bodrum and the new approach of nature-based solutions as blue-green infrastructure techniques.

- In order to answer the main questions of the study, “How water heritage knowledge of a place pave the way for an innovative and unique solution?”, “What are the innovative water management techniques with a sensitive approach to the ecosystems?”, “How can an integrated water management knowledge and contemporary nature-based solutions be integrated?”, different historical settlement’s water supply solutions, current water problems of the World and Turkey, and current water management practices of Turkey and innovative approaches to water management in urban areas from all around the World like blue-green infrastructures are introduced and investigated through the study.

In this chapter, a conclusion from all findings obtained during the research is presented as theoretical literature findings and the case study findings. The theoretical literature findings explain the historical and traditional water structures that had been used in different parts of the world for dealing with the lack of water. Moreover, it introduces water problems, and management approaches from around the world and Turkey. Additionally, different water management practices have generated by different countries are described as to understand how the countries dealt with the implementation of these innovative approaches for water management. The case study findings showed the existing local water supply methods of Bodrum could help in achieving an integrated blue-green infrastructure implementation by revealing the sensitivity and the habits of people that already exist in the near past.

Finding in the theoretical literature is given under two different scopes. The first part of the literature findings has displayed the used local methods on history by our ancestors for dealing with water scarcity. Their solutions were different and sometimes unique, but the aim and the way of using natural possibilities were all similar. Therefore, it is important to find out the indigenous solutions of the locality, however, it is also important to learn from these methods and combine them with new technological possibilities. In the second part of the literature findings, climate change, water pollution, water scarcity, and water cycle in urban areas are investigated as water problems related to freshwater scarcity around the World and in Turkey. The investigated water problems show the necessity of a different approach to water management in urban areas since water is the most vital resource for life and cannot be considered as a renewable source because of the pollution anymore. Later, within the provision of existing water problems, nature-based solutions are investigated as a new approach to the water management of cities, and under nature-based solutions, blue-green infrastructure is considered as an innovative stormwater management tool for urban areas. Lastly, different nature-based water sensitive approaches of urban water management practices like SUDS in the UK, WSUD in Australia, ABC Waters from Singapore, LID from the USA, Sponge City Concept from China and BGI as a new approach are discussed. It is important to understand how these approaches have been implemented by the countries to their cities for answering one of the main questions “How can an integrated water management knowledge and contemporary nature-based solutions be integrated?". In this sense, mostly the success of these implementations is coming from the public awareness and interaction with the local governments and also, with the sensitive management approach vision of authorities. However, regarding Turkey water management practices, even though there are some attempts to consider nature-based solutions within the scope of climate change adaptation programs, the conventional management practices are still dominating the general approach of water management.

The case study findings tried to answer the questions, "What are the water problems occurred in Bodrum?", "How can an integration of local water knowledge and the nature-based solutions be adapted to mediate the freshwater scarcity in Bodrum?" Bodrum has changed drastically after the 1970's with the announcement as a prior-degree tourism center. End of the '70s, the new main road between Milas and Bodrum, and the airport at the end of the '90s, have had significant impacts on the development of tourism in the Bodrum Peninsula. As discussed in the urbanization analysis, the biggest urban sprawl also had happened during the '90s. On the other hand, urban development has not grown with adequate infrastructure simultaneously. Today, one of the biggest problems of the peninsula is the inadequate infrastructure system. Similarly, buried streams for gaining space in urban areas create floods and disconnection with nature. On the other side, being in the arid region and lack of surface freshwater makes Bodrum concerning about the possible future freshwater scarcity. All these reasons lead the question "How can water heritages enlighten urban water management with the integration of contemporary nature-based solutions with a sensitive approach to the ecosystem?".

Besides the precious historical value, the region has also a deep cultural value that kept for years until today. Such as the typical cistern of the area that was located all around the peninsula, almost with one km range are unique water supply methods of the region that have been used for ages and even today in some parts of the peninsula, these cisterns are serving for animals or watering. Moreover, a survey is conducted around the peninsula with 51 people to understand the opinion of people about the re-usage of traditional water supply methods against water problems of the peninsula. According to the answers because of urbanization and tourism, people think that these methods cannot be useful anymore; however, their protection and meaning are essential for the city, and, with the combination of new technology, they may help with water scarcity. Additionally, the survey showed that there are remaining methods that are used by the locals. Even though people who do not use them anymore, they know the importance of rainwater for the peninsula thanks to the stories of these methods and structures spreading from ear to ear among them. In this sense, these local methods are necessary to revitalize the sensitivity and the values of the community for water management like sharing, recycling and respect. Therefore, bringing a new approach to stormwater management which bases on collecting and re-using it in the region will be easier to accept thanks to its tradition from the past.

The study offers an integration of strategies of the water heritages of the peninsula and blue-green infrastructure techniques to mitigate the essential freshwater scarcity and flooding problems of the region. Bodrum water supply heritage has become invisible with the emerging of conventional water supply systems and dense urbanization due to tourism investments. However, these water heritages embody valuable solutions and practices like private and collective rainwater harvesting that can be beneficial for current water and wastewater systems. The innovative and nature-based solutions of blue-green infrastructure can support these already existing inherited water methods and be a model for Turkey for creating a new approach to water management. Almost each part of Turkey has their own cultural method for dealing with water scarcity and all these unique methods can create their own sustainable water management model.

The approach for a better integrated water management plan must include;

- Improvement awareness of the public and policymakers about climate change, urbanization, and demographic and economic trends, which have seen as a treat for water security and heritage.
- Enhance water-related data and information systems within and between governmental institutions and civil organizations for more collaborative and integrated management.
- Adoption of a more sensitive and inclusive approach that combines innovative and conventional approaches rather than adopting only the conventional way of water management.
- Learning from inherited water management systems in relation to natural and urban landscape for sustainable and livable cities of future.

With the growing population, we lost our trust of each other and we believe that humans pollute and damage the nature and again the only way to clean this pollution is by human-made constructions. However, a different world is possible with a more sensitive perception together with nature and human collaboration. Our roots give us good examples of management which follows natural processes. In this sense, being aware of these traditional nature-based solutions and enriching them with the contemporary nature-based solutions may bring us respectful and sustainable future cities which will be exist with their own local solutions.

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APPENDIX

THE SURVEY QUESTIONS

1. **Adınız, Soyadınız? (İsteğe Bağlıdır. Sadece Gerektiğinde Tezde Referans Vermek için Kullanılacaktır.)**

2. **Yaşınız?**

3. **Bodrum'un Hangi Mahallesinde Yaşadınız?**

4. **Büyüklerinizden, Çevrenizden ve/veya Gençliğinizden Duyduğunuz/Bildiğiniz Eski Su Toplama ve Kullanma Yaklaşımları ile ilgili Anılarınızı Paylaşır mısınız? (Sarnıç, kuyu, çöplen gibi yerele özgü teknikler)**

5. **Bildiğiniz/hatırladığınız eskiden su ihtiyacının karşılandığı kuyuların, sarnıçların adları nelerdir? Bu ismin verilmesinin hikayesi nedir?**

6. **Sizce sarnıçların konumları ve güzergahları belirli bir neden ile mi yoksa gelişigüzel olarak mı seçilmiştir?**

7. **Bodrum'da Sarnıç Yapılarının Toplumsal ve Kentsel bir Değer Oluşturduğunu Düşünüyor musunuz? Evet/Hayır - Neden?**

8. **Sizce kuyuların ve sarnıçların korunmasına yönelik alınması gereken önlemler nelerdir?**

9. **Bildiğiniz sarnıçların ömürlerinin uzatılması için yapılan işlemler nelerdir? (örn: kireçle boyanırsa üstünde ot çıkmaz gibi)**

10. **Çevrenizde su kaynaklarını geleneksel yöntemlerle bulan kişiler var mı?**

11. **Çevrenizde bildiğiniz su kaynağı var mı? Varsa ismi nedir?**

12. Bodrum'un bugün su sorunu olduğunu düşünüyor musunuz? Evet/Hayır - Neden?

13. Sizce Kentte Bulunan Sarnıç Yapılarının Günümüzdeki Kullanım Amaçları Ne Olmalı?

Mark only one oval per row.

	Kesinlikle	Olabilir	Asla
Turistik Yerel bir İmge Olarak Korunmalı			
Kente Su Kaynağı Olarak Kullanılmalı			
Restore Edilerek Kültürel Amaç için Kullanılmalı			

14. Doğal temelli ve çevreci arıtma çözümleri ile sarnıçlardaki yağmursuyu arıtılsa hangi amaçlarla kullanılmasını/kullanmayı tercih edersiniz?

Tick all that apply.

	Kesinlikle	Olabilir	Asla
Refüj sulanmasında			
Bahçe sulanmasında			
Araba yıkamada			
İçme suyu olarak			
Çevre temizliğinde			

15. Eklemek İstediğiniz, Önemli Olup Tezde Bahsedilmesi Gerektiğini Düşündüğünüz Bir Şey Var mı? Teşekkürler.