THE FORGOTTEN VALUE: A STUDY ON THE RESTRUCTURING URBAN FABRIC WITH WATER

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ABSTRACT

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Water is regarded as a vital element in almost all contexts in the world. From early times, it has a significant role in both in nature and urban settlements. People from the past to the present have always dealt with the water issue for their needs. Basically, they are constantly trying to reach clean water in this process. Together with individuals in the society, the perception of water in cities and in countries have been changed in today's world. Generally, water is used in the urban areas for municipal, industrial or recreational purposes and then the water whose natural and clean structure deteriorates, is removed from the city and discharged directly to nature. When this process is repeated for many years together with the increasing population and climate change, natural hydrologic cycle is damaged. Depending on this problem, water management which includes flooding, heavy rain, sewerage and rainwater systems, degradation of urban streams etc. starts to become one of the major issue of urban areas.

To mitigate the water related problems and most importantly water scarcity, water should be a part of urban life instead of being seen a simple element. Urban planners and designers should pay attention to water when working with urban spaces because basic implementation from small scale to the wider scale can create a strong connection between nature and urban environment whether used for existing urban settlements or a new area. Re-establishing natural water cycles in the urban system is created while water quality and accessibility for all people are provided through scaling in the urban fabric. For this reason, design with water has multiple benefits from recreation and landscape quality to the sustainable growth.

The aim of the study is to show shaping urban form with water and this study concludes the applicability of some significant urban design guidelines and tools to restructure the urban fabric with water for the future practices together with applied examples in the world and in the context of three major scale: building scale, street scale and region scale. For this reason, water is represented as a core for design elements that shaping the urban spaces in this thesis.

Keywords: Water Sensitive Urban Design, Water management, Urban Design, Urban Infrastructure, Open Spaces, Urban Development, Re-structure, Green Infrastructure

ÖZ

UNUTULAN DEĞER: KENTSEL DOKUYU SU ILE YENIDEN YAPILANDIRMAK ÜZERINE BIR ÇALIŞMA

Gürsan, Hande
Yüksek Lisans, Kentsel Tasarım
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Su, dünyadaki hemen hemen tüm bağlamlarda hayati bir unsur olarak kabul edilmektedir. Erken dönemlerden itibaren hem doğada hem de kentsel yerleşimlerde önemli bir rol oynamaktadır. İnsanlar geçmişten günümüze her zaman ihtiyaçları için bu konuyla uğraşmışlardır. İnsanlar temel olarak bu süreçte sürekli olarak temiz suya ulaşmaya çalışmaktadırlar. Toplumdaki bireylerle birlikte, günümüzde dünyadaki yerleşimlerde su algısı değişmiştir. Su kentsel alanlarda genellikle belediye, sanayi veya eğlence amaçlı olarak kullanılmaktadır. Daha sonra doğal ve temiz yapısı bozulan su, şehirden uzaklaştırılarak doğrudan doğaya boşaltılır. Bu süreç artan nüfus ve iklim değişikliği ile birlikte uzun yıllar boyunca tekrarlandığında, doğal hidrolojik döngü zarar görmektedir. Bu soruna bağlı olarak, sel, şiddetli yağmur, kanalizasyon ve yağmur suyu sistemlerini içeren su yönetimi vb. durumlar kentsel alanların en önemli sorunlarından biri olmaya başlamaktadır.

Problemleri ve en önemlisi su kıtlığını azaltmak için, su, basit bir unsur olarak görülmek yerine kentsel yaşamın bir parçası olmalıdır. Şehir plancıları ve tasarımcılar kentsel alanlarla çalışırken su öğesine dikkat etmelidir, çünkü küçük ölçekliden geniş çaplı temel uygulamalara kadar doğa ile kentsel çevre arasında güçlü bir bağlantı oluşturulabilir. Kentsel sistemde doğal su döngülerinin yeniden oluşturulması, su kalitesi ve erişilebilirlik, kentsel dokuda ölçeklendirme yoluyla sağlanmaktadır. Bu nedenle, su ile tasarımın rekreasyon ve peyzaj kalitesinden sürdürülebilir büyümeye kadar birçok faydası vardır.

Çalışmanın amacı, dünyada uygulanan örneklerle birlikte ve üç ana ölçek bağlamında (bina ölçeği, sokak ölçeği ve bölge ölçeği) kentsel dokuyu gelecekteki uygulamalar için su ile yeniden yapılandırmaya yönelik bazı önemli kentsel tasarım kılavuzlarının ve araçlarının uygulanabilirliği olarak belirtilmiştir. Bu nedenle, bu çalışmada su, kentsel alanları şekillendiren tasarım öğeleri için bir çekirdek olarak temsil edilmektedir.

Anahtar Kelimeler: Suya Duyarlı Kentsel Tasarım, Su yönetimi, Kentsel Tasarım, Kentsel Altyapı, Açık Alanlar, Kentsel Gelişme, Yeniden Yapılanma, Yeşil Altyapı

To the blue on earth and sky…

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INTRODUCTION

Without water no life.

Water, is the most required source of mankind, has always been get in touch with urban development. The early settlements were built in fertile areas where water was accessible such as river valley or another water resources in the past. The main purpose of this action in human history is obviously agriculture. From Mesopotamia to the Nile and Indus Valleys, agricultural revolution spread with the permanent settlements depending upon the water accessibility. The first intervention to the water was for irrigation related with agricultural needs in the agricultural revolution. Irrigation canals were the major point of this effort. However, the urban water systems were the next step of the water concern issue.

Technology for water issue for the first city centers is based on Mohenjo- Daro, one of the major urban centers of Bronze Age and Indus civilization. It was an intentionally planned urban settlement which is established around 2450 B.C. (Jansen,1989). These settlement appearances in a semi-arid environment. For this reason, it has 700 wells which meet the needs of whole city. This means that one out of every three house has a well. In addition to this, water consumption has an important role in this planned city. There was a bathing platform in almost every house and the Great Bath of Mohenjo-Daro which has an area of 1.700m², had a pool in the center. Also, the sewage system was built along the streets. So, the Indus civilization had improved bathrooms in every house and sewer system in every street of the city.

In Early Greeks, there were advanced water distribution and management system such as wells, rainwater collection, cisterns and fountains. Cisterns were used to store runoff from surfaces. Greek Civilization and their cisterns, tanks and wells are similar to the Minoan but there is some variation about the engineering part of the system. Aqueducts which transport water from highlands to the city center were diverged at the entrance of the city and their purposes was feeding cisterns and public fountains (Mays,2007).

Tjallingii (2012) mentioned that in the ancient Greek mythology, Island of Atlantis was subject to a tale. It was thought that the waters fell to inside of the earth. After that, they could reappear as a source of the stream or waterway such as the Nile River. This story continues that when Vitruvius who was a Roman architect was in his bath and a cold water drop from the stone roof fell on his body. Vitruvius noticed that hot steam was concentrated and understood that in the water cycle, not only earth but also the air has significant role. This situation brings us the definition of the water cycle in today. UNESCO (2006) created the definition of the water cycle. This definition is:

"*Succession of stages through which water passes from the atmosphere to the earth and returns to the atmosphere: evaporation from the land or sea or inland water, condensation to form clouds, precipitation, accumulation in the soil or in bodies of water, and re-evaporation*."

With respect to definition and other researches, we understand that the water is not a mysterious and limitless source like in the mythology. On the contrary, it is a depleted and significant source of life cycle. It is a loop.

1.1. Problem Definition

In today's world, water is found in the urban areas in many different ways. It can be observed in cities as storm water, groundwater, river water, drinking water, waste water, flood and artificial water bodies like fountains, water basins. All of them contribute the urban life and were highly effective on human life. Understanding the water flow especially in cities is the major point of the water cycle. This is highly related with urban development in the big picture. The second important point of water flow is how it run through urban system and how it can be directed for flexible uses. Because water is not only a drinking water or using for irrigation purposes. There is more than that: rainstorms, waste water, grey water, floods etc. are the other elements of the hydrological system.

In natural system, water cycle can be defined as water falls as rain to the earth, moves through the environment, infiltrates to underground and is collected in the ground water resources. After that, it moves through streams and evaporates to the atmosphere and cloud systems. This loop continues in the earth system. Throughout this process, water interacts with natural systems. Transition part of the one to another can be done by trees by catching rainfall or by soil cleaning storm water runoff before it goes to the groundwater and finally vegetation transfer water to the air. In general, urban development interrupts these natural processes through removing natural areas aggregately and creating impermeable surfaces. The developed site collects all waters with huge pipe systems and these high level volumes is directly discharged lower catchment areas or rivers. In other words, urban areas bypass natural systems in terms of water management. It creates several negative results such as flooding, damaging to natural system etc.

Under normal conditions, water cycle which is continuing as precipitation, infiltration, surface runoff, and evaporation is natural process. However, as mentioned earlier, in urban settlements, this natural cycle cannot run properly. Urban water that is polluted by human and their actions cannot infiltrate because of paved and impermeable surfaces. So, urbanization increases the surface runoff. It flows from one point to another and the water is gathered in somewhere and discharged to natural and clean water sources. In this travel, unfortunately all steps of water cycle is corrupted. As a result, the natural cycle is broken, and water resources is abused.

In this hydrological cycle, storm water directly drops to the city and runs through the city or in an indirect way, elevations and highlands create precipitation, then rainwater comes to the urban areas through the instrument of river water or groundwater. Related with the amount of runoff, the city is a particular environment for storm water.

Tjallingii's study shows that a green landscape infiltrates the 50% of 100% rainwater that falls into ground and almost 40% of it evaporates. Run-off level is minimum (10 %). On the contrary, in urban areas that have highly impervious landscape such as asphalt etc. 85% of the rainfall is run-off and consequently evaporation and infiltration level will decrease. Obviously, there are lots of differences urban areas depending on the region. Not only climate, location and natural value but also urban density and land use decisions create differences in this water system.

In any case, cities can adopt themselves according to source of water. Harvested water can be used for irrigation of gardens, cleaning and washing etc. In this way contributing to the water system can be provided in the urban scale. When we came to the groundwater, it works in connection with storm water. Infiltration of rainfall is highly important element of the system in order to protect and sustain groundwater aquifers. The amount of permeable spaces in cities and related with the runoff issue, the level of groundwater can change and according to the demand of cities it can be affected. High level of impervious surface, lack of open and green areas and conventional piped infrastructure networks decrease storm water infiltration.

Today, over 25% of the developing world's urban population do not have sufficient sanitation system (Tjallingii, 2012). After the Industrial Revolution, health condition became the most common problem in cities which have inadequate sewer system. Basically there are 2 types of conventional sewage systems. First one is combined system and the second one is separate system. However, in general urban areas have combined systems because of some reasons such as economical or infrastructural. Moreover, storm water and wastewater are transported to the other water sources such as rivers, lakes or sea. Because of this situation, water sources faced with serious problems and it influenced the water cycle negatively in terms of water supply and accessibility. After that, treatment plants started to construct most cities in the world. However, some of them still don't have and use mixed sewer system. Because, treatment plants are expensive and not easily applicable. It is a central system, so when we think about the domestic level, it can be a problem in water efficiency.

Although urban water system is a small part of the regional cycle, effects of it creates huge changes in the whole system. In the recent times ‘closing the circle’ and sustain the natural system become more difficult day by day in the world. While the total volume of water on the globe doesn’t change significantly over time, its form and location as precipitation, water, ice or cloud does change. Also, freshwater distribution on Earth can vary from region to region. Apart from natural reasons, manmade activities in recent years such as urbanization, industry and technological development effect the earth and create a significant pressure on water systems of planet. These pressures are most often related with human development, economic growth and climate change.

The most necessary and important human needs for water is drinking and eating to life through. After that, cooking, washing of bodies and clothes and cleaning the living space are the secondary needs. According to the Wescoat and White (2003), drawing on data from the World Health Organization (WHO) and other sources, for the purpose of drinking and hygiene, a minimum daily consumption standard is about 25 L per person per day, and 25 L for bathing and food preparation. This is subject to tremendous variance according to differences in climate, people and mode of life.

One of the most crucial “water decision” can be count as the International Development Target set by the Millennium Assembly in 2000 at the global level. The main aim is “*to halve, by 2015, the proportion of people living in extreme poverty and to halve the proportion of people who suffer from hunger and are unable to reach or to afford safe drinking water resources*.” So, the water cycle, water related problems and urban areas draw attention in the international level. Many countries and their major cities lead in the context of “water decision” and look on water as a problematic issue now and future. Some of them are not. The question is that “ what is their solution?”

Many regions in the world have a sufficient supply of water when we consider the population and amount of freshwater resources such as North America and Europe.

Thanks to the advance technological development of water systems, supplying fresh drinking water and transferring of it is now easier and also discharging wastewater is applicable. Nevertheless, several countries of the world still have significant difficulty with water availability and treatment. The Third World Water Development Report (United Nations,2009) observed that in one hand, global water consumption is growing, on the other hand more than 4 billion people still do not have access to fresh water easily and safe. In addition to that World Water Council (2010) states that "*the average daily water consumption in European countries is 220 liters per person. In North America and Japan, it is 350 liters per person, while in sub-Saharan Africa only 10-20 liters per person is used.*". Another water user that have high level of water consumption is India, China and the United States as well as Pakistan, Japan, Thailand, Indonesia, Bangladesh, Mexico and the Russian Federation (United Nations,2009). This means that in time cities grow and water demands of cities also grow. Today, unfortunately many of them almost reached the limits of carrying capacity of water resources.

Global water demand is foreseen to increase significantly within next years. It is influenced by population growth, urbanization, food and energy sector, increasing life standards and climate change. Over the past century, water resources were depended by the demands of populations for food and energy. However, income growth and rising living standards, especially in the urban areas, led to powerful rises in water usage and this water use is generally excessive and unsustainable. According to the Managing Water Use in Scarce Environments which is published by 2030 Water Resource Group, If the water management approaches continue in same way, in other word there is no or less intervention, the difference between freshwater demand and supply will be about 40% in the world by 2030.

In the end, the major concern is accessing the fresh water. However, population growth is a significant factor that directly affects the demand for freshwater. According to the Water Development Report in 2015, the relationship between population and water demand is not linear. They said that "*Over the last decades, the* *rate of demand for water has doubled the rate of population growth*." So, freshwater resources are under the risk of excessive usage and depletion.

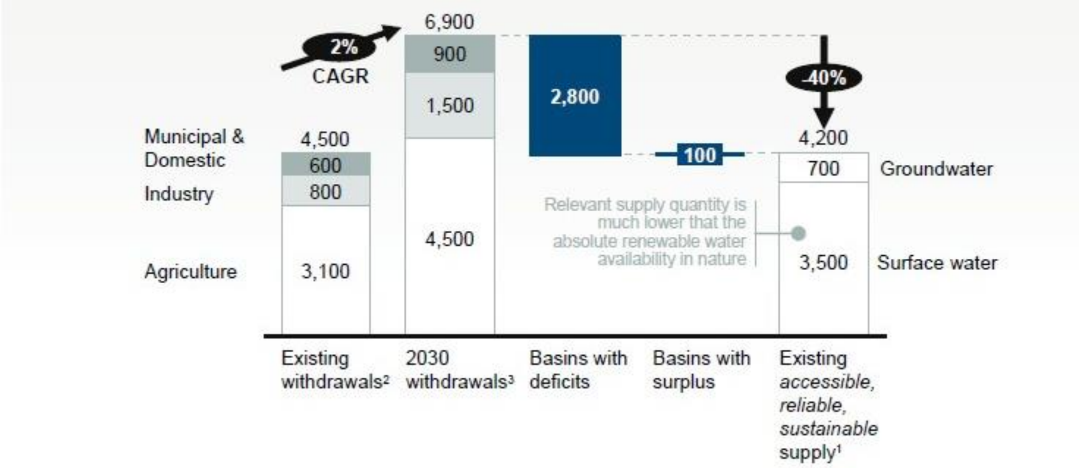

Figure 1.1. The gap between existing water supply and water withdrawals in 2030 (Charting Our Water Future,2009)

In addition to that increasing urbanization is highly effective on freshwater resources. Apart from daily usage, many activities need water in urban areas. According to the United Nations World Water Development Report (2012), the ratio of people who live in cities in the world is about 50% now and 30% of all city dwellers live in squatter settlements. In the meantime, In the 2050, urban populations will be increase to 6.3 billion Which means there will be lots of people in the city center and parallel with there will be more water supply in the near future. And lastly, agriculture and energy make more difficult water scarcity. For example, 70% of all freshwater sources in global is used by agricultural (WWAP, 2014).

According to the Third World Water Development Report (United Nations, 2009) one the one hand, today more than 4 billion people do not have access to safe, fresh water, on the other hand global water consumption increases day by day. With the growing population of all around the world, regions of high water stress are also growing. In 2030, almost half of the population in globally will live in regions that have high level water stress. Another remarkable point from The United Nations in 2017 is that two thirds of the world's population is under the condition of water scarcity for at least one month a year (WWDR, 2017).

Information mentioned above with excessive use of water make water quality and wastewater current issue. Increased discharges of untreated sewage, wastewater from industry and agricultural runoff end up with degradation of water quality around the world. In the wastewater issue, the 2017 World Water Development Report explained that wastewater which is directly discharged to the nature without any healing process is about 80% of waste water in worldwide. Pollution of water is getting worse in most region such as Asia and Africa. All these numeric data, ratio and regions shows that in different part of the world, there are several different kind of problematic situations. These situation, in the end, influence both living standards of people in urban or rural areas and also affect the hydrologic cycle in total.

In addition to whole situation, under this circumstance, climate change is a fact that influence water resources in the world negatively. Climate change and impacts of it to the earth have been discussing frequently around the world in recent years. Because, after 1970s, climate change and its several significant impacts were more observable in the international level. Its physical effects on earth have been increasing day by day. In fact, historically, people have coped with natural disasters and environmental changes. Humanity experiences now and will continue to deal with this situation.

Climate change can be described as statistically significant changes that last for decades or more in the average state of the climate or its variability (Türkeş, 2012). It can be caused by natural or anthropogenic processes and external coercion factors in the. From the industrial revolution, especially from the mid-19th century, in addition to the natural variability in the climate, human activities - greenhouse gas emissions above normal, wrong and excessive use of soil, water and biological resources, negative practices affect climate. For this reason, climate change is described by mainly taking into account of human activities. For example, according to United

Nations Framework Convention on Climate Change, which become valid in 1994, "*Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods*."

As a result of significant changes in the atmosphere originating from human activities, the warming started at the surface temperatures at the end of the 19th century. Global temperature is increasing almost every year, hotter than the previous year. Recent global assessments have also shown that warming in the climate system is strengthened. There is an important result in terms of strengthening the regional climate change signals. The observed tendency to warm up has accelerated in almost all stations in the 1980s whatever the level of urbanization, and has become a major hot turn in the last 20 years (Turkeş, 2012).

In the international level, there were arranged a lot of conferences and established several institutions for describing the consequences of climate change on people and other living creatures, urban and natural areas etc. In addition to that, several conventions were prepared among less developed, developing and developed countries in the international level. For this reason, there were several researches about climate change, global warming, GHG emissions, sea level rising, extreme weather etc. were conducted. According to location, these problems are generally flooding, heavy rain, urban heat island, biodiversity problems, water management problems etc. When we think about the relationship between climate and urban development, water related environmental changes are the most significant ones for all cities in recent days. Water availability, treatment and transport of wastewater and storm water, supplying fresh water are the main issues for cities to meeting their needs.

So, how cities are affected? The most likely effects seen in the world are floods, storm and temperature waves. This situation affects transportation systems, sewage systems and even biodiversity. Climate change creates pressure on our "hard" infrastructure, such as highways, homes and sewage systems. But at the same time, it creates pressure on our "soft" infrastructures, like health systems. Related with this situation, another significant problem of climate change is water issues in cities such as water resources management (waste water, storm water etc.), sea level rising and extreme weather events. According to the Global Climate Change Impacts in the United States (2009), after at least 2,000 years of little change, sea level rose by roughly 8 inches(20cm) over the past century. Satellite data available over the past 15 years show sea level rising at a rate roughly double the rate observed over the past century.

There are two reasons that behind the global warming issue effect the sea level. First one is that as water warms, ocean water expands, and therefore it covers up more space. Secondly, warming can cause the melting of ice in the northern part of the planet. In that way, extra water is added to the oceans. On one hand, sea level rising creates a risk for coastal cities, on the other hand several cities which is located in more inner side of the land suffer from water scarcity, especially in terms of potable water and irrigation water. Another water related example is that according to Floods of Meriç River occurred in the last fifteen years and protection projects, in the Meriç River Basin, the floods that are due to extreme precipitation, snow melting and/or released water from the Dams of Bulgarian Side are the most frequent example for Edirne in where three rivers are combined (Erkal & Topgül, 2015).

In the end, it doesn't matter that the reason is population, urbanization or climate change, urban areas have to deal with water related problems which is mentioned above. Moreover, main concern is accessing the fresh water and closing the natural water cycle in urban areas where occur high level disruption.

1.2. Aim of the Study and Research Questions

After all, whatever the reason, the water is scarce. So, how do cities adapt? The storm water and wastewater collection systems are generally using mixed concept in many urban areas. Managing the urban water infrastructure allows the system to keep up with changes. Generally, positive and negative environmental consequences of water infrastructure is emphasized in the last 20-30 years. Before that, people mainly focused on social and economic outcomes of urban infrastructure. This change in the idea caused to a perception that the central, large-scale system should be transformed into alternative systems and water management should be practiced reasonable.

After all, urban water management is a new concern in worldwide. In the role of water, interaction between urban and regional ecosystems has significant assignment. Not only regional but also cities itself, water management is a problem waiting to be solved. Developing a resilience solution and integrating water issue in plans can create more sustainable environment and livable places in urban life. Because water can create a significant opportunity to combine natural environment and urban development.

Integrated urban water system; component of water cycle such as water supply, wastewater transportation and treatment, storm water collection and disposal are taken into consideration separately for their operation and institutional management. This approach brings about to ineffective planning and problems of water related services.

To show the relationship of urban and nature, some concepts will be shown and new suggestions will be explained for the design guidelines in the urban context. Over the next few decades, central, large-scale systems will form the major component of water infrastructure in many regions because they built already and it is difficult to change the system because of environmental, engineering and cost issues. The basic and different small scale alternative systems will have an increasingly important role. In the adaptation and mitigation process, they change their cities according to their needs.

For example, sustainable water management, urban design and landscape design are taken into consideration together. In the Water Sensitive Design for Storm water guideline document of Auckland Council (2015), there are some intervention scales from the building to the open space to achieve sustainable water management. They determined some implementation tools such as cistern, rain garden, bioswales, on-site infiltration etc. for all scales. Re-establish natural water cycles in the urban system is created while providing water quality and an open spaces and recreational areas in the urban fabric are included.

Figure 1.2. Water sensitive urban design examples (Auckland Council,2015)

According to Resilient New Orleans Strategy report (2015), one of the most important strategies is green infrastructure demonstration project. They determine some green spaces in urban areas for both recreational purpose and flooding. In normal situation, these green spaces are used for relaxing and amusement. However, in the time period of flood which is caused by heavy rain or other extreme events, space is used by water. In other words, flexible spaces are the key interventions for flood control. Major point of these strategies is that "we must not only adopt, we must transform.”

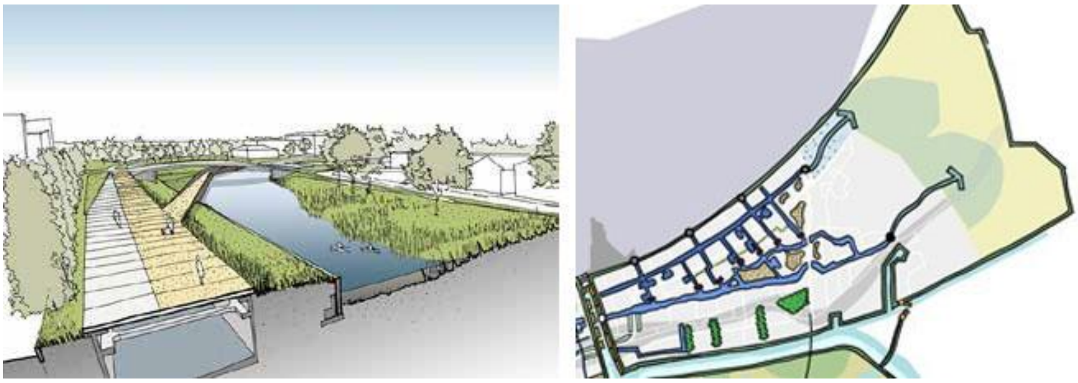

Figure 1.3. Urban Water Implementations and Solutions (Waggoner & Ball Architects, 2013)

The integrated water management should include all water resources, such as wastewater, storm water, grey water etc. More importantly, taking into consideration of integration of water and land use decisions and integration of human water use and natural water cycle processes and the accessible and fairly use of all water sources are the main concern of the system. In the water management system, there is a hierarchical process which generally requires consideration of issues at different scales from general to local. Each of them needs different kind of implementations.

Main hypothesis of this thesis is that, water is valuable and it is scarce. To solve this problem, centralized water system is not sufficient for the whole city form. It should be figured out with localize systems. So, the aim of this thesis is to find the new trends starting with the water management and shaping urban form in different implementation scales. In other words, re-structuring urban fabric with water sensitive urban design in three main implementation scales: building and lot level, street level and finally urban level. In urban level, watershed management is significant but in this study urban form will be considered. Watershed management detail will explain in appendix part. In total, all of them are connected with each other and this study claim that we can shape urban environment with water and it can be a part of daily life. In this context, research question is:

"How can water be used in re-structuring urban fabric and space with respect to water sensitive urban design?"

In accordance with the research question, sub questions are shown in following:

- What are the types of water in urban and natural context?
- What is the water cycle and elements of it?
- What is urban infrastructure and how can we categorize from past to today?
- What is conventional system (central), local system (decentralized) and differentiations?

- How can water be a design element for urban areas to sustain water source and be a part of daily life?

1.3. Methodology of the Research

Both qualitative and quantitative research data are used in this study as a mixed method. While a lot of scientific and numerical data contribute the thesis to prove existing situation in the world and to show the importance and causes of the problem, some qualitative data such as water cycle, infrastructure systems etc. are mentioned to define the structure and meaning of the study. Content analysis and categorizing the ideas are also in qualitative part. Selected examples from all over the world can be counted in mixed method because of the calculation and success of implementation. In addition to that both primary and secondary data are used. Primary data is used for calculating a case study as an example and secondary data consist of the majority of this study.

First of all, existing data are gathered from publications, books, articles, plans and international decisions, guidelines and acts. In the beginning of the study, usage of water from all over the world, demand and supply relations, distribution of water in urban areas, countries and world were investigated. Then, the definition of problem is formed according to observation and literature review that related with water. Some common problems were realized in all content. Population, urbanization and climate change are the major problems that were determined in all context and in the end the result is "water is scarce".

After categorizing the causes of the problems and explaining the existing situation of the system; definition of water cycle and elements of it, water types which include storm water, wastewater, surface water and groundwater and finally and the most importantly urban water infrastructure help to detect their relations in the discussion. To answer the problem statement, possible solutions are categorized according to the specific urban scales which are building scale, street scale and region scale in the adaptation of urban areas. With the implemented examples from different part of the world, re-structuring urban areas with water and relationships of these different types of implementation scales are clarified and illustrated as design guidelines. These guidelines are applicable for all urban areas.

Firstly, collection from Faculty of Architecture in METU for the building level implementations are explained in order to show how can water collect effectively in an existing structure and join to hydrologic cycle. Calculation and visualization were done by author from satellite view and there is a comparison between existing situation in other words "built environment" and vacant land. Secondly, an implemented plan and project which is New Orleans Urban Water Plan was analyzed and example of street scale were shown to explain the idea of water infrastructure in centralized or decentralized system. Apart from the conventional infrastructure system, blue corridors in other words linear open spaces were suggested as an alternative way in the decentralized system.

And finally, for the urban level solutions, two significant implemented project were analyzed. Qunli Stormwater Urban Wetland Park and Yanweizhou Park in Jinhua City were investigated. Data is gathered from plans and implementation projects that were published by official sites and architecture companies. All cases were selected according to the similar problematic situation in the water context. Excess surface flow, rainfall and flooding are the major reasons of that plans and projects.

After that, a hybrid water system which includes both centralized and decentralized system is suggested for re-structuring urban spaces for the completing and protecting hydrologic cycle and water demand-supply issue for people. Suggested design guidelines for the different scenarios in the context of rain water issue are illustrated. Comparison with the literature and outcomes as design guidelines are evaluated in the conclusion part.

1.4. Structure of the Study

This study consists of three main chapters differently from introduction and conclusion parts. It starts with definitions, background, causes and results related to water issue, then following with relationships between urban and water, then, examines solutions and options parallel with cases, and concludes with a discussion on water and re-structuring urban areas. The introduction part expresses the problem definition, aim of the study, methodology and follow of the study.

The first part of this study examines the idea of water management, relationships between urban, water and planning. Definitions, background information, causes and results of the water management are all discussed in this chapter. Cities and water cycle are also presented in the first part of the thesis. The water cycle and relationship with urban areas, elements of hydrologic cycle and impact of urbanization are the main parts of it. In addition to that, water types in urban area, in other words, how many different ways can water be found in the city will be explained in detail in this part.

The second part includes basically the urban water infrastructure and its function. There is some scientific information about population and water association, also some worldwide fact about water demand-supply and water scarcity. Historical development of water will be clarified briefly and ended with technologic development from past to present. In this part, the main infrastructure components will be grouped as water supply, drinking water, wastewater and finally storm water. Most importantly and finally, waste water and storm water relationships will be addressed under the topic of conventional (central) and local (decentralized) systems which is also the component of water management.

In the third part, re-structuring the urban fabric with water is the specific concern of the concept of hybrid system and principles of urban water management. With the "scaling" point of view, different kind of intervention methods under the urban design concept will be emphasized. Since worldwide examples and projects are analyzed; urban, street and building level of implementations and scenarios are shown in this part. Moreover, design guidelines which includes drawing, sketches and sections are demonstrated in this chapter.

And lastly, the conclusion part sums up the result of the research and overall findings. When we consider the earth's situation in terms of water scarcity, applicable design solutions at different scales and re-structuring urban fabric with water summarizes the situation in the last part of the thesis.

1.5. Brief overview: Nature will find its way

The destructive power of people against nature is increasing. With the use of technology, urbanization, population, development, etc., the use of resources is increasing in every region of the world. As the subject to be discussed in this study, as an output of human development, natural resources, especially water resources, are over-consumed, polluted and the natural cycle is broken for various reasons.

Although the problems are mainly divided into population, urbanization and climate change, the underlying issues are the current economic, political and social conditions. As long as the conditions continue in this way and the world's carrying capacity is full, the wear of the planet is inevitable. Bookchin (2014) said that the destructive power of this society has reached a level unparalleled in human history, and it has been used almost systematically as an insensitive destruction tool on the whole living world and its material foundations.

Over time, the deterioration of society's unity with nature, the loss of this perception in the scale of buildings, streets, neighborhoods and cities, the use of resources that exceed the carrying capacity, the excessive consumption of natural resources, especially water, and the relationship between the city and nature are seriously damaged. Bookchin (2014) explained this situation as follow:

"After the increasing weight of the city's against to the countryside and the ties to the land in the face of blood ties, the emergence of the city disrupted this relationship."

Considering the urban-nature relationship on the same subject, he said that the natural environment turns into a huge factory and the city becomes a market place. Thus, the existence of an order based on "consuming" in today's world is mentioned and clues are given on the human-nature relationship. The changing habits and the perspective of the people and the events taking place in the cities are not only there, so understanding of the rebalancing of the nature constitutes an important point. He explained that:

"It is no longer enough to talk about new techniques to protect and strengthen the natural environment; we must communally deal with the earth as a human collective that does not recognize humanity's view of life and private property barriers that have distorted nature since tribal societies." And he continued:

"From a broad perspective, thinking of ecology to a trade relationship does not save anything. It will not be effective to exchange most of the planet with a few small pieces of wild soil and small parks in a breathtaking world of concrete."

For this reason, planning and infrastructure systems which is considered with scaling factor should be developed with a new understanding of needs. As a design principle, the intervention forms determined on the building, street and regional scale should be handled with a new understanding starting from the human scale.

Continuing to consume the natural resources used under these population conditions and trying to provide the exchange relationship on the planet through discourse without putting into practice will not lead to a successful result. A new system that replaces the existing traditional system should be established in order to save and improve the rest of the society and to develop society on the least damaged environment.

In this study, it is clear that the traditional methods of water management do not respond to the current needs of the society, in addition to that it cannot be an answer to the needs or problems in the coming years. From the scale of the building to the scale of the region, determining the design principles which can be added to the existing system or creating a new system depend on the case is the basis of this study to create a balance between urban areas and nature, otherwise nature will find its way.

CHAPTER 2

SUSTAINING THE CIRCLE:URBAN WATER CYCLE AND HYDROLOGIC COMPONENTS

The earth does not belong to man; man belongs to earth.

Erlend Loe

This chapter focuses on the importance of water in urban areas. The water cycle in nature and urban has different path to complete the circle. How this path is differentiated with each other? The main aim of this part is to answer this question. The concept of hydrologic cycle or water cycle and its elements will be explained in detail. And then, impact of urbanization to the water resources and water cycle will be mentioned briefly. Its importance for human, earth and environment and role of the urban space are the essential perspective of the study.

Second part of this chapter is mainly focus on types of water which are located in an urban area. According to the scale, water can be differed from each other. So, three main scales which are came from literature view were determined and there are four types of water resources: *Storm water- The Key Issue: Storage, Wastewater and Pollution- The Key Issue: Reuse, Surface Water- The Key Issue: Maintenance, Groundwater-The Key Issue: Recharge*

2.1. Water Cycle

The water cycle defines the different kind of waters and relationships between each other. It also known as the hydrological cycle or water circulation. Hydrological cycle proceeds through the environment. Basically the water falls as rainwater, infiltrating to groundwater, moving toward streams, evaporating to cloud systems, and so on. When it moves through the environment, water can create natural systems. Most of the earth's surface is covered with water. It is stored in the oceans which is the biggest and largest water reservoirs, in the atmosphere, as well as on and under the land surface such as streams, lakes, ponds, ice caps and groundwater. The transport of water between these reservoirs in different phases plays a significant role in the Earth's natural systems. Balasubramanian and Nagaraju (2015) told that the duration of stay and storage of water in every reservoir varies due to varying geological, environmental and other conditions. This is called as the residence time of water. Water moves from one reservoir to the other. The sun's radiant energy plays a very significant role in this movement.

2.1.1. Concept of Hydrologic Cycle

Water changes to different states such as from liquid to solid, liquid to vapor, vapor to solid. There are some effective and regular ways to make this transformation like the sun's radiation, ability of the water to flow and several other properties of water.

Generally, the basic input to the world's water masses comes from precipitation. Rain or snow falls to the earth. Processes like infiltration moves the water down to the groundwater systems. Some amount of water flows towards the sea as runoff. The surface water which is collected in lakes, ponds and oceans evaporate into the atmosphere. Also, vegetation transfers the water which is collected from the soil to moisture. Evaporated and transported water come into the atmosphere as vapor. Finally, this water vapor creates the form of clouds and precipitation falls to the earth again. This infinite circulation of water is known as the hydrologic cycle. The hydrological cycle can be considered that it consists of two parts; regional and global cycle. Basically, their scales are different. On one hand regional hydrological cycle is a formation of water resources on an area of land, river basin etc. On the other hand, global hydrological cycle is related with global climate and other physical processes.

The major elements and processes of the hydrologic cycle are:

1. Temperature
2. Precipitation (rain, snow)
3. Evaporation
4. Infiltration process
5. Surface Runoff process
6. Topography

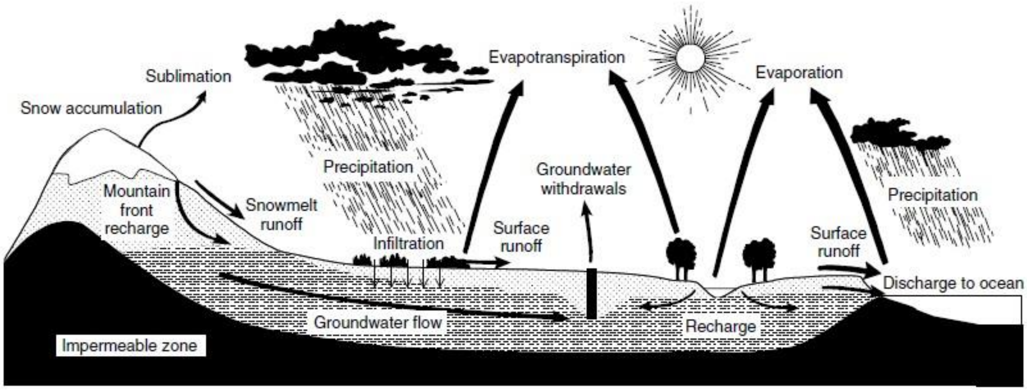

Figure 2.1. A diagram and component of the hydrologic cycle (Pagano & Sorooshian, 2002).

2.1.1.1. Basic Elements of the Water Cycle

Figure 2.1 shows the basic components of the hydrologic cycle in natural and urban areas. Each of them is briefly explained below.

Temperature: Generally, urban areas have high temperature around 4–7◦C than its surrounding. The high level of evaporation rates which is between 5–20% in urban areas is explained by these variations of temperature (Karamouz, Moridi and Nazif, 2010).

Precipitation: When there is a heavily rain in the cities, they became more vulnerable structure. Insufficient infrastructure and land use planning decisions can cause high level of urban water runoff (Karamouz, Moridi and Nazif, 2010).

Both temperature and precipitation elements can affect the cycle because urbanization causes the temperature rising and evaporation can be accelerated. Moreover, it influences the precipitation level in the urban context. To deal with this problem, open spaces and green areas should be increased in the city center to decrease temperature and infiltrate excess rainfall.

Evaporation: Because of the impervious surfaces, high level of activity and energy consumption in the city centers, temperature is high, relatedly evaporation is higher than its environment (Karamouz, Moridi and Nazif, 2010).

Infiltration& Runoff: Infiltration is the downward percolation of rainwater (or) snow melt water into the soil horizons. The downward movement of water happens in the topsoil layer, especially through the smaller pore spaces present in the soils (Balasubramanian and Nagaraju,2015)

Impervious areas such as asphalts, pavements, roof, parking lots etc. decrease infiltration rate in the urban areas. So, impervious materials which is used for covering the pavements, roads etc. create a high level runoff in urban areas (Karamouz, Moridi and Nazif, 2010).

2.1.2. Impact of Urbanization

In today's world, land development or urbanization disturbs these natural hydrological processes through some interventions such as vegetation clearance and soil modification, impervious surfaces etc. Because of the developed site, with impervious surfaces and pipe systems, water tends to bypass natural environment and change amount of precipitation, infiltration or evaporation levels.

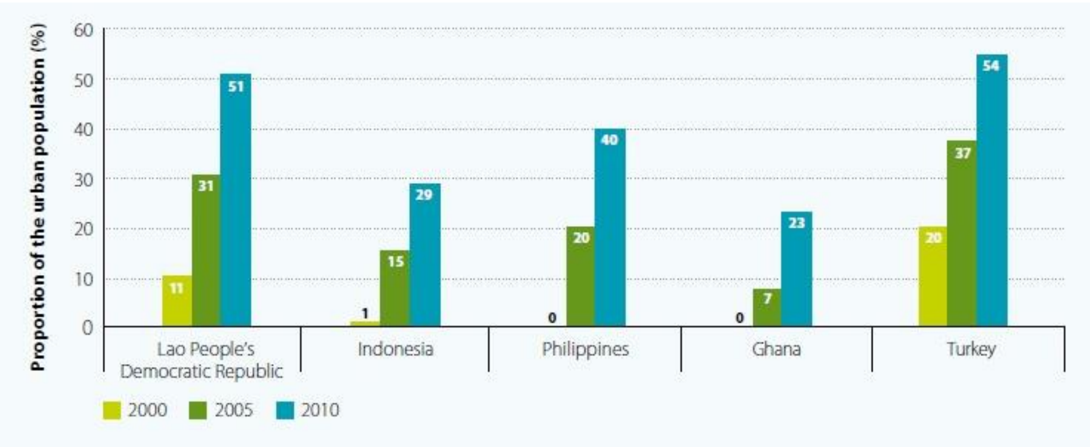

Figure 2.2. Increasing of bottled water as a main drinking water source in urban areas,2000-2012 (United Nations, 2015)

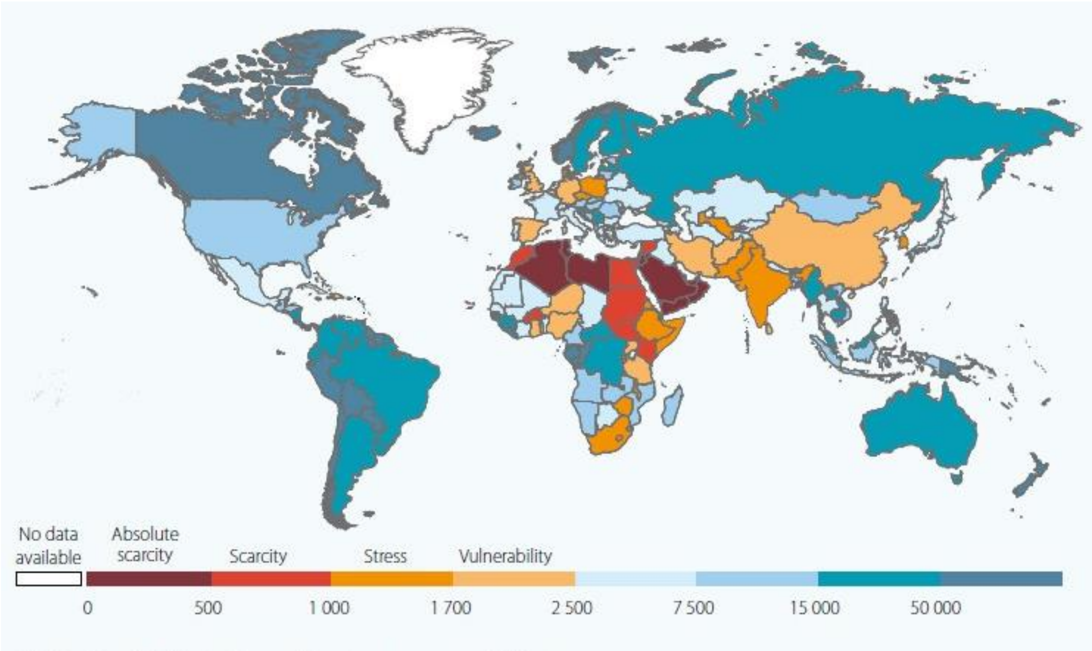

Figure 2.3. Total renewable water resources per capita(2013)
(United Nations World Water Development Report, 2015)

In many urban areas around the world, the physical and chemical effects on the water cycle resulted in negative and crucial depletion of water resources. Alterations of main drainage canals from natural to man-made systems has a significant and negative impact on runoff water. In addition to that, different negative impacts that is created by the consequences of urbanization can be thought short and long term results in the urban area and regional ecosystem.

Together with the urbanization, population also affects hydrological cycle. More people means that more water consume and much more usage of fresh water resources. As mentioned earlier, increasing population and increasing water demand is not linear. Apart from daily usage, many activities need water in urban areas. As mentioned earlier, according to the United Nations (2012), the ratio of people who live in cities in the world is about 50% now and 30% of all city dwellers live in squatter settlements. For the world to rehabilitate itself, the basic need is completing the water cycle successfully.

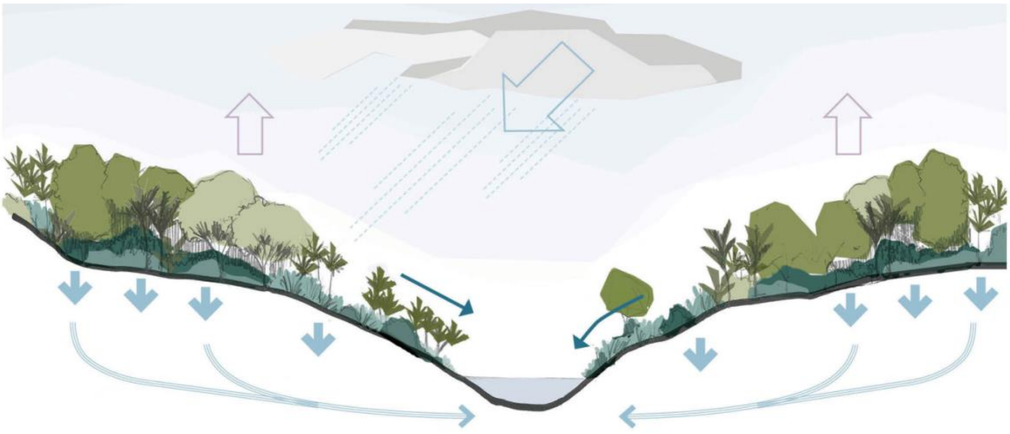

Figure 2.4. The water cycle - plant and soil relations (Auckland Council, 2015)

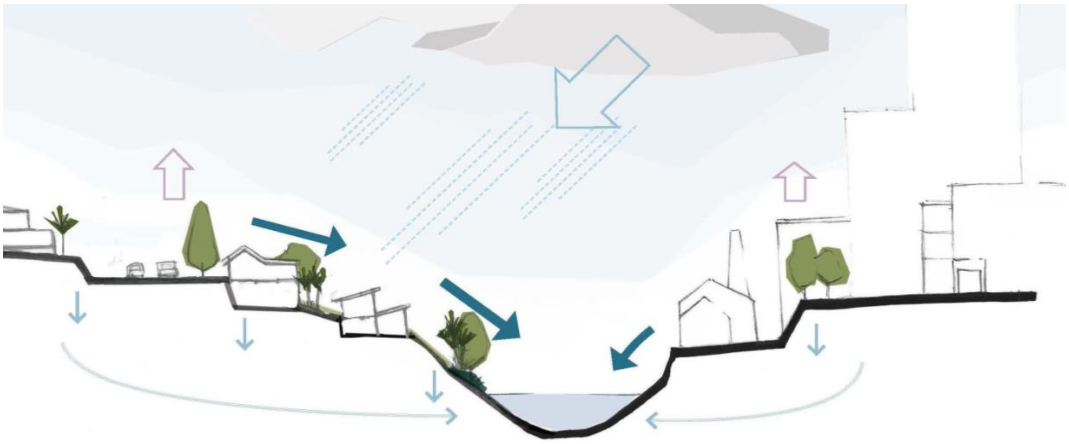

Figure 2.5. Low level of catchment areas, bypassing natural systems and flow directly to the water basin. (Auckland Council, 2015)

Figure 2.6. A Water sensitive design approach increased the interaction of natural process and urban areas and decrease the directs runoff (Auckland Council, 2015)

As previously mentioned, water cycle in the natural world depends on temperature, precipitation, infiltration, evaporation, runoff etc. It can be briefly summarized the changing situations with urbanization:

1- Surface Runoff: Changes in the amount of rainfall, evaporation, and infiltration in urban areas eventually ends up with characteristics of water cycle and associated with surface runoff. For instance, in most of urban areas, storm water collects on impervious surfaces like kerbs, pipes etc. Based on the research which is conducted by Paul and Meyer in 2001, when catchment area in other words imperviousness level is around 10-20%, storm water runoff increases two fold, 35-50% increase in impervious area will observe a threefold increase in storm water runoff; and if the imperviousness level is around 75-100%, there will be a 55% runoff which means fivefold increase. So, this runoff gathers in kerbs, pipes or sewage systems in the city and discharges to the nature in one point and at once. For this reason, the level of impervious areas in an urban area affects the hydrologic cycle (Figure 2.7).

2-Infiltration: Depending upon the impervious area, infiltration level is also affected. Like in the storm water runoff issue, if impervious areas in the city increase, infiltration rate will go down. That is to say, impervious surfaces and sewage systems diminish the ability of rain to infiltrate to the groundwater. This infiltration process is critical to sustain vegetation in the water cycle.

3-Pollution: When surface runoff discharges to the nature in one point and the water bypasses the infiltration process in the soil, pollution increase. Because, runoff water collects all garbage, waste material, plastics or leaves along the way. In addition to that, soil can clean up the water in its different layers until reaching groundwater. Instead of this process polluted water collects in the catchment areas such as river, lake or sea. In fact, according to the region, there can be seen flood problems. Another example of pollution is leakage from wastewater sewers to the soil and groundwater. It is the point sources that bring about pollution.

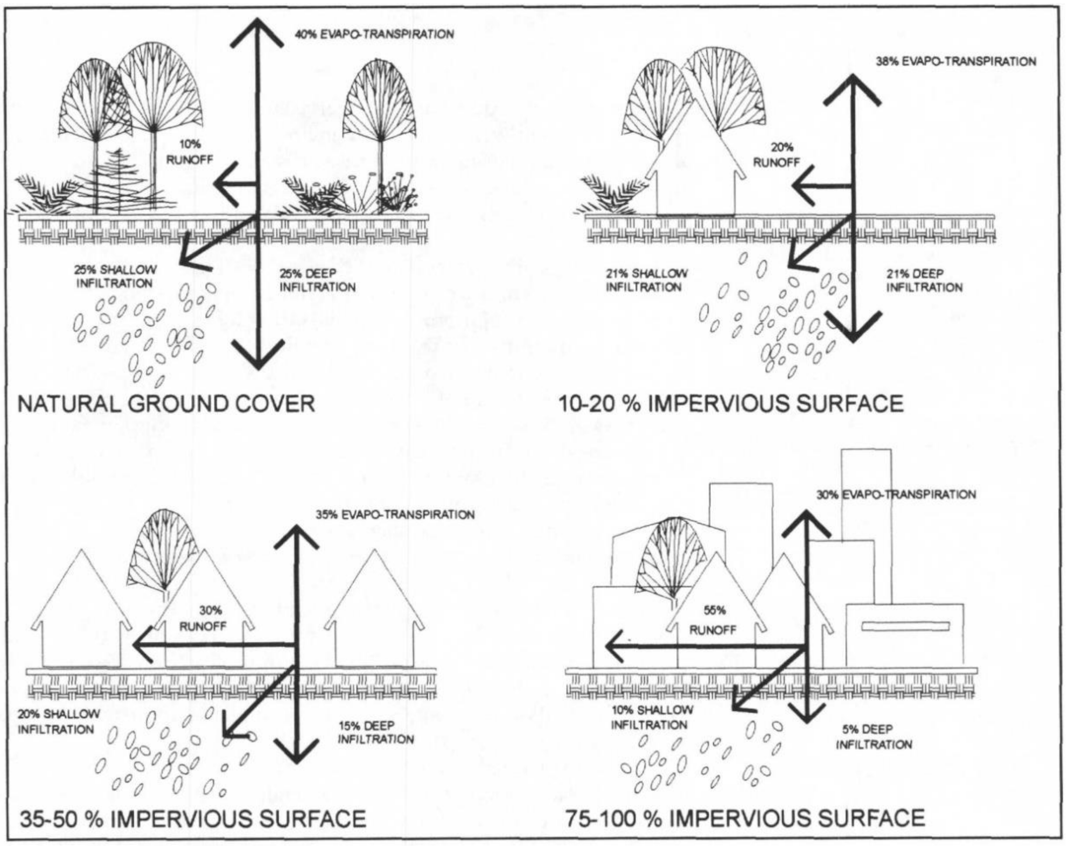

Figure 2.7. Relationship between hydrologic flows and impervious surface (Arnold & Gibbons 1996).

4-Groundwater: In general, groundwater is excessively used to meet the demand in the urban area and this consumption is rising day by day because of increasing population and activities. The urbanization process causes variation in groundwater level because of a decrease in recharge and increased withdrawal. According to the Todd & Mays (2005), there are three main conditions interrupt the underground hydrological balance and cause decreasing groundwater levels:

- “reduced groundwater recharge due to paved surface areas and storm sewers.
- increased groundwater discharge by pumping wells
- decreased groundwater recharge due to export of wastewater collected by sanitary sewers.”

2.2. Urban Space and Water Cycle

In recent years, some models related to water management and water cycle have been developed in the literature. According to Tjallingii (2012), as presented in Figure 2.8 closing the circle and cascading is one of the important approach. This scheme is called eco-device model which is displayed by Van Leeuwen and Van Wirdum. This model basically shows an ecosystem. The eco device model of Figure 2.9 demonstrates the relationships of different scales and flows. Cities are ecosystems that control flows by input and output. Moreover, they can collect a surplus of water and use this storage to prevent shortage. In this understanding closing the circle means that storing water and nutrients in this ecosystem. The main principle is an essential issue for fresh water and waste water. For urban environment the first priority is "cascading". It means "keeping water longer and keeping it clean".

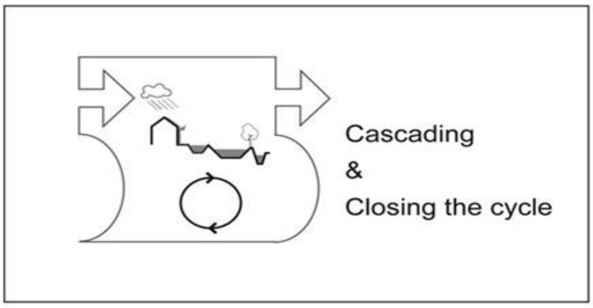

Figure 2.8. *Two guiding principles: Cascading and Closing the circle (Tjallingii,2012)*

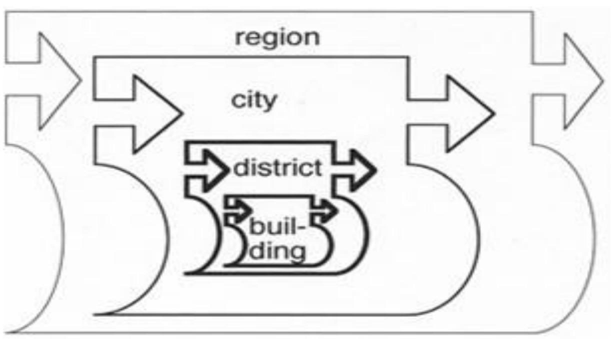

Figure 2.9. Ecosystems, from buildings to region (Tjallingii,2012)

In this debate, as illustrated in Figure 2.9, urban area consists of ecosystem levels. there is a reasonable attitude which starts with "bottom" and end up with "up". The main point of this issue is using the "*full potential of the local situation and local population*". In other words, the purpose of the processes is: there are existing local initiatives, so we should start to use this opportunity to create more sustainable and integrated urban environments in terms of water management. In urban planning proposals, this approach which contains the cascading and closing the circle principles is a guiding models at different levels, from a building level to the region.

To give some examples (Tjallingii,2012), different situations were examined in the context of bottom-up issue (Figure 2.10). First example is a single-family house having a small garden. According to that, daily water consumption of an average family with no special environmental commitment is around 135 liters per person per day. A reducing from 135 liters to 78 liters can be reached some combination of water saving such as reuse of grey water from bath and toilet flushing. In addition to that, rainwater is used for watering the garden. This model guides the design process of technical construction. Second example is in the street level which contains the two models: conventional street and a green space with surface water. Surface water contributes to the rainwater storages. Open channel or pipes carry runoff rainwater to the purifying vegetation that is located in the banks. It creates safety for people and decorative plants can survived easily and this zone create a healthy surface water and biodiversity and this path serves to the pedestrians and cyclist. Final and the third example is the district level. The infiltration system is beneficial in this situations of permeable soils. Generally, infiltration dykes or swales can develop permeability. Green structure in that area should contain a series of network between swales and these swales should transfer water from one point to another.

All examples can be implemented to different situations and locations in the world and the common goal of all of them is "cascading and closing the circle" for the big picture; water cycle or hydrologic cycle.

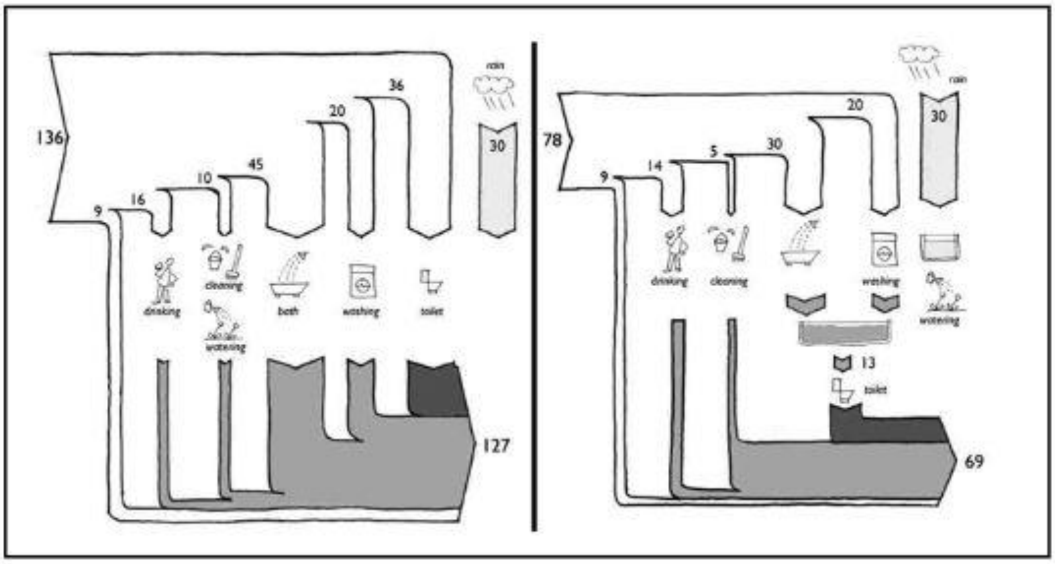

Figure 2.10. Guidelines for urban water planning (Tjallingii,2012)

2.3. Water in Urban Area

2.3.1. Storm water- The Key Issue: Storage

Rainfall is the primary water source on earth and urban areas have significant conditions for rainwater collection. Tjallingii (2012) indicated that "in an almost completely sealed urban landscape, up to 85% of the rainfall will become runoff ". The main reason is that evaporation and infiltration levels are very low. However, this situation highly depends on cities and locations. Effects of climate, closeness to the river, sea or mountains, density of building area or level of open spaces etc. create great differences between them. Variety of situations brings out different problems of opportunities.

So, how do urban areas react to the rain? Basically, the reaction is related with the paved surfaces or impermeable areas. With their high percentage of impervious areas, rainstorms are considered as a problem. According to the cities that means location or climate, annual rainfall can reach 10 m or 0.1 m and cities respond to this condition different way. In general, storm water is collected directly with pipes and sent to the sewage system. Conventional combined system is used by several cities around the world. To make it clear, this system is a large network of underground pipes that contain storm water, domestic wastewater, industrial wastewater in the same pipe. Systems quickly collect storm water runoff and drain it. However, in conventional system, the rain water is polluted by wastewaters and transferred to treatment plants or directly released to the nature. Additionally, it reduces groundwater infiltration. Thus, the level of groundwater decreases and available drinking water becomes limited. During heavy rain periods, there can be the risk of flooding. Sewage systems can intensify flood conditions.

While this is the general attitude towards rain water, more sustainable technologies and approaches are also gradually emerging. Cities are increasingly embracing design principles such as sustainable technology and rainwater harvesting. At the building level, rainwater cisterns that store rainwater for use as drinking water from the roof, an old tradition in many parts of the world. Also, rainwater is used for watering gardens and parks. Streets can transfer water to dykes or swales for the purpose of infiltration. In this way, thanks to storm water, water demand of green spaces is met and there is a positive effect in the part of water cycle discussion.

2.3.2. Wastewater and Pollution- The Key Issue: Reuse

The Cloaca Maxima which means the greatest sewer is famous for its first wastewater sewer in the city of Rome in the ancient time. Also, it is known that it brought clean water to the city and is one of the most well-known structure from the past. However, after almost 2000 years, industrialized cities from all over the world realize that sewer system and channels are the most crucial issue for urban areas and health condition. Today, still over 25% of the developing world's urban population needs sufficient sanitation (Tjallingii,2012).

When we compare with urban and natural systems, it shows an increase in surface flow, a significant decreasing in groundwater charge during precipitation and a lower evaporation rate. Several cities establish a sewage system that drains water to cope with surface runoff, water transfer or flooding. There are two types of sewage systems in general. First one is combined sewerage systems. It consists of one channel which is transfer both waste water and storm water together to the waste water treatment plants. After the cleaning process, it discharged to the aquifers like rivers. Second one is separate sewerage systems. In this system, storm water and wastewater are carried in two separate channels. In this case, although the storm water directly discharges to the natural water resources, the wastewater is transferred to the treatment plant. In the following chapter, these two systems will be explained in detail.

Sewage system is the central issue for most cities in today’s world. In the beginning, most sewers originate from rainwater sewers developed for use as sanitary sewers. First of all, they transferred storm water and wastewater to the river, sea, water resources. This transfer was done by one combined pipes that include wastewater and storm water. After that, sewage treatment plants were built, however because of the challenges of changing the existing structure, most of the historic cities still have the combined sewage system. In treatment plants, not only sewage system but also rainwater is cleaned with advanced treatment methods. This shows that facilities have to cope with high level of water and they are oversized and expensive. Actually, rainwater can be an obstacle for the treatment process because of having cleaner water. When there is a heavy rainfall, capacity of mixed or combined sewer systems can be exceeded and flooding occurs. The water that polluted by wastewaters with sewer sludge causes pollution of surface water. Source of pollution and in concern with health problems are significant problem in urban areas.

As a solution against these problems, collecting the overflow water in storage temporarily and using them later is the main issue. At first appearance, it makes sense the idea that disconnecting the storm water from sewer system. When it came to the implementation level, one option is constructing a new network of rain water. However, it is highly expensive way. More importantly, this method decreases the use of storm water directly near the source such as in building or gardens. The more sustainable approach is to guide rainwater to cisterns inside buildings or infiltration dykes or pools. This method is more cheap and applicable and is this way the water becomes more visible and design issue. Because, there is no chance to recycle and reuse the wastewater in the conventional system which means treatment plants. Home-based decentralized system is a significant alternative in this context. To give an example, Tjallingii (2012) mentioned that Western Europe separated rainwater from combined system to halve the amount of water that is sent to the treatment plants and its annual precipitation is about 800 mm. in this way, they want to meet the domestic water demand with separated storm water systems in a year.

2.3.3. Surface Water- The Key Issue: Maintenance

2.3.3.1. River Waters

Rivers are changeable sources. They can be a narrow form in summers, dry periods and then after the season of winter, when snow start to melt or after rainy days, they can reach the peak flow. If there is a heavy rain, flood can come to exist. According to the dynamics of river, natural basins or a delta can show up. These water bodies and formations create an environment for humans, animals and plants.

In the past, early settlements were established near the river by taking into consideration to water level and flood risk. They should be in the high enough to be safe condition but close to the drinking water. Also, these areas had more fertile lands for agriculture and had more livable spaces. As time progress, cities have developed and some water related problems emerged. Flood, water storage and water pollution are the most important ones. Against these problems, the dam projects started to suggest in general. In far from the cities, reservoirs and dams have some benefits such as big storage areas, however there is evaporation problem that is a significant one especially in the arid regions.

When we think about the irrigation issue, these dam projects are ahead of the game but water quality problems due to wastewater discharge and runoff from agricultural lands started to appear. This become a threat for humans and nature's health.

Today, urbanization with increased impermeable surfaces, deforestation, channels and related projects and climate change, all of them increase to risks for floods. The implementation is to create higher ditches to protect urban areas in most situation. However, higher dikes have negative effects on the system because they push the waterway into narrow channels. On the other side of the dike, there is a land subsidence because of drainage. So this case becomes riskier. The Netherlands and New Orleans faced with these situations already (Benton-Short and Short 2008).

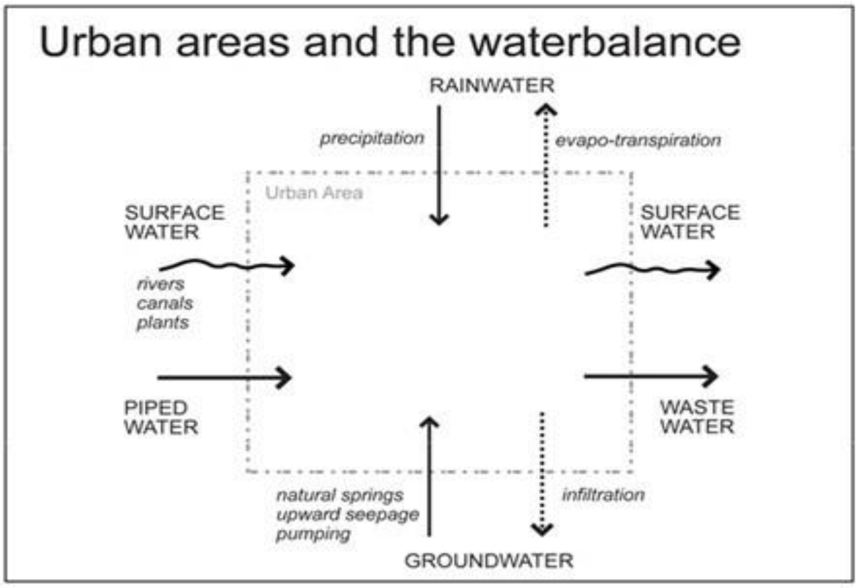

Figure 2.11. Urban areas and the water balance (Tjallingii,2012)

From this point, more sustainable and applicable approaches have developed in recent years. Instead of dam projects, smaller projects showed up within the urban areas. This kind of projects have less risks and they are more practicable. Traditional approach that have one strict implementation opinion like constructing a dam shifts to the idea of “space for water”. New Orleans, Holland and Bangladesh have comprehensive strategies for water because of the close relation with water in a very long time.

Several river valleys in the whole world have an opinion that floodplains should be cleaned from buildings and created spaces for water. Not all of them, but some countries that suffered from flood control have tried to adopt sustainable strategies. To give an example, the city of Curitiba which is located in Brazil, has a flood management program. The city was settled in a river basin which is named Upper Iguaçu, downtown of Curitiba has always been face with flood problems. The main aim of this project is create a space for flow. So correspondingly, the strategy is to create new bypass channel for the river. As a result, creating a space for water is more sustainable strategy for river management instead of building higher dikes (World Meteorological Organization, 2004).

2.3.3.2. Lakes and Wetlands

In addition to the river water, lakes and wetlands are other significant surface water supplies in the earth. Less than 3% of all water on the is fresh but only 0.014 % is readily available on the surface. Natural lakes of the world, on which millions of people rely on their tap and drinking water, involve more than 50% of this total. Lake Baikal and the Great Lakes in North America by themselves have more than 40% of the water contained in the earth's freshwater lakes (Dinar et al.,1995). This shows that amount and accessibility of fresh water is not same in everywhere. Some part of world population can reach freshwater easily. However, other part of it cannot. Water is limited.

The quality and amount of water in lakes and wetlands evolves from one place to another depending upon the location, climate, water demand etc. Despite lakes receives much more attention than wetlands in general, lately natural and artificial wetlands start to become critical issue in water management approach. According to the Wescoat, Gilbert and White (2003), it is estimated that almost 92% of 191 million km^2 of surface water in the earth consist of lakes and 60% of that volume is fresh water, with salt water accounting for the rest.

Wescoat, Gilbert and White also mentioned that (2003) the significant features of lakes in the earth are surface area and volume, landform, climate, water quality, plant and animal life, human use of land, human use of water, human changes in natural systems. Each of them has a different effect. According to Dinar et al. (1995), the main problem of lakes is that they do not have a “self-cleaning” ability unlike rivers. In other words, they have more fragile ecosystem than rivers because of the lack of water flow. So, they easily accumulate pollution. This situation makes them more vulnerable and require much more attentions.

In urban areas, lakes serve as flood control features and waste disposal sites. They are important elements of supplying foods, hydropower generation, tourism, transportation, a source of drinking and irrigation water. In the hydrologic cycle, they have several influence in terms of collecting storm water runoff, evaporation and biological diversity, so they have a vital role in the process of closing the circle.

The water comes from lakes cannot be used by humans depending on some criteria and also, it is unsuitable even for fishing. On the contrary, some lakes are used by human for irrigation purpose, transportation, fishing, recreation and domestic and industrial consumption. Depending on needs, some lakes are changed or destructed severely but a few of them are preserved its natural condition. Also, this situation is valid for wetlands. For example, about 100,000 lakes exist in the United States, excluding Alaska. These water bodies can provide significant services for urban and rural populations. Unlikely, comparison to the large lakes, small ones are more sensitive to changes. They are affected by external factors easily such as pollution and unhealthy development around them (Dinar et al.,1995).

The paper that is written by Dinar et al., in 1995 argues that the diversity of lake management practices in the world in the 1990s was reviewed by the World Bank in a policy statement. Institutional processes should be improved to ecosystem based, comprehensive and stakeholder driven strategies to maintain the resources. Complicated problems can be solved such a comprehensive approach with the help of the World Bank, UN agencies and other international support organizations.

When we come to the wetland areas, there is a historical perspective on them and noticeable changes in human perspectives in terms of their ecological value. Strabo who is the Greek geographer mentions Roman drainage of wetlands (Strabo,1917), while Darby rebuilds the drainage of the wetlands in the UK from medieval to modern times (Darby,1956). Although most counties and regions can take care of wetland environments, from the lower Mississippi and upper Amazon floodplains to the Shatt al-Arab and Bengal deltas, negative attitudes towards these environments continued until the twentieth century in the USA (Prince,1997).

In the Convention of Wetlands was signed as an intergovernmental agreement in Ramsar, İran in 1971. In this agreement, wetlands were determined as "*areas of marsh, fen, wetland or water, whether natural or artificial, permanent or salt, including areas of marine water the depth of which at low tide does not exceed six meters*". It was the first comprehensive action to determine types of wetland. There is no certain estimation about overall wetlands in the earth. However, the World Conservation Monitoring Center estimated that the total amount of wetlands is around 5.7 million km^2. 30% of them are bogs, 26 % are fens, 20% swamps, and 15% floodplains (Wescoat et al.,2003).

According to the World Bank Wetland Management Notes which is published in 2003, there is a classification of wetland types in keeping with Ramsar Convention and scientific literature. They can be separated into three major types as inland, marine (coastal) and artificial or human-made wetlands. All wetlands in the earth cover almost 8.6 million km^2 or 6.4 % of the world's land surface consists of wetland areas (OECD, 1996)

Beside human activities like fishery and economic benefits, wetlands contribute to the balance of hydrological features and natural services. Depending on the specific conditions of each individual wetland, they are huge storage of water supply and regulate the water table through maintenance and refill the surface water and also regulate the groundwater supply. Especially this situation is critical in arid and semi-arid regions where suffer from serious water problems. These areas are also storage of flood waters when the water reaches peak levels. In addition to that, decontamination function of wetlands is used for cleaning major pollutants such as organic and chemical sediments. With the help of the vegetation and organisms that live in this habitat, cleanification process is done by natural way.

2.3.4. Groundwater-The Key Issue: Recharge

When the rain falls to the surface, some of it flows to the rivers or lakes, and some is absorbed by the soil. Some part of the absorbed water is used by vegetation, other part of it returns to the air and even serious level of it infiltrate into the ground. Thus, the level of water table under the ground decreases. Groundwater is predominantly reloading by rain water, snowmelt or some surface water such as lakes and rivers.

Groundwater can be found almost everywhere depending upon the several factors such as quality of the area, the level of annual rainfall and recharge rates. Moreover, water table can be found in different levels like deep or shallow. Heavy rains have a potential to rise water table and increase recharge. On the contrary, dry weather can bring on the water table to fall. In addition to these, the quality of groundwater is generally in good condition because the water is collected in the layers under the surface. In the infiltration process, water that have contaminants is cleaned from surface to the underground. According to Shiklomonov (2000) approximately one-half of the stored groundwater is estimated to be at depths of less than 200m and the rest of them is estimated up to 2000 m.

Why is groundwater so important? Because according to the International Groundwater Resources Assessment Centre (Figure 2.12), almost 30% of world's fresh water is depended on groundwater resources. Reminder of it (70%) consist of mainly ice and snows from mountains (69&) and 1% of them is river and lakes. It is the major source for irrigation and food sector. Globally, irrigation explains more than 70% of total water withdrawal and 90% of consumptive water uses. And finally, 43% of the total irrigation water use comes from groundwater. As we understand, excessive usage of groundwater is decreasing the fresh water supply to a large extend.

Ministerial conference, Kyoto 2003 "*Whilst groundwater storage is vast (over 99% of fresh water reserves), its rate of replenishment is finite and mainly limited to the* *shallower aquifers, whose quality can also be seriously (and even irreversibly) degraded. Excessive resource development, uncontrolled urban and industrial discharges, and agricultural intensification are causing increasingly widespread degradation of aquifers*"

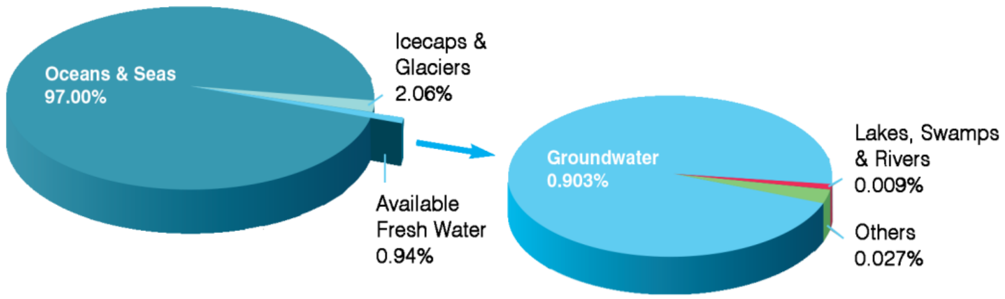

Figure 2.12. Earth's Water Distribution (International Groundwater Resources Assessment Centre, July 2019)

The most important issue regarding the use of groundwater is to consider balance between water withdrawal and over-exploitation of the aquifer level and to prevent pollution of this important source because in the big picture this situation depends on water cycle that is mentioned earlier. In other words, water resources rely on natural hydrologic cycle. To give an example, Russian hydrologists believed that approximately 29% of the world's freshwater is collected at any one time in aquifers. About 33% of that is on the Asian continent and 23% in Africa, 18% in North America, 13% in South America, 6% Europe and 5% in Australia (Shiklomonov,2000).

Not only over-exploitation but also pollution is another important problem in groundwater issue. Water quality can be changed depending upon the contaminations which is came from domestic and industrial wastewaters. Contamination can occur waste discharging directly through wells or through filtration of surface materials into ground waters. Irrigation can be thought as the largest volume of such pollution in many aquifers accessible to surface drainage.

2.4. Summary and Conclusion

In this chapter, urban water cycle and its components has been explained in detail to understanding the importance of water for urban. Major question of this part is: "*How urban areas affect the natural cycle and what is the differences between natural hydrologic system and urban water system?*". Especially, components of urban water cycle are similar to natural hydrological system. However, urban system includes specific intervention forms and decisions that require more attention. These questions help us to reveal the problematic parts in the big picture. So, negative effects should be considered for future plans and decisions in the urban design issue. The outcome of this part of the study can be summarized that it is important to understand the elements of water cycle and relationships among them in order to closing the natural water cycle successfully and sustain fresh water from region to building.

Sources	Types of Water:	The Key Issue:	Depending on:	Problem:
Rain	Storm water	Storage	Location and climate	Flood, overflow, street runoff
Used water	Wastewater	Reuse	Habit of use, Economical activity like industry	Pollution of fresh water supply
Lakes, Rivers	Surface water	Maintenance	Natural resources	Drought, polution, habitat destruction
Leakage	Ground water	Recharge	Natural resources	Excessive depletion Pollution of fresh water supply

Figure 2.13. Sources, Types of water, The key issue and problems

In the following chapters, management of urban water infrastructure which has mainly four groups: water supply, drinking water, wastewater and storm water drainage system will be defined. Related with the hydrological cycle, infrastructure system in an urban area is a significant part because the natural flow of water in nature is transformed into infrastructure systems in urban areas.

CHAPTER 3

ROOM FOR THE WATER:
URBAN WATER INFRASTRUCTURE

"The history of men is reflected in the history of sewers"
Victor Hugo (1892) Les Miserables

This chapter focuses on the consequence of urban and water relationship. This relationship or overlapping creates the concept of infrastructure. The definition of infrastructure will be examined in this part in detail because main problems that are mentioned previous chapter depends on basically urban water infrastructure. Current status of the infrastructure in today's world and problematic situation will be exemplified with specific numerical data from the significant report and studies that are accepted in worldwide.

This part starts with the definition and historical development of the infrastructure, not in detail but specifying the important points in history and explaining milestone events. After that, urban water infrastructure components divided into four groups: water supply, drinking water, wastewater and finally storm water. Especially, storm water and wastewater will be underlined in the urban context. For this reason, as the next step, centralized (conventional) and decentralized (local) infrastructure system will be clarified and compared. In the urban design concept, how these two systems affect the urban environment will be discussed. After all, the main purpose of this chapter is to express that in the current problematic situation, conventional system is not sufficient and it cannot meet the needs, so a new concept will be suggested as a solution that works with urban design guidelines.

3.1. Urban Water Infrastructure

In order to preserve the significant role of water in society, we should understand the water ecosystems in urban areas together with the tools of water infrastructure which are very important for the nature and its balance. For both water supply and sustain the existence of water in urban areas and integrated urban water management, developing a necessary infrastructure is the key point.

Management of water can be provided by some instruments which are referred to urban water infrastructure. It contains supply of water, distribution, collection and treatment. Also, taking into consideration the urban areas, all water cycle issue, resources and components which are mentioned previous chapter end up with same result. Dealing with water, creating a balance between demand and supply and protecting the natural hydrologic cycle are highly complex topics. In one hand, transfer and distribution of water to the users are main function of urban water infrastructure. On the other hand, collection of sewage and wastewater and transferring it to the treatment plants are the another function of this system. With the development of technologies, water infrastructure is also improved. Especially in last 30 years, environmental outcomes of water infrastructure gain importance instead of social and economic outcomes which is thought previously on water infrastructure.

In the urban areas, the intense changes in the hydrological system was governed by the construction of an urban infrastructure for several years. It started with water supply channel (aqueducts), after that rainwater and sewage collection showed up, and finally wastewater treatment plants became an element of the infrastructure system. Today it turns into interaction of the hydrologic cycle in urban areas. So, this system influences the water cycle in an urban area. For example, according to Marsalek et al., introducing of drinking fresh water affects the urban water budget commonly. Moreover, excessive storm water runoff should be controlled in urban areas with some source control methods. However, it is made real by increasing carrying capacity of natural channels or building new underground sewer systems. This implementation contributes to faster hydrological response of urban catchments and rises storm water flows. In the end, more water is introduced into urban areas. This means that more water is transferred to the wastewater which have to stored and purify (2006).

The interaction of these components of urban water system like resource, sewage, rainwater, treatment etc. are generally disregarded or underestimated. However, their negative effects have been started to show up in the environment, ecosystems or in this context urban water cycle. With the developing technology and excessive consuming of urban water resources give rise to an alternative and sustainable urban water system as an alternative to this central system. Particularly, sustainable system keeps some significant basic goals (Marsalek et al.,2006):

- provide a fresh and healthy drinking water to all people,
- ensure the wastewater collection system to protect environment and people from unhealthy conditions
- reuse and recycling of water for different purposes like irrigation or watering gardens.

In parallel with these goal, Sustainable Development Goals aims at similar solutions and results in 2018. SDG Reports (2018) mentioned that in 2015, drinking water supplies should be required for the 29 % of the whole world and 61% of them did not have safely managed sanitation services. Also, 27% of the population in less developed countries had “basic hand washing facilities”.

Consequently, urban areas will suffer from different challenges in the upcoming years. Urban water management emphases the provision of urban water services which include water infrastructures. In the management part, urban water services and related infrastructure that change the elements of the water cycle in urban areas should be constructed. In general, urban water infrastructures can consist of three major components. These are water supply, sewerage and storm water drainage. So, when we deal with the urban and natural water cycle, components of the urban water infrastructure and their relationships can be count as a particular concern.

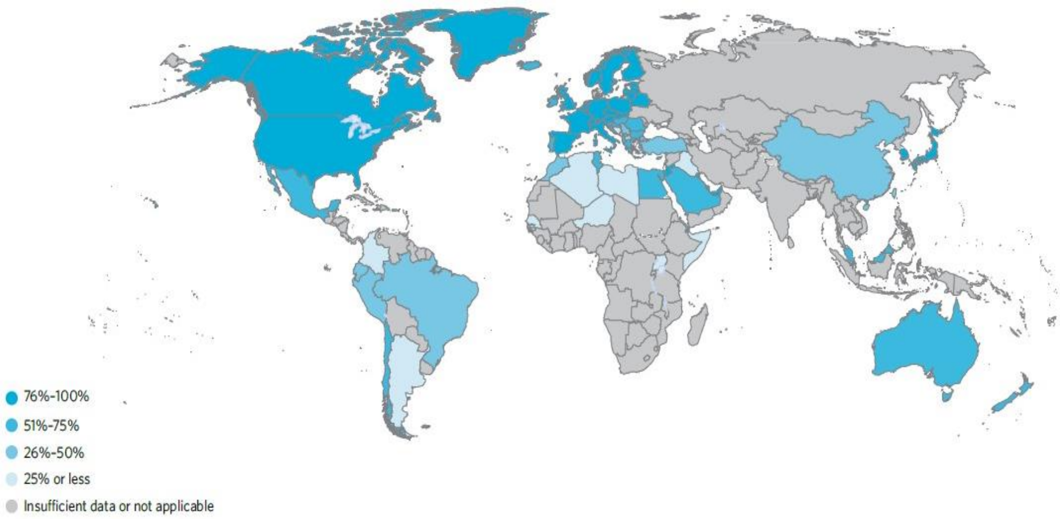

Figure 3.1. Percentage of safely managed and basic drinking water, sanitation and hygiene services in 2015 (The United Nations,2018)

According to the Sustainable Development Goals Report which is published by United Nation in 2018; future water scarcity all over the world has a strong probability when we look at the scientific researches but Northern Africa and Western Asia will be the most affected. 22 countries mostly located in this region, water stress level is more than 70%. This number shows the future water scarcity.

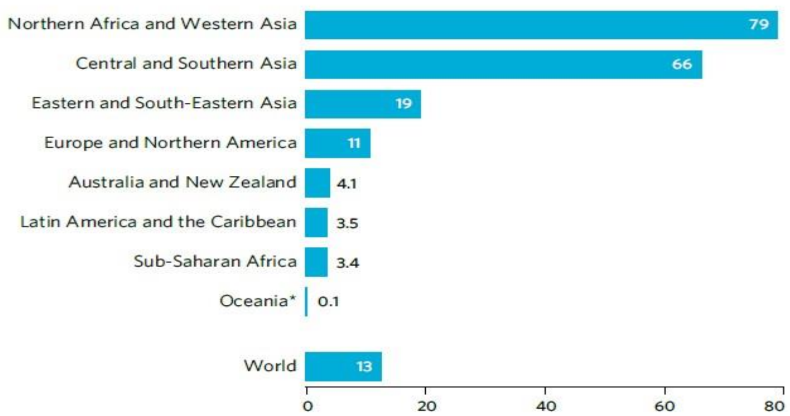

Figure 3.2. Percentage of water stress around 2014 (The United Nations,2018)

The report “Water and sanitation in the world’s cities – local action for global goals” (UN-HABITAT, 2003) shows some cities which have huge population in the worldwide in 2000 in Table 3.1. As we can see in there, large variation in water use per capita from 130 to 570 L/capita/day can change and significant water losses is about 15-56%. The main reason is related with the level of development in counties and habit of water usage. Finally,7 cities among them listed below were in developing countries.

Table 3.1. The world’s 10 most populated cities in water supply (2000 data) (UN-HABITAT, 2003)

City and Country	Inhabitants in 2000 (million)	Water supply (m^3/s)	Water supply (L/captia/day)
Tokyo, Japan	27.9	81	250
Mexico City, Mexico	19.7	69	331
Sao Paulo, Brazil	17.8	63	306
Shanghai, China	17.2	81	407
New York, USA	16.4	57	300
Mumbai, India	16.4	25	130
Beijing, China	14.2	39	239
Lagos, Nigeria	13.4	(missing data)	(missing data)
Los Angeles, USA	13.1	88	570
Calcutta, India	12.7	25	171

Water losses were reported just for 5 cities, ranging from 15 to 56%.

3.2. Historical Development

The first intervention to the water was for irrigation related with agricultural needs in the agricultural revolution. Irrigation canals were the major point of this effort. However, the urban water systems were the next step of water concern issue. Some important issues in the improvement of modern water systems will be analyzed.

Technology for water issue for the first city centers is based on Mohenjo- Daro, was the first city center that had significant technology for water issue, was one of the major urban centers of Bronze Age and Indus civilization. It was an intentionally planned urban settlement which is established around 2450 B.C. (Jansen,1989). These settlement appearances in a semi-arid environment. For this reason, it has 700 wells which meet the needs of whole city. This means that one out of every three house has a well. In addition to this, water consumption has an important role in this planned city. Almost every house in this settlement had a bath and the Great Bath of Mohenjo-Daro which has an area of 1.700 m^2, had a pool in the center. Also, the sewage system was built along the streets. So, the Indus civilization had improved bathrooms in every house and sewer system in every street of the city.

In the Early Greeks, there were advanced wells, cisterns fountains, water distribution. In Greece, there was already a distribution system with bronze pipes for drinking water before 3000 years ago than today. The Minoan settlements also, managed rainfall collection and cisterns. Cisterns were used to store runoff from roofs and impervious surfaces and these cisterns was functional to the modern times. Aqueducts which transport water from highlands to the city center were diverged at the entrance of the city and their purposes was feeding cisterns and public fountains (Jansen,1989).

Mays, Koutsoyiannis and Angelakis (2007) told that urban hydraulic systems technologies developed during the Greek civilization and reach an advanced point at the Hellenistic time. The Romans had high engineering technologies in that time and were able to adopt these technologies on large scale and different kind of projects. This progress of science and technology related to water issue reversed when Roman Empire fell. In the time of the Dark Ages, water sanitation system and water supply concern and public health started to get worse in Europe. All wastewater and human and animal wastes thrown out the streets. So, health condition in Europe were in a bad condition. On the contrary, during the same time, there was a highly developed civilization in a lot of Byzantine sites in Greece and Asia. Also, high levels of personal hygiene because of the effect of religion was obligated in Islamic region. By the 19^{th} century, Europe achieved again good condition and high level of water supply and waste water standards.

Halliday's 2001 study (as cited in Baker,2009) explained that in water system in London depended on Roman period in general. People generally carried water from distribution points, however, people who were in high class and in wealth have some employees who carried water from distribution point to houses. With the early 19th century, London and other cities improved their water systems but generally these improvements were based on rainwater collection systems, not sewerage system. Waste water was directly to the discharge sewage in latrines in that period. In 1810, the city of London had almost 200,000 latrines. In any case, the idea of building sewage system with underground channels was not used until the mid-19th century. In 1840s, there were some attempts related with storm sewer and sewage system like forming the Metropolitan Commission of Sewers in 1848, which collected reports and plans for the problems. After a while, Thames River was polluted because of discharges sewage. In 1958, government provide some funding for a huge renovation of its sewer system, after that health problems that caused by pollution were disappeared.

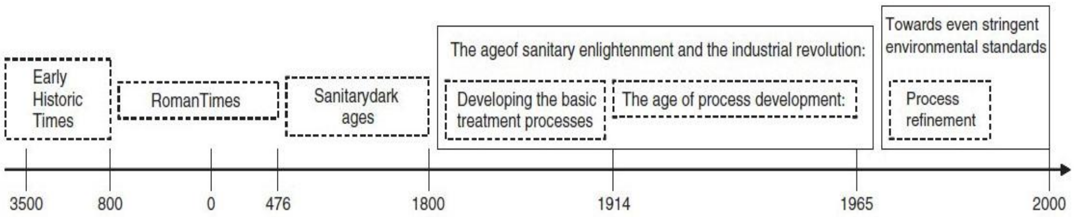

Figure 3.3. Evaluation of Sanitation (Lofrano& Brown, 2010)

On the other hand, construction of water system in the United States came to exist late. The main reason is that supply of water in most households relied upon local wells, rain cisterns and small water institution. The first urban water system in the United States was built in Philadelphia in 1802, but there were only 598 municipal water systems in 1880. In addition to that, almost all large U.S. cities throw their sewage water into existing storm sewers instead of building a separate “sanitary” sewers. So, some U.S. city didn’t have improved and separate water infrastructure systems by 1850. But the major transformation started to show up after mid-19th century. In 1940, only 57 % of United States’ cities had sewage treatment. Other part of settlements continued to discharged untreated wastewater for many years. Today, almost all major cities in the United States have developed water supply systems that often run by the public (Tarr,1996 as cited in Baker,2009).

Some significant laws such as Clean Water Act that is legislated in 1972, European Union Drinking Water Directive in 1998 and then World Health Organization in 2004 affected the Water treatment and regulation issue. Clean Water Act especially had an important effect on water quality standards for water resources and waste waters with the help of creating treatment standards. The main idea is that when urban runoff management come to a sufficient and good condition, pollution in the urban water system can be decreased.

3.3. The Main Components of Urban Water Infrastructure

In traditional urban water supply infrastructure issue, consideration of source water characteristics is generally ignored. Treatment and distribution comes before. However, when the natural waters interact with urban water infrastructure, this fresh water are affected by human decisions such as; land use decisions or external drivers like climate change and effects of it but negative effects of this situation cannot be recognized in short term depending on the level of interaction and urban areas. They can show up in long term.

The major aim of urban infrastructure is providing water to the settlements and evacuating wastewater and storm water. In this providing and evacuating part, there are some critical infrastructure components. All of them will be explained in the following pages in detail in the context of urban dynamics and natural water cycle. These components can be mainly divided into four part. These are:

- water supply,
- drinking water,
- wastewater
- storm water

3.3.1. Water Supply

Urban areas are highly complex and dynamic formations. Humans can change water quality and quantity rapidly intentionally or unintentionally. However, when one little intervention can affect the whole system especially in the context of water supply issue. In the end, all components of the hydrologic cycle are influenced by human activities. Basically, they need water for agricultural, industry and residential uses. Urban use large amount of source already and industries and agriculture sector as an important elements of urban areas also use large amount of water which is usually separate from treated water (Baker,2009).

Marsalek et.al.(2006) explained that the municipal water involves residential usage like apartments and houses, institutional usage such as hospitals and schools, industrial usage and other water uses like watering green areas. The source of this kind of usage is generally met by surface and groundwater sources. In addition to that, washing, cooking, bath, toilet flushing, gardening etc. cover domestic water usage. Public services water usage contains watering of open spaces, street cleaning, health services, commercial buildings, government offices and educational institutions such as schools, universities. Baker (2009) say that generally, average water consumption of a person in USA society is approximately 90 to 320 gallons (340 liters to 1210 liter) of treated potable water that drinking and cooking water, toilets, bathing and industries.

3.3.1.1. Conventional and Non-Conventional Water Resources

Water is not distributed equally in the world and also quality of it can change depend upon the location. So, the quality and distribution of water isn’t parallel with population. For example, 60% of the world’s population is living in Asia but they have only 36% of the world’s freshwater (Zimmerman et al., 2008). As the population increases, urbanization is increasing. In this point, inequality of water shows up. Parallel with inequality, water supply infrastructure, its sustainability and water availability are also affected by rising population. Water is also affected by alteration of global climate. It also affects that changes in water temperatures and extreme events will affect the water quality with changes in pollutant loads and natural system transformations.

The gap between the water needs of the society and the ability to meet these needs is constantly expanding. Water supply is the key point of this gap. Water comes from groundwater or surface water such as lakes, rivers which are called untreated water or raw water to the urban area. First, the water is usually transported to a water treatment plant, after treatment, it is distributed by water channel network in cities.

Westerhoff and Crittenden (2009) defines water supply issue in below:

"Rivers, lakes, reservoirs, and groundwater all can store and serve as water supply sources for urban uses. There are roughly 55,000 public water supply systems in the USA. Approximately 64% of public water supplies are surface waters and 36% are ground waters."

After all, water supply issue is divided into two categories. These are:

- Conventional (classic) methods; large-scale
- Non-conventional methods;

Dam reservoirs, well and water channels can be counted as one of the conventional methods of water supply in large-scale facilities. These large water storage areas are usually located far from cities and near rivers to fill the reservoirs. They have also "gates" at different depths to be able to discharge of water into the river when there is a need. Dam reservoirs are the most important source of water in a lot of cities around the world and they are the most common ones for years. Karamouz et.al. (2010), explain that he world has around 55.000 large dams and almost 50 % of them are used only for irrigation purposes and some of them (one-third of all) are used for multifunctional such as both irrigation and electricity production. On the other hand, water supply storage should not be considered as just dams that have huge and high capacity storage. When we think about the small scale, storage tanks can be used for water supply for small scale settlements, neighborhood or even building scale.

When it comes to groundwater, it has a lot of advantages for the water supply point. The first one is that there is no need to large construction like in the dam reservoirs. Secondly, in the drought period, water comes from underground can be pumped easily when compared to the large above ground reservoirs. Finally, water quality in groundwater is better condition because of infiltration process of surface water and storm water by comparison with dams. For wells, earth is dug throughout the ground with lots of meters to access the water. Westerhoff and Crittenden (2009) mention that surface water or treated wastewater is recharged intentionally into ground in many cities especially in arid regions. The reason is increasing future groundwater level to create sufficient water supply in long term and sustain the whole system.

Non-conventional methods of water supply basically involve desalination, wastewater reuse and rainwater harvesting. Essentially, it based on water reclamation and reuse. In this way, better quality water can be available without consuming existing and limited water aquifers.

Desalination: Especially in the arid region, seawater desalination is being used continually to deal with water scarcity. Ghaffer (2006) described that "*desalination is a water treatment process that removes salts from saline water using one of different technologies to produce water that is low in total dissolved solids.*" Desalination of seawater is being practiced in arid region such as Egypt in Mediterranean coast and around the Red sea. Potable water for urban centers is provided by these desalination plants. For example, more than 92.5 million cubic meters from fresh water per day is generated into the desalination plants which is the total number is 19.372 in the world (IDA, 2017).

Wastewater Reuse: Reuse means that the same water is used repeatedly after the treatment processes for its future use. After the agricultural and urban usage, water quality can decrease and this affect the management system because of direct discharge. Maximum use of wastewater should be made before discharge. Disposal should be done in such a way that the water quality of the river basin or other water sources will be maintained and the agricultural developments will not be put at risk. So, properly treated water can be used for irrigation, gardening, recreation, industry, the recharging of underground aquifers and in recent years recycled wastewater have been used for gardening or flushing in many cities.

Rainwater Harvesting: Rainwater harvesting is a non-conventional method but it is the most common methods for water supply in the world especially for the small settlements, islands, areas where have relatively high annual rainfall and also areas which are located in arid region. Moreover, in highly developed urban areas, the usage of runoff water for other purposes, gardening or irrigation is important issue for supporting environmental sustainability. Because in the urban areas roofs are the most widespread collecting surfaces. They diminish urban runoff and its impacts.

Today, Australia and India commonly use this system. Many rural settlements of Australia that are not linked to central water supply system because they are generally met their needs from wells. In order to reuse rain water in the garden is a simple system and sufficient. Many countries started to support this system because environmental risk is low, and drinking water can be saved if rainwater which is followed for water quality is used for toilet flushing or in the laundry, kitchen or bathroom. (Karamouz et al., 2003).

In designing rainfall harvesting systems the following issues should be considered (Marsalek et al.,2006).

- **Quantity issues:** The main problem of the rainwater collection systems is insufficient storage tanks or cisterns. There can be leakages from tanks because of the design fault, materials or construction. All of them create difficulty in the rainwater collection system. In order to meet the needs, sufficient water is essential for human. For the sustainability of society, there should be sufficient and available quantity of water. Current daily demands and estimated consumptions for the future are the most significant concerns in urban areas. In the planning process the amount of water supply and storage facilities should be taken into consideration and calculated according to the estimated maximum daily demand.

- **Quality issues:** Generally, the quality of rainwater all over the world is in good condition. However, in the collection part, some problems can arise. If inconvenient construction materials are used for tanks, cisterns, pipes or catchment surfaces, there can be physical, chemical, and biological pollutions. When there is a pollution concern, collected water can be used for gardening instead of drinking or potable water. There are a lot of documents that designate the quality water such as "*Safe Drinking Water Act in 1974*", amended in 1986 and 1999, is formed by U.S Environmental Protection Agency. These are basic guideline for primary and secondary standards of water

3.3.2. Drinking Water

On the earth, the total quantity of usable freshwater is only 1% of the total quantity of water and it is not evenly distributed around the world (Vanbrisen et al., 2013). This creates a serious problem on availability of drinking water supply in the world. Some nations are considered water rich and some are water stressed and others struggle somewhere in between. Relatedly, it has been estimated that when population of the earth exceeds nine billion people in 2050, lots of people could cannot meet basic daily needs because of insufficient drinking water (Vanbrisen et al., 2013).

According to World Health Organization report; Progress on Drinking Water, Sanitation and Hygiene which is published in 2017, 71 % of the global population that is approximately ion people can access safely managed drinking water service. Secondly, 35% of total population which means 96 countries has safely managed drinking water and finally, 1.9 billion people who live in rural areas can use fresh drinking water. As can be seen in the figure below (Figure 3.3) in 2015, 7 out of 10 people can access safely managed drinking water and estimates of safely managed drinking water services are available for four out of eight SDG regions. Main aim of this report is increasing the accessibility of fresh and drinking water under the Sustainable Development Goals.

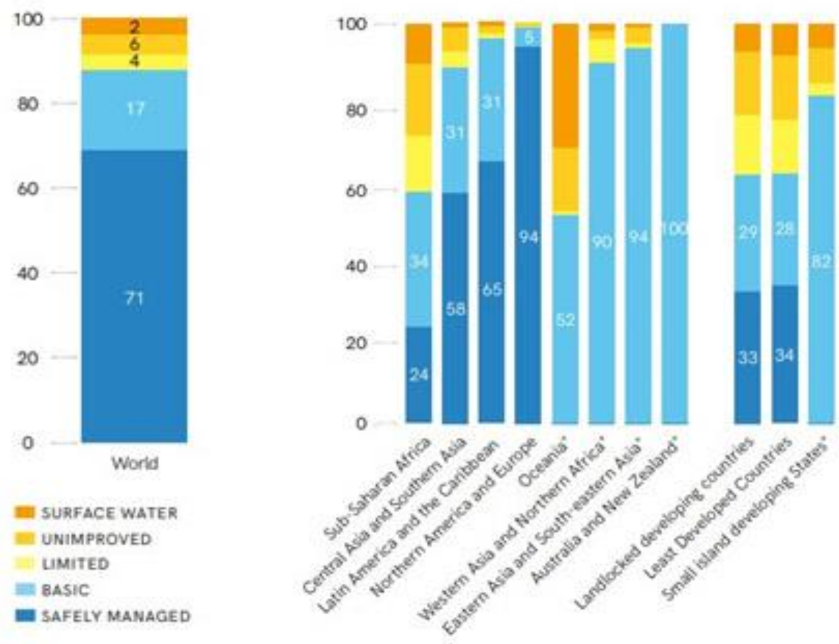

Figure 3.4. Safely managed drinking water services is used by 7 people out of 10 in 2015 (left) and Estimates of water condition for eight SDG regions(right) (The United Nations,2018)

In developing countries, drinking water supply system is a little bit problematic. Generally, this problematic situation is caused by water quality and hygiene. There are large variations in water quality in the urban context. Because reservoirs are poorly protected and seldom cleaned. In addition to that old pipe system can cause transferring the contaminated water. Increasing of diseases has high possibility in these countries.

So, public water must be potable in other words, it should be drinkable. The quality of drinking water is determined by some specific standards which is established by national and international rules. To evaluate the water quality, physical, chemical and biological content of water should be analyzed. As mentioned earlier, "*Safe Drinking*

Water Act in 1974" was formed by U.S Environmental Protection Agency (EPA), and some primary and secondary standards were determined. The primary standard is for protecting public health by limiting the levels of contaminants in drinking water and the secondary standard suggest enforceable standards by determining the maximum contamination levels.

World Health Organization (WHO) (2018), guidelines for drinking water quality is the most reliable and respectable document on drinking water quality on the international level. This document provides basic and practical guidance to help the development of water quality. Countries with limited resources and that are responsible for developing, implementing and enforcing drinking water quality regulations and standards benefit from this document. Agencies that are responsible for this topic can vary from region to region but generally the ministry of health, or ministry of environment are responsible for this topic. However, these guidelines do not replace the regulations that take into account local needs and priorities which are related to economic and health benefits.

3.3.3. Wastewater Collection and Treatment

Pollution control and maintaining public health throughout history was the biggest supporting idea behind the construction of the wastewater treatment plants. From the beginning, it focuses to protect fresh water supply such as streams, lakes, groundwater etc. So, especially in developing countries, construction of wastewater treatment ended up with significant developments in the living standards of people and their environments. Another significant point is that when there is high intensity rainfall in urban areas, local flooding can be occurred because of poorly designed drainage and sewer systems. Floods are usually related with urban catchment areas, impervious areas and surface runoff. The most important idea behind the waste water system is that it should be affordable.

The Sustainable Development Goals Report (2018) shows that 39% of the total population (estimates from 84 countries) use safely managed sanitation services in

2015. On the other hand, there is a lack of basic sanitation service and 844 million people which is 17% of the total population are affected from this situation. These numbers shows that all over the world, water related problem is still trying to solve with conventional methods in general.

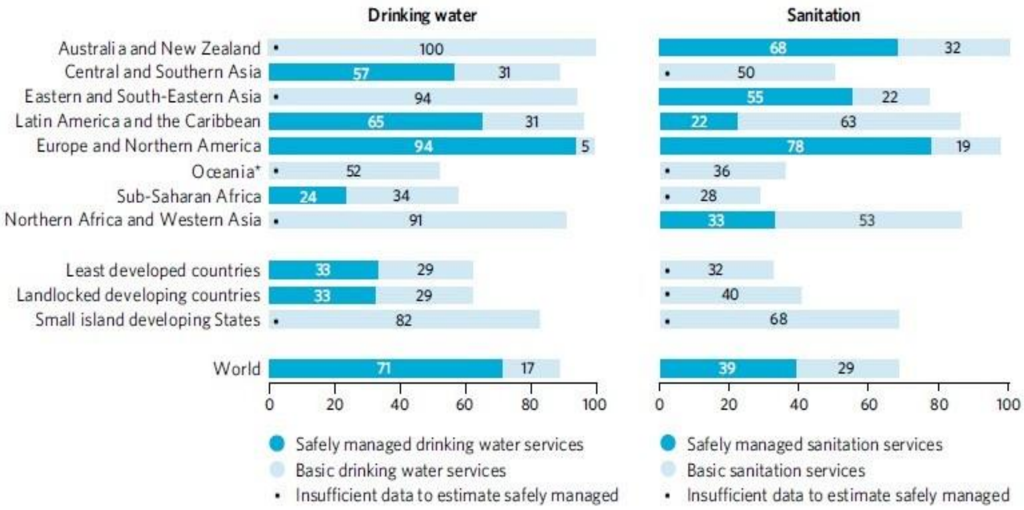

Figure 3.5. Situation of safely managed and basic drinking water and sanitation 2015 (The United Nations,2018)

And SDG Report (2018) continues to explain the current situation:

"Preliminary estimates from household data in 79 mostly high- and high-middle-income countries (excluding much of Africa and Asia) show that, in 22 countries, less than 50 % of all household wastewater flows are safely treated. Of the 59% of wastewater flows that are treated, 76% are households with a sewer connection, and 18% are treated through an on-site facility, such as a septic tank."

59 % treated waste water seems a good ratio comparison to the previous years, the untreated part of waste water and several countries located in Africa and Asia also affect the whole water cycle and urban relations. Urban areas have to deal with sufficient sanitation and waste water management. Unfortunately, the main problem is that because of the untreated wastewater, overall water quality decreases and it creates a risk to public health and relatedly freshwater sources.

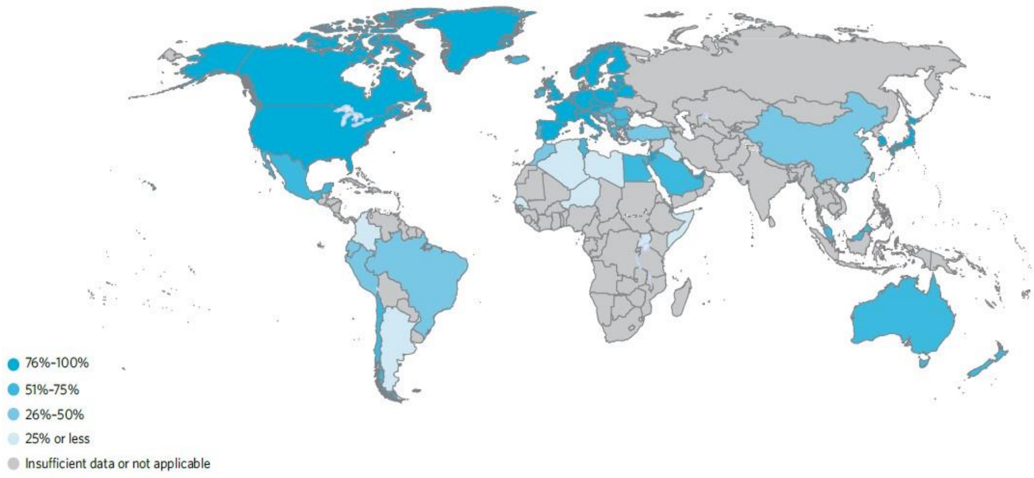

Figure 3.6 Safely treated wastewater flows from households in 2015 (percentage) (The United Nations, 2018)

If you need to give more details, Global Water Supply and Sanitation Assessment Report which is published by WHO&UNICEF in 2000 showed that the population of some part of the world that have access to facilities increased from 55% (2.9 billion) in 1990 to 60% (3.6 billion) in 2000. In the meantime, total world population grew from 5.2 billion to 6.1 billion. In addition, the number of people who have some form of developed water supply also raised from 79% (4.1 billion) in 1990 to 82% (4.9 billion) in 2000. However, 2.4 billion people did not connect to improved sanitation system in 2000. When it comes to 2015, the number that have improved sanitation systems was 5 billion people. In total, 8% of the population which is equal to 600 million people used improved but shared facilities, in other words, they had limited sanitation services. Meanwhile, the world population reached to 7.3 billion and in the end, about 68% of the total population had basic sanitation services in 2015.

For this first global SDG report *"Two out of five people globally (38 per cent), two thirds of those in urban areas (63 per cent) and 1 in 10 in rural areas (9 per cent) report having sewer connections. These households are classified as having safely managed sanitation services if the toilets are not shared, and if the wastes flushed out* *of the household reach a treatment plant and undergo at least a minimum level of treatment."*

Figure 3.7. The percentage of at least basic or limited sanitation services in 2015 (WHO&UNICEF,2017)

Globally, there are some large regional variations from region to region about people who have sewerage system connections and on-site sanitation. The chart below illustrates that some countries located in Africa generally use on-site sanitation systems (38%). However, when we look at the Northern America and Europe, this ratio is 15% and mostly sewer system is used for managing the wastewater (83%).

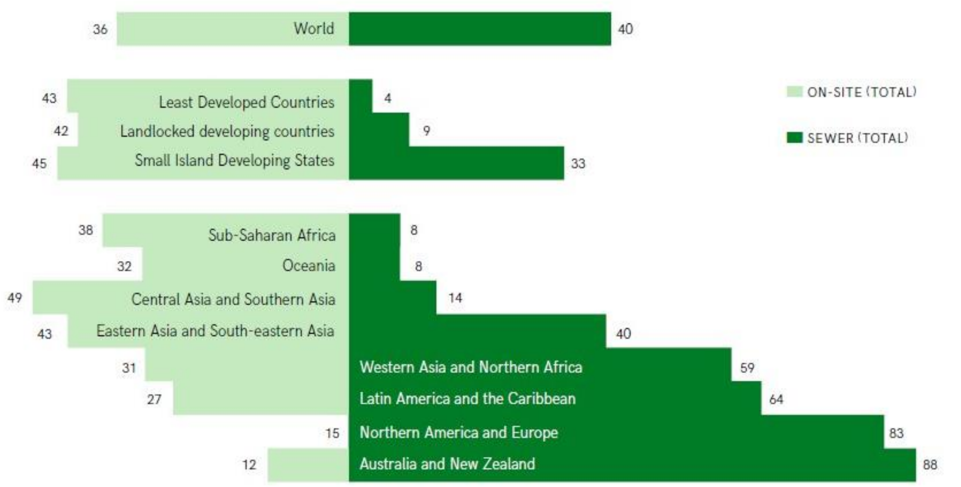

Figure 3.8. The number of on-site and sewer system, by region, 2015*(WHO & UNICEF,2017)*

3.4. Technological Development

From past to present, some important improvement in the development of centralized, decentralized and modern wastewater systems in the different part of the world are summarized below: (Wolfe, 2000)

Wastewater treatment technologies were rapidly developed from the end of the 19th century. Biological as well as chemical treatment systems have been consistently improved and installed, removing solids, organic matter, and nutrients from the wastewater. At the beginning of the 21st century, implementation of biological treatment and different types of method started to attract attentions. Some national laws such as European Union Waste Water Treatment Directive were legislated for the preservation of natural environment from wastewater discharge.

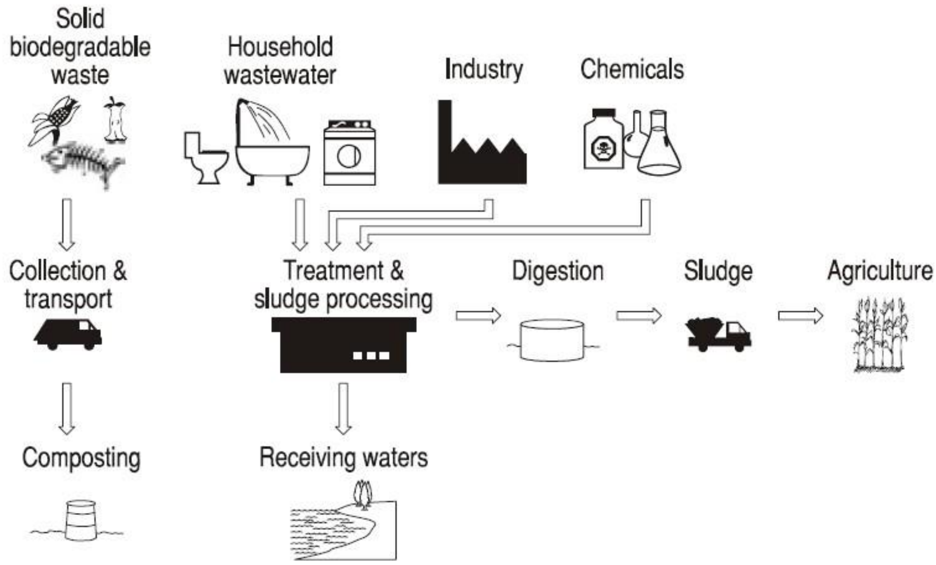

Figure 3.9. A conventional wastewater system (Marsalek, *et al.,2006)*

Lofrano and Brown (2010), Mesopotamian Empire in 3500 BC was one of the first civilization officially deal with sanitation problems in the society. For example, as far as it was understood, houses were connected to the drainage system of the city according to the ruins. Harappa and Mohenjo-Daro can be counted as "the world's first urban sanitation systems" about 2500 BC in Indus civilization. Houses were linked to drainage system and the wastewater was not discharged directly to channels, it was treated first.

In Egyptian period, finer houses that were in good condition in the city of Herakopolis in 2100 BC. The settlements had bathrooms and toilets seats made of limestone. The bathroom had a slightly sloping stone floor and the walls had a certain height with battered stone slabs. A sink was placed under the floor in the bathroom and channels that transfer waste water from bath to canal or desert.

When it comes to pioneer of modern sanitation systems, it was the Greeks. Toilets which is similar to Egyptian were found in Knossos. They were linked to a sewer and even today this system is still working after 4000 years. The ancient Greeks (300 BC - 500 AD) had pipes that carried waste water and rainwater into a collection pond outside the city. After, the wastewater was transmitted to agricultural fields with brick-lined pipes. According to some archaeological information, design of the water system starts with that wastewater first flowed into pipe from the structure to a larger pipe in the street and after that transferred to a single collector. Generally, crowded and complex cities such as Athens, Thasos, Pergamum and Pompeii had integrated and complex series of channels and pipes.

In the ancient Roman times, the most famous and impressive sewage system is “Cloaca Maxima” which was built in 6th century. Width of system was 4.50 m and height is about 3.30 m, and was about 12 m below the ground. After the Roman Empire collapsed, “the sanitary dark ages” began and lasted for several years. Idea of water culture that means a source of health was left in this era. At the end of the 19th century, just 50% of the society of Italy were used pipes for drinking water, and that more than 77% did not have sewerage system, summarizes the importance of situation when considering the complex and integrated water systems. In this period, major waste disposal in European cities like Paris was simply throw out it to the streets. Cooper (2001) said that the terms "Tout a la rue" (Paris), "All in the road", "Gare de l’eau" (Edinburgh) and "Gardyloo" (Glasgow) related with this period.

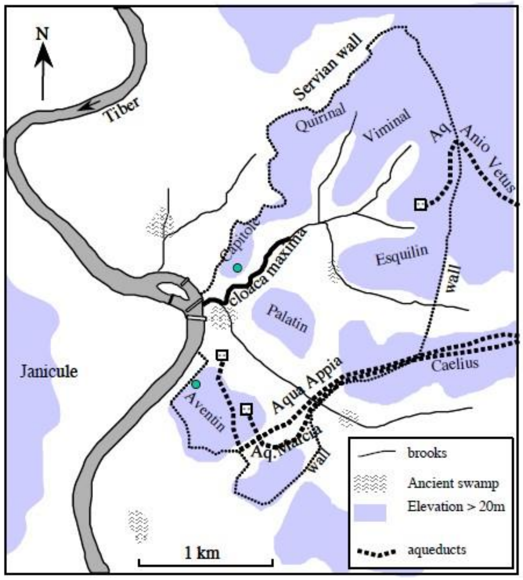

Figure 3.10. Cloaca Maxima (Viollet,2010)

After the end of Dark Ages, there were some improvement about wastewater topic. Through the 18th century, because of the high level of industrial activities and urbanization in Britain, pollution is the major problem of urban areas like London. For instance, the Thames started to pollute from the beginning of the 14th century. However, in 1859, it created a crisis in London. Aiello, Larson and Sedlak (2008) mentioned an interesting point in their studies:

"*In the middle 1800s, the sanitarians of those years believed, quite mistakenly, that disease was caused by ''miasmas,'' foul smelling emissions from decaying organic matter. For example, swamps and poorly drained farmlands smelled bad in the summer, just when people living near them became sick. Therefore, the sanitarians reasoned that the bad air, or mal-aria, must have been responsible for the illness. The sanitarians thought that experimental proof that controlling bad smells can control diseases.*"

In the 20th century, wastewater management, environmental science and pollution became one of the important issues considered in states, communities, academic environments and society. Increasingly serious problems, water shortages, demands of society and technological developments, as well as scientific research, social debates and the interests of government on wastewater management have become issues to be considered. Another important step was taken with the Eighth Report (1912) of the Royal Waste Water Disposal Commission. It has specific standards and tests for sewage and wastewater, which have been implemented by many other countries. The application of fully activated sludge process in the US was more rapid than United Kingdom. The main reason was First World War and very limited capital for this process and after that The Second World War also delayed development of wastewater treatment until mid-1950s (Cooper, 2007).

Shifrin (2005) as cited in Lofrano and Brown (2010), after 1950s, the perception of pollution shifted to water quality standards waste management policy. After that technologic evolution began. One by one primary treatment, secondary treatment, advance treatment, disinfection practices and solid processing started to be implemented. (Lutdzack and Ettinger,1962, as cited in Lofrano and Brown, 2010).

- **Primary treatment**: removing of heavier solids by using gravity sedimentation.
- **Secondary treatment**: changing the harmful materials in the wastewater to carbon dioxide by using micro-organisms
- **Advanced treatment**: preventing eutrophication in a biologic way (removing nitrogen)
- **Disinfection process**: removing pathogenic microorganisms for public health
- **Solid processing**: using waste solids as a fertilizer or renewable energy sources

In the end, water treatment is a significant component of not only urban infrastructure but also urban water cycle throughout the history. Wastewater treatment is affected by both upstream and downstream components of this hydrologic cycle. Treatment of wastewater creates a great opportunity for primary water sources and help to sustain water cycle.

3.4.1. Storm Water

Collecting and storing storm water is not a new idea. During the early civilizations, harvesting surface water from rainfall was the main clean water supply especially for people who lived in arid regions. After the collection part, storing was the second issue. The water was stored in man-made reservoirs or ‘cisterns’ from past to present. Kinkade-Levario (2007) was mentioned in her book “Design for Water”, “*a historical document of the time mentions water cisterns and the habit of having at least one rainwater-collecting cistern per home that would range in size from 35 to 200 cubic meters*”. These cisterns were located mostly below ground. Moreover, in ancient times, waterproof cisterns in other words tanks were firstly made up with sand and rock lined with plaster and in time they improved their skills like the Romans who built comprehensive structures. To give an example, in the central Negev Desert in Israel, the six urban centers that include Avdat, Mamshit, Nizzana, Shivta, Rehovot and Haluza, rainwater harvesting systems were built for huge population ranging from 25.000 to 71.000 people during the Nabatean-Byzantine times (Broshi, 1980; Bruins,2002). Zuhair et al. (1999) have shown that rainwater harvesting can provide a significant amount of freshwater in the Arabian Gulf States. Kuwait meets 12% of the water demand for landscape agriculture and Muscat,Oman also provides 27% of the water demand for industry.

In urban areas, storm water is mostly rainwater running of impermeable surfaces such as streets, parking lots, roads and roofs etc. The water is mostly collected by sewers or open channels to prevent flooding. Consequently, storm water is polluted with wastewater which comes from domestic and industrial flow during this process and there is environmental concern because of its discharges into water body. Floods are natural hydrological event that occur with high discharges leading to increase the water level of streams, lakes or other sources but in the end it results in loss of people and damages of settlements. In the urban context, there are two types of floods that are locally generated by excessive rainfall. Other floods may occur in coastal areas in the form of storm or tsunamis with catastrophic impacts. Only the first flood type, locally generated, will be discussed here.

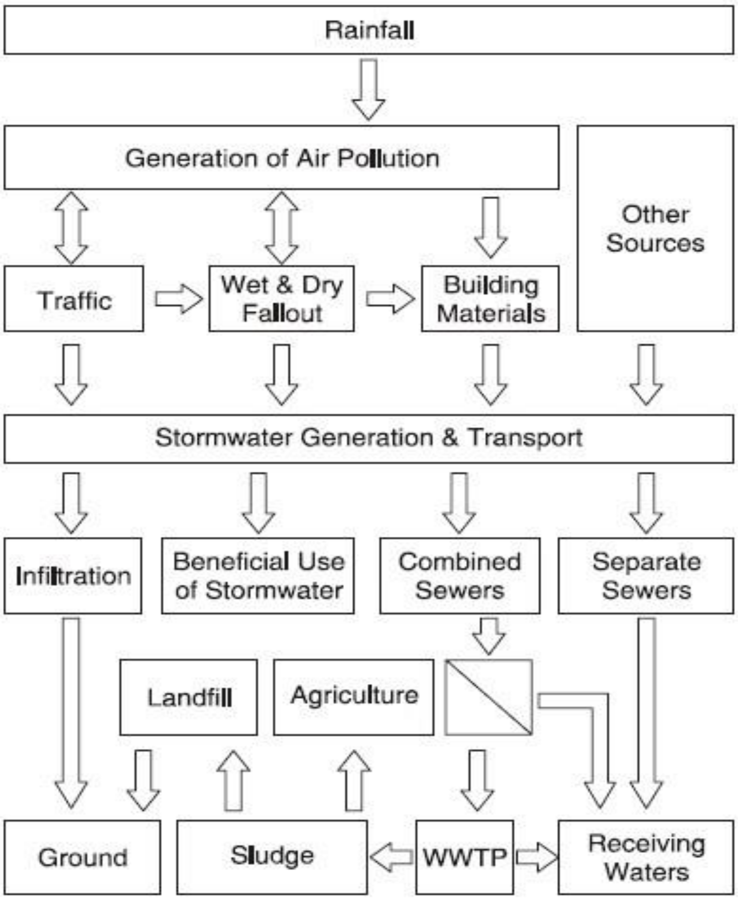

Figure 3.11. A schematics of runoff generation and pollution (Marsalek *et al. 2006)*

3.4.1.1. Storm Water Characterization

Urban storm water quality is very extensive in the literature. Marselek et al. (2007) mentioned that more than 600 chemicals were identified in storm water and this list is growing. In most cases, storm water is transferred by combined water channels, together with domestic and industrial wastewaters. In this scenario, high storm water inflows can exceed the carrying capacity and excess water goes to the nearest receiving waters. However, this combined sewer contains not only the storm water, but also untreated wastewater; their direct discharges into water body result in crucial pollution problems. The combined sewer also affects the manner of wastewater treatment plants (WWTP). When storm water mixed with domestic and industrial wastewaters, the volume of water that have to be cleaned increased. So, working time of WWTP have to increased. In parallel with, process will extend and efficiency can be an issue which have to be considered.

Excessive water runoff that comes from urban surfaces is carried by storm sewers which is located under the ground to the nearest body of water in older separate sewer systems but water is not controlled or passed any treatment phase. Basically during the last 30 years, the concept of storm water management has been introduced and practiced all around the world. In order to enhance the storm water quality, infiltration of the storm water through soil is the key point. In the next part, storm water management is explained comprehensively.

3.4.1.2. Storm Water Management

As an alternative water supply, storm water harvesting is the major one all over the world. Because when it falls to the ground, it can be used second time with small or no treatment process. In this way, municipal water can be saved for primary and high quality water needs. According to Kinkade-Levario (2007), fog con condensate and rainwater collection are the two water sources that need very little filtration but both of them have different and specific techniques for collection. In the one hand, fog collection depends on elevations of the region and geographic condition, large fog collection pipes. It is a little bit painful process and require more effort when we consider the rainwater collection system. In the other hand, efficient collection of rainwater is more widespread and feasible but it also depends on several and significant key factors.

These factors can be approached in different ways. The basis of all is the recovery of water while the methods or categorization may differ. One example is that because of the excessive discharges of storm water, and pollutant concentrations and their potential impacts on the environment, the storm water management have some alternative techniques in last years including the following:

- infiltration facilities,
- pavements and pervious surfaces
- ponds and wetlands,
- swales, terraces and ditches,
- phyto-remediation and riparian buffers

The overall key component of storm water management is the drainage system, which has the following key components (Urbonas and Roesner,1993):

- "The removal of storm water from streets permitting the functioning of transportation arteries.
- The drainage system controls the rate and velocity of runoff along gutters and other surface to reduce the hazards to residents and the potential for damage to pavement.
- The drainage system conveys runoff to natural or manmade major driveways.
- The system can be designed to control the mass of pollutants arriving at receiving water.
- Major open drainage ways and detention facilities offer opportunities for multiple use such as recreation, parks, and wildlife preserves."

Comprehensive drainage plans should involve purpose of the study and the background and drainage related problems. This plans also illustrate planning and design methods, research of alternative drainage systems and design guidelines and implementations. This process can be applied easily in developed countries; however, the situation in developing countries is more different and the principles or stages of master drainage plans are hardly followed. Because urbanization processes in developing countries can take place too fast and unpredictably. In addition, generally development proceeds from downstream to upstream. People who are in low income group are settled illegally some public areas that have flood risk without any protection or there are over construction because of economic reasons.

Geiger, Marsalek, Rawls and Zuidema (1987) mentioned that urban drainage plans should be prepared at two levels, short term (5-10 years) and long-term (25-50 years). Also, it should be contained a technical layout of the sewerage systems, also included drainage and sanitation for urban area. With respect to water, the master plans should be a part of the system which includes the components of minor and major system. In one hand, swales, open drains and surface and subsurface storages, storm water sewers etc. forms the minor system. On the other hand, the major drainage system consists of much larger components such as natural streams, large swales, streets etc. In this debate, in the management and design part, water should be handled comprehensively.

3.5. Discussion on Central and Local Systems

In the urban storm water management, there are two basic components that have be taken into consideration. These are central or conventional system and distributed, decentralized or in other words local systems.

The issue of urban infrastructure and supply of water services in developed countries depends on long tradition and providing good services to urban dwellers in infrastructure systems over centuries. It is also related with sufficient funding in these countries. As an alternative to these central systems, new approaches show up like distributed systems in recently. Especially in developing countries without central systems, building and maintaining the system may be a beneficial alternative.

In terms of system architecture, they can be designed as conventional centralized systems, or less common distributed systems (Marsalek.et al,2006). There are many types of water related with central or distributed (local) system. Kinkade-Levario defined the followings (2007):

- Atmospheric water: rain and fog.
- Blue water: water from aquifers, rivers and lakes.
- Storm water: rainwater that has hit the ground.
- Grey water: wastewater from a laundry, bathtub, shower.
- Black water: water from toilets and kitchen sinks.
- Reclaim water: water that has gone through a sewer treatment process and has been filtered and proceed for reuse in various ways, including large scale irrigation.

All these elements are the component of the system and each of them has a different role in the interaction of nature and urban concept. So, they will be examined both centralized and local systems in context of urban design and implementation concept.

3.5.1. Centralized Systems

Wastewater collection systems typically consist of a network of pipes and pumping stations for transporting wastewater to a final destination. In general, cities that have a centralized sewerage system consist of the same basic components. Collection of the wastewater in or near the houses, transfer by gravity sewers or pressure sewer to a treatment plants and discharges to the water bodies. And the key point of this system is that domestic (grey water, black water etc.) and industrial wastewater is collected with storm water in combined centralized sewers. In principle, wastewater collection and treatment systems are similar in all large cities of the world. At the beginning of the 1800s, wastewater systems have considered with centralized systemsand it considered as a primary role. At the moment, most cities have a centralized sewerage system with in different parts of the world. However, poor countries or cities and most of squatter settlements in Africa, Asia or other part of the world are the exceptions. They have different kind of wastewater systems.

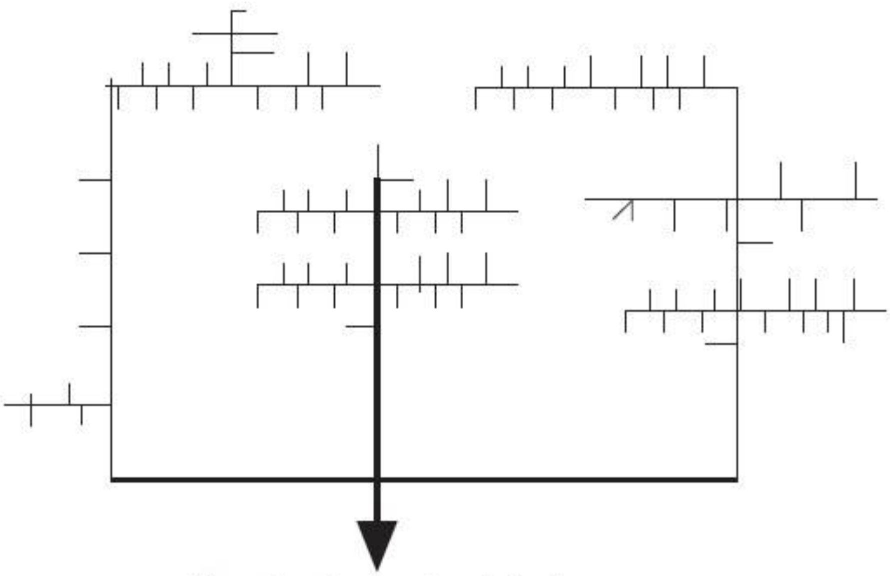

Figure 3.12. Schematic of centralized wastewater system (Bakir,2001)

Although many developing countries have centralized sewerage systems and sewage treatment, it is often reported that the facilities are not operating properly because of lack of management, funding and training. Dealing with water from the point of quantity and quality is mostly compelling process. The reason is that variability and uncertainty of water by location. Amount of wastewater depending upon the rituals of people, climate and relatedly rainfall, urbanization and industrial facilities highly affect the wastewater management and sewerage system in centralized systems.

Besides, sewerage systems in many developing countries are limited. For this reason, management with only centralized system may not be a solution for water resources. Centralized and conventional water systems come up against limitation of capacity in some countries. Mays indicates that (2009):

"In Palestine about %24 of the total population is served by a central public urban sewerage system with around 73% of households using cesspits and septic tanks, and 3% having no sanitation system. In Turkey about 50% of the urban population is connected to sewerage systems (Post, 2006)."

3.5.2. Decentralized (Local) Systems

Decentralized system is frequently defined that water is collected, treated and used next to the source (Wilderer and Schreff, 2000). Water also requires to be collected in this system, but the usage of large and long pipes is not necessary. Besides, creating a more composite collection system network is the key point of this issue. Another definition about the decentralized systems is that (Bakir,2001) water is managed as close as the place where it is generated and it should be reused. In this case, not only waste water but also rain water can be collected, treated and reused. Each unit has its own practical application.

Conventional (centralized) systems are common in the central parts of largest cities, but the approaches to wastewater management are quite different in small towns or in the peri-urban areas on the outskirts of cities. In addition to that, new approaches which includes decentralized (distributed) systems towards to water management issue become more widespread in the world to provide sustainability because wastewater or rainwater are considered as "a renewable resource" in today's world.

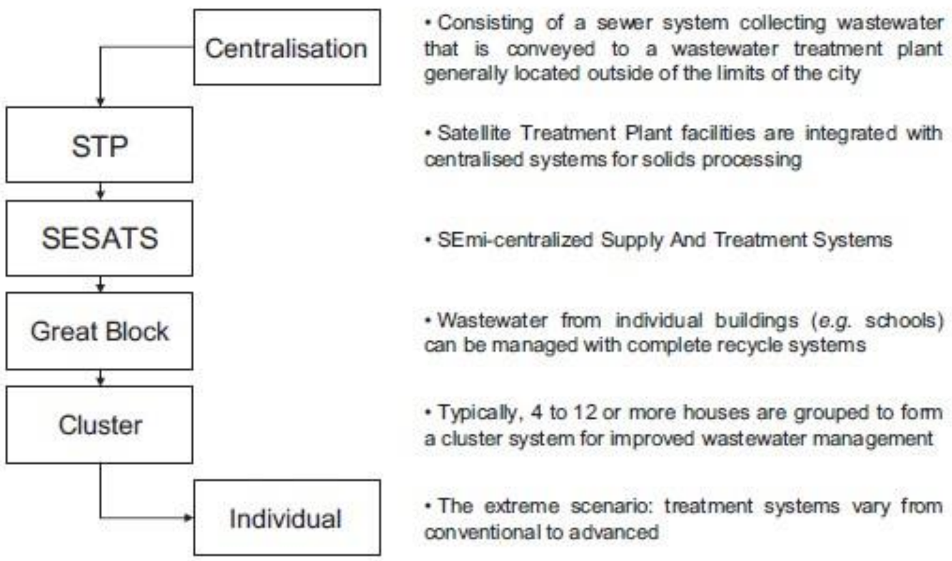

Figure 3.13. Treatment scaling: from centralization to decentralization. (*Libralato, Ghirardini, & Avezzu,2011)*

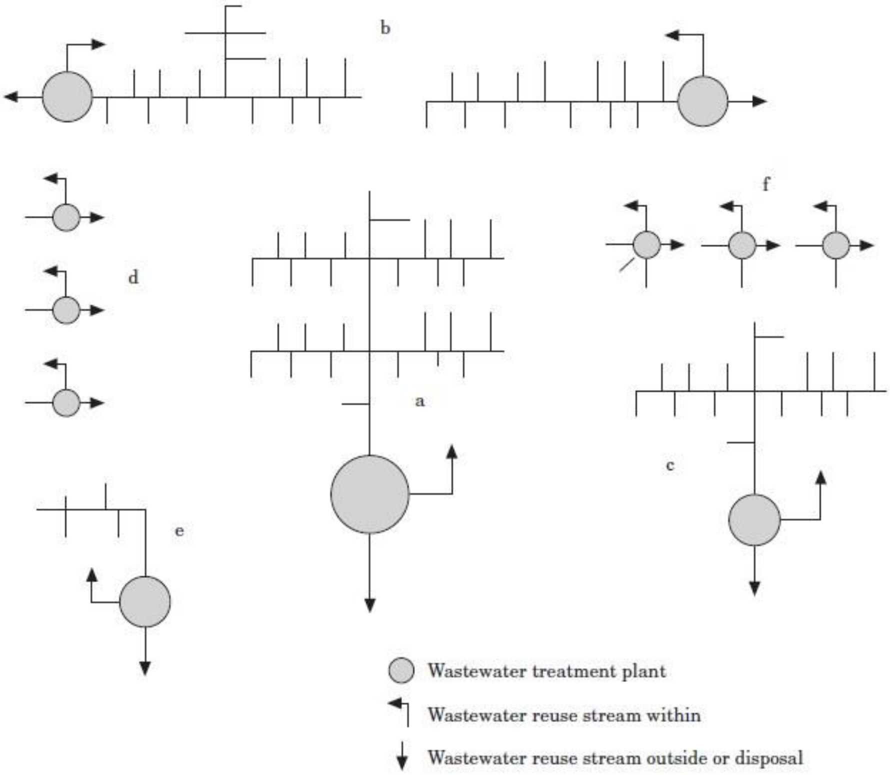

Figure 3.14. Different decentralized wastewater management concepts for a settlement (Bakir,2001)

Figure 3.14 shows that the schematic diagram of decentralized wastewater management concept for a small community(Bakir,2001).

"(a) subsystem for residential and commercial center

(b) Subsystems for residential neighborhoods.

(c) Subsystems for industrial development.

(d) Subsystem for individual residences.

(e) Subsystem for new development.

(f) Subsystems for establishments or clusters of homes."

As we can see in the diagram, decentralization can work both individual on-site system and a series of clusters. In other words, treatment or reuse of water from building level like single house or an apartment to some group of houses like 3-10 buildings can be applicable. In addition to that, schools, commercial centers or health centers can apply easily and support the whole system. Each unit uses its own waste water or harvesting water. When they came together in the upper level, they create a comprehensive and combined decentralized system. To give an example, Kimura et al., mentioned that in Japan, about 2500 individual buildings have on-site waste water and rainwater harvesting systems. Water is used for flushing, garden watering, cooling and fire protection in these buildings. Among these buildings, 25.9% is public offices, 12.5% is business offices and 15.7% is schools (Lazarova Valenti, 2013)

So, cheaper and easily applicable implementations are searched for the management of water in several countries all over the world. Examples of such technologies in the distributed (local) system are listed below and they will be explained in detail in the following part of the study:

- Rainwater harvesting from roofs and other surfaces
- Waste water and rainwater infiltration
- Constructed wetlands such as swales etc.
- Phyto-remediation areas

3.5.3. Centralization or Decentralization: Which is the best?

In this context, there is a continuously discussion about centralized and decentralized systems for water usage, wastewater reuse and which one is the best option. The first debate is that although conventional centralized system has a significant advantage like central control of the operation, there are also some critical weaknesses. One of them is the huge investment required for the pipe networks and the treatment plants and unfortunately for the cities that have some financial difficulties and sprawled settlements, building a central system is a little bit compelling situation. In this context Baker (2001) point out a critical perspective. "*The cost of conventional sewers is high and their cost becomes even higher when provided to sparsely populated small communities*". We understand that when there is an improved and densely populated urban center of the community, a conventional central system and treatment are become more efficient and system works properly but storm water collection is still a problem that should be coped with in the near future. On the contrary, on-site systems which include infiltration, ponds, wetlands and phyto-treatment areas works properly in the underpopulated neighborhoods in terms of economical and perception of accessibility.

Secondly, decentralized system is easily applicable to various levels of urban form from individual to whole community. However, in the central system, usage of wastewater at the building level (in situ) in terms of recycle and reuse, it almost impossible. So, negative effects of discharging wastewater at one point on water bodies can be reduced. In this way, some part of the problem can be solved at domestic level. There is an extreme example about the centralized and decentralized debate. It is rainwater harvesting. In Southern Australia, rainwater tanks are used as a main source of water supply in Southern Australia because of economic reasons and the ratio is about 42% of total households (Heyworth et al. 2001, as cited in Libralato, Gihirardini and Avezzu, 2011).

In the centralized systems, water transfer from one point to another with pipes and this distance is not short. However, water networks that consist of channels and pipes are vulnerable. Leakage is the main problem in this system especially when the system is old. Rehabilitation and decreasing the level of leakage is not a simple issue. So, in some cases decentralized water supply systems can be thought as more effective and more sustainable. The main reason behind this idea is that every 50-60 years, collection and distribution systems (pipes and channels) have to be renewed periodically (Maurer et al., 2006, as cited in Libralato et al.,2011).

The last point of view about decentralized system is that it gives an opportunity to urban areas for creating an open environment. Vegetation, public parks and green spaces serve as an infiltration and treatment spaces for wastewater and storm water. In the urban context, they can be categorized as a passive catchment. So, these environments can be used both cleaning, catchment and storage purposes and social and recreational purposes.

In this perspective, the challenges in the current urban infrastructure started to change by the reason of mainly population and climate change and the shift in the perception from centralized large scale systems to decentralized systems ends up with a new concept. Mix-systems or hybrid systems can be accepted as a solution according to location and time. The whole system can be controlled easily by natural to engineered water infrastructure. However, centralized large scale systems are more dominant infrastructure type all over the world because of history of the region, in other words, infrastructure is there and this system is difficult to change because of engineering, environmental, economic, political and social reasons. For example, it is too difficult to change dams and also is costly to replace to completely new system and alternatives. There are some challenges of installing a completely new alternative system. First one is economic reasons. Replacing centralized system and clear it away is highly expensive way to solving the problem. Existing systems still work until this time and from this point, to maintenance the sustainable environment and close the circle there should be an alternative system integrated with existing one. Doing so at the same time, ensuring the public health is the another significant challenge of it.

3.6. Summary and Conclusion

Water is valuable component of the urban areas in terms of its positive contribution. It is an essential elements of the life cycle related with natural cycle. In this "cycle part", water shows up as infrastructure in urban areas. In this chapter, mainly urban water infrastructure system discussed. Current situation and its problematic ways explained from past to present. Discussion continued with timeline of water infrastructure and types of it. Components of water infrastructure ended up with the most important two groups. These are waste water and storm water management. Water will have a new meaning thanks to dealing with these two in a proper way under the decentralized system concept.

It is significant to note that, problems caused by water cannot be solved with conventional methods such as dams, wastewater treatment plant or sewage system in the current situation. Problems of population, urbanization and climate which is mentioned previous chapters should be studied in the new urban design concept for the sustainability of urban water supply structure. They started to construct hundred years before today but supply of infrastructure, water availability and accessibility of fresh water face with critical problems. A new approach for sustainable urban water infrastructure will ensure fresh, safe and accessible water for population into the future.

CHAPTER 4

LET WATER IN:
RESTRUCTURING URBAN

You've to plant the water before you plant the trees.
Human Rights, United Nations,2002

This part presents a critical physical implementation of decentralized water systems on both existing system: centralized water infrastructure and a new water system. Also, it underlines that how centralized and decentralized local systems can get together. Dealing with centralized water, stormwater and wastewater for urban areas is not a new issue that was mentioned in previous part of the study. Although it is common practices for centuries, alternative practices begin to gain importance in urban water management in terms of efficiency and it get involved in a part of the solution.

In recent years, there is an understanding that increasing population, climate change and water supply can conflict with one another. Related with it, natural water cycle and urban water cycle are connected with each other and also affected. Countries, cities, natural areas and managers face with several and different challenges that is mainly depend on available water resources and limits. Replacing the old one completely a different and a new one is a complicated and huge process and it affects not only economy but also environment. In this perspective, hybrid system can be considered as an alternative to the conventional centralized system. Sapkota et al. (2015) said that combination of decentralized system into the centralized infrastructure is creating interactions between some significant components of the water cycle such as wastewater and storm water.

The basic concept includes harvesting of storm water and waste water treatment and reusing in the new system with some tools such as water tanks, swales etc. So, this part emphasizes the understanding the effects of hybrid water systems in practice, its principles and some examples that was applied in the different location of the world. This study identifies an important research and implementation gaps related with centralized and decentralized urban water system. *Finally, how this water sensitive system re-built the urban structure in different scales will be explained.*

4.1. A New Way: Centralized-Decentralized (Hybrid) Water Supply Systems

In the literature, definition of hybrid systems is explained in different aspect. There are lots of debate about its positive and negative effects on development. One example of the generalized definition of hybrid system is made by Daigger and Crawford (2007). According to them, "*hybrid water supply systems can be defined as systems provided for water services through a centralized water supply system in combination with decentralized water supply options such as rainwater tanks, storm water harvesting, and water reuse*".

Another phrases such as "semi-centralized supply and treatment" (Bieker,Cornel and Wagner,2010), "distributed water supply system", "semi-decentralized systems" (Wang,2014) are also internationally accepted. Comparison with these definitions of hybrid systems and "The Soft Path of Water" approach mentioned by Christian-Smith and Gleick in 2012, uses not only centralized water system but also some tools which are integrated with each other. In this concept, similarly in conventional centralized systems, the "hard path of water"consist of centralized infrastructure and technologies such as treatment plants, underground channels, large dams and reservoirs. But in any case, all of them have one common point and indicate the same idea: Fresh and accessible water is scarce. These systems can provide fresh water in local scale, easily applicable and working efficient considering with dominant central system. It helps to reduce the volume of wastewater and storm water discharge into the environment.

In order to achieve this, there are some basic types of intervention as mentioned shortly in the previous section. These are the basic tools used to shape the urban form with water and explained in detail in this part of the study with different world's examples and different implementation scales.

Rainwater harvesting, wetlands, phyto-remediation areas, rain gardens, surface runoff and pervious paving, all these basic applications constitute input in complementary planning scales. From upper scale to lower scale, it should contain scales of the region like urban level, the catchment like street level and the site: building level. Each of them involve active and passive methods in itself.

The Royal Commission Findings on Auckland Governance (Salmon et al., 2009) development of the region should be supported with strong, conceived and viable planning. At the regional scale, main aim is the supplying clean, mass and accessible water for the people who live in the urban and rural areas as a whole. On the other hand, hybrid water system contributes to connectivity of ecosystem services to 'close the circle'. It protects and cure the functions of natural ecosystems. Storm water collection in regional scale, phyto-treatment regions or riparian areas solve water problems as close to source as possible associated with creating large scale wetlands.

For the process of implementation of scale principles, the scale of catchment affects the volume of water and relatedly affect the beneficial spatial planning. Because there is a direct causal link between storm water runoff in a specific catchment boundary. So, planning process should be proceeded with respect to different scale of catchment area. According to the Auckland Council (2015), catchment areas are defined by topographic boundaries and catchment planning should need an understanding of three connected processes:

- *"Land use practices generating storm water runoff and contaminants*
- *The means in the catchment (natural or structural) to retain, treat, convey and decreasing storm water runoff*

The values, natural functions and intended uses of receiving environments.

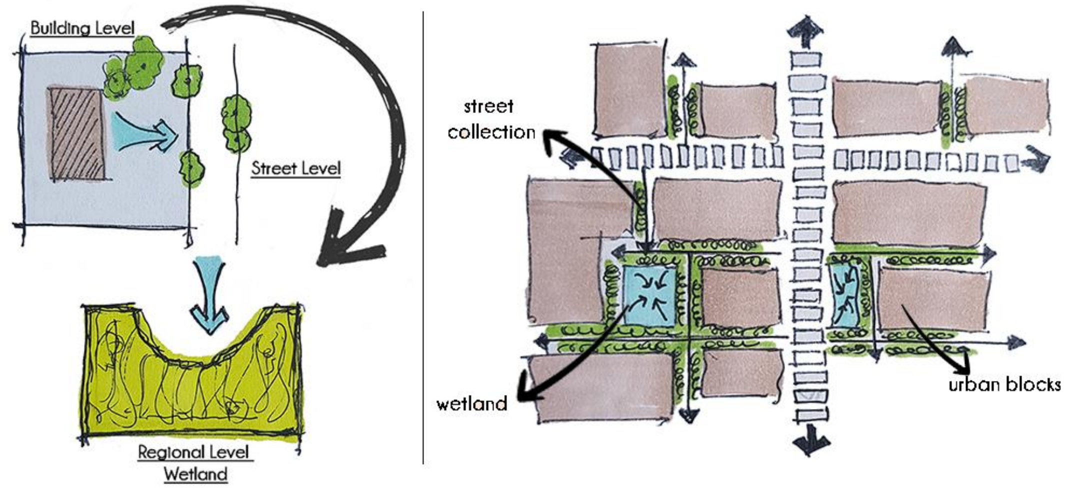

Figure 4.1. Scaling of catchment areas (Illustrated by author,2019)

As mentioned before, aim of the catchment areas is filtration. Catchment areas make a decision indirectly because of the environmental effects. The location of land uses is specified with location of catchments and natural lands. A treatment and filtration process can be ensured with elements of the catchments such as landscape areas, rain gardens, swales, etc. So it addresses storm water effects as close to source as possible.

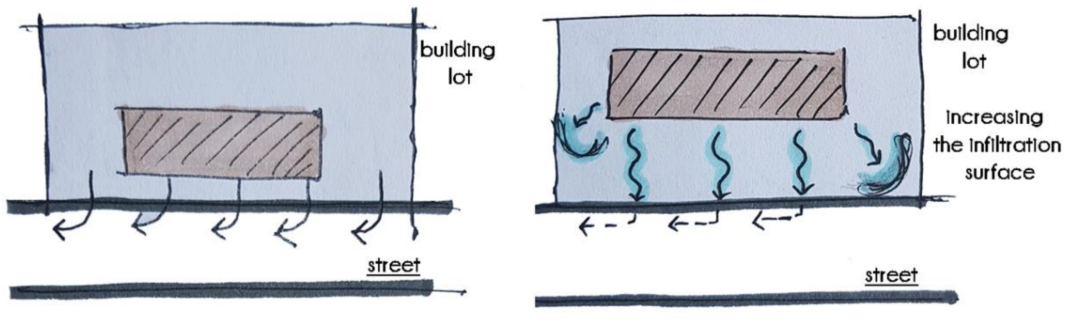

Figure 4.2. Building location in a lot (Illustrated by aıthor,2019)

The best way to implement the principles at the catchment scale can be done by the integration of planning processes with infrastructure systems and catchment areas. To create a balance between built and natural areas, this plans should change classical infrastructure to a new system. Storm water management, ecology, natural water cycle and urban design should be considered in this new system, it should not be ignored and waited to get better by itself. Details will be explained in the next pages.

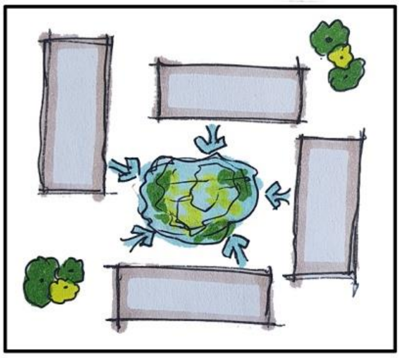

Figure 4.3. Catchment areas in an urban block (Illustrated by author,2019)

And finally, the site scale supports both architecture and a development layout that avoids valuable or sensitive ecosystems. These systems can guard the area from potential negative impacts of storm water runoff. A layout of site can maximize pervious surfaces and thus reduce storm water runoff. Figure 4.2 shows that building location in lot can affect the filtration of water because of the pervious surface. The excess water can be grabbed and treated near the source and used in the layout when it will need as irrigation or potable water, where runoff occurs. The storage area of storm water is generally a cistern or a tank in the site scale just like in the old settlements where rainwater harvesting was a primary water supply quite a long time.

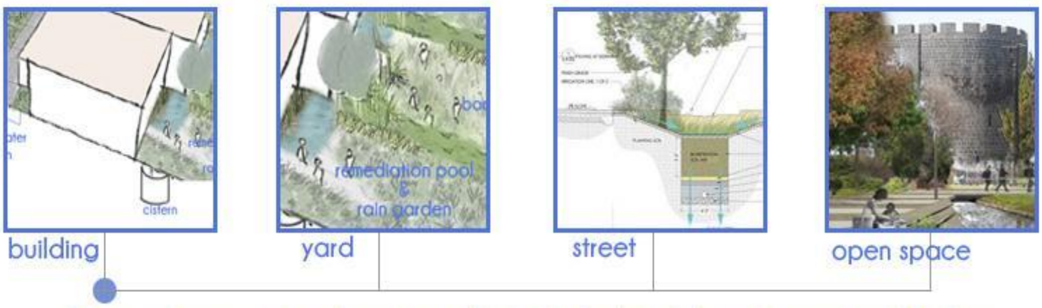

Figure 4.4. Water management from private to public spaces (Illustrated by author,2019)

In addition to this scaling factor, there are two main branches in the horizontal perspective of the rain water collection in terms of design inputs. First one is active rainwater catchment system and the second one is the passive storm water catchment system.

While it comes to the water collection from any hard surfaces such as concrete, metal or asphalt surfaces, rooftop catchments which means rainwater catchment or harvesting is the most common and the easiest method for harvesting. Kinkade-Levario (2007) said that "*typically, once the rain hits the ground it is no longer referred to as rain, but as storm water*." So; landscape, green areas, driveways, parking lots can also be evaluated as catchment areas for the storm water. However, storm water collected directly from ground has high level of contamination, for this reason, it should not be used potable purposes because of health issue if there is no purification system.

In the literature, on the one hand harvesting rainwater from roof is generally named active rainwater catchment system, on the other hand, landscape holding area is essentially a passive storm water distribution system. The phrase "active catchment" is mostly related with manmade catchment with using pipes, tanks etc. and what's more, "passive catchment" is mainly referred to a more natural approach using soil, plants etc. It is also explained that is used to irrigate plants through an overland flow system: water infiltrates through the soil and is then conserved in a plant's root zone-green water-for its consumptive use (Kinkade-Levario,2007).

In Design for Water (Kinkade-Levario,2007) indicate that the volume of collected water relies on some criteria such as slope, catchment size, surface texture, pervious surface. Depending on the material of catchment surface, runoff efficiencies may be expected to vary from 90 to 30 percentage due to runoff material absorption, evaporation and inefficiencies in the collection process.

Table 4.1. .Estimated Runoff Efficiencies for Urban Surfaces(*Kinkade-Levario 2007)*

Estimated Runoff Efficiencies for Urban Surfaces	
90%	Smooth, impervious roof surface, such as metal, tile, built-up and asphalt shingle roof
80%	Gravel roof and paved surfaces
60%	Treated soil
30%	Natural soil

In any case either rooftop or groundwater level, this system can provide a self-sufficient and high quality water supply that is close to the people. Harvesting systems are easy to conduct, cheaper than other water resources.

4.1.1. Active Rainwater Catchment Systems

Active rainwater catchment means that water collect actively, then filter and finally store. Storage is the most significant component of the 'active' part of this system. Cisterns and large storage tanks which capture water from roofs or other surfaces such as terraces, walkways or parking lots, provide water quality treatment and generally use pumps for a distribution system. Water which is collected from surfaces in the active system is generally used for irrigation, gardening, toilet flushing etc. Implementation of this active system requires some principles. First one is determining the cistern/tank size according to water demand. Secondly, there is a decision about the location of tank and finally configuration of pipe and distribution system for harvested water.

There are six primary components in rainwater harvesting and storm water catchment systems. These components include catchment, conveyance, filtration, storage, distribution and purification. Purification is only required for portable systems. If the water is used for irrigation and gardening, this phase is not strictly necessary

(Kinkade-Levario,2007). In this case, catchment means roof, conveyance means pipes, filtration is gutter, storage is tank, distribution means gardening with pipes.

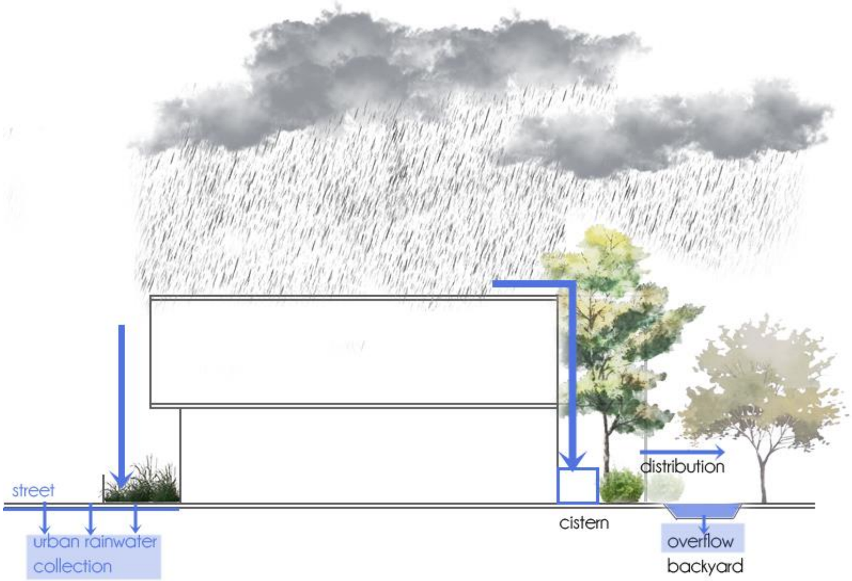

Figure 4.5. Active rain water collection system (Illustrated by author,2019)

4.1.2. Passive Storm Water Catchment: Earthwork

In this part, catchment area means landscape or garden use. Water harvesting is done by earthworks in passive storm water catchment areas. As the name "earthwork" implies that earth works. Landscapes, rain gardens, infiltration basins, terraces and water flows are the elements of this system.

The relationships between building and lots, street and infrastructure, and urban basin and nature in terms of rainwater collection essentially depends on this 'earthwork' system. Buildings (roofs) and catchment areas are the main design guidelines for water management from the smallest part of urban area which is buildings and lot to the urban scale are going to be explained and exemplified in this chapter.

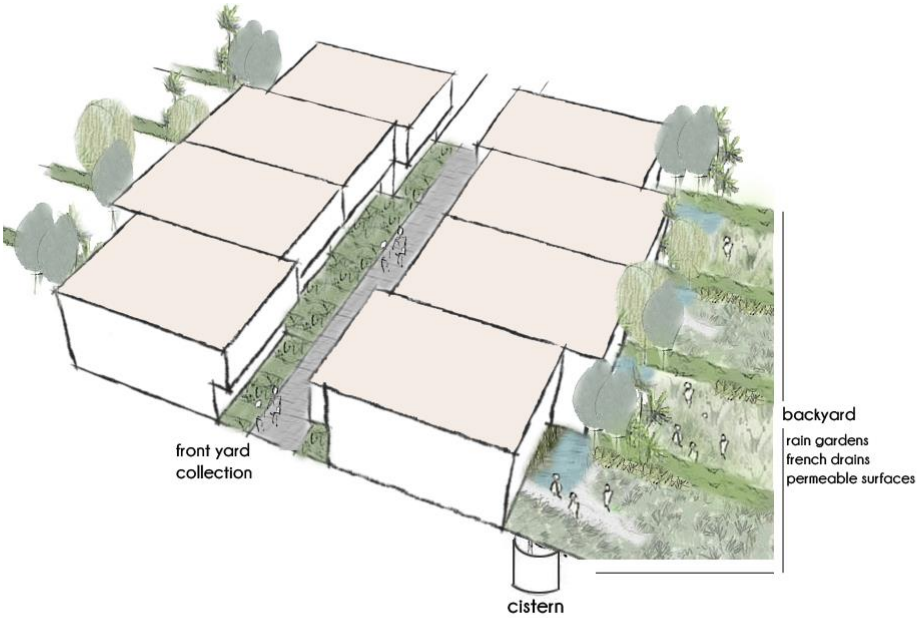

Figure 4.6. Passive stormwater collection system (Illustrated by author,2019)

Basic logic behind earthwork is increasing the time of flow and infiltration which starts from surface to the ground or water tanks, in other words from source to sink. In the conventional system, water has direct and quick flow from source to traditional storm water infrastructure. In the end, this direct flow creates some problems in today's urban areas such as overflow or flood, increasing wastewater volume and excessive usage of natural body of water. So, from source to sink idea is parallel with the idea of "closing the circle" which is mentioned in the second chapter of the study.

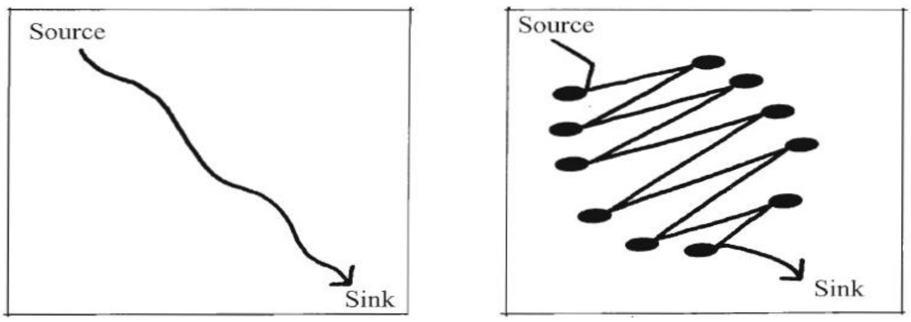

Figure 4.7. Fast and directly water flow to the landscape (left) and the zig zag method increases the time of water flow and water travels more distance and the level of infiltration increases from source to sink (right) (Lancaster,2006)

According to Lanchester, overflow should not be treated as a problem or a waste. Instead, design the overflow route so that surplus water becomes a resource. Overflow water starts to filling and then overflowing one earthwork to fill another and another. Creating a wetland is the key factor of the system. In the wetland processes, water is passing through vegetated areas and filtering process of sediments and pollutants is realized.

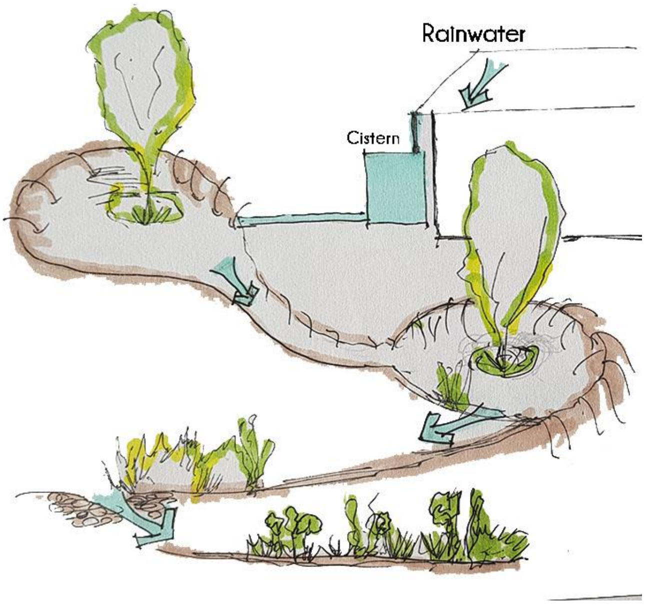

Figure 4.8. Overflow water fills one earthwork and then surplus water starts to fill another to another (Illustrated by author,2019)

Micro basins, swales, french drains, rain gardens, permeable pavements, curbs etc. are the most common ways to direct, store and infiltrate the storm water. Planning for this earthworks requires an integrated design process. The following pages describe and illustrate various techniques that can be used in designing process.

Earthworks consist of some significant component in order to sustain water flow, collecting and filtration. The first one is **infiltration basins or rain gardens**. Rainwater runoff from roofs and other surfaces can be collected in the planted and shallow areas. They are basically planted with vegetation that can hold water on the land. Another definition of rain garden that is explained by Bayside City Council

(2009), "*rain garden is a specially designed garden bed that takes rainwater directly from a roof or any outdoor surface that produces run-off. It has a sand base and can be planted with a range of plant species.*" So, infiltration basins or raingardens can work both flat landscapes like terraced basin, water harvesting tree wells.Similarly, in the storage tanks or cisterns, rain gardens also can be located in ground or above ground as a planter box but the function is same. It should be located as close as possible to water source which means gutters, downspouts, rain chain, tank overflow or driveway. This will help the minimizing water loss and provide convenience for reuse of water in gardening.

The size of your rain garden is an another issue. Melbourne Water published a guideline and instruction sheet for people who want to build their own rain gardens in 2010. According to them the size of the rain garden should be approximately 2% of the run-off area.

Bioswales or swales serve the same goals as rain gardens by slowing and filtering storm water. According to the definition of Brad Lancaster, *"Swales are gently sloping trenches meant to slow sheet flow and to allow longer standing /infiltration periods. They are best for low to medium volumes of storm water."*So, they are designed to deal with a high amount of runoff from a large impervious area, such as a parking lots, streets or roadways. On the contrary, rain gardens, generally, are used for residential systems. In addition to that, bioswales are deeper than rain gardens, because they should be a huge shelter for much greater quantities of storm water. Similar to rain gardens, bioswales are vegetated with aquatic plants which can absorb and store run-off water or drought according to the location and climate.

Figure 4.9. Bio-swales examples throughout the streets (Waggoner & Ball Architects, 2013)

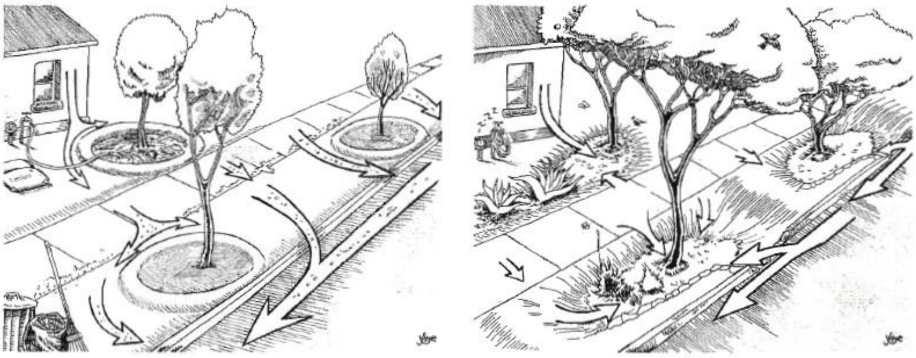

Figure 4.10. A landscape on the wasteful path to scarcity (Lancaster,2006)

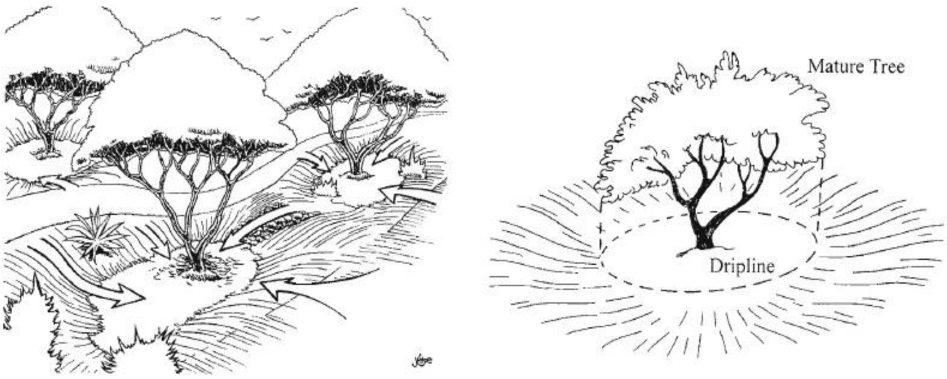

Figure 4.11. A series of infiltration basins intercepting and infiltrating rainfall and runoff from adjoin street and footpath (Lancaster,2006)

French drain interrupts storm water with a trench or basin that is covered with porous materials. In other words, french drains are enveloped with rocks and gravels. These porous material which have minimal spaces between them can permit water into the ground or root zone of the soil. French drains can be constructed with or without perforated pipe and can be dug vertically or horizontally (Lancaster,2006). This pipe transfer water from roof to porous material. Water is directed away from building and filtered. In addition to that these french drains can be used not only roof but also tree pits in the lots to reach same purpose.

Figure 4.12. An example of french drain with gravel- ODTU Teknokent (Personal Archive,2019) (left) French drain infiltrating intercepted runoff from a roof and patio (Lancaster,2006) (right)

Another component which is highly effective way of catching and infiltrating high level of rain water is **terraces.** According to Lanchester (2006), a terrace, sometimes called a bench, should be built in a gently sloped areas. However, if there is an extreme slope, there should be a low wall for the purpose of border and capturing storm water. It is also defined as flat “shelf” of soil. Terraces can have some specific purposes such as gardens, orchards and other plantings. In this system, water flows through terraces incrementally. In this way, infiltration and remediation process are successfully completed and the level of water that is kept by soil and vegetation is increased. However, depending on the terrain, water needs to be bordered by low walls, if the slope is high, or berms for lower slope.

Other significant component of the system is **riparian areas** that create the physical and ecological links between natural land and settlements. They cover much bigger areas and in the world, there are some laws and regulations related with the riparian buffers to retain or repair the natural areas like vegetation. Moreover, they restrict some decision of land use in order to preserve water quality and ecosystems.

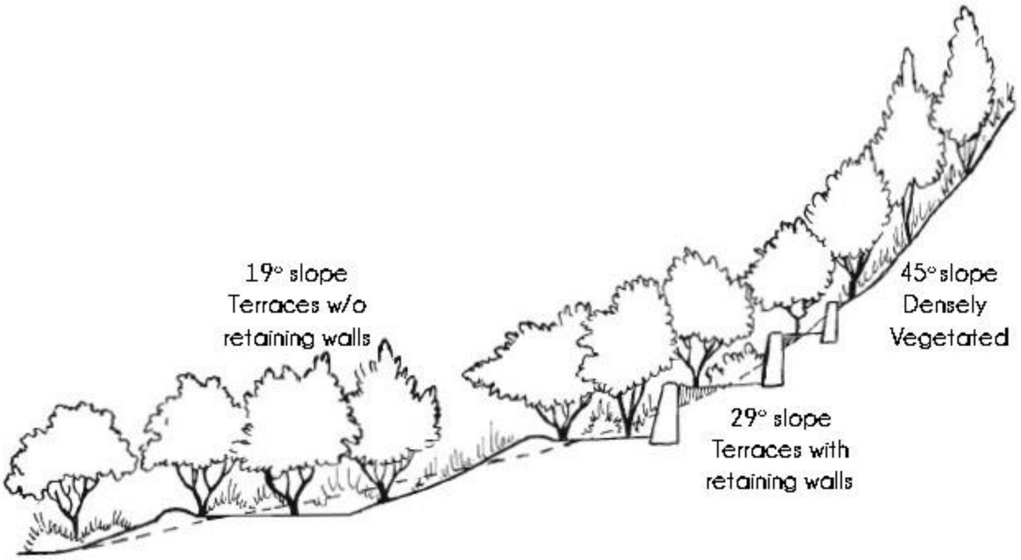

Figure 4.13. Different terracing strategies for different grades of slope (Lancaster,2006)

According to the National Research Council (2002),

"For over 100 years, the term riparian has been closely associated with water law. A riparian water right generally provides a landowner whose property borders a stream, river, or other body of water the right to use a portion of that water for various purposes".

And Council continued to explain the issue as in the urban or regional scale, riparian areas consist of streams, rivers and lakes. Riparian areas receive water from three main sources: groundwater discharge, direct precipitation and overland and shallow subsurface flow from adjacent uplands, and finally flow from the adjacent surface water body. However, groundwater recharge and evapotranspiration are the major losses of riparian buffers.

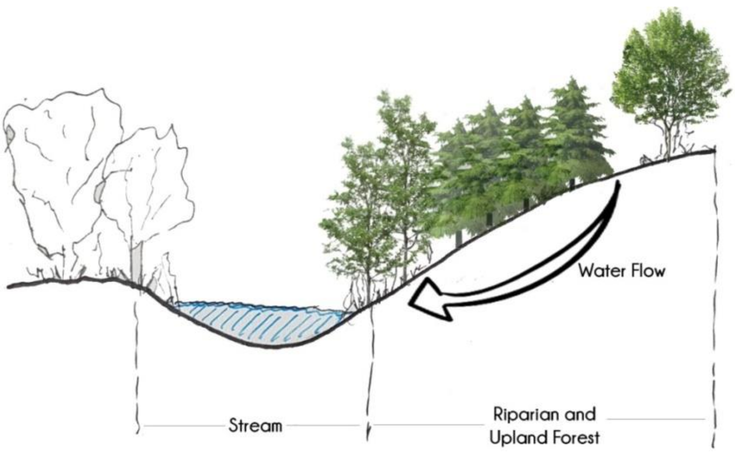

Figure 4.14. Riparian Buffer (Illustrated by author,2019)

So, interaction and relationship with riparian buffers and development areas effects the urban water cycle positively in the background of the system. They are secret and invisible elements of "closing the circle" issue. Precisely for this reason they are necessary and vital.

And lastly, other significant method is phyto-treatment regions. The U.S. Environmental Protection Agency (2002) explain that the concept of **phytoremediation** as below:"*the term phytoremediation (phyto = plant and remediation = correct evil) is relatively new, coined in 1991. Basic information for what is now called phytoremediation comes from a variety of research areas including constructed wetlands, oil spills, and agricultural plant accumulation of heavy metals.*". Many countries all over the world clean up the huge sites with these methods in recent years. These remediation areas serve as both cleaning purpose and recreation purpose in the urban and region context. Because of the vegetation and plants that is used in this system, there is no health or odor problems and phytotreatment regions have high applicability and the cost is low. In the end, interaction of the whole system in the city ends up with phytoremediation areas. This biotechnology and landscape area that absorb the almost whole wastewater and storm water which come from urban land count as a significant passive water catchment area.

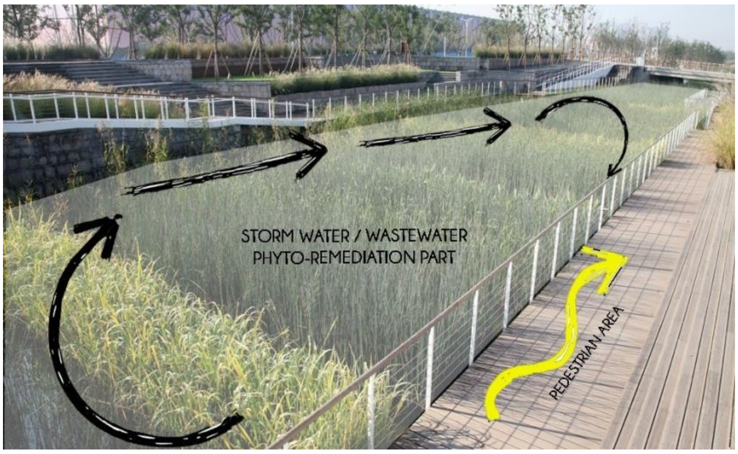

Figure 4.15. Phytoremediation areas with pedestrian access(Adopted from https://events.development.asia/system/files/materials/2015/05/201505-shanghai-houtan-park-landscape-living-system.pdf)

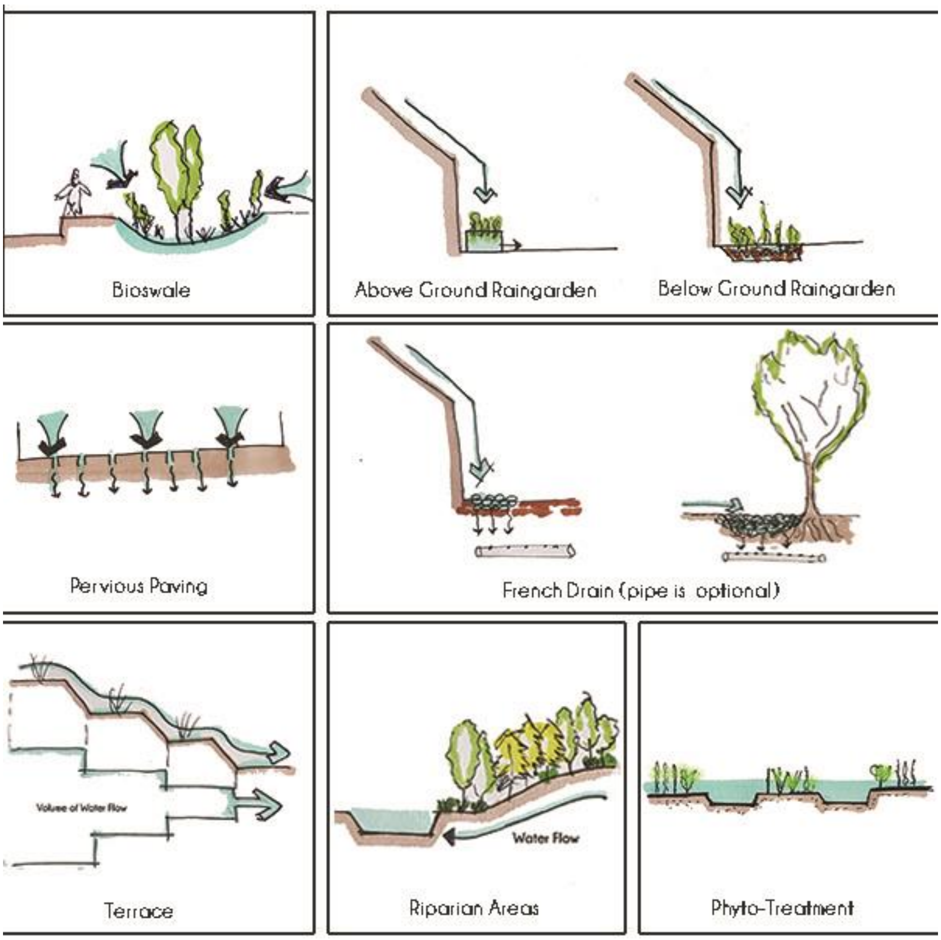

Figure 4.16. Design Guidelines for Passive Storm Water Collection "Earthworks" (Illustrated by author,2019)

4.2. Scaling of Design

4.2.1. In Building Level

In existing system, all buildings have a roof, gutters and downspouts and most of them, one way or another, can be adapted for the water collection system. For this reason most of the elements of a rooftop rainwater harvesting system were already built in the structure. Most houses, apartments or commercial buildings also have landscapes and the structure have irrigation systems. For this reasons, the largest investment in a rainwater harvesting system will be a cistern or a storage tank because in the most houses or commercial buildings, this system was not built with a storage system primarily. Storage systems can be divided mainly into two classes:

- Surface, at-grade or above-ground cisterns
- Below-grade, underground (including partially underground) tanks

Storage of the rainwater can be in above-ground or below-grade cisterns as mentioned earlier but the below-grade storage would be more suitable because of the valuable land especially in the city centers where have limited spaces. So, land provides buildings, green areas or parking lots. On the other hand, if there is an enough land for harvesting and other activities, above ground tanks can be used in the rural settlements or suburban.

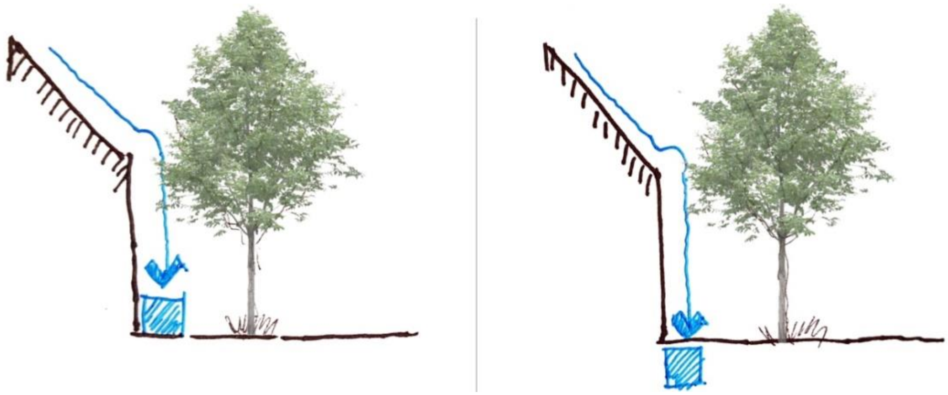

Figure 4.17. Above-ground water tank (left) and below-grade water tank (right) (Illustrated by author,2019)

Gutters, downspouts and rain chains are the most commonly used methods for transferring the captured water from roof to the storage area. Generally, gutters and downspouts carry rainwater from roof surfaces to cisterns and storage tanks. They also transport rain water away from fragile areas such as walkways, doors and protected soils and protect buildings from water damage. On the other hands, rain chains are used mainly in the passive storm water catchment process because they direct water from rooftop to the landscape area by minimizing splash. Gutters and downspouts can be counted as standard household construction materials. Kinkade-Levario (2007) also say that "gutters should have an outer edge higher than the roof-side edge, have splash guards at roof valleys".

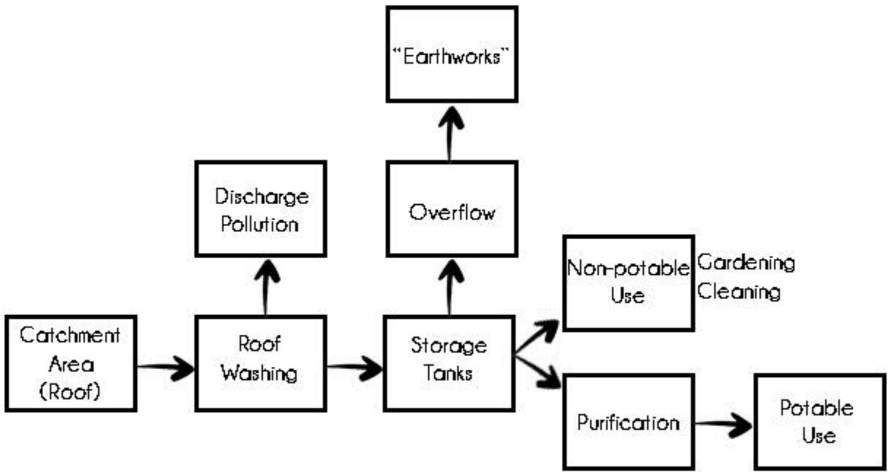

Figure 4.18. Rainwater Harvesting Process (Illustrated by author,2019)

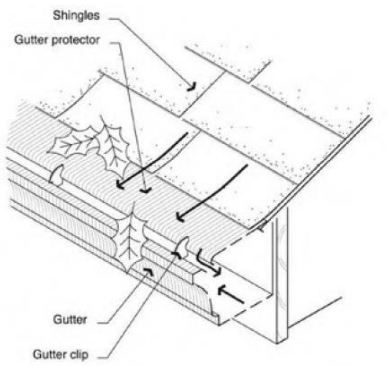

Figure 4.19. Gutter and its protector. Gutter protection is necessary to keep some materials away like leaves. (Kinkade-Levario 2007)

Building a **rain garden** is a simple tool to collect and filter water and help the environment due to water scarce. It is a garden which is designed to filter rain water comes from roofs or other surfaces in the building lots. There are two types of raingarden in general. First one is planter box (Figure 4.17) and the other one is in ground raingarden system (Figure 4.18).

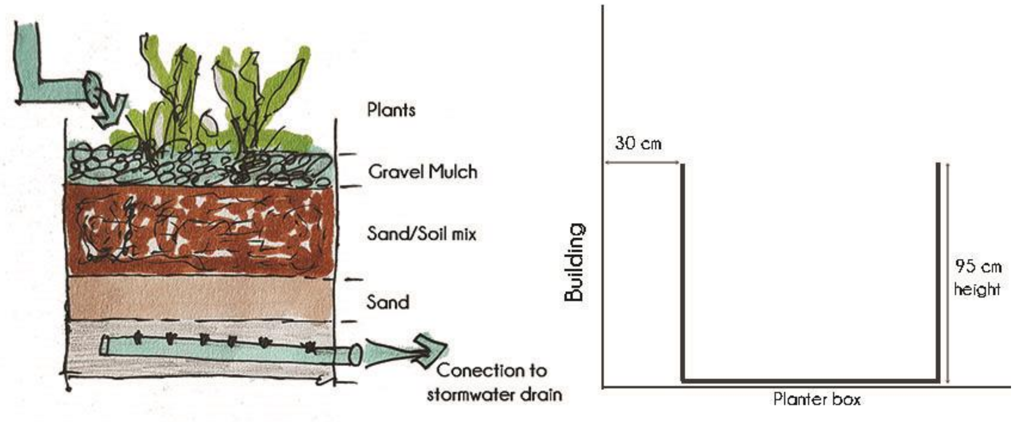

Figure 4.20. Above ground raingarden- Planter Box (Adopted from Melbourne Water,2009)

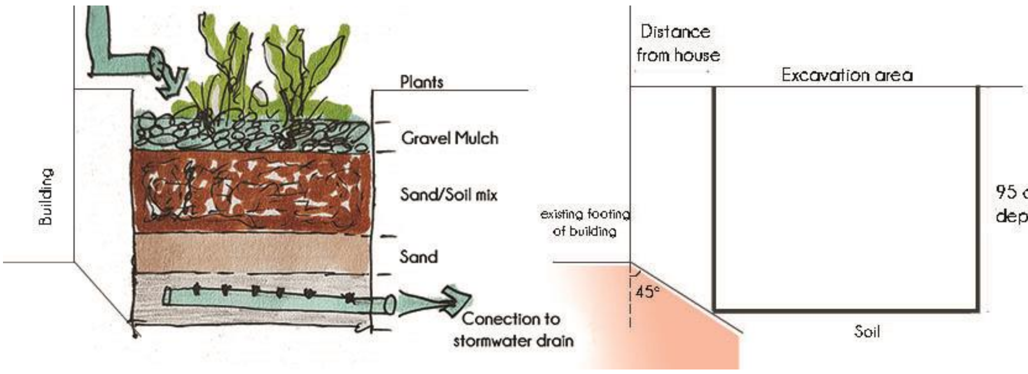

Figure 4.21. Below ground raingarden- Inground (Adopted from Melbourne Water,2009)

According to the Melbourne Water (2009), the most important point in-ground rainwater is relationship between existing footing of building and raingarden minimum distance from building. If the building depth is 15cm, 25cm, 35cm and 45cm, minimum distance of raingarden should be in order 80cm, 70cm, 60cm and 50cm.The required information is given in the table below.

Table 4.2. Building raingarden standards (Melbourne Water,2009)

Area of Runoff (m²)	Raingarden Size (m²)	Existing House Foundation Depth (cm)	Raingarden Min. Distance from Footing (cm)
50	1	15	80
100	2	25	70
150	3	35	60
200	4	45	50
250	5	55	40
300	6	65	30

The second important component of the system is **french drain** or in other words dry well. The aim is stopping storm water with a trench or basin filled with porous materials such as gravel. Thanks to this spaces between material, water can be filtrated in a proper way.

French drains can be constructed both horizontal or vertical. In any case, the function of it does not change. In vertical type of french drain, pipe can transfer water deeper into soil and encouraging root growth. This can increase plant survival in basins up to 65 % (Lancaster,2006). French drain without pipe generally are built in horizontally. Overflow water is transferred directly to the infiltration basin like raingarden or tree pits.

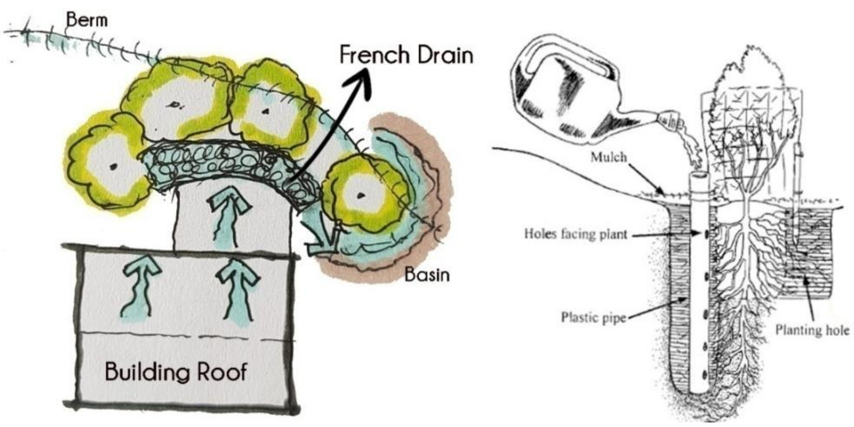

Figure 4.22. French drain in a building lots and its function-horizontal (Illustrated by author,2019) (left), Vertical french drain example (Lancaster,2006) (right)

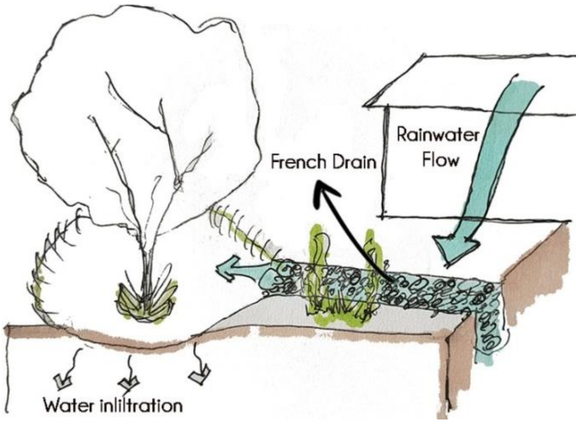

Figure 4.23. French drain without pipe-horizontal (Illustrated by author,2019)

Basically, if **permeable surfaces** are used instead of concrete or asphalt surfaces for driveways or parking area in the lots, estimated runoff efficiency of paved surfaces will be %80 (Lancaster,2006). Relationship with parking space and the rest of lot should be provided with curbs and gently slope land.

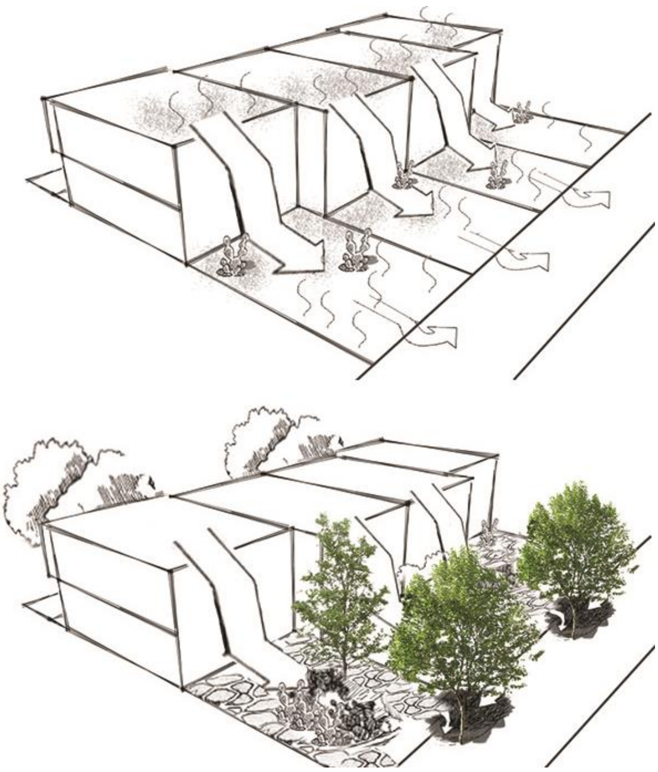

Figure 4.24. *Building level water harvesting with rain gardens and permeable surfaces (Illustrated by author,2019)*

Figure 4.25. Permeable surfaces (gravel) and pavement with vegetation - ODTÜ Teknokent - İkizler Building (Personal Archive,2019)

4.2.1.1. Water Budget

When we came to the amount of water that can be collected from surfaces or catchment area, its estimated calculation depends on some variables. The calculated water determines that the water will meet the people's water demand who live in that area. So, water budget helps us to understand the size of the storage area or tanks and a supply and demand analysis can be estimated by water budget on a weekly, monthly or yearly.

Lancaster (2006) calculated the amount of water on a specific catchment area according to this formula:

"Lot size or catchment area (in square meter) x Average annual rainfall (in millimeters) = Total rainwater falling on a catchment area in an average year (in liters)"

However, runoff efficiencies for urban surfaces can differ from each other. In other words, water collects in different percentage when it falls.

Table 4.3. Estimated Runoff Efficiencies for Urban Surfaces(*Kinkade-Levario 2007)*

Estimated Runoff Efficiencies for Urban Surfaces	
90%	Smooth, impervious roof surface, such as metal, tile, built-up and asphalt shingle roof
80%	Gravel roof and paved surfaces
60%	Treated soil
30%	Natural soil

Kinkade-Levario (2007) explain that the first step is to multiply the catchment area in square feet or meter by the average annual rainfall and then this number is multiplied by the percent efficiency afforded by the collection surface. The result is the amount of rainwater collected from the catchment area. Thus;

"Catchment area (in square meter) x Average annual rainfall (in millimeters) x Efficiency = Total rainwater falling on a catchment area in an average year (in liters)"

After the catchment area is determined as a roof or pavement for car parking etc., if there are some excess storm water, it can be captured and filtered by 'earthwork'. Generally, the earthwork elements for building and lot scale are rain gardens, french drains and parking areas.

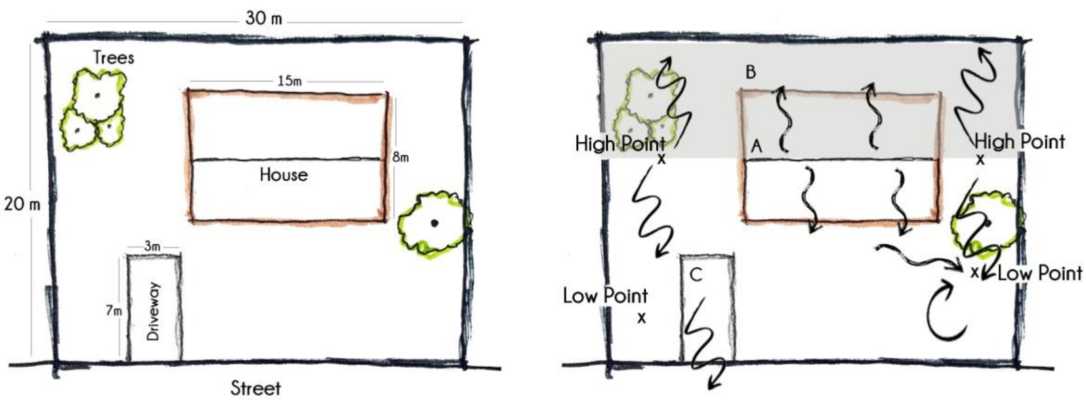

Figure 4.26. Site map 600 m^2 property (left) and a rainy day (right) (Illustrated by author,2019)

Site map of a 600 m^2 property has driveway, house and a few trees. When the rain drops, water flows according to the land through the street.

A- 32400 liters runoff lost from 120 m^2 metal or concrete roof having a 90 % runoff efficient.

B- 36000 liters of runoff lost from 150 m^2 gravel surface having 80 % runoff efficient.

C- 5670 liters of runoff lost from 21 m^2 asphalt driveway having 90 % runoff efficient.

In an average year of 300 mm of rainfall, this area can collect 74070 liters of rainfall. If the landscape is changed, the total volume of water from this site can be increased. Let's say the total area excepted house and driveways is about 300 m^2, according to the formula below, collected storm water is about 27000 liters if there is natural soil having a 30 % efficient. Thus, total volume can be increase 101070 liters from 600 m^2 site.

4.2.2. Case: Rainwater Collection from Faculty of Architecture in METU

Total roof catchment area of the faculty is about 6000 m^2 and total car parking area is about 2300 m^2. In addition to that, according to the Turkish State Meteorological Service (2018), annual rainfall of the city of Ankara is about 388 mm. So, the calculation:

6000 m^2 x 388 mm x 0.90 = 2095200 Total rainwater falling on a catchment area in an average year (in liters)

2300 m^2 x 388 mm x 0.80 = 713920 Total stormwater falling on parking area in an average year (in liters)

When external factors are taken into consideration such as high temperature, drought, the total volume of water can be counted 2000 tons from roof and 700 tons from surface of parking area. And the total amount is about 2700 ton.

And the total water that is joined in water cycle by infiltration and evaporation:

6000 m^2 x 388 mm x 0.10 = 232800 in an average year (in liters)

2300 m^2 x 388 mm x 0.20 = 178480 in an average year (in liters)

So, the total amount of water is about 411280 liters. If we assume that there is no development in that land, total area is 8300 m^2 that is consist of natural soil which have 30% of estimated runoff efficiencies. So, water harvesting calculation is that:

8300 *m^2 x 388 mm x 0.30 = 966120 Total stormwater falling on the area in an average year (in liters)*

And the water that is joined in water cycle by infiltration and evaporation:

8300 m^2 x 388 mm x 0.70 = 2254280 in an average year (in liters)

As a result, differences between developed and undeveloped area in terms of water cycle issue:

2254280 – 411280 = 1843000 liters in an average year. For this reason, 1843 tons of water in the current situation that is in developed land should be regained by active rainwater harvesting from the building roof.

Figure 4.27. Satellite Image of Faculty of Architecture (Google Earth,2019)

4.3. Street Level

Apart from the buildings and lots; roads, boulevards and streets also cover a huge area in urban areas. For this reason, their harvesting and catchment role cannot be underestimated. In the conventional system, they, actually, transfer water and other harmful materials in it to aquifers, rivers or treatment facilities. However, in this water sensitive system, they do not only transfer water. Also, roads and streets slow down storm water and filter some part of it and then carry to aquifer or large scale urban catchment areas such as phytoremediation or riparian ecosystems. They are all connected with each other. Connection is ensured with swales, curbs, tree pits or trenches, parking space, pervious paving and street and front garden relations.

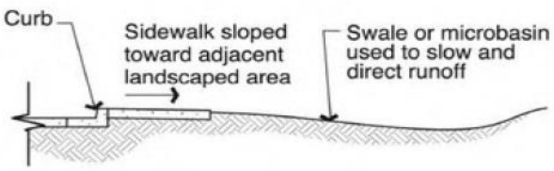

Figure 4.28. Passive rainwater harvesting: parking lot basin accepts site runoff and irrigates vegetation (Lancaster,2006)

Bioswales or swales serve slowing and filtering storm water as mentioned earlier. They have gently slope trenches which slow down and hold the storm water. So, they should be placed next to sidewalks, paths and roads in different size to directly transfer water to vegetation and away from streets and buildings. Figure 4.24 shows that if the sidewalk sloped to drain its water runoff to the street, there will be overflow or flood in the road. However, if the sidewalk wisely sloped to drain its runoff to tree basin and swale which is located next to the pathway, overflow water will be moved away from the road and it directed to swales.

Figure 4.29. Street section with bioswale, pervious pavement and collection (Illustrated by author,2019)

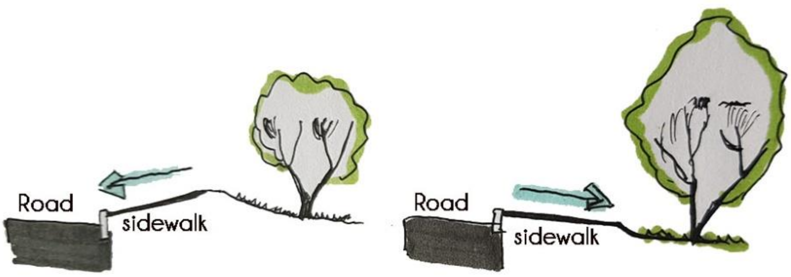

Figure 4.30. Sidewalk wastefully sloped to drain its runoff to the street (left) and sidewalk wisely sloped to drain its runoff to adjoining tree basin. (right) (Illustrated by author,2019)

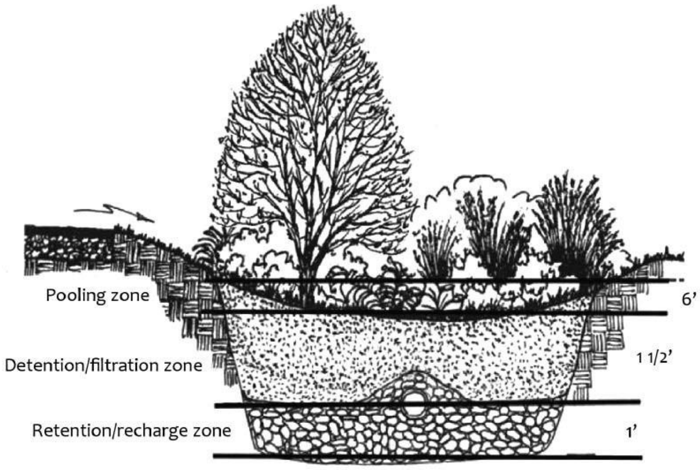

Figure 4.31. Typical cross section of a swale (Texas A&M Agrilife Extention,2012)

A typical swale should have some zones for successful infiltrating and harvesting. As it is seen in the drawing above, pool zone which has vegetation, filtration zone and recharge zone with gravels and rocks. Filtrated water can be collected with pipes or directly infiltrated by earth.

Pathways should be elevated as regards the path which is followed by surface water. While raised pathways design can help people to access from one point to another, in the meantime water can transfer from drive and walkway to planted areas. So, pedestrian way can be protected from surface flow.

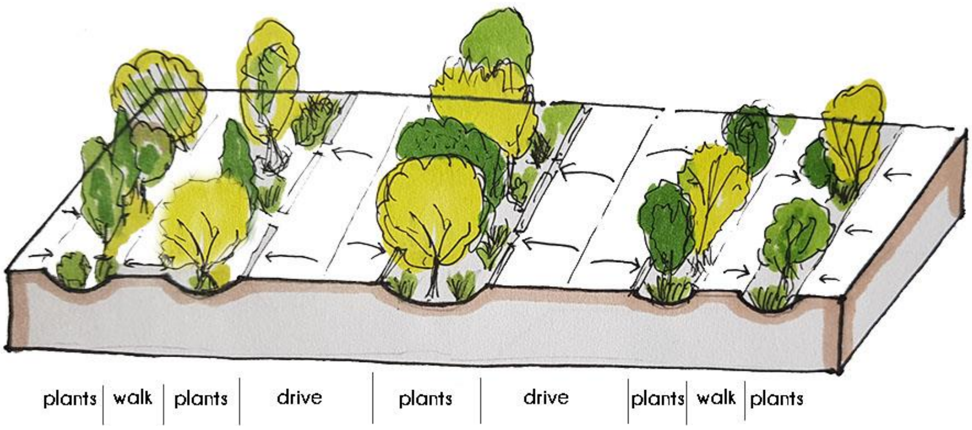

Figure 4.32. Rised pathway and driveway (Illustrated by author,2019)

In order to capture the overflow water in the street level, another design strategy is building a french drain beside a driveway. Like in the implementation of swale, stormwater is filtrated by gravel and rocks and overflow can transfer to the ground or depending on the volume of water it can be directed to vegetated areas.

Figure 4.33. A pipeless french drain beside a driveway (left) and tree pits (right) (Illustrated by author,2019)

As it seen in the below (Figure 4.28 and Figure 4.29), when the permeable surfaces increase, filtration of water starts to become easier. Thus, more water is involved in the hydrologic cycle. This method tries to use as many surfaces as possible in the street level to achieve maximum efficiency for collection. In addition, angular particles are more porous and stable compared to mixed size particles.

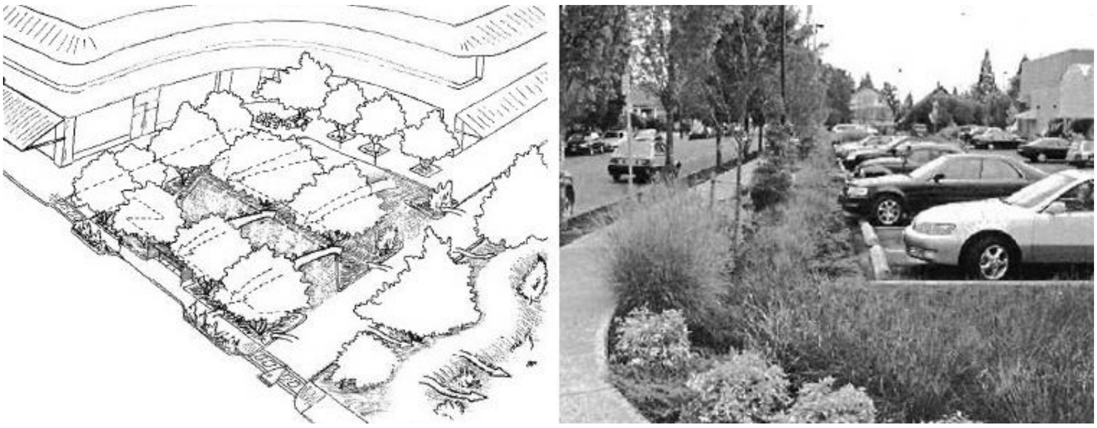

Figure 4.34. Parking lot with permeable pavement and planting of trees**(**Lancaster,2006)

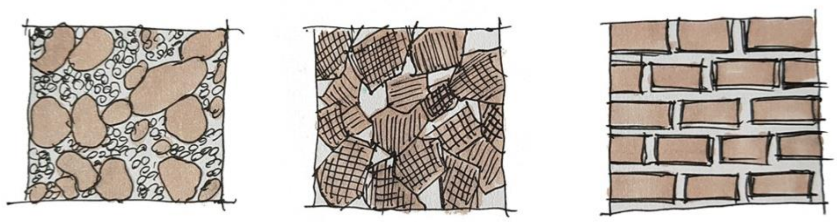

Figure 4.35. Mixed size particles (left), Angular particles (middle) and big Regular particles (Illustrated by author, 2019)

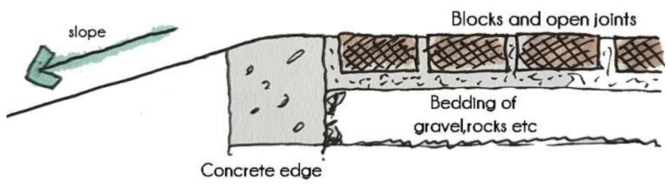

Figure 4.36. Typical open jointed pavement (Illustrated by author, 2019)

4.3.1. Case: New Orleans Urban Water Plan

The Greater New Orleans Urban Water Plan consist of water-based infrastructure and urban design proposals. Because the area has always deal with flooding from rainfall. In addition to that, in the near future the city will face with some new problems such as rising seas, climate change and population density because of the coastal location.

The Urban water plan is not about a single solution for the water related problems. Long-term strategies which includes region, street and neighborhood level implementations. In this part of the study, street scale design strategies and guidelines will be explained.

Many streets are in poor condition in terms of dealing with overflows. This plan proposes a "Lafitte Blueway Corridors" which is a linear open spaces. It includes pedestrian way, bicycle path and recreational amenities throughout the streets. This corridor creates an opportunity within the heart of the city by collecting and storing the water. Waggoner and Ball Architecture (2013) explain that *" the Blueway is a key element of a sustainable water management system, necessary for mitigating flooding, recharging groundwater, and improving water quality."*

Figure 4.37. Lafitte Blueway Context Map (Waggoner & Ball Architects, 2013)

Figure 4.38. Existing situation (left) and potential (right)
(Waggoner & Ball Architects, 2013)

Another example is "Eastern Water Walk" which is sited in a commercial area of New Orleans. Water Walk searches to identify the design conflict between stormwater management and economic development. To define stormwater demands on-site, this proposal integrates a system for stormwater collection in the street. This main street is considered as the main spine of the system with swales and tree pits which is located on both side of the street and pedestrian way.

Figure 4.39. Water Walk stormwater conceptual (left) and potential implementation (right) (Waggoner & Ball Architects, 2013)

4.4. Region or Urban Level

In the region or urban level, the system ends up with a much bigger spaces where rehabilitative and comprehensive water system is sustained. These areas can be located both in the city center, near the city and close to water resources like river or lakes. It can be thought that these regional scale design implementations are buffer areas between urban and natural areas. Negative effects of urban settlements can be decreased in this kind of area and consolidation of water system can be provided. Street scale and building scale implementations need a wider perspective in this system. How do these small scale design parts affect urban in total and what is needed for completion of the system? Consolidation of water cycle system highly depends on supplementary region. So, relationship from building to regional scale implementations have a significant role.

In this study, there are mainly two types of regional scale implementation. First one is riparian areas and the second one is phyto-treatment or phytoremediation areas.

Riparian areas are highly vegetated to retain and repair the natural water systems. They can create a physical and ecological link between urban settlements and natural land

and are mainly located near streams, lakes and water resources. This regional part of the system collect water from three major sources: groundwater discharge, direct rainfall and subsurface flow from uplands.

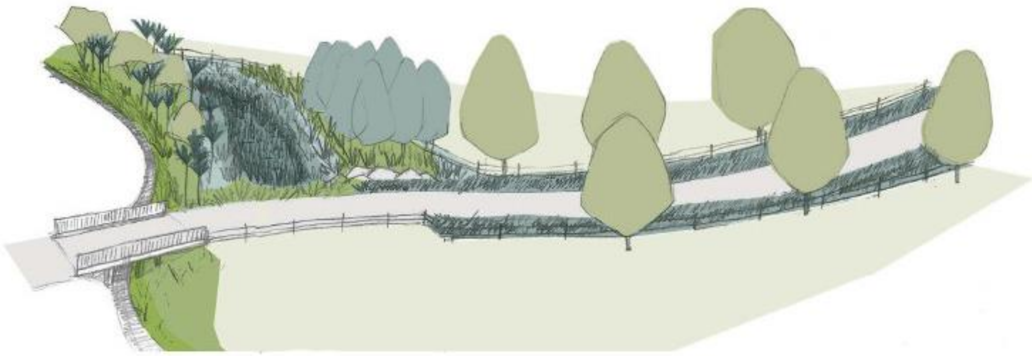

Figure 4.40. Riparian areas as an example of passive treatment of storm water (Auckland Council,2015)

In this hybrid and integrated system, storm water can be a significant supply because storm water is not collected with waste water in the conventional infrastructure system mainly. Excess water and floods can be handled in this kind of natural large scale implementations. Also, riparian buffers balance environmental systems and habitat. Water is transferred beyond rooting zone in vegetated areas with deep well-drained soils. However, there is an excess surface water in arid landscapes which have low permeability (Figure 4.41).

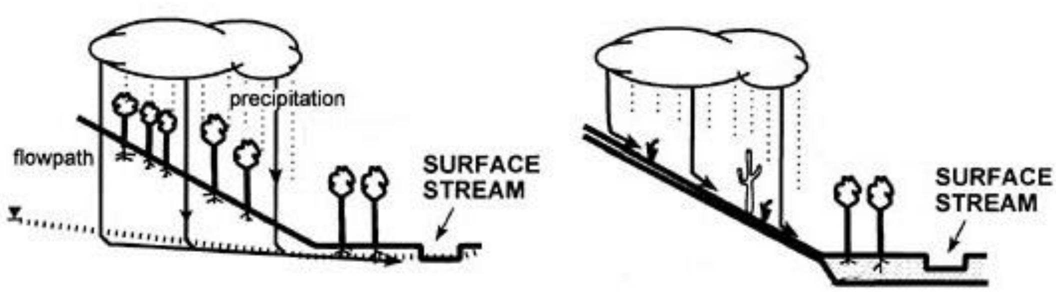

Figure 4.41. With riparian (left) and without riparian regions (right) (Adopted from National Academy of Sciences,2002)

When it comes to **phyto-remediation** areas, it is a little bit different than riparian areas. These remediation areas consist of some kind of pool, water and vegetation which can grow in water and absorb contaminations. They work as a treatment plant but it is a natural system and more economic compared to treatment plants. According to the slope, it can be designed with terraces method. Thus, water can be slow downed and captured easily.

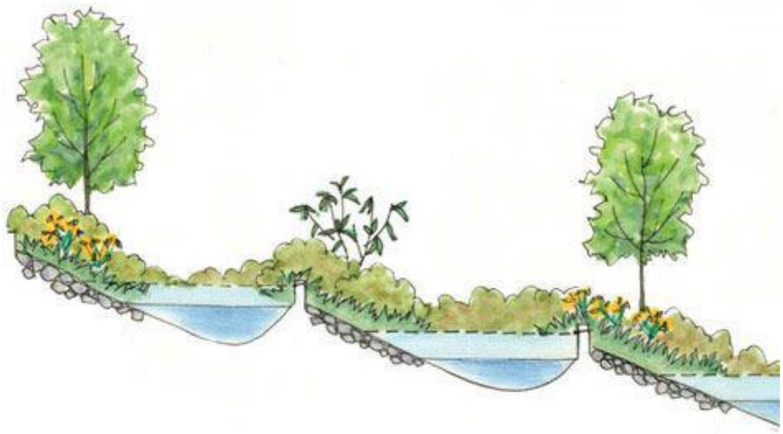

Figure 4.42. Phyto-remediation pools in the system (Source: Pinterest, Accessed in March 2019)

Phyto-treatment areas can clean both wastewater and storm water according to the needs and design guidelines in the system. Remediation areas also cover huge area but it can work small scale implementation. Vegetation which is selected according to climate condition can decontaminate the water in a sustainable way and cleaned water can be used for gardening, irrigation and toilet flushing.

Like riparian areas, phyto-treatment regions can create a physical and ecological link between urban settlements and natural land. The water which are collected by earthworks in small scale implementation transferred to remediation areas in this integrated system. When the water is cleaned up, in the meantime people can use this area as a recreational purpose. It contributes the idea of "closing the circle".

4.4.1. Case: Qunli Stormwater Urban Wetland Park

In 2006, Qunli New Town was planned as a new urban settlement which cover 2733 hectares near the Haerbin City of North China. However, 16.4 % of the land was designed as permeable green space. The area has 567 mm annual rainfall in June through August and water problems have been showed up before (Turenscape,2010).

Figure 4.43. Qunli Stormwater wetland park (Turenscape Landscape Architecture,2010)

So, planners decided to design a park that cover almost 34 hectares in the city center. Selected area is a former wetland but it is under the threat of disappear because of wetland is surrounded by roads and dense urban development. To protect the natural wetland area, decision makers transform the area into the urban stormwater park.

Figure 4.44. Location of the wetland park in the urban area (Turenscape Landscape Architecture,2010)

Solution is basically cut and fill technique to create ponds but major core of wetland will be maintained as it is. The major implementation will be done mainly periphery of the site, in other words, ponds and mounds surrounds the area. Moreover, network of the site is created with pathways, skywalks and bridges between ponds and wetland. Planners explain the idea (2010):

"The pond-and-mound ring surrounding the periphery of the wetland creates a stormwater filtrating and cleansing buffer zone for the core wetland, and a welcoming landscape filter between nature and city."

Stormwater that comes from built area is collected with pipes around the wetland parks and then filtrated and stored, finally the water is transferred to ponds and wetland. There are also native vegetation and trees to filtrate and clean the water in this site. This project shows that on one hand, remediation areas in the city center protect the natural land, on the other hand, ecosystem services used by people are supported with this kind of regional wetlands.

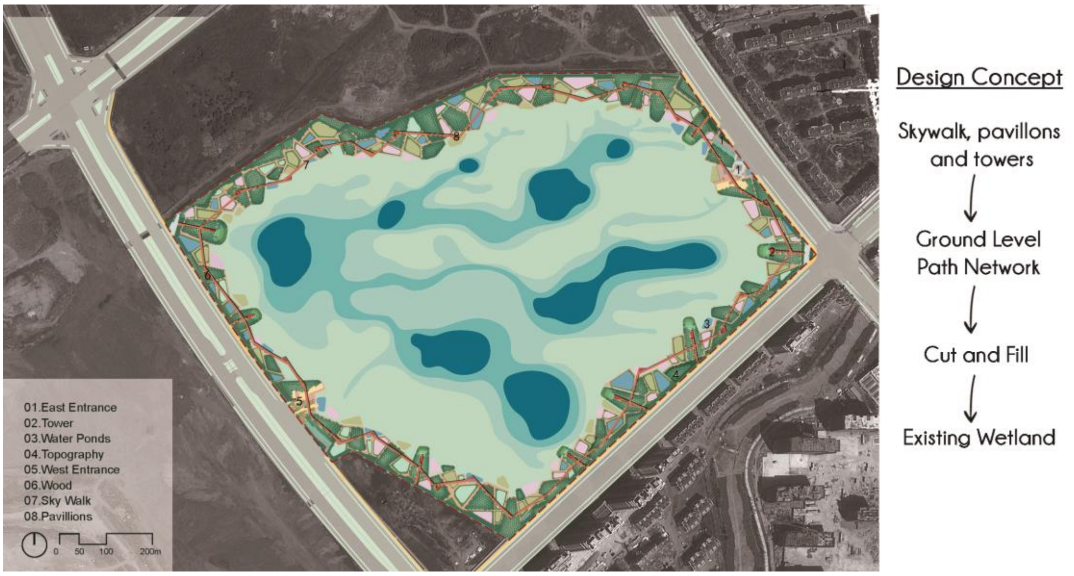

Figure 4.45. Master plan of the site (Turenscape Landscape Architecture,2010)

4.4.2. Case: Yanweizhou Park in Jinhua City

The park is located in the center of densely populated Jinhua City, China and it locates at the intersection of three 100 meter wider rivers (Turenscape,2010). So, there is a bridge connection for city and nature. Total natural wetland area is about 26 ha and this place had remained undeveloped until cultural activities (concert hall and green spaces) begin to take place. One of the main question in this project is that how can the existing structure be integrated into surrounding environment to create sustainable and riparian landscape?

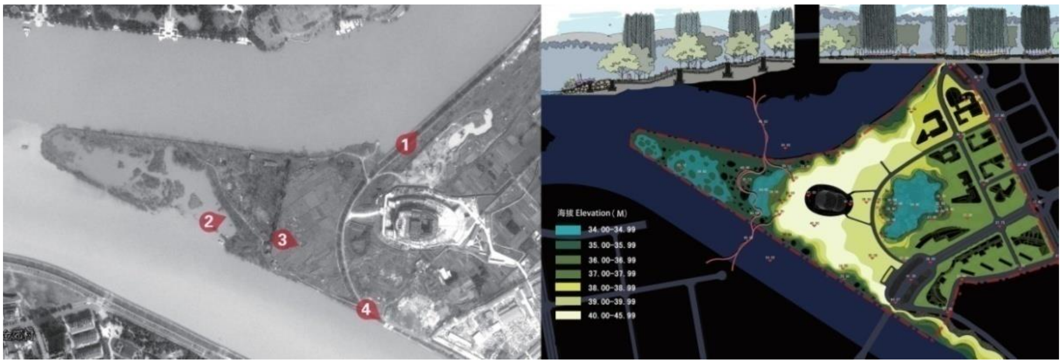

Figure 4.46. Existing site (left) and the site plan for a resilient landscape (right) (Turenscape Landscape Architecture,2014)

For this reason, it is a successful example for riparian areas in the scale of region. To achieve successful project, they used some adaptive strategies. First one is using existing riparian areas and vegetation to protect habitat. Second strategy is that, instead of concrete floodwalls which destroy the ecosystem, they used a "cut and fill strategy" by implementing water resilient terraced river embankment that contain flood adapted native vegetation. This terraces works not only for flood but also remediate and filtrate the stormwater from the pavement.

Figure 4.47. Preexisting site in 2011 (left) and transformation in 2014 (right) (Turenscape Landscape Architecture,2014)

In addition to the terrace strategy, permeable space strategy is created in the inland area of this park. The surface of the inland area is mainly covered with permeable surfaces. Gravel that is reused material from the site, bioswales and vegetation can filtrate the water and protect the cultural centers and pedestrian areas. Permeable concrete pavement is used for driveway and parking areas. The terraces create safety zone for people to use that area as a recreational purpose.

Also, there are some inner ponds on the inland area. The reason behind its construction is allowing water to infiltrate from the river through the gravel layers, thus water can clean up and become swimmable.

Figure 4.48. Permeable surfaces from inland area
(Turenscape Landscape Architecture,2014)

Figure 4.49. Inner pond and pathways in terraces
(Turenscape Landscape Architecture,2014)

CHAPTER 5

CONCLUSION

Arguments over water are resolved by rain.

Japanese proverb

The final chapter discuss that water scarcity and fresh water supply start to become primary concern for sustainable urban life in today's world. Because accessing fresh water is not equal for everyone. It mainly depends on location, climate, existing water resources, population and density. In addition to that, people's habit can also affect water needs. So, urban and nature should be in balanced relationship to maintain the fresh water. When nature and urban areas come across, urban water infrastructure appears. Apart from conventional water system, new sustainable implementations also started to appear. In this part of the study, main concern of the thesis which is "design with water" discussed and it includes evaluation of the study, a summary of design guidelines, contribution and limitation of the study.

5.1. A Summary and Evaluation of the Thesis

First of all, the framework of the study has been defined in the introduction part. Importance and meaning of water for human and environment has been discussed and in this sense, problem definition which is determined as “water scarcity for all”, has emphasized. When built environment and natural areas come across with each other, we can recognize the reflection of effects in a negative way into both urban and natural areas. In this case, this negative effects show up as water related problems. This is why this study focuses on urban-water relationship. So, this thesis is consisted of four major section:

-Aim of the study

-Urban water cycle and hydrologic components

-Urban water infrastructure

-Re-structuring urban with water

In the second part, definition of water cycle and its components have been identified in detail. This section is an important issue in terms of understanding the different kinds of water and relationships with each other's. Hydrologic cycle or in other words water cycle, in nature and urban settlements differentiated because of the path that is followed by water. Moreover, in general opinion, urban areas change the water cycle concept in a negative way or it set obstacle to flow of water. While water cycle and its basic elements which are temperature, precipitation, evaporation, infiltration and runoff were mentioned, impact of urbanization and land development also examined. The most significant point is impervious surfaces in urban settlements. Because, handicap as mentioned earlier as an obstacle is decreasing hydrologic flow in cities. So, water types which are located in urban areas have explained in four parts: storm water, wastewater, surface water and groundwater.

Table 5.1. Sources, Types of water, The key issue and problems(Illustrated by author,2019)

Soures	Types of Water:	The Key Issue:	Depending on:	Problem:
Rain	Storm water	Storage	Location and climate	Flood, overflow, street runoff
Used water	Wastewater	Reuse	Habit of use, Economical activity like industry	Pollution of fresh water supply
Lakes, Rivers	Surface water	Maintenance	Natural resources	Drought, polution, habitat destruction
Leakage	Ground water	Recharge	Natural resources	Excessive depletion Pollution of fresh water supply

All water types and relationships end up with infrastructure issue in the urban context for water management. The following section has focused the infrastructure concept. Stormwater, wastewater surface water and groundwater are related with infrastructure but especially, wastewater and stormwater are the most problematic ones in urban settlements. Historical development of infrastructure system shows that people have always marvelous ability to deal with water.

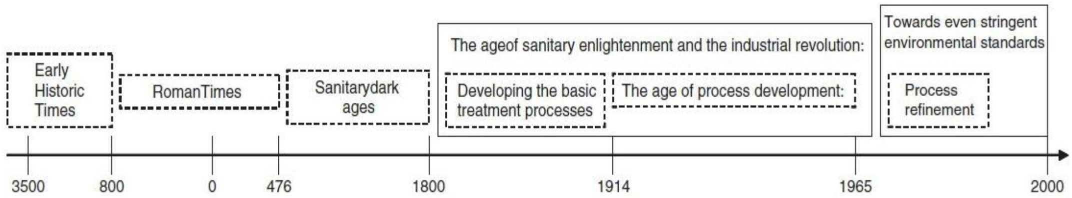

Figure 5.1. Sanitation Timeline (Brown & Lofrano,2010)

Components of the urban water infrastructure can be summarized as water supply, drinking water, wastewater and finally storm water. For the water supply issue, conventional and non-conventional water resources have explained because water is not distributed equally in the world and quality of water also can change. For this reason, the gap between water demand and supply is a component of water infrastructure. The other subject is drinking water. Because freshwater supply is primarily used for municipal, industrial and irrigation purposes, drinking water supply system is a little bit problematic. When it comes to wastewater collection and treatment, public health is the major concern. From past to present, general trend for solution is building a treatment plants for municipal and industrial wastewaters. However, in today’s world there are a lot of regions and urban areas where lack of wastewater treatment and management. 76% of high and high-middle income countries, excluding much of Africa and Asia, have a sewer connection and 18% of them used on-site facilities like septic tank (UN,2018). Most importantly, wastewater is treated together with stormwater because they are combined in the infrastructure systems in the urban area. From there, we come to a discussion on central and local management and system. There are some positive and negative sides both centralized and decentralized system. Building completely a new system has some difficulties such as economic and environmental because of the existing conventional system. Thus, from decentralized building scale to centralized regional scale, each phase has some significant implementations and all of them can be practicable for sustain fresh water supply and natural water cycle.

Table 5.2. Enter Water in Physical, Social, Ecological and Economic Meaning Illustrated by author,2019

MEANING OF WATER			
PHYSICAL	**SOCIAL**	**ECOLOGICAL**	**ECONOMIC**
-Landuse decision -Architectural decision -Infrastructure	-Sense of place -Open spaces -Green areas -Recreational areas and flexible uses	-Closing the circle -Habitat -Rehabilitation of nature	-Easily applicable for everyone -More cheaper than treatment plants and conventional water infrastructure

Finally, let water in! In the last chapter, water is allowed to enter the city for shaping "urban". It is not seen as something to prevent, on the contrary, water should be located into the city. To illustrate how water can be a tool for urban design and implementation guidelines, worldwide applied examples were examined and analyzed. The water is not only a recreational and aesthetic value but also it is a need for people and environments. It is easy to manage water in nature but in the urban settlements it needs more attentions. The method is dividing urban settlements some different scales. These are building scale, street scale, region scale.

Following that, there are two main branches in this vertical perspective of the system. These are active rainwater and passive stormwater catchment system. While active collection needs a specific intervention such as tanks and pipes, passive collection system can collect, filtrate and transfer water by itself with the help of "earthworks". People and society should try to understand the land as a whole and think that rain can be a primary water source for specific usage. The new understand should include starting at the top point of catchment area and following to the down. So, runoff and overflow water can be slowed down and infiltrated with native vegetation, trees and soil.

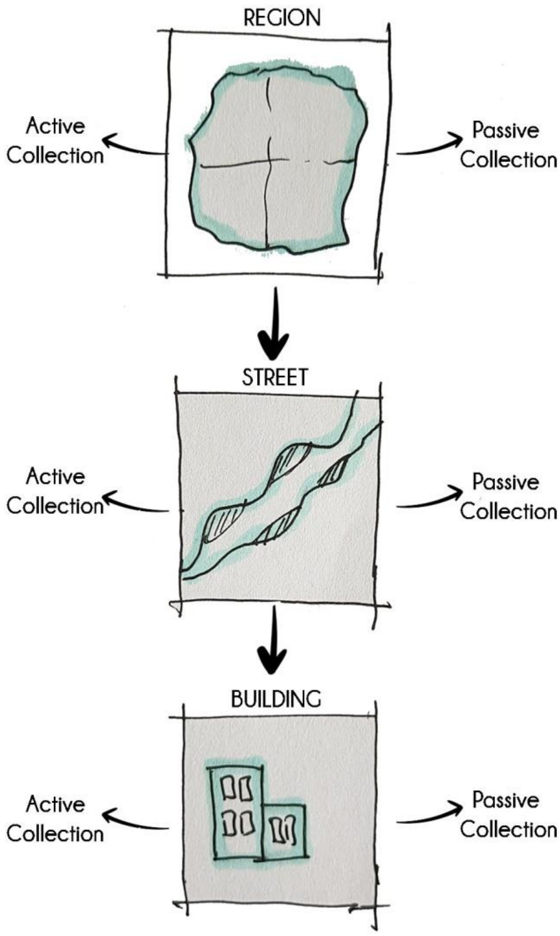

Figure 5.2. Vertical and horizontal scaling

The main hypothesis of this study is that water is valuable but scarce. No matter the location, region or country; whole world is suffering from scarcity and it will increase because of demand-supply relation, population and climate change. So, aim of this thesis is to find a "space" for water in the urban areas. The idea has been supported by literature review and applied examples in the world as case studies. Researches on water sensitive design from region to building level has showed the impact of water on urban areas. The problem of water supply issue can be solved successfully through a new approach.

5.2. Design with Water: Re-structuring Urban Fabric Design Guidelines

At the end of the study, it is concluded that urban areas can be shaped with these design guidelines. They consist of both active and passive collection types in the three major scales which is building, street and region. All implementations can be adopted almost in any scale and in the end these three scale dimensions form the integrated urban design. Major aim of implementation is that first slowing down the water, after that capturing and finally reusing the water according to needs. Design guidelines focus on the water in the urban areas not under the urban settlements.

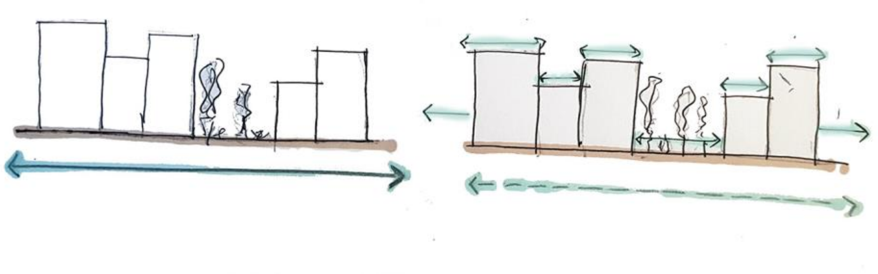

Figure 5.3. Centralized (under the city) - Decentralized (in the city) urban areas

Table 5.3. Comparison with Active Stormwater Collection and Passive Rainwater Collection

	ACTIVE STORMWATER COLLECTION EARTHWORKS	PASSIVE RAINWATER COLLECTION TANKS / CISTERNS
Water uses	Catches large quantity of water and supply high quality rainwater for garden and landscape	Water quality can change according to catchment surface and tank material. It provides water for drinking, gardening, washing and toilet flushing.
Water collection areas	From roofs,streets,vegetated areas, gardens, grey water from bath etc	Mostly metal and tiled roof surfaces.
Water storage	Large potential because of soil, infiltration is high	Capacity is limited by the size of tanks and roofs. Excess water transfers to "earthworks".
Cost	Construction is not expensive. You can shape earth with basic tools.	It is more expensive than earthworks because it changes according to construction of tanks, materials, pipes etc.
Location	It should not be located with in 3 m of wall or building. It is difficult to use in very small yards.	It can be located within 3 m of wall or building, also located in ground or in building.
Storage	Water can be stored for a short time.	Water is available for a long time. It can be used after storage process.
Impacts on urban infrastructure	It can capture large volumes of water, decreasing need for municipal water, stormwater treatment and decreasing overflow.	It can catch low to moderate volumes of water, it also reducing demand for municipal water, storm water treaatment and decreasing overflow.
Efects on water cycle	It can recharge water to the groundwater, highly positive effects on pollution control	It reduces groundwater depletion because of using rainwater storage instead of municipal water.

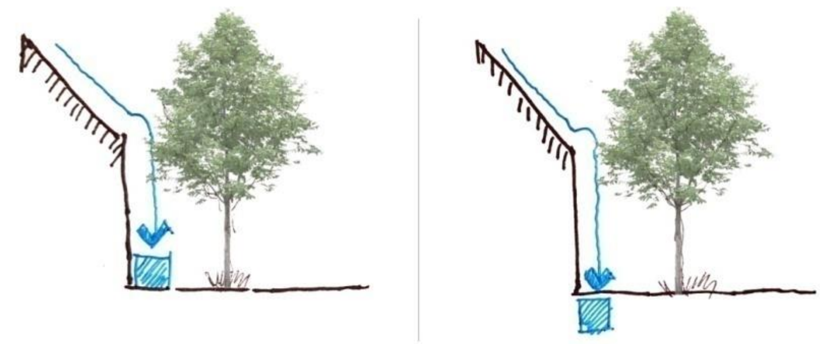

Figure 5.4. Active rainwater collection system-Above and Below ground tank (Illustrated by author,2019)

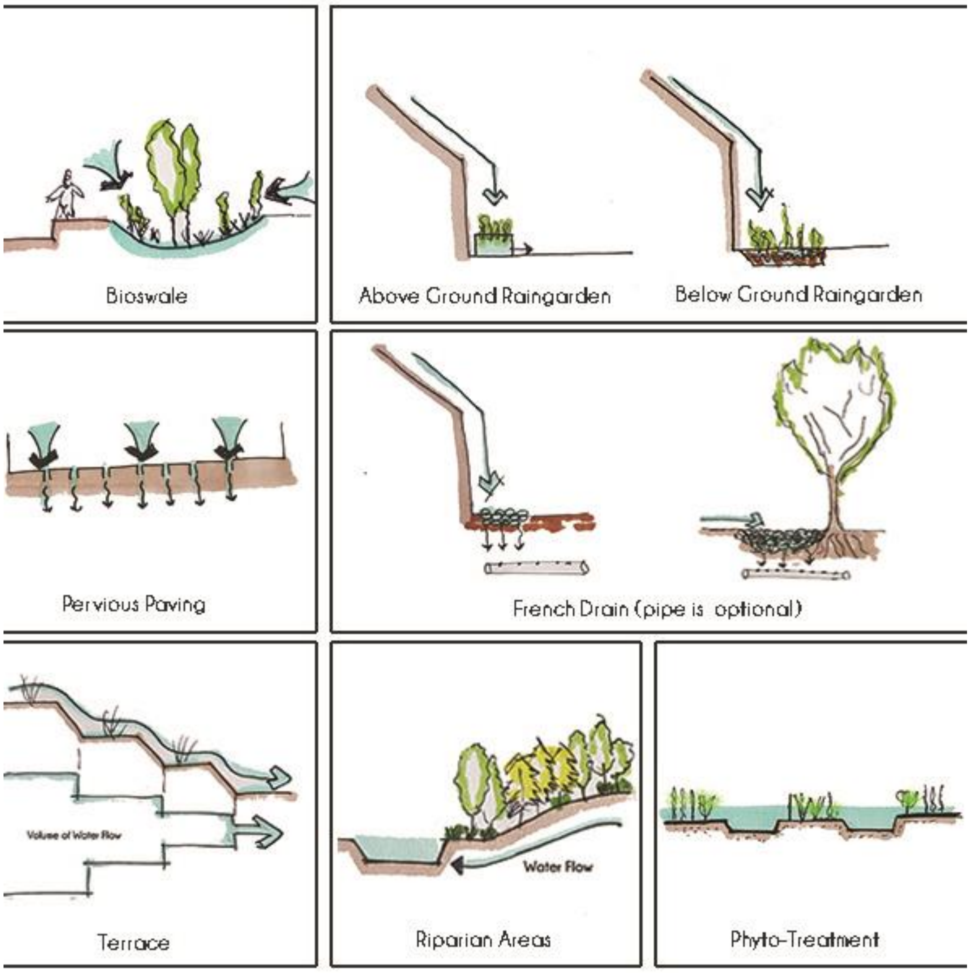

Figure 5.5. Passive stormwater collection design guidelines (Illustrated by author,2019)

The new hybrid system causes significant changes in urban form. When the existing infrastructure system and city form are considered together, there is a network covering the whole city. And in this system, all rain water and waste water are squeezed under the urban fabric and tried to be removed. Consequently, trying to solve the problems under the city does not save the current situation and does not provide a solution for the future. Taking water into the city provides important opportunities for rain water, both in terms of achieving a natural balance and reusing water.

It is also important to draw attention to the following points about water:

- Water is not only for human needs.
- Water should not be considered as only a decorative element.
- Interaction of water and urban creates infrastructure systems.
- Water sensitive design can form common spaces for people in the city while closing the water cycle in the upper scale.
- Implementation in building, street and region scales can link urban and natural system.

As mentioned in the previous chapters, it is the most basic way of ensuring the water cycle in the city by reusing the rain water in the building-parcel relationship with the design principles provided at the local scale and ensuring the infiltration of excess water to the soil. The advocated point is to collect and use rain water that removes from the city scale through pipe systems and to provide local resources. In other words, most of the infrastructure lines covering the whole city will not be needed in the local system.

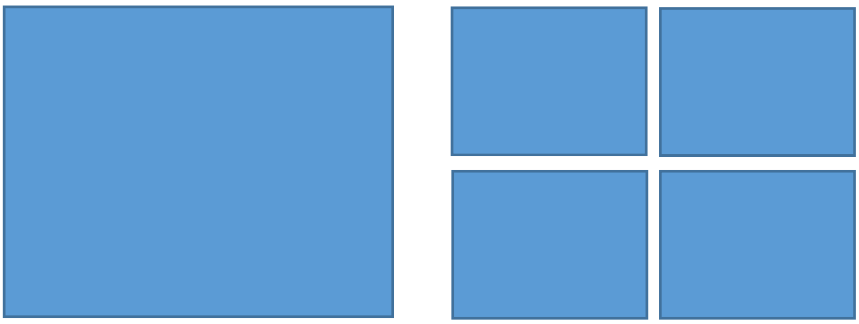

Figure 5.6. Centralized- Decentralized System (Localization)

On the building-parcel scale, water can be collected and stored by the roof, parking area or garden. However, due to the density of buildings in the city centers, the parcel-building relationship can differ from the housing areas. Therefore, in the context of water harvesting, the roof of the building is more important than the open area in the parcel. For this reason, the water problem in the city center should be solved by transferring excess water to the designated areas on the street scale like bio-swales. As the parcel-building relationship changes as we move away from the city center, the catchment area can be used to transmit excess rain water to the soil and from there to ground water. Rain gardens and french drains can be used for that purpose.

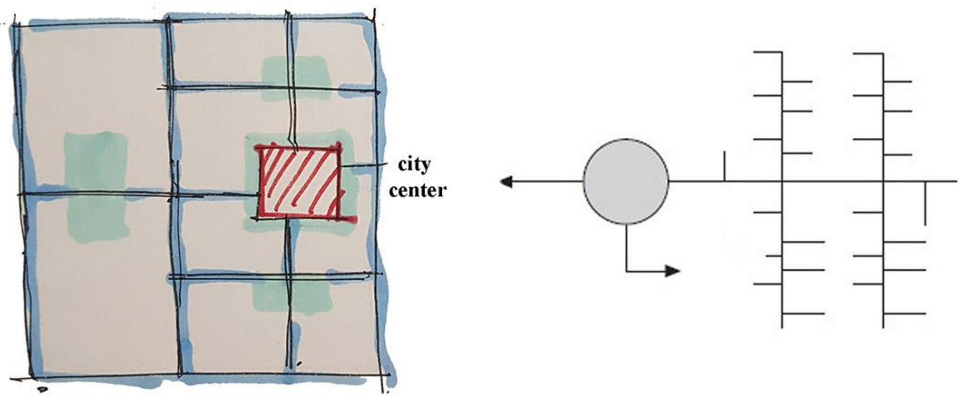

Figure 5.7. From rural to urban center infrastructure system (Bakir,2001)

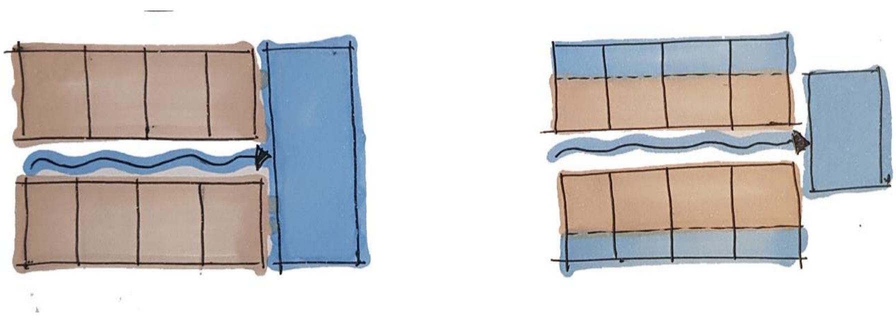

Figure 5.8. Building-lot relationship in city center (left) and residential areas (right) (Illustrated by author, 2019)

In connection with water reconstruction, can it be thought that the division of the urban areas in the decentralized system is similar with golden ratio? Can the decentralized system be the solution to water related problems and sustaining water cycle when urban form and golden ratio are overlapped? From city center to rural area implementation scale can vary and the water issue can be solved from different group of the urban areas. As mentioned before, high level of population and density in the city center requires different kind of solution such as harvesting from building roof and transferring excess water away from the city center. So, excess water can be transferred from the smallest square to the next one, in other words, from building to urban level. Water harvesting, cleaning and reusing can be done in each square, so infrastructure lines under the urban settlements may not be needed.

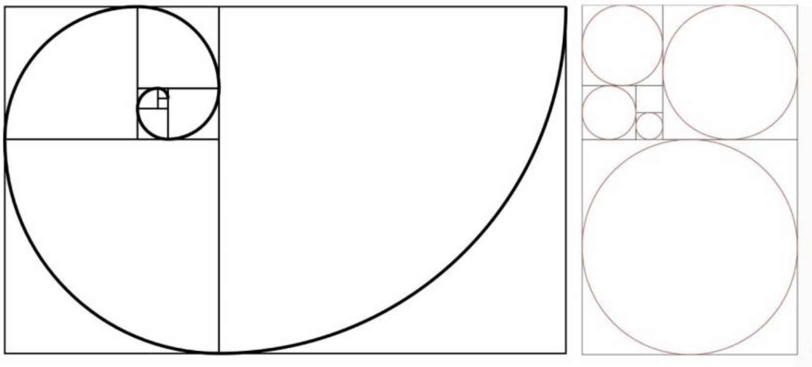

Figure 5.9. Are golden ratio and decentralized urban water system similar?

Street-scale intervention forms can be used to transfer water to larger-scale riparian or phyto-treatment areas, such as neighborhoods or districts. The zig-zag model emphasized on the parcel scale can also be considered on a larger scale (Figure 5.9). This model can be applied to the city together with the topography and stream beds considering that the small open areas reach to larger open areas in total. Here comes the issue of riparian areas and phyto-treatment regions. These regions can be considered as the areas mentioned in the design principles that water has reached in the city last. Although these areas, which can accommodate natural river beds and basins, are considered as water resources and treatment areas, they are considered as flexible spaces in this study. As in the case of Qunli, it contains both rooms for water and recreational areas for people. As it is more difficult to locate such large areas in the city center, street level design guideline is an important point in this issue.

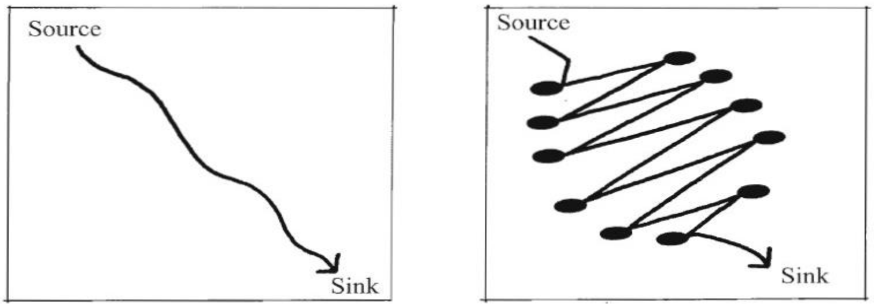

Figure 5.10. Fast and directly water flow to the landscape (left) and the zig zag method increases the time of water flow and water travels more distance and the level of infiltration increases from source to sink (right) (Lancaster,2006)

Figure 5.11. Undeveloped land (right) and post development (left) (Tjandraatmadja et al., 2014)

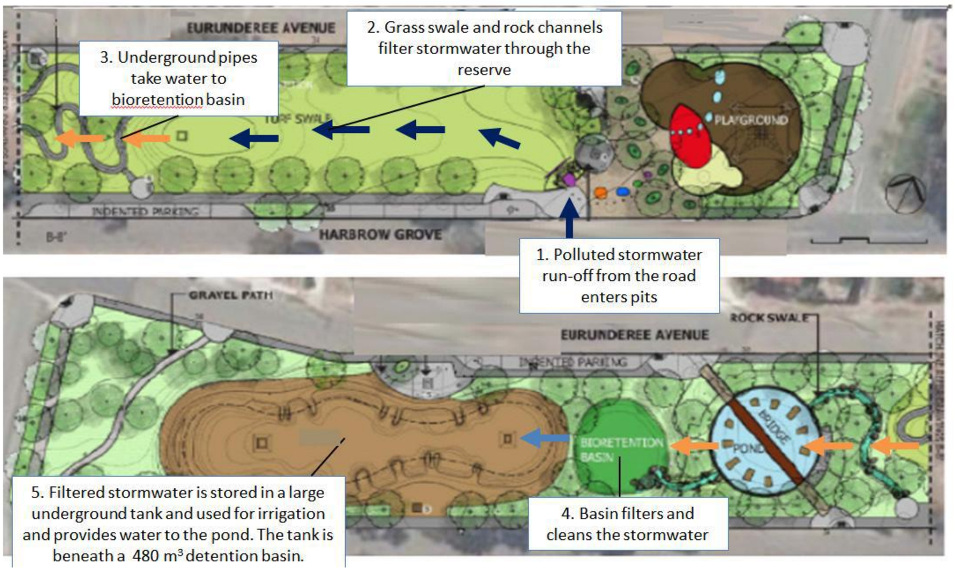

Figure 5.12. Water elements of the area (Tjandraatmadja et al., 2014)

Tjandraatmadja et al. (2014) mentioned that flood mitigation and stormwater reuse were the main priorities for the project that was designed as an open and flexible space in Australia. This area located in 400-600 mm rainfall zone and the system has swale, sedimentation pond bioretention area and underground “rain vault” to store treated runoff. As mentioned before zig zag model with water elements from building to neighborhood level is a successful method for water harvesting.

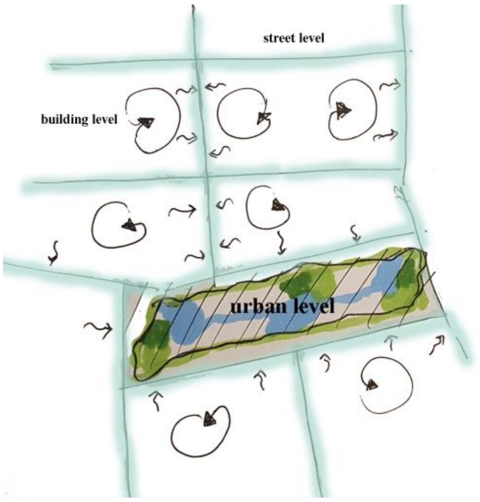

Figure 5.13. Water elements of the area in three scales (Illustrated by author,2019)

For the riparian or pyto-treatment areas, when the urban settlement is located next to the stream (Figure 5.12), street scale design guidelines form a corridor between water source and urban areas. As a result, creating localized open spaces in the city and determining different forms of intervention are effective in water management. The urban form is divided into sub-units of different size with the density in the tissue and thus, the urban contains the subject of water which can be solved in itself.

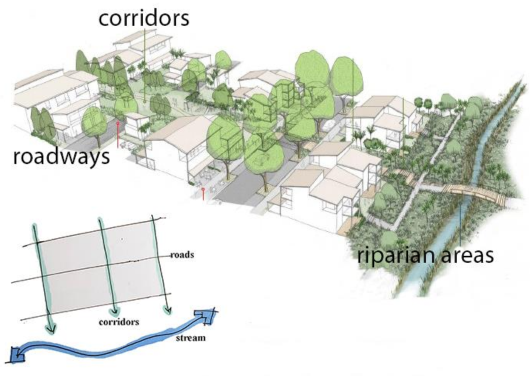

Figure 5.14. Street scale design guidelines can form a corridor between urban and riparian areas (Adopted from Auckland Council,2015)

Figure 5.15. Water can shape the urban areas in a different way (Auckland Council,2015)

In conclusion, design with water in different scales is a new concept for urban planning, although a lot of methods such as cistern, on-site solution etc. were used in the past. Main aim of this study is that water can restructure the urban areas for the sake of accessing fresh water supply, closing the natural water cycle and decreasing scarcity for all. This is a valuable and significant point of view for adopting cities into a new form. From top point which is a regional catchment area to the small units, water can be used as a network. It can create natural infrastructure to control a whole city. As a design element, water is a fundamental feature for both people and places in the urban area.

In the context of field of study, the question is that what is the boundary of the area? From building to urban level, implementations were determined but from broader perspective the boundary- maybe it can be designated as watershed for starting point- should be considered because it has multi-layer processes. People who live in that region, climate, topography, sources, urbanization, transportation etc. affect the whole situation and water harvesting cannot be thought as a single element of the system. For example, an intervention in the upper river basin can influence the lower level of that basin or near area. It is not an isolated area. In addition to that, this topic is an interdisciplinary issue. Apart from the planning process and design guidelines, calculation, engineering and landscape processes should be included especially for the rainwater harvesting calculation. For this reason, planners, architects, landscape architects and engineers should be worked together.

5.3. Limitation of The Study

Beside contribution of the research, this study has also some limitations. First one is local researches and examples. In other words, there are some limitation about water issue in Turkey context. Implementation tools and techniques are also limited and its reflection to urban plans is not clear. Moreover, major aim of regional or implementation plans do not directly focus on water, infrastructure or comprehensively natural areas of the regions. Generally, examples of water issue consist of upper scale such as region or basin level. The decisions of the plan remain mostly in the political part and the implementation decisions constitute a limited part. Even some ideas appear in planning and design part, the question of how much is being implemented still exists. So, we can say that there is a lack of water related design decisions in planning process. For this reason, successful examples in any scales, building, street, neighborhood or urban scale, are problematic issue for this study.

Second limitation of the study is that there is a couple of example which contain all scales and their relationships. In other words, when there is a building or lot scale case study, its reflection and effects to the streets and region scale can be a problematic issue. Most of the implemented water or infrastructure plans do not adequately cover the 3 stages mentioned: building, street and region. Also, appropriate strategies and design guidelines to show their interconnections in one case study or a specific region from all over the world was limited. To conclude, Turkey examples and comprehensive water plan in any part of the world which involve all implementation scales are the major limitations of the study.

5.4. Implications for Further Studies

This research has put forward the significance of water for sustaining life cycle through urban design implementation in different urban scales. Each scale has analyzed into detail by demonstrating drawings of implementations. Different examples all around the world in the context of urban water management have shown and grouped. In addition to that design guidelines have presented in building, street and region scales.

A further research can be carry out in the context of water management in Turkey and its sub-regions. In which ways is water being handled? How does water affect planning decision and implementation stages? Another point of water issue is social dimension. In this study, it has explained in briefly in street and regional scale in the previous chapter. It can be said that water creates a common space for people in the urban context such as open and green areas, recreation and flexible spaces. However, there is a comprehensive dimension in the background from past to present. So, social effect of water issue in society can be together with a historical perspective. The other recommendation can be predominantly a water management and implementation issue in the rural part. When we think about the city center, there are lots of negative effects on freshwater such as population, pollution etc. But when it comes to the rural part, how can it be managed successively. The combination of water and rural part can be examined in detail and differences between urban and rural can be explained.

And as a final suggestion, a site like building plot or neighborhood can be selected, recommended applications can be made and the consequences of the study can be shown in the context of numerical data, time and economic issue. So that, adaptation process can be analyzed in detail in an urban area.

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APPENDICES

A. Watershed Management

The definition of watershed can be summarized that these are large pieces of land that collect rainwater on a regional scale. However, this regional scale is not determined with political boundaries. Instead of this, it should be determined with river basin and watershed management.

River basin management is necessary to meet the needs of the population, to control floods and water related problems and to ensure the natural cycle of water in urban parts. Therefore, management of natural resources should be sustainable according to the characteristics of the basin. According to the Yıldırım, Yılmaz & Benliay (2013) as cited in Şahin and Yenil (2016) the rivers consist of three longitudinal zones from the beginning to the end. These regions can be referred to as the source region, transfer region and deposition region. Vegetation, which is an important element of river corridors, also varies according to these regions. Stream corridors limit water resources and vary in width depending on stream size.

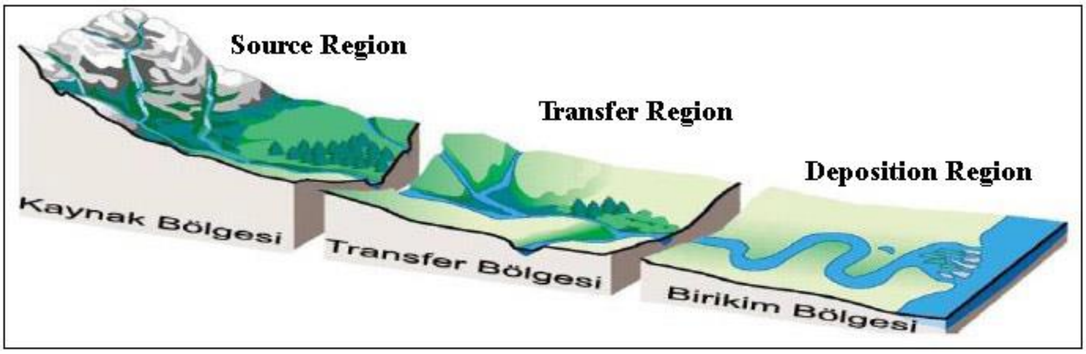

Figure 6.1. River Corridors (Yıldırım, Yılmaz & Benliay (2013) as cited in Şahin and Yenil (2016)

Population growth, water supply, protection and improvement of existing water resources and control of their usage are subject to some rules in our country as in the whole world. The best starting point for controlling water should be on the basin scale.

However, in the current conditions in our country, problems arise from institutions and infrastructure. So, water management policies have not been fully achieved.

Basin management should be established through interdisciplinary cooperation. This area requires flexible and sustainable management. There are some basic topics that are important in watershed management. These are:

- location of the watershed
- dimension of the basin,
- topography,
- population that located in the river basin,
- transportation,
- natural areas and habitats etc.

According to the regulation on the preparation of watershed management plans (2012), the definition of the units constituting the watershed has been made. These are:

- lower basin
- waste water
- pollutants
- environmental target
- environmental water requirement
- discharge
- ecological status
- watershed management plan
- protected areas
- landscaping etc.

The regulation describes the watershed management plan as follows:

These plans are based on the whole basin with a participatory approach by considering a sustainable balance of conservation and use for water resources in order to ensure the protection, development and deterioration of water resources and living life in a watershed.

Basin protection plans are prepared by the Ministry. In order to ensure coordination among institutions in the process of preparing, implementing and monitoring the implementation of watershed scale management plans; Basin Management Central Board, Basin Management Delegations and Provincial Water Management Coordination Committees are formed.

The Water Management Coordination Board is responsible for evaluating the implementation of the issues to be fulfilled by the public institutions and organizations in the watershed plans and ensuring the high level of coordination and cooperation. Ensuring the implementation of the decisions taken by the Water Management Coordination Board at the watershed scale, ensuring coordination between the central institutions and organizations related to water and monitoring the decisions are carried out by the Watershed Management Central Board. Basin protection action and management plans and flood and drought management plans are prepared, monitored, updated and evaluated by the Basin Management Delegations.

Preparation, monitoring, updating and evaluation of basin protection action and management plans and flood management plans and drought management plans are provided by Provincial Water Management Coordination Committees at provincial scale.

Basin management plans come into force with the approval of the Water Management Coordination Board. The watershed management plans measure program is implemented by the competent administrations under the coordination of the Ministry and under the control of the Watershed Management Delegations in the basins and the Provincial Water Management Coordination Boards in the provinces.

Implementations are followed by Provincial Water Management Coordination Boards in provinces and Basin Management Delegations in basins.

General provisions of that regulation can be listed as:

- Using the water potential of the basins primarily within the basin,
- Recycling, control and disposal of wastewater and wastes, especially at the source,
- Protection of water-dependent terrestrial and aquatic ecosystems

In order to use water resources, the following priority order shall be applied:

- Water needs for drinking and use purposes,
- Environmental water requirement,
- Agricultural irrigation water needs
- Energy production and industrial water needs,
- Trade, tourism, recreation, mining, transportation

The EU Water Framework Directive

The EU's water history consists of at least 40 years. One of the most important developments is The EU Water Framework Directive in 2000. The aim of this directive is further destruction of water resources prevention, protection; reduction of pollution in water resources and reduction of flood and drought effects. In order to achieve this goal, some key issues have been identified such as integrated management of river basins, protection of surface and groundwater etc. So, there are some planning requirements of the water framework directive.

One of the most important characteristics of the water framework directive is the introduction of a single water resource management system called "river basin management". Accordingly, resources will not be managed according to administrative or political boundaries, but will be managed by allocating river basin regions to be determined according to natural geographical and hydrological principles. A “river basin management plan” for each river basin region some of which may also cross national borders, needs to be prepared and updated every 6 years.

While the priority is on drinking and potable water, the main subject of the regulation is to use natural resources in a sustainable manner while providing this. In addition to that although the purpose of the articles specified in the regulation is explained, the method is not specified or does not give any explanation about how to do it in practice. For this reason, urban design guidelines from upper level (region) to lower level (building) can help to solve this problematic situation. Phyto-treatment region and riparian buffers affect the regional level, bioswales, pervious pavement, french drain etc. affect the street level and finally tanks, rain gardens and permeable pavement are the design guidelines to reach implementation issue.