Strategies of Water Management in Outdoor Space of Sustainable Housing-Water Material Heritage of Historic City of Nineveh

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Abstract. The research addressed the most important lessons learned from the material heritage of water management strategies in housing complexes, as the research thesis emerges from the technical understanding of the local water heritage of the historic city of Nineveh in water management, which developed over the centuries, since it is one of the cities with important water resources of the Tigris River, in addition to the high level of aquifer waters and abundant rain and well waters. This research also sheds the light on the Assyrian heritage of sustainable strategies in water recycling and management in the outdoor spaces of natural and constructed urban spaces, as well as the mechanism of inspiration of these techniques as they are self-sustained and in line with the propositions of sustainability of our time. There are many important questions raised by the study: questions about where the water resources come from to the site and where to go, the source and destination of stagnant water, how to get rainwater, aquifers waters, wells and rivers waters, their evaporation, movement, their graduated appearance and their use on site. All these questions can be answered depending on the calculative experiences of ancient civilizations as an important technical heritage that preceded modern technological development with the self-sustaining mechanism. The research aims at developing a theoretical framework for water management strategies of housing complexes, represented in each of (dominance and control strategy, conservation strategy, sustainability strategy), and to look for the similarities and differences between the material heritage of the ancient city and modern treatments concerning those strategies.

Keywords: Housing · Water · Management · Heritage · Sustainability · Nineveh

1 Introduction

Water has a special place in the multiple-face relationship between human beings and nature. It is a permanent and basic human need as water forms 80% of the mass of the human body and in different shapes, that is why it is essential to maintain the permanent ecological-biological balance as water is irreplaceable for the humans and wildlife always grows close to water resources and adapts to them, especially in terms of the evolution of creatures. Through technical responses and social organization, man is trying hard to break free from the absolute sureness of this situation to control and their

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access to those resources and sustainably manage them. Access to water is vital for all civilizations without exception, which means that each civilization has its water heritage, and throughout history, this led to the formation of a wide range of material and social changes that we consider as among the images of the human cultural heritage of water [1].

The ICOMOS study by the International Council on Monuments and Sites in 2019 indicates the encouragement of the sustainable development of human societies, specifical assistance for cultural, social, and technical factors related to water, its uses, and access to its resources, and this is something logical in light of the expanding regional conditions of the rapidly growing population and the wide changes in individual and social behaviors. In recent years, a series of urgent and sometimes catastrophic conditions emerged as methods for accessing water resources. In this context, a return to traditional water-related cultural heritage, some of which dates back thousands of years, seems to be a necessary approach or at least a useful approach to the sustainability of those resources. The ultimate purpose of this approach is to provide assistance and support to recognize, study and protect this type of heritage. In addition to providing techniques for identifying and protecting archaeological sites in a broader context not only those sites but also sites of regional and local importance [1].

LEED v4.1 blog, which is specialized in setting the conditions for the environmental sustainability of multi-story housing complexes, also noted in its items (1, 3) relating to both of the item of the intelligent site and things related to it, this blog refers to the preservation of wetlands and water surfaces. In the building and green technology item, it refers to the need to reduce the use of water, rainwater management, and sewage water management, and that reinforces the need to study the surrounding water heritage as it is the reality of the origin of the site [2].

In light of the importance of water heritage, it usually consists of several levels, each level has its own social and cultural repercussions, and it directly penetrates the society, which means that any technical or social deterioration or improvement in the water management system will have its effect, with its dimensions, on the community fabric [3]. This heritage is introduced as the basic component of a social structure that is considered in a broad sense overlapping among the traditions and regulations of water and economic incomes and political control on people and regions. Generally, any technical system for water management inevitably develops overtime in its keeping up with the situation that may change at the technical and social level and on a scale of different times, depending on the hydrological climatic circumstances and the diversity in the aquifers and local demographic changes, in addition to changes in individual and collective human needs, agricultural or urban transformations, water pollution and deterioration of its quality [1], i.e. any living system is adjustable to suit users' demand according to the available resources, and this ability to adapt to circumstances is a prerequisite for the sustainability of the system.

When studying the water heritage in human daily life, we find on the other side of the built facilities and urban environments, we find practices on a simpler level linked to the daily activities of people, public establishments, and services, and in these practices, there is also a great geographical and historical diversity as water is indispensable for any society because it is the backbone of development and expansion, and we witness these practices at the urban and rural levels [2]. The elements that witness water heritage daily are simple, clear, stable, and frequent over time, such as house bathrooms, water fountains, and water control systems, these techniques in daily water management were supported by safe water control facilities, whether permanent or temporary, such as barriers, drainage trenches, control of water gathering and conservation basins in case of heavy rains and so on [3].

The research problem is reflected in the lack of knowledge about principles and strategies based on the fundamentals of environmental sustainability in the process of water management of housing complexes and the importance of employing the ancient historical civilizational heritage in water management, which is reflected in the possibility of ensuring facilitated living conditions and needs of the residents within the components of the natural and urban environments, as well as enhancing modern propositions for environmental sustainability.

To complete this cognitive deficiency, the research adopted the following axes:

- Defining the lessons and experiences that are derived from the civilizational heritage in the mechanism of water treatment and management.
- Stating what the principles and modern strategies are in water management mechanisms within the environmental sustainability propositions for residential complexes (LEED v4.1 Residential Multifamily).
- Concluding similarities and differences between heritage and modernism regarding water management in vertical housing complexes.

2 The Material Water Heritage of Mesopotamia Civilization

Any civilization always produces material equipment and social rules to ensure meeting the multiple needs of human groups, and any civilization should be able to adapt to the development and changes in water conditions, as many traditional societies provided sustainable and adapted solutions according to stable and adapted technical systems to a specific situation and time, and without this rational management of water, those communities would not have lived long [3]. Depending on that, it is clear that every society has a product of a water culture that we can recognize through the heritage that reached us today in the form of living or archaeological heritage, its components directly related to the data of regional hydrological or climatic systems.

Iraq, which is part of the arid belt of the northern hemisphere, is characterized by hot and dry summers, and cold and semi-dry winters, rain falls only in winter. Iraq's topography consists of four main regions: the mountainous region of southeast Taurus and northwest Zagros, a moderately high region on the slopes of these mountains, the south-eastern alluvial plain, and the Western Sahara region. In winter, western wind currents and storms from the Mediterranean carry up to 1,000 mm of annual rainfall towards the northeastern highlands and reaches the mountain peaks of 4,000 m above sea level as deep streams compressed among rugged highlands are considered as settlement units but restricted. The region, which lies to the east of the line between Mosul and Kirkuk, is characterized with hilly terrain and receives rainfall exceeding its annual average of 400 mm, making the area suitable for rain-fed agriculture, and therefore it belongs to those parts that were earlier chosen by human beings for long-term settlement since the eighth millennium BC. Settlements are located near riverbanks and often pass through ancient geological formations that rely entirely on sustainable riverbank agriculture based on water lift and drainage systems [1]. Figure 1 represents one of the artificial canals since the third millennium BC through the geophysical scan.

2.1 Water Management in the Mesopotamia Civilization

Since the Middle Assyrian era (13th century B.C.), Assyrian kings had invested in the creation of sophisticated canals to divert water to their capitals, industrial parks, and vast agricultural territories, specifically, the water control systems implemented by Sennacherib (704-681), one of the kings of the Neo-Assyrian Empire, are among the most extraordinary technical achievements in ancient Iraq, and the giant dimensions of these projects and their technical aspects confirm their uniqueness in the ancient Near East. The Fig. 2 refers to the water lifting methods in the Assyrian Empire.

Fig. 1. Artificial canals, Uruk

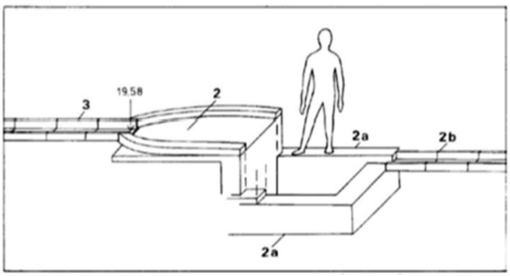

Fig. 2. Water-lifting tools rooted back to the fourth millennium BC [1]

Archaeological excavations discovered large numbers of wells, especially in the northern cities, where excavators found many wells inside one Assyrian city which had palaces, temples, and even residential houses that were constructed with bricks from the inside and have stone covers and the linking materials of clay. The reason behind the use of bricks to encapsulate wells is to ensure that they do not collapse due to the continuous daily use of well water for daily needs or due to the high aquifer water levels in the good cavity, especially in the winter season [4]. They also dug many wells, the most famous of which were discovered in Kamkho (Nimrod) which were usually dug either inside the houses or in the gardens or central squares and were built with pottered building bricks and up to ninety feet deep. And these wells provided the city with water in peace and war times, and they are considered as among the properties of the houses, fields, and land, as stated in the land sale contracts [3].

The Assyrians also used the Kahriz water system, which is very similar to the system of the project of the Al-Naqoub Canal and is the first project of its kind to deliver clean water to cities, because of the lack of rainfall in the city and its fluctuation most of the time in addition to the water level reduction of the Tigris River below the level of the lands near to it and because of the change in the taste of the water of this river due to its mixture with the sulfur water-eyes located on the opposite side of the city of Nineveh. All these reasons called for the establishment of this canal in the city of Nineveh to deliver fresh water to the city through establishing an underground canal through which the water of the river could be transported to the city [5]. The sewage streams were not absent from the mind of the Assyrian engineer. Although there was little information available on the construction of projects by Assyrian kings which were comparable to large water processing projects, they did not forget to provide their palaces and public and private buildings with sewage systems in the form of canals, taking into account the smoothness of the water flow from several courses, they used asphalt as a linking material for the constructional materials and also it was widely used for cladding or painting the whole stream. This is found in the central square of the North-West palace in Kamkho in the Harem Wing, where they cover these streams using large and heavy limestone rocks and we can find such a thing in the palace of King Adad-Nirari III (811-783 B.C.) which is to the south of the palace of King Ashurnasirpal II, which was discovered during excavations of 1993, they discovered a building which was used as a toilet and was also constructed using square bricks, starting from the used part and connected by a stream which slopped extremely towards the sewage water tank which was heavily cladded with a layer of asphalt and the water is drained into those streams through circular openings in the middle of procedures used for this purpose [6].

The most important techniques used in water management for the residential territories can be summarized as the following:

- Water-drawing canals: they represent the main source of information about the channels of Iraq's hilling territories, which are regarded as a reward to the central territory of the Assyrian Empire in the royal inscriptions, while currently, satellite maps represent the main source of information. The Kings of Ashur ordered to construct water-drawing canals to meet their needs of large quantities of water to provide their cities, and Ashur-Ubalit I was the first to mention (Al-Wafra canal) while Tokoliti Ninorta I (1244-1208 B.C.) established a canal to draw water for his capital and called it (Canal of Justice). Later on, Ashurnasirpal II (883-859 B.C.), who was the first to construct larger canals such as (Patti-hegali), which carried water from the upper Zab to the Nimrod. Sennacherib (704-681 B.C.) had set up a water management system in greater dimensions than the previous one, as this system transported water to his capital Nineveh - now Mosul- to expand the agricultural area and provide food for more people. Generally, four different water systems of over 150 km long worked on directing water through territories. Modern archaeological scans will profoundly change our relationship with the canals systems, as these channels were studied in detail, as Khins-Al-Khoser canal is famous for being its technical components are well preserved, the head of the canal is considered one of the best-preserved construction models in the Assyrian era, Fig. 7, which is an artificial canal dug in rocks and gathered water from the Rivers Atrush and Komel. The presence of two dams, one of which is a submersible dam, helped to control the quantities of water, and the canal directs water for 35 km before flowing into the River Al-Khoser (Fig. 3).

- Dams: The Canal (Kisiri) which runs along the River Al-Khoser for about 16 km and was previously diverting water to the modern Assyrian canal system, and requires the construction of the head of the canal as a preserved barrier inside the dam basin, which continues to be used till now in the waterfalls area.
- Docks: The canals were sometimes equipped with dock walls and docks for ships to dock and they are thought that they helped to load goods or to strengthen the sides of the river, and the archaeological research confirmed the presence of these docks along the canals in the Assyrian water systems in the north of Nineveh as large limestone blocks were used to build them.
- Tunnel Canals: a technique for harvesting water in which it is picked up at a high point of the ground through deep wells and converted in a precise degree of inclination through an underground canal to the desired location. Usually, air wells were drilled at distances ranging from 20 to 30 m from one to the other to help remove the rubble resulting from the construction and subsequent maintenance of the tunnel. From above, the canals appear in the form of a long row of cross-Earth holes, which are familiar features in many territories of Iraq and the development of this technique is still unknown, but the first scan confirms that the water-drawing canal was created in the style of tunnel canals, i.e. using vertical tunnels of equal distances among them [1].
- Water conservation tools: That water is preserved before being distributed in large pottery containers (hib) that often had a capacity of (100 gallons), many of which are found inside houses in various Assyrian capitals and cities and are fixed approximately to their halves into the ground near the kitchen or in the middle courtyards of the house to be close to the place of domestic use or other uses [7], indicating that the residents were able to get water by bringing it from the rivers or wells and store them in their designated places for use (Fig. 4).

- Kahriz: It is an underground canal with a normally low depth of 1/1000–1/500 miles drilled in areas where rainfall is non or low in order to transport water from a water reservoir in the area where the water level is high to other flat areas where the water level is low to use that water for irrigation, watering and agriculture. The kahriz consists of several components, including the mother well, the vertical wells, the appearance and the dug canal. The kahriz is a matter of drilling several wells which are close to each other and linked from the bottom of the one to the other where the water runs and comes out of a crater or opening like the fountain or to flow on the surface of the ground for various uses. They are known and used frequently in northern Iraq, Kirkuk, Erbil and Ainkawa, where countryside people there used to (and still) rely on drilling wells to extract potable water and then draw it by buckets and then to harvest and store them in large pottery pots or in padded pits and then rely on moving and transporting water by the kahriz and its canals and conduits, and the water of these kahriz runs from east to west due to the land slop of the region which descends from east to west. The kahriz requires annual maintenance and hard work to clean their course from the inside, where dirt, mud, gravel and sand are constantly falling inside of their courses and obstruct or slow down the water flow, besides being the only source of potable and watering the cattle. UNESCO recently took an interest in restoring a kahriz in northern Iraq, as it celebrated four years ago (2010) the opening of a traditional canal for the kahriz of Sheikh Mahmoud Dayan village in northern Iraq on the occasion of its restoration and being again made as a source of water for the small village community in that place where the water flow had been cut off since 2007 (Fig. 5) [8].
- Drainage canals: During excavations of the Directorate of Archeology and Heritage in 1999, the drainage canals were also found in the palace of King Ashurnasirpal II in the southwestern part of it, in several rooms, one of which is a circular cavity cladded with bricks of approximately 8 m deep for water draining which forms what is similar to an outlet or a tank that was cleaned of dirt and sediment and in which a well-made alabaster flask was found, confirming that this discovery is of a drainage stream [9] (Fig. 6).

Fig. 3. Drawing water canal for transporting water

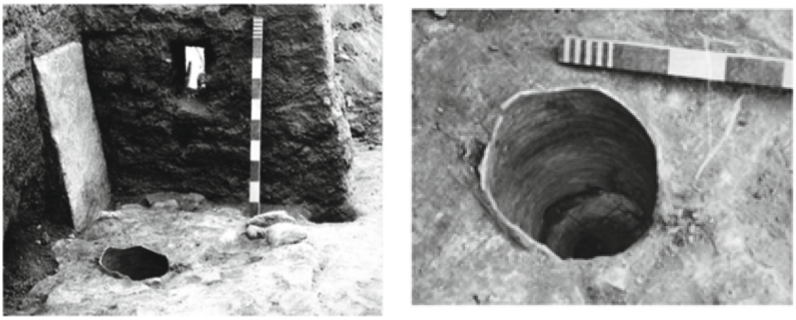

Fig. 4. The remains of the storage

Fig. 5. The kahriz

It is made clear above that the mechanism of water management in housing complexes in the territories of ancient Iraq relied on the systems of canals, wells and storage basins that support the use of river water or harvesting rainwater. Canal systems were of three types:

- Water-drawing channels from rivers (extended surface channels)
- Tunnel canals (harvesting and directing wells water)
- Deep underground channels (kahriz that capture aquafer water and harvest rainwater)

These systems are considered as a cultural legacy in water management in cities and housing complexes, and the sustainable mechanism that depends on the self-management of water must be inspired without the intervention of mechanization or electric motors, but to study the levels, volumes, meeting points of water and direct and connect it to nearby tanks for daily use.

Fig. 6. Drainage stream in the city of Tarbiso

3 Modern Principles and Strategies of Water Management

The urbanization and development of mechanisms and techniques associated with the characteristics of the outdoor spaces of vertical housing led to the emergence of many concepts of sustainability-related to water management in these complexes, which emerged from the mechanisms of water sustainability, reducing waste and minimizing consumption. Among studies related to the sustainability of outdoor spaces for vertical housing are:

3.1 The Principles and Mechanism of Sustainability According to (Highlights of LEED V4.1 Residential Multifamily) Blog

The LEED v4.1 blog, which specializes in multi-story housing, in its proposals for efficient water use management within the residential sector, refers to the combination of reducing indoor water use and reducing outdoor water use to achieve a total water use reduction for the project and to develop new compliant ways for projects that seek to obtain the achievement of improving water use efficiency in reducing water use indoors and/or outdoors.

The blog stated the regulations of the management and use of water resources by conducting a primary analysis of the environmental balance of water before completing the planning design that explores how to reduce potable water loads in the building, and to reduce the burden on municipal supplies or sewage water treatment systems, and to achieve relevant sustainability objectives and to assess and estimate potential non-potable water supply sources and water demand amount, including the following:

– Internal water demand: to assess the size of demand of the water flow design status and flow installation, calculated according to the WE requirements and the creditability of water use reduction.

- External water demand: to assess the size of demand when designing the irrigation of green spaces which is calculated according to the WE requirements and the creditability of water use reduction.
- Supply sources: to assess all the sizes of non-potable water supply sources, such as rainwater, greywater on-site, non-potable water supplied by the municipality and the HVAC capacitors, and to analyze how non-potable water supply sources can contribute to the components of the above-mentioned water demand.

It is clear from all above that one of the most important principles of modern sustainability of residential complexes in their management of water is to achieve the environmental balance between water resources in all their patterns, and the quantities of water drainage and use to preserve the water existence of the site [10].

3.2 "Siti Jamaludin" Study: Designing Conducive Residential Outdoor Environment for Community: Klang Valley, Malaysia

This study pointed out that the need to deal with the site on the environmental level in the same way of dealing with it on the material level, as it is usually required to allocate 10% of it to provide green space in an attempt to develop it. The urban site has to take into account the conditions of environmental sustainability in the mini model design of the site of the residential neighboring spaces, as it effectively represents the importance of neighboring landscape design and its water sources and vegetation cover which may reach 50–80% of the area of outdoor spaces. Such projects in future development should also be encouraged to develop sustainable outdoor environmental wildlife. This study aims at identifying the principles of sustainable landscape design and studying the wide range of use of natural sites and their importance in achieving sustainable housing development in the Klang Valley as a study case. These objectives are to identify important elements of the method of using sustainable natural elements and to make recommendations and strategies on the best design of sustainable residential landscapes according to the needs of the sustainable housing scene. Nowadays, people are more aware of the dimensions and benefits of environmental sustainability through their need for green space such as parks to achieve levels of psychological and physical comfort and quality of life including water sources, as the presence of parks contributed to protecting biodiversity, environmental balance and reducing drought, floods, wind and temperature control, as well as maintaining energy and enhancing parks for aesthetic value. The research methodology is to compare two residential projects established in a natural environment called the Klang Valley and carried out according to the adopted ALSA environmental standards, (Geos Net Zero Energy Neighborhood). Seven miles of traditional waterways in Seoul were restored to provide residents there with clean potable water, irrigate crops and use it as a sustainable transportation means. This new park creates a vibrant public space with which nearby neighborhoods meet and reconnect Seoul's residents with the old waterway. In Arvada Colorado, rainwater is harvested in the pond in the southern part of the new sector, and the pond prevents floods and re-establishes a long-term balanced water ecosystem. The study compared the two projects: Setia Eco Park and Phuket Jetta Bayou Park. In both projects, one of the principles of sustainable architecture was followed, and it is according to the American standards of water use efficiency, they are:

– Adopting rainwater harvesting systems
– Recycling sewage water
– Coordinating water-saving parks - sprinkler system and wetlands
– Preserving the water system (ponds and lakes) as home to balanced aquatic wildlife

As for the first project, the efficiency of water use and management was achieved by adding a water pond for entertainment, protecting local trees, harvesting water from rain and thermal evaporation of the pond, and reusing it to irrigate plants, and rocks were reused to create rainwater-permeable walks, wooden materials for seats, garbage containers made of copper materials and paved pavements with concrete pieces to reduce water flow. As for the second project, as far as the efficiency of using and recycling water is concerned, the pond was used as an area of entertainment and water preservation, and for harvesting rainwater to be reused to water plants and other purposes as well as harvesting water from drainage after filtering it in the water conservation pond and returning it to natural water bodies, in addition to using rocks and tiles and paved gravels in a permeable way to reduce water flow [11].

All above made it clear that the mechanism of water management for the residential sectors understudy was represented in the recycling of pond water that was on site since ancient times, as well as adopting ponds for harvesting rainwater and as tanks of drained water after purification, and using the highly permeable paving method for surfaces to enable water to penetrate and reduce the speed of rainwater flow.

3.3 "Residential Landscape Sustainability, Smith, 2008" Study

Smith's 2008 study referred to a strategy to reduce the consumption of used water, as the sharp increase in water consumption in the UK led to significant infrastructure works for water supply and transport with associated impacts on energy resources, materials and natural landscapes. The most sustainable approach is to develop ways to reduce water consumption, and therefore priority should be given to users in the housing sector in efforts to enhance a water-saving strategy. In the mid-1990s, it was estimated that nearly 3% of total household water consumption was used to irrigate the garden, equivalent to 3.5 L per person per day, therefore, suitable plant species for the site's soil and climate, which have a relatively short construction phase, can be used to reduce water consumption by residents through their interest in plants in their gardens. Furthermore, water loss from cultivated areas due to evaporation of the soil surface can be significantly reduced. In addition to the design of green spaces, household water consumption can also be reduced through other elements of outdoor gardens, as garden water ends can be connected to the pipes that transport water from the roof of the house to the sewage system, and can then be used to irrigate the garden or for other "low quality" uses instead of potable water. Water ends are a very simple form of water har, but other more complex systems can be used to store rainwater in the back garden, before pumping it back into the house to be used in the toilet. However, more complex systems can be used to store greywater from bathrooms, showers and laundry basins inside the tanks below the garden that can be pumped back home after chemical pill treatment, along with the harvested rainwater to be used not only in toilets but also in washing machines and external irrigation and car wash. Such a comprehensive greywater recycling system can save 80% of daily household consumption.

Managing surface water flow contributes to reducing the consumption of the required water, harvesting rainwater from surfaces also prevents large amounts of water from joining surface flow in extended areas in housing complexes, therefore, surface water flow must be managed if we want to meet the challenge of sustainable housing development. The main effects of hydrological development occur by replacing vegetation with unfinished surfaces and buildings, reducing the flow of water into the soil, and reducing gathering, evaporation, and transpiration of plants in green surfaces, and therefore increasing flow from the site. The main step for an alternative and sustainable water management solution is to reduce the area of impermeable surface on-site, by increasing the area of green spaces, i.e. meadows, farms, trees, green surfaces, and conducting permeable paved surfaces, which could reduce the amount of surface water flow. Traditional drainage systems seek to remove rainwater from the site as quickly as possible, however, this method, which is based on transferring rainwater flow directly into a waterway through a tube, can cause several environmental impacts. Uncontrolled water flow increases the risk of floods from the receiving water stream and can damage river rims, and this will also reduce the amount of water that penetrates the ground, so, the adopted methods used to prevent large amounts of surface water flow are to reduce unfulfilled areas and maximize green spaces through reducing impermeable paved surfaces, increasing the green spaces and/or harvesting rainwater from surfaces to be reused as other preventive methods. To deal with the rest of the water flow, more control techniques should be considered for the source. These techniques include:

- Permeable pavements: They are the surfaces that allow surface water to pass through them down to a permeable level and this pattern includes many different methods of varying complexity, from untethered granular materials, such as gravels, to permeable blocks, porous asphalt, and tethered gravels. Permeable pavements can be designed to allow either direct penetration into the basic beneath a layer or when the soil of the site is too heavy or fragile or when the surface water flow is highly contaminated,

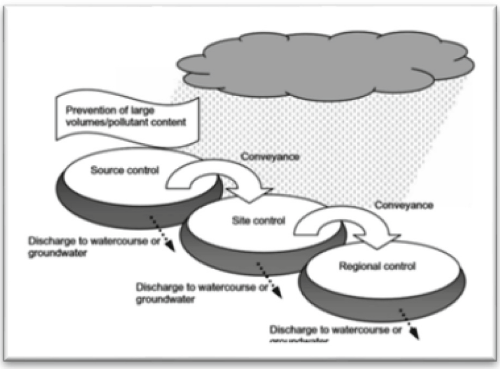

Fig. 7. Stages of surface rainwater flow

the subbase can be confined from below and can be used to store the flow in order to manage water drainage cycle.

- Trenches and sealants: This technique drains water directly into the ground by enhancing the natural capacity of the soil to store and drain water, and submerged trenches and absorption ways are back canals submerged with broken stones that pour water into underground tanks.
- Filtration and deposition strips: These are plant surface bodies that drain water evenly from surfaces. Swamps are long shallow canals while filtration strips are gently descended areas of the ground. Both simulate the natural drainage method in that they allow rainwater to pass through vegetation, allowing the processing of flow speed and the filtration of pollutants. Swamps can also be used as an input tool that can be made more effective by relying on the nature of the soil and by using inspection dams. Nets can also be used to receive the flow directly from impermeable surfaces, as there is no upstream control.
- The filter or the French drainage: These trenches are similar to the sedimentation trenches that were previously presented as linear canals filled with stone, yet, their main function, in this case, is to transport water in a rounded manner towards the river stream. If there is sufficient flow through the trench wall and its lower part into the surrounding soil, the drainage effectively acts as a water trench-like swamp, and these features can act as source control as well as moving the downstream i.e. reducing the water available for extraction. Figure 7 shows the stages of control and domination in harvesting rainwater and surface flow from the source to site and then to the place of use [12].

All above made it clear that sustainability strategies in water management emerged from traditional methods of water drainage but with various new treatments such as replacing extended drainage canals with plant swamps to drain through the soil, adopting horizontal trenches instead of exposed canals, and replacing permeable stone surfaces with more permeable footpaths according to auxiliary pavements and plant surfaces for drainage (Fig. 8).

3.4 Sustainable Landscape Construction a Guide to Green Building Outdoors, 2008 by William Thompson

Regarding water management, the study referred to water harvesting and conservation mechanisms, as reducing human water use and waste may protect natural water systems. Differences between converting water for human use and leaving it to flow to support aquatic life are increasingly common, especially in the western United States. Water conservation, through a wide range of techniques, is essential by itself, and it is necessary to protect wetlands and streams, and it is important in maintaining clean water supplies. Among those techniques are:

- Harvesting water from natural surfaces and sites: it means harvesting and storing rainwater from regular surfaces, paved surfaces, and natural sites near the source.

Fig. 8. Some of water management treatments

Harvesting rainwater from ceilings was common in old American homes, and storage tanks were often downstairs. Harvesting water from natural sites was for the permanence of human life in ancient times. The use of various slopping terraces, which are usually small in size, low stone walls or dams, all work on filtering water at strategic points of harvesting, trapping fertile sediment and moisture in some of the earth's driest environments. These shallow and almost slightly deep trenches that flow into the main plate-covered wide paths are used to harvest water in ponds beneath the highlands. The results of water harvesting in arid lands can be as astonishing as stopping the corrosion of grooves, raising the aquifer water level, and greening the desert with no industrial irrigation. Water harvesting may modify both peak flows and seasonal water availability, water availability in the local ecosystem as whole increases with filtration and sedimentation, and intensive water harvesting can delay the flow of water streams at peak.

- Water filtration simply on site: the on-site filtration process is very simple and depends on two basic principles: slowing or holding water flow, and increasing soil permeability. Both are easy to achieve near the water source because large quantities or rapid flow are difficult to be reserved and require a high level of porousness for quick permeability. Vegetation and small terraces are used to slow and absorb water, as wetlands slow down their water absorption (whether natural, treated, or built) and retain water due to terrain and vegetation, and harvesting sites are often main, and porous paving over the reservoir provides on-site filtration. The aim of harvesting water, which is sometimes stored, is often the direct impact of dams, terraces, mainline trenches, and much other biotechnology and sustainable agriculture techniques that hold water in small reservoirs from which it seeps into the soil.

- Water storage for later uses: one of water harvesting common cons resulted from decreasing the required storage volume, as rainfall usually comes in one season and must be retained for use in another season, therefore, the accumulation of the whole season determines the size of the required storage reservoir. Most people are surprised by how much water can be harvested from a single storm and tend to steam in storage. Harvested water can be stored in tanks above or below the ground or regular basis. The basins lose a lot of evaporation and that makes them effective as irrigation tanks and unsuitable for potable water. Prefabricated tanks of metal, glass, plastic, or precast concrete are available, and can also be built on-site from stone or iron cement (thin cement layer over a steel-reinforced grid). Wood tanks must be made from sustainably cut wood, and if they are above the ground they should be dim as sunlight may enhance algae growth.
- The adoption of the natural drainage system: three main factors interact to determine how water performs on-site, they are:
- The same amount of water
  The material (materials) on which it takes place, including vegetation
  The shape of the surface on which the flow occurs, especially the slope.

Once the dynamic balance between these factors is changed and within any part of the system, all links in the water network are reset towards a new balance. This modification occurs gradually all the time in natural watersheds and is a key concept in the origin that deals with water. Planning for water at a site requires understanding the local patterns that had evolved over centuries and this is specific to the site and the region. Important questions are:

– Where does the water come from to the site, and where does it go from the site? Even stagnant water has a source and destination unless it is rainwater and evaporation.
– Does on-site flow move in the form of veins or canals? Are surfaces solid or porous, and where does water leak from one type to another?
– Where does stagnant water accumulate, and why? How could the stable and moving waters be connected?
– Regionally, what are the forms of river systems? Do they branch out like trees at sharp angles, or do they make sudden changes in the right corner in the direction? [13] (Fig. 9).

Fig. 9. Some of the sustainable water management treatments

3.5 Mumin Bani Mustafa's Study: Rainwater Harvesting Techniques

The study referred to the adopted techniques in harvesting rainwater as it is considered as pure water suitable for human use, as well as its use in irrigation of outdoor gardens and unclean use. These techniques may be included in the details of the building on the one hand or at the level of details of the constructed and natural surroundings on the other, they are as the following:

- Surface flow harvesting: rainwater is harvested in natural reservoirs through surface water leakage to aquifers that are lost in the form of surface flow.
- Surface rainwater harvesting (RRH): it includes rainwater harvesting on the surface, converting and recharging (or) storing a part of the rainwater falling on the roof of the house, as harvested water is directed to the recharge pit, which gathers and recharges slowly in the aquifer storage and the aquifer layer in that area.
- Dams: they are barriers designed to reserve water, where rainwater can accumulate directly or drainage systems can be established to draw water towards them, and it is often used for irrigation, or it is treated and then distributed for domestic use.

- Underground reservoirs: these tanks are created by drilling in the ground and are then installed to reduce water leakage, water in this technique can be obtained through pipes directed to the tank.
- Rain dish: in this technique rainwater is collected directly when it falls from the sky using the rain dish, these dishes look like upside-down umbrellas or large passages and are usually connected to a pipe so that the collected water is directed elsewhere. Sometimes the collection container is placed underground with only a rain plate above the ground, it is a simple but effective method.
- Trenches: this is another traditional way to harvest rainwater, which is still in frequent use today, when it rains, water is directed to the farm using trenches.
- Rain barrels: they are specially designed for this purpose and can be purchased from retail stores, the rain barrels are used to collect rainwater falling on the roofs of buildings [14].

4 Stratiges of Water Management

Studies related to the most important water management strategies in residential complexes, in general, show that these strategies form in three main mechanisms.

4.1 Control and Domination Strategy

Which starts from the water source itself to the details of its transport, distribution, and storage in control and storage systems, these systems share in principle with the water heritage as being varying in the patterns of horizontal and vertical canals and control points that could be exposed as conduits or closed subterranean canal.

4.2 Conservation Strategy

Which also begins from the same source in terms of the amount of flow, type of soil and its slope, and use of vegetation in reducing waste, harvesting rainwater, using water-saving gardens and the permeable surface. As a whole, they are different from the mechanisms of water heritage in that aspect, as the mechanisms of preservation are limited in the past to the open or underground storage that based on the preservation of the amounts of water obtained without engaging with the mechanisms of dynamic preservation of water from the stage of its natural existence in ponds, swamps and rains to its spatial existence in the basins.

4.3 Environmental Sustainability Strategy

Which is based on the on-site filtration of water sources and recycling and storage mechanisms in both natural and automated parts, as well as the treatment of used and gray waters, which water management mechanisms in the water heritage lack.

Table 1 shows the main and secondary most important items and possible applications for water management strategies in housing complexes.

Table 1. Water management's strategies in housing complexes

	Main strategies	Secondary item	Applications
Water management's strategies in housing complexes	Control and domination strategy	Resources evaluation	Supplied potable water
			Supplied non-potable water
			Rainwater
			Aquafer water (well water, swamps, and ponds water)
			Greywater
		Achieving environmental balance	The number of internal demands (usage)
			The number of external demands (watering plants and gardens)
		Usage control	Controlling the water flow for the equipment
			Controlling the water storage
		Controlling surface flow	Reducing impermeable surfaces
			Enlarging green areas
			Harvesting building's roofs water
			Using permeable surfaces
			Using permeable soil and materials
			Using plant leakage and filtration strips
			Using horizontal trenches
	Conservation strategy	Rainwater harvesting	Canals for harvesting descending surfaces water

(*continued*)

Table 1. (*continued*)

	Main strategies	Secondary item	Applications
			Canals for transporting rainwater to plants ends
			Rainwater storage basins
			Permeable surfaces of footpaths
			Plan strips for increasing leakage and filtration
		Coordination of water-saving gardens - sprinkler system and wetlands	
		Reserving wet plane lands and wild swamps	
		Storage mechanisms	Natural storage of natural resources (ponds and swamps)
			Automated storage of the available resources (storage basins)
			Condensers
		Water treatment	Used water treatment
			Gray water treatment
	Sustainability strategy	On-site filtration of water sources	Slowing down water flow
			Using high-permeable soil
			Using vegetation of low evaporation capacity
		Recycling usage	Storing and treating usage water
			Storing and recycling gray water (chemical treatment)
		Recycling natural materials (natural system)	The material on which water flows
			The surfaces shape and the amount of slop
		Maintaining the aquafer storage	The kind of vegetation and soil

5 Conclusions

Through reviewing the works of literature related to water management mechanisms in residential complexes and the most important practical applications in our water heritage of the historic city of Nineveh and comparing it to the most important modern theses on water sustainability and management, the research reached the following conclusions:

1. Many water management strategies between the past and the present are similar because any civilization always produces material equipment and management strategies of its own to ensure meeting the multiple needs of human communities and being able to adapt to the development and changes in the water situations available. Many traditional societies provided sustainable solutions according to stable technical systems adapted to a specific situation and time. Without this rational management of water, these societies would not have lived long, of course, this is done according to a variation in some possible mechanisms and techniques for any age.
2. The historical water heritage and the modern reality concerning the mechanism of conservation and sustainability are different, the important role of vegetation, the types of water-saving plants, rational irrigation systems, and plant surfaces for sedimentation and filtration is highlighted in the current treatments, it is a strategy that adopted principles derived from the natural system of the wildlife in the permanence of water through its basic factors (water, soil, and plant).
3. There is a need to review the lessons derived from ancient civilizations regarding water management strategies in the housing sectors and make use of most of them, because these strategies mainly adopted the principles of natural sustainability of resources and methods of dealing with water flooding in its seasons and investing it in times of need on one hand, and not relying on mechanization and technology on the other, and this is the most important principle in the sustainability of energy sources in our time.

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