

## Mechanical Engineering in Ancient Egypt, Part 90: Water Management

Galal Ali Hassaan\*

*Department of Mechanical Design & Production, Faculty of Engineering, Cairo University, Giza, Egypt (Emeritus Professor)*

*\*Corresponding Author: Galal Ali Hassaan, Department of Mechanical Design & Production, Faculty of Engineering, Cairo University, Giza, Egypt*

### ABSTRACT

*This paper investigates the water management in ancient Egypt and how the ancient Egyptians achieved an optimal use of the sweet water available. It outlines the effect of the River Nile on the ancient Egyptian life and how they appreciated it. It studies in some details some aspects related to water management such as canals, wells, marshes, dams, irrigation machines gardens and ponds. All aspects studied is supported by scenes, reliefs, models and full-scale structures from the era of ancient Egypt.*

**Keywords:** *Mechanical engineering, ancient Egypt, water supply, water management*

### INTRODUCTION

This research paper is the 90<sup>th</sup> paper in a series of research papers aiming at investigating the evolution of Mechanical Engineering in ancient Egypt through studying the management of water in ancient Egypt required to support life activities in the old Egyptian societies.

Murray (1955) outlined that ancient Egyptians have built the oldest dam in the world, 'Sad el-Kafara', seven miles South-East of Helwan [1]. Bazza (2006) presented an overview of the history of water management and irrigation developments in the Near-East regions. He claimed that water diversion and true irrigation systems were developed and used in Egypt as far as 5000 BC. According to him, the people of the Near-East civilizations were the first to know water provision needed for growing crops and ensuring food production [2]. Shaheen (2007) in his paper about water carrier in the ancient Egyptian sources stated that vessels carried by men were for personal use or gift presented to a King or a temple. He presented a photo for a 1.29 m pole with four jars from an 18<sup>th</sup> Dynasty tomb at Qurneh [3]. Franzmeier (2008) in his paper about wells and sisterns in Pharaonic Egypt outlined that wells and sisterns can improve the amount of water available. He pointed out that ancient Egyptians digged wells dating to 6000-5250 BC in the Western Desert. He presented the well of Amarna having about nine meters depth. Besides he presented also the

wells in Samana in the Eastern Delta during the Ramesside times and the wells within the temple of Medinet Habu. Some of the wells were dated to the time of Ramses III [4].

Mays (2010) in his book-chapter about water technology in ancient Egypt stated that the great civilization of ancient Egypt started 5000 years ago depending entirely on the River Nile. He traced the history of water engineering in ancient Egypt from the use of water from annual inundation of the River Nile for natural irrigation to the development of methodologies to advance the use of River Nile for irrigation [5]. El-Gohary(2012) in his book-chapter about the development of water supply in Egypt discussed the water resources in ancient Egypt, agriculture, development of water supply systems, water treatment, sanitation and plumbing [6]. Hendricks, Forster and Eycherman (2013) in their book-chapter about the Pharaonic pottery of Abu Ballas outlined that large storage jars for water were found in Abu Ballas sites dating to the Late Old Kingdom and First Intermediate Period. The presented line diagrams for the design of of those jars having maximum diameter of 400 mm. They presented also line diagrams for small jars of about 250 mm maximum diameter [7].

Torpey (2015) in her study of gardens in ancient Egypt declared that gardens in ancient Egypt were surrounded by mud-brick walls with a gate and pointed out to a garden model of Chancellor

Meketre at Thebes from the Middle Kingdom. She presented scenes for gardens in the Great Temple of Amun at Karnak, garden of Queen Tey from the 18<sup>th</sup> Dynasty, garden of Meryre I at Amarna with steps leading down into a pool (dynasty 18) and a scene for Neferhotep from the 13<sup>th</sup> Dynasty receiving a large bouquet of flowers [8]. Driaux (2016) declared that water supply of inhabitants was managed by the state through the local administration charged to bring water from rural area into towns to redistribute it to the inhabitants. He illustrated the method of supply by several sources of evidence [9]. Hassaan (2016-2019) in a series of research papers investigated some River Nile post existence of some industries in the ancient Egyptian society such as models industry [10], pottery industry [11],[12], [13], mud-bricks industry [14], farming industry [15], bread, beer, wine and perfume industries [16], robe industry [17], basketry industry [18], papyrus industry [19] boats industry [20] and sea going ships industry [22].

Wood (2017) in his paper about watering Deir el-Medina studied how water was supplied to Deir el-Medina for the workers and their families. He pointed out that according to Cerny [23], the Turin Strike Papyrus (from year 29 of the reign of Pharaoh Ramses III) listed the names of five water carriers led by a Chief water carrier. He referred also to Ostrakon MM 14126 in the Stockholm's Museum of Mediterranean and Near Eastern Antiquities containing a list of water supply to 14 names in Deir el-Medina in 'khar' (a volume unit in ancient Egypt) in the late reigns of the 19<sup>th</sup> Dynasty [24]. Othman (2017) in his paper about use of water in the Egyptian Eastern Desert pointed out that wells of the desert were the main water sources. He stated the story of Neb-Taui-Re who was sent by King Mentuhotep IV of the 11<sup>th</sup> Dynasty to Wadi Hammamat where he found a well according to Wadi Hammamat inscriptions. He showed that water was used in the gold mining process to crack the quartz veins and in gold washing since the Middle Kingdom [25]. Wikipedia (2020) wrote an article about ancient Egyptian pottery. They discussed the different materials used in the pottery industry and presented pottery examples from the first and 18<sup>th</sup> Dynasties. They presented also decorated storage vessels from the 18<sup>th</sup> Dynasty [26].

### THE RIVER NILE

- The River Nile has a total length of 6650 km, depth of 8 to 11 m, maximum width of 2.8 km and goes through 11 countries [27].

- Sayings about the River Nile:
  - Prophet Mohammed peace be upon him (609-632 AC) said: 'Saihan, Jaihan, Euphrates and Nile are all among rivers of Paradise' [28]. This means that they are the good and best rivers [29].
  - The Greek Historian Herodotus (died 425 BC) said: 'Egypt is the gift of the Nile'. He meant that all Egyptians water came solely from the Nile and used for drinking, washing, irrigation and operation of water wheels [30].
- The ancient Egyptians appreciated and realized this fact. They were keen to represent the River Nile as a man wearing a Lotus-flower crown, carrying water pots and flowers and presenting them to the Egyptians as depicted in a relief in the Temple of Seti I, the 2<sup>nd</sup> Pharaoh of the 19<sup>th</sup> Dynasty, 1290-1279 BC shown in Fig.1 [31].



**Figure1.** Relief in the Temple of Pharaoh Seti I from the 19<sup>th</sup> Dynasty [31].

- Life in ancient Egypt depended on the River Nile. It was Egypt's main highway for transportation of goods, crops, people using boats and barges [32].
- The ancient Egyptians recorded annually the water level of the River Nile in official records [33]:
  - The oldest water-level record was in the 'Palermo stone' inscribed during the 5<sup>th</sup> Dynasty, 2494-2345 BC.
  - 63 River Nile levels were recorded.
  - They were used to estimate the taxes and amount of land that could be irrigated per year.

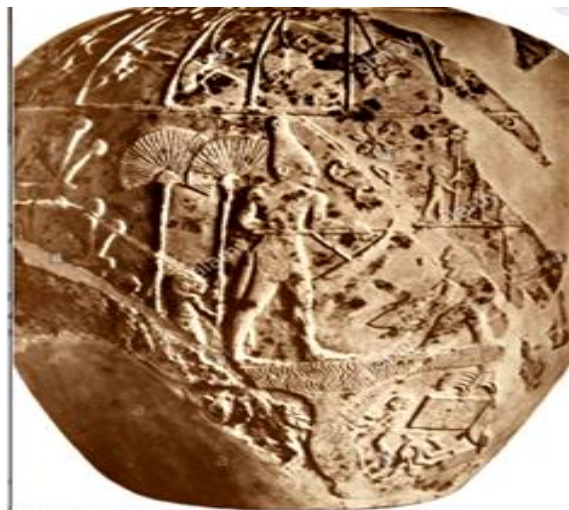
- The civilization in the Nile Valley depended on the efficiency with which the central government organized the best use of River water [33]. This is a very true and realistic statement because by this approach from the central government they saved the fertile land around the River Nile path for thousands of years down to 1952.
- Because ancient Egyptians were pioneers in agriculture, Egypt became a '*bread basket*' for the whole Roman Empire through the cultivation of one million hectares of land [34].
- The flood in the River Nile had a direct effect on the economics of Egypt. It was reported that during the disappointing of flood between the reigns of Ramses III and Ramses VII (1186-1129BC) of the 20<sup>th</sup> Dynasty, flood shortage caused the wheat price to rise markedly. Prices stabilized at their high level until the reign of Ramses X (1111-1107 BC) and fallen rapidly when the flood increased by the end of the 20<sup>th</sup> Dynasty [35].
- The authority of the ancient Egyptian State was keen to record the level of water in the River Nile in different locations allowing them to compare daily levels with past years and predict the level of water in the next year. To do this, at least 20 '*nilometers*' were constructed along the River Nile and the maximum level of each year's flood was recorded in the palace and temple archives [36]. This is something unbelievable that the ancient Egyptians can invent and apply this documentation and forecasting technology which are features of the present computerized technologies. I hope, as an Egyptian, that our present authorities apply this old water management technique used by their grandfathers thousands of years ago.
- Why ancient Egypt survived for a long time?. Mr. Fekri Hassan tried to answer this good question. He said that this was because production did not depend on a centralized state. The collapse of government or the turn over of dynasties did little to irrigation and agricultural production on the Local State [37].

### ANCIENT EGYPTIAN CANALS

- The construction of canals was a major work for the Kings and their administrative personnel beginning from the time of King Scorpion of Upper Egypt during the time of Naqada III, the Last Period of the Predynastic Periods, also known

as Dynasty 0 (3200-3000 BC). The Kings assigned one of the first duties of their Provincial Governors to be the digging and repair of canals [38].

- The mace head of King Scorpion indicated that the ancient Egyptians practiced water management for agriculture more than 5000 years ago [39]. Fig.2 shows the mace head of King Scorpion showing the King holding a hoe by both hands and supervising the finishing of digging a canal with T-shaped end [40].
- The waterway of Yousuf was known in ancient Egypt as '*Mer-Wer*' (i.e. Great Canal). It was a water project enhanced by Amenhotep III, the 6<sup>th</sup> King of the 12<sup>th</sup> Dynasty, 1860-1814 BC, to control water flow into '*Qarun Lake*' at Fayoum. He created a canal of 15 km length and 5 m depth between Asyut and Fayoum. The objectives of Amenhotep III' canal were [41]:
  - Controlling the River Nile flood.
  - Regulating the water level during dry seasons.
- Irrigating surrounding area.



**Figure2.** Mace head of King Scorpion from the 0 Dynasty [40].

- Owners and farmers were responsible for proper construction and maintenance of canals after receiving permissions to dig canals [42].
- It was said that Hatshepsut, the 5<sup>th</sup> Pharaoh of the 18<sup>th</sup> Dynasty, 1479-1458 BC, was the actual originator of the canal connecting the River Nile with the Red Sea [43].
- Seti I, the 2<sup>nd</sup> Pharaoh of the 19<sup>th</sup> Dynasty, 1290-1279 BC, started digging a canal connecting the Red Sea and the Mediterranean Sea during his reign. His son Ramses II, the 3<sup>rd</sup>

- Pharaoh of the 19<sup>th</sup> Dynasty, 1279-1213 BC completed the task originated by his father [43].
- Pharaoh Ramses II, 1279-1213 BC, digged a number of canals said to be the most impressive in all Egypt [42].
- Those canals may be the canals and lakes surrounded his new city 'Pi-Ramesses'. He constructed 'Pi-Ramesses' as a new capital for his reign in the location of modern 'Qantir' and 'Tell el-Deba' belonging to 'Al-Sharqia Governorate' over 18 km<sup>2</sup> area [44].
- The global map of 'Pi-Ramesses' is shown in Fig.3 [45].

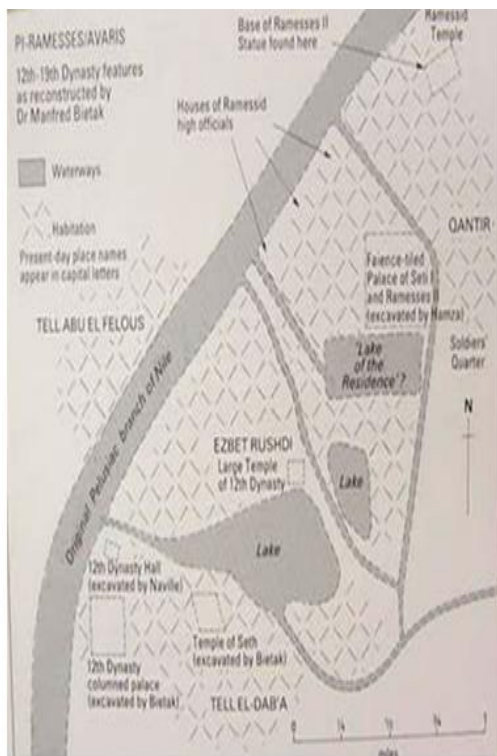


Figure3. Map of Pi-Ramesses from the 19<sup>th</sup> Dynasty [45].

- Great Pharaoh Ramses II selected the location of his city to be in the territories in the East of the Pelusaic Branch of the River Nile because of two reasons:
  - ▼ To guarantee supporting the city with continuous sweet water.
  - ▼ To be the first place in Egypt where the enemies coming from the East where they face the Pharaoh of Egypt with his soldiers, weapons and officials.
- He digged a number of canals around and within the city supported by three lakes to store water for drinking, poultry, livestock farming and cultivation.
- The three lakes were fed by three canals.

- The canals helped the people lived in the city to move easily between its areas.
- In the South of the city, there were: Set's Temple, military barracks, factories, training grounds, stables for the horses, commercial districts and two harbours serving the city [46].
- The stable housed over 450 horses and structurally designed with a slightly slanting floor allowing the waste to drop down into troughs [46]. This is a very advanced and intelligent technology allowing even very effective cleaning process and effective discharge of the waste and cleaning water.
- There was a bronze smelting factory which was the largest of its kind [46].
- The tradition of controlling water distribution for irrigation purposes was recorded using different ways:
  - Using tombs decorating colored scenes: Fig.4 shows a colored scene from the tomb of Sennedjem, Artisan during the reigns of Pharaohs Seti I and Ramses II of the 19<sup>th</sup> Dynasty, 1290-1213 BC [47]. The scene beside presenting some agricultural processes, it presents a complex design of a number of canals surrounding the fields and crossing them longitudinally.

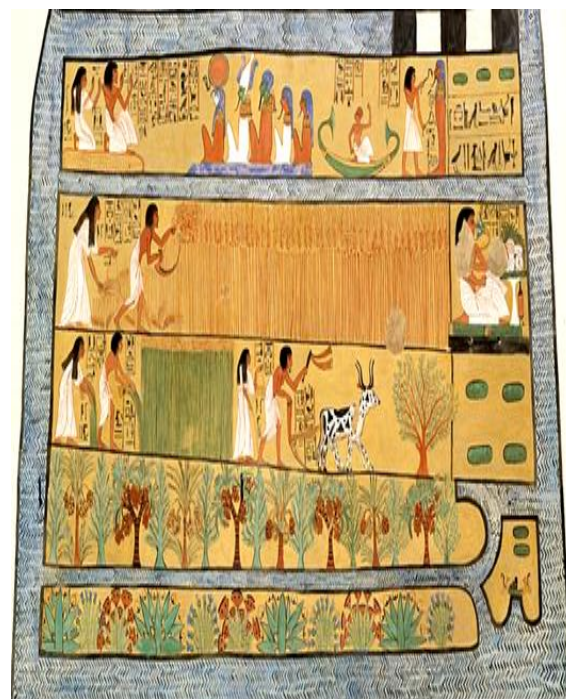


Figure4. Colored scene for canals from the 19<sup>th</sup> Dynasty [47].

- Using papyrus books supported by wonderful colored scenes and text as that of Scribe Ani, written in 1250 BC during the reign of Pharaoh Ramses II, found in Ani's tomb and

now located in the British Museum at London [48]. One of the colored scenes of Ani's papyrus is shown in Fig.5 [49]. The scene presents an extensive use of canals in Ani's field in the hereafter as he imagines it. The canals are surrounding his field all over its border and then longitudinally there are three canals meeting the border canals. In the third canal there is a branch in the shape of a sector. This may be a rest-branch for boats sailing through this branch not to disturb the sailing of other boats through the canal. In the bottom border canal, the hydrological designer provided to sub-canals, one rectangular and one straight. I think this may be a boat-yard for the production of boats near the bottom canal while not disturbing the sailing. This is a much elaborated design for system of canals for optimum management of the available water resources for sailing and irrigation.



Figure 5. Colored scene from Ani's papyrus from the 19<sup>th</sup> Dynasty [49].

- Later on, the ancient Egyptians dug the 'Canal of the Pharaohs' between Zagaziq (on the River Nile Branch) and Sarapeum (on the Red Sea) through 'Wadi Tumilat' by Necho II, the 2<sup>nd</sup> Pharaoh of the 26<sup>th</sup> Dynasty, 610-595 BC, and completed by Darius the Great, the King of Persia during 522-486 BC [50]. Fig.6 shows the location of the 'Canal of the Pharaohs' between the Nile and the Red Sea [50].

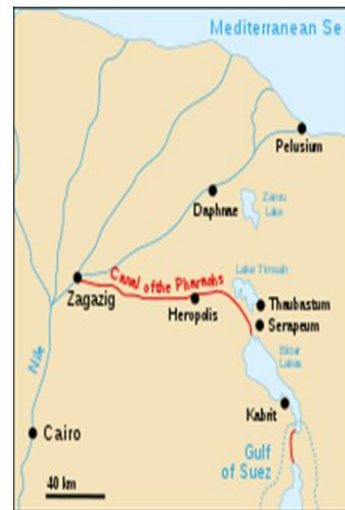


Figure 6. Canal of the Pharaohs originated in the 26<sup>th</sup> Dynasty [50].

### ANCIENT EGYPTIAN WELLS

- Even though the ancient Egyptians had the Great River Nile providing sweet water for all human activities sufficient to build a great civilization they had another alternatives for water resources. They had the knowledge about the existence of underground water and how to extract it through digging of wells.
- **DOCUMENTATION OF ANCIENT EGYPTIAN WELLS:** The ancient Egyptians were pioneers in activities documentation using different media. Here, is how they documented the establishment of wells in Egypt:
  - Ostracon documentation (Ostracon DeM92): This Ostracon was dated to year 15 of the reign of Ramses III, the 2<sup>nd</sup> Pharaoh of the 20<sup>th</sup> Dynasty, 1186-1155 BC, where it was inscribed listing the work done in establishing a well in two stages with total depth of 43 Royal Cubits (22.4 m) [51].
  - Papyrus documentation (Turin 1923): This papyrus was written during the reign of Ramses VI, the 5<sup>th</sup> Pharaoh of the 20<sup>th</sup> Dynasty, 1145-1137 BC. The papyrus stated that they brought a professional supervisor who calculated the remaining distance to the water table which was 60 Royal Cubits (31.5 m) [51]. This means that ancient Egyptians were well educated and experienced to run scientific calculations and plan successful well design and establishment.
- During the reign of Pharaoh Ramses III of the 20<sup>th</sup> Dynasty, the people of Deir el-Medina dugged a 'Great Pit' to be used as a 'water well'. It had a 50 m depth and 30 m diameter [51]. There was a dispute about the success of this pit as a water well. Some

researchers see that it was never functioned [52] and [53]. However, some others see that it did functioned [54]. The great pit of Deir el-Medina is still existing as a witness for the capability of the ancient Egyptians do dig wells with depth above 50 m in the rocks with fixed structure facilities for the users to reach the water level in the well. Fig.7 shows the 'Great Pit' at Deir el-Medina [55]. They used stairs to take the user down through stages ending with the water level.



Figure7. Great pit in Deir el-Medina from the 20<sup>th</sup> Dynasty [55].

- Amennakhte, Scribe of the Tomb during the reign of Pharaoh Ramses IV of the 20<sup>th</sup> Dynasty draw a map in 1150 BC for the quarry expedition of the Pharaoh sent to Wadi Hammamat in the Eastern Desert. The map was drawn on a papyrus which is now located in the Egyptian Museum at Turin of Italy and a part of it is shown in Fig.8 [56]. The map identifies the location of the quarry, the mountains, routs and other things. The scribe identified the various elements of the map using a text. This is the map in which David Lister pointed out to the features identified as water well and cistern [57].



Figure8. Papyrus map from the 20<sup>th</sup> Dynasty [56].

## ANCIENT EGYPTIAN MARSHES

- Marshes are found at the edges of water streams such as rivers and canals and lakes dominated by herbaceous rather than woody plants [58].
- In marshes it was easy for the ancient Egyptians to find different type of fishes, birds and herbaceous plants such as papyrus, lotus, reed and other swamp plants [59].
- The ancient Egyptians produced light papyrus boats to manoeuvre through the marshes for purpose of hunting, fishing, collecting papyrus and collecting flowers [21].
- The optimal utility of marshes as natural resources is illustrated by the following examples from various ancient Egyptian Dynasties:
  - The first example is fishing relief in the tomb of Kagemni at Saqqara, Vizier during the reign of Tata, the founder King of the 6<sup>th</sup> Dynasty, 2345-2333 BC shown in Fig.9 [60]. The relief depicts three fishermen on a papyrus boat fishing in a marsh.



Figure9. Fishing relief in Kagemni's tomb from the 6<sup>th</sup> Dynasty [60].

- The second example is a colored scene of a marsh dominated by the papyrus plant in the tomb of Menna, Scribe and Overseer of the Works of Amun during the reign of Thutmose IV, the 8<sup>th</sup> Pharaoh of the 18<sup>th</sup> Dynasty, 1398-1388 BC shown in Fig.10 [61]. Two men on papyrus boats are collecting papyrus flowers while Menna is fishing. Birds are on the papyrus plant and in the water.
- The third example is a bird-hunting scene in a marsh in the tomb of Overseer Menna of

the 18<sup>th</sup> Dynasty, 1398-1388 BC shown in Fig.11 [62]. The scene shows Menna holding a bird by his left hand and hunting

another one using a throw-stick in his right hand. His family is enjoying the hunting trip with him.



**Figure10.** Scene of a marsh in Menna's tomb from the 18<sup>th</sup> Dynasty [61].



**Figure11.** Bird-hunting scene in a marsh in Menna's tomb from the 18<sup>th</sup> Dynasty [62]

- The fourth example is a scene for a fishing using a net scene in a marsh in the tomb of Overseer Menna of the 18<sup>th</sup> Dynasty, 1398-1388 BC shown in Fig.12 [63]. The ancient Egyptians designed nets using natural materials available for purpose of fishing and birds hunting.

- The fifth example is scene for a girl from the family of Overseer Menna collecting ducks and papyrus flowers from the marsh shown in Fig.13 [63]. It is one of the symbolic arts showing how a marsh is supporting the ancient Egyptians with: food, good smell and flower vases and bouquets.



**Figure12.** Net fishing scene in a marsh in Menna's tomb from the 18<sup>th</sup> Dynasty [63].



**Figure13.** Girl scene in a marsh in Menna's tomb from the 18<sup>th</sup> Dynasty [63]

- The sixth example is a birds-hunting scene using a net pulled by three men under supervision during the reign of Pharaoh Thutmose IV of

the 18<sup>th</sup> Dynasty, 1398-1388 BC shown in Fig.14 [64].



**Figure14.** Birds hunting scene from the 18<sup>th</sup> Dynasty [64].

- The seventh example is a birds-hunting scene in the marshes in the tomb of Nebamun, Scribe and Grain Accountant during the reign of Pharaohs Thutmose IV and Amenhotep III of the 18<sup>th</sup> Dynasty, 1398-1350 BC shown in Fig.15 [65]. The scene shows the Scribe hunting birds using a throw-stick while he is on a papyrus boat (not shown), his wife is behind him holding a bouquet of flowers and his daughter is between his legs enjoying the journey.
- The eighth example is a colored scene in the



Figure15. Bird-hunting scene in a marsh in Nebamun's tomb from the 18<sup>th</sup> Dynasty [65].



Figure16. Marsh scene in Neferhotep's tomb from the 18<sup>th</sup> Dynasty [66].



Figure17. Marsh relief from the 25<sup>th</sup>/26<sup>th</sup> Dynasties [67].

### ANCIENT EGYPTIAN DAMS

- Dams are very important item in water management helping in controlling water flow and optimum utility of water.
- During the 3<sup>rd</sup> Dynasty of ancient Egypt in 2650 BC, the ancient Egyptians started building a masonry dam located 10 km South of Helwan called 'Sadd el-Kafara', It had: 14 m height, 110 m length, 56 m width at crest , 98 m width at base and  $5.7 \times 10^5$  m<sup>3</sup> reservoir capacity. They took 10-12 years to build the dam for flood control. The dam was destroyed by a flood before final completion [68].

tomb of Neferhotep, Chief Scribe of Amun during the reign of Pharaohs Tutankhamun, Ay and Horemheb of the 18<sup>th</sup> Dynasty, 1332-1292 BC shown in Fig.16 [66]. The scene depicts papyrus plant with open and closed flowers and a lot of various birds besides some animals all living in the marsh.

- The ninth example is a marsh relief from the 25<sup>th</sup>/26<sup>th</sup> Dynasties shown in Fig.17 [67]. The relief depicts papyrus with open and closed flowers, different type of birds and a cat.

- 'Sadd el-Kafara' was the first known dam to exist. The ancient Egyptians used 100,000 ton of gravel and stones lined with limestone to construct the dam [69].
- The second example ancient Egyptian dams is the 'Ha-Uar Dam':
- The canal between Assiut and Fayoum and the Fayoum depression were natural during the time of Mena, the founder King of the 1<sup>st</sup> Dynasty, 2900 BC [70].
- Amenemhat III, the 6<sup>th</sup> King of the 12<sup>th</sup> Dynasty, 1860-1814 BC, widened and deepened the canal from the Nile to Fayoum depression and converted the lake to an artificial reservoir of 1700 km<sup>2</sup> area and 45 m depth below the sea level [70].
- They constructed the 'Ha-Uar Dam' at both ends of the canal with gates to control the water flow in both directions [70].
- The Eastern 'Ha-Uar Dam' structure blocked the valley connecting the River Nile to the Fayoum depression with 1.55 km depth structure from South to North and used sluice gate valve to control a water flow of 5m height and 10 m width [70].
- Prophet Yusuf peace be upon him who lived in Egypt during the reign of Hyksos during



the 15<sup>th</sup> Dynasty, 1630-1521 BC, conducted a restoration work for both the canal and the lake [70] after which the Egyptians called the canal 'Bahr Yusuf'.

- Senusret III, the 5<sup>th</sup> King of the 12<sup>th</sup> Dynasty, 1878-1844 BC, constructed a dam at Semna on the River Nile raising the level of the Nile water allowing trading expeditions to the interior of Africa. The clever ancient Egyptians recorded the effect of building this dam through inscriptions on the rocks below the Nile fortress of Semna recording Nile flood levels during the Middle Kingdom [71].

### ANCIENT EGYPTIAN IRRIGATION MACHINES

- Water pots: The ancient Egyptians used pottery water pots to raise water from canals or ponds to working sites and agricultural field. Here, are some examples:
  - Single-pot porters: The porter carries only one pot on his shoulder as illustrated in Fig.18 which is a scene brick production from the tomb of Rekhmire, Vizier during the reign of Pharaohs Thutmose III and Amenhotep II of the 18<sup>th</sup> Dynasty, 1479-1398 BC [72].

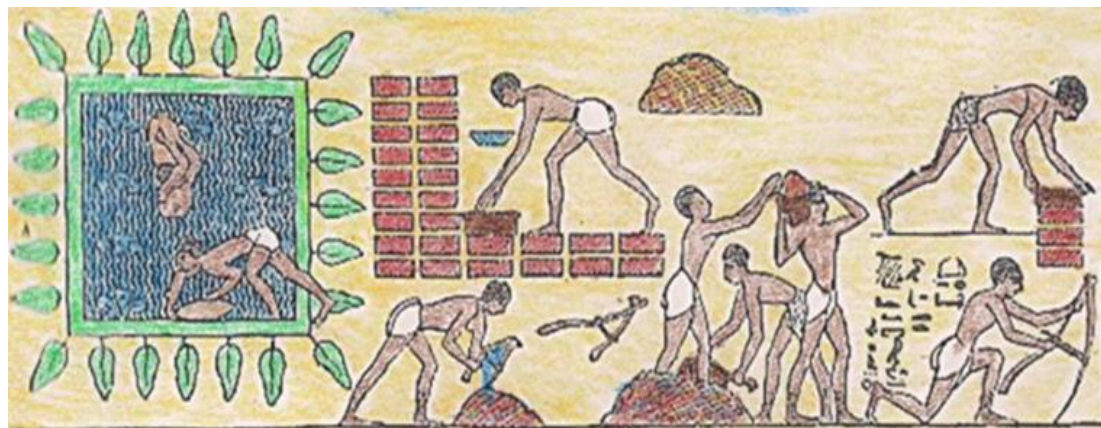


Figure18. Single-pot porters from the 18<sup>th</sup> Dynasty [72].

- Double-pot porters: To increase the water flow rate from water source to where water is required, they invented a mechanism for carrying water in two pots carried by one porter using a yoke on the porter-shoulder and two pieces or robes as illustrated in Fig.19. The scene is from a tomb at Beni-Hassan during the reign of Amnemhat II, the 3<sup>rd</sup> King of the 12<sup>th</sup> Dynasty, 1929-1893 BC [73].



Figure19. Double-pot porters, 18<sup>th</sup> Dynasty [73].

- Shadoof: The 'shadoof' is a simple machine used by the ancient Egyptians since 2000 BC (i.e. during the 11<sup>th</sup> Dynasty of the Middle Kingdom [74]. It consists of a lever of the

first type, a counterweight at the back end and a bucket connected to the front end through a robe. Some shadoof scenes are presented:

- The first example is a tomb scene from the reign of Thutmose I, the 3<sup>rd</sup> Pharaoh of the 18<sup>th</sup> Dynasty, 1503-1493 BC, shown in Fig.20 [73]. The lever was joined to a long vertical pole using an revolute-type joint. This design was for one operating man where the effort in at the bucket side where the load is the counter weight. In such a case the operator will pull the robe down to overcome the load and move the bucket down to the canal or well level. The two lever dimensions (length from joint to load and effort) are adjusted to raise the bucket full of water freely under the effect of the counterweight. In such case the operator will use very little effort to manoeuvre with the bucket to discharge its water.
- The second example is a reproduction of a colored scene of a farmer irrigating a garden using a shadoof from the tomb of Ipuuy, one of the Nobles of the 19<sup>th</sup> Dynasty during the reign of Pharaoh Ramses II, 1279-1213 BC, located in the Metropolitan Museum of Art and shown in

Fig.21 [75]. It has the same engineering design of the shadoof of the 18<sup>th</sup> Dynasty of Fig.20. Here, the farmer is pulling down the robe to fill

the bucket with water, while in the 18<sup>th</sup> Dynasty scene; the farmer is pouring the water into a channel to irrigate palm trees.

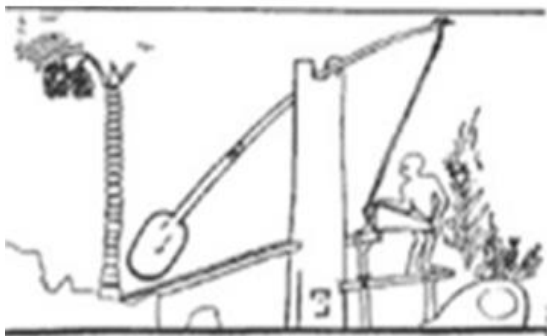


Figure 20. Shadoof from the 18<sup>th</sup> Dynasty [73]



Figure 21. Shadoof scene from the 19<sup>th</sup> Dynasty [75].

- Waterwheels: The ancient Egyptians used waterwheels to raise water from canals, lakes and wells. They were invented by Greeks during their Ptolemaic Dynasty in Egypt, 305-30 BC. Still there are more than 200 of them distributed in the Fayoum city South of Cairo [76], [77].

#### ANCIENT EGYPTIAN GARDENS AND PONDS

- The availability of sweet water in Egypt through its River Nile made the ancient Egyptians pioneer in designing gardens and adding amazing activities producing high levels of beauty.
- The pond is a small volume of water without moving water formed naturally or man-made and has a depth not more than 1.8 m [78].
- Ancient Egyptians new 'ponds' and used them for various applications and designed gardens. Here are some examples:
- The first example is a pond in a construction site supporting the production of bricks recorded

in the tomb of Rekhmire, Vizier during the reign of Pharaohs Thutmose III and Amenhotep II of the 18<sup>th</sup> Dynasty, shown in Fig.18 [72]. The pond was surrounded by a single type of trees from its four sides.

- The second example is a rectangular pond in the garden of Puyemre, Architect and Priest of Amun during the reign of Pharaoh Thutmose III of the 18<sup>th</sup> Dynasty, 1479-1425 BC, shown in Fig.22 [79]. The artist had drawn the tree in the owner's garden pouring liquid from a spouted amphora in the bowl of the owner. A wonderful symbol having too many meanings.
- The third example is a rectangular pond in the garden of Nebamun, Scribe and Grain Accountant during the reign of Pharaohs Thutmose IV and Amenhotep III of the 18<sup>th</sup> Dynasty, 1398-1350 BC, shown in Fig.23 and located in the British Museum at London [80]. The pond is full of birds, fish and some flowers.



Figure 22. Pond of Puyemre from 18<sup>th</sup> Dynasty [79]



Figure 23. Pond and garden of Nebamun from the 18<sup>th</sup> Dynasty [80].

- The fourth example is a pond in the garden of Akhenaten, the 10<sup>th</sup> Pharaoh of the 18<sup>th</sup> Dynasty, 1351-1334 BC, in his Palace at Amarna located in the Egyptian Museum at Cairo and shown in Fig.24 [81]. This was

something abnormal since usually they paint gardens on tomb walls but here they selected a huge area on one of the floors of the Pharaoh's Palace to draw a wonderful scene for a garden with a rectangular pond.



Figure24. Garden and pond scene in the Palace of Akhenaten from the 18<sup>th</sup> Dynasty [81]

- The fifth example is a garden scene in the tomb of Neferhotep, Chief Scribe of Amun during the reign of Pharaohs Tutankhamun, Ay and Horemheb of the 18<sup>th</sup> Dynasty, 1332-1292 BC shown in Fig.25 [82]. The scene represents a garden outside the Karnak Temple incorporating a T-shaped pond. It depicts the tomb owner presenting a flower-bouquet to his wife.
- The sixth example is a T-shaped pond in the garden of Nakhtamon, Overseer of the Altar during the reign of Pharaoh Ramses II of the

19<sup>th</sup> Dynasty, 1279-1213 BC, shown in Fig.26 [79]. The confusion here is because of the tomb number TT341 in some of the information resources.

- The seventh example is a rectangular pond in the garden of Nedjemger, Overseer of the Garden during the reign of Pharaoh Ramses II of the 19<sup>th</sup> Dynasty shown in Fig.27 [82]. The colored scene depicts the Overseer doing his work from his office located inside his garden while looking towards the rectangular pond in his garden.

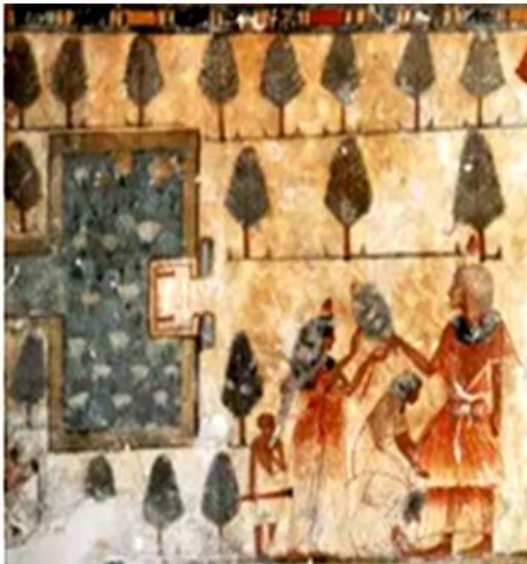


Figure25. Garden outside Karnak Temple during the 18<sup>th</sup> Dynasty [82].



Figure26. T-pond of Nakhtamon from the 19<sup>th</sup> Dynasty [83]

- The eighth example is T-shaped pond in the garden of Tjanefer, Priest during the reign of Psusennes I, 3<sup>rd</sup> Pharaoh of the 21<sup>st</sup> Dynasty, 1049-1001 BC [83]. The scene depicts the

owner drinking from the pond; palm trees are surrounding the pond and another- type tree providing its fruits in baskets (symbolic representation of some of the tree benefits).



**Figure 27.** Garden of Nedjmenger from the 18<sup>th</sup> Dynasty [82]. **Figure 28.** T-Pond of Tjanefer from the 21<sup>st</sup> Dynasty [83].

## CONCLUSION

- The paper investigated the evolution of mechanical engineering in ancient Egypt through studying the water management.
- They appreciated the running of the River Nile through their lands using scenes and reliefs symbolizing the offerings of the River Nile to them.
- They recorded the maximum water level of the Nile during the annual flood since the 5<sup>th</sup> Dynasty.
- They used the maximum water levels to estimate taxes and expected area of land cultivated per year.
- Because of their optimal utilization of the Nile water, Egypt was considered as the 'bread basket' of the surrounding civilizations.
- The flood of the Nile had a direct effect on Egypt's economy.
- Kings were keen to dig canals to transfer water to a wide area of land since the time of the King Scorpion of Naqada III. They recorded this important activity on his mace head.
- King Amenemhat III of the 12<sup>th</sup> Dynasty achieved outstanding water works through enhancing a 'Great Canal' between Asyut and Fayoum feeding water to 'Qarun Lake' with dams at both ends of the canal.
- State officials, land owners and farmers participated in digging new canals to increase the crops productivity.
- Pharaoh Ramses II of the 19<sup>th</sup> Dynasty dug impressive canals and lakes in his city 'Pi-Ramesses'.
- They recorded their tradition in controlling water distribution for irrigation purposes using: tomb scenes and papyrus documentation.

- They connected the River Nile and the Red Sea through digging the 'Canal of the Pharaohs' across 'Wadi Tumilat'.
- They looked for another sources for sweet water through digging wells. They documented their efforts to achieve this purpose through ostracons and papyri documentations. One of the famous efforts was digging the 'Great Pit' at Deir el-Medina during the reign of Ramses II.
- They could sustain optimal utilization of marshes and recorded this in tomb scenes and reliefs.
- To control water flow through the Nile and big canals, they started constructing dams since the time of the 3<sup>rd</sup> Dynasty.
- To raise water to higher levels than those of the Nile water level, they designed some irrigation devices such as: 'water pots', 'shadoof' and 'waterwheels'.
- To support small and medium industries, they digged ponds.
- The availability of water through the River Nile helped them to design amazing gardens with or without ponds (rectangular and T-shaped). They documented this activity through tomb scenes and wooden models.

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