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Irrigation System in Ancient Mesopotamia

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Hunter-gatherer groups first began agriculture in Mesopotamia more than 12000 years ago. Over time, these groups learned how to plant crops in Mesopotamia to produce their own food. Each year, the floods of the rivers Tigris and Euphrates brought silt to the land, a mixture of rich soil and tiny rocks. The fertile silt has made the region ideal for farming. Though there was fertile soil in Mesopotamia, farming was not easy there. There was little rain in the area. This meant that the levels of water in the rivers Tigris and Euphrates depended on how much rain fell in the east, where the two rivers fell. Water levels were very high after a significant amount of rain fell there. The floods damaged crops, killed animals, and washed away houses, and the crops dried up when the water levels became too low. The farmers realized that they needed a way to regulate the flow of the rivers. Thus, in both the rainy and dry seasons, early farmers faced the difficulties of learning how to regulate the flow of river water to their fields, and early settlements in Mesopotamia were situated near rivers. They could not regulate the water, and flooding was a big issue. Later, people constructed canals to safeguard houses from floods and pass water to their fields. Mesopotamians used irrigation, a method of providing water to a region of land, to solve their problems. They dug out large storage basins to carry water sources to irrigate their property. Then they dug canals, rivers created by humans, linking these basins to a network of ditches. These ditches supplied the fields with water. The farmers constructed the banks of the Tigris and Euphrates in order to protect their fields from flooding. Even when river levels were heavily irrigated, these built-up banks held back flood waters, raising the amount of food farmers were able to produce. Farmers might potentially generate a food surplus, or more than they needed. Farmers also used irrigation for cattle and sheep to water grazing areas. Mesopotamians consumed a number of foods as a result. There were abundant fish, meat, wheat, barley, and dates since irrigation made farmers more productive, which meant farming required fewer individuals. Some individuals thus would have been free to do other work. As a consequence, new occupations experienced growth - people became crafters, religious figures, and government employees as distinct from farmers doing these things 'on the side' for the first time. Division of labor here becomes the type of arrangement in which each worker specializes in a specific assignment or task.

Introduction

The control of irrigation in early complex societies has been of classical interest to historians and archaeologists for fundamental reasons. Large-scale irrigation (construction/ operation, water distribution, dispute resolution) management requirements were considered necessary for state development, as most early civilizations in the Old World were located in river valleys. This study assumes that

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for the management of large-scale irrigation systems, centralized control was needed, and developed as claimed.

Irrigation was of great economic significance to many early states, as it played a key role in agricultural intensification and surplus production. The agricultural surpluses produced were the main source of wealth in many early state societies, and political power was largely based on the exploitation of these surpluses by small centralized management classes. In addition, agricultural surpluses were required to maintain the key features of statehood, such as urbanism, full-time labor specialization, state institutions, and status hierarchy.

Scholarly interest in the cross-cultural study of ancient irrigation has declined considerably over the last few decades. As a result, several critical questions have been left only partly answered. The study of ancient irrigation presents great opportunities to understand the early states' socio-political and economic organization. We do not know how states can assumed control over irrigation management, or perhaps abstained from it, and – even more importantly, why they would have. But the implications of either option, so important to understand cross-cultural changes, have not been systematically explored.

Therefore, the object of this paper is to reconstruct elements in the creation of an early Mesopotamian irrigation system. The research is organized into component parts, each discussing one of the key elements of developing irrigation: the climate under which these occur, the source of water they regulate, the kinds of crops they irrigate, the length of their use, and how they are handled. The case studies discussed in this paper discuss the relationships between water flow, the atmosphere and the agency of humans.

Geography of Mesopotamia

Mesopotamia is a triangle that occupies an area of around 240,000 square kilometers, so to make our study effective, the area is limited by arbitrary lines drawn between Aleppo, Lake Urmiah and the Shatt-el-Arab mouth. Cities such as Ur, Uruk, Nippur, Agade, Babylon, Assur and Nineveh, all situated on or near the Tigris or the Euphrates, within the boundaries of modern Iraq, are called Chaldaean, Assyria-Babylonian, Summero-Akkadian or Mesopotamian civilizations, according to the system of their particular day. The sequence of cultures that flourished within our triangle was equaled only by the civilization of Egypt, measured either by quality, or by meaning for later history.[1]

Babylonia, the area between the Persian Gulf and modern-day Bagdad forms an area which shows relatively little topographical diversity, but all variations relied on irrigation from the Euphrates and Tigris rivers for settlement survival. The north was a desert plateau where the rivers created plunging 'canyons,' where

1. *Roux G., (1992) ancient Iraq, third edition, penguin books, London, p.4.*

agriculture was only possible at bottom of the narrow river valleys; downstream the rivers spread out onto flat alluvium, but still had clearly defined parallel channels, allowing for irrigation agriculture in squares formed by cross-canals.[2]

Mesopotamia is the region of southwestern Asia (but the area under discussion extends, with the rivers, to north central West Asia between the Black and Caspian Seas) where the earliest known civilization in the world developed. The term 'Mesopotamia' derives from the Greek word meaning 'between rivers' – it refers to the land in this case between the Tigris and Euphrates rivers, but the area can be broadly defined to include eastern Syria, southeast Turkey, and much of the region that is now eastern Syria, Around Iraq. This region was the home to cultures from the Indian subcontinent (as for example the Indus Valley), and across Mesopotamia to the Mediterranean and Egypt. [3]

Flanked by hills and undulating plains in the north where wheat growing and cattle-rearing could be practiced, the area is very diverse. The rivers are abundant with fish further south, and the river banks, full of wild animals and birds, were once forests of vegetation where lions roamed and wild boars could be caught. The rich biodiversity may have drawn humans first to the Mesopotamian plain, the southern plain is beyond the zone of rain-fed agriculture, but over the centuries, the rivers have laid dense deposits of very fertile silt, and once this soil is brought into ditches and canals, it proves to be a very desirable place for farmers for materials including wood, stone, and metals. As far as archaeologists can say, farmers and fishermen began to settle the southern Mesopotamian plain around 5500 B.C. However, people have to look north and east, to the mountains. Over time, some of their tiny villages have grown into large settlements. The cornerstone of the classes managing the farmers was the temple of the town's patron god or goddess in monumental buildings such as those found at Erode, Uruk and Ur, the rich farmland provided an extra amount of agricultural property and some of the wealth produced was invested. Using the reeds and mud that lined the river banks, temples, craftshops and regular households were constructed. Centuries of renewal using sun-dried mud bricks to replace those washed away by floods culminated in the high mounds, or the open plazas and canals, each replaced layer of the constructed city rising a little higher than the last. It was ancient Greek explorers and historians who first gave the land the name by which we know it. In the native cultures of Mesopotamia there was no name for the entire land, or a culture-name for the early Mesopotamians; instead, their conceptual horizons were limited to the names of the towns and kingdoms where they lived. Today, much of the earliest Mesopotamia lies within the boundaries of modern Iraq, with some parts of Syrian and Turkish territories to the west and north.[4]

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2. Van De Mieroop, M. (2024). *A history of the ancient Near East ca. 3000-323 BC*. John Wiley & Sons., *p49*.

3. Kuiper, K. (Ed.). (2010). *Mesopotamia: the world's earliest civilization*. Britannica Educational Publishing, *p18*

4. Bertman, S. (2003) *Handbook to life in ancient Mesopotamia*. Infobase Publishing, *P4.*

There were many floods in Mesopotamia every year. Mud and clay taken from the northern mountains and the cliff-walls of upper Mesopotamia, were carried south, and then deposited by two great rivers, the Tigris and the Euphrates, where the landforms widened and flattened, the deposits making and re-making the farm-able land. As these twin rivers descended from, and cut through the softer foothills of the northern mountains, they descend through hilly grasslands toward the southeast, and finally crossed (as they formed farmland in it) a swampy plain (Sumeria) to enter the Persian Gulf.[5]

The Tigris and Euphrates both have their bases in mountains of eastern Turkey and when they appear from the Taurus Mountains, the two rivers are separated by some 400 kilometers of open plain (often called 'Assyrian') from each other.[6]

There were two primary rivers in Ancient Mesopotamia – the Tigris and the Euphrates. In much of western Asia, the majority of land was very dry. There, plants could not grow. But the land was fertile and rich close to these two rivers. The soil deposited was brilliant for plant growth. People settled down and founded towns there. For travel, rivers were also important. The inhabitants of ancient Mesopotamia were able to travel from one region to another using small vessels. They could buy and sell food, trading with folk of neighboring cities.[7]

Tigris River

The watercourses that joint to form the Tigris River arise in high mountains that rim Lake Van in northern Kurdistan. Once having left Turkey, the Tigris touches the northeastern border of Syria and then streams southeastward across Iraq, where it is joined by branches from the east—principally the Great Zab, Little Zab, and Diyala. The Euphrates, west of the Tigris, runs in the same overall direction. In ancient times the two rivers had distinct mouths when they reached the Persian Gulf; now they meet in a swamp in southern Iraq and form a single stream, the Shatt al 'Arab, which flows into the head of the Gulf. The Tigris, 1,180 miles (1,900 kilometers) long, is shorter than the Euphrates, but it is more important commercially because its channel is deeper. The Tigris was the great river of the kingdom of Assyria. The earliest city of Assur, which gave its name to Assyria, stood on its banks, as did Nineveh, Assyria's splendid capital.[8]

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5. Loria, L. (2016) *Ancient Mesopotamian Religion and Beliefs*, the Rosen Publishing Group, Inc, p11.

6. *Roux, G. op. ct. p5.*

7. Klingel, C. F., & Noyed, R. B. (2003), *Ancient Mesopotamia*, Capstone, *P.16.*

8. Ali, A. A., Al-Ansari, N. A., & Knutsson, S. (2012), morphology of Tigris River within Baghdad city *Hydrology and Earth System Sciences*, *16*(10), P379.

Euphrates River

The 1700-mile (2,700-kilometer) Euphrates is Western Asia's longest river. It starts in eastern Turkey's high mountains, crosses eastern Syria, and then flows through Iraq to the southeast.

Maps of the 3rd millennium B.C. channels show some Euphrates branches. The main channel though probably passed through the Mesopotamia region during the 3rd and 2nd millennia B.C. primarily by what we now call the Irnina and Zubi branches (to the north) and the Kish branch (to the south). Although the history of these channels is not known in detail, their presence is recorded from Akkadian place names on clay tablets. It has, therefore, been possible to relate these place names and their associated named channels to ancient levees evident on large-scale topographic maps beginning about the first half of the 2nd millennium and ending about 900 B.C. Between floods and human work, a gradual shift of these multiple channel networks took place. during the Isin-Larsa and Old Babylonian periods in the earlier half of the 2nd millennium B.C. A previously insignificant Babylonian branch, for example, became the most important of the Euphrates courses, and probably indicates some further westward shift in flow that began in the 3rd millennium B.C. Repetitive avulsions (where a watercourse rapidly abandons one channel and forms one or more others) took place near Sippar/Fallujah, where the Euphrates, called Purattum in Sumerian and Akkadian vocabularies, emerges from its canyon-incised valley and could spread out. From the beginning of the 1st millennium B.C., another branch of the Euphrates, called Pallukkatu existed west of the Babylonian branch, its position closely approximating that of the Hindiya branch of the modern Euphrates.[9]

In addition or alluvial wandering, much of this river's water is lost by evaporation and (once settled by human colonies) use of waters for irrigation due to Iraq's hot, dry climate. The river gets most of its water from the winter rains and snowfall, gaining relatively little from feeder watercourses downstream. Only flat bottomed riverboats can navigate the shallow channels.

The Tigris runs almost parallel to the Euphrates and together they form a broad, agriculturally fertile alluvial plain, a plain made of rivers deposited silt, sand, clay, and gravel from the upper mountains and soft, friable canyonwalls. Each year, there are two flood cycles.[10]

The rivers of the Tigris and Euphrates that began in the Kurdistan Mountains, flow as they reach the flatter country below Akkad southeast across the plains of southernmost Iraq. They join together to build the Shatt-al-Arab River there. Through upper fringe of the Persian Gulf, this channel extending the banks of the

9. Morozoya, G. (2005), A review Holocene Avulsions of the Tigris and Euphrates and possible effects on the evolution of civilizations in lower Mesopotamia, Article in Geoarchaeology pp402-423. April 2005, https://www.researchgate.net/publication/ 230035623

10. Sherman Holer, op.ct, 11.

Tigris into the marshes is often referred to as "a civilization cradle." Civilization originated in the valleys of the Tigris and Euphrates rivers because this region offered abundant resources, such as plants that grew well there and game to hunt. These rivers would flood their banks in spring, and, as the floodwaters receded, the soil left behind was rich in many nutrients required by plants to grow as more permanent settlements were develop, adding religious and social character, as well as reflecting changes in farming methods - the growth of settlements are always encouraged by rich soil and water supply.

The floodwaters enriched the soil particularly often here, but being highly variable - frequently too high or too low, they just as often disrupted agriculture. Over time, farmers learned to construct drainage ditches to direct the river's water to the fields in manageable amounts, as well as dikes to hold back the excess floodwater and channel it to reservoirs for later use This was very important because as year after year the floods varied (and the generating weather occurred too far from the region to predict), so farmers were forced to learn to monitor the unpredictable flooding as it happened, and to store food for potential use. It was necessary to structure dikes, reservoirs, and irrigation ditches on a scale that was suitable for individuals working together, not only inside villages, but from village to village. And this last allowed the start of centralized power.[11]

To review, the Mesopotamia region was bounded by mountains in the north and east and desert in the west and restricted in the south by the Persian Gulf. Both rivers provided water for agriculture and daily life and were the main highways for communication between those barriers. Within them, major environmental differences divided Mesopotamia into two diverse regions, the northern plains of Assyria and the southern Babylonian alluvial marsh. Further differences below the river 'narrows' (Babylonia) divided a northern river plain region (Akkad) from the southerly, marshy delta plain. These geographical contrasts were mirrored by cultural, political, and economic differences. Marshes separated Babylonia from Elam, the eastern alluvial border-plain and hills, and north of that the tighter-impinging Zagros Mountains, a borderland whose migratory and herding history regularly intertwined with that of Mesopotamia. At times, cities and states beyond the desert and the mountains were also involved with Mesopotamia, while mountain and desert fringes were home to tribal groups who regularly raided their settled neighbors.[12]

11. E.D Hirsch E.D. (2019), Mesopotamia History and Geography, core Knowledge programs, London, p.18.

12. McIntosh, J. R. (2005). Ancient Mesopotamia: new perspectives. Bloomsbury Publishing USA, p9.

Temperature Range and Climate Change

One of the clear environmental impactors on Mesopotamian history is the atmospheric and weather profile of the Mesopotamian plains.

While the winters are cold, often even freezing, with strong winds and rain, the summers are contrastingly warm and dry. To grasp this, note that the monthly mean temperature in summer is about 95p and the temperature can rise to 50°C (120°F) in July. The temperature can drop as low as -5°C in December and January, with a monthly average of around 10°C (50°P). Monthly mean temperature in the north in the summer is not quite as high as south, but the winters are not as severe, either. After November, frosts can be common and small falls of snow occur very regularly in the northern plains. Every winter, the Kurdish and Zagros mountains are covered in snow.[13]

It is interesting that, where the climate of Mesopotamia is concerned, there has been no significant shift since very early times, according to geologists' findings. When the melting snows in the mountains of Taurus and Zagros feed their tributaries in early Spring, (and, paradoxically, this can also occur between April and June, which is also late for watering the main crop), the farm produce normally harvested in April can be short-changed during its late-development perion. A climate regime then, with seasonal variations on top of it, meant as often as not too much water at the wrong time or not enough at the right one. The ancient farmers of southern Mesopotamia encountered rain in insufficient quantities when plants needed it, while river water could accumulate in almost unmanageable quantities along the riverways at the wrong times. In the end, water had to be supplied to the local cultures at critical moments through the objects of human ingenuity: a complicated system of canals, reservoirs, dykes and regulator-sluices.[14]

Water Resources

The Tigris and Euphrates Rivers would fill the mountain valleys with water from melting snow, and so again and again the rivers would overflow. The floods of course carried fertile land to settled provinces in this way, but unpredictably. Remember that the weather in the region was very hot and dry. It is no surprise that the ancient Greek historian Herodotus considered the Nile the gods' gift to Egypt, and so the Tigris and the Euphrates the gods' gifts to Mesopotamia; this was particularly true of the alluvial plain to the south, where such staples of the human diet as barley, sesame, and dates were nurtured by the well-watered fertility of transported soil.

13. Ibid.

14. Lloyd, S. (1978). The archaeology of Mesopotamia from the old stone age to the Persian conquest Thames and Hudson, P, 17.

Southern Mesopotamia's alluvial and deltaic plains occupy part of the "Mesopotamian depression," a foreland basin confined to the northeast by the Zagros Mountains, and by the Arabian platform to the southwest plain, up to 200 km wide, where a fine-grained alluvium underlies the desert fringe. Of the rivers Euphrates and Tigris, active channels, natural levees, crevasse splays, and flood basins compose the central flood plain (at least in its current, observable form), with regions that have been eroded by avulsion or channel migration. Active fluvial deposition, elian landforms, including sand dunes and deflation basins, often show such areas and all undergo intense salinization from the higher tides (and southerly storms) of the Persian Gulf. The southern portion of the plain, called "Ahwar," consists of fresh- and salt-water lakes surrounded by reed marshes (often salt-marshes) along with large levees and inland delta lobes. Natural levees stand up to 3-4 m above the surrounding flood basins, these marshlands currently occupy only about one tenth of their former territory, drastically reduced in response to irrigation practices, global warming, and different petroleum-related and other industrial processing activities.[15]

In the mountains of southern Turkey, the Euphrates and Tigris rise, flow along this "Mesopotamian Depression," and join near its southeastern end, where they traverse the marshes and gradually form the Shatt al-Arab estuary to the Persian Gulf, together with the Karun River. The Euphrates to the west of this forms an exotic, lower land Mesopotamian stream, while four major tributaries are accepted by the Tigris. The Euphrates divides between Hindiya and Samawah into two branches: Hindiya, the main channel, and its neighboring hills. The desert area in the western part of the lower Mesopotamian plain is also complicated by relict or 'legacy' alluvial fans produced during a wetter climate mid-Holocene period.

In general, several ephemeral streams impact the region perpendicular to the flow of the Euphrates.[16] The intersection of these create 'fan piedmont' stretches along the 'feet' of the Zagros Mountains at the northeast edge of the plains. The climate is arid, with about 100-150 mm of average annual rainfall. In January, temperatures range from 10 to 12.5°C to 34-35.5°C in July. Winds blow from the north and northwest much of the year, with some southeasterly winds from April to mid-June and from September to November. Low-pressure areas and cold fronts occur with rapid variation, and are hard to predict.

The only reliable tendency (prediction will have been as important to the early farming settlers as it is now) is that most rainfall concentrates in winter and spring. And, as Lower Mesopotamia was more reliably irrigated by water from the Euphrates rather than the flash-flood and landslide-prone Tigris, the annual rainfall numbers above provide only a rough indication of the variation that can be expected between locations. In order to give a picture of the rainfall settings in their

15. Morozoya, G. op. ct. pp402-423

16. Ellison, E. R. (1978) A study of diet in Mesopotamia 3000-600 BC and associated agricultural techniques and methods of food preparation, University of London, P.7.

region at any particular time (historic or modern), the conditions of important excavated archaeological sites nearest to these rainfall stations have to be involved. And, while the reliability of the rain and the time of year in which it falls is very significant for farming, the overall amount of rainfall per year is the imperative 'bottom line.' Any region in Mesopotamia may have heavy rain in one year, but almost none in the next.[17]

Agricultural Techniques

More than anything else, it is for their many inventions, or new ways of solving old problems, that the people of Mesopotamia, especially the Sumerians, are remembered. The instances important to this article are those new agricultural techniques, such as irrigation, that were created by early farmers, leading to economic surpluses. The Mesopotamians appear to have used only basic farming technologies at first. Early instruments were made of copper and very hard-fired clay (apparently attempts to replicate bronze without any available tin), such as sickles and hoes in both materials. Metalworkers began combining copper and tin over time to create bronze as it became available (it is much stronger than copper alone), by 2500 B.C., bronze instruments (esp. those that worked hard to maximize tiny amounts of tin, such as bronze-tipped rather than full-bronze plows) were used by many farmers. Farmers could shift the soil more quickly and transformatively with stronger plows, which led to larger fields that yielded greater crops. Next, by adding a funnel filled with seeds to the plow, farmers found a way to plow and plant at the same time. The seeds were freed from the funnel as the plow moved along each row. This agricultural technique allowed more crops to be planted by fewer farmers. The Sumerians also wrote farmers' advice, which expanded into crop-soil matches, plant husbandry, etc..[18]

Mesopotamia being in the Near East sub-desert region, with its low rainfall and low precipitation, meant that irrigation became a must for reliable farming. The region we are concerned with held possibilities far beyond its dry land cultivation limits.[19] Irrigation – to compound an average dictionary definition, is "the artificial application of water to land to assist in crop production." 7000 years ago, this is where the Mesopotamians started. The base technique did not really need to be improved by much human ingenuity, since moderate irrigation was effective and simple from the beginning with almost any soil. Adjust the challenge though to large-scale farming (large communities supporting multiple crafts), and

17. Ibid.

18. Woolley,C. L. (1962)Mesopotamian Achievements, The Sumerians. W.W. Norton & Company, P2.

19. Postgate, J. N., & Powell, M. A. (1988) Irrigation and cultivation in Mesopotamia, Sumerian Agriculture Group, p1.

especially in the middle of the desert, and irrigation needed to become a bit more complex. The central drawback was that, for Mesopotamian use, farming had to be closer to a water source than heat and evaporation could defeat, and practical ways to move water were essential. Irrigation, in fact, became the first of the Mesopotamian problem-solving successes we can really call "engineering."[20]

So, Mesopotamian agriculture was impossible without irrigation. The earliest settlers of the region drained swampy sections of land that were not crop-adaptable, and constructed canals through the dry areas in order to irrigate the the areas that were adaptable. This itself was older than Mesopotamia. What made "the land between the rivers" the home of the first irrigation culture is that the irrigation systems were constructed according to a schedule, and to sustain that systematic schedule needed an organized workforce. Irrigation experiments there seem to have started on a small-scales and grown into a large-scale project that in turn needed more government control. Mesopotamia as a 'raw' landscape was swampy in some places and dry in others; the climate in most areas was too hot and dry to grow crops without any assistance, but human settlers adapted it. Archaeologists have discovered 3,300-year-old plow furrows lying near Ur in southern Iraq with water jars still lying by small feeder canals. Water movement was at first labor-intensive, and water distribution schemes were developed by local government and legislation in the hope the local processes ran smoothly.[21]

Remember our earlier point – as far as the climate of Mesopotamia is concerned, geologists have found no perceptible change since the earliest times (and that this is true even today). The country has summer temperatures ranging from 130 degrees Fahrenheit in the shade, and eight months without precipitation in the year. Rivers are reduced to stagnant brown meanders in the waste of dried mud by the end of the dry season. Then winter arrives, with pale midday sunshine and freezing nights, bringing with it occasional rainstorms. But until spring, when the melting snows of the Taurus and Zagros Mountains feed their tributaries, the rivers do not obtain their maximum volume of water until the spring floods that erode devastating loads of soil from the northern canyon walls and carry it south. These load-bearing flash floods were considered virtually uncontrollable as little as a century ago, and posed an ominous danger to the inhabitants of the lower plain throughout history, especially as the south most heavily damaged by these had no way of predicting how they developed in the north. Paradoxically, these eruptions of water and soil often occur between April and June, which is too late to water the main crop anywhere to the south, where normal harvest is in April. The 'feel' of this to farmers was dysfunctional, and formed a stock farmers' complaint.

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20. Mays, L. W., Irrigation Systems, Ancient Water Encyclopedia, JRank, www.wateren cyclopedia.com/Hy-La/Irrigation-System-Ancient.ht.

21. Merle, S. (1991) Agriculture, crops, irrigation and livestock in Mesopotamia, Geograhic, Smithsonian Magaznien, http://factsanddetails.com/world/cat56/sub363/item1513.html

Add up the climate and seasonal variations faced by the ancient farmers of southern Mesopotamia: rain at the wrong time in insufficient amounts; river water, even at the wrong time, concentrated in almost unmanageable quantities along the river beds. In the end, it is little surprise that water had to be supplied to the farm-scape simply through the architecture of human ingenuity backed by local law - a complex system of canals, reservoirs, dykes and regulator-sluices. These required a great deal of organization, resilience in the face of failed attempts, and patience. The canals themselves filled their beds very quickly with silt, so that creating new canals constantly competed with dredging old ones. And, as this process went on, the canal-banks grew too high to throw spoilage and clogging soil out, so a new canal had to be excavated parallel to the first one.[22]

A method developed across the 'land between the rivers.' A canal would bring water out of one river and separate it into several agricultural fields, leading to effluent to drain into another river. Canals were built by trench-digging through drier ground, but then piling up soil on both sides to allow digging through sections of swamp where necessary, creating breaks in the bank or berm where necessary to water farm plots going into use. Later on, the Sumer folk (a local cross-cultural mix of settlers that tackled the worst regions of the marshes, created their own levees, essentially a larger berm-sided canals that could hold even more water, and which tried to use natural embankment formed by floods, built up over time where possible. These attempted to create perpendicular faces where they face large water-courses or the actual seas of the Gulf, but tried to feature backwards slopes that were more gentle when facing inward toward the marsh-lands. The Sumer repeated this by creating intricately-woven walls in which fire-hardened reeds reinforced clay, tying them together and packing mud (sometimes using water-resistant oil seeping from the marsh-bed just as it does today) around them.[23]

A term like "engineering" implies use of mathematics in some form, and in the irrigation systems of the early civilizations in Mesopotamia, Kazuo Muroi wrote that digging, maintaining, and quantifying work on canals was an important activity for the rulers of Mesopotamia, as canals were not only necessary for irrigation, but also useful for transporting goods and armies. Babylonian mathematicians may have been instructed by the rulers or high government officials to measure the manual workers' salaries or expenses. [24]

Difficulties in Building and Maintaining a Complex Irrigation Scheme

22. Lloyd, S., op.ct., p11.

23. Maria, k. (2017), Ancient Sumerian Levees & Canals. Sciencing, Sciencing.com, 25 Apr. 2017, sciencing.com/ancient-sumerian-levees-canals-16874l. http://factsanddetails.com/world/cat56/sub363/item1513.html

24. Ibid.

There were many problems facing the farmers who migrated to Sumer's southern marsh-cropland. The unpredictable (and sometimes unmanageable) availability of water was one of the main concerns. The rain and melted snow poured from the mountains into the Tigris and Euphrates Rivers during the spring, concentrated in the northern canyon country (adding silt and rock) and then exploded into the southern flatlands, causing high-energy floods across the plains. But no one could be sure when the floods would arrive, exactly, and for the farmers this was critical. If it happened after farmers planted their crops, it would wash away their young plants. The sunbaked soil was dry and hard as stone for most of the remainder of the year. Thick clouds of dust drifted across the field from the heavy, powerful winds. Faced with these drastic seasonal shifts, farmers had to work constantly to grow crops. They either had too little water, or had too much water. They needed a way to regulate the water to succeed in growing healthy food-crops, and what they really needed was a stable water source all year round.[25]

Irrigation systems gave Sumerian farmers ample, adaptable supplies of water to produce plenty of food. But with those a new issue arose: how to sustain the irrigation system outside the limits of the village – the limits of the labor it could supply or the limit it could defend from raiders or a hostile environment. As an irrigation system brought water from the river to the fields, it would pass through several villages, sometimes villages with competing needs or goals. It was vital to continually manage the system at each point. The canals had to be frequently washed as they were clogged with silt (very fine mud often containing clay or even oil), and of course the whole system could be spoiled by one clogged canal. To keep them from clogging, they cleared the silt off the canals. To ensure the water levels were balanced, they scooped water using manual or animal-driven well-sweeps, painstakingly from one reservoir into another.[26]

Farmers could not live separately, even in small groups, anymore. They were connected by canals for miles around them, and to be sustainable the system made them work together for the common good. Steadily, to develop and maintain their complex irrigation system, villagers began to rely on each other. Problem-solving workforces had to come together from various villages.

Conclusions

Mesopotamia was not (in spite of the popular image today), was not a suitable land for living and farming without an irrigation scheme. The northern portion

25. Nicholas R. Magliocca & Erle C. Ellis (2016) Evolving human landscapes: a virtual laboratory approach, Journal of Land Use Science, pp643-671, 11:6, 642-671, DOI: 10.1080/1747423X.2016.1241314.

26. Ibid.

was hilly, always subject to rain. There were small plains and marshes in the southern portion, flat ground and shallow water. On the plains between the Tigris River and the Euphrates River, the sun beat down brutally even when there was slight rain. Yet the Mesopotamians were farmers, demanding the water that allows farms to function. When the rivers flooded, they carried water to the lowlands, but the soil remained parched and dry for much of the year.

In spite of the full effect such an unpredictable and even hostile enrivonment produced, these rivers came to furnish a lifeline for growing and adorning the resilient civilizations we think of as Mesopotamia today, let them access forms of transportation, to source a healthy diet and medicines, forms of defense against both raiders and weather, and finally collaborative engineering and culture. As early human beings have improvised skills to adapt to their environments, they did so here, mainly driven by the need to use of water to serve their community. They adapted the social and technical traits we call the Neolithic Revolution to allow themselves a life in an unlikely setting.

Their irrigation systems turned the dangerous water of northern floods and southern salt tides into to great stretches of productive agricultural territory thru a vast-branching network of canals and their support-works. Although the soil 'imported' by the yearly floods might have been be very fertile in an abstract sense, and could produce in abundance if managed, reinforced, maintained and drained, southern Mesopotamia was never an easy place to base the large population it attracted and fed. The natural result of all this collaborative creativity and its rich dividends supported a cultural hegemony of northern Mesopotamia, which seems to have lasted many centuries, even if the south had in the end to hire military cultures to defend it, and though the north would one day turn the tables.

The development of irrigation, and all the developing economic and organizing behaviors associated then, were the gears by which this success turned. Such complexity so long in the past makes attempts to assess the technological performance and impact of ancient Mesopotamian water technologies reveal that the task is very difficult, but no less vital and important.

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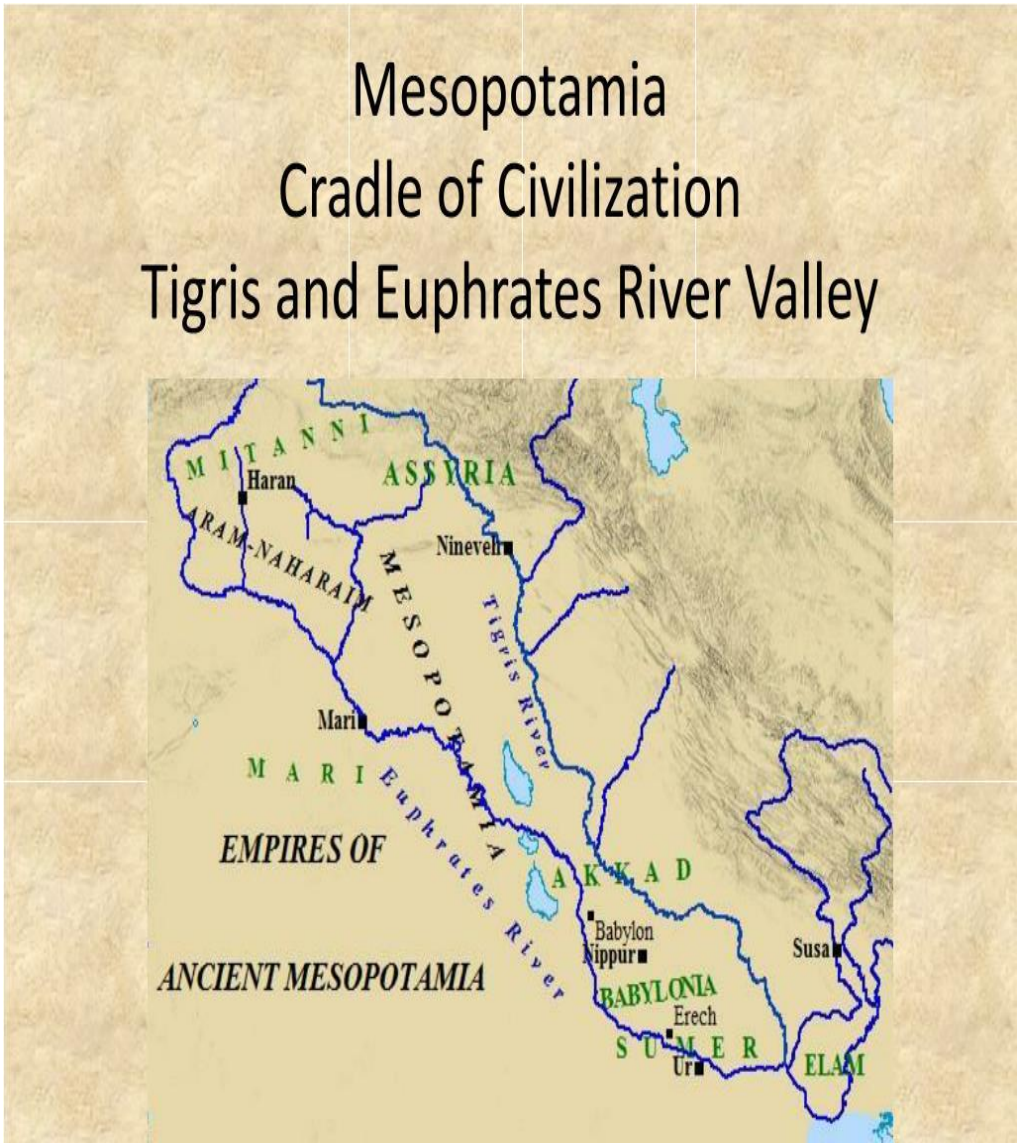
Appendix: Mesopotamia Rivers

Source: Encyclopaedia Britannica, Inc.



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