AGRICULTURAL HYDRAULIC WORKS IN ANCIENT GREECE

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1. INTRODUCTION

Agricultural development requires hydraulic works including flood protection of agricultural areas, land reclamation and drainage. In addition, in a Mediterranean climate, irrigation of crops is necessary to sustain agricultural production and, at the same time, water storage projects are necessary to remedy the scarcity of water resources during the irrigation period. In modern Greece, irrigation is responsible for more than 85% of the water consumption and to provide this quantity several large hydraulic works have been built. Similarly, in ancient times, Greeks had to develop technological means to capture, store, and convey water and simultaneously to make agricultural areas productive and protect them from flooding. Agricultural developments in Greece, traced to the Minoan and Mycenaean states (1, 2), were responsible for the increase of agricultural productivity, the growth of large populations, and the economic progress that led to the creation of classical civilization. Some examples of agricultural hydraulic projects of the ancient times chronologically extend from the Mycenaean to the Hellenistic period are discussed in this chapter.

2. THE EARLY DEVELOPMENTS AND THE MYTH OF HERACLES

Urban water projects such as water supply aqueducts and sewer systems have been common in many ancient civilizations. Archeological and historical evidence suggests that several such projects were constructed in ancient Greece, some of which are astonishing (3). Obviously, agricultural projects, in comparison to urban ones are rougher and also exposed to damages and decay, and thus can hardly be preserved for millennia. However, there is convincing evidence at several places of Greece and in several stages of the Greek civilization that

important agricultural hydraulic works have been built. This evidence comes from mythology, scripts including epigraphs, and remnants of certain works.

The first actions of hydraulic engineering in mainland Greece are traced to around 1600 B.C. (4); there is no written information about these actions, which however survived in the mythic folklore in the legend of the Hero Heracles (also known with the Latin name Hercules). Even from the ancient times, several authors like the historian Diodoros Siculus (90-20 B.C.) the geographer Strabo (67 B.C.-23 A.D.) and the traveler Pausanias (2nd century A.D.) explained Heracles in a historic way demystifying him from a mythic hero into a hydraulic engineer; this continues today (4, 5, 6). The myth of Heracles fighting against Acheloos indicates the struggle of the early Greeks against the destructive power of floods. Acheloos, the river with the highest mean flow rate in Greece, was then worshipped as a god. As depicted on Greek vessels, Acheloos was metamorphosed into a snake and then a bull, but finally was defeated by Heracles who won Deianira as his wife. According to the historian Diodoros Siculus (IV 35) and the geographer Strabo (X 458-459), the meaning of the victory is related to channel excavation and construction of dikes to confine the shifting bed of Acheloos. There are no technical descriptions of these works; only some presumed remnants of dikes (4).

Figure 1. Heracles fighting against Acheloos as depicted on a Greek vessel kept in the British Museum, London (Photograph from http://www.perseus.tufts.edu, copyright by the British Museum, London)

From Strabo (IX 440) and Diodoros (IV 18) it is also known that similar structures had been built on another large river located at the Thessaly plain, Peneios at Larissa, which are

again attributed to Heracles. Other labors of Heracles such as those of the Lernaean Hydra and the Augean stables also symbolize hydraulic works. Lernaean Hydra was a legendary creature in the form of a water snake with nine heads that lived in the Lerna swamp near Argos. Hydra possibly symbolizes the karstic springs of the area or the Lerna swamp itself and its annihilation by Heracles has been interpreted as the drying up of the swamp. The Augean stables were cleaned by Heracles who diverted two rivers to run through the stables (a more sanitary-environmental labor).

3. THE MYCENAEAN GREECE AND THE LAND RECLAMATION SYSTEM IN KOPAIS

Archeological evidence traces the earliest significant hydraulic works in Greece to the Minoan civilization (3) at Crete. These, however, were related to urban water developments and no traces of agricultural hydraulic projects have been found to date in Crete. Nevertheless, Platon (7) believed that the Minoans had practiced irrigation and developed irrigation and land reclamation projects. In addition, according to Marinatos (8), many agricultural crops of the present day such as vegetables, cereals, olives, grapes and aromatic species were grown in Minoan Crete.

After the decline of the Minoan civilization (*ca.* 15th century B.C.), the Mycenaean civilization in mainland Greece achieved supremacy. The great Mycenaean cities (Mycenae, Tiryns, and Pylos in Peloponnese and Thebes and Orchomenos in Boeotia, north of Athens) were noted for their heavy fortifications with their massive, cyclopean masonry, while Minoan cities were totally unfortified. Close to Thebes and Orchomenos, there was a large shallow lake, named Kopais, where the Boeoticos Kephisos River discharged. Natural karstic sinkholes (katabothres) discharged some of the water, above a certain level, towards the sea. At the end of the 19th century A.D. the lake was permanently drained and converted into an irrigated plain, one of central Greece's most fertile agricultural areas. The modern drainage of Kopais has also revealed massive hydraulic engineering works that most probably drained it in late Mycenaean times (*ca.* 1450-1300 B.C.). According to Strabo (IX 406-407, 414-415), the draining of Kopais was achieved by the Minyae people who lived there. Huge earthen dykes furnished with cyclopean walls were built in Kopais. Three main canals with length 40-50 km, width 40-80 m and parallel walls up to 2-3 m thick traverse the former lake area (6, pp. 444-458; 9, p.33). The whole project included the construction of polders (Figure 2) and artificial reservoirs for flood water retention and storage, and the improvement of the drainage capacity of the natural sinkholes. The scale of this vast project, which includes the construction of the enormous citadel at Gla, another Mycenaean palatial site on a low

limestone island rising up from the floor of the basin, dwarfs any other Mycenaean building project. According to Knauss (10), the sophisticated hydraulic system in the Kopais and its advantages in developing the country and especially the agricultural production allows the hypothesis that Kopais was the "fat province" of Boeotia mentioned by Homer in Iliad, book 7 (219-224). Knauss is so much impressed by the system as to write "As an hydraulic engineer of today, always advised to look for the best economic and ecologic solution of a given hydrotechnical problem, I admire my early colleagues in what they could do and what they did, with simple tools and materials, but with an intensive and sensitive observation of natural processes, some thousands years before modern hydraulic engineering could reach a similar standard."

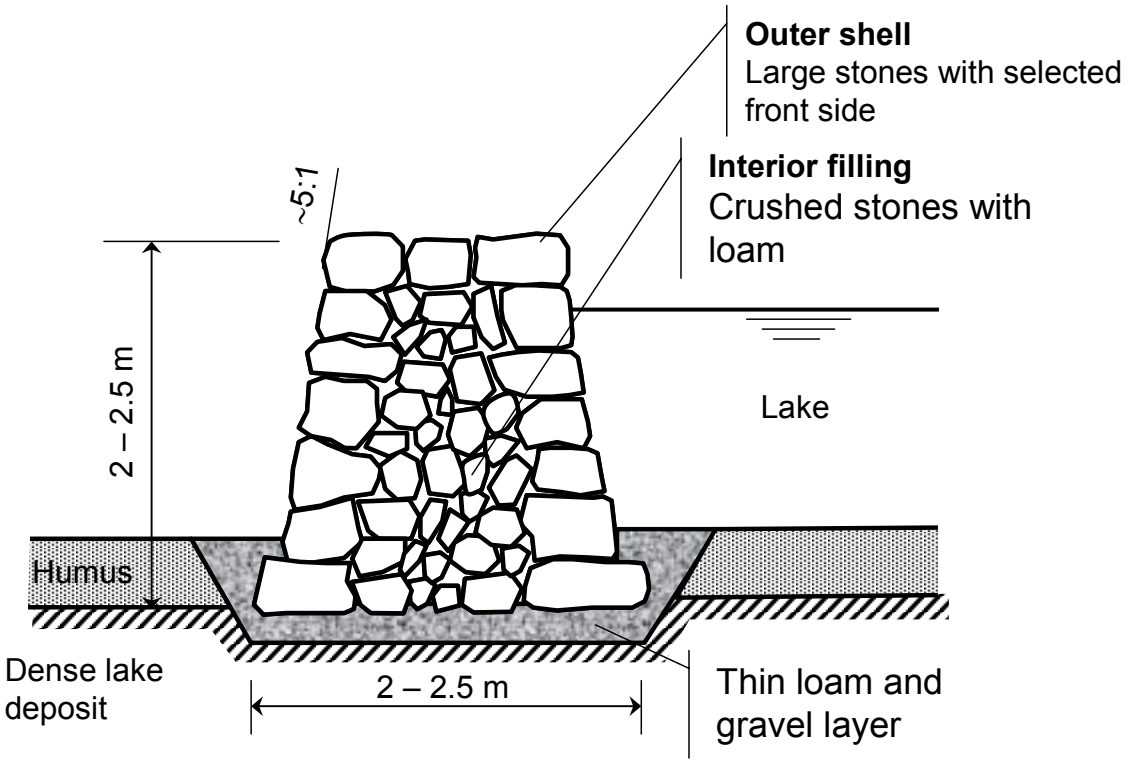

Figure 2. Cross section of the polder dyke in Kopais made of loam-sealed stone (adapted from 11).

According to Strabo and newer evidence, the area became re-flooded sometime later, probably due to earthquakes (*ca.* 1100 B.C.). Interestingly, in the case of Kopais, the myth relates Heracles with the destruction, rather than construction, of the project and the re-flooding of the area, thus indicating that war actions (related to the intra-Mycenaean rivalry) probably contributed to the collapse of the project.

Another important project of the same Mycenaean period (*ca.* 1250-1200 B.C.) is the Tiryns dam. It seems that, during a flood, a stream south of Tiryns abandoned its bed and shifted to the north of the Tiryns. To protect the lower town from future floods the inhabitants of Tiryns installed an artificial river diversion consisting of a 10 m high and 300 m long dam

and a 1.5 km long canal (12). The dam is a huge earthen embankment lined with cyclopean masonry across the earlier streambed. Yet another massive hydraulic project of the same period has been found in Olympia. This includes a dyke in Cladeios river with length 800 m, width 3 m and height 3 m, and a dam in Alpheios river with length 1000 m, height 2 m at least and width 30 m (11). The two rivers may be those related to the Augean stables myth mentioned above and it has been conjectured (11) that the project is related to an initial stage of the Olympic Games.

4. THE DRAINING OF THE LAKE IN PTECHAE AND THE GREEK INSTITUTIONS FOR CONSTRUCTING PUBLIC WORKS

The hydrotechnical skill achieved by the Mycenaean engineers on their land reclamation activities was lost in the centuries after the decline and finally the collapse of the Mycenaean world (*ca*. 1100-900 B.C.). Later, in the classical Greece civilization, the progress in construction of hydraulic projects is accompanied by improvement in the understanding of water related natural phenomena (13). However, most findings of hydraulic works of that period are related to the urban rather than agricultural water use (3).

There is evidence, however, that the draining of the Kopais plain was also attempted at later times. Thus, another salient work, a tunnel 2.5 km long, 1.8 m high and 1.5 m wide leading from Kopais to the sea has been revealed. This would provide discharge capacity, additional to that of the natural sinkholes, for draining the lake. Shafts up to 60 m high were lowered at distances 40 to 200 m that helped excavating the tunnel, allowed some daylight and made orientation easy. This tunnel has not been explored to date and it is not known whether the project was completed and operated until it went damaged some time later, or was never completed. Papademos (6, p. 450) maintains that this tunnel was not built at Mycenaean times and it was never completed. Strabo (IX 406) mentions that draining works were executed in the Copais Lake by Crates, engineer of Alexander the Great in 336-323 B.C.

At the same period, the draining of another lake in Ptechae, which is probably identified with the Dystos Lake in Southern Euboea, was done. To validate the fact that *scripta manent*, the contract of this project was revealed in excavations in Chalkis in 1860 (6, pp. 490-498). The contract for draining and exploitation of the lake is between the Eretrians and the engineer-contractor Chairephanes. The project is what we call today BOOT (Build, Own, Operate, Transfer). The rather wordy (like those of today) contract is written on a Pentelian marble stele (87 × 47 × 9 cm). On the surface, relief sculptures show the Gods that were worshiped in the region, Apollo, Artemis and Leto. A carved scripture in 66 verses signed by more than 150 people contains the construction contract, starting as «Κατὰ τάδε Χαιρεφάνης

ἐπαγγέλλεται Ἐρετριεῦσιν ἐξάξειν καὶ ξηρὰν ποιήσειν την λίμνην τὴν ἐν Πτέχαις ...» (In this, Chairephanes promises to the Eretrians that he will drive away the lake in Ptechae and make it land …). The first 35 verses are the main contract. In the continuation two resolutions of the parliament and the Demos are given. With the first one (verses 36-42) asylum is granted to Chairephanes and his collaborators for the whole duration of the contract and in the second resolution (verses 42-60) the keeping of the contract is confirmed by oath to Apollo and Artemis. Moral and material sanctions (penalty for breach of contract) such as the confiscation of their property and the dedication of it to Artemis are foreseen against misdemeanors. A summary of the main contract is as follows (adapted from 6, p. 497):

1. Between the city of the Eretrians representing the 31 municipalities of the Eretrian region and the contractor Chairephanes, a contract is signed concerning the draining of the lake in Ptechae.
2. The draining works include the construction of drainage canals, sewers, and wells for the drainage of water to natural underground holes or cracks and miscellaneous protection works, including wooden or metallic railings.
3. Irrigation works, such as the construction of a reservoir with side length up to 2 stadia (360 m) for storing irrigation water, and sluice gates, are included in the project.
4. A 4-year construction period is agreed, which can be extended in case of war.
5. The contractor is granted the right to exploit the dried fields for 10 years (extended in case of war), commencing by the finishing of the drying works.
6. The contractor is granted the privilege of customs-free import of materials (stones and wood).
7. The contractor is obliged (a) to pay all labor costs without any charge for the people of Eretria; (b) to pay the amount of 30 talents in monthly installments as a rental for the exploit the project for 10 years; (c) to maintain all works for the exploitation period, in order to be in good condition after the finishing of the contract; (d) to compensate the land owners by one drachma per foot of land area that is to be expropriated for the construction of works; and (e) to avoid harm on private property as much as possible by locating the works in non cultivating land.
8. In case of death of the contractor, his heirs and collaborators will substitute him in the relations to the city.
9. Penalties are enforced against any person trying to annul the contract.
10. The contractor is obliged to submit a good construction guarantee up to the amount of 30 talents.

Interestingly, the epigraph mentions that it would be erected in the temple of Apollo at Eretria and copies of it would be deposited at Megara and Andros. It appears that it was common practice in ancient Greece that detailed competition announcements, project specifications and project contracts written on marble steles were erected in public sites so that everyone would have known all project details and, simultaneously, the breach of contract would be difficult; as Tassios (14) puts it, if someone wished to avoid some terms, he would "stumble on them".

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