Fahlbusch, H. (2007): Water and its use in early history. In: Lozán, J. L., H. Grassl, P. Hupfer, L.Menzel & C.-D. Schönwiese. Global Change: Enough water for all?. Wissenschaftliche Auswertungen, Hamburg. Online: www.klima-warnsignale.uni-hamburg.de

1.10 Water and its use in early history

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SUMMARY: *»There is no life without water«- this fact all people knew instinctively since the beginning of mankind. People were supplied from local resources, which already very early were improved by digging wells.*

People in antiquity studied the natural phenomena, analysed and interpreted them in an excellent way. This resulted in a splendid water management, which is shown at Egypt and the Marib dam as examples. When the local water resources were no longer sufficient to meet the water demand of the societies there have been only two methods to increase the available water, i.e. the local and temporal transfer. These transfers are also demonstrated at various examples.

There is no life without water – this fact all people knew instinctively since the beginning of mankind. The availability of water in order to meet the water demand of human beings, animals, and plants was prerequisite for the foundation of communities, their development into towns and cities and finally the existence of cultures. Springs, rivers, or lakes were the resources available locally.

These local water resources could be improved by digging wells, although these could supply only a small number of people and animals. One of the most famous structures is the well of Be'er-Sheva in the Holy Land, which is already mentioned in the bible. However, it is not known when it was exactly constructed.

After the increase of aridity, probably in the 6th millennium B.C., large cultures already existed in the river valleys of the Nile, the Indus, in the Euphratus-Tigris basin and the Yellow river basin. As the survival of the population and thus the daily life of the people depended on the water resources of the rivers it is understandable that these cultures are called »hydraulic civilisations«. This shall be underlined by looking to Egypt as an example.

The Nile-Valley

According to Herodotus »Egypt is a gift of the river Nile«. At least in history this was true. The river Nile originates mainly from three sources. The White Nile comes from the Sudd-swamps and big lakes in Eastern Africa. Its discharge varies only little over the year and can be looked upon as comparatively constant. The Blue Nile and the Atbara, the main tributary, come from the mountains in Ethiopia. The heavy rainfall in summer time in this area, caused by the monsoon, results in a big runoff and consequently in large floods in the rivers. The hydrological pattern of the Nile therefore is characterised by this flood in summer at an unusual time for European spectators. The discharge reaches its peak in Egypt with generally about 10,000 m³/s. Afterwards it slowly decreases until March/April, when the low water period begins.

Before the flood arrived the embankments and ditches had to be maintained and repaired. During the flood the water inundated the fields in the Nile valley which is restricted on both sides by hills running more or less parallel to the river in a south-north direction. On the fields the water could infiltrate into the soil and was stored there. After the flood, when the fields became dry again, the crops had to be sown, cultivated and later harvested. This cycle was repeated again and again.

This pattern of the river dominated the life of the people throughout the year. It is therefore not astonishing that this theme is shown in the pictures of the so-called book of the

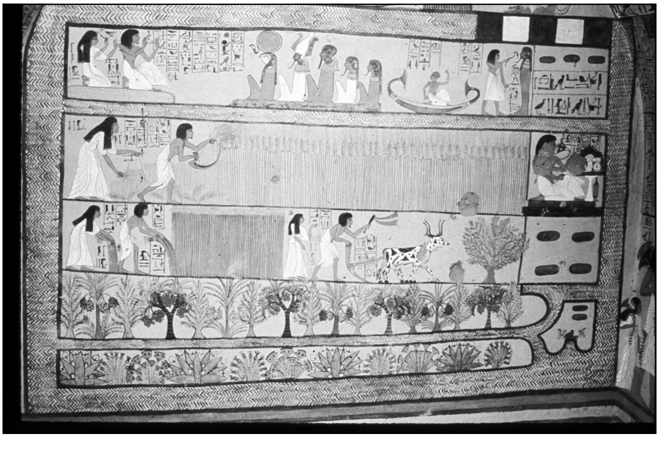

Fig. 1.10-1: Painting in the Tomb of Sennedjem at Thebes showing the Pattern of the Cultivation throughout the Year.

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dead (HORNUNG 1990). The painting in the tomb of Sennadjem (about 1200 B.C.) in the valley of the workers at Thebes illustrates this (*Fig. 1.10-1*). In this painting the Nile flood with a ship on it can be seen in the bottom right hand corner (*Fig. 1.10-2*) (the stepped figure on the ship may probably refer to the gauges). It is pointing towards orchards and fields irrigated by a channel. Above grain can be seen being cultivated, harvested and threshed. At the end of the season, at the top of the picture, the prayer to the gods is shown. The painting, which refers to all seasons of the year, is entirely surrounded by water of the river Nile.

Such paintings have been found on several papyri. Obviously the artists showed their own experiences of life in these pictures.

The quality of the yield depended on the height of the flood. If it was too low, not all fields could be inundated. If it was too high the current caused much damage and the end of the flood was delayed because the soil was too wet. Under these circumstances it is not surprising that the level of the river Nile was measured and registered since early times. This is known not only from a remark in the so-called »book of wisdom« (BRUNNER 1992) where a note addressed to the younger son of pharaoh Cheops states »Look for a field which will be inundated sufficiently according to the records«, but even more precisely from the so-called Palermo-stone. In this inscription, which is also dated into the fifth dynasty (around 2500 B.C.) the height of several floods is mentioned.

The level of the river was determined by gauges, the so-called nilometers. They were installed at several locations along the river. The gauges were installed along steps as can be seen at Elephantine island. There, such a gauge is well known since centuries. Along the steps four different gauge-systems were applied, obviously representing four different operation phases. But this »nilometer« does not fit to the description already given by STRABO (2005). The Roman author wrote:

»The nilometer is a well constructed from ashlars at the shore of the river. The rise and fall of the water level is indicated by it, the highest, the lowest and the medium, as the water in the well behaves according to the river. On the walls of the well there are marks of insufficient as well as other Nile-floods. These are observed, then the people will be informed, that they will know it«.

Some years ago a second nilometer was excavated on Elephantine island by Jaritz, close to the first (*Fig. 1.10-4*). The newly excavated structure is obviously the one, which Strabo probably saw and described.

According to the registered water level at these nilometers the expected agricultural yield could be estimated. According to PLINY THE ELDER (1882) a water level

at the 12th ell meant starvation
at the 13th scarcity
at the 14th cheerfulness
at the 15th safety
at the 16th exultation.

Extreme floods higher than the 16th ell, especially up the 18th ell, resulted in severe destructions. Thus the 16th ell was obviously regarded as the best level for getting the highest yield. This is confirmed by a coin minted in Alexandria and dated to the era of Emperor Hadrian, showing the god Nile with the number 16 as symbol. The same applies to a 5th century A.D. mosaic found in Sepphoris (Israel) where a nilometer is shown and the best level of 16 ells is emphasised.

The regular flood in the Nile valley also leached the soil and prevented salinization. Therefore the hydrological and hydrogeological system in the Nile valley in Egypt was in an ecological equilibrium. This was changed with the construction of the high dam at Assuan in the 20th century. Most of the water during the Nile flood was stored since then in the new reservoir. This completely modified the environment causing huge ecological damages. But during

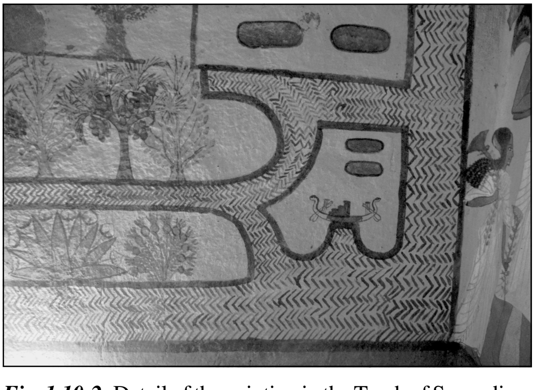

Fig. 1.10-2: Detail of the painting in the Tomb of Sennedjem (*Fig. 1.10-1*) showing a ship on the Nile during the flood.

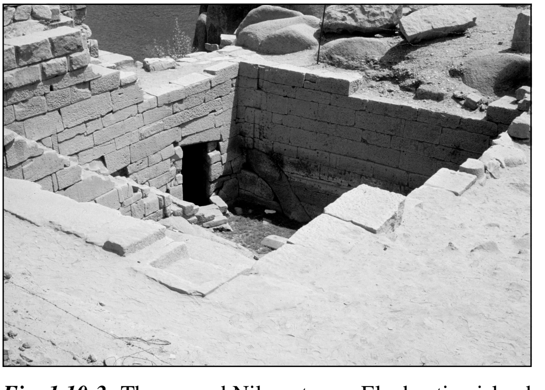

Fig. 1.10-3: The second Nilometer on Elephantine island near Assuan.

the drought at the end of the seventies and the beginning of the eighties of the 20th century the stored water in the reservoir prevented an extensive famine in Egypt. When criticising the structure the benefits must also been taken into account.

Marib-dam

People in antiquity studied the natural phenomena, analysed and interpreted them in an excellent way. Today we have often lost this ability. Looking to the situation in Yemen, namely to the Marib-oasis with its famous dam may illustrate this fact.

The irrigation of the Marib-oasis is a splendid example to demonstrate how people's work was adapted to the environmental conditions and what devastating consequences result from neglecting the studies of ancient or traditional structures. That can be concluded from the fact that the destruction of the dam (between 550 and 570 A.D.) is mentioned in the Holy Koran and interpreted there as a punishment of Allah.

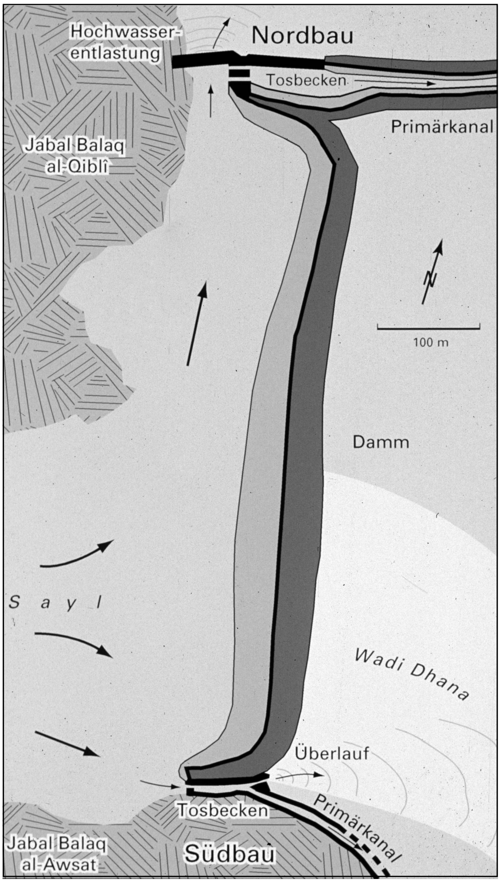

Fig. 1.10-4: The remains of the Marib-dam in Yemen and one outlet structure (Photo: Brunner).

The Maib-dam, which was constructed in the middle of the 1. millennium B.C., was a weir, which only backed up the water of the »sayls«, the floods occurring in the Wadi Dhana twice in summer (BRUNNER 2000). It did not store the water. Thus lifted, the water could flow into the various parts of the oasis irrigating its fields. The floodwater transported huge amounts of sediments, which were deposited upstream of the dam as well as on the fields. Therefore the dam had to be raised several times. In addition it was also manifold damaged by severe floods. Inscriptions record the necessary repairs.

The length of the dam amounted to 620 m and its height at the deepest point of the wadi and in the last phase before it was destroyed was around 20 m. The width at the bottom measured nearly 100 m (*Fig. 1.10-4* and *-5*). 120 m³/s to 150 m³/s discharged through the inlet structures into the irrigation canals at both ends of the dam to supply the fields in north- as well as the south-oasis. The dam itself functioned as a spillway having a capacity of about 850 m³/s.

The structure was thus excellently adapted to the local conditions. The direct irrigation without intermediate storage minimised the evaporation losses and avoided salinization. The simple diversion of the water and its distribution worked on their own without constant human control by day and by night. The sediment fertilised the soil and in the absence of stagnant water there were no diseases like malaria or schistosomiasis.

At the end of the 20th century a new dam was constructed about 2 km upstream of the old structure, financed by the Abu Dhabi Fund. The new 720 m long earthfill-dam has a height of 38 m. Its planned storage volume amounts to 398 million m³. In 1986 the new structure was inaugurated by storing the first water.

About 6,300 ha should be irrigated all over the year to gain manifold harvests in future. However, it did not take a long time before the first disadvantages to occur, first of all the salinization of the soil and the outbreak of the diseases mentioned above. They had been omitted by the old system

Fig. 1.10-5: Map of the Marib-dam and the water diversion into the Oasis (Photo: BRUNNER 2000).

and its traditional irrigation method. Newly developed social problems also have to be mentioned in this context.

A thorough study of the history would have revealed the hydrological pattern of the »sayls« and the consequences for the irrigation. The newly created problems could have been avoided.

Transfers

What happened, when the local water resources were no longer sufficient to meet the water demand of the societies? This was often the case under the arid or semi-arid conditions of the Near East. Already very early it was realised at many places that the available water had to be managed and to be augmented if necessary. Until the recently developed desalination of sea water there have been only two methods to increase the available water, i.e. the local and temporal transfer. For the local transfer water is led in aqueducts from its source (springs, lakes or rivers) to the places of demand, mostly cities or farms. For the temporal transfer water is caught and stored in times of a surplus to be used in times of shortage. For this purpose storage capacity has to be constructed, i.e. cisterns on a small scale or dams on a large scale. The example for the transfers are determined by nature: rivers for the local transfer, and ponds or lakes for the temporal one. People thus had the task to imitate nature by technical means.

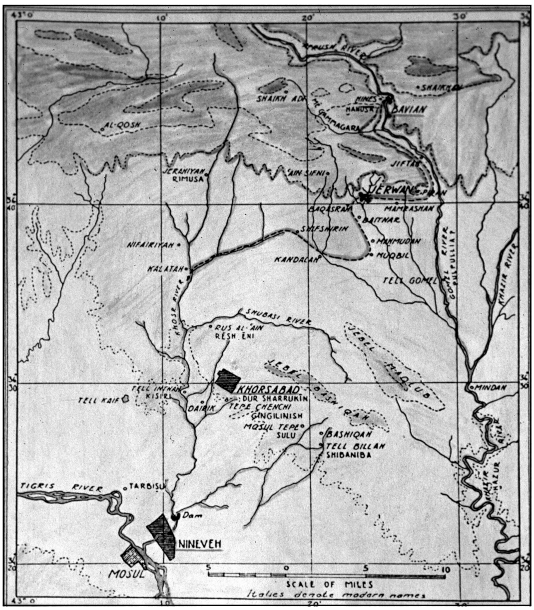

Fig. 1.10-6: Map of the Jerwan aqueduct (Forbes 1964, supplemented by Buske).

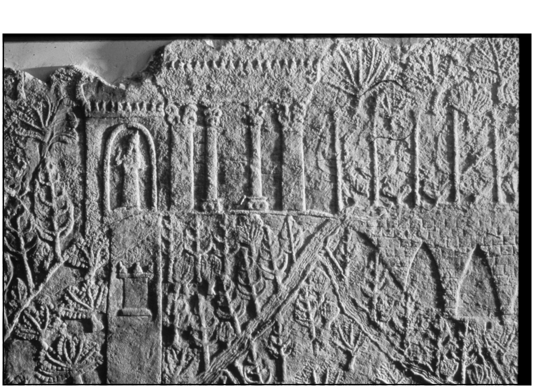

Fig. 1.10-7: Relief from the palace of Ashurbanipal (645 B.C.) showing the irrigation of a garden (British Museum London).

Local transfer – Jerwan aqueduct

In order to irrigate the fields many irrigation canals had already been constructed in Mesepotamia, by which water was led from the rivers to the fields. In this context the Assysrian king Sennacherib (705–681 B.C.) ordered the construction of the Jerwan aqueduct - apparently the largest canal in antiquity. Besides other measures, this canal was designed to improve the available irrigation water in the vicinity of the capital Nineveh (Forbes 1964). Due to three construction inscriptions there is much information about this project (Bagg 2000).

A diversion structure in the gorge near Bavian led water from the Atrush-river in a canal of about 35 km length in order to increase the discharge in the Khosr-river (*Fig 1.10-6*). The most impressive structure along the canal was a 290 m long bridge of 9 m height near Jerwan. The remains of this bridge, which showed five pointed arches were excavated 1933. The width of the canal was determined to be 19 m at the bridge, more than ten times wider than the famous aqueducts of ancient Rome. The height of the canal measured around 2 m and the slope more than 1 %. Taking into account a depth of the flowing water of 1.0 m the discharge would have amounted to more than 100 m³/s.

The repair of some damage has been proven archaeologically. Therefore it can be said that the canal was indeed being operated. For how long it functioned is unknown. *Fig. 1.10-7* shows a relief, which can today be seen in the British Museum in London and which originates from the palace of the Assyrian king Ashurbanipal (645 B.C.). It shows the irrigation of an orchard. The water comes from a bridge constructed with pointed arches, probably the Jerwan-aqueduct.

This relief is possibly one of the first technical presentations in history, at least for hydraulic structures. Politically it can be looked upon as method for the transfer of technology. Visitors were surly explained how the water was led across valleys or depressions by means of bridges.

Irrigation-project Hujayrat-al-Ghuzlan

The construction of the Jerwan-aqueduct as well as the Menua-canal in southern Anatolia, for example, were technical highlights. The discharge in both exceeded by far that of the later famous Roman aqueducts. Certainly it cannot be assumed that such world records occur all of a sudden. Most probably the structures are the result of a long development. As far as canals are concerned, this development is unknown, most probably because the smaller, but locally very important earlier structures have vanished in the course of history.

However, in Jordan research work has started at Tell Hujayrat-al-Ghuzlan near Aqaba for an irrigation project that existed already in prehistoric times. It is dated to the first half of the 4th millennium B.C.. There, quite a number of wells were dug into a geological fault. Groundwater was most probably under pressure when it came out to the surface and was then led to the terraced fields in canals which were edged by stones (*Fig. 1.10-8*). Crusts of calcium carbonate, so-called sinter, deposited on the stones confirm the underground origin on the water. The canals will not have been very long. But the finds prove that the methods to build aqueducts was already common sense in the bronze age.

The research results of this project will certainly widen the knowledge about the early use of water in history.

Temporal transfer – small scale storage in cisterns

In many regions of the world rainwater is stored in cisterns. For this purpose cavities are excavated out of the rock and plastered in order to seal the walls and guarantee impermeability. Probably the oldest cistern has been excavated in Cyprus and is dated as early as the 8. millennium B.C. *Fig. 1.10-8* shows a cistern in Aspendos (Turkey). There, at the corner of the acropolis the rock has been broken away and together with it parts of the cistern. Thus its cross-section is clearly visible as well as remains of the plaster.

The cisterns were probably covered with wooden plates to prevent contamination by rubbish as well as the penetration of light. Thus excellent hygienic conditions and an excellent water quality free of dirt and algae were guaranteed.

In many centres in antiquity cisterns were often the backbone of the water supply system. Here only Pergamum may be mentioned as a representative location. The city grew from a strong castle on the top of a hill to an important capital of an empire in the 3rd cent. B.C.. This never would have happened without an excellent system of cisterns, as there are neither spring nor deep well on top of the acropolis.

The size of the storage volume in the cisterns varied between less than 10 m³ and more than 90 m³. Assuming the same climatic conditions in antiquity as today and an average water consumption of 10 l/person GARBRECHT

Fig. 1.10-8: Stones edging an irrigation canal at Hujayrat-al-Ghuzlan near Aqaba (Jordan) (Photo:Heemeier).

Fig. 1.10-9: Broken cistern at the corner of the acropolis of Aspendos (Turkey).

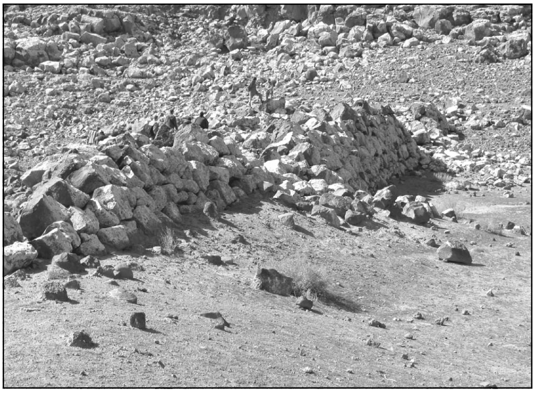

Fig. 1.10-10: The Jawa-dam in Jordan – view from the upstream side (Photo: Ohlig).

Fig. 1.10-11: Jawa (Jordan) – view of a supplementary pond (Photo: Ohlig).

(2001) calculated that nearly 8,000 inhabitants could have survived a siege of a whole year. This fact demonstrates the importance of the cisterns for Pergamum.

The storage system remained in operation for many centuries, even when the acropolis had obtained free flowing freshwater from an aqueduct via an inverted siphon. The discharge was stored in the largest cistern on top of the acropolis. As the water flowed constantly an overflow soon occurred, which was led from one cistern to the next down the slope of the castle- mountain. Thus the cisterns became an integrated element of the flowing water supply system as long as the aqueduct worked.

The cisterns, which were carefully maintained. This can be concluded from the famous »Astynomen« inscription, which is dated into the 2nd century A.D. Here the rules for the maintenance of the cisterns are described as well as the punishment in case of neglect.

The storage volume of the early cisterns was relatively small. But in the Roman era huge cisterns were constructed at the end of aqueducts, showing a storage volume of more than 10,000 m³. A splendid example is the »Piscina Mirabilis« near Misenum at the Gulf of Naples at the end of the Serino aqueduct.

Large scale storage behind dams

From a Sumerian myth of creation (Pettinato 1971) dated to the 3rd millennium B.C. it can be concluded, that the climate in Mesopotamia was already arid or semi-arid, because the fields had to be irrigated in order to obtain agricultural products. In this text a »wall made of stones« is mentioned, which undoubtedly is to be interpreted as »dam«, which was used to store water in order to overcome the problems of the dry seasons. According to this text it was obviously common knowledge at that time to use temporal transfer methods as well as the requirement of regular repair and maintenance of hydraulic installations.

The oldest known dam in the world can roughly be dated to the same period as the quoted myth. It is the dam of Jawa in the basalt desert in the north of Jordan, close to the Syrian border. The structure shows a length of about 80 m and it was 5 m high (Vogel 1991). The remains of today indicate that the wall was constructed of two dry walls made of basalt stones with a core of earthfill. In front of it a wedge of loam was applied (*Fig. 1.10-10*).

The storage volume behind this dam and in additional three ponds (*Fig. 1.10-11*) amounted in total to 42,000 m³. The runoff from precipitation in the upstream catchment of the wadi during winter-times could thus be caught and stored. The dam and the ponds were obviously the backbone of the water supply of the people living here in the desert in the bronze age.

Conclusion

The examples which are mentioned demonstrate that water related problems were managed in an excellent way already thousands of years ago. Up to now no new methods of water management have been developed. Looking from the scientific point of view, these examples manifest a very high standard, which must have been the result of a gradual and lengthy development process. However, it is not known when, and under which conditions, this process started.