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Hydraulic landscapes and imperial power in the Near East

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Abstract Over the past 20 years archaeological surveys and remote sensing have contributed significantly to the discovery of ancient hydraulic systems in the Middle East. The significance of this increase, namely in the scale and number of canals, conduits and qanats, is examined and related to the role of power and the administration of the later territorial empires which date from the first millennium BC and later. We demonstrate that hydraulic systems spread into the rain-fed zone of northern Iraq, Syria and southern Turkey, especially during the past 3000 years. These systems contributed to the intensification of agricultural production and to the colonization of the Near Eastern landscape.

Keywords Irrigation · Satellite imagery · Landscape archaeology · Middle East · Syria

Introduction

Most accounts of the historical development of Old World water systems have focussed on the history or archaeology of technology (Wikander 2000; Oleson 1984; Hodge 1992; Ortloff 2009). In contrast, this article builds upon the results of archaeological landscape surveys to outline the development of water systems in the Middle East beyond the riverine zone of southern Mesopotamia. This study has benefitted from the increasing numbers of archaeological surveys conducted in recent years as well as the availability of high resolution satellite imagery. The primary focus is upon the introduction of large-scale water systems in what had previously been an area of mainly rain-fed cultivation. This article, which builds upon a more general perspective presented in a forthcoming article for the UNESCO Water and Humanity Volume VII (Wilkinson, in press), is a work in progress

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intended to highlight recent landscape research and to identify directions for future research.

The area under discussion is limited to the rain-fed zone of northern Iraq, northern Syria and adjacent parts of southern Turkey (Fig. 1), but occasional reference is made to neighbouring parts of Iran, Southern Syria, Jordan and Palestine. This article initially discusses the role of landscape archaeology and remote sensing in the recognition of hydraulic systems in the Middle East. This is followed by a summary outlining the main developmental stages of water supply in northern Iraq, the Levant and Turkey, followed by an example laying out the evidence for the colonization and partial infilling of the landscape between irrigated southern Mesopotamia and the rain-fed zone to the north. The main section then provides case studies outlining the evidence for ancient water systems emerging from the rain-fed zone of northern Syria, Iraq and southern Turkey. Finally, the conclusions examine the above examples within the context of the deployment of power by the later territorial empires of the first millennium BC and first millennium AD.

Theoretical perspective

As noted in the Introduction to this volume, the Wittfogel (1957) debate has dominated discussions of ancient water management within archaeology and anthropology. In fact a superficial study of ancient water systems (and indeed modern ones) suggests that there is indeed a relationship between the exercise of political power and major hydraulic systems. However, the Wittfogel model that posits that hydraulic management led to the development of the early state and civilizations is regarded as overly simplistic. Here, rather than attempting to tackle this long-debated question, this article examines the evidence for the

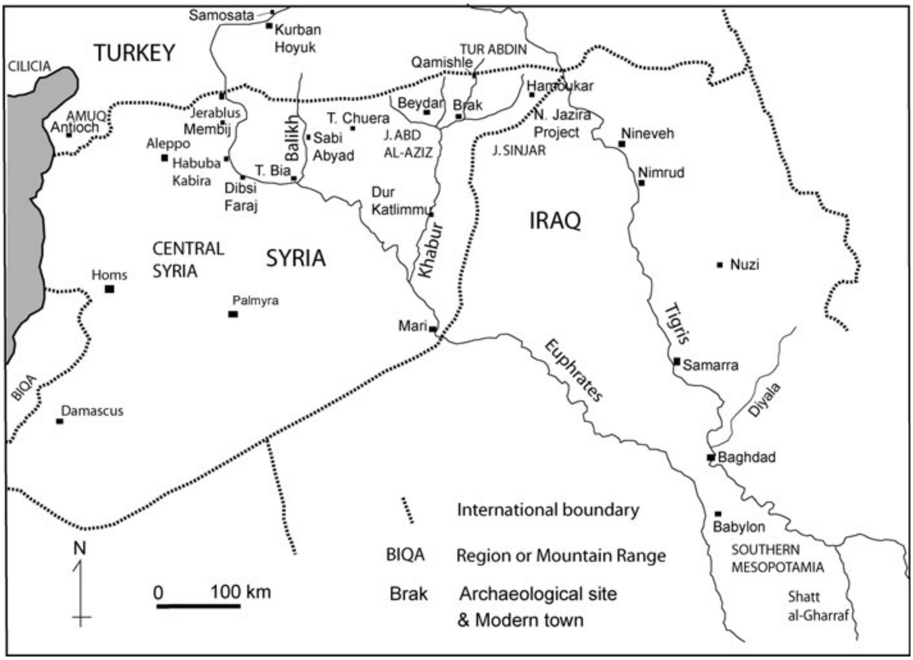


Fig. 1 Location of the main water systems discussed in text

chronological spread of hydraulic systems from the dry lands of Mesopotamia and SW Iran to more verdant areas where the manipulation of water via canals appears to provide a supplement to rainfall. The data presented have become evident during the last 20 years as a result of the use of landscape archaeology aided by satellite image analysis in the Middle East.

One aim of this article is to contextualize ancient water systems in the Middle East and to place their development within the framework of imperial political power. In contrast to Wittfogel's model which saw water management as playing a pivotal role in the development of early states, there is gathering evidence to suggest that the later empires enabled and indeed encouraged the spread of water systems throughout the old world, in part, by the exertion of political power over vast areas. Therefore, this article explores the evidence for the converse of Wittfogel's model, namely how the development of large territorial empires in the first millennium BC and AD enabled major systems of water supply to develop and spread. More generally, however, it marshals a new body of data to explore the spread of irrigation systems through so-called Upper Mesopotamia, namely the belt of land that has primarily been the domain of rain-fed cultivation together with pastoralism. This perspective revolves around Wittfogel's distinction between the hydraulically compact societies of Lower Mesopotamia and the loose (and chronologically later) societies of the north.

From the perspective of the archaeological landscape it can be argued that regional-scale canals in Upper Mesopotamia were constructed mainly when large-scale territorial empires were in existence. Therefore, the adoption of large-scale canals from the first millennium BC throughout Mesopotamia may have occurred only when it was possible to gather water and distribute it on a regional scale. The presence of an administrative structure over large areas provided the opportunity for irrigation systems to be extended over very large hydraulic catchments rather than restricted to limited areas (Wilkinson 2003). It will be one objective of this article to test this model.

The role of landscape archaeology

Several classic studies of irrigation and society have appeared from the Mesopotamian heartland including Adams (1965, 2006) as well as the seminal volume "Heartland of Cities" (Adams 1981). In addition, Adams' article on the development of settlement and water supply in Khuzestan tackles the relationship between settlement and large-scale irrigation (Adams 1962). Other important twentieth century studies are those of Oates (1968) on Neo-Assyrian systems; Oleson (1991) on Humeyma, Jordan; Ergenzinger and Kühne (1991) on the Khabur River, Syria, and Wenke's (1975–1976) re-examination of the Khuzestan plain. However, because these were isolated case studies, it was difficult to perceive broader development trends from them.

The increased use of remote sensing and archaeological surveys has resulted in a massive increase in the evidence for water supply technology throughout the Middle East, most of which appears to be later than approximately 1000 BC. This corresponds to the period of the later territorial empires of the Neo-Assyrian through Early Islamic periods. Although irrigated southern Mesopotamia may be referred to, the primary focus is upon areas that fringe Mesopotamia to the northeast, the north and the west. These areas usually receive sufficient rainfall for successful crops, although the annual variations can be large: mean annual rainfall ranges from 250 to 600 mm within the northern parts of the region, to rather less within the climatically marginal areas to the south.

Table 1 The chronology of the main later empires in the northern Fertile Crescent

Period	Approximate dates
Neo-Assyrian empire	911–612 BC
Persian/Achaemenid	539–333 BC
Hellenistic/Seleucid (to west)	333–64 BC
Parthian/Arsacid (to east)	247 BC–224 AD
Sasanian (to east)	224–651 AD
Roman (to west)	64 BC–395 AD
Byzantine (to west)	395 AD–636 AD
Umayyad (early Islamic)	661–750 AD
Abbasid (early Islamic)	750–968 AD

Note that gaps in the chronology indicate periods of transition

The empires in question include the Middle Assyrian and Neo-Assyrian empires, the Achaemenid, Median, Seleucid, Parthian and Sasanian Empires as well as the Roman, Byzantine and Early Islamic Empires (see Table 1).

Chronological perspective

Prehistoric and Bronze Age

Southern Mesopotamia is well known as the centre of development of cities, and the extensive anastomosing river systems of the Tigris and Euphrates Rivers have nurtured a complex and long-lived tradition of irrigation. The enhanced crop yields that result from irrigation are only one part of the so-called "Mesopotamian Advantage" (Algaze 2001), because the ease of transporting bulk products along canals and the low sinuosity rivers also fuelled the development and growth of cities.

In Upper Mesopotamia and the Levant, by contrast, evidence for canal systems before around 1000 BC (i.e. before the Neo-Assyrian Empire) is rather elusive (Miller 1980). Although many Neolithic and Chalcolithic settlements were situated close to water, except for some recent evidence for Neolithic water control structures in southern Jordan (Fujii 2007), there is little evidence for ancient irrigation at this time. On the other hand fourth millennium BC Habuba Kabira is suggested to have received water via a long-distance conduit (Ludwig 1978; Jansen 2000, p. 104), but it is difficult to conceive how water could have been raised the 10 m from the Euphrates River up to the canal (Reichel 2004, p. 229). Nevertheless, the presence of terracotta pipes on this site does suggest an early introduction of piped water. Also, the site of Khirbet al-Umbashi in southern Syria exhibits a late fourth millennium BC dam (Braemer et al. 2004, 2009, p. 42), and the water deflection structures at Jawa in north Jordan are well known (Helms 1981; Whitehead et al. 2008). In the case of dams, some authorities allow for a third or second millennium BC phase of the Homs Dam in Syria (Kamash 2006, p. 69). Further evidence for the use of hydraulic installations in the third millennium BC comes in the form of a canal, presumably for irrigation, at Tell Chuera in northern Syria (Fig. 1; Meyer 2010, pp. 209–210) and from a small canal of perhaps Bronze Age date recorded in section within the nearby Balikh Valley (Wilkinson 1998a).

Palaeobotanical evidence from carbonized plant remains demonstrates that most crops grown around Early Bronze Age sites in northern Syria were nurtured by rainfall (Riehl

2008), although cuneiform texts from Arraphe/Nuzi to the east of the Tigris in Iraq suggest that in the early second millennium BC some land in the marginal lands of the rain-fed zone was irrigated (Zacagnini 1979; Fincke 2000). Occasional reference to irrigation structures comes from the Middle Assyrian texts from Sabi Abyad and these also support the perspective that irrigation was taking place in the rain-fed zone during the second millennium BC (Wiggermans 2000, p. 177). Early second millennium BC cuneiform texts from Mari supply persuasive evidence for the operation of water competition between Middle Bronze Age Tutul, namely modern Tell Bi'a downstream of Sabi Abyad near the Euphrates/Balikh junction (Fig. 1), and Zalpah, some distance upstream (perhaps modern day Tell Hammam et-Turkman). The Mari letters in question list the complaints of the downstream community of Tutul against the upstream users at Zalpah who were depriving them of essential irrigation water (Dossin 1974; Villard 1987). This provides a clear ancient example of water conflict initiated between upstream and downstream users.

Whereas the above examples fall within the rain-fed zone or its arid margins, the situation further south within the Euphrates Valley at Mari (rainfall: less than 150 mm per annum) is rather different. Developed within a transition zone between upper and lower Mesopotamia this large third and early second millennium city with its plethora of major canal earthworks can be seen as an extension of irrigated lower Mesopotamia (Geyer and Monchambert 2003). Cuneiform texts from Mari demonstrate that a wide range of irrigation terms were used during the Old Babylonian period (Durand 1990; Lafont 2000) thereby implying that a considerable amount of irrigation was practised in this arid region. As most relict canals and their earthworks have not been securely dated (Lafont 2000, p. 138) this mainstream view has been challenged to suggest that the meagre dating of the canal systems can hardly support the idea of major irrigation systems at this early date (Lyonnet 2009). Lyonnet, therefore, suggests a Neo-Assyrian or even an Islamic date for the construction of the large canals that follow the Euphrates Valley (Lyonnet 2009), bringing them in chronological alignment with equivalent systems along the Khabur Valley. Whichever view is taken, the case of the Mari canals underscores that whereever canals have been found in the region they have proved difficult to date. An early date should not, therefore, be assumed, because when canals are excavated they frequently turn out to be of more recent date than expected.

In terms of the relationship between irrigation and the exercise of power Lafont suggests:

> …there is no choice but to accept that it was necessary to firmly control a very large area in the Middle Euphrates valley, and to be able to mobilize the entire population in order to exploit its potential agricultural resources. Lafont (2000, p. 138).

In the area of Mari, Nuzi and the Balikh Valley, cuneiform texts provide evidence for irrigation canals or water installations somewhat earlier than archaeology. Although archaeology does supply hints of pre Iron Age hydraulic installations, the lack of direct dating evidence makes it difficult to provide field evidence to corroborate the texts. Nevertheless, with more intensive fieldwork and excavation of hydraulic features, the archaeological and textual evidence may eventually be brought into alignment.

In sum, archaeological and textual evidence for canals and hydraulic installations in rain-fed northern Syria and Iraq is limited and often appears to have been restricted to special circumstances. These include an association with "intrusive" Uruk sites, the inhabitants of which introduced cultural practices from southern Mesopotamia, or because the sites in question were located in climatically marginal parts of the region such as Mari and Tell Chuera.

Assyrian systems of northern Iraq

The Middle and Neo-Assyrian empires were responsible for a significant re-organization of the landscape of the Middle East (Wilkinson 2003, pp. 128–150). In addition to making radical changes to the pattern of settlement, such changes included the construction of major water supply systems to the Assyrian capitals of Assur, Nimrud, Khorsabad and Nineveh (Fig. 2), as well as to regional centres such as Dur Katlimmu on the Syrian Khabur and at Arbila (Erbil), in Iraq (Oates 1968; Bagg 2000, 2004; Ur 2005; Ergenzinger et al. 1988; Ergenzinger and Kühne 1991). Although all these systems were in operation in the Neo-Assyrian period, earlier Middle Assyrian canals (*ca*. 1200 BC) have been verified at Dur Katlimmu and Kar Tikulti Ninurta thereby indicating that the better known Neo-Assyrian systems of the eighth century BC and later were preceded by Middle Assyrian prototypes.

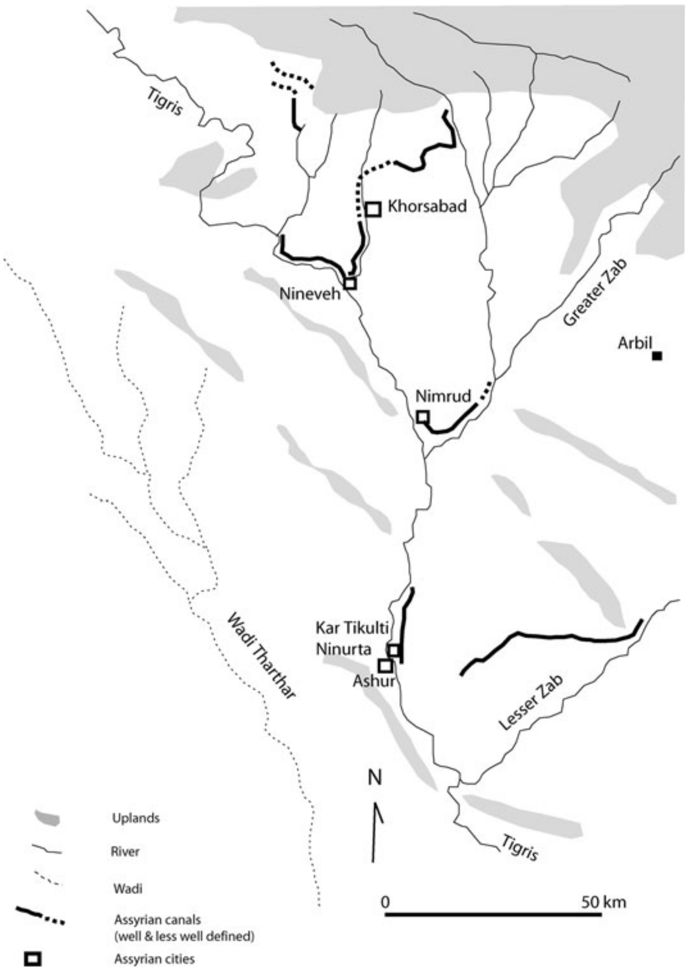


Fig. 2 Some significant water systems in the area of the Assyrian capitals (based upon Curtis and Reade 1995; Bagg 2000)

Whereas the Middle Assyrian canals at Dur Katlimmu and Kar Tikulti Ninurta were evidently aimed at providing water for irrigation in a landscape that was climatically marginal for agriculture and where cultivation would be a risky enterprise, the Neo-Assyrian systems around the northern capitals of Nimrud, Khorsabad and Nineveh supplied water to areas that were primarily devoted to rain-fed cultivation. The presence of these hydraulic systems in the northern zone of rain-fed cultivation, therefore, suggests that it was during the Neo-Assyrian period when large-scale water management really took off (Dalley 2002).

The best-known Assyrian canals are those of Sennacherib behind Nineveh (Oates 1968; Reade 1978; Ur 2005 and Bagg 2000). These also best exemplify the application of imperial power, as indicated by the Bavian inscription inscribed in a rock face near the head of one of these canals. Written in 690 BC, this describes massive monumental works as well as the role of the king in their construction:

> At that time I greatly enlarged the site of Nineveh…it's wall I built anew….18 canals I dug…. I led out the waters from mount Tas on the border of Urartu…. I directed the waters to Nineveh the great metropolis…. Up to where the waters could not reach I let them down over the thirsty ground…. I irrigated annually (so that it was possible) to cultivate grain and sesame…offering of sacrifices…at the mouth I fashioned 6 great steles with the images of the great gods my lords upon them and my royal image in the attitude of salutation.
> Jacobsen and Lloyd (1935, p. 36).

In addition, the main inscription B at the aqueduct of Jerwan reinforces the message of power:

> Sennacherib, king of the world, king of Assyria (says) "for a long distance, adding to it the waters of the twain Hazur river (namely) the waters of the River Pulpullia (and) the waters of the town of Hanusa, the waters of the town of Gammagara (and) the waters of the springs of the mountains to the right and left at its sides, I caused a canal to be dug to the meadows of Nineveh. Over deep-cut ravines I spanned (lit. caused to step) a bridge of white stone blocks. Those waters I caused to pass upon it."
> Jacobsen and Lloyd (1935, p. 20).

If the inscriptions alone had been discovered one might be led to believe that this was simply an example of the boasts of the king, but both field studies and satellite image analyses have demonstrated the substantial scale of the canals and other hydraulic structures, some of which are in direct proximity to the inscriptions (Reade 1978; Bagg 2000; Ur 2005).

Parthian and Sasanian water supply systems in Iraq and Iran

As Parthian and Sasanian archaeology is less well developed than the archaeology of the Roman-Byzantine empires to the west, we know less about their water systems. Nevertheless, thanks to the monumental scale of some Sasanian canals, certain features have become well known within the literature of survey and regional analysis. However, disagreements over the archaeological dating evidence weaken arguments that favour Parthian contributions to hydraulic engineering (Christensen 1993; Wenke 1975–1976). Nevertheless, the better known Sasanian systems clearly rest upon a much longer history of Parthian and Achaemenid achievements, which include the irrigation works, dams and canals constructed within the region of the Achaemenid capitals in the plain of Persepolis (Sumner 1986, pp. 13–17).

Of greatest size are Sasanian systems, particularly the massive Nahrawan Canal, which led water down a 230 km long channel from the Tigris north of Samarra across the Diyala lowlands to the east of Baghdad (Adams 1965, 2006). Built probably in the sixth century AD, this system enabled some 8000 sq km of land to be irrigated at the height of Sasanian power. Later Arab historians were clearly impressed by the administrative hierarchy required to build such engineering works and according to Mas ‘udi such achievements rested on a massive administrative structure:

> Royal power rests upon the army, and the army upon money, and money upon the land tax (*kharaj*), and the land tax upon agriculture, and agriculture upon just administration, and just administration upon the integrity of government officials, and the integrity of government officials upon the reliability of the vizier, and the pinnacle of all these is the vigilance of the king in resisting his own inclinations, and his capability so to guide them that he rules them and they do not rule him.
> Altheim and Stiehl (1954); cited by Adams (2006, p. 22)

Such engineering works, did not, however, simply result from the exercise of raw power, the money raised by increased taxation could then be invested in additional canal construction, thereby raising production and revenues still further. This positive feedback perhaps encouraged further growth and the extension of the canal networks. Nevertheless such feedback spirals, resulting in ever larger canal systems, were fragile and apparently not necessarily sustainable, and many of these state investments had only a relatively short life span (Christensen 1998).

Massive canal systems of Achaemenid, Parthian and especially Sasanian date are also known from the Khuzestan plain of southwest Iran (Adams 1962; Wenke 1975–1976; Moghaddam and Miri 2007; Christensen 1993), the nearby Deh Luran Plain (Neely and Wright 1994), as well as northeast Iran (Omrani et al. 2007), the Atrek Valley of Turkmenistan (Lecomte 2007, pp. 304–306) and elsewhere in Central Asia. Overall, such systems, and the administrative systems that enabled them to be built, appear to have formed a foundation upon which the better known systems of the Romans and Byzantines partially rested.

Roman/Byzantine and Early Islamic Syria

Roman, Byzantine and Early Islamic engineers of the first centuries BC and first millennium AD were able to build upon an illustrious tradition of water management and distribution. In terms of the design and construction of dams Kamash asserts that Roman engineers took a fresh approach to an indigenous technology and “fine tuned” it to produce a more sophisticated end product (Kamash 2006, p. 73). Overall, the thesis of Kamash (2006), compiled from published and written sources supported by fieldwork, demonstrates that for Syria and neighbouring regions Roman/Byzantine hydraulic features became prominent features of the landscape and included the installation and use of ever more sophisticated water technologies. Although many of these were already in use, the Roman and Byzantine engineers appeared to develop these techniques to a degree of sophistication hitherto unknown:

> …by 63 BC most areas of the Near East were already equipped with water-lifting devices, dams, tunnelling technology, water-storage facilities and well-developed irrigation systems as well as legal infrastructure for the protection of the water supply.
> (Kamash 2006, p. 40)

Although the Romans introduced some new technologies, they also built upon the long and durable history of the Assyrian, Persian, Urartian, Arabian, Nabataean, Babylonian and Sumerian traditions that preceded them. In addition, they also diversified the use of water conduits, specifically in terms of the water supply of cities and installations such as public baths, fountains and public waste disposal systems (Wilson 2000a, b; Wikander 2000).

One technology that was widely adopted by the Romans and later empires was the qanat (or falaj, karez, foggara), the systems of underground conduits equipped with vertical access shafts thought to have been introduced in the first millennium BC (Lambton 1989; Mostafaeipour 2010; Beaumont et al. 1989). There is currently some debate about whether these underground channels originated in Iran (as conventionally held) or southeast Arabia (Wikander 2000; Lightfoot 1996, 2000; Al-Tikriti 2002). Although satellite imagery is demonstrating that relict qanats are common in Syria and northern Iraq, unfortunately, they are notoriously difficult to date, except by associated artefacts or sites they lead to, or by occasional textual references. Conventionally, qanats drain water from within gravel alluvial fans, leading it via tunnels, and then open channels, to ultimately supply the water to qanat/falaj communities and their fields in the lowlands downstream. Such systems of tunnels with access shafts, which were built upon similar lines to bedrock tunnels dating back to the first millennium BC in Assyria and Palestine (Lamon 1935; Oates 1968; Davey 1985; Tsuk 1997), are very flexible. They can be adapted to a variety of hydraulic contexts such as channelling through hillsides, or tapping waters from within solid rock as well. Variants of qanat technology became particularly common in Syria and Iraq during the Roman/Byzantine period, and it is likely that some of these water tunnels are variants of the so-called "spring flow tunnels" of Palestine (Ron 1989).

The above overview of the history of water systems in the Near East suggests that there is a significant, but un-quantified, increase in the number and perhaps scale of water supply systems through time so that by the late first millennium BC and the early first millennium AD the number of water supply conduits and canals outside Mesopotamia had increased considerably. Although it might be argued that there was a major decline in the construction of qanats and canals after their heyday in the Sasanian or Early Islamic periods, historical sources indicate that the water supply systems continued to be used and perhaps constructed throughout the second millennium AD, although whether these were built at the frequency or scale of the earlier systems is less clear.[1] Certainly satellite images reveal that by the twentieth century AD, some areas of the Near East were densely packed with qanats and other water systems of various degrees of antiquity.

Landscape infilling between upper and lower Mesopotamia

Between the irrigated lands of southern Mesopotamia and the rain-fed zone to the north exists an area of terrain that falls into neither zone. This area, falling between roughly the 250 mm isohyet and the Euphrates River and Baghdad, had been sparsely populated before the Middle Bronze Age (early second millennium BC). Then, from the late second millennium or the first millennium BC the area became progressively settled by sedentary

[1] Christensen (1998) paints a picture of continued decline of water systems. However, Ottoman tax records demonstrate the continued use of irrigation systems in northern Syria through the sixteenth and seventeenth centuries (Hütteroth 1990). The innovation of building new water supplies as far afield as from the Sajur River appears to have continued during the Ayyubid and Ottoman periods (Marcus 1989, p. 303).

communities nourished by substantial irrigation canals. These canals, mapped by three different groups of field workers, occurred in three main areas (Fig. 3):

- Along the Tigris Valley within Iraq the construction of the Dujayl canal system to the west of Samarra (Adams 1972) resulted in the colonization of a previously sparsely settled region. According to the archaeological surveys of Adams (1972), settlement and associated canal construction was initiated in the Neo-Babylonian period (*ca*. 6th–4th century BC). The Dujayl canals then attained their maximum scale during Parthian, Sasanian and Islamic times when they comprised a complex dendritic network of canals and associated settlements. Although the earlier phases of this system can only be inferred from the pattern of settlement that presumably received their water from canals, the later phases, consisting of both archaeological sites and the earthworks of associated canals, have been verified by later research using air photographs.
- To the west within Syria, the north bank Euphrates tributary, the Khabur River, witnessed the construction of a major longitudinal canal system (Fig. 3). Although the main phases of this system are of Neo-Assyrian date (*ca*. 8th and 7th centuries BC), excavated evidence from the city of Dur Katlimmu demonstrates that the early phase of canal construction is of the Middle Assyrian period (*ca*. thirteenth century BC: Ergenzinger et al. 1988). As was the case for the Dujayl, this canal system resulted in the colonization of a large area of previously sparsely populated terrain.
- Finally, the Balikh Valley to the west of the Khabur, which had already experienced water competition during the early second millennium BC, witnessed the construction of a series of long canals during the Hellenistic, Roman/Parthian, Byzantine/Sasanian and Early Islamic periods (Wilkinson 1998b). A revised assessment of these is provided below.

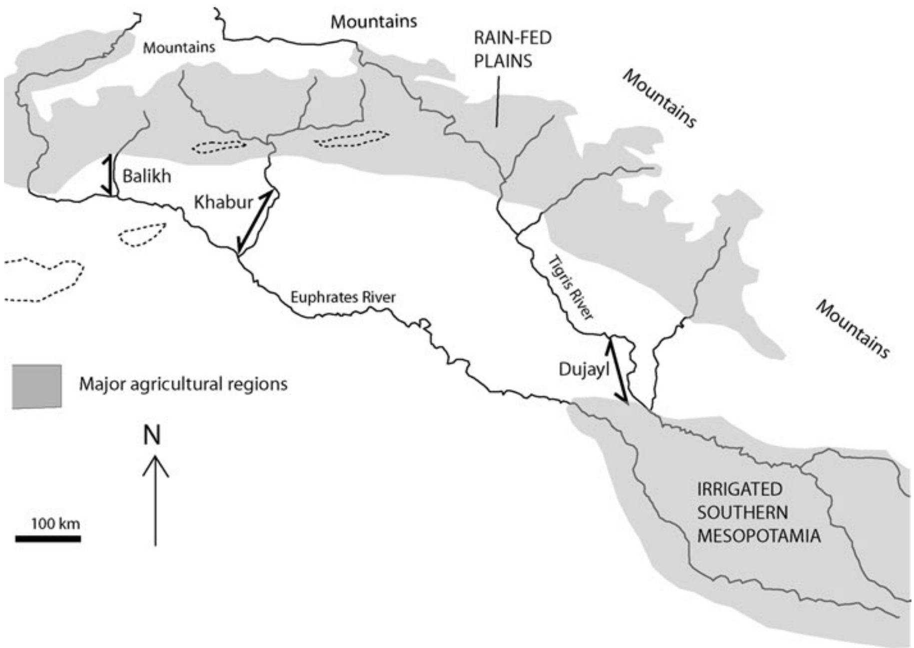


Fig. 3 The infilling of the landscape between the Tigris and Euphrates

Together, the construction of these three major canal networks resulted not only in the colonization and infilling of a large area of previously sparsely settled terrain, they also set the stage for the extension of hydraulic systems further north into the rain-fed zone during much of the first millennium BC and AD.

Hydraulic landscapes within rain-fed upper Mesopotamia

Methods

In Upper Mesopotamia hydraulic features are now being recognized from geoarchaeological studies combined with the use of high resolution satellite imagery and radar data. The latter include archival imagery from the American CORONA programme (taken in the late 1960s and early 1970s) or the new generation of high resolution imagery such as Quickbird and GeoEye (many of which are now incorporated into *Google Earth*).

For the Balikh study area, identifiable water features (natural, artificial and of uncertain origin) were digitized from a mosaic of 1967 CORONA satellite images. Analysis and preparation of maps employed Erdas 9.3, ArcGIS 9.3 and Adobe illustrator. A histogram equalizer stretch was applied to the CORONA, and further adjustments were made to the histograms applied in order to highlight the canals and qanats. A Shuttle Radar Topographic Mission (SRTM) digital elevation model (DEM) was constructed and manipulated to differentiate between areas of subtle topographical variation which are nevertheless significant for water management. At this stage in the analysis the SRTM data, with data points 90 m apart, has proved to be more easily processed and representative of the landscape than NASA's recently (2009) released 30 m Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM product. Therefore, SRTM was used for most of the topographical analysis and the use of ASTER is confined to providing a background for the general maps, and for representing the gradients of canals.

Canals and conduits are usually visible on satellite images because they form dark lines, often flanked on each side by a paler alignment corresponding to the banks of up-cast thrown up as a result of excavation (Fig. 4; Wilkinson 2003, pp. 45–52). In contrast, where these features have been subsumed within an aggraded landscape such as a river floodplain they will be obscured and the channel will be difficult to detect.

Qanats are visible thanks to distinctive alignments of ring-shaped up-cast mounds on the land surface. Whereas the massive soil banks of major canals are difficult to miss on the ground, qanat shafts and their upcast mounds are more recognizable on high resolution satellite images and air photographs. Unfortunately, because many Syrian qanats and hydraulic tunnels are cut into the limestone and are not surrounded by debris mounds, these can also be difficult to recognize except by ground survey.

The following examples drawn mainly from north Syria and southern Turkey illustrate the types of information that are now emerging from archaeological surveys.

Case studies

Dibsi Faraj

Dibsi Faraj is located on a limestone plateau overlooking the Euphrates flood plain, which exhibits traces of occasional relict meanders of the river, together with modern settlements

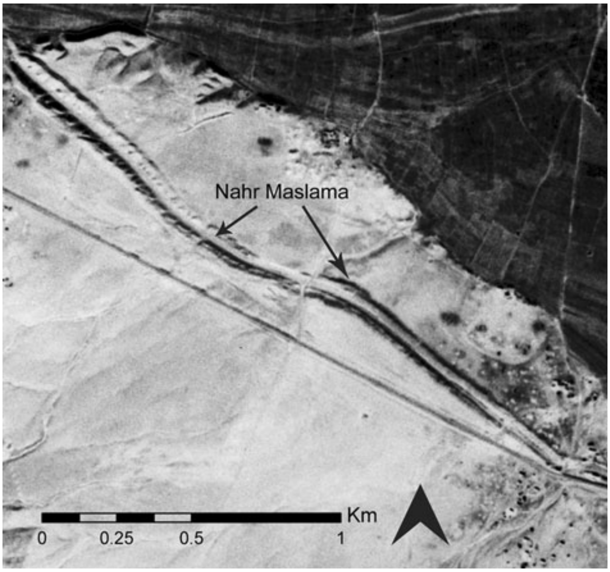


Fig. 4 Part of the Early Islamic Nahr Maslama canal. A standard deviation stretch was applied, the image sharpened × 3 and the contrasted adjusted minimally. The preserved feature, about 2.3 km long, is probably only part of the original feature

and fields. The citadel of Dibsi Faraj is now obscured by the waters of Lake Tabqa, Syria; however, the site originated in the Late Roman period and consisted of a military fort and houses as well as public and administrative buildings. Occupation declined after the ninth century AD (Harper 1975).

Although geomorphological processes have removed archaeological traces on the floodplain, a number of features are present on the edge of the steppe. Two artificial hydraulic features in the environs of the site are visible on historical satellite imagery: the Nahr Maslama is a canal dated by excavation and associated artefacts (Fig. 5; Wilkinson 1975); in addition, a qanat leading towards the site, discovered through satellite image analysis, can be dated by association with the settlement (Fig. 6).

A segment of the Nahr Maslama is preserved and is identifiable by its prominent up-cast banks (Figs. 4, 5). An excavated section (Wilkinson 1975) revealed a plaster-lined conduit associated with Early Islamic coins from the excavated fill (Fig. 5). Additional sections through the up-cast banks to the east suggest that the main Early Islamic phase was apparently preceded by an earlier phase of canal construction. Shafts located just within the

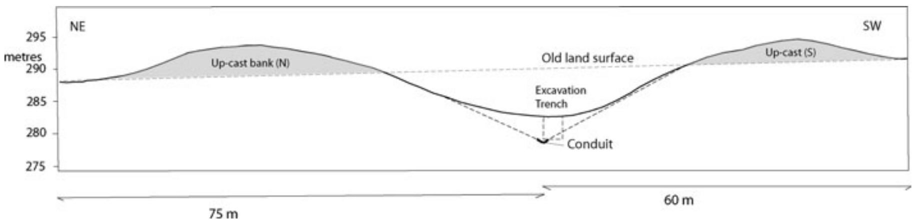


Fig. 5 Cross section of the canal near Dibsi Faraj (see Fig. 4)

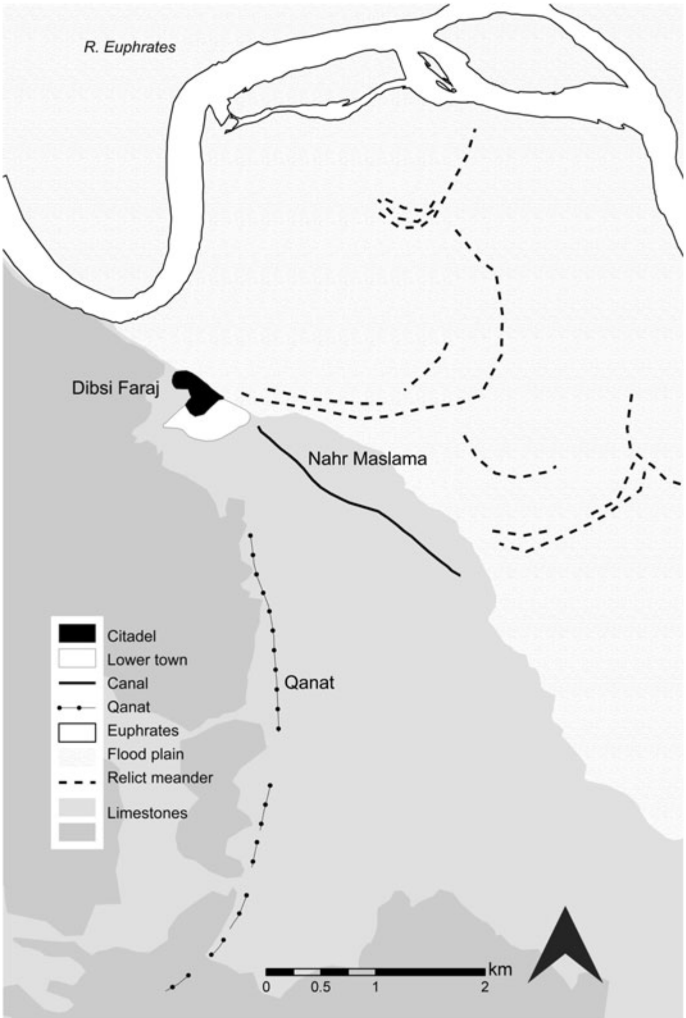


Fig. 6 The hydraulic landscape of Dibsi Faraj on the Syrian Euphrates

defensive walls of the site may have enabled water to be extracted from an earlier phase of the channel (Wilkinson 1975). The canal probably originally extended for an estimated 8.5–20 km distance upstream, however, other than this short stretch visible on the satellite imagery, it has been obliterated by a later channel and silt accretions from the Euphrates River (Wilkinson 1999).

The qanat, the other prominent water feature in this landscape, flows for about 4 km from the limestone steppe to the south of the site northwards towards the site itself. It appears to have conveyed water into the settlement; either to the baths and hypocausts, and perhaps hydraulic installations to the west, but also to the lower town located to the south of the citadel (Fig. 6). Given the absence of other occupation in the vicinity it is likely that the underground channel was associated with Dibsi Faraj; and a date of construction during the Late Roman, Byzantine Early Islamic period, therefore, seems likely, although whether there was continued use cannot be ascertained.

The function and date of the canal and qanat may not have been the same. The canal, which is referred to by the Early Islamic writer al-Baladuri as being built by the Ummayyad land-owner Maslamah (Harper 1975, p. 324), must have supplied water for irrigating the area southeast of the citadel. Moreover, suggestions that this represents the cleaning out of an earlier canal (Musil 1927, p. 316; Decker 2009, p. 179) are supported by the evidence, noted above, of two phases of bank construction. On the other hand the qanat appears to have led directly to the site itself, perhaps functioning as the primary source of domestic water during its Late Roman and Byzantine heyday. Unfortunately, the hydraulic landscape of Dibsi Faraj now lies beneath the lake created by the construction of the Tabqa dam. Whilst further ground work is, therefore, impossible, historical CORONA satellite imagery provides a way of undertaking further investigations.

Jerablus area, Syria

This area of the right (west) bank of the Euphrates River immediately south of the Turkish border at Jerablus/Carchemish has yielded an unexpectedly large number of hydraulic features. These can be divided into two classes:

- Small channels between 20 cm and 100 cm wide and 30–100 cm deep lined with ashlar blocks of limestone or cut into the host limestone bedrock (Wilkinson et al. 2007: Fig. 17). Of the eight systems recorded, some are clearly open channels that guided water from the perennial flow of the local rivers such as the Nahr al-Amarna and the Nahr Sajur, whereas others appear to be qanat-type tunnels that drained water from the local water tables. In the latter case, like an example from Shallalah Saghirah southeast of Aleppo (Wessels and Hoogeveen n.d.), these probably tapped water from where variations in the limestone layers allowed groundwater to accumulate. Others appear to resemble the so- called “spring flow tunnels” of Palestine (Ron 1989).
- A single large earth-cut open channel now virtually completely filled with sediment. The Euphrates River was tapped via this 9–14 m wide canal which was visible for a distance of some 4–5 km between Tell Jerablus Tahtani and al-Jamel (Wilkinson et al. 2007: Figs. 14 and 15).

The eight small channels mainly flow at roughly right angles to the Euphrates, that is along the tributary wadis or parallel to them, whereas the major canal tapping the Euphrates followed longitudinally parallel to the valley axis (Fig. 7). Dating evidence for the minor conduits consists of occasional claw chisel marks on some of the component ashlar blocks (in the case of the Nahr al-Amarna system) and by their relationship with archaeologically dated sites (in the case of the Wadis Seraisat (LCP 1), Serai (LCP 17) and Sha ‘ir (LCP 4). The Euphrates canal was associated with the Byzantine-Early Islamic sites LCP 7, 8 and 9, which suggests that the canal was probably in use during these periods. None of the channels are in use today, and most have clearly been abandoned for centuries. According to local people, a complex of rock-cut channels along the north (left) bank of the Sajur may have been in use during the period of the French Mandate (or perhaps the late Ottoman period), but a number of long-abandoned qanat shafts associated with it suggests it is probably an earlier feature of Roman-Byzantine date subsequently cleaned out during the Ottoman or French mandate periods.

In the Jerablus area nearly every tributary valley, together with the main Euphrates Valley itself, carried a water supply system. Although only some can be dated, most have the

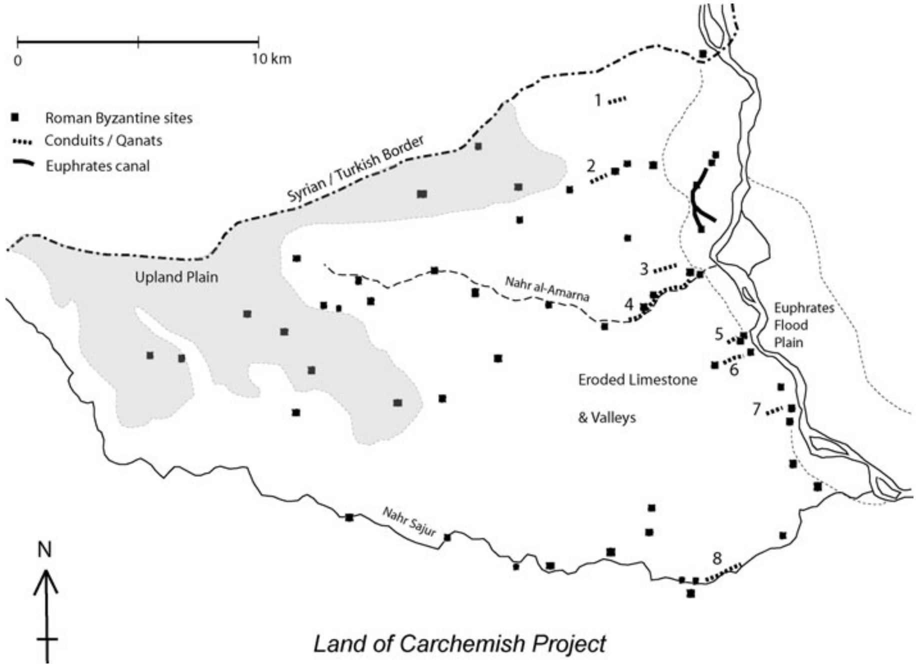


Fig. 7 Canals, conduits and qanats of the land of Carchemish

characteristic features of Hellenistic—Early Islamic conduits or underground tunnels, and because this was the period when both the overall number of sites as well as their geographical dispersal across the landscape achieved its peak, it is likely that these features were in use during this broad period from around the third century BC until the tenth century AD. Their discharge appears to have exceeded that required for domestic water supplies (or even facilities such as bath houses) and it is more likely that each was used to irrigate fields associated with settlements occupied during this peak in settlement. Whether they just provided irrigation water for farmsteads and villages, or for larger estates is unclear. Although the structure of the water supply systems resembles that of the Dibsi Faraj area, namely smaller "lateral" flows via qanats and related channels, with a major axial flow canal along the main valley, the function of these two systems appears to have been different.

The Amuq Plain, southern Turkey

The Amuq Plain, located within Hatay in southern Turkey, being in close proximity to Roman-Byzantine Antioch, was well supplied with conduits and aqueducts (Downey 1961). In contrast, the water systems of the Amuq Plain immediately to the east of the city were primarily canals for irrigation and power. These occurred within a broad flat lake basin surrounded by the high Amanus Mountains to the west and the lower limestone hills to the east and south. With a mean annual rainfall of about 500–700 mm per annum, the prehistoric, Bronze and Iron Age settlements were able to rely on rainfall for all agricultural requirements. However, by the Hellenistic and Roman periods, archaeological surveys have recorded numerous canals and conduits.

In the southeast of the plain, near the Roman town of Imma, a conduit powered at least three Roman-Byzantine penstock water mills (Casana and Wilkinson 2005, pp. 43, 63, 64).

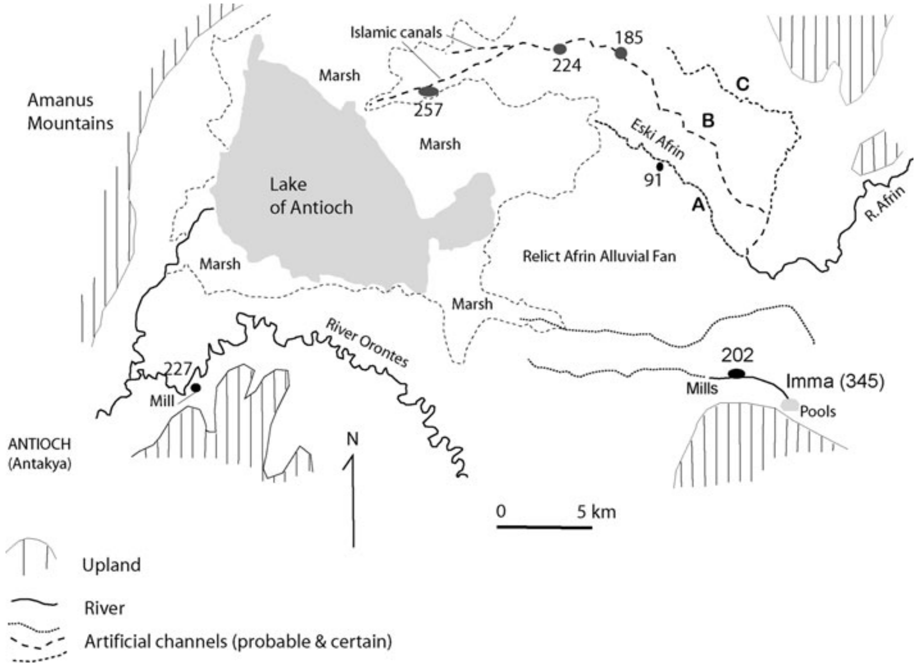


Fig. 8 Map of the later canal system, lake and marshes in the Amuq (after Eger 2008; Wilkinson 1997)

In addition, diversions of the Afrin River led the water via three different canals or canalized rivers to form the arcs A,B and C to the north and east of the Lake (Fig. 8; Gerritsen et al. 2008). Archaeological sites associated with these three branch channels provide "dates by association" for the canals thereby indicating that diversions had been made from perhaps the first century BC through to the Early Islamic period (Fig. 8; de Giorgi and Eger in Gerritsen et al. 2008). By the Early Islamic period the association of archaeological sites with the silt/sand levee of canal B was particularly clear (AS 185, 224 and 257) thus demonstrating that this canal continued in use until at least this time. The Afrin canals led directly into the Lake of Antioch, which existed in Roman times but not much earlier (Wilkinson 1997; Casana 2003; Gerritsen et al. 2008), to discharge excess flow into the lake causing it to expand and form perimeter marshlands around the lake as noted by Islamic historians (Wilkinson 1997; Eger in Gerritsen et al. 2008).

Overall, this canal system appears to have both reduced the flow of the main Afrin River and re-directed its water (in the form of excess irrigation flow) into the lake which then expanded to encroach on to pre-existing agricultural land (Fig. 8).

The Balikh Valley

The Balikh River (the ancient Balissus), which occupies a broad corridor of cultivable land within the north Syrian steppe, is fed primarily by the spring of ʻAin al ʻArous close to the Turkish border, and drains into the Euphrates near Raqqa. In the past there may also have been flow from the Harran Plain to the north, and this contribution has now returned thanks to Turkish irrigation schemes which discharge poor quality outflow water into the Syrian Balikh. In addition, Syrian farmers now receive a more usable water supply directed along modern canals leading from Lake Tabqa on the Syrian Euphrates. Before the Hellenistic

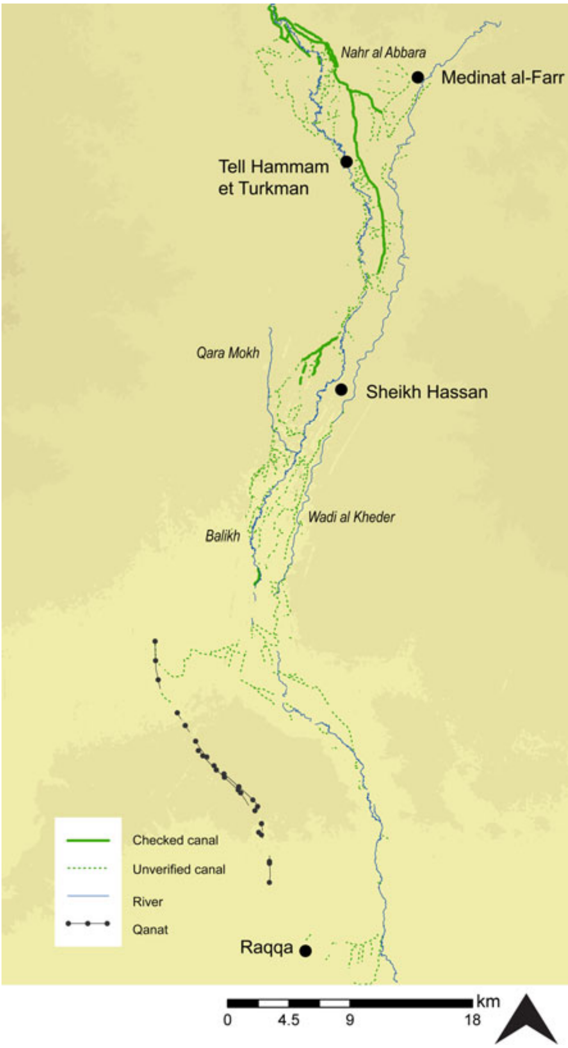


Fig. 9 Canals and qanats of the Balikh Valley

period, the distribution of settlements suggests that rain-fed cultivation was the norm and was concentrated primarily in the north of the valley. In contrast, the south of the valley is too arid for much rainfall cultivation (Mulders 1969). During most archaeological periods archaeological sites had been clustered close to the River Balikh. However, land use intensification, perhaps initiated during the first millennium BC as a result of Neo-Assyrian or Hellenistic investments, entailed the construction of water supply systems and expansion into the steppe (Fig. 9).

The complex palimpsest of irrigation reflects developing links between water management and the power of the later territorial empires. Several artificial channels in the Balikh have been checked in the field (Wilkinson 1998b) and one canal has been dated through excavation. In addition, archaeological survey has provided dates for settlements and their associated canals. Such "dating by association" suggests that this phase of water management was initiated from the Hellenistic onwards, with evidence of particularly intensive activity during the Early Islamic period. Other features visible on 1967 CORONA imagery, although unverified by fieldwork, appear to be related to features already recognized during the original fieldwork (Fig. 9).

Whereas canals were sometimes evident from up-cast banks on either side of a central (canal) void as noted above, others were more subtle soil marks recognized by soil surveys. Analysis of digital elevation models indicates that canals either followed the topographical slope or ran obliquely to it, usually at a shallow gradient of around 1:1000 (cf. Hodge 1992, pp. 347–348). This relationship to the topography distinguishes them from hollow ways (of ancient tracks and routes), which can cross the watershed indiscriminately of slope.

Hellenistic water supply

A section dug through the Sahlan-Hammam canal, running between Tell Sahlan and Tell Hammam-et-Turkman, was excavated and on the basis of artefacts contained in the channel fill and a single radiocarbon date, appears to have been constructed in the Hellenistic period continuing in use until around the sixth century AD (Wilkinson 1998b). The gradient of the canal is around 0.002 m (*ca*. 1:500, Wilkinson 1998b) and the land irrigated may have been capable of supporting around 1,173 individuals (Wilkinson 1998b).

A canal trace along the west bank of the Balikh near Tell Sheikh Hassan was associated with numerous Hellenistic sites. Again, "dating by association" suggests that the canal was probably in use at this time. According to the traces on the CORONA imagery, water was carried to the fields through a system of off-takes, after which the canal drained into the Qara Mokh, a west bank tributary of the Balikh.

This canal system fell within the hinterland of the Seleucid city of Callinicum/Nicephorium, and the associated settlement has been suggested to relate to the Macedonian settlement of the region as indicated in the Parthian Stations of Isidore of Charax (first century AD; Schoff 1914; Decker 2009, p. 181).

Byzantine and Early Islamic water management

During Byzantine times, the Balikh Valley also fell within the hinterland of Callinicum, and the modest pattern of settlement was again associated with canals, both the Sahlan-Hammam, as well as perhaps the earlier stages of the Nahr al-Abbara on the east bank of the Balikh.

By the Ummayyad and Abbasid periods the Balikh Valley had become politically important, in contrast to the Byzantine period, when the region was more sparsely settled because of its location close to the Byzantine and Sasanian frontier (Decker 2007, p. 251). This Early Islamic peak in settlement was probably a result of substantial investments by the caliphs, especially in the immediate area of Raqqa (Bartl 1996; Challis et al. 2002–2004), as well as around the significant sites of Medinat al-Far and Harran located upstream. As a result of its strategic, industrial and political significance, the Abbasid authorities considered it expedient to manipulate the physical and cultural landscape of the Balikh, a process which is reflected by the hydraulic developments in the valley.

This political and industrial importance (Challis 2002–2004) was associated with denser settlement throughout the valley and cultivation that was intensified by irrigation with canals and qanats (Figs. 9, 10). The Nahr al-Abbara appears to have functioned as an irrigation channel and the associated archaeological sites imply that it was constructed around the sixth to eighth centuries AD (Wilkinson 1998b). The SRTM digital elevation

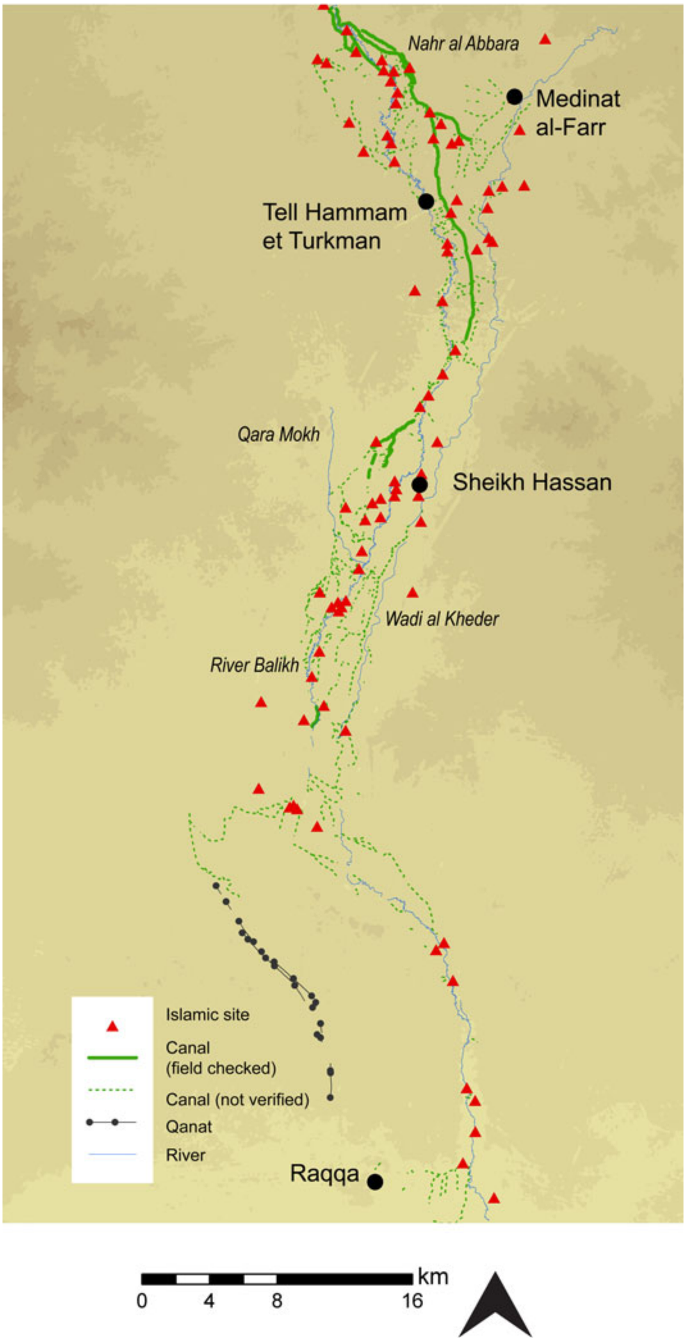


Fig. 10 Early Islamic sites in the Balikh Valley in relation to canals; surveyed and recorded by Wilkinson (1998b), Bartl (1994)

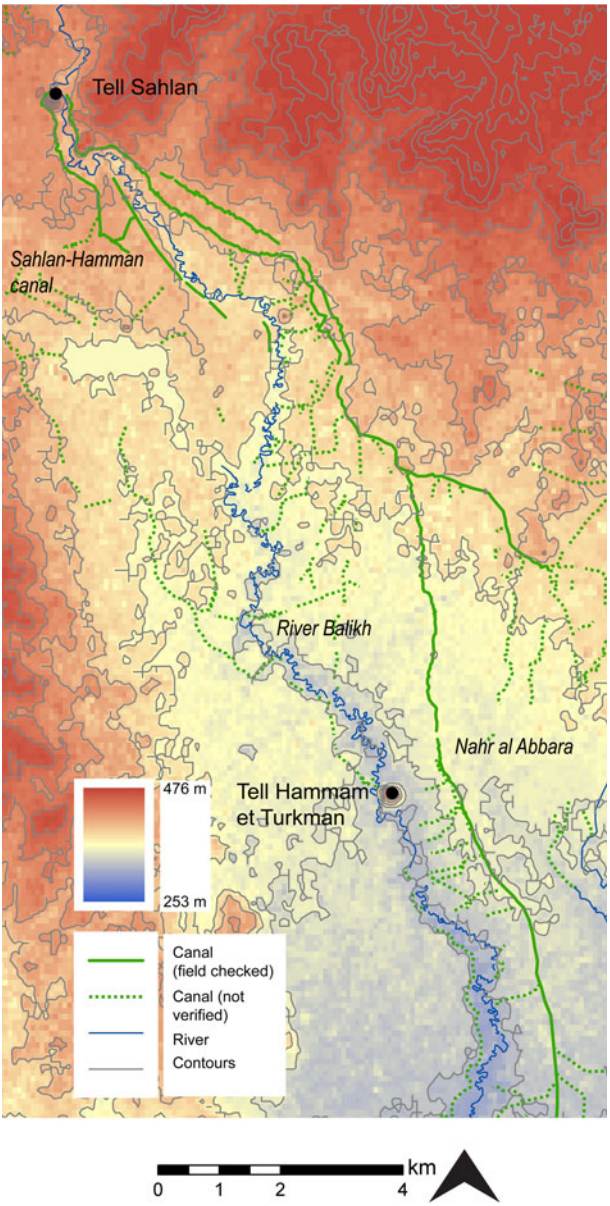
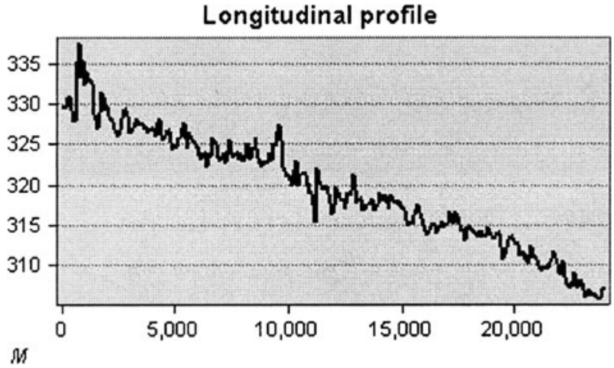


Fig. 11 Part of the Nahr al-Abbara canal in the Balikh Valley. Note how the Nahr al-Abbara canal flows along the crest of the low ridge thereby aiding the dispersal of flow by gravity. Contours and raster DEM generated from SRTM data

model indicates that it flowed from close to the confluence of the Balikh with the Jullab, along a slightly raised ridge (Fig. 11) between the River Balikh and the Wadi al-Keder (possibly a contemporaneous channel), at a gradient of approximately 1:1:1000 (Fig. 12). What appear to have been sluice stones occurred at intervals along the canal trace, suggesting the location of off-takes for field irrigation; and the canal apparently discharged the outflow back into the Balikh a few kilometers south of Tell Hammam et-Turkman. This

Fig. 12 Longitudinal profile of the visible extent of the Nahr al-Abbara, from ASTER DEM



suggests that much of the system from source to the terminus remains in place. It is not clear whether the prominent Islamic site of Medinat al-Far, a few kilometers to the east, received water directly from this canal, but it appears that the fields of the town were probably irrigated by the Nahr al-Abbara.

Within the southern part of the valley a qanat (Fig. 13) drew its water supply from the Balikh, after which it flowed straight towards the Abbasid palaces immediately north of Raqqa. At its upstream end the channel appears to have been open, after which it went underground as a tunnel with qanat shafts, to negotiate an upland area apparently mostly devoid of settlement. As the qanat led directly towards the major palaces and related structures of Abbasid Raqqa an Early Islamic date for this canal/qanat system seems acceptable. Remains of various built structures associated with the qanat include a square feature close to the qanat (Fig. 13) as well as possible cisterns or tanks and buildings of unknown function.

Overall, the hydraulic landscape of the Balikh Valley is very complex. However, past fieldwork, and further image analysis has revealed not only that the Early Islamic period was the most significant in terms of artificial water supply, but also that there was an apparent relationship between water and political power. This was primarily because Harun al-Rashid re-located from Baghdad to Raqqa between 766 and 808 AD, making Raqqa his temporary capital (Eger 2008, p. 274). The Caliph Harun al-Rashid invested considerable money and effort around the city, perhaps even directly sponsoring canal construction (Toueir 1983). The area certainly had strategic importance, being located at the Byzantine frontier of the Abbasid Empire (Kennedy 1981) and its location on a major route to the Byzantine/Early Islamic borderlands of the Thughur appears to have made it a target for imperial investments.

Although rain-fed cultivation was possible, and had indeed been practiced, irrigation provided a means of ensuring higher and more secure yields. It may well have been such investment in hydraulic management that enabled the agricultural, demographical and perhaps also industrial expansion that took place at this time, factors which were surely the basis of the regions' political and strategic significance.

Other examples of hydraulic landscapes

Overall, satellite images, DEM analysis, field surveys and textual sources have demonstrated the existence of major canals and bifurcating systems of artificial channels of ancient but unknown date in the following areas:

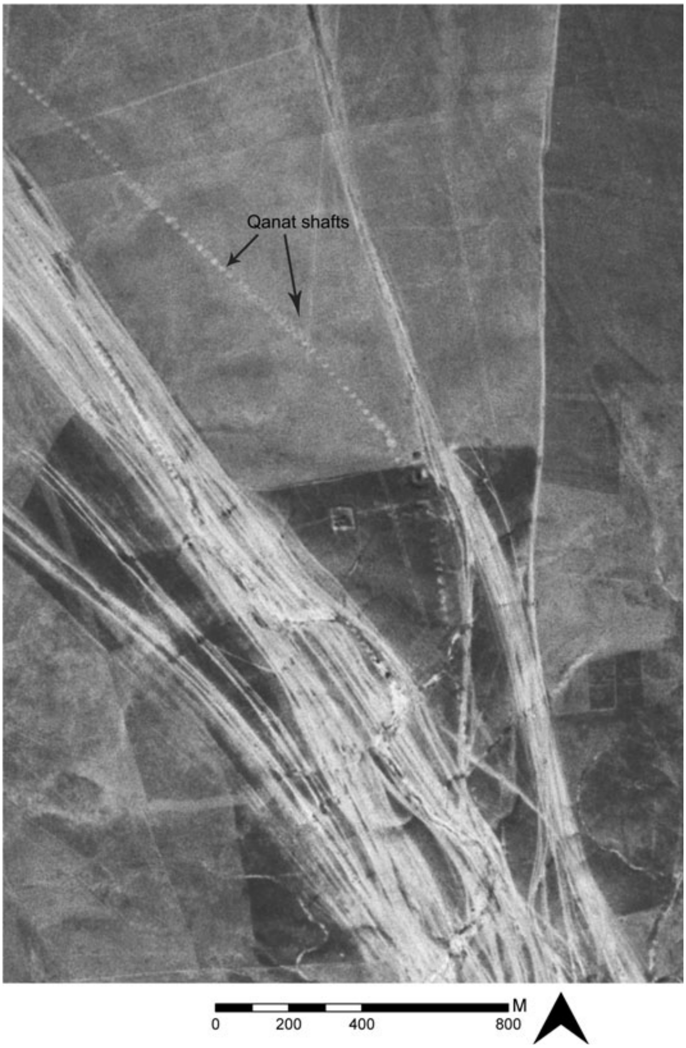


Fig. 13 1967 CORONA image of part of a qanat leading from the Balikh to the Early Islamic palaces north of Raqqa

The Khabur basin

- A series of canals in the Khabur basin, including those near Tell Tamr (ancient Theodosiopolis) and Tell Tunaynir (ancient Thannouris) downstream of Hasseka (Lauffray 1983, 1991; Van Liere and Lauffray 1954–1955; Decker 2009, pp. 182–183; Kamash 2006, pp. 76–78 and v. 3).
- A large canal to the south of Tell Brak on the Wadi Jaghjagh/Radd as well as a possible canal leading to the castellum at Brak (Ur, in press).
- A dendritic system near Tell Barri revealed in section along the Wadi Jaghjagh.
- Dendritic canal systems south of Qamishle SW of Tell Hamoukar (Ur, in press).

In sum, the significant discharge of the Khabur River, together with the presence of large sources of spring water, provided a wealth of opportunities for the development of irrigation canals. In fact, Decker suggests that the investment in canal systems in the Khabur "was sizeable, involving multiple canal systems over the entire length of the river" (Decker 2009, p. 184). These canals supplied sufficient water to irrigate some 30,000 ha, perhaps sufficient to feed some 62,000 inhabitants (Decker 2009, p. 184).

In addition canals and conduits have been recognized from other parts of Upper Mesopotamia and northern Syria including:

- Northwest Iraq: near the Roman/Parthian fort of 'Ain Sinu, perhaps in association with a water mill.
- Near Umm al Marra, east of Aleppo.
- West of Raqqa near Early Islamic Heraqla (Toueir 1983).
- In southeast Turkey, for example the aqueduct and water supply of Samsat as well as in the Incesu Dere near Kurban Höyük (with associated water mill; Wilkinson 1990).

The above-mentioned examples appear to represent an unknown proportion of the canal systems that are present. However, this does not mean that such systems were everywhere; some survey areas are apparently entirely without evidence of water supply conduits, qanats or relict irrigation systems of any date. These include: (a) The North Jazira Project in Iraq (Wilkinson and Tucker 1995); (b) The Tell Beydar region in Syria (Ur and Wilkinson 2008) and (c) the Tell Sweyhat area in Syria (Wilkinson 2004). The field data, therefore, suggest that the development and uptake of hydraulic systems varied from place to place, in part depending upon access to perennial water sources, and that some areas continued to practice rain-fed cultivation even after irrigation was commonplace elsewhere.

Discussion

The above case studies supply only snapshots of hydraulic systems from within a limited area of northern Syria, southern Turkey and northern Iraq. Despite the limitations in the dating evidence for many channels, they create the impression that there was a considerable amount of canal, conduit and qanat construction over the last 3000 years, and especially over the past 2000 years. Archaeological survey as well as air photo, satellite image and DEM analysis, together with textual sources, have increased the number of recorded features significantly, and even though many are not closely dated, the association of large numbers of dated archaeological sites with the canals, or the fact that they led to major sites or even cities (in the case of the underground channel to Raqqa or the Dibsi Faraj qanat) provides compelling dating evidence for at least part of the use life of the channels in question.

If the area of analysis is enlarged to encompass much of the Middle East, and the dates of the chosen hydraulic systems are plotted according to mean annual rainfall, it appears that the older canals and conduits are concentrated in the drier areas, whereas during the Iron Age and later, they became more frequent in moister regions, particularly those with rainfall greater than 400 mm per annum (Fig. 14). Of course, modern rainfall can only provide a rough index, because Fig. 14 does not utilize the rainfall that prevailed at the time; however, existing proxy climate records are not sufficiently precise to provide a robust indicator of past climate for such a wide range of locations. Nevertheless, this suggests that there was an expansion of irrigation works, out of areas where irrigation was required to satisfy a complete water deficit (southern Mesopotamia and arid parts of the Levant) to where canals were able to supply water that was supplementary to rainfall.

During the later empires there also appears to have been an increase in the functions performed by the hydraulic systems. For example, by the Neo-Assyrian period canals were not simply providing irrigation water, they were also used to create pleasure gardens and hunting areas. This trend had gone even further by the Roman period at which time urban uses became important and included supplies to bathhouses, cult and religious installations, nymphaea, and latrines (Kamash 2006; Glaser 2000). Of the hydraulic systems discussed, some in the Amuq Plain powered water mills, and then continued to supply irrigation water to the plains. The qanat at Dibsi Faraj must have supplied water to some of the baths and hypocausts within the citadel, and beyond the site, the spare flow may have provided supplementary water to fields on the plain. Moreover, water supplies were also presumably employed for industrial purposes as well as sanitation (Wilson 2000b).

The tendency for irrigation to be employed increasingly in humid areas suggests that hydraulic works were not only used to satisfy absolute water deficits, but were also used to increase the yield of the land (that is to intensify production), to stabilize yields, or to increase the control over when to plant or harvest (Hastorf 2009, p. 68). This may have been because of the increased role of taxation in the economy. For example, in Hopkins'(1980) model of the Roman economy the imposition of cash taxes forced cultivators:

> "to produce, and to sell, more food in order to pay taxes." He continues: The impact was greatest in those regions in which simple cultivators were forced to produce and sell a surplus which they had not previously produced, or which they had previously consumed themselves (Pollard 2000, p. 199).

These results echo the statement of Kamash who asserts:

> The trend towards higher levels of irrigation fits in with the picture of general agricultural intensification in the late Roman period, particularly in Syria. (Kamash 2006, p. 245).

By including a longer chronological range of dated features, it can be seen that the Late Roman tendency towards intensification formed part of a longer trend over the past three millennia (Wilkinson, in press). In addition, and most clearly demonstrated by the data from the Dujayl, Khabur and Balikh (above) was the colonization of lands between the irrigated and rain-fed zones. There, hydraulic systems were agents in the settlement and colonization of areas that formerly had been sparsely settled. This is particularly the case

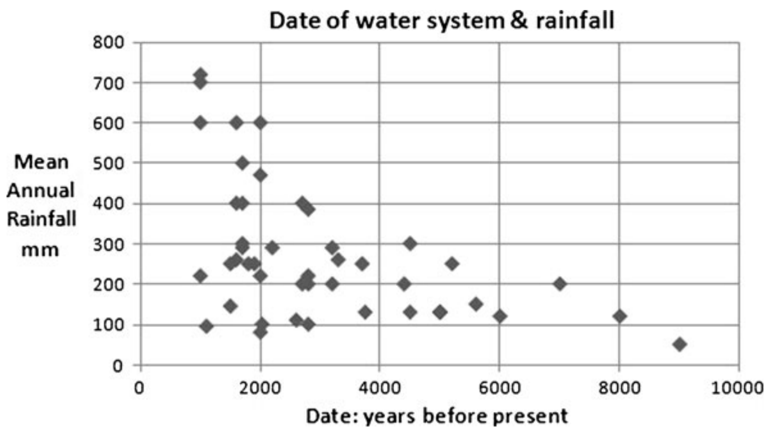


Fig. 14 Scatter chart showing the date of irrigation systems versus rainfall through time (years before present, BP)

for the Lower Balikh where archaeological surveys have demonstrated a significant increase in settlement within the lower reaches of the valley (Wilkinson 1998b; Bartl 1996). Other scholars also argue that water technology played a significant role in the colonization of new lands (Braemer, this volume).

Another key element in both the colonization of new land and the intensification of production was the rapid spread of qanats. Although these had been known and used from the early first millennium BC, by the Roman period *qanats* were common throughout the Middle East whereever conditions were suitable (Wessels and Hoogeveen n.d.; Kamash 2006).

The spread of hydraulic systems throughout the Middle East during the past 3000 years does not simply relate to the exercise of administrative power. Although this must have enabled some Neo-Assyrian and Sasanian systems to be constructed, the presence of regional administrations over vast areas must also have encouraged both information flow and technology transfer thereby creating conditions more favourable for the diffusion of innovations, especially those with such practical applications as hydraulic technologies. The case of the capture of Roman troops by the Sasanian king, Shapur I, who then put them to work on dams and irrigation works in Khuzestan, is a well-known example of such knowledge transfer (Oleson 2000, p. 196). Other instances include the spread of tunnel technology (Bagg 2004) and the spread of iron working which made excavation and tunnelling easier (Adams, R.MCc. pers. comm. February 2010).

The "span of control" within empires also made the benefits of irrigation more widely felt. For example, in AD 362, drought and a poor grain harvest in the area of Antioch coincided with a large buildup of troops for the fight against the Persian army. This dearth of cereals resulted in a massive increase in prices as well as famine in the city (Downey 1961; Casana 2004, p. 110). However, the crisis was eventually averted when Julian ordered the import of grain from Chalcis and Hieropolis (southwest and east of Aleppo, respectively). If these towns had been under a different administration such a solution would have required considerable negotiation, and may not have been possible. Moreover, it is remarkable that relatively arid areas like Membij were capable of supplying a verdant area, such as Antioch, with grain. However, the plethora of canals and conduits in the Jerablus area, together with the discovery of a 30 km long qanat of probable Roman date (N. Galiatsatos pers. comm. 2009), provides a context for such transactions.

The increased span of control of the later territorial empires reflects the concept of "internal" and "external" water as coined by the FAO[2] for modern states. In other words water that is sourced from within a state (internal water) has greater utility than that which derives from beyond its borders (Allen 2001, p. 60). It can, therefore, be assumed that as the size of ancient polities increased with the growth of empires, it was easier to tap and transport water over progressively large areas.

Recent data also suggest that the use of water for rural water supplies and irrigation was more significant than previously suspected (Kamash 2006, p. 250). This is certainly the case from the case studies discussed above. None of the conduits in the Carchemish area flowed in the direction of major towns, and although the Amuq Plain did provide part of the supply for Antioch, the newly discovered systems, in use from at least Roman to Early Islamic times, were predominantly for irrigation. Even when they were associated with towns (such as Roman Imma), parts of the associated channels led away from the town towards water mills and agricultural areas. Nevertheless, some channels did supply towns and cities as was the case for the underground channel that led to the palaces and built-up

[2] The Food and Agriculture Organization of the United Nations.

areas around Early Islamic Raqqa. In addition, the Dibsi Faraj qanat appears to have combined the functions of military as well as urban water supply.

The above evidence suggests that water systems increased in both scale and number after the Late Bronze Age. The results from the study of Braemer and colleagues in semi-arid central and southern Syria (see also Newson 2000) provide a parallel, but somewhat different narrative. In southern Syria dams dated to the late fourth millennium BC and subsequent hydraulic developments during the Early Bronze Age led to the proliferation of reservoirs and canals during the Middle Bronze Age (Braemer et al. 2009). Then, from the first century BC the construction of longer canals opened up new areas for settlement. That some of these Nabataean, Roman, Byzantine and Early Islamic hydraulic installations were associated with a state level society (Braemer et al. 2009) is indicated by the erection of steles near Suweida to commemorate aqueduct construction as well as direct involvement by the emperor Trajan in such investments (Braemer et al. 2009). Although imperial power played a significant role in the investment and construction of water supply systems, at Suweida subsequent maintenance was the responsibility of the city. This point is echoed by Kamash who states that not only were aqueducts (i.e. conduits) extremely expensive to build, cities such as Antioch benefitted from a large amount of imperial investment in aqueducts. However, maintenance was the responsibility of the landowner through whose land the aqueduct passed and the day-to-day upkeep was under the city officials (Kamash 2006, pp. 115–123).

Furthermore, systems administered by a centralized state are not necessarily stable, long-term features and major state-built systems were often more vulnerable to collapse and less sustainable than modest community-run systems (Christensen 1998; Wilkinson 2006, p. 64). Whereas large state-controlled systems (that conspicuously collapsed) are well known, modest systems that endured appear to have been less common or obvious. However, recently discovered hydraulic systems in northern Syria (e.g. those near Qamishle in the Khabur basin) although probably dug under Sasanian rule appear to have continued into Ottoman times, suggesting a period of use of 1000 years or more. More striking is the case from the Wadi Zerqa area in the Jordan Valley, where intensive archaeological surveys have traced the late Ottoman system back to the Iron Age and perhaps the Late Bronze Age giving an estimated age of the system of around 3000 years (Kaptijn 2009, this volume). However, unlike many Sasanian and Roman systems, this canal network has apparently been so successful that it became "embedded" in the landscape and is virtually invisible today.

Conclusions

Mesopotamia has long been heralded as a heartland of ancient hydraulic management, but it is clear that early hydraulic systems also extended into the rain-fed zone and its margins in both northern Syria and the Levant. It also appears that there has been an increase in the scale and number of water systems during the last 3000 years, although more research is required to demonstrate this empirically. Not only has the cleaning out of canals and conduits resulted in the destruction of evidence of earlier use, where landscapes have been densely settled for millennia, or where irrigation itself has deposited a veneer of sedimentation, the evidence of earlier systems may be obscured.

Just how the new sources of data will contribute to an understanding of the last millennium of water use remains to be seen. Whereas Christensen (1998) argues for substantial decline after the Sasanians, the evidence that some canals and conduits show continuity into the Ottoman period may indicate that only the vulnerable sector of hydraulic systems suffered terminal decline. This is a research question for future investigation.

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