Chapter 4: Dams

4.1 Introduction

Dams formed a significant element in the water supply of the Near East from the Bronze Age onwards (see Chapter 2.2). Their use seems to have been particularly important in areas with low rainfall [Fig. 4.1]. It is not surprising, therefore, to find that dams also played an important role in water supply and management in the Roman and late Roman periods. Dams fulfil several roles in the overall scheme of water management. These include storage of water in the form of reservoirs, provision of water to aqueducts for water supply of settlements (derivation), provision of water for irrigation and water diversion and/or flood alleviation. In most instances dams perform a combination of two or more of the above roles as well as providing water for subsidiary purposes such as milling.

Conventionally, there are three basic forms of dam design: the gravity dam, the arched dam and the arch dam.[1] A gravity dam functions on the principle that it is too massive to be affected by the pressure exerted by water stored behind it [Fig. 4.2]. Pressure on a gravity dam is concentrated at its base, hence its design as a wide-based structure. Gravity dams can be constructed out of either masonry (rubble core with a dressed-stone face) or earth, sometimes with a stone facing. In general, gravity dams are long and low. The arched dam is very similar to the gravity dam since it too resists water pressure due to its weight. It is, however, usually curved in shape. The arch dam functions on a different basis and its existence in the Roman and late Roman periods is controversial. The arch dam has a convex water face and resists water pressure by transmitting the stress horizontally and hence does not require the weight or thick base of a gravity dam [Fig. 4.3].

Almost all dams that survive in the archaeological record in the Roman Empire were either gravity or arched dams and this was no exception in the Near East. An arch dam, one of three known from the empire, may have existed at Dara (see section 4.3).[2] Despite their importance, dams have escaped detailed study and investigation. While the seminal work by Calvet and Geyer has been of great use and value in the field of dam research, it considers only dams located within modern Syria. There are also some errors in

[1] Hodge 1992, 80.
[2] The others are at Glanum, France and Kasserine, Tunisia.

their data, such as the common supposition that the Homs dam is no longer extant.[3] In addition, there is a bias towards early dates for dams, some of which do not appear justified. Work on dams in general has suffered from poor dating, partly due to the lack of scholarly interest. This problem has caused complications in the interpretation of these structures as a meaningful group.[4]

Major research questions on dams have, therefore, been left unresolved, but personal fieldwork and reconnaissance focussing on dams in modern Syria, Jordan and south-eastern Turkey has been undertaken to help rectify these problems and has provided accurate, up-to-date data.[5] These data have been used below in conjunction with previous research to answer several aspects of the research agenda: the dating of dams and the importance, if any, of the impact of Rome, the purpose of dams and their role in irrigation and urban supply, including a consideration of the constant-offtake principle and the implications of dams for investment in agriculture.

The data and references for the dams discussed here are presented in tables 4.1-2, which function as and replace a potential gazetteer [Fig. 4.4].

4.2 Purpose and function

The attribution of a primary role to a particular dam can prove complicated, and even unhelpful, because of the multifunctional nature of dams (see section 4.1). The identification of the function of a particular dam is often aided by the analysis of the channels associated with the dam structure. This is particularly useful when trying to determine whether a dam was used for urban supply or irrigation because the channel can often be traced and its destination found or deduced. It is noteworthy here that Nabataean dams tended not to have offtake points, but more frequently were reservoirs with steps that seemed to function as water-drawing points, for example the Nabataean dam at Auara.[6]

The late Roman dam at Caesarea had one of the clearest primary purposes: it raised the level of water in the Zerqa River to provide water for the Low Level aqueduct for urban

[3] Calvet and Geyer 1992a.
[4] See Kamash 2006.
[5] Fieldwork was still not possible for me in Israel and the Occupied Territories and Iraq.
[6] Oleson 1991, 49. Also see Al-Muheisen and Tarrier 2001-2002, 515 for similar practices at Petra.

water supply. In addition, the water from the dam had a subsidiary purpose: milling.[7] Even in this case, however, it has been claimed that the water was not suitable for the urban drinking supply as it was too brackish, but rather that it supplied water for industrial activities in the northern zone of the city.[8]

Another important function of a dam is flood control and prevention. Dams at Dara and Seleucia Pieria were designed with this as a clear primary purpose. In both cases special measures appear to have been associated with them: an innovative design at Dara and a protective evil eye at Seleucia Pieria (see sections 4.3 and 4.5). While these special measures are very different, both may be said to illustrate the importance of this type of dam.

One example of a storage dam is the Harbaqa dam on the Wadi al-Barde. This dam created a large lake that could store water for use during the dry season.[9] The dam was used later for derivation to supply Qasr al-Heir al-Gharbi in the Ummayad period. It is commonly said that the dam provided water for Palmyra in its earlier phases. This seems unlikely, however, as Palmyra was a long distance away and with its qanats and springs had no need for extra water at this distance and expense. The presence of the dam suggests that there must have been more Roman occupation in the area than is currently thought.

The Khanouqa dam at Halabiyya-Zenobia on the Euphrates fulfilled two, equally valuable roles. One of its functions was to be a diversion dam that regulated the flow of the water in the notoriously capricious river. In addition, its other purpose was to raise the water level so that the water could be diverted into the Semiramis irrigation channel.[10]

The function of the Homs dam was more complicated and highlights problems with using channels to identify the sole function of a dam. This dam not only performed a storage function in the form of the very large lake created behind it, but also fed channels for both irrigation and urban supply. With a dam such as this, which performs multiple vital functions, it is very difficult to pinpoint one purpose as the primary function and it is more likely that it was constructed with all three functions in mind.

[7] Oleson 1984.
[8] This idea was presented at the *Cura Aquarum in Ephesus* conference, 2004 by Yosef Porath: 'Was the low level aqueduct to Caesarea Maritima built for industrial purposes?'.
[9] Calvet and Geyer 1992a, 84.
[10] Isidore of Charax, *Parthian Stations*, 5; Lauffray 1983, 75.

One of the most important functions of the dam is its role as reservoir. The fact that a dam is built to store water contradicts the constant-offtake principle adduced for Roman aqueducts i.e. that water flowed constantly through the system and was not stored in significant quantities at any point in that system. Even Hodge, who is one of the strongest supporters of the constant-offtake principle, is forced to admit that dams were 'at variance with the traditional Roman aqueduct principle of constant offtake.'[11] Hodge continues with the idea that dams represent a step away from the constant-offtake principle towards a more economical use of water. It is undeniable that dams do not conform to a constant-offtake principle, but is it true that they represent a move away from it? In order for dams to represent a move away from the constant-offtake principle, it is necessary first to prove that water in the Roman period of the Near East functioned on such a system.

The theory that all Roman water works function according to the constant-offtake principle has recently been brought under increasing scrutiny especially in the Roman provinces in North Africa. Evidence from North Africa, in particular from large storage reservoirs, has pointed strongly for a need to revise this theory.[12] This question will receive further attention in Chapter 7; suffice it to say here that it is viable to propose that dams providing water for urban supply represent evidence against the constant-offtake principle in the Near East and not necessarily a move away from it as an assumed norm.

What is clear from the above analysis is that several dams formed the starting point for some of the largest and more complex irrigation and urban supply systems in the Near East. These dams provided water for some of the major cities in the Near East, for example Caesarea. In addition, dams such as that outside Homs and also possibly that outside Caesarea Maritima, illustrate that the creation of large storage reservoirs from large dams across broad valleys led to the possibility of providing water for both urban and rural needs, pointing to an interesting overlap and possible interdependence between the two (see Chapter 6.3.2).[13] Furthermore, the amount of water made available for irrigation and agriculture from these dams suggests an increased investment and interest in the agricultural yield from the region, as well as raising the possibility of a more centralised

[11] Hodge 1992, 79.
[12] Wilson 1998, 81-84, 89-91; Wilson 2001, 83-92.
[13] Wilson 1999, 328: small holes in the low-level aqueduct to Caesarea Maritima may have been used as offtake points for rural pipelines or channels.

approach to agricultural practices; aspects that will be considered more fully in Chapter 5 (on the negative aspects of these changes see below Section 4.5).

4.3 Design and location

As noted above (section 4.1), most of the dams in the Near East, and Roman Empire in general, were gravity or arched types, both of which resist water pressure due to their weight. It has been proposed, however, that a dam at Dara was not a gravity dam, but an arch dam, which resists pressure due to its shape.[14] This proposition has been founded on a passage from Procopius that asserts that Justinian built a dam in order to protect the city of Dara from flood damage:[15]

Ἐν χώρῳ διέχοντι τοῦ τῆς πόλεως προτειχίσματος ἐς τεσσαράκοντα μάλιστα πόδας, μεταξὺ σκοπέλου ἑκατέρου, ὧν δὴ κατὰ μέσον ὁ ποταμὸς προϊὼν φέρεται, ἀντιτείχισμα ἐτεκτήνατο ὕφους τε καὶ εὔρους ἱκανῶς ἔχον. οὗπερ τὰ πέρατα οὕτω δὴ ὄρει ἑκατέρῳ πανταχόθι ἐνῆφεν, ὡς τῷ ὕδατι τοῦ ποταμοῦ, ἢν καὶ σφοδρότατα ἐπιρρεύσειεν, ἐνταῦθα ἐσιτητὰ μηδαμῆ ἔσεθαι. τοῦτο δὲ τὸ ἔργον οἱ περὶ ταῦτα σοφοὶ φράκτην ἢ ἀρίδα καλοῦσιν, ἢ ὅ τί ποτε ἄλλο ἐθέλουσιν. οὐκ ἐπευθείας δὲ τὸ ἀντιτείχισμα πεποίηται τοῦτο, ἀλλ′ ἐπὶ τὸ μηνοιεδὲς τετραμμένον, ὅπως ἂν τὸ κύρτωμα πρὸς τῇ τοῦ ποταμοῦ ἐπιρροῇ κείμενον ἔτι μᾶλλον ἀντέχειν τῷ ῥείθῳ βιαζομένῳ δυνατὸν εἴη.

'At a place about forty feet removed from the outer fortifications of the city, between the two cliffs between which the river runs, [Justinian] constructed a barrier of proper thickness and height. The ends of this he so mortised into each of the two cliffs, that the water of the river could not possibly get by at that point, even if it should come down very violently. This structure is called by those skilled in such matters a dam or flood-gate,

[14] Hodge 1992, 92.
[15] Procopius, *De Aed.* 2.2.13-17; 2.3. Quoted passage taken from 2.3.16-20.

or whatever else they please. This barrier was not built in a straight line, but was bent into the shape of a crescent, so that the curve, by lying against the current of the river, might be able to offer still more resistance to the force of the stream.'

Most importantly, the passage seems to suggest that the dam was designed as an arch, which is important for the history of technology and assessments of the Roman contribution to it. The passage has been thrown into doubt, however, because the remains of such a dam have not yet been found. Three dams have been located at Dara, but are not of the design suggested by this passage.[16] This leads to two possibilities. Firstly, there was never an arch dam at Dara and that Procopius has been misinterpreted and/or was not writing truthfully. Secondly, there was an arch dam at Dara in addition to the ones already found, but it has been destroyed and is no longer visible.

The likelihood of this second possibility rests to some extent on the likelihood of the first: how likely is it that Procopius could make up this description of an arch dam at Dara? Although Croke and Crow have cast doubt on the verity of some of Procopius' claims, it seems unlikely that Procopius was speaking pure fantasy.[17] Procopius tended to embellish on the truth, rather than lie outright. In particular, he claimed that Justinian was responsible for virtually all the changes and new additions to the water works of Dara, but it was more credible that at least some of these should be credited to Anastasius. Therefore, this evidence should not be ignored outright.

There is also a second point strongly in favour of the existence of an arch dam. The description Procopius gave was quite precise in its description of the attributes of the dam. Of particular interest is his apparent understanding of fluid dynamics and the effect of pressure and force upon a curved surface. It seems hardly credible that Procopius could have explained only accidentally the action of an arch dam. Therefore, even if there was no arch dam at Dara, it still must stand that the technology was known and available. Furthermore, if Procopius were fabricating the arch dam description in order to embellish Justinian's reputation, would it go too far to suggest that the arch dam was also recognised as the 'superior' dam design?

[16] Garbrecht, and Vogel 1991; Sinclair 1989, 221, pl. 101.
[17] Croke and Crow 1983, *passim.*

If the technology of the arch dam was available in our period, one must ask: why was it not used more often? An important issue in the construction style of dams is the location and this may offer a first explanation. In general terms, gravity dams are suited to shallow, wide valleys whereas arch dams are suited to narrow gorges. It has been suggested that one reason for the lack of arch dams in the Roman world was that Romans preferred to build dams in broad valleys.[18] The statistics for the Roman dams recorded in the Near East, however, appear to show a rather different story.

Of the 45 dams that definitely belong to the Roman and late Roman periods 18 were narrow and sited in narrow locations such as gorges or small wadis and 18 were broad and sited in broad valleys across larger rivers (Table 4.1 and Figs 4.5-6). The dam at Tell Kazel, which is one of the 18 dams in narrow locations, was positioned parallel to the river and is the longest dam in this category: 60 m. This dam may belong arguably in the broad category. Data on the geographical milieu of nine of the dams are not available. These figures, therefore, seem to indicate a rather different story, i.e. that the dams of the Roman and late Roman periods do not seem to favour a broad location over a narrow one. Of dams with known lengths from elsewhere in the empire, seven were over 100 m long (Cornalvo, Proserpina, Alcantarilla, Consuegra, Esparragalejo, Böget, Kasserine and up to 900 m at Wadi Caam), three were between 50 m and 100 m long (Subiaco, Çavdarhisar and Löştügün) and three were 50 m or under (Faruk, Semalı and Örükaya).[19] This shows a reasonably similar variety. It may be significant that the majority of the shorter dams were geographically closest in Asia Minor, though as three of these were not included in the empire-wide studies of Hodge, Schnitter and Smith, it is also possible that other short dams may be found with further work on dams in eg Spain and North Africa.

[18] Hodge 1992, 81.
[19] Bildirici 2002; Hodge 1992, 82, table 39; Schnitter 1967; Schnitter 1979; Smith 1971.

Table 4.1 Lengths and geographical locations of Roman and late Roman dams in the Near East.

Name	Length (m)	Height (m)	Geographical milieu	References
Al Bre'ij				Lauffray 1983, 61.
Antioch	c. 10	Over 20	Narrow gorge	Sinclair 1990, 248.
Auzara			Euphrates	Decker 2001, 11; Lauffray 1983, 54
Caesarea – N	900	3.5	River Zerqa	Peleg 2002a, 146.
Caesarea – W	190	7	River Zerqa	Oleson 1984, 140; Schnitter 1987, 10; Peleg 2002a, 146.
Dara 1	56 + 72	4 – 5		Garbrecht and Vogel 1991, 268.
Dara 2	15	2 – 2.5		Garbrecht and Vogel 1991, 272.
Dara 3	c. 6	5		Garbrecht and Vogel 1991, 273.
Diyateh			Wadi	Sadler 1990, 428-9.
Dmeyr	c. 20		Foot of mountain	Calvet and Geyer 1992a, 120; Poidebard 1934; personal observations.
Gweyf				Calvet and Geyer 1992a, 120; Poidebard 1934, pl. 95.
Harbaqa	365	20.5 (c. 10 m in phase 1?)	Wadi al-Barde; large wadi	Calvet and Geyer 1992a, 81; Schlumberger 1939, 200; Schnitter 1979, 24; Poidebard 1934, pls 32-34; personal observations.
Haseke 1			Khabour	Lauffray 1983, 62
Haseke 2			Khabour	Decker 2001, 103; Lauffray 1983, 61.
Hit	Over 50		Head of wadi	Stein 1940, 430.
Homs	850	4	Broad valley	Calvet and Geyer 1992a, 31. Personal observations.
Horbat Kohal	50		Wadi	Negev 1999, 88*.
Jilat	58	6.5	Wadi	Politis 1993.
Kara Kavak				Sinclair 1989, 37.
Khan al-Manqoura 1	19	1.5 (minimum)		Calvet and Geyer 1992a, 95; Poidebard 1934, pls 24 and 25.
Khan al-Manqoura 2				Calvet and Geyer 1992a, 98.
Khan al-Qattar				Calvet and Geyer 1992a, 100.
Laqiya– Nahal Rosh 2				Katz 1999, 87*
Laqiya-Nahal Rosh 1				Katz 1999, 87*
Ma'ale Safir	13.3	2.9		Kloner 1973, 30*; Peleg 1991b, 107.
Nahal Hevron 1			Wadi	Negev 1996, 128, fig. 141.
Nahal Hevron 2			Wadi	Negev 1996, 129, fig. 142.
Nahal Hevron 3	30		Wadi	Negev 1996, 129, fig. 143
Nahal Hevron 4			Wadi	Negev 1996, 129, fig. 144
Nahal Hevron 5			Wadi	Negev 1996, 129, fig. 145.
Nahal Hevron 6			Wadi	Negev 1996, 130, fig. 146.
Nahal Hevron 7			Wadi	Negev 1996, 131, fig. 147.
Nahal Safit	22	3.5	Narrow gorge	Kloner 1973, 30*; Peleg 1991b, 105.
Nahr Dawwarin (Tell Seker)			Khabour	Decker 2001, 104; Lauffray 1983, 51.
Nessana area 1			Wadi	Mayerson 1960a, 34.
Nessana area 2			Wadi	Mayerson 1960a, 34.
Resafe	480	3	Wadi	Calvet and Geyer 1992a, 120; Garbrecht 1991c, 244.
Sad ar-Richa				Calvet and Geyer 1992a, 120; Poidebard 1934.
Seleucia-Pieria	175	16	Musa Dagh	Sinclair 1990, 258; Garbrecht 1991b, 86.
Tel Dibs/Thallaba 1			Khabour	Decker 2001, 103; Lauffray 1983, 61.
Tel Dibs/Thallaba 2			Khabour	Lauffray 1983, 61.
Tell Kazel	60	2.7	Small river: Nahr al-Abrash	Calvet and Geyer 1992a, 54.Personal observations.
Thallaba			Khabour	Lauffray 1983, 61.
Thannouris			Khabour	Decker 2001, 103; Lauffray 1983, 61.
Urfa	30			Sinclair 1990, 14.

This diversity in choice of site is brought into sharp relief by a comparison with Nabataean dams. Eleven of the fifteen well-dated Nabataean dams were located in narrow clefts, gorges or necks of wadis, one was parallel to a wadi and for three geographical data are not available (Table 4.2 and Fig. 4.7). These data indicate a clear preference for siting dams in narrow locations (discussed further in section 4.6). It is difficult to see if this pattern extended across the empire, as evidence for pre-Roman dams elsewhere is limited. It is clear though that in the East, at least, dam construction was not constrained by using only one type of location. Therefore, we are still left to explain why full use was not made of the arch design.

Table 4.2 Lengths and geographical locations of Nabataean dams.

Name	Length (m)	Height (m)	Geographical milieu	References
Acropolis, Petra			Narrow	Lindner 1987, 149-151.
Auara	10.66	3.65	Small cavern	Oleson 1991, 49.
Bab as-Siq, Petra			Narrow wadi	Lindner 1987, 149-151; personal observations.
Katuteh, Pet			Narrow cleft	Al-Muheisen and Tarrier 2001-2002, fig. 2.
Monastery, Petra	10	c. 3	Narrow cleft	Personal observations.
Qasr adh-Dherih				Glueck 1935, 102.
Qasr bir Zeit				Glueck 1939, 77.
Ramliye				Evenari *et al.* 1982, 119.
Rekhmentein			Wedge-shaped fissure	Glueck 1935, 56.
Sela			Narrow cleft	Glueck 1939, 26.
Siq al-Bared, Petra			Narrow gorge	Al Muheisen and Tarrier 2001-2002, fig. 8.
Siq Bajeh			Narrow corridor	Al Muheisen 1990, 508; Al Muheisen and Tarrier 2001-2002, 519f.
Wadi Metaha, Petra	17		Parallel to wadi	Lindner 1987, 149; personal observations.
Wadi Mudhlin, Petra	2		Narrow wadi	Personal observations.
Wadi Sabra, Petra			Narrow	Lindner 1987, 149-151; Lindner 2005, 39-41.

A second alternative and plausible explanation could be survival bias. It is possible that if breached, an arch dam may leave little or no trace due to its small span and lesser thickness (in comparison to the broad and thick gravity dams), as may have happened at Dara. Thirdly, it is possible that since arch dam technology appears to have developed at a late stage, after the main period of dam building in the East in the 3rd and 4th centuries (see section 4.4), fewer dams needed to be constructed and therefore the technology was not used to its full potential.

A further important point is that it does not necessarily follow that because a technology was 'superior' it would be used. There may, for example, have been only a limited number of engineers able to design and construct such a new and sophisticated technology. This must surely have been an important factor when selecting from a suite of designs. In such cases there would have to be a strong over-riding reason for choosing a more complicated and unfamiliar design (with the potential construction problems that that may entail), over a 'tried-and-tested' technique that works effectively. In the case of Dara this reason may have been the need for the greater resistance of an arch dam against violent floodwaters, coupled with the fact that the location made its use possible.

Contrary to expectation that narrow dams would be taller than broad dams (and so potentially have similar reservoir volumes), the width of a dam did not have a clear relationship to its height. The data in Table 4.1 show that the majority of Roman and late Roman dams whose height is known were less than 6.5 m high. It is possible that this may in part be due to survival and some dams may have been taller. It seems common for dams elsewhere in the empire to have been between 10 m and 16 m high, for example: Cornalvo, Mérida, Alcantarilla, Kasserine, Orukaya and Cavdarhisar.[20] The two tallest dams in the East at Seleucia-Pieria (16 m) and Harbaqa (20.5 m) arguably have exceptional reasons for their height. As Seleucia-Pieria was primarily used for flood diversion its height was dictated by the potential height the floodwaters could reach as illustrated by the evil eye above the maximum line (see sections 4.3 and 4.5). The dam at Harbaqa seems to have been built in two phases, its height being increased probably in the Umayyad period (see section 4.4), so the original structure would have been substantially lower, c. 10 m high.

As well as design choices concerning the type of dam, there were further design choices involving the actual fabric of the dam, for example building material, bond, and coursing. To some extent there was little or no choice in these matters. In general, the building material tended to be that which was locally available and so depended on the local geology, for example basalt for the Homs dam and limestone for the Harbaqa dam. With only one exception, all the dams in the study area were built with a rubble core faced by well-dressed stone blocks. The exception was the dam at Antioch, which included some brick courses [Fig. 4.8]. This dam is a somewhat exceptional case anyway since it was originally a viaduct that was converted into a dam. This unusual history may account for its unconventional use of brick and stone. The fact that almost all the dams were built of stone

[20] Hodge 1992, 82, table 39. The tallest known dam was at Subiaco: 40m-50 m.

with a rubble core is one of the only features that relates the dams of the Roman and late Roman periods. This is a pattern that extends across the rest of the Roman Empire where all other masonry dams have a rubble core faced with stone blocks bonded by mortar.[21] In North Africa there was a propensity towards earth dams (across broad and shallow watercourses) that is not found in the East.[22] Other elements such as spillways and sluices do not seem to show any patterns of distribution.

The presence or absence of stepped courses presents some interesting evidence. At least six of the Roman and late Roman dams catalogued had been stepped on their air and/or water faces. No dams from the Nabataean period were stepped. Indeed the dam at Wadi al-Jilat was the only dam of the Roman period in the Nabataean realm that was stepped.[23] This suggests that this was a technique introduced by the Romans into the Near East. Indeed, it was used on other Roman dams in the empire, for example on the Proserpina dam, which fed Mérida, Spain [Fig. 4.9].[24] In all cases the steps served to broaden the dam at its base. In some cases stepping was only provided for the lowest courses of the dam, for example Harbaqa [Fig. 4.10]. The Homs dam displays an interesting range of techniques, in particular the intriguing waving step on the air face [Fig. 4.11].

This diversity of design elements coupled with the variety of locations noted above, leads to some interesting conclusions. One of the most pertinent aspects of the sites chosen for the dams is how well suited they are to gathering water, especially in areas with low rainfall [see Fig. 4.1]. It has been said that the location of the Harbaqa dam was one of its failures because it was prone to silting.[25] Two factors argue against this. Firstly all dams by their very nature are prone to silting because the action of the dam against the water movement means that particles carried by the water settle out. Secondly, and of importance here, the dam is located in a particularly good position. Its reservoir is fed not only by the Wadi al-Barde, but also by other large wadis that flow into the al-Barde a few hundred metres further up. In addition, the ring of mountains that almost entirely encircle the area around the dam must also contribute large quantities of runoff water [Figs 4.12-4.13].

[21] Smith 1971, 37.
[22] Hodge 1992, 84.
[23] On the stepped dam at Jilat, see Politis 1993, 45.
[24] Hodge 1992, 80.
[25] Calvet and Geyer 1992a, 126.

The design of the Homs dam at Lake Qattina on the Orontes also seems to have been affected by its location. It was shaped like a long, flat V with the point facing upstream into the impounded lake [Fig. 4.14]. The reason for this shape seems to be the presence of a basalt spur that does not extend across the whole lake.[26] It appears that the dam followed the basalt spur across the lake because it provided excellent foundations. Where the basalt spur runs out the dam changed direction in order to reach the other side of the lake in the shortest distance.

Here it would seem is the real art of dam building: the ability to choose the right location and design a dam that would suit the needs of that location most economically. Strategies concerning physical conditions and the locations of dams have not been looked at explicitly elsewhere in the empire, though there does seem to be a propensity for earth gravity dams across broad and shallow watercourses in North Africa.[27] It seems clear in the East, however, that dams were not constructed according to a strict template and that a more fluid approach was taken for dam designs that reflected the chosen location.

4.4 Dating

As discussed above, dams in the Near East showed little or no stylistic coherence, which makes their dating problematic. One of the biggest problems encountered in dating dams is the fact that they have been utilised over several periods, either continuously or reconstructed for use at a later date. One of the most extreme cases is the Homs dam. This dam, which was built during the late Roman period, probably under Diocletian (see below), was the main source of water supply for Homs until the 1930s when a new dam was built. Even the new dam built by the French still uses the ancient dam as a support for its base, thus leading, contrary to widespread belief that the late Roman dam was destroyed, to the dam's remarkable state of preservation. As well as the emplacement of the French dam on the water side of the Homs dam, the actual late Roman dam itself has undergone several less drastic changes. All along the course of the dam are the remains of rebuilds and repairs, mostly in the form of later supporting buttresses, but also later sluices and other design modifications, which show at least four phases of use and renovation.

[26] Hodge 1992, 91.
[27] Hodge 1992, 84.

In some cases, such as the Harbaqa dam, the continuity of use of the dam has led to controversy over the original date of the structure. It has been suggested that the Harbaqa dam was not built in the Roman period, but rather was an Umayyad construction.[28] Examination of the actual structure revealed two clearly distinct building phases [Fig. 4.15]. Both the lower and upper parts of the dam consisted of a rubble core faced with limestone ashlar masonry. The rubble core of the lower part of the dam, however, used cobbles from the wadi bed, whereas the rubble core of the upper part of the dam comprised local limestone gathered from the surrounding area, but not from the wadi. In addition, the lower courses of ashlar were bonded with a pinkish/purplish grey mortar with a high ash and crushed terracotta content. The upper courses, on the other hand, were bonded with a lighter mortar. These differences point to two phases of construction that appear to tally with the Roman and Umayyad phases of use.

The Harbaqa example would seem to suggest that construction style is a useful tool for dating dam structures. All is not, however, as it first seems. As discussed above, very few dams of the Roman and late Roman periods seem to share a common template and using design and construction to date dams poses a problem because they were not built on an established formula.[29] Two basic design traits can be used to establish whether a dam is Roman or earlier: a stepped construction and/or longer length (in excess of c. 50 m) point to a *terminus post quem* of the Roman period. Although these two dating guides are useful in some respects, they are nevertheless limited. Firstly, not all Roman dams were longer in length nor did they all have steps, i.e. the absence of these factors does not preclude a dam from being Roman. Secondly, the presence of these traits can only prove that a dam is not pre-Roman, i.e. the dam in question could date from any time during or after the Roman period. Therefore, supplementary supporting evidence is also required to date a dam firmly.

In some cases the dam is referred to in the literary and/or epigraphic record and thus its date is secure. Sadly the number of such cases in any period of history in the Near East is very small. Inscriptions along the course of the dam and tunnel at Seleucia Pieria indicate that the work was undertaken during the reigns of Vespasian (AD 69-79) and Titus (AD 79-

[28] See Saliby 1990, 485.
[29] *Contra* Politis 1993, 48.

81) and finished in the reign of Antoninus Pius (AD 137-61) [Fig. 4.16].[30] Furthermore, it would appear that the *legiones IIII Scythicae, XVI Flaviae Firmae* and possibly the *X Fretensis* may have been involved in the construction of this dam.[31] This fits with evidence from aqueduct construction where the military were used for complicated engineering tasks (Chapter 6.3.1). The Khanouqa dam on the Euphrates has been given a *terminus ante quem* of 1st century AD from a reference in Isidore of Charax, which describes the damming of the Euphrates in that location.[32] Procopius referred to the construction of a dam at Dara in the reign of Justinian (see section 4.2).[33] The dam at Auara is probably associated with a nearby Nabataean inscription cut into the canyon wall, thus dating the dam to the Nabataean period.[34] A Nabataean inscription at Ramliye, which reads 'This is the dam which Garmo and his friends built in the 18th year of our Lord Rabbel (II), who brought life and deliverance to his people', dates the dam to AD 88-89.[35]

For the many other dams that do not have literary or epigraphic dating evidence other solutions have to be found. The dam at Wadi al-Jilat, for example, was successfully dated by pottery. Sherds of Nabataean pottery were found in the fabric of the dam providing a *terminus post quem* for its construction.[36] The chance of finding dateable pottery associated with a dam is, however, very slim and many dams do not provide such evidence.

Radiocarbon dating proved useful in the case of Tell Kazel on the Nahr al-Abrach. In lieu of any distinguishing features or firm settlement data, samples from the sediments and alluvial terraces were radiocarbon dated giving dates of between AD 334-585 and AD 263-595 for the use of the dam.[37] It should be noted that in this case the dam was actually stepped, but this was not observed by Calvet and Geyer [Fig. 4.17].

[30] *IGLS* 3.1133-1139. Garbrecht 1991b, 85; Sinclair 1990, 258. The Vespasian and Titus inscription, not published in *IGLS*, is curious. The space allotted to the inscription is too large for the extant inscription to the two divinised emperors, which suggests that the work was attributed to Domitian originally, but his name was later erased under *damnatio memoriae* [A. Hirt and F. Millar pers. comm.].
DIVVS VESPASIANVS ET DIVVS TITUS [(…)] F(ACIENDUM) C(VRAVERVNT).
[31] *IGLS* 3.1135 and 3.1139.
[32] Isidore of Charax, *Parthian Stations*, 5.
[33] Procopius, *Buildings* II.3.
[34] Oleson 1991, 49. The content of the inscription itself is not given in the publication.
[35] Evenari *et al*. 1982, 119.
[36] Politis 1993.
[37] Calvet and Geyer 1992a, 62; radiocarbon dates are given in the format originally provided: calibrated and non-calibrated dates were not provided.

In cases where there is no epigraphic, literary, artefactual or radiocarbon-dating evidence, settlement data can be used to provide a date for the dam structure. In this situation, dams are dated by inference from the closest large settlement. This method works satisfactorily if there was only one viable site nearby, for example the dam at Resafe or the one near the Roman *castellum* 40 miles from Hit.[38]

In several cases, however, there was more than one possible site in the vicinity, which has led to some heated debates, for example the Wadi as-Souab dam. This dam, located on a wadi on the right bank of the Euphrates, was 250 m long, 2.2 m high and constructed from rough-hewn dolomitic limestone blocks bonded by a gravelly mortar.[39] Three construction dates, with a range of over 2000 years, have been suggested for the dam each of which tallies with a period of large-scale settlement in the area: Bronze Age (Mari), Seleuco-Parthian (Dura Europos) and Islamic. On the settlement data alone, none is preferable to the other two. The length of the dam may suggest a post-Bronze Age date and the rough construction may point to a post-Roman date.

Another problem with this kind of settlement data is encountered even when there was only one viable site in question. The site of Mampsis/Kurnub, for example, spans two periods: Nabataean and Roman. The dams on this site have been dated to both periods with Glueck supporting a Nabataean date and Kloner and Peleg a Roman date.[40] Kloner and Peleg both cite the use of concrete (*opus caementicium*) as proof of the dam's Roman date, but neither provides firm evidence for the date of the introduction of concrete to the Nabataean kingdom. Using settlement data in this way, then, can be problematic and does not actually seem to make full use of its potential.

An alternative approach to dating by settlement data may be to look at shifts in settlement in the hinterlands of the larger settlements. As discussed below (section 4.5), it is likely that the construction of a dam would involve the flooding of large tracts of land and therefore the displacement of a significant amount of the population. If this is the case, one may expect to find shifts in settlement patterns in the vicinity of a dam. Intensive survey would be needed to provide enough data for such a method, but when one considers the

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[38] Resafe: Calvet and Geyer 1992a, 120. Hit: Stein 1940, 430.
[39] Calvet and Geyer 1992a, 109.
[40] Glueck 1959, 79-80; Kloner 1973, 30*; Peleg 1991b.

potential problem of sites having been buried by alluvial material, even this method might be unsuccessful.

The ideal method for dating these structures would, of course, be to use all the above techniques in combination, as can be shown be the Homs dam. The date of the Homs dam is one of the most controversial in the Near East. It has been attributed to both the Bronze Age and the late Roman period and has several proponents for both dates. Supporters of a Bronze Age date cite a reference to an Egyptian 'wall' in Strabo as referring to the Homs dam.[41] The translation of τεῖχους as 'wall' does, however, seem to stretch the text and it is arguable that 'fortress' (as used in the Loeb translation) is a more appropriate translation. Proponents of the Bronze Age date also cite a stele found at Tell Nebi Mend/Qadesh that alludes to Pharaoh Sethi I making use of the basalt spur in order to divert water for his irrigation schemes.[42] A late Roman date is supported by a Talmudic reference to the Sea of Hamec being created by Diocletian, which has been interpreted as Lake Qattine, also known as Lake Homs.[43] This latter piece of evidence has often been overlooked. The problem with both references is that neither is contemporary nor makes explicit mention of the dam. The problem is compounded as both Qadesh/Tell Nebi Mend and Emesa (Homs) could make viable foci for the construction of a dam. The settlement patterns of smaller settlements in the area, however, favour a late Roman date over a Bronze Age date.[44]

Following a recent examination of the dam itself, various aspects of its construction also seem to favour a Roman or late Roman date. Firstly, its location and extraordinary length (880 m) are indicative of such a date. As noted above, pre-Roman dams tended to be located in narrower locations such as gorges or small wadis. The notable exception is the Khanouqa dam, which is sited on the Euphrates. This dam, however, was not long and was

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[41] Major proponents of this date include Dussaud 1921-1922, Brossé 1923 and Calvet and Geyer 1992a, 27-39.
Strabo, *Geography* 16.2.19:
αἳ πλησίον τοῦ τε Λιβάνου καὶ τοῦ Παραδείσου καὶ τοῦ Αἰγυπτίου τείχους
περὶ τὴν Ἀπαμέων γῆν εἰσι.
'*These sources are near Mt. Libanus and Paradeisus and the Egyptian fortress (wall) situated in the neighbourhood of the land of the Apameians.*'
[42] Stele: Dussaud 1921-1922, 140; Brossé 1923, 234.
[43] Neubauer 1868.
[44] Decker 2001, 95.

constructed almost as though it was in a narrow location, diverting a small sector of the river rather than damming the whole. Secondly, the style of construction of the Homs dam points in the direction of a date in our period, for example the dam is stepped in at least three places. Thirdly, an assessment of the offtake points and channels suggests that the dam was intended for the use of Emesa rather than Qadesh. The aqueduct leaving from the eastern sector of the dam seems to be heading in the direction of Emesa, an impression that is confirmed by an examination of the 1930s dam constructed by the French [Figs 4.14 and 4.18]. This later dam appears to follow the design of the late Roman dam in almost all its aspects and so it is not far-fetched to suggest that the modern aqueduct supplying Homs follows the line of the original late Roman aqueduct.

So, while it is possible that the pharaoh did use the basalt spur for irrigation purposes, the evidence from the dam that is now extant points strongly to a Roman or late Roman date. A Diocletianic date for the dam would fit with a pattern seen across the Near East as a whole. Twenty-eight of the forty-four dams (63.6%) firmly dated to the Roman and late Roman periods (not including Homs) seem to have been built in the 3rd century AD or later, six of which (17.6%) seem to have been constructed in the 3rd or early 4th centuries themselves. The Homs dam would, therefore, fit comfortably within this trend towards dams in the later Roman period. This increase of dams in the late Roman period reflects an intensification of agricultural production and irrigation in the period (see Chapter 5.8). The construction of dams as part of this intensification, in particular large undertakings, such as the Homs dam, point to high degree of centralised investment in agriculture in the period.

4.5 The cultural importance of dams and damming

One of the most important and often overlooked aspects of dam use and construction is its cultural importance. There are some indicators suggesting that dams were seen as valuable and highly important structures. Carved into the rock between the dam and the tunnel at Seleucia Pieria was an 'evil eye' intended to act as protecting force over the installations [Fig. 4.19]. Above this eye there was also a line carved into the rock; if the floodwater reached this level, the dam/tunnel complex would no longer be effective in protecting the settlement below from flooding.[45] So, the 'evil eye' can be seen as a protective symbol to prevent the floodwater reaching destructive levels.

It must not be forgotten, however, that there is another side to dam building. As modern controversy has shown over recent dam projects, particularly in the Middle East, the building of a dam does not have only positive aspects and to many it is not viewed as a valuable means of providing more water. In many cases the construction of a dam involves the displacement of large numbers of settled and itinerant people, including the loss not only of their homes, but also of their agricultural land.[46] Furthermore, the effect of impeded water supply further downstream has in modern times led to heightened tensions between neighbouring countries, including threats of air attacks. There is also evidence from the 8th century BC for conflicts arising between authorities over the availability of river water: the king of Assyria, Shamshi-Adad, ordered the release of water from the Balikh River to irrigate Tuttul, but a local authority blocked the river to irrigate another city.[47] The impact of dams on the environment is also of concern, for example the creation of large lakes in south-eastern Turkey has seen the introduction of malaria into a previously non-malarial region. While evidence for such effects is hard to identify in the archaeological record, one can safely assume that similar considerations would have affected inhabitants of the Near East during the Roman period.

As well as the use of the military in dam construction, as at Seleucia Pieria, there is also some limited evidence that suggests that dams played a role in military tactics and frontier protection. As noted above, 23% of dams definitely dated to the Roman period

[45] Thanks to Dr Klaus Grewe for bringing this line to my attention.
[46] See Métral 1987 for an interesting discussion on the modern implications of the Tabqa-Thaoura dam in Syria.
[47] Wilkinson 1998b, 151; Bagg 2002, 228.

were constructed between the 3rd and early 4th centuries AD. Three of these dams (two at Khan al-Manqoura and one at Khan al-Qattar) were located along the *Strata Diocletiana* and were constructed to provide water for the troops stationed at the forts along this line. This trend underlines the importance of water supply installations for military and defence purposes (see Chapters 5.8 and 7.8).

4.6 Innovations in dam construction

The art of damming cannot be claimed as a Roman revolution in hydraulic technology. Examples of dams occur many centuries before the arrival of the Romans in the Near East and they began to be built in large numbers by the Nabataeans. Furthermore, dams are a strongly eastern phenomenon; convincing examples of dams dating before the Roman period in other areas of the empire, for example in Spain and North Africa, have not been discovered so far. Calvet and Geyer are of the opinion that the Romans brought no new techniques and innovations to dam building other than the numbers in which they were built and their size.[48] This does not seem to credit fully the Roman input to dam construction. It can be argued, conversely, that several highly important contributions to dam technology in the Near East occurred after the arrival of the Romans.

One of the most important of these contributions was the introduction of pragmatic design. For the first time it would seem that a location-first approach was taken for the design of dams. The locations chosen by the dam engineers show an in-depth understanding of the physical geography and hydrology of the region and how best to maximise its potential in a harsh and unforgiving climate. This location-first approach also influenced the scale of the dams and led to the use of longer dams as well as shorter dams.

The longer-dam phenomenon has two interesting implications. From a purely pragmatic point of view, a longer dam across a broader channel or valley must create a larger reservoir and thus higher storage capacity, which has obvious benefits whether the dam waters were used for irrigation or urban supply. In addition, these great construction projects cannot have been a light and easy undertaking, requiring not only a great deal of manpower, but also significant financial investment. The high numbers of small dams at Petra (see Table 4.2), for example, point to a fragmented solution to water management by

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[48] Calvet and Geyer 1992a, 126.

dams, possibly at personal discretion.[49] In comparison, the large dam construction projects in the Roman period, for example, Homs, Harbaqa, Caesarea Maritima and Pieria, point to centralised organisation and investment: an important progression from the Nabataean period.

The Roman and late Roman periods also saw interesting developments in the construction style of dams. Stepped dams seem to feature initially in the Roman period. This is maybe only a small aspect of a dam's design, but one that adds strength to a gravity dam while minimising the materials used. Furthermore, the late Roman period at the latest saw the important introduction of the arch dam. This design and the surviving description of it reveal a very high level of understanding of engineering principles. The use of the arch dam provides a solution to two of the three modes of failure in dams. While a gravity dam remains the best design against sliding, an arch dam performs strongly against tipping and over-stressing. This is because the large distance provided by the arch between the front and the back of the base prevents the rotation that leads to tipping and provides a large area for the resultant water pressure and weight to pass through, thus reducing the stress on the dam foundations.

It is significant that the skills of the Romans seem to have had some renown further east. One of the tasks that Roman prisoners of war, taken after the Battle of Edessa in AD 260, were given in Susiana was to build a massive dam and bridge over the river at Shushtar. Indeed, the structure is known today as *Band-i Qaysar* or 'Caesar's Dam'.[50]

One can conclude, therefore, that the Roman dam engineers contributed an innovative and fresh approach to dam design and construction, often in a centrally organised framework, as well as developing the pre-existing knowledge and principles. This seems to have been an example of an indigenous technology that moved into the Roman sphere where it underwent 'fine-tuning' and was then used in its more sophisticated state in the Near East, its area of origin, as well as in Asia Minor, Spain and North Africa.

[49] Al Muheisen and Tarrier 2001-2002, 517. It can be argued that there is some evidence for centralised organisation in Nabataean dams, but it would seem that this is confined to the flood-control dam at Bab es-Siq, Petra.
[50] Ball 2000, 115-7.