THE ROMAN AQUEDUCT AT CHESTER

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As long ago as 1892, George Shrubsole (1895) suggested that the Roman fortress at Chester had been supplied with water by an aqueduct. The aqueduct's existence was henceforth accepted, but no detailed discussion of it has hitherto been published. It warrants fuller treatment, for it is the only example of its type about which there is sufficient information to reconstruct even partially both the aqueduct's layout and its distribution system.

The aqueduct almost certainly tapped springs at Boughton, about 1.5 km. to the east of the fortress, where the best water in the Chester area was once obtained (Shrubsole, 1895, 176). In 1821, an altar (*RIB* 460) dedicated by Legion XX to the Nymphs and Springs (*Nymphis et Fontibus*) was found to the east of Boughton Cross, by what is now Cherry Road. The altar can be interpreted as a dedication to the nymphs of the spring supplying the aqueduct and may be contrasted with three altars from the *praetorium* at Öhringen, which were dedications to the nymphs of the aqueducts (*CIL* XII 11757-9). The altar was found with the remains of a building (Hanshall, 1823). This may well have been a shrine and well house, within which water issued into a cistern, from which pipes were fed. There are many classical examples of such buildings, each of which will have had its own nymphs or tutelary deity. The best known British example is Coventina's Well at Carrawburgh (Clayton, 1880), but the well house at Darenth provides a closer analogy, for this building doubled as the shrine of a nymph or nymphs (Smith, 1978, 122).

The inscription and possibly its associated well house, must post date the arrival of the Legion XX in the nineties. That an aqueduct existed before this date is, however, shown by the discovery of water pipes dating from 79 A.D. The altar may thus have commemorated the amplification or refurbishment of a water supply system first established for Legion II.

Use of the plural 'springs' (*fontibus*) suggests that more than one spring was tapped. This was by no means unusual. The fortress aqueduct at *Aquincum* (Budapest) was fed by at least fourteen enclosed springs (Póczy, 1972, fig. 10), while in Britain, the medieval cathedral and religious houses at Exeter were supplied from enclosed springs which may well also have supplied the Roman fortress (Hooker, 1947, 38-9; Tucker, 1858; Bidwell, 1979, 43).

The springs at Boughton must have risen at a height of about 27 m. This is roughly the same height that water had to be delivered in order to supply some of the fortress's buildings and shows that these springs cannot have been tapped at ground level. Water must have been raised in height at source, a common practice which would also serve to increase the rate of flow and thereby discharge. This was normally accomplished by means of dams. At Exeter, on the other hand, springs were enclosed beneath a 1.8 m. deep raft of clay; the pressure of water beneath the raft forced water up lead stand pipes, to feed a well house erected some 5 m. above the level of the springs. The well house(s) at Boughton may have functioned in the same manner.

As will be seen, there is evidence that the aqueduct took the form of a battery of pipelines. Pipelines were used because the direct route from the springs (*c.* 27.4 m.), falls steadily to the Bars (18.4 m.); it then rises gradually to the east gate of the fortress, which in the Roman period lay at less than 21 m. (Mason, 1976, fig. 10). Hence a leat or masonry channel would have required a long viaduct (*substructio*) rising to about 9 m. in height. The Greeks, however, had discovered that water rises to its own level in an enclosed channel (Hero, *Pneumaticon,* Introduction), or pipeline, so that provided the pipeline never rises above the point of intake, it can follow the contours of the land without requiring either viaducts or tunnelling. The term 'inverted siphon' is normally (if incorrectly) used to describe a pipeline when it follows a depression in the ground.

In 1814, a line of ceramic pipes was uncovered at Boughton, near Steam Mill Street. They were tapered and measured something like 0.5 m. in length and 38 mm. in diameter. Hemingway (1831, 429-30) conjectured that they had been laid in the medieval period to convey water from the Abbot's Well at Christleton, to St. Werburgh's Abbey. Another line of pipes was discovered in Grosvenor Park in 1867, where they measured 0.55-0.58 m. in length and had a diameter of 165-178 mm., narrowing to 127-133 mm. at the narrow end (Shrubsole, 1895, 32). A third line uncovered on Foregate Street, closer to the east gate, were of similar diameter but 0.66 m. long (Hewitt, 1895, 328). More recently, a fourth line has been uncovered between St. John Street and Love Street (Whitwell and McNamee, 1964, 10). There can be little doubt that three of these finds comprised part of the Roman aqueduct, but it is doubtful whether the Boughton pipes can have done, given their different form and much smaller bore. They were probably, as Hemingway conjectured, medieval.

Vitruvius recommended the use of ceramic pipes because these delivered more wholesome water than lead pipes (*de arch.,* 8.6.10-11). His general recommendation was repeated by Faventinus and Palladius (*de div.*, 6; *de re rust.*, 1.17, 9.11). Ceramic pipeline aqueducts were not uncommon in some provinces, for example, at Geneva (Blondel, 1928) and *Lucus Feroniae* (Jones, 1962, 198-9), but in Britain, ceramic pipes were normally used for distribution, generally in bath houses. At Netherby, the extra mural bath house was supplied by a ceramic pipeline (Bruce, 1867, 439), while the presence of ceramic pipes at Newstead (Curle, 1911, 99) and Holt (Grimes, 1930, 15), suggests that these sites may have been supplied in the same manner. With the possible exception of a few villas, the only other certain example of this type of

aqueduct was at Lincoln (Thompson, 1955). The Lincoln aqueduct is difficult to interpret, while that at Netherby is virtually unknown. Hence the Chester aqueduct is the only British example of its type currently amenable to interpretation. Chester is also the only site at which more than one ceramic pipeline can be postulated.

Aqueducts comprising a single pipeline are known from a number of military sites (Stephens, forthcoming a). At Colchester, however, the aqueduct comprised a battery of four wooden pipelines (Crummy, 1967, 100). These functioned in the pre Boudiccan period, when intra mural distribution is attested (Dunnett, 1966, 31) and could date back to the fortress period. Similarly, the Severan vexillation fortress at Carpow was supplied by three wooden pipelines (Wilson, 1971, 248), while its extra mural bath house seems to have been supplied by a leat (St. Joseph, 1958, 91; Birley, 1962-3, 196). Most wooden pipes appear to have had a bore of only about 50-75 mm. (Wheeler, 1930, 30; Manning, 1976, 40.151), or about half that of the Chester pipes. Nevertheless, Carpow occupied only 13.26 ha., little more than half the area of Chester (24.33 ha.) and housed only vexillations of two legions (Wright, 1971), rather than a legion at full strength. This suggests that a single ceramic pipeline would have been insufficient to supply the water requirements of a legion, especially where, as at Chester, there may have been no intra mural wells.

The main aqueduct to the fortress is presumably denoted by the pipes found on Foregate Street (Thompson, 1965, fig. 11). This cannot have supplied the two other pipelines (for its delivery would have been insufficient), so they too must have run from Boughton. It is conceivable that one of these pipelines supplied water to the amphitheatre, but the absence of large drains (Thompson, 1975, 151-2) argues otherwise. A more likely candidate is a bath house attached to the *mansio,* for although this building was provided with wells (Mason, 1980, 12, 16-20), the *mansio* at Godmanchester was provided with both a well and a leat (Green, 1975, 198-9). The construction of aqueducts to supply *mansiones* seems to have been relatively common, with other examples known at Chesterholm, Kelvedon, Chelmsford and Catterick (Stephens, forthcoming b), so that it would be surprising if the *mansio* at Chester had not at some point been provided with a piped water supply. Two other extra mural supply points can be suggested. A bath house is known to the west of the fortress, near Lower Watergate Street (Nash-Williams, 1969, 40), with perhaps a second to the south, at the Castle (Mason, 1980, 84), but this is unlikely to constitute a complete list, given that there were at least four extra mural bath houses at Caerleon. It is possible that there was a bath house to the east of the fortress. It is also conceivable that water was supplied to the adjacent civilian settlement, or *canabae,* as was certainly the case at *Aquincum* (Mócsy, 1974, 161-2). If this was the case, the most likely area is to the east, where there is substantive evidence for civilian occupation (Mason, 1978, 31-2).

Water delivered by the aqueduct will have supplied a settling tank. This might have been technologically sophisticated, as were those in the *principia* at Benwell and at civilian Corbridge (Simpson and Richmond, 1941, 12-17; Forster, 1908, 272-9; Richmond and Gillam, 1950, 158-68). It might, alternatively, have been a larger version of the simple and no doubt inefficient tank at Brough-on-Noe (Taylor and Coll-

ingwood, 1940, pl. XII.2). The settling tank could have been erected within the defences, as at Benwell and Brough-on-Noe, or have lain without, as at Lanchester, probably at Piercebridge and perhaps at Dover (Hodgson, 1816, 120; Wooler, 1915, 433; Philip, 1981, 80).

The intra mural structures known to have been supplied with water, or where this can be safely surmised, establish that the distribution pipes were fed from the settling tank at a height of not less than about 24 m. and probably closer to 27 m. (*cf.* Mason, 1976, fig. 10), for otherwise they could not have functioned. This could suggest that the tank lay on higher ground to the north of the headquarters building (the *basilica principiorum*). However, pipes have been found running in an east to west direction near Eastgate Street and this suggests strongly that the tank was erected in an elevated position close to the east defences. It could have been erected on a platform abutting the inside of the wall, as was the reservoir in the upper *colonia* at Lincoln (Jones, 1980, fig. 8), or, more probably, either on the defensive wall, as has been suggested at Brough-on-Humber (Wacher, 1969, 42), or on a tower outside the wall, as was the case at Colchester (Selkirk, 1974-4a, 241). Presumably the pipelines of the aqueduct ran below ground level until they approached the tank. They will then have been carried above ground level on embankments, which at Aspendos, at least, were inclined at an angle of not more than 30° (Ward Perkins, 1955, 119), in order to discharge into the tank. Distribution pipes will have been fed through circular openings in the opposite side of the tank, as were the lead siphons in the great aqueduct at Lyon (Germain de Montauzon, 1980, figs. 20, 29).

Water was distributed in lead pipes, although wooden distribution pipes seem to have been far more common in Britain and in the Germanies (Samesreuther, 1936, 137-9, 153). The Chester pipes comprise both service pipes, which will have supplied individual buildings and tanks and at least one much larger main, which had a maximum diameter of 216 mm. (Newstead, 1939, 93-5). This is much larger than the mains at York and Caerleon, which measure only 114 mm. and 178 mm. respectively (RCHM; 1962, 38; Nash-Williams, 1929, 145; Boon, 1972, 66-7); at Red House, Corbridge, the bath house of the vexillation fortress was supplied by a pear shaped lead pipeline measuring only 89 mm. by 63 mm. (Daniels, 1959, 105, 167). The size of the Chester main suggests that it supplied either a large bath house or a distribution tank. It may perhaps have supplied or been attached to the length of piping found in Lower Bridge Street in 1977 (Goodburn, ed., 1978, 430). Lead service pipes have been found running to the north of Eastgate Street, in the Elliptical Building (where its intended destination was apparently a fountain) and to the north of the Elliptical Building; lead piping has also been found on the Crook Street and Abbey Green sites (Newstead, 1902, 90-1; Strickland, 1980, 9; Petch, 1970-1, 9-11).

It is possible to identify a number of delivery points in the fortress. These were presumably supplied by service pipes laid beside or close to the *via principalis* (Eastgate Street). It is likely that the *basilica principiorum* was supplied with water, for aqueducts supplied tanks in the *principia* at Benwell, High Rochester and apparently at Birdoswald and Pen Llystyn (Stephens, forthcoming a). The intra mural bath house must have been supplied with water, probably by a main, but just possibly by more

than one service pipe, as at Exeter (Bidwell, 1979, 35-6). If the bath house was supplied by a main, then the Eastgate Street pipeline might have been laid to supply the *basilica principiorum*. It is also likely that the *praetorium* was provided with piped water, for the legate's dwelling invariably included a bath suite. The hospital may also have been supplied, for tanks were found in the corresponding building at Caerleon (Threipland, 1969, 92, 95) and apparently at Wallsend (Goodburn, ed., 1978, 419). At Exeter, a workshop was supplied by a pipeline (Selkirk, 1973-4b, 105). A similar building at Chester was found to be associated with a *c.* 25 m.^{2} masonry platform; this may have been the base of a tank and if so implies that water was piped in this area (Petch, 1970-1, 9-10).

Other supply points can only be conjectured. A stray piece of piping found on the Crook Street site could originally have supplied a dipping tank. There were presumably a number of such tanks, together with others positioned for industrial purposes and watering horses. The extra mural bath house to the west (Mason, 1978, 36-7) could probably only have been supplied from within the fortress, no doubt by means of a pipeline passing through the west gate. It is also probable that the fortress had at least one latrine block comparable to that known at Caerleon (Nash-Williams, 1931, 133-5). It was presumably positioned so as to be regularly flushed with waste water from the bath house. This suggests that it lay behind the south east rampart, its waste perhaps passing into the large drain which has been traced running obliquely beneath Cuppin Street (Watkin, 1886, 115; Mason, 1978, 35). It might well also have been flushed with the overflow of the aqueduct (*aqua caduca*), for water (presumably fresh) was piped to the latrine block at Newstead and apparently also at Holt (Curle, 1911, 99; Grimes, 1930, 15).

A large number of Roman fortresses have produced evidence establishing that they were supplied by aqueducts (von Petrikovits, 1975, 183*n.*134). Indeed, it is probable that all permanent legionary fortresses were supplied in this manner. The Chester aqueduct is, nevertheless, of considerable interest. It was not the earliest fortress aqueduct in Britain, for that at Lake was Claudian and that at Exeter Neronian; at Caerleon, where distribution pipes dating from, if not before, *c.* 80 have been recovered, the aqueduct could also be slightly earlier (Stephens, forthcoming a). The system at Chester is, however, the only one in Britain where both the aqueduct and its distribution system are even partially understood. It is also the only aqueduct which can be precisely dated, for some of its service pipes are unique in Britain in being stamped with a consular date, showing that they were manufactured in 79 (Wright and Richmond, 1955, 48.199; Wright and Hassall, 1971, 292.17). Construction may well have commenced before 79, but the system is unlikely to have taken long to complete: 37 km. of aqueduct were constructed in eight months at *Lambaesis*, the base of Legion III Augusta.

The aqueduct was probably one of the last features of the fortress to be completed, but was clearly an integral feature of its plan. This was also the case at a number of other sites, for example, Exeter and Fendoch (Bidwell, 1979, 35; Richmond and McIntyre, 1938-9, 116, 121). It cannot be a coincidence that the intra mural bath house was also dedicated in 79 (*RIB* 463). The water requirements of a large bath

house were probably very heavy, as were its fuel requirements (Rook, 1976, 184). The contemporaneity of the aqueducts and bath houses at Chester, Exeter and presumably Caerleon, suggests that one of the chief reasons for the construction of aqueducts was to provide water for bath houses. This is hardly surprising in view of the various baths uncovered in the intra mural bath house at Caerleon, where there was a *piscina* with a capacity of over 140m.^{3} and a *natatio* with a capacity of 275 m.^{3}; this, to put it in context, was almost eight times larger than the *natatio* in the *thermae* at Bath (Boon, 1972, 79, 81; Cunliffe, 1969, 106). One of the extra mural bath houses at Caerleon, the 'Castle' baths, also had a shower bath or douche, which would have required a constantly running supply of water (Nash-Williams, 1930, fig. 2; Boon, 1972, 102-3). Similar amenities and baths of comparable size, must also have been provided at Chester. Hence the need for an aqueduct supply. The common provision of aqueducts suggests further that water was normally changed daily in bath houses, presumably at night, when they will have been closed (*CIL* II 5181) and human and industrial demands were at their lowest. Thus most of the aqueduct's water was probably used for drinking and industrial purposes during the day; at night, it will have replenished the various bath houses in the fortress and *canabae*.

The aqueduct at Chester not only illustrates the organisational ability of the Roman army, but also the high standard of the amenities provided for (and no doubt taken for granted by) Roman soldiers. The water supply system provided for these soldiers tapped pure spring water at source. It may be contrasted with the water supply of mid Victorian Chester, which was pumped up from the river Dee (Rance, 1882, 432). The Roman aqueduct delivered pure spring water, as opposed to largely untreated river water. It was not until the late nineteenth century that the inhabitants of Chester were to be as well supplied with water.

APPENDIX

The hypothetical delivery of the aqueduct

It is impossible to calculate the delivery of any aqueduct with complete accuracy, for $\pm$ 5% would be considered a high order of accuracy, while $\pm$ 10% is often the best that can be expected (Twort *et al.*, 1974, 315).

Modern pipes have a uniform bore. They are joined by stop ridges, so that water flows along a channel of consistent size. Roman ceramic pipes, however, were made with one end smaller than the other; pipelines were formed by inserting the narrow end of one pipe into the large end of the adjacent pipe. Thus the channel widened and contracted at regular intervals, thereby giving rise to deceleration and acceleration. This would cause severe eddying, which would retard the rate of flow and thereby discharge. The minimum cross sectional area of the pipes (the *vena contracta*) is used to calculate velocity and delivery, but will still overestimate delivery (Duckworth, 1977, 175-8).

According to Manning's formula (Twort *et al.*, 1974, 319), the velocity (V) of water is equal to

$$\frac{0.397 \times d^{2/3} \times H^{1/2}}{n \qquad L}$$

where n = the coefficient of surface roughness of the pipes (which for Roman pipes may be taken as 0.017, that for modern rough concrete pipes), d = the internal diameter of the pipes and H/L = the hydraulic gradient. Discharge (D) is calculated by multiplying the velocity (V) by the cross sectional area (H).

The aqueduct might have fallen some 2.3 m. in 1.5 km., or about 1:650. Pipes with an internal diameter at the narrow end of 0.1334 m. (Shrubsole, 1895, 32) were capable of delivering:

$$V = \frac{0.397 \times 0.133^{1/3} \times 1^{1/2}}{0.017 \qquad 650}$$

$$= 0.2384$$

$$D = 0.2384 \times 0.0141$$

$$= 0.0034 \text{ m.}^3\text{/sec} = 290 \text{ m.}^3\text{/day}$$

If a mean error of 10% is assumed, each pipeline could have delivered 261 m.^{3}/day; a battery of four pipelines could have delivered 1044 m.^{3}/day (= 230,000 gallons). However, the fall is uncertain. If it was 1:375 (which is unlikely), each pipeline could have delivered 345 m.^{3}/day; if 1:1300, 185 m.^{3}/day.

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