VIII: The Construction and Operation of a Legionary Fortress

Logistical and Engineering Aspects

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The installation of a garrison of 6,000 men accompanied by several thousand non-combatants and a very considerable number of pack and draught animals required a great deal of forward planning and logistical support. This was something at which the Roman army excelled, but it is only when one seriously contemplates the quantities of materials needed, as well as the effort required to bring them to the place of use, that the true scale of the task involved in building a legionary fortress becomes clear. This exercise does carry connotations of the 'anorak' or 'train-spotter' pastime but it is nonetheless extremely worthwhile in realising the magnificent achievements of which the Roman army was capable on a regular basis.

A secure supply of food for both men and animals was obviously the primary need but this is not an area that will be covered in this paper. That subject has been discussed extensively in print in recent years and so here, instead, we will concentrate on the logistical aspects of the raw and manufactured materials required for the actual construction of the fortress, their production and transportation to site. Also explored will be those features of the infrastructure needed to make the fortress function efficiently, where 6,000 men could live at close quarters in a controlled and healthy environment. The results of calculations made in preparation for this paper are set out in the tables below, and they make the point more than adequately. It remains to preface them with some observations of a more general nature and to highlight the most thought-provoking results of those calculations.

Vast amounts of timber had to be stockpiled before work began and a steady and reliable supply maintained thereafter so that progress would not be interrupted by a shortage of this most essential of materials (Table VIII.1). Before work started on the building of the fortress, however, the accommodation to house the workforce had to be erected — a not inconsiderable enterprise in its own right as the construction party probably numbered 2–3000 men. All this timber had to be felled, roughly shaped and transported to the fortress, where it was cut up into the required lengths and sizes. Wood was also needed for fuel, not so much for keeping warm in winter as for feeding the large number of kilns, furnaces and other industrial facilities needed to manufacture the wide range of building materials required: hundreds of tonnes of lime were needed to produce mortar and concrete, thousands of everyday items such as iron nails and bronze fittings, and hundreds of thousands of bricks and tiles. Excavations over the years have yielded valuable informa-

Table VIII.1 Flavian fortress construction: timber requirements

	Worked timber (m³)	*Uncut timber (m³)*	*Weight (tonnes)*	*Wagon loads (800 kg)*
Barracks incl centurions' quarters	14,476	19,301	12,546	15,682
Rampart buildings	1 ,080	1,440	936	1,170
Senior officers' houses	1,200	1,600	1,040	1,300
Auxiliary barracks	1,365	1,820	1,182	1,479
Principia	850	1,133	737	921
Hospital	1,000	1,333	866	1,083
Praetorium	400	533	347	433
Other *retentura*	1,350	1,800	1,170	1,462
Store	300	400	259	325
Workshops	500	666	433	542
Tabernae	1,425	1,900	1,235	1,543
Rampart	4,350	5,800	3,770	4,712
Gates & towers	625	833	541	677
Totals	**28,921**	**38,559**	**25, 062**	**31,329**
Construction camp/annexe	5,000	6,665	4,332	5,415
Amphitheatre	378	504	328	410
Mansio	500	667	434	542
Harbour works	1,200	1,600	1,040	1,300
Bridge	400	533	346	433
Scaffolding	100	133	86	108
Totals	**36,449**	**48,661**	**31, 628**	**39, 537**

Woodland felled to provide 31,628 tonnes of timber:
744 ha (yield = 42.5 tonnes per ha)
372 ha (yield = 85 tonnes per ha)
197 ha (yield = 127.5 tonnes per ha)

tion about the size and spacing of the main vertical wall timbers in a variety of buildings within and without the early fortress, while general studies of Roman timber buildings undertaken in recent years provide a useful guide for estimating average volumes of timber needed for various forms of superstructure.

Thus, it can be calculated that over 14,000 m^3 of worked timber would have been needed simply to construct the barracks, while the total for the fortress as a whole, including the vital extramural facilities such as the amphitheatre and the harbour works, comes to over 36,000 m^3. This last figure equates to at least 39,000 wagonloads, assuming a carrying capacity of 800 kg, which demonstrates the transportation logistics involved and the requirement for a very sizeable fleet of wagons and a large number of draught animals. The sandstone ridge where the fortress was to be built probably had only a light tree cover, although the heavier clay land to the south and east may have been more densely forested. Yet there is evidence which indicates that even these areas had apparently already been subjected to significant clearance well before the advent of Rome, and so timber for the construction of the fortress probably had to be brought from some distance. The yield of usable timber per hectare must have varied widely and it is quite likely that several square kilometres were deforested to provide the timber needed. Had one been required in those days, it is doubtful if the environmental impact assessment would have proved favourable!

A few of the fortress buildings, principally the bath buildings, were built of masonry and concrete right from the beginning. Building stone was readily available from the rock outcrops in the close vicinity of the fortress, especially where the Dee had carved its way through the ridge to the south. Sand and clay were also to hand in vast quantities, while the cobbles which were used as aggregate in the concrete foundations of Flavian buildings could be picked up from the banks of the river. While only a few buildings were constructed in stone in this period, the quantities of materials involved were still very considerable, as is demonstrated by Table VIII.2 which lists those required for the main fortress baths. Over 400,000 blocks of stone were needed for the wall facing alone, and while it might have been possible to obtain some of this from the rock excavated to form the foundation trenches and hypocaust basements, the rest had to be transported by ox-drawn wagon up the steep slope of what is now Lower Bridge Street. With its extensive underfloor heating systems, this building required an enormous number of bricks — over 70,000 of the type 1 Roman foot square — as well as the vast quantity of tiles — 33,000 *tegulae* and 40,000 *imbrices* — needed to cover the roof. In all, the construction of this building consumed approximately 1,670 tonnes of brick and tile, including the 60 tonnes (200,000) of very small bricks employed in the herringbone-patterned flooring of the cold plunge baths. There was also about 1,460 m^2 of mosaic flooring composed of just over 3 million individually manufactured *tesserae*. Obviously water was the most important commodity in a bath building and the means of storing it and conveying it to where it was needed within this vast building consumed large amounts of another material — lead. Several hundred metres of pipework would have been necessary, while the two large reservoirs at the south end of the complex would have been lined with sheet lead. This equates to something like 75 tonnes of lead, or nearly 1,000 ingots of the 80 kg type which have been found at Chester (Ill VIII.1).

Table VIII.2 Flavian baths construction: material requirements

	Quantity (m³)	*Weight (tonnes)*	*Wagonloads (800 kg)*
Rock excavated	7, 000	17,500	21,875
Facing stones	418,600	7,500	9,375
Mortar	2,200	4,400	5,500
Concrete	1,350	2,700	3,375
Tile and brick			
Roof tiles			
Tegulae	33,176	376.5	471
Imbrices	40,001	127.2	159
Hypocaust pillars and suspended floors			
Pedales	70,000	339.2	424
Sesquipedales	2,800	62.8	78
Bipedales	2,200	65.1	81
Wall and vault lining			
Flue tiles	54,736	645	807
Flooring			
Opus spiccatum	200,000	60	75
Tesserae	3,057,175	9.8	12
Lead Distribution pipes			
Duodenaria and centenaria	39.6	50	
Reservoir linings	34.6	43	
Total = 927 ingots @ 80 kg ea			
Totals	**33,859.8**	**42, 325**	

Ill VIII.1 Lead ingot typical of those found at Chester.
(Copyright Chester City Council, Grosvenor Museum)

The reference to metals reminds us that some of the materials needed for the construction of the fortress were not available locally and had to be imported from the surrounding hinterland, sometimes entailing the transportation of bulky and/or weighty items over many kilometres. Extending the last calculation to the fortress as a whole, which we know had an internal distribution system using lead mains averaging 60 mm in diameter (although that serving the main baths may have been nearly three times this size), it is probable that the overall requirement was for 4–5,000 ingots of the type just mentioned. The lead ore or galena was mined in that part of Flintshire stretching from Talargoch, near Prestatyn, in the north to Minera, near Wrexham, in the south where it occurs in veins close to the surface. The beginning of imperial, as opposed to private, exploitation of these deposits is dated to AD 74 by the earliest surviving ingots, and this was presumably associated with preparations for the building of the fortress at Chester. The main refining centre from *c* AD 90 lay at Pentre Ffwrndan near Flint, and it is likely that an earlier facility lies nearby awaiting discovery. The ingots would have been transported to Chester by ship, and indeed one such was found in association with the remains of an early jetty beneath the Roodee.

Limestone, or rather its derivative lime, was also vital for the production of the thousands of tonnes of mortar and concrete needed for the construction of the various bath buildings in and around the primary fortress and the few other structures built of masonry in this period. The main baths would have needed around 3,500 cubic metres of mortar and concrete, and if we follow Vitruvius' recommended proportion of sand to lime of 2:1 then about 1,170 m^3 of lime would have been needed for this building alone and probably around 4,000 m^3 in total, which roughly equates to 4,800 tonnes. The main area of limestone in the region is more or less coincident with that containing the lead deposits and, in its reduced form, it too may have been transported to the fortress by sea rather than overland. This may also have been true of any exploitation of the iron and copper deposits lying further to the west. Right from its earliest days, therefore, it can be seen that the fortress drew upon the resources of an extensive hinterland. Some of this would have lain within the boundary of the *prata* or *territorium legionis*, the area under the direct control of the military, while the more outlying facilities came within the compass of its 'command area'.

Quite apart from water, the consumption of natural resources did not of course stop with the completion of the building of the fortress. Significant quantities of timber were required for everyday activities like cooking and heating, general building repairs, the manufacture of items spanning everything from writing tablets all the way through to furniture and vehicles, as well as fuel to keep the voracious furnaces of the bath buildings satisfied. In order to minimise the distances from which timber had to be brought, and also to ensure the quality of the timber, the military authorities would surely have practised some form of woodland management. The exploitation of metal ores would have continued, as would that of the extremely valuable salt deposits in central Cheshire.

There were, of course, times when the scale of consumption rocketed, most particularly when the fortress underwent one of its periodic reconstructions. Probably the best illustration of this is the renovation which took place in the second and third decades of the third century when every building inside the fortress was reconstructed, many from ground level, and when for the first time every building plot was fully utilised. The figures for the amount of building stone required (Table VIII.3) are quite astounding. Even making a 50% reduction of the total to allow for reusable stone in those cases where the earlier building was also constructed of masonry, the overall total still comes out at over 300,000 tonnes. Equally staggering is the 378,000 wagonloads which this represents. If the defences are included as well, then these figures increase to 359,000 and 448,000 respectively. One can now begin to see why the dating evidence associated with this event suggests some buildings were rebuilt *c* 220 and others *c* 230 or even later: it was simply that the logistics meant that it had to be a long drawn-out process.

While some of the earlier building stone would have been reusable this is most unlikely to have been the case with tile (Tables VIII.4, 5). Many of the earlier tiles would have become brittle and fragmented with age, while even the more robust examples are unlikely to have survived the dismantling process. One feels fairly certain therefore that most of the tile employed on the new Severan buildings was itself of recent manufacture. The plans of many buildings are known and the general form of the remainder can be estimated with reasonable confidence, and from this the size and form of their roof structures can be extrapolated. Allowing for breakages, the total number of *tegulae* and *imbrices* comes out at 930,000 and 1,156,000 respectively. Upwards of 70,000 antefixes might also have been required. The heating systems of the bath buildings were also included in the rebuilding programme, and although many of the bricks used for the hypocaust pillars would have been salvageable, those used for the underpinning of the concrete floors above them,

Table VIII.3 Severan fortress reconstruction: stone requirements

	Quantity (m3)	*Weight (tonnes)*	*Wagonloads (800 kg)*
Barracks	49,650	124,125	155,155
Rampart buildings*	4,288	10,720	13,400
Building behind HQ*	4,945	12,362	15,453
Granaries (x4)*	2,401	6,002	7,503
Granaries (x2)**	1,200	3,000	3,750
*Principia**	8,832	22,080	27,600
Elliptical Building**	7,450	18,625	23,280
Baths south of Elliptical Building*	510	1,275	1,594
Tabernae north of Elliptical Building*	671	1,677	2,096
Building north of Elliptical Building *insula***	2,808	7,020	8,775
Building/s in equivalent *insula* in east *latera praetorii***	2,808	7,020	8,775
Other buildings in *latera praetorii**	3,500	8,750	10,938
*Praetorium**	5,000	12,500	15,625
Main workshops*	2,246	5,615	7,019
Store*	2,500	6,250	7,813
Hospital*	3,500	8,750	10,938
Tribunes' houses*	7,500	18,750	23,438
Building/s opposite baths**	4,000	10,000	12,500
Other buildings in *praetentura***	3,500	8,750	10, 938
Other *tabernae**	3,575	8,937	11,170
Gates and towers	4,768	11,920	14,900
Totals	**125,652**	**314,128**	**392,660**

* Earlier stone building completely reconstructed

** New building

Table VIII.4 Severan fortress reconstruction: roof tile requirements

	Tegulae	*Imbrices*	*Antefixes*	*Weight (tonnes)*
Barracks*	377,664	446,205	27,486	5,758.33
Rampart buildings*	42,560	50,160	4,180	640.26
*Principia**	34,102	41,385	2,834	524.02
Building at rear of *principia**	53,578	65,466	3,484	823.17
Granaries* (6)	31,760	37,908	1,957	484.92
Elliptical Building (Laconian system for main range)*	6,536	43,035	1,570	214. 40
Building N of Elliptical Building*	7,680	9,508	771	118.83
Equivalent building in east *latera praetorii***	7,680	9,508	771	118.83
Store, east *latera praetorii***	17,940	22,020	1,160	275.91
Building N of *praetorium***	16,146	19,800	1,044	248.29
Main workshops*	24,288	30,008	1,898	374.74
Tribunes' etc houses**	50,416	63,824	5,528	785. 29
*Praetorium***	25,200	31,500	2,000	390.02
Other buildings in east *praetentura***	24,528	28,780	2,144	373.92
Hospital**	36,628	47,098	1,446	568.75
Remainder west *praetentura***	6,132	7,195	436	93.32
Remainder of *retentura***	12,264	14,390	872	186.64
*Tabernae**	60,780	74,926	4,050	936. 09
Gates and towers*	13,360	15,820	1,236	204.23
Major baths*	33,176	40,001	1,800	507.43
Minor baths*	2,364	3,064	100	36. 79
Totals incl 5% for breakages	**929,021**	**1,156,681**	**70,105**	**14,377.90**

* Building form known

** Building form estimated

Table VIII.5 Severan fortress reconstruction: other tile requirements

	Pedales	*Solid brick Sesquipedales*	*Bipedales*	*Box-tile (double)*	*Weight (tonnes)*
Major baths*	70,000	2,800	2,200	54,736	1,112.48
Minor baths*	3,200	236	183	1,600	44.74
Other hot bath suites and hypocausts**	12,000	1,000	800	1,600	121.68
Totals incl 5% for breakages	**89,460**	**4,237**	**3,342**	**60,832**	**1,342.84**

Total weight of brick and tile = 15,690.75 tonnes

= *c* 19,613 wagonloads @ 800 kg capacity

= 314 bargeloads @ 50 tonne capacity

* – Building form known

** – Building form estimated

Notes

1 Considerable amounts also required for official extramural structures such as bath-buildings and the *mansio*.

2 Broken brick and tile could be used as aggregate in, for example, concrete floors, road surfaces etc

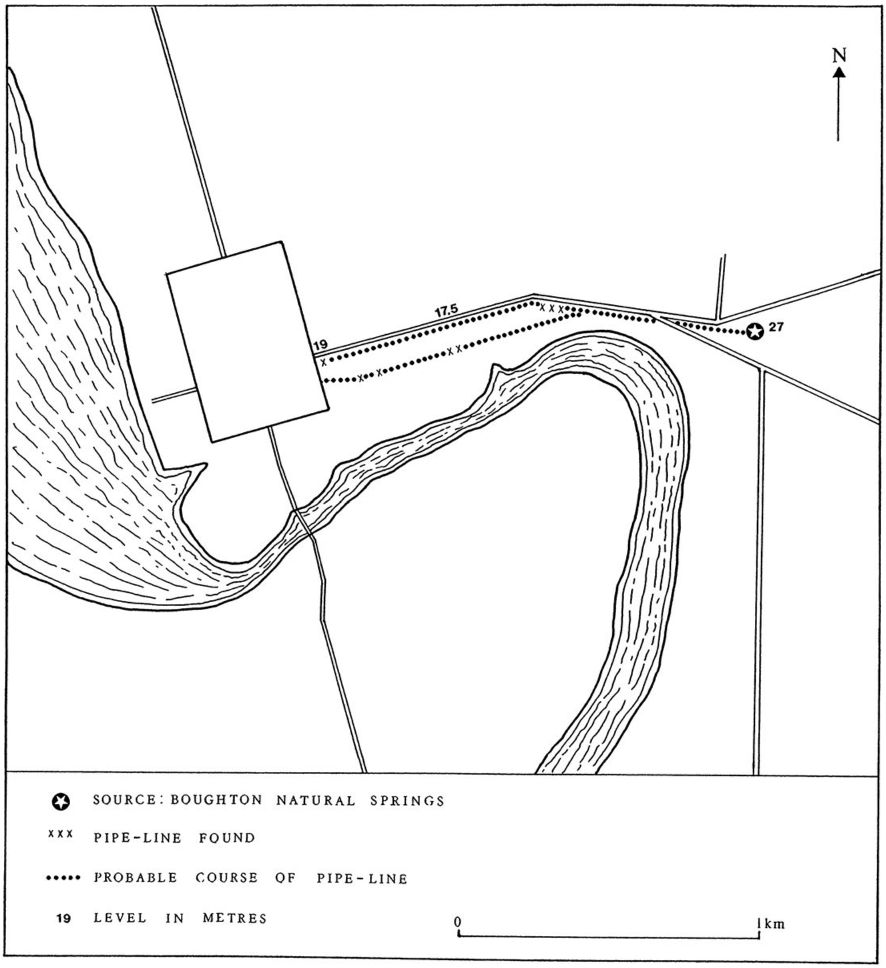
3 High percentage of solid brick probably available for re-use

which were also replaced, would not. The hollow box tiles used for lining the walls in these buildings would also have had to be renewed. In addition, more buildings than ever before, especially the residences of junior officers and centurions, were equipped with hypocausts. In total, somewhere around 15,000 tonnes of brick and tile were needed for the rebuilding programme of the early to mid-third century, and this figure does not include the official buildings in the extramural area which are also likely to have been refurbished at this time: buildings such as the major baths complex near the present Water Gate and the *mansio* south of the fortress.

As far as we know, all of this brick and tile was produced in the legion's works depot at Holt and would undoubtedly have been transported the 12 km down river to the fortress by barge. On the assumption that the average load for a barge was 50 tonnes, this would have taken 300 barge-loads. Whether unloaded at a quay in the main harbour at the Roodee or at one located on the riverbank somewhere below the amphitheatre, there still remained the considerable task of moving this material up a steep slope to the fortress. The rebuilding programme would have been impossible without thousands of tonnes of lime and this, too, would have been transported by water, in this case by sea from one or more ports (Prestatyn and/or Flint) on the coast of north-east Wales. These two commodities demonstrate, if demonstration were needed, both the vital role played by water transport in supplying the garrison and the importance of Chester's possession of a decent harbour. This was true at all times, of course, not just during periodic rebuildings. Various types of pottery, glassware and other manufactured goods were imported by sea from abroad, along with wine and olive oil. Given the vast quantities of grain required, the bulk of this, too, was probably brought by ship from the south of the province, or even from other provinces as is known to have happened at both Caerleon and York.

The most important natural resource for any military or civilian community in the ancient world was a reliable and secure supply of good quality water, and for the Romans, whose lavish bathing facilities were a place for socialising and relaxation as much for cleansing and exercise, the supply also had to be copious. The remains of the civil engineering works carried out by the Romans to guarantee their water supplies constitute some of the most impressive monuments to have survived from the classical world. The mention of aqueducts usually conjures up images of tall arched masonry structures striding across the countryside and spanning steep-sided river valleys. Where the local geology and hydrology permitted, however, Roman aqueducts took a different form. The most common alternative was an underground pipeline, and such was the case at Chester. Before describing Chester's aqueduct in detail, it must be remembered that Roman water-supply systems were generally based on the principle of continuous flow. Taps and stopcocks certainly existed but they could not cope with the enormous pressures that their modern counterparts can endure, and so when the supply was shut off at one point there was usually at least one other part of the system to which it could be diverted and continue to flow unchecked. This may seem wasteful to modern eyes, but a great excess of supply over demand was the only way of ensuring a constant flow of fresh water in an age without chemical treatments, while the continuously overflowing fountains, water troughs and other outlets provided a volume of water sufficient to flush and purge the drainage system. This explains why, as it has been calculated, the typical Roman household consumed in one day the amount of water that a modern household would use over two months. Because there were certain times of the day and night when there was a rapid increase in demand, for example when the pools in the baths were drained and replenished, Roman supply systems also incorporated a considerable storage capability in the form of reservoirs — *castella aquae*. The principal reservoir, the *castellum divisorium*, was sited at the point where the aqueduct entered the town or fortress and, as one might guess from its name, it was built with mechanisms which allowed the amount of water supplied to different areas to be regulated.

The source of Deva's water supply lay 2 km east of the fortress, in the area now occupied by the suburb of Boughton, where a water-bearing layer of sand emerged from between two layers of boulder clay (Ill VIII.2). Although long since covered by housing developments, this was once a major source of fresh water, and the scale of its output can be judged by the fact that when this aquifer was cut through by an excavation for a railway cutting in 1885 it flooded Chester station to a depth of three feet. The remains of the Roman waterworks structure were found in 1821, together with an altar dedicated by the Twentieth Legion to the 'nymphs and fountains'. This spot lies at a height of 27 m OD, and the fall to 21.5 m OD at the point where the aqueduct entered the fortress at the east gate

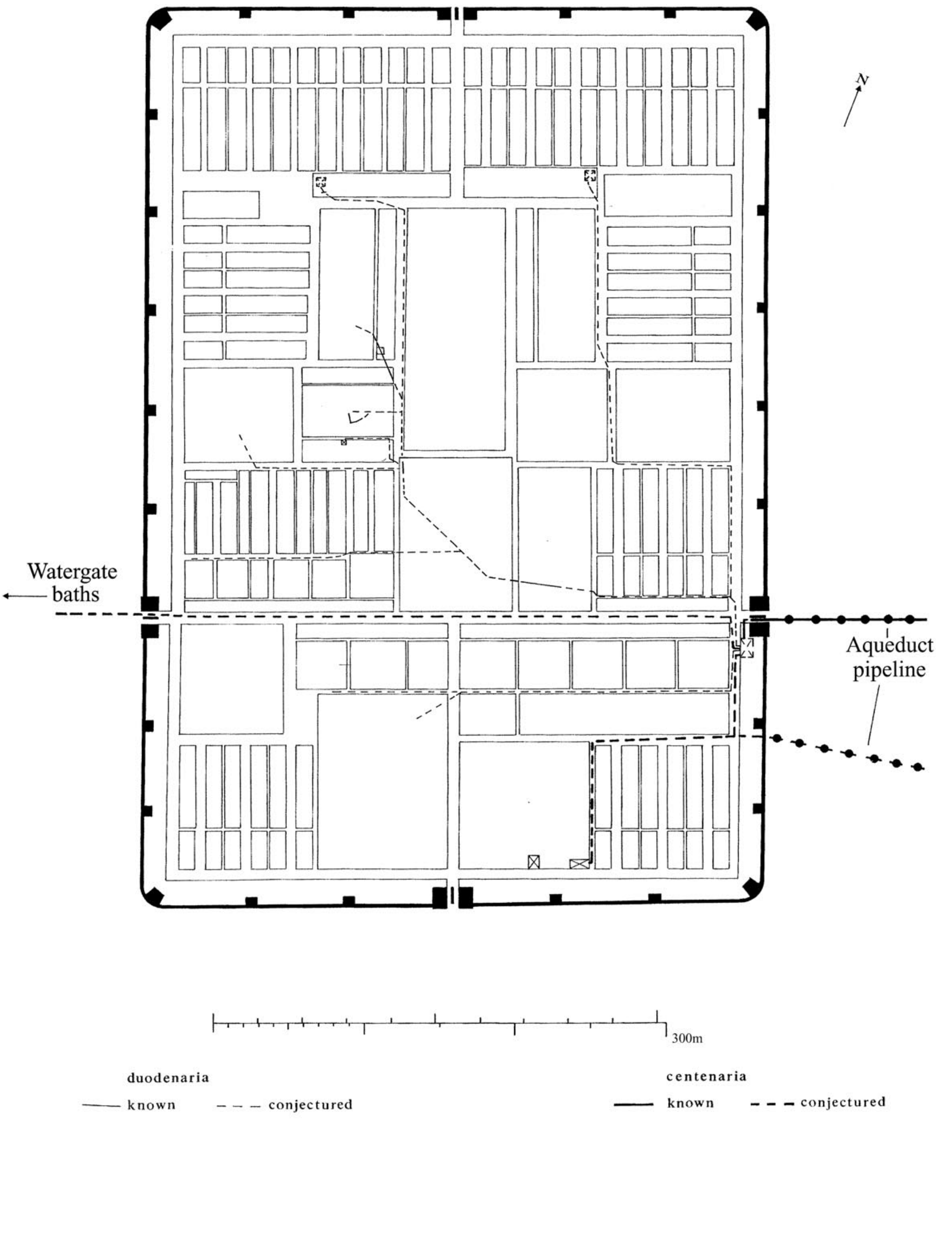


Ill VIII.2 Source of fortress water supply and course of aqueduct: map. (Scale 1/25 000)

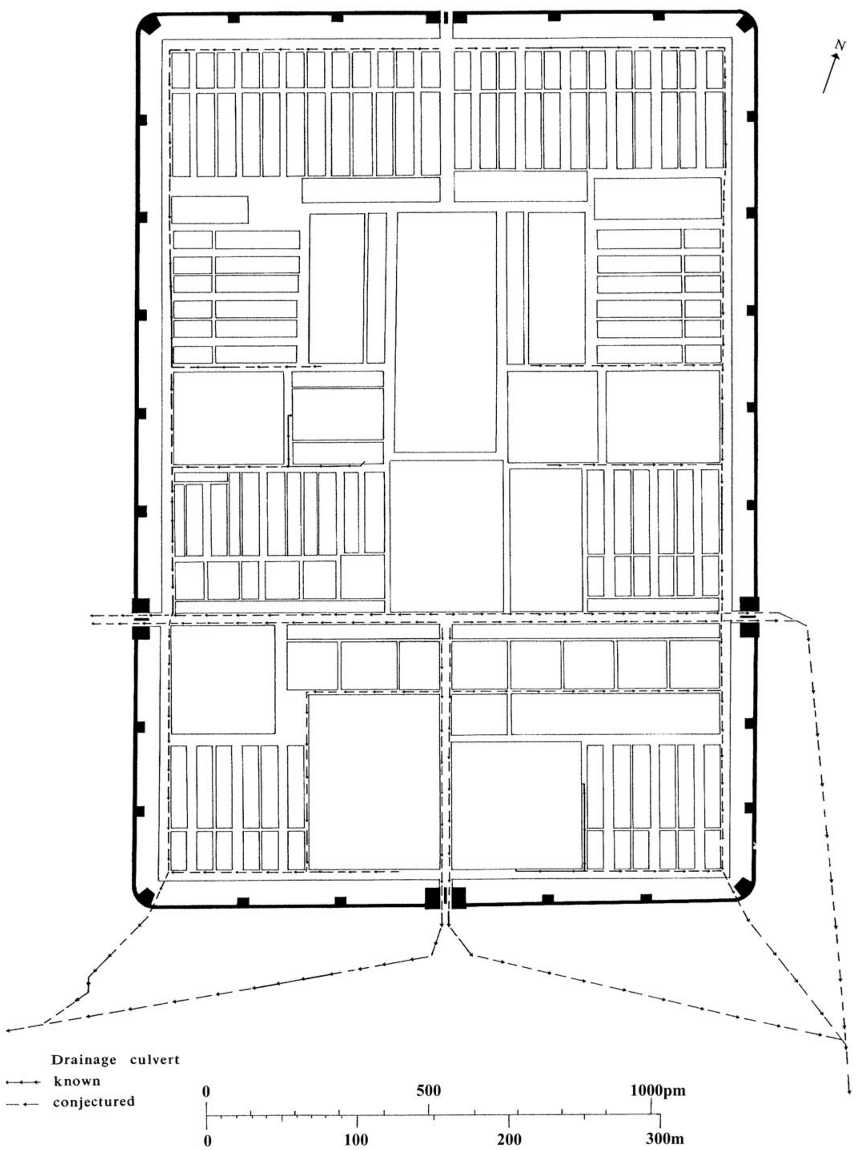
was more than sufficient for a gravity feed system. However, in order that water could be supplied to all areas of the fortress, the water level in the *castellum divisorium* must have been raised to a height about 1 m higher than that of the highest point of the interior (the north end), that is about 31.5 m OD. This means that not only would the water reservoir beside the east gate have been quite an impressive structure, with a height in excess of 10 m, but also the water must have been raised artificially at the point where it entered the system. This would have been perfectly feasible as the land around the source at Boughton rises to a height greater than that of the high point of the fortress. Most probably, the structure found in 1821 was a reservoir, served by adits radiating out into the surrounding sand stratum, where the water was raised to a height of about 32 m OD. The water was conveyed to the fortress by means of a pipeline formed of interlocking terracotta pipes (averaging 700 mm in length with a bore of 130 mm) laid in the base of a 2-m-deep trench which was then backfilled with solid clay so as to contain the pressure at the joints. Given the weight of the clay, this must have been a fairly tricky operation, and one imagines the successful employment of this technique must have entailed a considerable degree of previous experimentation. The pipe ran along the south side of the road leading to the east gate of the fortress, where it would have risen up the side of the *castellum divisorium*. There was in fact a second identical pipeline running almost parallel with the first but some 100 m further to the south. This may have been a dedicated pipeline serving the main baths in the forward area of the fortress, in whose general direction it was heading. However, it soon passed out of use — if it was ever actually completed — and it would appear that one pipeline was sufficient for the entire needs of the fortress.

Lengths of water main found at various points within the fortress show that the internal distribution system consisted of lead pipes with a bore of *c* 60mm, which is close to the standard Roman pipe size known as the *duodenaria*. That serving the baths, however, may have been considerably larger, perhaps of *centenaria* size (bore of *c* 200 mm), and there may have been a pipe of similar size running beneath the *via principalis* on its way to the extensive extramural baths complex situated in the vicinity of the Water Gate. The location of known and assumed components of the distribution system are shown on Ill VIII.3. These pipes, or smaller bore take-offs from them, would have fed drinking fountains, water troughs, and minor reservoirs distributed throughout the fortress, as well as individual buildings. Based on the number, type and known dimensions of the facilities in several of the bath buildings, the likely capacities and consumption rates of the other major water-consuming buildings, and the probable needs of the garrison for water used for drinking and cooking, an estimate can be made of the minimum water requirement of the fortress and the official extramural buildings per 24-hour cycle. As can be seen from Table VIII.6 below, the total comes to nearly 2.4 million litres. Calculations suggest that even one pipeline of the size known, operating with fairly modest head of 1 m, could have supplied the fortresss with *c* 3 million litres per 24 hours. Given that the distribution system as well as some of the buildings themselves incorporated a significant storage capacity, it appears that just one pipeline could have satisfied the entire needs of both the fortress and the official extramural buildings.

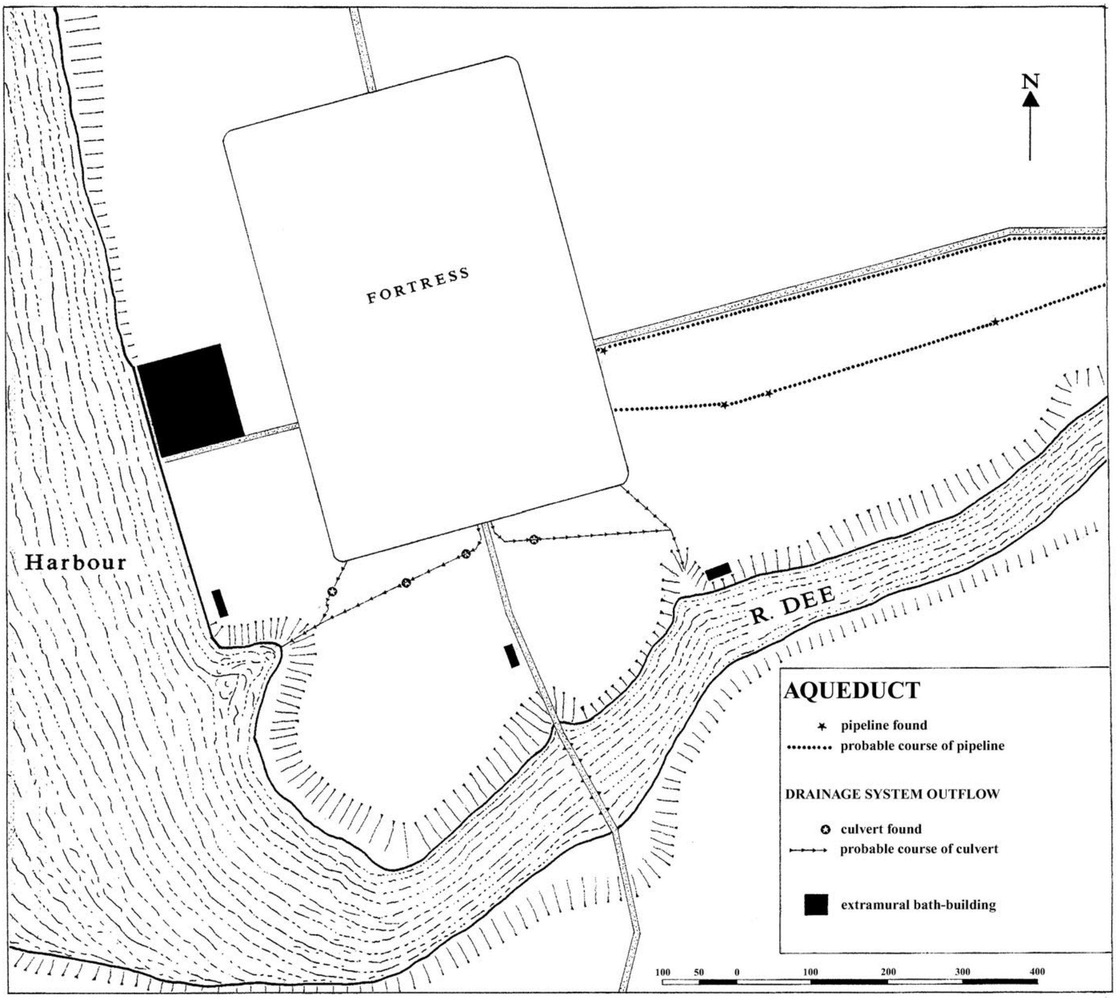
Disposing of all this water was equally important and, as one might expect, this was achieved with equal efficiency and economy. In this, the Roman engineers were helped by the natural topography of the fortress site; or perhaps a consideration of the drainage requirements was one of the reasons behind the choice of this precise site. Overall, the site sloped from north to south while the ‘hog’s back’ shape of the ridge, with the longitudinal axis of the fortress positioned along the ‘spine’, meant that the ground fell away to the east and west of its centre line — all facts which greatly facilitated a speedy and thus effective rate of flow in the drainage system (Ill VIII.4). A large drain ran beneath many of the secondary streets, into which the lesser drains as well as the simple, open eavesdrip gulleys along the edges of the streets disgorged. Although opportunities to test the point have not arisen so far, it is probable that there were two such sewers beneath the major streets such as the *via principalis* and *via praetoria*. All of the above flowed into an intercepting sewer which ran around the entire fortress beneath and beside the inner edge of the *intervallum* road. This had its principal outfalls beneath the south-east and south-west angles of the



Ill VIII.3 Water distribution system within fortress: plan. (Scale 1/5000)



Ill VIII.4 Fortress drainage system: plan. (Scale 1/5000)



Ill VIII.5 Main outflows of fortress drainage system: plan. (Scale 1/10 000)

fortress where, some distance outside the defences, each was joined by one of the sewers which exited from the south gate (*see* Ill VIII.5). Ultimately, these outfalls debouched into the natural declivities in the area of Souter's Lane and Nun's Road respectively.

Bath buildings have featured prominently in the foregoing and it is logical that the concluding part of this paper should concentrate on the most extensively explored and, in the light of recent research, the best understood of Chester's examples — the fortress baths. The north end of this complex was uncovered during building works in 1863 and, fortunately, some of the founding members of the Society were on hand to record its remains. An extensive report written by Dr Thomas Brushfield was published in volume 3 of the old series of the Society's *Journal* and included what must be some of the earliest photographs taken for the purposes of archaeological recording (*see* Ills VIII.6 and 7). Further remains were uncovered in the opening decades of the twentieth century and then,

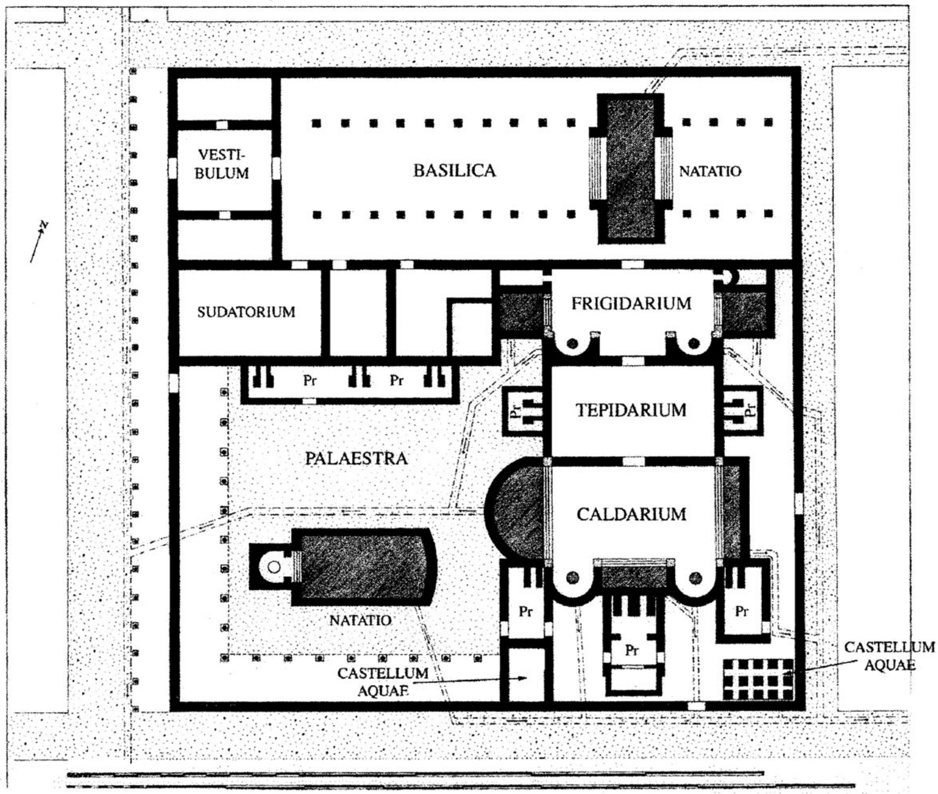
Ill VIII.6 Remains of exercise hall of fortress baths exposed by clearance of Feathers Hotel, Bridge Street, 1863. The bases of the two rows of columns of the *basilica* are clearly visible. (*J Chester Archaeol Soc* old ser **3**, 1885, frontispiece)

in 1963, almost the whole of the eastern half of this enormous building was uncovered and then rapidly destroyed with only the minimum of archaeological recording to make way for the construction of a shopping precinct. Quite apart from the wealth of irreplaceable archaeological information that was lost forever, the City missed out on the opportunity to display some of the most impressive Roman remains ever found in Chester, including rooms with completely intact hypocaust heating systems and walls still standing to a height of nearly 4 m. All was not completely lost, however, because Dennis Petch (then Curator of the Grosvenor Museum), despite the very trying circumstances, was able to retrieve a considerable amount of information which, together with the details recorded earlier, the speaker was recently commissioned by Chester Archaeology to analyse and work up into a comprehensive report. This process is very close to completion and it is intended that the report will be published in 2002.

The fortress baths complex was approximately 84 m square overall and consisted of four principal elements (Ill VIII.8). Across the north end was a large covered exercise hall of basilical form 12 m wide and more than 50 m long. Attached to the western half of its south side was a suite of three hypocausted rooms which provided a bathing regime of dry heat like a modern sauna. East of these was the first of three large, barrel-vaulted halls, each measuring 12 m across and a minimum of 20 m in length arranged in a north–south progression of increasing temperature — *frigidarium*, *tepidarium* and *caldarium*. The atmosphere in this part of the baths was very humid, much like that in Turkish baths. A feature of both the *frigidarium* and the *caldarium* was the provision of semi-circular recesses containing free-standing communal washbasins (*labra*) as well as large bathing

Ill VIII.7 Close-up of column base and fallen column drum found on Feathers Hotel site 1863.
(*J Chester Archaeol Soc* old ser **3**, 1885, facing 56)

pools, cold *piscinae* in the former and hot (*alvei*) in the latter. The pool at the west end of the *caldarium* was particularly large, about 11 m across, and was housed in an apsidal bay which projected from the main body of the building in order to catch the maximum amount of sunlight. Centrally positioned against the south wall of the *caldarium* lay the main furnace house or *praefurnium* containing two large furnaces. These supplied heat to the *caldarium* hypocaust, which then passed into the *tepidarium* beyond through arched flues in the base of the party wall, and also heated boilers which supplied hot water to the pool and *labra* ranged along its south side. Auxiliary *praefurnia* to either side of the main furnace house heated the pools located at the ends of the *caldarium.* In case it was necessary to boost the temperature in the neighbouring *tepidarium*, this was provided with two smaller *praefurnia*, one in the middle of each of its shorter sides. The main water reservoir (*castellum aquae*) was sited in the south-east comer of the complex. Its foundation consisted of a massive concrete base 11 m long, 7 m wide and 1.2 m thick (Ill VIII.9). The fact that this was surmounted by fifteen substantial blocks of sandstone arranged in three



Ill VIII.8 Fortress baths as built *c* AD 75: plan. (Scale 1/10 000)

rows of five indicates that the reservoir tank was raised off the ground, probably taking the form of a wood and iron frame clad with lead sheeting supported by fifteen stone pillars. The other *castellum* lay to the west beside the fourth element of the complex, the open air exercise yard or *palaestra* whose principal feature was a swimming bath (*natatio*).

The operation and maintenance of such a massive, comparatively sophisticated and intensively used complex must have been a major enterprise. Including those which heated the dry air sweat baths, there were nine furnaces, and keeping these supplied with fuel very probably required at least 2,000 tonnes of wood per annum. The quantity of water consumed was even more prodigious. The large fountains-cum-washbasins were supplied with running water throughout the day, as probably were the fountains which fed the large cold swimming baths in the *basilica*, the *frigidarium* and the *palaestra*. Without chemicals to treat the water and because of the extensive use of oils as part of the Roman bathing process, the pools had to be drained and replenished every day after dusk. This would have entailed the furnaces serving the *caldarium* providing a minimum of 63,000 litres of hot water by the following morning and the re-supply of the cold baths with approximately 555,000 litres. It was only after the last customers of the day had vacated the building that the real work began. Taking into account the supply to fountains and similar facilities

Ill VIII.9 Concrete bases which supported the main reservoir for the fortress baths, photographed during destruction in 1963 to make way for the Grosvenor Shopping Centre. (Copyright Chester City Council)

during the day, it is estimated the fortress baths consumed something of the order of 850,000 litres of water in each 24-hour cycle (Tables VIII.6–7).

As with many Roman buildings one can detect in their dimensions the use, or apparent use, of standard units of measurement. Thus, the columns in the exercise hall were spaced at intervals, centre to centre, of 12 Roman feet (the Roman foot here taken to be the *pes Monetalis* (pM), corresponding to 295 mm), while the distance between the two rows of columns was 11.80 m or 40 pM and the width of each aisle 5.95 m = 20 pM. The suite of dry heat rooms was also 11.80 m or 40pM wide, while the core area of all three halls in the main bathing suite measured 11.80 x 20.65 m = 40 x 70 pM.

Legionary bath buildings, both those built in fortresses and in the veteran settlements (*coloniae*), were the forerunners of the great imperial baths constructed in Rome from the late first century onwards — structures such as the Baths of Titus, the Baths of Trajan and so on. Comparing the plans of bath buildings belonging to Claudian, Neronian and Flavian legionary fortresses and *coloniae*, it is clear that the design of these complexes, with their sophisticated heating and water-supply systems and pioneering use of large-scale concrete roof vaulting, underwent rapid development during the middle decades of the first century. In early examples in the series, such as the Claudian baths at Vindonissa, the *frigidarium* was not yet fully integrated but had become so by the time the legionary baths at Exeter were built *c* AD 55. The development of the covered exercise hall also illustrates the evolution of these buildings. A *basilica* was not provided in the legionary baths at Vindonissa nor in the contemporary colonial baths at Augusta Raurica. It was also absent

Table VIII.6 Minimum fortress and official building water requirement per 24-hour cycle

	Facility	*Quantity (litres)*
Hygiene	Fortress baths	850,000
	Elliptical Building baths	80,000
	Watergate baths	850,000
	Amphitheatre baths	100,000
	Mansio baths	100,000
	Blackfriars baths	80,000
	Hospital	20,000
Industrial	Workshops	40,000
Refreshment and cooking	Fountains and troughs	15,000
Ornamental	Fountains (*Praetorium*, Elliptical Building etc)	100,000
Total		**2,370,000**

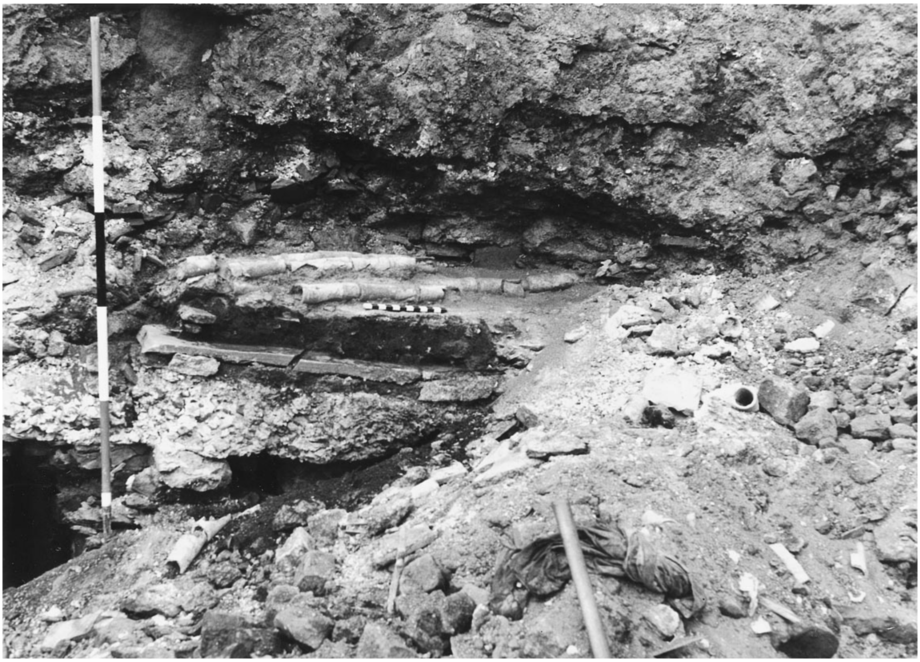
from the (probably early Flavian) extramural baths at Wroxeter, while at Caerleon, founded within a year or two of Chester, it appears to have been an afterthought. It was, however, clearly part of the original design for the Chester baths, which at present have the distinction of being the earliest legionary baths to have this facility as an integral feature. The possession of an exercise hall of basilical form subsequently became *de rigueur* for major bathing complexes both civil and military, as is demonstrated by the town baths at Wroxeter (Hadrianic), the legionary baths at Aquincum (Trajanic) and the colonial baths at Xanten (Trajanic). The Chester baths are also notable for their rare provision of a swimming bath within the *basilica*, a feature only found elsewhere in the legionary baths of Trajanic date at Aquincum, a fortress also built by Legion II *Adiutrix*, the initial garrison of the Chester fortress.

Despite the execrable conditions under which the 1960s investigations took place, some remarkable details of the construction techniques employed in the roof vaulting of the baths were recovered. In the *tepidarium*, the floor overlying the hypocaust was found to be intact in many places, and overlying it were the deposits which had accumulated in the period when the building had ceased to function as a working baths but was still standing. Over what had obviously been a very long period the floor became covered to a depth of about 400 mm by a layer of earth which, in addition to fragments of mortar and plaster which presumably originated from the decaying fabric of the bathing hall, also contained pieces of animal bone and a significant amount of charcoal. The inference would seem to be that the baths were occupied by ‘squatters’ for a substantial length of time in the sub-Roman period and possibly later. In the absence of scientific analysis of the deposits

Table VIII.7 Fortress baths: water requirement per 24-hour cycle

	Facility	*Quantity (litres)*
Hot		
Basilica	*natatio*	197,400
	fountain	55,000
Palaestra	*natatio*	302,400
	fountain	55,000
Frigidarium	*piscinae* *labra*	54,000 55,000
	latrine & drinking fountain	12,000
Total		**730,800**
Hot		
Caldarium	*alveus* (east)	23,100
	alveus (west)	23,100
	alveus (south)	20,064
	labra	55,000
Total		**121,264**
Grand total		**852,064**

overlying the floor it is obviously impossible to tell how long this form of occupation lasted, but it was clear that use of the building, or at least this part of it, was terminated by the collapse of a major portion of the roof structure which crashed down onto the earth covered floor (Ill VIII.10). This earth deposit cushioned the impact and thus prevented the disintegration of the components of the roof vaulting. At the top of the *c* 600-mm-thick layer of debris were the *tegulae* and *imbrices* of the external tile cladding. Below these were the remains of the main body of the roof, the concrete vault itself and below this again the shattered fragments of box tiles belonging to the inner, hollow lining of the vault. The latter was a continuation of the wall jacketing through which hot gases from the hypocaust were conducted. Thus, not only the floor but also the walls and the ceiling radiated heat. At one point within the mass of fragmented box tile were five or six lines of small, interlocking ceramic pipes, each one about the size of a milk bottle, bonded together with a rich lime plaster (Ill VIII.11). Known as *tubi fittili*, these were commonly employed in vault and dome construction in the later Roman period and there are many surviving examples of their use in fourth-century churches in northern Italy, especially those at Ravenna. The technique appears to have originated somewhat earlier in North Africa where they were used, principally in bath buildings, as a substitute for timber centring to form a continuous framework on which concrete vaults could be laid. The particularly fine



Ill VIII.10 Concrete floor of *tepidarium* of fortress baths with debris of collapsed roofing vault resting on dark sub-Roman dereliction layer; lines of *tubi fittili* clearly visible. (Copyright Chester City Council)

Ill VIII.11 Close-up of *tubi fittili*. (Copyright Chester City Council)

Ill VIII.12 Examples of *tubi fittili* in position used as inner lining of vault at Bulla Regia, Tunisia. (Photo courtesy T J Strickland)

example shown here is the vault of the *frigidarium* in the baths at Bulla Regia in Tunisia (Ill VIII.12). In all these examples, however, the *tubuli* were used to form a continuous lining, whereas in the Chester baths by contrast they appear to have been employed in groups of five or six lines at intervals. It would seem , therefore, that they were used in the same way as the single lines of bricks or solid voussoirs incorporated in the vaults of other bath buildings, that is as ribs placed at intervals which, by dividing up the vault into compartments, made it both stronger and easier to construct. As *tubi fittili* of this form are not known to have been used before the middle of the second century the vault of which they formed part was probably erected during the extensive reconstruction of the fortress and its buildings which occurred in the second and third decades of the third century.

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