

Tantam pecuniam male perdiderunt: Aqueducts and municipal investment in Hispania

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{p. 59} One of the most-discussed passages of Pliny’s letters is that in which he describes the failed attempts at building an aqueduct by the Nicomedenses. In this letter, Pliny writes:

*In aquae ductum, domine, Nicomedenses impenderunt HS |XXX| CCCXVIII, qui imperfectus adhuc omissus, destructus etiam est; rursus in alium ductum erogata sunt CC. Hoc quoque relicto novo impendio est opus, ut aquam habeant, qui tantam pecuniam male perdiderunt.*²

The episode reveals the gross technical incompetence of the contractors (which Pliny seems to understand, for later in his letter he asks Trajan for a skilled builder: *Sed in primis necessarium est mitti a te vel aquilegem vel architectum, ne rursus eveniat quod accidit*). It could also hint at shady municipal business where contractors were making a juicy benefit. The bottom line is, nevertheless, that the city wanted desperately to build an aqueduct, no matter what the cost.

This obsession with aqueducts (and this disregard for the expenditure of public money) is something which, in my opinion, can be seen also in the towns and cities of the Iberian Peninsula. In this paper, I want to put forward to ideas: first that aqueduct construction happened independently from municipalisation and second, that their role as prestigious constructions was as important as their functional purpose. The {60} overall conclusion will be that aqueducts were very desirable as constructions to have in a city – even if they were too expensive to build or (especially) maintain.

¹ This paper has been written within the “Impact of the Ancient City Project” led by Prof. Andrew Wallace-Hadrill (Faculty of Classics, University of Cambridge). This project has received funding from the European Research Council (ERC) under the European Union’s Horizon 2020 research and innovation programme (grant agreement n° 693418). I want to thank Alessandro Launaro and Jo Quinn for reading through the text and their very useful comments.

² PLINY, Epist. X.37: “The citizens of Nicomedia, sir, have spent 3,318,000 sesterces on an aqueduct which they abandoned before it was finished and finally demolished. Then they made a grant of 200,000 [sesterces] towards another one, but this too was abandoned, so that even after squandering such enormous sums of money they must spend more if they are to have a water supply” (Loeb transl.)

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The chronology of Roman aqueducts

The history of Roman-style aqueducts (long-distance, covered and levelled conduits built with Roman concrete), leaving aside their Etruscan precedents,³ begins in Rome in the 4th c. BC with the construction of the Aqua Appia.⁴ From there, they slowly spread across Italy. However, the real expansion of hydraulic architecture (aqueducts, cisterns, baths) in Italy and the provinces was facilitated by the development of pozzolanic Roman concrete from the 1st c. BC onwards.⁵

In Spain, aqueducts appear first in the main cities, and are always linked to private investment. The first was that of Cartagena, built by Pompey the Great after the Sertorian Wars,⁶ followed by those of Tarragona, Córdoba, Mérida, Cádiz and *Conimbriga*. The first three were built with imperial patronage as part of the (re)foundational efforts.⁷ According to the most recent archaeological data, during the first half of the 1st c. AD there were eight functioning aqueducts in the Iberian Peninsula, with a possible ninth. During the second half, the overall number had multiplied manifold, so a total of 31 can be securely dated to have been in use in this period, with another possible 25, in an overall total of 46 different cities. This is between four and seven times the number of Augustan and late Republican aqueducts (figure 1). The number of aqueducts would continue to slightly increase during the first decades of the 2nd c., after which the trend would slowly turn.

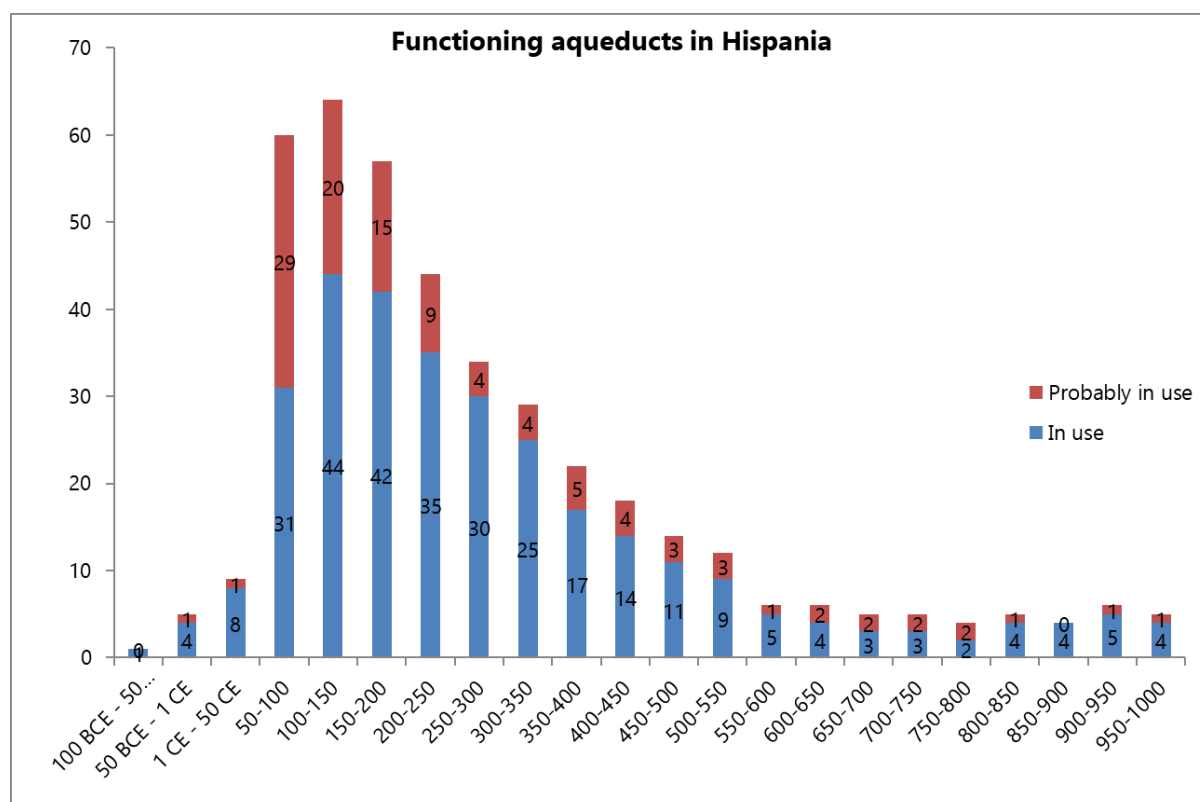
³ T. HODGE, *Roman Aqueducts and Water Supply*, London, p. 45.

⁴ FRONT., *Aq. I.4-5*; cf. T. ASHBY, *The Aqueducts of Ancient Rome*, Oxford, 1935.

⁵ L. HOBBS AND R. SIDDALL. *Cementitious materials of the Ancient World*, in: *Building Roma Aeterna: Current Research on Roman Mortar and Concrete*, Helsinki, 2010, 35-59, esp. 53-4; G.R.H. WRIGHT. *Ancient Building Technology. Volume 2: Materials*, Leiden, 2005, pp. 183-4.

⁶ E. SÁNCHEZ LÓPEZ AND J. MARTÍNEZ JIMÉNEZ. *Los acueductos de Hispania: construcción y abandono*, Madrid, 2016, p. 110.

⁷ *Ibid.*, pp. 164, 184, 204, 235, 244, 246.



[Figure 1: graph showing the evolution of functioning aqueducts in the Iberian Peninsula from the late Republic down to the Umayyad Caliphate]

This geometrical increase in the number of aqueducts roughly coincides chronologically with the extension of Latin rights to the towns and cities of Hispania through the Edict of Vespasian. With this gesture, the Flavian emperors integrated large numbers of urban Hispanic elites into the Imperial social and political system, which has been linked to a general process of investment in large buildings like fora, basilicae, and *spectacula*.⁸ Aqueducts are part of this process, and there are various examples (e.g., Almuñécar, Segobriga, Mellaria, and Valencia) where the chronological correlation between access to municipal status and a more general monumental development is clearly shown in inscriptions or archaeology. However, this chronological {61} correlation may not imply a direct causal relation between change in status and aqueduct building. In *Baelo Claudia*, *Conimbriga*, and *Ilipla* (and maybe Cartagena) the construction of the aqueduct appears to predate the change of status, but corresponds to larger phases of city-wide construction.⁹

Aqueducts were very desirable buildings for many reasons, and the fact that they were almost always built in cities which had existed before they were built underlines the fact that they were not essentially an urban necessity but a luxurious commodity. Other sources of water like wells, springs, and cisterns never really disappear, even in urban contexts where

⁸ Cf. P. LEROUX, *Le Haut-Empire romain en Occident d'Auguste aux Sévères*, Paris, 1997; E. MELCHOR GIL, *Construcciones cívicas y evergetismo en Hispania romana*, *Espacio Tiempo y Forma, Serie II* 6 (1993), 443-66.

⁹ SANCHEZ LOPEZ AND MARTINEZ JIMENEZ, *op. cit.* (n. 5), pp. 69-71.

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aqueducts were later built.¹⁰ Similarly, it should not be assumed that they were used as ways of celebrating achieving municipal status; they were built whenever the technical, social, and economic circumstances were favourable, which can coincide with status promotion but does not necessarily do so. {62}

Why aqueducts?

Whereas aqueducts are part of what it is publicly perceived to be the ‘Roman city monument pack’, they are not the only ones. Fora and basilicae are perhaps the most important, because they are the buildings that represent the Italic-style curial government: an open space to vote and assemble for the citizens, and to display the statues and inscriptions dedicated to and by prominent citizens. Other types of monuments imported as part of the ‘set’ were temples, which could be dedicated to local and syncretic deities, or to properly Roman cults, like *genii coloniae*, the Capitoline triad, or the figure of the emperor.¹¹ *Spectacula* also fall within this category. In this regard, circuses, theatres and amphitheatres are all structures that could be found in many Roman cities and linked to private patronage. However, these are fewer in number, and more widely spread. In the Iberian Peninsula, for instance, we know only of seventeen amphitheatres and 23 theatres.¹² This sharply contrasts with the total number of Roman aqueducts, which add up to 70,¹³ and there are many reasons why aqueducts could have been more popular than spectacle buildings.

Aqueducts are, by definition, water supply systems, and in many cases the distance to an adequate source could be quite considerable.¹⁴ This is not necessarily to say that they were built solely for drinking water, as has been suggested,¹⁵ because water was needed for many other uses. Water was used for drinking and cooking, true – but that is only a minimal proportion of the water which is daily consumed in a city. Washing and cleaning, gardening, flushing latrines and sewers, bathing, ornamental fountains, industries and workshops; all of these were activities which consumed large quantities of water which did not have to be good drinking water and all these were activities which took place inside cities. In cases where there were several aqueducts, some might have brought good drinking water, whereas others

¹⁰ M. M. CASTRO GARCÍA, Modelos de abastecimiento urbano de aguas en la Bética romana: las cisternas, *Espacio, Tiempo y Forma, Serie II* 30 (2017), 97-124.

¹¹ Cf. J. C. QUINN AND A. WILSON, *Capitolia*, *Journal of Roman Studies* 103 (2013), 117–73.

¹² A. CEBALLOS HORNERO AND D. CEBALLOS HORNERO, Los espectáculos del anfiteatro en Hispania, *Iberia* 6 (2003), 57-70; J. L. JIMÉNEZ SALVADOR, Teatro y desarrollo monumental urbano en Hispania, *Cuadernos de Arquitectura Romana* 2 (1993), 225-38; J. A. JIMÉNEZ SÁNCHEZ, La desaparición de los espectáculos de gladiadores en Hispania, *Hispania Antiqua* 33-34 (2009-2010), 273-94.

¹³ Only counting urban ones: SÁNCHEZ LÓPEZ AND MARTÍNEZ JIMÉNEZ, op. cit. (n. 5), plus those identified in the years since that study was published.

¹⁴ Ideal characteristics for an aqueduct source were a constant annual flow, good quality water, and enough altitude difference to ensure a gravity flow into the city.

¹⁵ S. FEIJOO MARTÍNEZ, Las presas y los acueductos de agua potable. Una asociación incompatible en la antigüedad. El abastecimiento a Augusta Emerita, in *Augusta Emerita. Territorios, espacios, imágenes y gentes en Lusitania Romana*, Mérida, 2005, 171-205; ID., Las presas y el agua potable en época romana: dudas y certezas, in *Nuevos elementos de ingeniería romana*, Madrid, 2006, 145-60.

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would have brought water of inferior quality, as we know happened in Rome.¹⁶ From the ethnographic record¹⁷ we know {63} that in communities in rural Spain locals know which springs or fountains are good for drinking and which are not, something which could also be true of the Roman period. Overall, the main advantage of an aqueduct supply is that it provides water in quantity, and with quality when possible.

The advantages of having an abundance of water in an urban space are many: for one, it enables a much denser settlement pattern. Of the list of uses of water given in the previous paragraph bathing is paramount. The fact that aqueducts appear in public and private contexts underlines their desirability. They were perhaps the most important Roman structure, especially if we take into consideration that they remained popular in Late Antiquity when other monuments had been abandoned.¹⁸ Italic-style bathing became a deeply-rooted social construct in the Roman world, not only in Hispania¹⁹, and whereas it is possible to have baths without aqueducts (as we know from early periods, e.g. in Pompeii) once Roman concrete and aqueduct technologies are fully developed, aqueducts and baths became directly connected. In some cases, as in Segovia, Andelos, and Los Bañales, the aqueducts seem to have been built explicitly to supply baths.

Aqueducts were, from all perspectives, desirable for a city to have, especially if baths were to be built. From Pliny’s letter above we know that they must have been very expensive to build, and this seems to be a fair comparison with other aqueduct construction costs, like Verona (HS 600,000) or Aspendos (HS 8mill), as preserved in inscriptions and written sources.²⁰ From Janet DeLaine’s calculations, the costs of aqueduct building seem to be lower than those of large projects like imperial *thermae*. This is to be expected, not only in rough terms of the simple volume of building material (see appendix), but also because aqueducts do not get decorated with expensive materials (marbles) or techniques which require skilled workmen (mosaics). They required precise engineering calculations,²¹ but so did other vaulted structures (baths, theatres, etc.) with complex elliptical or semicircular spaces.

In a political context where private munificence was the way to hold an office, such an expense of private capital on an aqueduct made a strong statement, and there are various inscriptions which attest to this, as in *Ebusus*, *Cartagena*, *Ilugo*, *Castulo*, *Barcelona*, *Cabra*, or *Jaén*.²²

¹⁶ FRONT., Aq.

¹⁷ J.M. GARDE GARDE, Estudio etnográfico del abastecimiento tradicional de agua y hielo en la villa de Mérida (Navarra), *Revista del Centro de Estudios Merindad de Tudela* 18 (2010), 15-31; M.C. NARANJO SANTANA, El agua y las construcciones de la necesidad en las Medianías y Cumbres de Gran Canaria (España), in: *Arquitectura vernácula en el mundo ibérico*, Sevilla, 2007, 420-8.

¹⁸ M. MANGO, Building and Architecture, in *The Cambridge Ancient History*, vol. XIV, Cambridge, 2000, 918-71, esp. p. 934.

¹⁹ Y. FIKRET, *Baths and Bathing in Classical Antiquity*. Cambridge, Mass., 1991.

²⁰ J. DELAINE, *The Baths of Caracalla*, Portsmouth, 1997, p. 219.

²¹ T. HODGE, op. cit. (n. 3); cf. J. MARTÍNEZ JIMÉNEZ AND P. GONZÁLEZ GUTIÉRREZ, Knowledge and Specialised Trades in the Late Antique West: Medicine vs Engineering, *Journal for Late Antique Religion and Culture* 11 (2017), 38-58.

²² CIL II 1614, 3240, 3280, 3421, 3663, 4509; II² 5,30.

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{64} Whereas theatres and amphitheatres might have been monumental, large and prestigious buildings, perhaps they were not as pragmatic and useful as aqueducts.²³ They were not structures to be used for occasional events, like games, or which represent solely civic power and the administrative needs of the curial-based magistrate system, like fora and basilicae. They actually made a difference in the daily life of citizens by feeding baths and fountains. This is the impression we get from ancient sources, where aqueducts are seen as worthy of admiration as early as Strabo and as late as Cassiodorus including, of course, by Frontinus himself.²⁴ Visually, aqueducts had a very striking impact on the visitor, especially when they approached the city in lofty arches. Aqueducts can be also used to provide a very strong sensation of integrating the territory with the city and an even stronger statement of power of people over nature by controlling and diverting the natural flow of water. Having an aqueduct was also a way of claiming territory for a city and demonstrating the reach of the city's power, the further the better.

In this last sense of territorial control, aqueducts had a very important symbolic significance. With aqueducts being also (relatively) more affordable than circuses or theatres, and eminently functional, it is perhaps not surprising that they were so widespread. If we look back at the period of expansion of aqueducts, during the 1st c. AD, we could see that whether because of recent statutory promotion or because of improving local economic circumstances, local councils became very keen on investing in architecture. In these contexts, where various urban centres start nearly simultaneously to develop their own local monumentalities within a Roman architectural language, the archaeological concept of peer polity interaction may prove useful.²⁵ The wide range of urban donors attested in inscriptions (male, female, locals, foreigners, holding office, or not, etc.) who were involved in urban munificence would certainly confirm that there was competition within the cities amongst the local elites.²⁶ Competitive construction and building between cities is more evident in the East, where there is a longer and richer epigraphic and textual tradition, but it should not be ruled out (considering the limited evidence) that it happened similarly in the West.

In modern-day Spain a similar wave of conspicuous consumption of architecture and large investment in public infrastructures has also been taking place: international airports have become a nation-wide phenomenon.²⁷ Whereas in 1977 there were 32 {65} civil airports (all except for Madrid and Valladolid located on the coast or the islands), in 2017 there were 50, with almost all of the new ones built in inland cities which wanted to promote their status as regional centres. This correlation between city status and access to an international airport is even explicitly stated in political manifestos, demanding airports for all urban areas over

²³ Furthermore, on Pliny's letter above aqueducts seem to balance the Vitruvian principles for public buildings of *venustas*, *firmitas*, and *utilitas* (VITR., Arch., I.3.2).

²⁴ CASSIODORUS, Var. VII.6.2; FRONT., Aq.: I.16; STRABO, Geo., VI.8.

²⁵ C. RENFREW AND J. CHERRY, Peer Polity Interaction and Socio-political Change, Cambridge, 1986; cf. J. MA, Peer Polity Interaction in the Hellenistic Age, Past & Present 180 (2003), 9-39.

²⁶ N. MACKIE, Urban munificence and the growth of urban consciousness in Roman Spain, in: The Early Roman Empire in the West, Oxford, 1990, 179-92.

²⁷ High-speed trains, additional motorways, or de-centralised local archaeological museums could have also been good current Spanish examples.

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250,000 inhabitants.²⁸ While airports serve a specific functional purpose and improve the connectivity and international accessibility of the city, we see also that they have a very important symbolic role, and nearby cities (Castellon-Valencia, Bilbao-San Sebastián, Pamplona-Logroño) insist in having an airport each. Some even (Murcia) have two.

Aqueducts: blessing or curse?

Despite their inherent usefulness and symbolic importance, aqueducts (and to an extent, airports) as opposed to theatres or amphitheatres come with a concerning negative side: a constant need for maintenance. Building an aqueduct for a city out of private money seems like a large individual investment, but the long-term costs of maintenance were not included in the original donation. The cost of running baths (which consumed large quantities of fuel and required a number of employees) has been studied more carefully, and it is clear that endowments of forests to supply firewood were common.²⁹ Aqueducts do not seem to have been endowed in such a way, so all maintenance had to rely on municipal resources like public slaves and engineers (the *hydrophilakai*, *aquarii* or *curatores aquarum*) who kept watch on trees damaging the fabric, clearing the silts (*sordes*) and sinter (calcium crust) deposits from the conduit, fixed leaks, etc.³⁰

During Late Antiquity, and with the changes imposed in local administration (esp. from the 4th c. onwards), it seems as if fewer municipal resources were available to spend on public maintenance of these aqueducts.³¹ Imperial legislation suggests that maintenance responsibility was handed over to private individuals whose lands were {66} crossed by an aqueduct, in exchange for tax remissions,³² although in late provincial contexts, such as late 5th-c. Vienne, we still hear of an aqueduct *artifex*.³³

The general trend is, however, for the number of aqueducts to decrease from the 4th c. onwards (fig. 1 above). It has to be assumed that there was an interest in preserving the aqueduct supply, for the reasons (practical and symbolic) outlined above. The evidence for aqueduct repairs in main cities through the 4th and 5th c. (Narbonne, Rome, Arles, Mérida, Ravenna, Nîmes, etc.) speaks for itself. And the continuity of water supply in the main administrative and economic cities of the Iberian Peninsula (like Tarragona, Córdoba,

²⁸ PARTIDO CASTELLANO, Programa Marco electoral, Mayo 2015, <http://prueba.partidocastellano.org/wp-content/uploads/2013/05/programa-marco-PCAS-2015.pdf>, accessed 14/3/18, p. 62.

²⁹ P. BLYTH, The consumption and cost of fuel in hypocaust baths, in: *Roman Baths and Bathing*, Newport, 1999, 87-93.

³⁰ FRONT., *Aq.*; Cf. CASSIODORUS, *Var.* III.31, V.38, VII.6; C. BRUNN, Water legislation in the ancient world (c. 2200 BC – c. AD 500), in: *Handbook of Ancient Water Technology*, Leiden, 2000, 539-606; ID. Roman emperors and legislation on public water in the Roman Empire: clarifications and problems, *Water History* 4.1 (2012), 11-34; For a particular example, see E. DENIAUX, L'aqueduc de Dyrrachium, construction et restauration, in: *Le réseaux d'eau courante dans l'antiquité*, Rennes, 2011, 27-34.

³¹ M. KULIKOWSKI, The interdependence of town and country in late antique Spain, in: *Urban Centres and Rural Contexts in Late Antiquity*, Ann Harbor, 2001, 147-62, esp. p. 149; W. LIEBESCHUETZ, The end of the ancient city, in: *The City in Late Antiquity*, London, 1992, 1-50.

³² C. THEOD. XV.2.1 = C. IUST. XI.43.1.1.

³³ GREG. TURON., *HF*, II.3: *artifex ille, cui de aquaeducto cura manebat*.

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Valencia, Mérida, or Lisbon) into the 5th century should be linked to regular maintenance and care.³⁴ However, these sites were privileged because they were connected to the central and imperial administration, and its related networks of power and patronage.

Those aqueducts which fall into disuse during the early period are largely to be found in secondary nuclei. These smaller sites do not seem to have been investing in regular aqueduct maintenance – the main cause of eventual aqueduct abandonment. As an extreme example we have the broken aqueduct of Baelo Claudia, damaged by a 3rd or 4th-c. earthquake (fig. 2), that was never repaired,³⁵ even if it was at that time technically possible to do so.³⁶ Places like Ibiza, Calahorra, Los Bañales, *Castulo*, *Vergilia*, Cella, Sasamón, *Iliberris*, *Ucubi*, *Uxama*, Toledo, Jaén, *Celti*, *Ammaia*, etc., not only lose their aqueduct supply,³⁷ but also enter a period of constructive inactivity.

³⁴ J. MARTÍNEZ JIMÉNEZ, *Aqueducts and Water Supply in the Towns of Post-Roman Spain (AD 400-1000)*, DPhil thesis, Oxford, 2014.

³⁵ SANCHEZ LOPEZ AND MARTINEZ JIMENEZ, *op. cit.* (n. 5), pp. 199-201.

³⁶ MARTÍNEZ JIMÉNEZ AND GONZÁLEZ GUTIÉRREZ, *op. cit.* (n. 21).

³⁷ Although in various cases the lack of urban activity is used to date the end of the aqueduct, there are some others when the end of the aqueduct is dated independently – SÁNCHEZ LÓPEZ AND MARTÍNEZ JIMÉNEZ, *op. cit.* (n. 5).



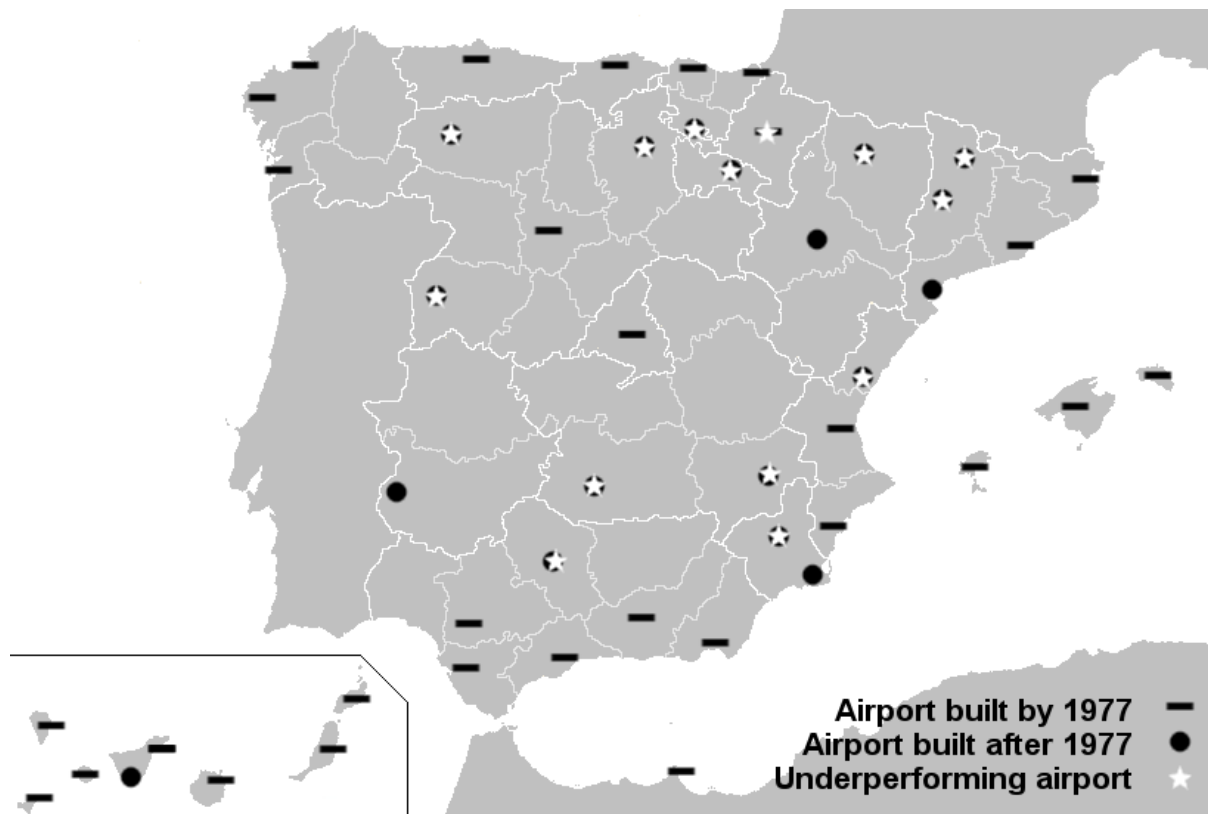
[Figure 2: aqueduct of Baelo Claudia, damaged by an earthquake and never repaired]

This stagnation, together with the end of aqueduct maintenance has to be directly linked to the administrative reforms of Diocletian and Constantine. The two main forms of urban funding, taxes and *ex officio* payments, had become drastically reduced. On the one hand this was a result of the new centralised administration, and on the other the lack of political incentive to invest in civic munificence. Aqueducts were not essential to urban living, even if they made it more comfortable, so it may be that aqueduct maintenance dropped down in the list of municipal priorities. The economic burden of aqueduct maintenance on its own cannot explain the changes of the small secondary towns (in the same way that aqueduct building was potentially bankruptcy), but it was a sign of the changing tide.

{67} If we again compare aqueducts with airports, the latter were usually built during times of economic bonanza, and suddenly became an unbearable expense for many cities or authorities – especially when they did not receive as many flights as expected (like Huesca, Albacete or Ciudad Real) or never even opened (Castellón, Murcia). Fourteen Spanish airports in the late 2010s are grossly underperforming or even closed, they roughly coincide with those built in the post-1977 period, and are largely linked to smaller provincial capitals

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(fig. 3). These airports might have been built with promises of prosperity and obviously linked to (potentially) symbolic and economic benefits, but after the economic crisis they ceased to be a priority. They preserve still that feeling of having been a huge waste of money.³⁸



[Figure 3: Spanish airports as of 2017 – highlighting those built after 1977 and those currently underused] {68}

Conclusions

One way of reading the evolution of aqueducts is as a cautionary tale, with a moral much in the line of the current *Zeitgeist* (i.e., both the dangers of cuts in public spending and the lack of foresight in the investment of large quantities in infrastructure), but this would be a very short-sighted analysis. The construction of aqueducts was a very expensive enterprise, but town councils and private individuals could afford such sums during the early Empire. It was part of the civic duty to invest into the town, and despite personal, ulterior political motivations, the overall benefits for the civic community were many. There is no doubt: aqueducts improved the quality of life, enabled the spread of Italic-style bathing, and allowed

³⁸ Cf. EUROPEAN COURT OF ACCOUNTS, Informe especial. Infraestructuras aeroportuarias financiadas por la UE: escasa rentabilidad, Luxembourg, 2014.
https://www.eca.europa.eu/Lists/ECADocuments/SR14_21/QJAB14020ESN.pdf

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for a denser and populous urban setting. And while the early imperial administrative system continued to function as originally established, aqueducts continued to function.

The exponential growth of aqueducts during the 1st c. AD has to be explained by taking into account various factors, out of which municipalisation and change of status is only one. Towns did not wait to change status to invest into large hydraulic infrastructure. In fact, acquiring an aqueduct before status change would have been a great way to promote a stipendiary city that aimed to obtain municipal rights. Aqueducts were a symbol of political and civic status, and inherently useful and beneficial. After the first ones were built in the large, new, imperially-funded capitals it was only a matter of technical and economic circumstances to be right for individual cities to embark in such constructions.

{69} The decline in the number of aqueducts, especially considering the difference between main cities and secondary nuclei, highlights how essential municipal investment in maintenance was. It could also be used as an indicator of how successful the municipal system was in some areas as opposed to others, a transition clearly visible in late Antiquity.³⁹ Overall, the symbolic desirability of aqueducts and their inherent usefulness made them too attractive a monument to be left unbuilt, and it cannot be said that building them was money badly spent (*tantae pecuniae male perditae*) as they were in use for several generations before they became too onerous to maintain.

Appendix: Calculations

Building materials formed a large part of the building budgets,⁴⁰ so a rough comparative approximation between a theatre and an aqueduct could be highly illustrative.

Theatre: Volume of half the cylinder, as defined by the radius of the theatre (r_t) from the centre of the *scaena* to the outer wall and the height of said wall (h), minus half the volume of the truncated cone given by the radius of the theatre (r_t), the height of the outer wall (h), and the radius of the *scaena* (r_s).

$$V = \frac{r_t^2 \cdot \pi \cdot h - \frac{(r_t^2 + r_t \cdot r_s + r_s^2) \cdot \pi \cdot h}{3}}{2}$$

Aqueduct: Cross-section of the aqueduct *substructio* ($w_{ss} \times h_{ss}$) minus cross-section of the *specus* ($w_{sp} \times h_{sp}$) multiplied by its length, plus the volume of the vault, as given by half the volume of the hollow cylinder defined by the length of the conduit, the width of the *specus* and of the *substructio* as internal and external diametres.

$$V = (w_{ss} \cdot h_{ss} - w_{sp} \cdot h_{sp}) \cdot L + \frac{\left[\left(\frac{w_{ss}}{2}\right)^2 - \left(\frac{w_{sp}}{2}\right)^2\right] \cdot \pi \cdot L}{2}$$

³⁹ Cf. J. MARTÍNEZ JIMÉNEZ AND C. TEJERIZO GARCÍA, Central places in the post-Roman Mediterranean: Regional models for the Iberian Peninsula, *Journal of Mediterranean Archaeology* 28.1 (2015), 81-103.

⁴⁰ DELAINE, op. cit. (n. 20).

Martínez Jiménez, J. 2019. “Tantum pecuniam male perdiderunt: Aqueducts and municipal investment in Hispania,” in J. Andreu and A. Blanco-Pérez (eds.), *Signs of Weakness and Crisis in the Western Cities of the Roman Empire (c. II-III AD)*, 59-70. Potsdamer Altertumwissenschaftliche Beiträge 68. Stuttgart: Franz Steiner Verlag

These are rough approximations, which do not account for *vomitoria* or the *proscenium* wall and peristyle (in theatres) or for occasional *arcuationes* (in aqueducts). They only serve as a guide to the order of magnitude of the amount of building materials (lime, stone, water, timber) which would have been necessary. Both measurements are most certainly understatements when compared to the real final amount of material.

{70} Using Sagunto as an example of an average size theatre ($r_t= 39.5$, $h= 16.9$, $r_s= 8$), the volume resulting is 24,250 m³.

Lisbon, with a median length aqueduct ($L=10k$, $w_{ss}= 1.1$, $h_{ss}= 0.8$, $w_{sp}= 0.4$, $h_{sp}= 0.3$), gives us a volume of 11,723 m³.