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Technology of Grandeur: Early Modern Aqueducts in Portugal

Anatole Tchikine

Abstract
Aqueduct construction remains an important yet understudied chapter in the history of early modern European technology and urbanism. Combining the symbolism of form with the utility of function, aqueducts spoke the revived language of classical architecture, serving as monumental statements of princely beneficence, civic pride, and local identity. Mobilizing community resources in an act of political will, such projects marked the consolidating power of central authorities that spearheaded urban renewal through the creation and display of the improved water supply. The case of early modern Portugal is crucial for broadening the scope of this discussion, which is usually focused on sixteenth century Italy, situating it within a larger geographical and chronological context. While revealing the deep rootedness of Portuguese aqueducts in the local traditions of construction and water management, their analysis sheds new light on the central question of continuity and rupture in the transfer of hydraulic technology and knowledge from antiquity through the Middle Ages.

1 Water and Power

Among various building types that medieval and early modern Europe inherited from classical antiquity, aqueducts arguably had the most monumental impact and, at the same time, utilitarian significance. Extending for miles across the open countryside, like the Acqua Claudia outside of Rome, or bridging valleys and rivers, like the Pont du Gard near Nîmes, these imposing, arcaded structures were

A. Tchikine (✉)
Dumbarton Oaks (Trustees for Harvard University), Washington, DC, USA
e-mail: TchikineA@doaks.org

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remnants of the ancient grandeur as much as they were witness to the achievements of Roman technology and engineering. Using the natural topography and the physics of gravity flow, they offered the most effective means of creating a stable water supply known to early modern authorities, enabling the provision of households and industries and the functioning of fountains. This functionality, coupled with the aesthetics of majestic yet simple forms, continued to win the admiration of both professionals and enthusiasts, from Renaissance architects and humanists to Grand Tour travelers (Evans, 2002).

Scholars of early modern technology and urbanism mainly focus on the restoration and enlargement of ancient aqueducts, beginning with the early efforts by Pope Nicholas V (r. 1447–55) soon after the return of the papacy from Avignon and culminating in the Renovatio Urbis Romae under his sixteenth century successors. They also tend to prioritize the developments in Italy, especially Rome, over those in the rest of Europe (Long, 2010; Rinne, 2010). Yet, this period marked a revival of hydraulic projects on a monumental scale, both across and beyond the territories of the former Roman Empire, to supply the growing cities with fresh running water. Old aqueducts were repaired and new ones were built based on the same hydrodynamic principles as their antique prototypes. One example was Spain, where the restoration of the spectacular Roman aqueduct of Segovia (1484–89) was followed by a series of novel initiatives, such as the Acueducto Los Arcos in Teruel (1537–58) and the Acueducto de los Pilares (1570–99) in Oviedo (Delgado, 2017, 1: 44; Llaguno y Amirola, 1829, 2: 66–67; Criado, 1987). This wide range of locations within the Iberian Peninsula—from central Castile to Aragon in the east and Asturias in the north—was echoed by an even broader geography of aqueduct construction across the Mediterranean. Such infrastructural feats included the Ottoman project (ca. 1525–30) at Kavala in northern Greece, pursued under the patronage of Grand Vizier Ibrahim Pasha (Lowry, 2008, 236–39), and the Wignacourt Aqueduct (1610–15) in Malta, built by the knights of the Order of Saint John to supply their new capital Valletta with water. Fusing with the local Aztec and Inca traditions of construction, this grand architectural idiom soon reached the Americas, as exemplified by the over 48 km long Acueducto del Padre Tembleque (1555–72) in Mexico, whose crisply delineated adobe arcades span the arid landscape of the Papalote ravine near Santiago Tepeyahualco (Olvera García and Ocaña Ponce, 2016).

While the ultimate goal of these ambitious improvement schemes was to supply urban communities with water, the combination of monumental architecture and advanced technology made aqueduct construction an effective political tool. The importance of such projects as acts of civic beneficence is illustrated by an engraving by Jacques Callot, one of a series of prints commissioned in 1614 to commemorate the notable deeds of the late Ferdinando I de' Medici (r. 1587–1609), grand duke of Tuscany (Fig. 1). This image shows the Tuscan ruler authorizing the creation of the 6 km long, mostly aboveground, aqueduct (1592–95) that brought water to Pisa from the hills near the village of Asciano to the northeast. Although largely continuing the efforts of his father, Cosimo I (r. 1537–74), who, in the

Fig. 1 Jacques Callot, Ferdinando I orders the building of the aqueduct of Pisa, engraving, ca. 1614. Washington, DC: National Gallery of Art

1550s–60s, provided the city as well as his capital, Florence, with a system of subterranean conduits,[1] Ferdinando's initiative gave a visible expression to grand ducal authority through the use of antique-style arcaded forms. A portion of another aqueduct, known as the Acquedotto Vasariano (1593–1603), which he built at Arezzo, similarly rose above the ground carried by a long series of round arches (Fig. 2). A clear recognition of this deliberate appropriation of the monumental language of antiquity was the reverse side of the medal of Cosimo I (1567) celebrating the improved water supply of Florence (Fig. 3). Along its rim ran the inscription "OPTABILIOR QVO MELIOR" ("More desirable, just as better"), referring, in the words of Giorgio Vasari (1568), to the "benefit and convenience" that the city was to gain from its new hydraulic infrastructure (Vasari, 1568, 933); while the center featured the still mostly projected Fountain of Neptune connected to the zigzag outline of an arched aqueduct, contrary to the fact that the water was to be brought by underground piping.

[1]This work—which, in the case of Pisa, involved bringing water to the Palazzo Medici, the Piazza Cairoli, and the Piazza San Nicola—was carried out by the Medici engineer David Fortini; ASF, MP, 219, fol. 136v (Cosimo I to David Fortini 23 June 1563). For Cosimo's hydraulic projects in Florence, see Tchikine (2014), Ferretti (2016).

Fig. 2 The Acquedotto Vasariano, Arezzo, 1593–1603. *Photo* Anatole Tchikine

Fig. 3 Pietro Paolo Galeotti, bronze medal celebrating the Fountain of Neptune (reverse), ca. 1566. Trustees of the British Museum

Although carried out under princely patronage—as evidenced by the decree of February 1484, with which the Catholic Monarchs, Ferdinand and Isabella, launched work on the aqueduct of Segovia—such projects were usually funded by municipal authorities with money raised by imposing special levies on vital consumer goods. The burden of this taxation was borne by the urban population, which, in this way, directly contributed to the creation and restoration of the public water supply. In August 1572, for example, the city council of Palermo sought to extend the existing tax on wine and impose an additional one on flour—a heavy toll on the poor—to subsidize the acquisition of a fountain for the future Piazza Pretoria and the related work on conducting water from the Ainisindi torrent to the center of the city.[2] Similar duties on wine and cider, sanctioned by the royal decree of September 1570, enabled the construction of the late sixteenth century aqueduct in Oviedo (Criado, 1987, 40). Less common were direct financial interventions by the ruling authorities, whose sponsorship was often linked to large garden projects, as was the case with the Acqua Felice aqueduct, initiated, according to a contemporary source, by Pope Sixtus V (r. 1585–90) to "quench the thirst of his *vigna*" (the Villa Montalto, formerly in the area of the Termini Station in Rome).[3] A later example of this characteristic symbiosis of princely agendas and public gains was the Aqueduc Médicis (Aqueduc de Rungis), commissioned in 1612 by Queen-Regent Marie de' Medici (1575–1642) to bring water to the Luxembourg Gardens in Paris.[4] Partially retracing the course of an earlier Roman aqueduct, it would receive an extra story built in 1867–74 by the engineer Eugène Belgrand (1810–78) during the capital's "Hausmannian" renovation under the Second Empire, adding a new layer to the complex architectural and historical stratigraphy of this singular structure.

Visibly, although not always historically, linked to the distant Roman past, early modern aqueducts naturalized the consolidating power of the central authorities, serving as monumental symbols of their commitment to improving the conditions of the urban population. Whether subsidized by municipal or government funds, the success of these structures was crucial to the prestige of the ruling elite. A calculation error, an engineering failure, or financial mismanagement could lead to disastrous consequences, charges of incompetence or corruption and the damaging of professional reputation and political influence. While still cardinal, Ferdinando I gained this wisdom as the papal overseer of the Acqua Felice, whose initial fiasco, attributed to the incorrect leveling of the gradient (a subtle incline that needed to be maintained to enable the movement of water) as performed by the architect Matteo Bartolani da Città di Castello, nearly precipitated his downfall.[5] Gian Lorenzo Bernini (1598–1680) suffered a similar embarrassment in trying to conduct water from Lake Bracciano to Rome through the extended Acqua Paola aqueduct, when, contrary to his expectations, the flow failed to reach the required height in one of the twin fountains in the square of Saint Peter's (Fontana, 1696, 179–81). Such a

[2]See documents transcribed in Pedone (1986), documents section, unpaginated.

[3]ASF, MP, 5120, fol. 118r (Ferdinando de' Medici to Francesco I, 22 July 1586): "che potessi cavar' la sete alla sua vigna."

[4]For the history of this aqueduct, see Belgrand (1873–78, 3.1: 147–166).

[5]ASF, MP, 5120, fol. 118r (Ferdinando de' Medici to Francesco I, 22 July 1586).

poor display was not merely an aesthetic problem. The number of fountains and the abundance of their water served as the main measure of an aqueduct's success, which, in the absence of visible infrastructure, as in the case of the Fountain of Neptune in Florence, attested to the government's efforts to harness the liquid resource for public use (see Fig. 3).

2 Survival or Revival?

A fundamental question in the study of early modern aqueducts, as posed by Magnusson (2001), is the issue of "survival or revival," which concerns the degree of continuity in the transfer of hydraulic knowledge and technology from late antiquity through the Middle Ages. The collapse of imperial rule in the Western provinces of the Roman Empire did not mean a disintegration of their urban infrastructure, leading instead to the increased role of the ecclesiastical authorities, such as bishops and abbots, in the provision and distribution of water. In the papal capital, aqueducts continued to be maintained and occasionally restored, as testified to by the eighth century fountain decorated with a colossal bronze pinecone (the Pigna) in the atrium of the old Saint Peter's basilica, supplied by the late antique Acqua Damasiana (Rinne, 2010, 16, 18). New structures were also built, such as the aqueduct of Salerno (before 850), atypical due to its patronage by a secular, rather than an ecclesiastical, prince (Squatriti, 1998, 17–18). The urban renewal of the twelfth and thirteenth centuries marked another period of transition, with the communal authorities assuming primary responsibility for managing the public water supply. Arguably, the most remarkable hydraulic system of that age was the *bottini* of Siena, an underground network of relatively short aqueducts that fed a number of large, low-placed fountains. Taking advantage of the hilly topography of the city, this technology may have derived from earlier, pre-Roman times, drawing inspiration from the Etruscan waterworks, as exemplified by the mysterious "Labyrinth of Porsenna" in the nearby hill town of Chiusi.

Humanist scholarship—with its mission to revive ancient learning, corrupted by the ostensible period of ignorance and neglect, through the recovery of classical texts—distanced itself from this living tradition, opening an apparent rift between the practical and the theoretical foundations of Renaissance engineering. The rapid diffusion of antique writings, first in manuscript and later in print, produced a semblance of "rediscovery" of the lost knowledge that was ready to revolutionize the established modes of thinking and practice. The texts newly put into broad circulation included the first century BC architectural treatise by Vitruvius, which, in Book 8, offered a brief summary of the Roman hydraulic technology of the Augustan era. Indeed, the large wooden instrument handled by the three men on the right of Callot's print, with a long shallow groove for running a stream of water, was a close replica of the Vitruvian *chorobates*, a device for laying horizontal planes that was necessary in aqueduct design (see Fig. 1). These scholarly efforts were followed by a body of original work, such as notes and drawings illustrating hydraulic and pneumatic machinery and principles by Mariano Taccola, Antonio Filarete, Francesco di Giorgio Martini, and Leonardo da Vinci, consolidating the idea that fifteenth century theorists were breaking new ground through the infusion of ancient thought.

Professional knowledge, however, can be transmitted not only through travel, observation, and theoretical writings, but, perhaps most effectively, through artisanal practice. The notion that ancient hydraulic technology was gradually lost in the course of the Middle Ages only to be recuperated through Renaissance theory finds a curious confutation in an episode involving a group of technicians, who, in August 1612, entered what they assumed to be a medieval aqueduct on the outskirts of Florence. Laid underground and only 90 m long, it presented a low passageway wide enough for two men to walk along holding a burning torch, with a channel in between. The aqueduct supplied the thirteenth century roadside fountain, the Fonti di San Gaggio, on the present Via Senese, well outside of the perimeter of the original Roman settlement. For this reason, it could not be mistaken for part of the city's ancient water supply. Given this later origin, the aqueduct's most striking feature, according to the technicians, was the mastery of its design, proportions, and stonework, including the use of an overhead masonry vault that clearly paralleled antique examples.[6] In a city that was believed to lack fresh running water between the collapse of the Roman Val di Marina aqueduct and the new conduit system inaugurated by Cosimo I, the presence of this medieval structure signaled an unbroken tradition of hydraulic engineering that connected the recent and distant past.

The thesis that, in the case of aqueduct technology, architectural theory came after, rather than before, engineering practice finds an indirect confirmation in the fact that both Taccola and Francesco di Giorgio were born in Siena, a city long celebrated for its advanced water supply. Rather than marking a new point of departure, their theoretical output codified the professional knowledge accumulated by previous generations of craftsmen, whose practical experience offered a viable alternative to the interrupted written tradition. The popularity of Vitruvius, whose first printed edition by Fra Giocondo appeared in 1511, largely served the same goals. Moreover, the revival of hydraulic learning during the Renaissance followed an odd trajectory. After a period of intensive interest in the fifteenth century, it fell outside of the scope of mainstream architectural theory—as exemplified by the treatises by Sebastiano Serlio, Jacopo Barozzi da Vignola, and Andrea Palladio—only to reemerge towards the end of the 1580s as a narrow specialized discipline through the writings of Agostino Ramelli and Giovan Battista Aleotti (Tuttle, 2018). Unsurprisingly, the designers of early modern aqueducts differed in terms of background and training. Their examples ranged from the French-born Quinto Pierres Bedel (Vedel) (d. 1567)—the architect responsible for the Acueducto Los Arcos in Teruel and the ingenious stormwater management tunnel, Mina de Daroca

[6]ASF, CPG, neri, 797 (1629), supplica 292 (Ufficiali dei Fiumi to Cosimo II, 31 August 1612): "I condotti di questa fonte sono fatti con magnificenza, e senza risparmio di spesa, perché sono murati con molta maestria, e con la sua volticiuola sopra…".

(1555–60), in the nearby town of Daroca in Aragon—to Fray Francisco de Tembleque (d. 1589), a native of Castile who spent most of his career as a Franciscan missionary in the Viceroyalty of New Spain (Sebastian, 1962; Marcuello, 1987; Valdés, 1946).

3 Early Modern Aqueducts at Work

The construction and operation of early modern aqueducts received a detailed discussion in Carlo Fontana's *Utilissimo trattato dell'acque correnti…* (1696), an ambitious treatise that drew both on the legacy of antiquity—such as the first century AD text by the Roman engineer Frontinus—and contemporary hydraulic theory, especially the work of Galileo's student Benedetto Castelli (1628). Water, originating within a catchment area, where it was supposed to abound in quantity regardless of the season, was collected from multiple veins and diverted into a closed reservoir that served as a filtering chamber (Fontana, 1696, 17–18). From there, it entered the aqueduct, whose vaulting protected the flow from being adulterated by rain, while the windows let in enough air and light to keep the interior properly ventilated (Fig. 4). The ground below often had to be reinforced with buttressing, adding to the overall costs. Service passages both inside and outside of the aqueduct needed to be sufficiently wide to accommodate the action of two men who performed the maintenance operations.

After identifying and harnessing the source of water, the next task was to conduct it to the specified destination. While negotiating the uneven topography, the aqueduct's design was supposed to avoid unfolding in long straight lines and needed to maintain the correct gradient (Fig. 5). According to Fontana, the incline that enabled gravity flow should be at least ½ *oncia* (0.93 cm) for each *canna* (2.23 m) of length (Fontana, 1696, 19). Arches that carried the visible part of the aqueduct not only raised it to the required height, but also prevented it from getting flooded from underneath by seasonal torrents. The aqueduct's course was punctuated by a series of openings, which, while marking the underground route, also served as outlets for releasing the buildup of noxious fumes and provided access to maintenance workers (Fontana, 1696, 23–24).

Once the aqueduct reached the desired location, the last challenge was the distribution of water. The terminus was another reservoir called the *castellum aquae* in Latin, generally elevated to increase pressure. Its interior walls were perforated with multiple holes of different diameter depending on the amount of water allocated to each consumer, whether private or institutional, who received their share through underground piping. As a rule, such apportions were not free. The civic authorities of Palermo, for example, planned to cover the cost of their sixteenth century aqueduct through the sale of water concessions.[7] The standard diameter of measuring holes could range from ¼ *oncia* (0.46 cm) to 8 *once* (14.88 cm), with 1

[7]See documents transcribed in Pedone (1986), documents section, unpaginated.

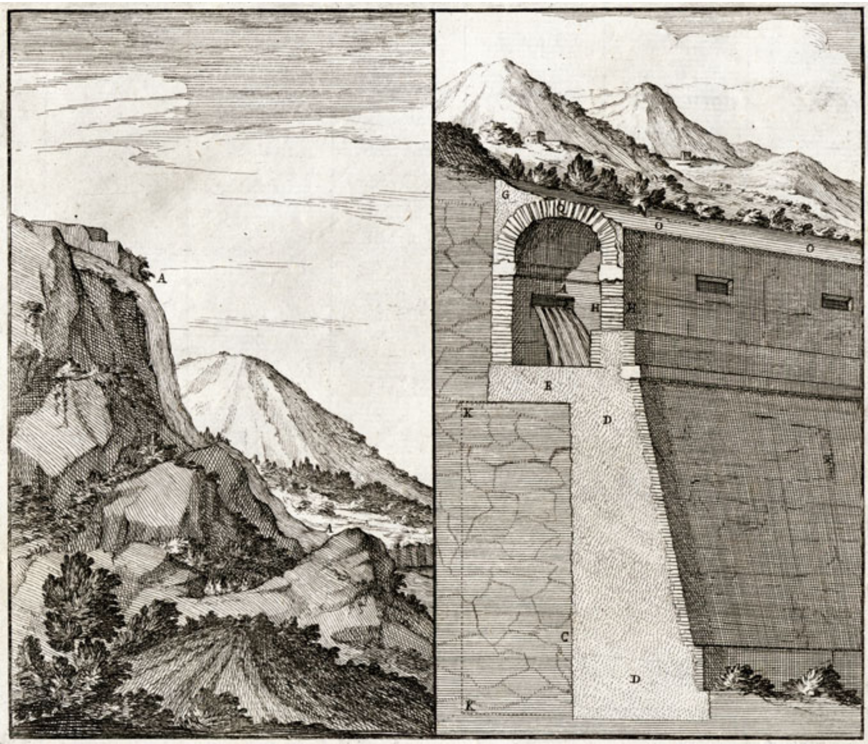

Fig. 4 Interior and exterior of an aqueduct, from C. Fontana, Utilissimo trattato dell'acque correnti… (1696). Washington, DC: Dumbarton Oaks

oncia (1.86 cm) yielding, on average, 23 l per minute. The capacity of the Acqua Vergine in Rome, for example, was around 1200 *once*, while the Acqua Felice generated 700 *once*, 30 of which (that is, about 600,000 l per day) were reserved by Sixtus V for the Villa Montalto. These measurements, however, could never be precise. In fact, in terms of the actual volume, 1 *oncia* of the Acqua Felice amounted to only half of that of the Acqua Vergine, which, therefore, through an opening of the same size, passed almost double the amount of water (Rinne, 2010, 123). The reason for this discrepancy was not only the gradient of the aqueduct, but also such factors as velocity and pressure. The incorporation of these variables—generally based on Castelli's observations—into technical calculations was Fontana's main contribution to the hydraulic theory of his day (Fontana, 1696, 28).

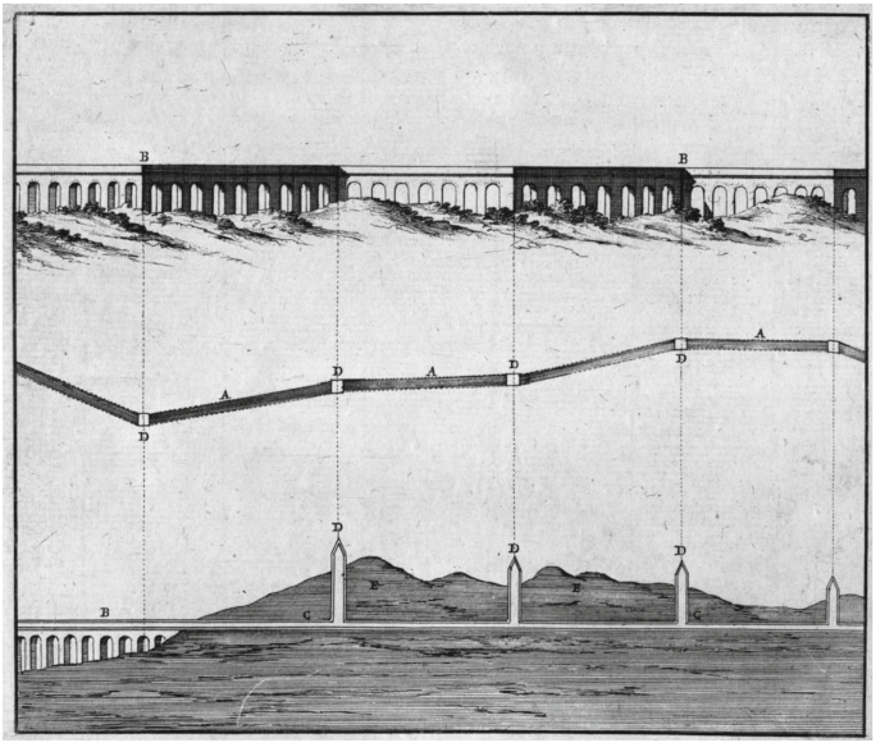

Fig. 5 Elevation, plan, and section of an aqueduct, from C. Fontana, Utilissimo trattato dell'acque correnti… (1696). Washington, DC: Dumbarton Oaks

4 The Case of Portugal

Portugal, a country with old and rich traditions of water management, presents an important case in point for broadening our perspective on both the history and the symbolic meaning of early modern aqueducts. Formerly the core of a Roman province, Lusitania, it went through a period of Muslim domination during which it adopted advanced methods of Islamic hydraulic technology, whose impact continued to resonate across the Iberian Peninsula for centuries to come. In fact, the word for fountain in Portuguese, *chafariz,* is of Arabic origin. Portugal is also home to arguably the greatest eighteenth century aqueduct, the Águas Livres (1731–48) in Lisbon, rivaled in its day only by the slightly later, but equally spectacular, Acquedotto Carolino (1754–62) in Caserta. Commissioned by King João V (r. 1706–50) and built in less than two decades, this marvel of Portuguese engineering was one of the most ambitious projects of its kind initiated in an early modern European capital and carried out on a truly majestic scale (Fig. 6).

Fig. 6 R. Black, A prospect of the new Aqueduct of Lisbon…, ca. 1750, etching with watercolor. Lisbon: Biblioteca Nacional de Portugal

In its historical trajectory, Portugal followed a pattern broadly analogous to the rest of post-Roman Europe, characterized by prolonged urban decline, with the balance of power shifting from civic to religious and feudal authorities, a process interrupted in 711 by the Muslim occupation. The ensuing period of Islamic influence not only left a lasting imprint on the practice of Portuguese agriculture, particularly strong in the southern regions of Alentejo and Algarve (see Chap. 15 in this volume), but also extended to other spheres of life, for example, the balneary culture, as evidenced by the proliferation of bathhouses (Veloso, 2012, 165–66; Trindade, 2014, 375–76). The Christian Reconquista of the twelfth and thirteenth centuries marked the consolidation of the royal authority, with new kings of Portugal, in tandem with civic councils, playing an increasingly important role in promoting the efforts of urban improvement. The presence of large medieval fountains with crenellated roofs, usually located on the outskirts of cities and displaying, often side-by-side, monarchic and municipal insignia, testifies to the collaborative nature of these attempts to supply local communities with water (Trindade, 2014, 369–73).

The best-known of these structures, the thirteenth century Chafariz de El-Rei, rebuilt by King João II (r. 1481–95) in 1487, but heavily modified since, stands at the foot of São Jorge Hill in Alfama to the east of the center of Lisbon, not far from the terminus of the ruined Roman aqueduct that used to supply the future Portuguese capital (Trindade, 2014, 379; Mascarenhas et al., 2012). Judging by its sixteenth

Fig. 7 The Chafariz de El-Rei, ca. 1570–80, Lisbon: Coleção Berardo

century depiction, this fountain, in its earlier form, presented a three-bay loggia supported by Solomonic columns and crowned with a royal coat-of-arms, with a sunken enclosed plaza at the front and featuring six sculpted animal heads that served as spouts (Fig. 7). Located in close proximity to the Tagus, one of the fountain's principal functions was to provide water to seafaring crews, as is, perhaps, suggested by the relief of a ship with billowing sails, the emblem of Lisbon, in the center. What remains unclear, however, is the exact means by which this resource was collected and directed to reach its consumers. Since the painting shows a dense crowd of people gathered next to the fountain, many of them carrying earthenware jugs, its supply must have been quite abundant. A likely analogy is the Fonti di San Gaggio in Florence, which received water from a nearby hill via a short underground aqueduct. If this parallel holds, the idea of continuity in the transfer of hydraulic technology from antiquity through the Middle Ages, as attested to by Portuguese sources (Trindade, 2014, 368), gains further ground, suggesting that, in cities with the ancient tradition of water supply, this knowledge and expertise, while no longer supported by a corpus of theoretical texts, have never fully died out.[8] Accordingly, in the case of early modern aqueducts, their impressive design mainly reflected a shift in patronage and scale, rather than marking a technological breakthrough owed to the influx of Italian Renaissance writings on architecture and engineering.

[8]Roman aqueducts existed in a number of Portuguese cities, including Lisbon, Beja, Évora, and Faro; the best preserved example is in Conimbriga (Caetano 1991, 15).

This deep-rootedness in regional traditions and historical memory—the country's unique ancient past—rather than the desire to imitate the papal ambition to restore the Eternal City to its imperial glory, remained the key principle that guided the construction of aqueducts in Portugal through the early modern period. The earliest of these efforts went back to the final decades of the fifteenth century, during the reign of João II, signaling the strengthened royal support for local attempts to spur urban renewal. This process was pioneered by the Aqueduto dos Arcos in the port city of Setúbal, south of Lisbon, begun in 1488 and financed through a combination of specially imposed taxes (known as *real de água*) and the royal subvention (Mascarenhas et al. 2013, 195).[9] Relatively short, it extended for over 3 km, bringing water from the springs of Alferrara in the hills to the northwest to the central Praça do Sapal (now Praça do Bocage). The subterranean portion of the aqueduct that was adjacent to the catchment area presented a vaulted tunnel of varying height flanked by two narrow service passages, while the aboveground part was a two-tier structure carried by a series of wide round arches (Mascarenhas et al., 2013, 197).

A similar initiative promoted by João II, parallel with the work at Setúbal, concerned the city of Évora, which, among its many antiquities, boasted the remains of an ancient aqueduct. Interrupted by the king's untimely death in 1495, this project was revived in 1533 by one of his successors, João III (r. 1521–57), at the time when the city served as a seat of the royal court. During this phase, the aqueduct's creation assumed a distinctly ideological flavor due to its championship by the country's leading humanist, André de Resende (1498–73), a native of Évora (Espanca, 1944, 10–11). Often claimed to be the founder of Portuguese archeology, he sought to enhance his antiquarian findings through the use of dubious and occasionally forged evidence, much in the tradition of a fellow Dominican, the notorious mythmaker Annius of Viterbo (1437–1502).[10] The focus of Resende's interests was the rebellious Roman general Quintus Sertorius (ca. 120–72 BC), who, from his headquarters in Évora, had made himself master of most of the Iberian Peninsula by successfully fighting, with the support of the local population, numerous armies sent against him from Italy. Developed in a polemic with another humanist scholar, Miguel da Silva (ca. 1480–1556), Bishop of Viseu, this method led to the alleged discovery of various vestiges of the antique aqueduct—especially in the area of the ruined classical temple, the so-called Templo de Diana (which, according to Resende, had served as a *castellum aquae*)—postulating the Sertorian lineage of the original watercourse, and thereby reclaiming its status as an intrinsic part of the city's historic identity (Senos, 2018).[11]

[9]Cf. the analogous situation in Elvas, where the initial work on the Aqueduto da Amoreira was also funded by a special levy on meat and fish. This tax had to be reintroduced in the early seventeenth century to continue the aqueduct's construction (Mascarenhas and Carvalho Quintela, 2008, 92, 93–94).

[10]For Resende's practice of forgery, see Spann (1981); Senos (2018).

[11]My discussion of the Água de Prata is indebted to the recent work by Francisco Bilou.

Fig. 8 The Água de Prata, Évora, 1534–56, designed by Francisco de Arruda. *Photo* Anatole Tchikine

Known as the Água de Prata by reference to the spring where its water originated, the new aqueduct, 18 km long, was supposed to overlay the ancient one, bringing it back to life both functionally and symbolically. Work was carried out under the supervision of the royal architect Francisco de Arruda (d. 1547), the creator of the Torre de Belém (1514–20), a prime example of the decorative "Manueline" style associated with the reign of King Manuel (r. 1495–1521), as echoed in the aqueduct's diminutive domed turrets that presumably marked the location of vertical shafts used as access points or air vents.[12] Such ornamental accents, however, could not compete with the monumental simplicity of tall round arcades, whose imposing forms—much more convincing than Resende's erudite arguments or forged inscriptions—served as unambiguous proof of the ancient origins of the Água de Prata (Fig. 8). This architectural strategy was particularly evident in the design of the elegant Caixa de Água (*castellum aquae*) at the aqueduct's terminus in Rua Nova (Fig. 9). Attributed to Francisco's son Miguel de Arruda (d. 1563), this building was an accomplished essay in Roman classicism, with an engaged portico that made a clear reference to the Templo de Diana as it appeared before its nineteenth century restorations, conveying a sense of unbroken continuity with the city's real or imagined antique past.

Francisco de Arruda's next related project, which he oversaw from 1537 until his death in 1547, was the Aqueduto da Amoreira in the strategically important city of Elvas on the border with Castile. Extending for only 8.5 km, and hence less than half the length of the Água de Prata, it became one of the most iconic structures associated with early modern Portugal, featuring, at its tallest part, four tiers of

[12]For Arruda, see de Sousa Viterbo (1899–1922, 1: 55–65).

Fig. 9 The Caixa de Água, Évora, ca. 1540s, attributed to Miguel de Arruda. *Photo* Wikimedia Commons

superimposed arcades. Built in a series of discrete campaigns interrupted by a chronic lack of funds and a period of political turmoil following the death of King Sebastião (r. 1557–78) during his abortive North African crusade, its design was altered several times to add extra height, necessitating the use of colossal and somewhat overbearing buttressing (Mascarenhas and Carvalho Quintela, 2008). The resulting structure was the product of successive interventions by four different architects, who, in addition to Arruda, included Afonso Álvares (d. 1580), Diogo Marques Lucas (d. 1640), and Pero Vaz Pereira (d. 1643).[13] Similarly to the Água

[13]For these architects, see, respectively, de Sousa Viterbo (1899–1922, 1: 12–15; 2: 139–141; and 2: 249).

de Prata, the Aqueduto da Amoreira was distinguished by its wildly meandering route, especially at the point where it displayed the largest number of stories. This zigzag outline was probably due less to the desire to increase the movement of water (cf. Fig. 5) than to the need to negotiate the patchwork of different properties that lay in the aqueduct's way.

Such prolonged periods of construction closely followed by repair and expansion projects meant that early modern Portuguese aqueducts were constantly works in progress.[14] Supervised by special officials with the title of *visitadores* or *provedores do cano*,[15] their operation was governed by statutes known as *regimentos* that regulated the distribution of water and imposed fines for its illegal diversion or acts of vandalism. A prerogative of the crown, such ordinances were issued or amended with notable frequency, typically by each successive ruler, and often involved the imposition of special taxes, especially on meat and fish, to support the maintenance work (Conde and Magalhães, 2008, 94).[16] They could not, however, avert damage caused by natural disasters, especially earthquakes, or the exigencies of warfare, as in the case of the Aqueduto da Amoreira, which suffered partial destruction only a few decades after its completion in 1628 due to a major fortification campaign in Elvas in the second half of the seventeenth century (Mascarenhas and Carvalho Quintela, 2008, 94–95). The principal beneficiaries of water concessions were large religious institutions, such as monasteries and hospitals, as well as members of the high nobility, who sometimes received runoff from public fountains (Espanca, 1944, 25–27).[17] The needs of the rest of the urban population were satisfied by a system of *chafarizes* and numerous water sellers, whose profession continued to thrive into the early twentieth century.[18]

Urban renewal and expansion, however, were not the only factors that brought early modern aqueducts into existence. A prominent monument of sixteenth century Portuguese engineering was the Aqueduto dos Pegões Altos of the Convento de Cristo in Tomar, the seat of the military Order of the Knights of Christ and an important monastic establishment (Antunes, 2012). Begun in 1593 by the Bolognese architect Filippo Terzi (1520–97) in the service of King Philip II of Spain (r. 1556–98)—the first monarch of the Philippine Dynasty that ruled Portugal from

[14]For example, by 1575, the Água de Prata, although still unfinished, was already in need of urgent repairs (Espanca, 1944, 24–25). The Aqueduto dos Arcos in Setúbal had to undergo similar maintenance operations in 1601–13 (Mascarenhas et al., 2013, 196).

[15]In the case of the Água de Prata, the office of *visitador do cano* was held by Francisco de Arruda, from 1542 until his death in 1547 (Sousa Viterbo, 1899–1922, 1: 64). For this position, see also Conde and Magalhães, 2008, 95.

[16]For the *regimentos* of the Água de Prata, see Espanca, 1944, 21–24, 33–37; Conde and Magalhães, 2008. For the regulations concerning the aqueduct of Setúbal, see Mascarenhas et al., 2013, 195.

[17]On August 26, 1557, for example, Dowager Queen Catarina of Austria (1507–78), acting as regent during the minority of King Sebastião, conceded runoff of the Chafariz das Portas de Moura (1556) in Évora to Teodósio (1510–63), Duke of Braganza, for the irrigation of his orchards (Espanca, 1944, 22).

[18]For water sellers in Coimbra, still active through the late nineteenth century, see Veloso, 2012, 175.

Fig. 10 The Aqueduto dos Pegões Altos, Tomar, 1593–1619, designed by Filippo Terzi. *Photo* Wikimedia Commons

1581 until the Restoration War of 1640—this aqueduct stretched for over 6 km, featuring, in its most imposing part, a two-story arcade that carried an open channel with a service passage running along the side (Fig. 10).[19] What made this structure distinct, however, was the lower order of arches, whose pointed profile gave them an unmistakably Gothic character (Caetano, 1991, 49). Using the additional buttressing strength of medieval construction, the Aqueduto dos Pegões Altos thus sported a distinctly national style of Portuguese conventual architecture, as exemplified by the Jerónimos monastery in Belém, a jewel of the glorious Manueline era.

[19]The need for this walkway, however, is not entirely clear, since service passages in the part of an aqueduct elevated above ground were not common in Portugal. Compared to the adjacent open channel, it has a flat, rather than rounded, bottom, is positioned at a lower level, and, instead of sidewalls of equal height, is flanked by a low parapet. Adding a secondary conduit to increase the capacity of the aqueduct would have involved widening the whole structure, unless the new watercourse could be placed above the original one (as in the Aqueduto da Amoreira in Elvas). Such massive rebuilding was clearly not the case at Tomar, suggesting that the passage in question was part of the original design and that its function was different. A likely reason for its inclusion concerns the substantial financial resources commanded by the monastery, which could afford this additional expense.

While employing hydraulic technology that derived from antiquity, the aqueduct's Gothic appearance subtly related it to the monastic water management practices of the Middle Ages, tying the ancient tradition to the more recent past.

The construction of the Águas Livres in Lisbon—begun almost a century and a half later, after the end of the Spanish supremacy—bolstered these symbolic connections by bringing them together in an ambitious display that celebrated the new golden age of the Portuguese monarchy (see Fig. 6). Necessitated by rapid urban expansion to the west, beyond the dominant Convento do Carmo, work on the new aqueduct was initiated by João V in response to the 1728 plea by Cláudio Gorgel do Amaral—the civic official (*procurador*) responsible for the western half of the city (divided, between 1716 and 1740, into two municipal entities)—and was the collective work of a brilliant constellation of architects and engineers who were active in Portugal at the time (Cunha Saraiva, 1938, 6–7). Beginning at the Águas Livres spring in Belas, north of Queluz, it extended for 18 km, uniting along its way a number of different branches that comprised 58 km of under- and aboveground channels (Caetano, 1991, 66). Its terminus was the Mãe de Água in the Amoreiras district, a capacious reservoir designed by the Hungarian Carlos Mardel (1695–1763) close to the point marked by the prominent triumphal arch where the water entered the city. The aqueduct's origin, as conveyed by its name, was not accidental. The need to provide the Portuguese capital with a better system of water supply, already pressing in the early sixteenth century, was famously voiced by the artist Francisco de Hollanda (1517–85), who, in his treatise *Da fábrica que falece à cidade de Lisboa* (1571), addressed to King Sebastião, urged the monarch to restore the ancient Roman aqueduct that had been fed by the same source (Hollanda, 1929, 217–218). The accompanying drawing represented Hollanda's project for a colossal fountain in the Rossio area decorated with the crowned figure of Lisbon holding a ship, which was surrounded by four elephants spouting the Águas Livres water from their gigantic trunks.

A realization of this Renaissance dream, the Águas Livres made a particularly spectacular show as it crossed the valley of Alcântara, with its series of tall pointed arches, the largest of which, 65 m high, reached 29 m in width. Although primarily considered a functional choice (Murphy, 1795, 179–180), this use of a Gothic structure, which withstood the disastrous earthquake of 1755, left no doubt as to the aqueduct's post-classical origin. Combining ancient hydraulic technology and medieval construction technique on an unprecedented scale, the Águas Livres was a tour de force of early modern engineering whose dramatic effect and utilitarian role opened a path towards the modernization of Lisbon during the Pombaline reforms under King José I (r. 1750–77). A prodigious architectural monument, the aqueduct proudly asserted its place as a bridge linking the past and the future.

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