Original paper
UDC 628.14 (497.5 Dubrovnik) "14"

THE MIRACLE OF WATER: PROLEGOMENA TO THE EARLY RENAISSANCE AQUEDUCT OF DUBROVNIK

RELJA SEFEROVIĆ AND MARA STOJAN

ABSTRACT: Inadequate water supply prompted the Ragusan authorities in the first half of the fifteenth century to consider the construction of an aqueduct. The latter owes its design to Italian master Onofrio della Cava, bearing witness to his engineering skill but also to the far-sighted politics of the Ragusan commune. Based on archival material and field research, the authors trace the construction of the aqueduct from the spring in Šumet to the City fountains and industrial facilities.

Ante aquaeductum

Archeological research in the wake of the 1979 earthquake cast a new light on the origins and development of Dubrovnik.[1] Traditional historiography was

[1] Josip Stošić, »Sažeti prikaz istraživanja nalaza i problema prezentacije pod katedralom i Bunićevom poljanom u Dubrovniku«. *Godišnjak zaštite spomenika kulture Hrvatske* 12 (1986): pp. 241-247.

Relja Seferović, member of the Institute for Historical Sciences of the Institute for Historical Sciences of the Croatian Academy of Sciences and Arts in Dubrovnik. Address: Zavod za povijesne znanosti HAZU, Lapadska obala 6, 20000 Dubrovnik, Croatia. E-mail: reljaseferovic@yahoo.co.uk.
Mara Stojan, member of the Environmental Engineering Department, Civil Engineering Institute of Croatia. Address: Institut građevinarstva Hrvatske, Zavod za ekologiju, J. Rakuše 1, 10000 Zagreb, Croatia. E-mail: mara.stojan@igh.hr.

This article has already been published in Croatian under the following title: »Čudo vode: Prolegomena za ranorenesansni vodovod u Dubrovniku«. *Anali Zavoda za povijesne znanosti HAZU u Dubrovniku* 44 (2006): pp. 95-137. Translated by Vesna Baće.

inclined to Constantine Porphyrogenitus' account of the destruction of Epidaurum and foundation of Dubrovnik, by which, seeking refuge, the inhabitants of Epidaurum settled on the site of today's Dubrovnik. Historians Jorjo Tadić, Risto Jeremić, Vinko Foretić and others persisted on the interpretation that Dubrovnik was founded on barren land, deficient in fresh water resources.[2] Supposing this assumption were true, it does strike as curious that a rugged cliff and not a safe haven offering food and water was chosen for settlement.[3]

The probing results of a multidisciplinary research undertaken in the inner City area after the 1979 earthquake provided a completely different picture. It showed that a settlement had existed on the site at a very early date, during the Greek migrations to the east coast of the Adriatic Sea, and later during Roman colonisation.[4] In addition, discoveries made during archeological excavations on the site of the Cathedral and Bunićeva poljana between 1981 and 1988 confirmed the existence of fresh water springs which are still active.[5]

Tackling the origin of Dubrovnik and its port, Antun Ničetić proved that the west part of the shore was sandy and had fresh water springs, and that the area of today's Placa may have been arrable land at the time.[6] This, along with a number of other studies, has clearly shown that the story of the settlement on a rocky and hostile cliff has fairly little historical ground.

The outlying area of Dubrovnik is extremely rich in water sources thanks mainly to the geographical layout of the massifs of Bosnia and Herzegovina, Montenegro and the mountains surrounding Konavle, from which water percolates into underground galleries and wells. This drainage basin includes a number of surface and ground river flows, streams and many natural springs. Josip Lučić has compiled a long list of hydronyms from the area of Župa

---

[2] Vinko Foretić, *Povijest Dubrovnika do 1808*., vol. I. Zagreb: Nakladni zavod Matice hrvatske, 1980: p. 17; Risto Jeremić and Jorjo Tadić, *Prilozi za istoriju zdravstvene kulture starog Dubrovnika*, vol. I. Beograd: Biblioteka Centralnog higijenskog zavoda, 1938: p. 36.

[3] Ivica Žile, »Naselje prije Grada«. *Dubrovnik* N. S. 8/4 (1997): pp. 97-124.

[4] Antun Ničetić, *Povijest dubrovačke luke*. Dubrovnik: Zavod za povijesne znanosti HAZU u Dubrovniku, 1996: p. 23.

[5] Josip Stošić, »Prikaz nalaza ispod katedrale i Bunićeve poljane u Dubrovniku«, in: *Arheološka istraživanja u Dubrovniku i dubrovačkom području*. [Izdanja Hrvatskog arheološkog društva, XII]. Zagreb: Hrvatsko arheološko društvo: pp. 15-38. Ivica Žile, »Arheološki nalazi unutar perimetra povijesne jezgre grada Dubrovnika«. *Opuscula archeologica* 23-24 (1999-2000): pp. 337-345.

[6] A. Ničetić, *Povijest dubrovačke luke*: p. 24.

dubrovačka, Šumet, Rijeka dubrovačka and Zaton.[7] They testify to a rare wealth of freshwater resources in the region, as well as to significant groundwater sources, which provide continuous water supply of Dubrovnik and the surroundings.[8] The narrow coastal strip has a number of abounding natural springs at or below sea level, or even several hundred metres above it. Namely, a belt of flysch parallel to the coastline prevents the accumulated groundwater from overflowing except in places where the flysch, due to its layered structure, allowed it.[9] It is on these spots where the flysch barrier is thin and shallow that groundwater finds its way to the surface (Vrelo in Zaton, River Ombla, Vrelo in Župa dubrovačka). The flyschy layer ascends towards Šumet, where the spring zone is situated at about one hundred metres above sea level—gradient being an essential prerequistite for the construction of a free-fall aqueduct.

Wells initially served as major fresh water sources for the City and its dwellers. They were dug out in the lowers sections of the Quaternary deposit which abounded in groundwater. Excessive daily use of these ancient wells eventually closed them down, as the water became salty.[10] Yet it is certain that early Dubrovnik did not suffer from water shortage. Writing about Dubrovnik in the fifteenth century, Philippus de Diversis commended its founders for having built it on the site abounding in fresh water and healthy climate.[11]

Natural springs located on the site of today's Cathedral, Bunićeva poljana, Ulica of puča, under the Church of St Saviour, in the close vicinity of Onofrio's Great Fountain, in the Convent of St Clare, in the upper cloister of the Franciscan Monastery and elsewhere in the City must have sufficed the water requirements of Dubrovnik's inhabitants in its early days. But the population growth and economic development towards the end of the Middle Ages by far surpassed the urban water needs from the previous centuries. Excessive draining of the extant wells inevitably led to the mixing of the fresh and seawater. Brackish water was not drinkable, although it could still be used for washing and cooking.

---

[7] Josip Lučić, *Prošlost dubrovačke Astareje*. Dubrovnik: Matica hrvatska, 1970: pp. 15-18.

[8] According to engineer Tomislav Paviša and his hydrotechnical expertise of the Dubrovnik region, 450 days of drought could not halt the flow of the river Ombla.

[9] See Veselin Simović, *Leksikon građevinarstva*. Zagreb: Masmedia, 2002: p. 231.

[10] Lukša Beritić holds that the first wells were built in the fourteenth century and later (»Dubrovački vodovod«. *Anali Historijskog instituta JAZU u Dubrovniku* 8-9 (1962): p. 99).

[11] Filip de Diversis, *Opis slavnoga grada Dubrovnika*, ed. Zdenka Janeković-Römer. Zagreb: Dom i svijet, 2004: pp. 59-62.

The building of cisterns which, during rainy seasons, collected rainwater from the roofs could not significantly improve Dubrovnik's acute water problem in the late Middle Ages. In dry summer months ships transported water from the springs in Mlini to the City. It was sold in the city port, but this too was another in a series of palliative measures unable to resolve Dubrovnik's water supply.

Water was an important attribute in the culture of the Humanism and the Renaissance. Architecture and urbanism of the period introduced a number of water elements. Indulgence in fresh and transparent waterflows, admiration of the surrounding pastoral environment but also of its more practical use became a frequent motif in the works of the Ragusan writers and philosophers of the Renaissance, not as a mere literary device but as an expression of Dubrovnik's reality and its everyday needs. The beauty and freshness of the upper flow of the Ombla River owes its fame to the verse of Ilija Cerva.[12] The renowned Renaissance playwright Marin Držić also dedicates his lines to the crystal freshwaters of Dubrovnik: "Ma zlato se u vodi i drago kamenje najveće nahodi".[13] In his *Dialogo sopra la sfera del mondo*, Nikola Nalješković, poet and astronomer, described Vrelo in Župa dubrovačka.[14] On his estate in Trsteno, Nikola Gozze installed an aqueduct to carry water to the gardens and the grinding mill, testifying in his famous work to the importance of water and its quality for the development and well-being of family and estate. Thus he advises those who drink water from the wells to cover the bottom with sea sand in order to keep the water fresh, clear and transparent. In his opinion, mud was a serious threat to the wells, as also confirmed by medical experts.[15] Poet Miho Monaldi extolls the transparency of water, comparing it to that of air.[16]

Water found its use in industry as well. Dubrovnik's tradition in cloth manufacturing depended most directly on the regular supply of fresh water. It

---

[12] Ilija Crijević, »S tobom meni, Marijane«, in: *Hrvatski latinisti*, I, ed. Vladimir Vratović, trans. Tomislav Ladan. [Pet stoljeća hrvatske književnosti, II]. Zagreb: Zora, Matica hrvatska, 1969: p. 408.

[13] Marin Držić, »Tirena«, in: Marin Držić, *Djela*, ed. Frano Čale. Zagreb: Sveučilišna naklada Liber, 1979: p. 238.

[14] Tomislav Macan, *Dubrovnik Martola Dupca*. Dubrovnik: Matica hrvatska, 1997: p. 367.

[15] Nikola Gučetić, *Upravljanje obitelji*. Zagreb: Biblioteka Scopus, 1998: pp. 87-89.

[16] Michele Monaldi, *Irene overo della bellezza*. In Venetia: Presso Francesco Bariletto, 1590: 59v.

was not until the construction of larger textile workshops and the arrival of an Italian weaver Paolo Cornelo of Piacenza, his half-brother and nephew Filippo in 1416 that this branch of industry began to face a serious problem of inadequate water supply.[17] Increasing water consumption was more than apparent and the construction of an aqueduct seemed the only reasonable solution.[18]

Towards realisation of a water supply system

East coast of the Adriatic had witnessed similar attempts at water supply as early as the antiquity, such as Diocletian's gravity aqueduct which carried water from the Jadro River to Split at a distance of 11 km.[19] Aqueducts were also constructed in the area surrounding Dubrovnik. The region of Konavle was named after the canals that transported water along a ten-kilometer aqueduct from the springs in Vodovađa to the ancient settlement of Epidaurum. The water supply system expanded, and apart from the main canal, a network distributed water to the *villae rusticae* that flanked Konavosko polje. Mierski potok in Butkovina, Konavle, a hydronym no longer in use, Milorad Medini interpreted as the remains of an ancient aqueduct supported by a wall (Lat. *murus*).[20] The organisation of communal water supplies and the management of water resources on its territory were among the imperative concerns of Dubrovnik's government. In Mlini, Župa dubrovačka, works were carried out on the local stream so as to facilitate the building of mills in the fifteenth and early sixteenth century.[21] In Ston, then the second urban settlement of the Republic, fresh water supply was organised in the latter half of the sixteenth century, and in 1581 a public fountain was installed on the main square.[22]

---

[17] Dragan Roller, *Dubrovački zanati u XV i XVI stoljeću*. (Građa za gospodarsku povijest Hrvatske, II(. Zagreb: JAZU, 1951: p. 13.

[18] L. Beritić, »Dubrovački vodovod«: pp. 99-115.

[19] *Dioklecijanov akvedukt*, ed. Joško Belamarić. Split: Ministarstvo kulture Republike Hrvatske, 1999; Petar Požar, »Vodovod do Dioklecijanove palače - od palače do Grada«. *Građevinar* 48/8 (1996): pp. 537-538; Jasenko Zekić, »Vodooskrbni sustav rimske kolonije Pule«. *Nova Istra* 4 (1999): pp. 184-189.

[20] Milorad Medini, *Starine dubrovačke*. Dubrovnik: Štamparija Jadran, 1935: p. 167.

[21] J. Lučić, *Prošlost dubrovačke Astareje*: pp. 15-18.

[22] Marija Planić-Lončarić, »Organizacija prostora i urbanizam«, in: *Zlatno doba Dubrovnika*: *XV i XVI stoljeće*, ed. Vladimir Marković, Margarita Šimat and Ivana Čukman-Nikolić. Zagreb: MTM, 1987: p. 302.

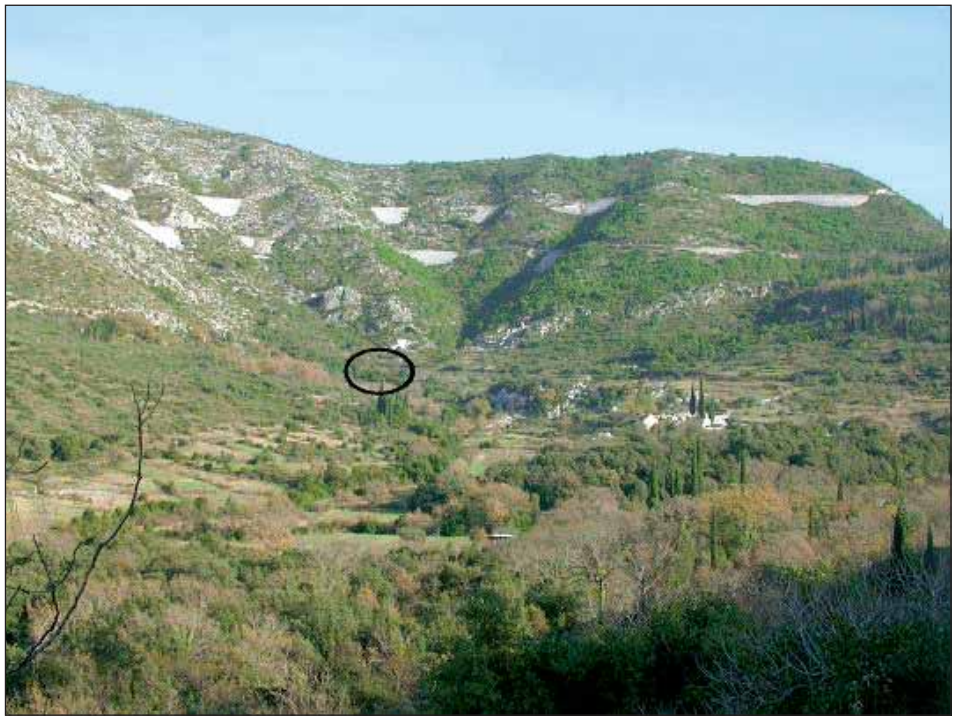

Figure 1: View of Vrelo, spring in Šumet and starting-point of the aqueduct route

Apparently, plan for the construction of a major water supply system in the fifteenth century continued to occupy the minds and communal agendas of the Ragusan senators. Given its geodesic, engineering, urban and sanitary significance, the project no doubt was an epoch-making one. The abundant source of the Ombla River proved inadequate for the purpose, as its location slightly above sea level failed to provide the necessary incline for the water to be distributed to the city. Thus the list of potential locations narrowed down to the zone of Vrelo near Šumet, a village 12 km from the city and at elevation of 109 metres. From there water could be carried to the city by a free-fall aqueduct which, thanks to the layout of the landscape, need not be supported by high stone arches typical of the water supply constructions of the antiquity.

The water zone of Vrelo includes two springs—Baba and Đed—from which water wells up from an underground source bordering the layer of flysch and limestone. These springs never dry out during the long summer months, while

Figure 2: The natural springs of Baba and Đed

in winter jets up to 15 metres high sprinkle the surrounding area with water.[23] Local tradition has it that cows were known to fall victim to the raging torrents of these springs, being pulled downstream Slavjan (*Patagus magnus*). Today not only summers but also winters have become periods of low water, mainly the result of a series of earthquakes in this area of high seismicity, but also because of the organised water consumption in the Herzegovinian hinterland as, for example, the construction of the Grančarevo dam and power plant. At present, Vrelo's optimum stream flow could be compared to its summer minimum from the first few centuries following the building of the water supply.

As requirements for water increased, the realisation of the water supply system could no longer be postponed. The city authorities were to produce a

[23] According to Beritić, Vrelo's discharge varied between the natural minimum of 3-4 litres per second and the winter maximum of 1,500 litres per second. L. Beritić, »Dubrovački vodovod«: pp. 99-116.

person able to carry out this impressive assignment over a fairly short period of time. As chance would have it, contractor Andreuzzo de Bulbito of Tramonte in Apulia was commissioned to build the ceilings of the Rector's Palace in Dubrovnik. He, too, ran the commercial affairs of Jakov Kotruljević, a commoner and distinguished Ragusan businessman on either side of the Adriatic.[24] In dealing with the matters of public interest and welfare, it was the government's established practice to use the advice, acquaintances and connections of its influential citizens, as was here the case. With Bulbito came an experienced engineer from Cava near Naples—Onofrio de Giordano della Cava.[25]

The signing of the construction contract for the future aqueduct between the government of Dubrovnik and the aforementioned foreign experts was preceded by lengthy preparations. The Major Council appointed nobles—*officiales* (surveyors)—presumably men whose experience and expert knowledge could contribute to the successful realisation of the construction works. They were responsible for the preparation of the investment plan, surveyed the land, detected weak spots, provided expenditure estimates, presented the project to the authorities and provided the conditions for its execution. Simultaneously, they were instructed and authorised to negotiate the terms as well as the cost with the master builders (*meštri*). In an attempt to reach a most favourable agreement, the surveyors met with the contractors on a number of occasions. Two surveyors were also responsible for measuring the route of the future aqueduct. Given the significance and volume of the works, the Major Council deemed that the surveyors themselves ought to elaborate the terms of the contract on *Consilium rogatorum* (called also the Senate).[26] The Senate minutes testify to the contract's lengthy preparation but also bargaining, for which the surveyors were mandated. Prior to the signing, both parties met on 16 June 1436 to reconsider and articulate the articles of the final draft.[27] On 20 June 1436, the contract was duly approved and confirmed

[24] Jakov Kotruljević was the father of Benedikt Kotruljević, famous author of the first manual in economy and pioneer of the method of double-entry bookkeeping. See Nenad Vekarić, »Dubrovački rod Kotrulj«, in: *Dubrovčanin Benedikt Kotruljević. Hrvatski i svjetski ekonomist XV. stoljeća*, ed. Vladimir Stipetić. Zagreb: HAZU and Hrvatski računovođa, 1996: pp. 33-52.

[25] F. de Diversis, *Opis slavnoga grada Dubrovnika*: pp. 59-62.

[26] *Acta Consilii Rogatorum*, ser. 3, vol. 6, ff. 57r, 59r (State Archives of Dubrovnik, hereafter cited as: SAD).

[27] Ibidem, f. 60r.

by the Major Council.[28] Clearly formulated, the contract provides information on all the parties involved in this paramount engineering project and their responsibilities. In modern words,

Investor: Dubrovnik Republic

Decision on the investment: Senate (*Consilium rogatorum*)

Investment supervision: three members of the Senate responsible for weekly supervision of the works

Technical consultants: project planning, supervision, expenditures—surveyors (*officiales*) of the quality and cost of the works

Contractors:

Building contractor: Andreuzzo de Bulbito

Architect and chief engineer on the site: Onofrio de Giordano

Foremen, section foremen and chief builders came from abroad, Apulia mainly, while the local community supplied labourers and carriers.

Contract for the construction of aqueduct submitted to the Major Council

The aqueduct construction contract by which water was to be delivered inside the city to a site *magister Adriutius de Bulbito* and *magister Honofrius de Jordano* considered most adequate for a public fountain was read out before the Major Council on 20 June 1436.[29] The contract had previously been revised by *Consilium rogatorum* and upon its prompting was shortened considerably.[30] The text details the structure to be undertaken—aqueduct from the spring in Šumet to the fountain inside the city walls, overall expenditure in monetary value (8,250 ducats),[31] and the deadline by which the works were to be completed (October 1437).

---

[28] *Acta Consilii Maioris*, ser. 8, vol. 5, ff. 79v-81v (SAD). The original text of the contract was published by Risto Jeremić and Jorjo Tadić, *Prilozi za istoriju zdravstvene kulture starog Dubrovnika*, vol. III. Beograd: Biblioteka Centralnog higijenskog zavoda, 1940: pp. 11-14.

[29] *Acta Consilii Maioris*, vol. 5, f. 79v.

[30] *Acta Consilii Rogatorum*, vol. 6, f. 57r.

[31] From its first mint in 1284 until the end of the Republic, the gold Venetian ducat remained the basic currency in Dubrovnik. It served as a standard unit of account, and was used for the payment of higher sums. The quality of the Venetian ducat varied little over the centuries, and with minor deviations was of the finest purity. Unlike silver coins which were subject to devaluation, Venetian ducat was a steady currency. Milan Rešetar, *Dubrovačka numizmatika*, I. Sremski Karlovci: Srpska manastirska štamparija, 1924: pp. 470-473.

The items defined the necessary construction characteristics: dimensions of the water-supply canal, its sides, technology of watertight lining, covering of the canal with uncut stones, construction of small distribution reservoirs every half-a-mile, etc. The quality to be obtained was easily formulated: the quantity of water conveyed at the source was to be discharged at the aqueduct's end, in the city. Otherwise, the contractors agreed to refund the large costs. The contract fails to mention the payment of penalties in case the works were not completed by the set date.

The analysis of the construction costs distinguishes three major expenditures: building materials, labour fees and equipment (tools, transport, scaffolding). Most of the building material could be found along the aqueduct route or in its vicinity, and under the terms of the contract the contractors were allowed to exploit stone, lime, aggregate clay and sand without any compensation. Lime was produced in a kiln by the route. By the permission of the Republic, wood from the surroundings was exploited. Red clay as an aggregate with mortar was found on different sites, most likely in the Šumet valley itself. Highly valued was the reddish clay from Župa dubrovačka.[33] Brick and similar building material was used in particular sections only and had to be obtained from elsewhere, for which the contractors demanded the same purchase price as the ones the Republic obtained from the local manufacturers. The supply of cut stone was also among Republic's expenditures. The builders were not subject to compensation claims for the damages of vineyards, orchards or other property through which the canal passed. Apart from master builders, Andreuzzo de Bulbito and Onofrio de Giordano, the construction team included skilled stone masons commissioned from Apulia and elsewhere, foreigners mainly, along with the less skilled local labour, as indicated by the substantial labour costs in the overall expenditure.

For the accommodation of the stone masons commissioned from Apulia the contractors required two houses at a reasonable annual rent of between 30 and 40 perpers, one of which was to be in the City, suburb of Pile or Ploče, and the other near the construction site, probably in Šumet, where the most demanding works of the whole project were to be carried out. Bulbito, who spent most of his time in the City, and Onofrio, who was irreplaceable on the demanding section of the water supply in Šumet and the surrounding area,

[32] As evidenced by Hrvoje Macan, civil engineer, who took part in the reconstruction of the reservoir and the mill in Posat (formerly Ulica od Mlina).

had with them a certain number of stone masons, Italians and other foreigners, who resided in the mentioned houses. The employed labour, peasants mostly, came from the villages along the construction route. Provisions such as food and particularly wine were among higher expenditure items covered by the contractors. The consumption and cost of wine being set at two *quinqua* per worker, the contractors asked for a monthly purchase of 150 *quinqua* from the wineries of Ston and Pelješac, so as to avoid the higher price at the local retailers.[33] The contract benefitted the contractors in that their workers could not be recalled to some other communal site before they completed the work on the aqueduct.

The proposed overall cost, duly approved by the Ragusan government, amounted to 8,250 Venetian ducats in instalments: 1,000 ducats in advance, 2,000 ducats upon the completion of one-quarter of the works, 2,000 ducats halfway, 2,000 ducats upon the completion of three-quarters of the project, and the remaining 1,250 ducats when the aqueduct was completed. It was on 24 June 1436 that *magister* Onofrio de Giordano and Ivan Kotrulj,[34] legal representative of Adreuzzo de Bulbito, received the advance from the Republic treasurers.

The details of the contract reveal that all the parties involved in the project—builders, contractor Bulbito and designer and engineer Onofrio de Giordano together with the surveyors appointed by *Consilium rogatorum*—had fully mastered their part of the assignment as well as the conditions on the site. In order to convey water over irregular terrain, the contract bounded the construction of passages and tunnels if necessary, but also high walls so as to traverse depressions or unstable surfaces as in the first one-mile section from the spring.

The first quarter of the works on the aqueduct was completed on 6 December 1436, when the contractors Onofrio de Giordano and Andreuzzo de Bulbito received and confirmed the payment of the second instalment. Halfway through the project, on 12 January 1437, Onofrio de Giordano confirmed the payment of the third instalment. The completion of three-quarters of the overall works and the receipt of the fourth instalment was signed on 9 May 1437 by Onofrio

[33] Large *quinquum* was equivalent to 21 litres, and the small one to 18.75 litres. According to Diversi, the builders consumed 200 *quinqua* of wine per month or approximately 4,000 litres (*Opis slavnoga grada Dubrovnika*: p. 60).

[34] Ivan Kotrulj (1404-1451) was Jakov's brother—that is, uncle of the well-known economic writer Benedikt Kotruljević. See: N. Vekarić, »Dubrovački rod Kotrulj«: pp. 33-52.

de Giordano and Ivan Kotrulj as Bulbito's representative. The last instalment of 1,500 ducats was disbursed on 26 October 1437, an amount exceeding the agreed price for 250 ducats. These ducats were to cover the cost of the fountain construction, as formerly decided by *Consilium rogatorum*. It is amazing how the engineers could approximate the last days of October 1437 as their deadline, and even more so managed to meet it. The disbursement of the final instalment took place on 26 October 1437, which implies that the aqueduct may have been completed several days earlier, for in the meanwhile the surveyors had to inspect the site. This fact unquestionably shows that it was on this day that the aqueduct delivered water inside the city walls.

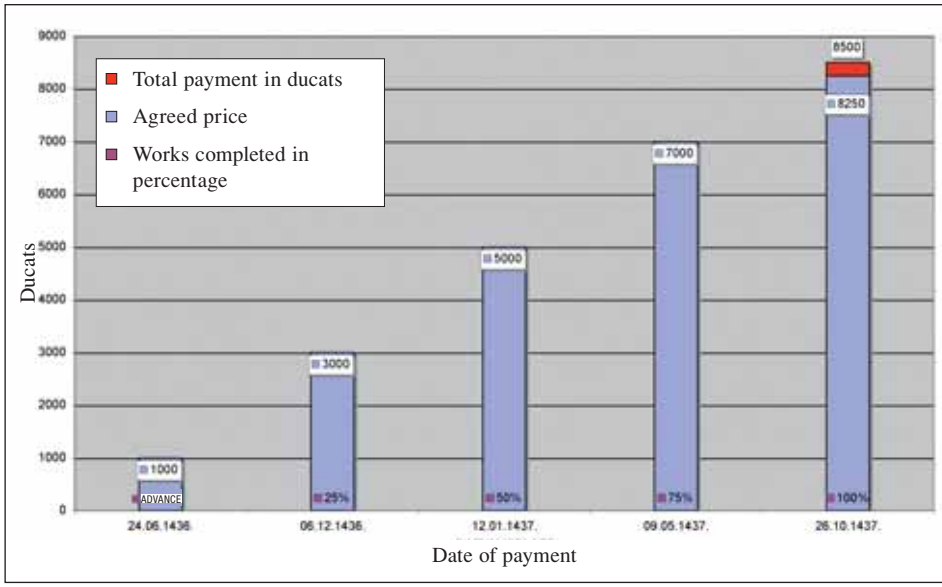

Table 1: Payment of the instalments for the construction of the aqueduct

Course of the construction

The construction of an 11,700 metre-long aqueduct closely followed the ground's surface practically along its entire route, and mainly consisted of buttresses that supported the canal. From the engineering perspective, the first kilometre proved the most difficult as, due to unstable terrain, the canal winds through the flysch. Apart from torrents and floods during the rainy months, above this part of the route are several smaller springs—Vrijesna glavica, Plazine and Marcino—also active during summer. As they represented a potential threat to the aqueduct's buttress, it was decided to divert these waters

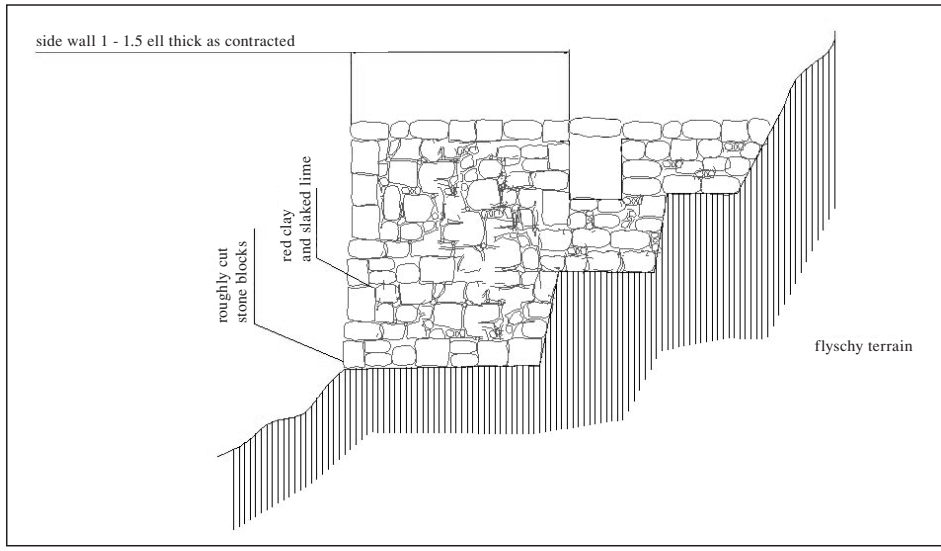

Figure 3: Typical cross section of the canal built on the flysch

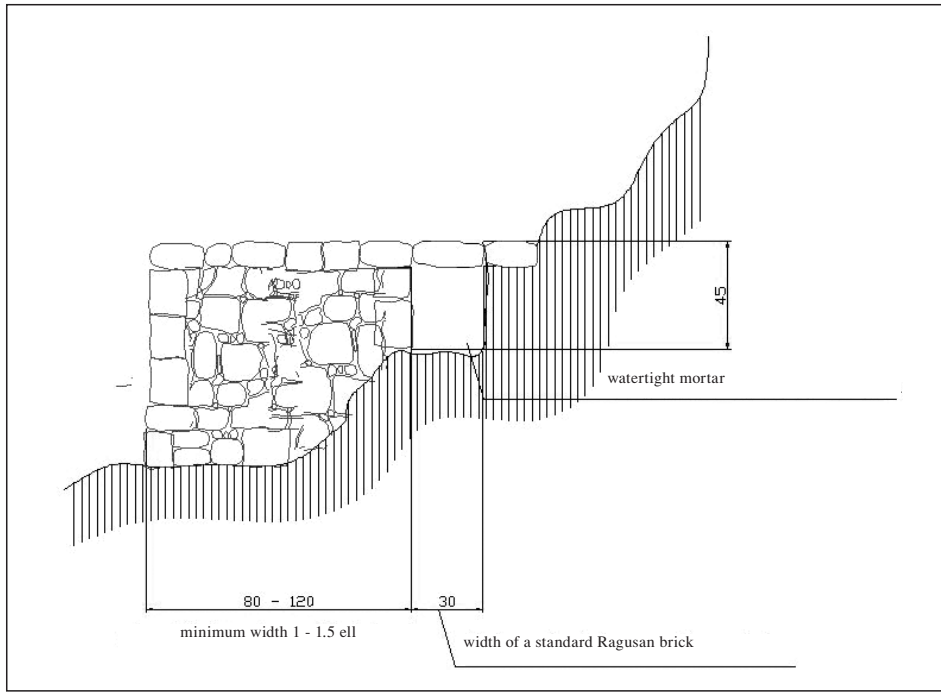

Figure 4: Typical cross section of the canal built on bedrock

Figure 5: Initial part of the aqueduct route on flyschy terrain

for the original purpose as well. The chief engineer was well aware that if the ground here sank, the whole water system would collapse. Following the first kilometre, excavation in limerock was made, which contributed to the construction's stability and safety. The size of the buttresses was the smallest possible, allowing for the building of a closed stone canal, the top of which could be used for communication purposes.

Considering its 12-kilometre length and the set deadline, the construction was launched on several sites at the same time in order to meet the daily norm of 30 metres, the whole route being completed in 16 months. One should bear in mind that, without Sundays, holidays as well as cold and rainy winter days (the bulk of the works was to be undertaken through autumn and winter of 1436/7), the contractors had 400 weekdays ahead of them. Severe cold nor outbreak of plague could distract the builders from completing half of the construction by mid-winter, on 12 January 1437. The epidemic, however, abated by the summer of the same year, as testified by Philippus de Diversis.[35]

[35] *Opis slavnoga grada Dubrovnika*: pp. 42 and 98.

Figure 6: Buttress of the aqueduct route

Apparently, there were three main construction sections: Šumet, Rijeka dubrovačka, and the last section from Nuncijata to the end of the canal. On 16 July 1436, *Consilium rogatorum* appointed three noblemen to oversee certain section every week. Horses and travel expenses of 18 grossi per day were provided by the municipality. Andrija Bobali, Marin Resti and Jakov Giorgi were chosen for the duty. The fact that each of the mentioned patricians made a regular weekly inspection of the site leads to an assumption that each of them controlled his own 3- to 4-kilometer section. On 4 August 1436, additional five patricians were appointed: Ivan Zrieva, Paladin Gondola, Petar Menze, Damjan Sorgo and Nikola Caboga.[36] It was through them that *Consilium rogatorum* controlled most directly the execution of the project.

Early-Renaissance Dubrovnik aqueduct, as designed and laid out by masters Bulbito and Onofrio, was no doubt a challenging geo-engineering project,

[36] *Acta Consilii Rogatorum*, vol. 6, ff. 70v-71r. Philippus de Diversis mentions the noblemen Paladin Gondola and Marin Resti as surveyors appointed by the Senate to sign the contract with the builders of the aqueduct (*Opis slavnoga grada Dubrovnika*: p. 60).

Figure 7: Contours of the earth-covered canal

because the grade line, due to relatively small elevation difference between the source and the point where the canal entered the city, had to be most carefully calculated. In this respect, the opening of several parallel construction sites ran the risk of error which could bring the functioning of the aqueduct into question. In order to convey water to the City it was not necessary to

traverse larger barriers or depressions. Should such a situation arise, under the contract terms the aqueduct was to be supported by arches. To facilitate construction, higher buttresses and arches were built only on few locations: at the outskirts of Šumet, between the small reservoir and the Minčeta Tower, and at the location where the aqueduct from the city wall entered the Great Fountain. Judging by the epithets the city authorities used to describe the engineers and builders—good and intelligent—and their results as equally 'good', the investors were pleased with both the course of the construction and the quality attained.[37]

Problems, however, did arise. On 2 August 1436, *Consilium rogatorum* decided to punish accordingly all those intruding on the aqueduct, with special emphasis on the population of the local villages. On this occasion the Senate even authorised the Rector and the Minor Council to examine the offenders "by torture also, or without it … according to the seriousness of the offence and to their own judgement".[38] Only a few days later, on 24 August, the Senate decided to release the villagers of Šumet imprisoned on account of the aqueduct.[39] Some of the actions were filed by Onofrio himself. Thus, acting upon the complaint filed by Onofrio, on 9 September 1436 the Senate ordered that the inhabitants of Šumet be interrogated under torture.[40] They were released a week later, on 17 September.[41]

The fact that this capital engineering project met with resistance from the villagers of Šumet may, unquestionably, be attributed to the actions of the builders themselves. On the Senate's meeting agenda of 1 October 1436 was a case of an unnamed poor widow whose house had been destroyed during the construction. It was decided that the Rector and the Minor Council were to hear Onofrio's testimony and have her house rebuilt.[42] The proposal on having the municipality rebuilt the house of an unnamed widow from Šumet was approved on the next Senate session until decided whether the municipality or Onofrio himself should cover the costs. It was also decided to send a good

[37] *Acta Consilii Rogatorum*, vol. 6, f. 80v.

[38] *cum tortura et sine… prout facti qualitas exigit et ipsis melius videbitur* (ibidem, f. 73r).

[39] *Prima pars est de franchando illos de Zoncheto qui carcerati sunt pro conductu aque* (ibidem, f. 75v).

[40] *…pro querela facta per magistrum Nofrium…de examinando diligentius cum tortura…* (ibidem, f. 77v).

[41] Ibidem, f. 78v.

[42] *… pro domo ... cuidam pauperrime vidue destructe in conducendo aquam de Zoncheto, cum quo laborerio pertransitum est per ipsam domum…* (ibidem, f. 79r).

and skilled mason to oversee the works and make sure that the structure was solid and of lasting quality.[43]

The project proved an excellent investment. The route of the conduit supported by buttresses is approximately 1.5 metre in width, allowing for communication along the canal not only for repair or maintenance, but as a footpath leading from the City to Rijeka dubrovačka, and ultimately to Šumet.[44] The canal was not built to a standard profile, as its dimensions were known to vary and approximated to 30 x 45 cm. In its entire length of 11,700 metres from Vrelo to the Mlini reservoir, the aqueduct was built to a U-shaped cross section. According to Lukša Beritić, the size of its cross section provided for a winter maxima of 70 litres per second.[45] The canal was built of cut and roughly cut stones, lined with red clay as aggregate and slaked lime as hydraulic cement.[46] There is no evidence as to whether on the technically more demanding sections (excessive discharge causing erosion) the builders used volcanic ash as hydraulic cement, also applied in the construction of the Kaše breakwater in the City port. The canal was lined with exceptionally good watertight mortar, the quality of which has been retained to our day. Mortar of this kind, used for the construction of aqueducts in antiquity, the Ragusans had previously used in the building of cisterns. The canal was closed with flat stone blocks, cemented and lined with the same mortar—that is, a combination of red clay and lime.

Unauthorised draining of water along the conduit for livestock or irrigation was regulated in 1443, when the government passed strict measures governing the utilisation of aqueduct. Anyone attempting to open, damage or choke the flow of the aqueduct may have been punished by the cutting of his right arm.[47]

---

[43] *… murari debeat et laborari dictus aqueductus pulcro et durabili modo prout ipsi magistri aqueductus facere tenentur et nobis obligati sunt* (ibidem, f. 80v).

[44] Serafino Razzi, Italian Dominican friar, strolled along the aqueduct route in 1587, enjoying the beauty of Rijeka dubrovačka. Cp. Serafino Razzi, *La storia di Ragusa*. Ragusa: Tipografia Serbo-Ragusea, 1903: pp. 216-217.

[45] L. Beritić, »Dubrovački vodovod«: p. 101. This astonishing quantity implies that a dweller of early-Renaissance Dubrovnik had a lavish winter supply of water equal to that of a Roman consumer: one cubic metre per capita per day. In dry season, however, water supply was drastically reduced.

[46] Red clay is of medium to high plasticity with small fragments of nonclastic limestone. On this see Ervin Nonveiller, *Mehanika tla i temeljenje građevina*. Zagreb: Školska knjiga, 1979: p. 43.

[47] *Liber viridis*, ed. Branislav M. Nedeljković. Beograd: SANU, 1984: pp. 288-290 (c. 341). See also R. Jeremić – J. Tadić, *Prilozi za istoriju zdravstvene kulture starog Dubrovnika*, I: p. 43; L. Beritić, »Dubrovački vodovod«: p. 102.

Figure 8: Traversed depression in Šumet

As early as 17 November 1440 the Senate established a post of the aqueduct supervisor.[48] Apparently, his responsibilities later extended to the repairs of the canals and mills. In his *Prolegomena in sacram metropolim Ragusinam*, great Ragusan historian Serafin Cerva made a record of this, stressing that an office for water supplies was established around 1440, to which three young patricians were elected.[49]

On leaving Šumet it was necessary to traverse a larger depression. The engineers, however, did not opt for the arch-supported construction but a 30-metre long and about 15-metre high stone wall, with a minor semi-circular outlet for surface water. That was also the only larger free-standing construction that Bulbito and Onofrio had to build, in addition to several storage reservoirs along the route and at the very source, as well as an aqueduct-traversed passage that connected the smaller reservoir with the Minčeta Tower. On the spots where the muddy surface waters flowed over the canal, it was closed with

[48] *Acta Consilii Rogatorum*, vol. 7, f. 202r.

[49] Library of the Dominican Friary in Dubrovnik, MS 36-IV-13, p. 83.

Figure 9: Reservoir above Gruž

concave stone blocks which prevented the fresh water from contamination. Several storage reservoirs were built along the route, only three of which—the so-called 'deposits'—still exist. A compensation reservoir was built at the very source, of which no remains have survived. Another reservoir was built on the locality known as *Pod Nuncijatom* where the aqueduct leaves the section of Rijeka dubrovačka and enters Gruž. The next stood on the site where the Bay of Gruž opens (commonly known as 'Depozit'). Before the aqueduct descended over the Srđ slopes to the City an even larger reservoir was built in front of the house of Pietro Pantella, cloth manufacturer.

Several outlets were constructed along the route, equipped with troughs for cattle watering or washing. They could be used only if the amount of water sufficed for the excess to be let out at this level. These outlets with stone containers remained in use until the middle of the twentieth century. None have survived the increasing urbanisation along both sides of the conduit route in the mid-twentieth century, the aqueduct itself having served as an access road to most of the new houses.

Figure 10: Layout of the aqueduct route with the springs indicated on topographic chart

Beneficent powers of water

Once the canal had been completed, the Senate became increasingly concerned with the building of mills and two public fountains inside the city walls. By this time the name of Andreuzzo de Bulbito could no longer be traced in the documents, because on 4 August 1439 the members of *Consilium rogatorum* cancelled his services. Thenceforward the entire water project rested upon a single name, that of Onofrio della Cava.[50] Apparently, disagreements between Andreuzzo and Onofrio arose as early as December of 1438, when Pietro Pantella, well-known weaver, and Aniel Cichapessi, weaver and well-off merchant of Naples with residence in Dubrovnik, were asked to arbitrate in the dispute. As Andreuzzi's replacement, master Jacopo de Venusio Correr of Trani was soon commissioned to complete one-quarter of the task involving the installment of the carved stone fountain, at a fee of 60 perpers.[51]

[50] *Acta Consilii Rogatorum*, vol. 7, f. 82r.

[51] Renata Novak Klemenčič, »Dubrovniška velika fontana«. *Zbornik za umetnosno zgodovino* N.S. 39 (2003): p. 80, citing *Diversa Notariae*, ser. 26, vol. 22, ff. 132v-133r (SAD).

Figure 11: Uz Mline (‘Up the Mills’)

Figure 12: The site of the first mill and parts of the aqueduct that carried water inside the City

Figure 13: Remains of the first mill

Figure 14: Minčeta Tower through which water was distributed to the City (the sealed opening)

In *Ulica od mlinova* ('The Street of Mills'), facing the Minčeta Tower, there was a smaller storage reservoir supplying the first of the four mills in a row. The plan included the construction of ten additional mills, as well as thirteen rolling and washing cloth workshops, a tiny house and bakery, as itemised by the contract Onofrio di Giordano della Cava had submitted before *Consilium rogatorum* on 15 December 1442.[52]

From this reservoir at a higher level, also known as Mala Minčeta ('Small Minčeta'), water was diverted to the mills and textile workshops in the small bay of Kolorina. The pipe-line distributing water to the City was at a lower reservoir level. A three- or possibly four-arched aqueduct conveyed water to the Minčeta Tower, from where the canal descended along the inner side of the city wall to Pile. Still visible is a tiny door leading to the reservoir's interior, from which it was possible to control the quantity of water distributed to the City–that is, reduce it to facilitate the operating of the mills.

[52] *Acta Consilii Rogatorum*, vol. 8, ff. 183v-185r.

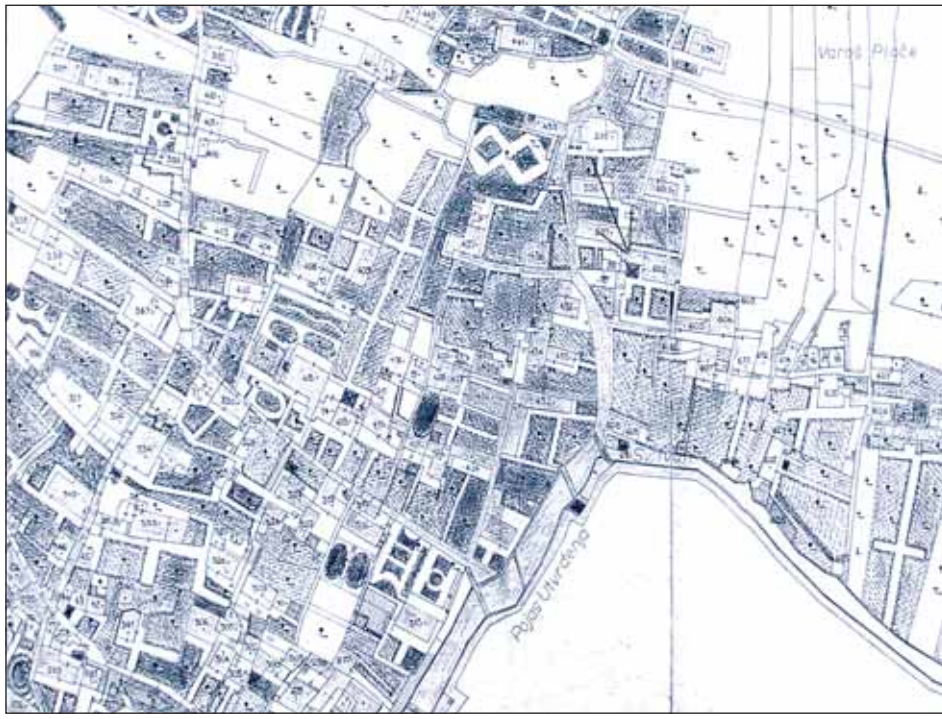

Figure 15: Geodetic chart from the period of Austrian rule 1837-1878, indicating part of the water supply route

The western slopes of Mount Srđ through which the aqueduct descended and approached the City was declared protected zone and property of the state. As such, construction of any kind was prohibited here until the middle of the eighteenth century. Geotechnically, the slopes were secured by drainage ditches, still visible. It is after them that this street has been named Posat (after Ital. *fossato* – water ditch). The canal route bringing water to Kolorina at Pile was remodelled during Austrian rule in the nineteenth century, in that this part of the canal was shifted to the edge of the quarry, towards the site of today's Posat, where it has been recently reconstructed.

Inside the Minčeta Tower water was diverted into two flows. However, the tower itself was never used as a reservoir, as erroneously assumed by certain authors.[53] The first pipe-line descended along the inner side of the western city

[53] Branka Beović, »Opskrba vodom u vrijeme prije izgradnje vodovoda«. *Hrvatske vode* 12/48 (2004): pp. 269-278.

Figure 16: Canal route towards Kolorina

walls, entering the City from the west. Adjoining a three-metre high and one-metre wide wall inside the Franciscan monastic complex there still stand the well-preserved remains of a settling basin (there were several in the City area). From there the canal conveyed water along a newly-built wall, as depicted on the picture of Dubrovnik in the Franciscan Museum (before the 1667 earthquake). Water was transported to the Great Fountain by a stone conduit along the inner side of the city walls. As Philippus de Diversis implied, the Great Fountain was built in front of the Convent of St Clare, for that site proved most convenient for the erection of such a magnificant structure.[54] The second canal carried water from Minčeta along the northern city walls towards the eastern part of the City, supplying a well on the site later known as Buža or northern City Gates, opened in 1908. Water supply was essential to the many skinners who inhabited Peline—street running below the northern city walls. The canal diverted again: one route delivered water to the Dominican Monastery and Revelin Fortress, while the other carried water along Zlatarićeva

[54] *Opis slavnoga grada Dubrovnika*: p. 60.

ulica to the reservoir located in the immediate vicinity of St Nicholas Church in Prijeko—the site of the former salt warehouse. From there a lead pipe-line conveyed water to the Small Fountain, the work of Pietro di Martino from Milan, twenty years after Onofrio had completed the Great Fountain.[55]

The Great Fountain, crown of the water supply project, was completed by Onofrio della Cava once the works on the aqueduct route had come to an end. On 7 February 1438, Onofrio and eight surveyors signed the contract for the erection of the Great Fountain.[56] Yet, the volume of his work on the Rector's Palace forced him to sign a contract with Bellus della Cava on 29 October 1438, commissioning him to complete the fountain under the terms of the contract made between Onofrio and the city authorities, bring water from the Great Fountain to Loggia, and install another fountain there.[57] Despite Onofrio's commission on the Rector's Palace, in August 1439 the Senate demanded that he resumed his work on the Great Fountain and had it completed by January 1441, when he received his final instalment.[58] Viewed architecturally, the Great Fountain was designed as a simple polygon with sixteen spouts, fitting perfectly into the space between the Franciscan Monastery and the Convent of St Clare.[59]

On 31 August 1442 master Onofrio testified before judge Župan Bona and Nikola Stella that, on behalf of the Dubrovnik municipality, he had received from Petar Bona and other surveyors of the water supply works an amount of 725 golden ducats as a remainder and final disbursement of the aqueduct

---

[55] Igor Fisković, *Reljef renesansnog Dubrovnika*. Dubrovnik: Matica hrvatska Dubrovnik, 1993: p. 126. Today's location of the Small Fountain is an urban curiosity. Designed as an octagon, each side depicts in low relief a manner in which water was carried from the fountain. Given the shape, the fountain should stand in the middle of a square, or at least in a space providing free access to all of its eight spouts. Its current position (the fountain virtually leans onto the adjacent building), hinders the use of three spouts. At the time of its erection, the site was occupied by a building which no longer exists, and contrary to the assumptions, must have been farther apart from the fountain, for it would bring into question the architectural skill of Pietro di Martino and his ability to establish harmony between the fountain's shape and the urban space in which it was installed. According to the painting representing Dubrovnik before the 1667 earthquake, there seems to have been enough space around the Small Fountain allowing access to all of its spouts, no longer possible.

[56] The text of the contract was published by R. Jeremić i J. Tadić, *Prilozi za istoriju*, III: pp. 15-18, as well as by R. Novak Klemenčič, »Dubrovniška velika fontana«: pp. 83-86.

[57] R. Novak Klemenčič »Dubrovniška velika fontana«: p. 81. The author points to the fact that Bellus della Cava also built the water supply of the Monastery of St Mary in Rožat.

[58] R. Novak Klemenčič, »Dubrovniška velika fontana«: pp. 81-82.

[59] On the fountain see R. Novak Klemenčič, »Dubrovniška velika fontana«: pp. 60-77.

Figure 17: Canal on the inner side of the city walls

expenditures. The statement Nalko Nale, representative of Andreuzzo de Bulbito, gave on 14 October 1442 concerning the payment corresponds to that of Onofrio.[60] Upon the completion of works, as he was earning a state salary for two years, by the contract with *Consilium rogatorum* master Onofrio was to be granted an 8-year concession on the structures, canals and the two fountains for an annual amount of 1,200 perpers.[61] In other words, the state was to finance the construction of the mills and other works with 8,000 perpers, which Onofrio was to take into concession for a period of eight years and the total cost of 9,600 perpers.[62]

The construction contract for the flour and fulling mills signed with the Senate on 1442 bound Onofrio della Cava to complete the works by the end of 1444. Similar to the terms defining the *aquaeductus magnus* contract, this agreement imposed no penalties for the breach of dead-line. Yet the contract

[60] *Acta Consilii Maioris*, vol. 5, f. 80v.

[61] *Acta Consilii Rogatorum*, vol. 8, ff. 183r-185r.

[62] At the time of the aqueduct's construction, a Venetian gold ducat equalled three silver perpers. See: M. Rešetar, *Dubrovačka numizmatika* I: pp. 470-473.

Figure 18: Settling basin within the Franciscan complex

did underline that a possible overdue caused by insufficient funds, outbreak of plague or war would be taken into consideration. This was a project the state was willing to finance with 8,000 perpers on Onofrio's terms.[63] The Senate granted an eight-year concession with effect from 1 August 1444. The

[63] *Acta Consilii Rogatorum*, vol. 8, f. 185r.

Figure 19: Remains of the canal on the inner side of the city walls that carried water to the Great Fountain

agreement bound Onofrio to restrict certain fees (for instance, grinding of wheat could not be charged more than 3 grossi a *starium* (equivalent to about 150 pounds) in June, July, August and September, and 1,5 grossi rest of the year, whereas bleaching in the earlier-mentioned months could be charged 1 perper, and 7 grossi rest of the year; equally defined was the fee for washing wool and other cloths.[64] The contract bound Onofrio to secure a sufficient supply of water for both fountains (the second of which on the eastern end of Placa had not yet been installed) in the period between an hour before dawn and 2 in the morning, meaning that during most of the night (from about 8 in the evening to 4 in the morning) he had no restriction on the water consumption.

Repair expenditures Onofrio was to cover himself, while the flour and fulling mills as well as other buildings under his concession could not be let out to another person. Onofrio was to receive an annual salary of 300 perpers

[64] One *starium* of grain weighed 71.5 kg, and one star of rye 64.5 kg (source: I. Žile, »Arheološki nalazi unutar perimetra povijesne jezgre grada Dubrovnika«: p. 341).

plus 16 grossi for each day spent on the public construction sites, and was obliged to go wherever the Major Council commissioned him. He was allowed a four-month leave to visit his family (apparently in Italy at the time), his absence from work also being covered by the salary. In case of pestilence, Onofrio was permitted to take an absence leave as long as the circumstances required. The signing of the contract also implied Ragusan citizenship for Onofrio and his family, with the responsibilities this status entailed and the formalities suiting such occasions.[65]

From the reservoir opposite the Minčeta Tower a separate branch of the aqueduct carried water to Kolorina, at Pile. Onofrio agreed the building of this canal in February 1442, and had it completed by April that same year.[66] According to the contract, the quantity of water diverted to Kolorina was consumed and paid by the weavers and dyers Aniel Cichapessi,[67] Vladislav Gozze, Pietro Pantella, Đuho Đunković and Petar Luetić. Water was discharged into their wells (*pucali*), two of which were used by Pantella and others had one each. As the water from the existing wells could not meet the requirements of dyeing, the canal conveying water from the main aqueduct to their workshops gave a fresh impetus to Dubrovnik's textile industry.[68] Apparently, that same year Onofrio della Cava built four mills and was even planning another ten fulling mills (which Lukša Beritić assumes to have been built), noting that for their operating more springs would have to be tapped to increase the water supply.[69]

Located in the immediate vicinity, the flour mills could easily meet the City's large daily requirements of bread, as well as hardtack for the crews that sailed in and out of Dubrovnik's busy port. From the small reservoir in the 'Street of the Mills' water powered the first mill located exactly below the reservoir facing the Minčeta Tower, whose remains are clearly visible after recent reconstruction. The mill itself was a one-storey building, as witnessed by the recesses of the floor beams. Sacks full of grain ready to be ground were

[65] *Acta Consilii Rogatorum*, vol. 8, f. 185r.

[66] *Diversa Notariae*, vol. 25, f. 188r; compare R. Jeremić-J. Tadić, *Prilozi za istoriju*, I: p. 42.

[67] Merchant and weaver Cichapessi traded on credit in Dubrovnik as early as 1470. Ignacij Voje, *Poslovna uspešnost trgovcev v srednjeveškem Dubrovniku*. Ljubljana: Znanstveni inštitut Filozofske fakultete, 2003: p. 121.

[68] *Diversa Notariae*, vol. 25, f. 188r.

[69] *Acta Consilii Rogatorum*, vol. 8, f. 183r-185r. Cf. R. Jeremić-J. Tadić, *Prilozi za istoriju* I: p. 44.

Figure 20: The site of the reservoir ('Depozit');
salt warehouse adjoining the Church of St Nicholas

probably stored on the upper floor. Water dropped from a large height of 3.5 metres, considering that the mills in Župa dubrovačka were driven by 1 or 1.5 metre waterfalls. Having powered the first mill, water was carried down a fairly steep canal to the next mill, of which, unfortunately, no remains have survived, mainly because of the large-scale ditch dug around the City and the Minčeta Tower in the nineteenth century. Remains of possibly the lowest mill are discernible below the *Gornji Ugao* Tower facing north, at elevation of about 15 metres below the first mill. The plan of building another ten mills was obviously never executed, presumably because of the lack of funds or more likely because of insufficient water discharge. Water powering the mills was either delivered to the fountain in Pile or was discharged into a well which provided water for the hospice for the poor. All things considering, it would be difficult to assume that the Ragusans, renowned for their concern for rational water consumption, would allow such large quantities of uncontaminated water utilised for industrial purposes to be wasted.

Water was widely used for industrial purposes in the then Dubrovnik Republic. Fifteen mills were built on the falls of the Ljuta River in Konavle. Two streams in Župa powered flour mills though only in winter months. Unlike the stream in Mlini which powered as many as seventeen mills and varied seasonally, the discharge of the River Ombla in Rijeka dubrovačka has shown minimum fluctuation over the centuries. Accordingly, its waters powered six mills irrespective of the season and were also used for cloth dyeing. The spring in the Bay of Zaton powered four mills during rainy seasons. A calm stream by the name of Kono flows through Ston's field, supplying the Ston public fountain with water. There used to be two mills on it, while on the rest of the Pelješac Peninsula grain was ground manually, as on the Dubrovnik islands.[70]

First reconstructions of the aqueduct

Unfortunately, Dubrovnik's water needs could only be met in the short rainy season, while the discharge in the dry summer months was grossly deficient –water tended to heat up and was often contaminated. According to more recent estimates, summer discharge of all the springs feeding the aqueduct amounted to 5 litres per second, most definitely an inadequate water supply for Dubrovnik's population, let alone for its industry.[71] However, one should bear in mind that the source's capacity dropped over the centuries for reasons already mentioned. Shortage of water was probably the main reason why, despite seemingly agreeable terms, Onofrio de Giordano della Cava failed to sign the contract with the Dubrovnik Republic concerning concession of the mills and other water supply structures and, following the completion of the Great Fountain, returned to Italy in 1443. The water supply system constructed in the form of a longitudinal canal delivering water to the City failed to meet the water demands of the mills and workshops, some of which moved to the mouth of the Ombla River. Despite the possibility of diverting water from the reservoir opposite the Minčeta Tower to the mills during the night hours, during the day, however, the City had to be supplied with a sufficient amount, the

[70] Lorenzo Vitelleschi, *Povijesne i statističke bilješke o dubrovačkom okružju*. Dubrovnik: Matica hrvatska Dubrovnik, Državni arhiv u Dubrovniku, 2002: p. 1.

[71] Data on the aqueduct discharge have been traced in the 1940 and 1954 records of engineer Josip Ježov, former employer of Dubrovnik's Public Water Supplies, kindly supplied by engineer Ilija Knežević, current employer.

surplus being diverted for the mills and workshops. Rainy years as well as the usual seasonal rainfall—end of autumn, winter and early spring—produced an adequate supply of water for both the population and the workshops, but in dry season the source minimum could not even remotely meet the aqueduct's capacity.

For this reason, less than twenty years after the Šumet aqueduct had been completed, Ragusan government started making plans to increase the water supply by tapping more springs and extending the canal. The plan involved the upstream source zone of Bota, 1.3 km north of Vrelo, including the springs of Orahovac and Račevica that never ran dry. The latter or *patago Lastre*, commonly referred to by older sources, wells up from the hill of Lastra. The new extension of the aqueduct along the north-south axis towards the sources Bota, Orahovac and Račevica, the so-called '*novi kono*' (new canal), traversed an even more dangerous terrain and landslide, thus prolonging its building and witnessing a number of reconstructions and remodellings. Apart from technical problems, the reason why the construction was prolonged by almost a hundred years probably lies in the fact that Dubrovnik's problem of water was not as acute as it used to be in the first half of the fifteenth century when masters Bulbito and Onofrio were building it, and because the source zones they intended to embrace with the new canal were not as abundant as Šumet's Vrelo, bringing such an investment into question. The completion of the new canal and its joining to the old must have initiated the problem of mills located in the western extramural area which could not operate in dry season. The joining of the new and old canal was yet another challenge to the engineers. A high wall exceeding in height the source zone of Vrelo was built in such a way that below Vrelo a semi-circular outlet supported by two arches was constructed to prevent the high winter waters of Vrelo from destroying the wall and the new canal on it, which may have taken place in the course of the construction of the new section. *Consilium rogatorum* often discussed this problem. Successful reconstruction or rather renovation of the new aqueduct section which suffered from landslide was undertaken by master Pasquale of Naples in 1550. Namely, on 21 October 1550, the Senate unanimously accepted the instructions for the aqueduct surveyors, in which the work of master Pasquale was mentioned.[72]

[72] R. Jeremić-J. Tadić, *Prilozi za istoriju* III: pp. 27-29.

Conclusion

Early Renaissance aqueduct of Dubrovnik was a typical large-scale communal project undertaken by a small state such as that of the Dubrovnik Republic, with a population estimate of 50-60,000 in the first half of the fifteenth century,[73] the City itself 6,000 in the mid-fifteenth century.[74] The building of an aqueduct improved the living conditions of its dwellers and allowed the growth of industry. The installing of cloth mills at Pile spurred the development of wool industry. Large supplies of fresh water delivered to the city fountains transformed the prevailing conditions of public (and individual) hygiene. Water as an urban design element added to the already advanced level of architectural expression, gratifying the city atmosphere with its murmur.

Government's determination to undertake such a project, the senators' estimate on its feasibility, promptly secured funds facilitating short deadline accompanied by speedily brought decisions following the necessary administrative procedures testify to a highly responsible and efficient government which competently and without hesitation led this project to its realisation. Symbolically, the project of the Ragusan aqueduct marked the beginning of the Republic's Golden Era. Although the water elements were not as elaborately designed as the fountains of the Late Renaissance adorned with mythological motifs, cascades and waterfalls in, for example, the gardens of the Villa d'Este,[75] the magnificance and size of Onofrio's Great Fountain dominated the new urban structure of the City. Its sixteen spouts attracted people of diverse social strata and trade, locals and foreigners alike.[76] Moreover, fountain was a gathering place even at night, as evidenced by one of Marin Držić's best comedies, *Novela od Stanca,* in which the fountain itself was

---

[73] In the first half of the fifteenth century Dubrovnik Republic had 50-60,000 inhabitants, and more than 80,000 by the turn of the century (Nenad Vekarić, »Broj stanovnika Dubrovačke Republike u 15., 16. i 17. stoljeću«. *Anali Zavoda za povijesne znanosti HAZU u Dubrovniku* 29 (1991): p. 19).

[74] Stjepan Krivošić, *Stanovništvo Dubrovnika i demografske promjene u prošlosti*. Dubrovnik: Zavod za povijesne znanosti JAZU u Dubrovniku, 1990: p. 51.

[75] Laura Ferrari, »Acqua che ricorre nei luoghi«. *Quaderni della Ri-Vista. Richerche per la progettazione del paesaggio* 2/1(2004): p. 4.

[76] Dušan Ogrin, *Vrtna umjetnost svijeta*. Ljubljana: Pudon and EWO, 1993: p. 54. Philippus de Diversis spoke most highly of Onofrio's Fountain in his *Opis slavnoga grada Dubrovnika* (p. 61).

chosen for the setting.[77] Early Renaissance aqueduct of Dubrovnik, the crown of which was a polygon fountain installed on one of the City's central spaces, bears witness to the architect's engineering and hydrotechnical knowledge and skill, as well as to the prudent government of the Dubrovnik Republic which was able to anticipate the benefit and importance of such a challenging and costly engineering project.

[77] Slavica Stojan, *Slast tartare. Marin Držić u svakodnevici renesansnog Dubrovnika*. Zagreb-Dubrovnik: Zavod za povijesne znanosti HAZU u Dubrovniku, 2007: pp. 138-139.