Historical development of the Augustan Aqueduct in Southern Italy: twenty centuries of works from Serino to Naples

G. De Feo* and R.M.A Napoli**

*Dept. of Civil Engin., Univ. of Salerno, via Ponte don Melillo, 1-84084 Fisciano (SA), Italy
(E-mail: g.defeo@unisa.it)

**Faculty of Engin., Univ. of Naples “Parthenope”, via Acton 38, 80133 Napoli, Italy

Abstract The aim of the present study was to investigate the historical development of the Augustan Aqueduct Serino-Naples-Miseno in the Campania Region, in Southern Italy. The Serino aqueduct is not well known because there are no remains of spectacular bridges, but it was a masterpiece of engineering and one of the largest aqueduct systems in the whole Roman Empire. The Serino aqueduct was constructed during the Augustus period of the Roman Empire, probably between 33 and 12 BC when Marcus Vipsanius Agrippa was curator aquarum in Rome, principally in order to refurnish the Roman fleet of Misenum and secondarily to supply water for the increasing demand of the important commercial harbour of Puteoli as well as drinking water for big cities such as Cumae and Neapolis. The main channel of the Serino aqueduct was approximately 96 km long, and had 7 main branches to towns along its trace such as Nola, Pompeii, Acerra, Herculaneum, Atella, Pausillipon, Nisida, Puteoli, Cumae and Baiae. Since the total length of all the branches was approximately 49 km, the Serino aqueduct complex had a length of around 145 km and therefore it should be considered the largest aqueduct system in the Roman world.

Keywords Miseno; Naples; Piscina Mirabilis; Roman aqueduct; Serino

Introduction Ancient Rome is famous all over the world for its aqueducts. As a matter of fact, Rome’s water supply system was considered one of the marvels of the ancient world. The aqueducts went wherever Rome went, an outward symbol of all that Rome stood for and all that Rome had to offer (Hodge, 2002). The Romans were not the first to construct aqueducts. In fact, it is well known that the Greeks were the first to realize an aqueduct (Adam, 1988). One of the most famous aqueducts in ancient Greece is the tunnel of Eupalinos for the water supply of Samos (Angelakis et al., 2005). In general, the Roman aqueducts were not built to provide drinking water, nor to promote hygiene, but to supply the bats (Hodge, 2002) or for military aims. Other purposes were the following (Hodge, 2002; Tolle-Kastenbein, 2005): domestic supplies, garden irrigation, aquatic shows, flour mills, decorative fountains and public fountains.

In the historic literature concerning Roman aqueducts, there are two authentic milestones (Panimolle, 1984; Adam, 1988; Hodge, 2002; Tolle-Kastenbein, 2005): De Aquis Urbis Romae by Sextus Julius Frontinus and Book VIII of De Architectura by Vitruvius Pollio. Sextus Julius Frontinus born probably around 35 A.D. and in 97 A.D. was appointed by Trajan curator aquarum (water commissioner) of Rome (Panimolle, 1984; Hodge, 2002). De Aquis Urbis Romae was the fruit of his tenure of this post. Vitruvius Pollio lived in the early first century A.D. and his De Architectura can be considered the only ancient treatise on architecture to have survived (Hodge, 2002). Nowadays, the popular but inaccurate image is that Roman aqueducts were elevated throughout their entire length on lines of arches. Roman engineers were very practical and therefore whenever possible the
aqueduct followed a steady downhill course at or below ground level (Hansen, 2006). The water in the aqueducts descended gently through concrete channels. Multi-tiered viaducts were used to cross low areas; inverted siphons were employed (sparingly) when valleys were particularly deep; tunnels, burrowed through hill too difficult to skirt, were equipped with vertical shafts for inspection and cleaning. Debris cleaned from the tunnels was dumped beside the openings to the vertical shafts. Figure 1 proposes a scheme representing the general path of a whole aqueduct with the basic elements.

The aim of the present study was to investigate the historical development of the Augustan Aqueduct Serino-Naples-Miseno (shortly “Serino aqueduct”) in the Campania Region, in Southern Italy. The Serino aqueduct is not well known because there are no remains of spectacular bridges, but it was a significant piece of engineering and one of the largest aqueduct systems in the whole Roman Empire. Its importance is testified by several bibliographic references concerning specific books of local authors (Pavesio, 1985; Pescatore, 1996; Moscati, 2005; De Biase, 2006) as well as academic studies (Catalano, 2003), historical technical treaties (Giustiniani, 1797; Abate, 1864; Società Veneta, 1885; Sgobbo, 1938), web sites (Potenza, 1996; Nocella and Abbate, 2003; Passchier and Schram, 2005), and even a novel (Harris, 2003).

The caput aquae of the aqueduct was the Acquaro-Pelosi spring in the village of Serino, in the province of Avellino (the ancient Abellinum). The source, the Fontis Augustei, lies at an altitude of 376 meters in a karst aquifer, known as “Terminio-Tuoro”, that still today originates several springs (Serino, Cassano Irpino, Baiardo) with a total flowrate greater than 6 m³/s (De Feo et al., 2007). Nowadays, after two millennia, the Fontis Augustei together with a nearby lower spring at 320 m, the Urciuoli source, still continue to supply clear, fresh and sweet water for the inhabitants of Naples.

Chronology
The Serino aqueduct was constructed during the Augustus period of the Roman Empire, probably between 33 and 12 B.C. when Marcus Vipsanius Agrippa was curator aquarum in Rome, principally in order to refurbish the Roman fleet of Misenum (Miseno) and secondarily to supply water for the increasing demand of the important commercial harbour of Puteoli (Pozzuoli) as well as drinking water for big cities such as Cumae (Cuma) and Neapolis (Naples). Rogge (2006) dated back to ca. 35 B.C. linking of Pompeii to the Serino aqueduct, but in our opinion it appears almost impossible. More realistic appears the 27 B.C. suggested by Ohlig (2001) in Jones and Robinson (2005), as a possible arrival of pressurized water from the new Serino aqueduct as a branch of the Campanian aqueduct system.

For a long time, up to 1938, the Serino aqueduct was usually reported as the Claudius aqueduct, being retained that it was realized in the Claudius period (41–54 A.C.).

Figure 1 Flow sheet and components of a Roman aqueduct: (1) source – caput aquae; (2) steep chutes (dropshafts); (3) settling tank; (4) tunnel and shafts; (5) covered trench; (6) aqueduct bridge; (7) inverted siphon; (8) substruction; (9) arcade; (10) distribution basin/castellum aquae divisorium; (11) water distribution system (modified from Passchier and Schram, 2004)
The mistake was due to the discovery in Puteoli, in the 14th century, of big *fistulae plumbee* (lead pipes) on which there was impressed the name of the Emperor Claudius (Moscati, 2005). The enigma was resolved only in the last century, in the 1930s, during the excavation for the construction of the new aqueduct of Naples, near the Acquaro-Pelosi spring. During this work, in fact, an important marble epigraph was discovered. The archaeological find gives information on the repairs executed in the period July-November 324 A.C. by Constantine as well as the name of the cities of the Campania Region served by the repaired aqueduct; in order of importance (decreasing flowrate supplied), they were: Puteoli, Neapolis, Nola, Atella, Cumae, Acerra, Baiae and Misenum (Sgobbo, 1938; Pavesio, 1985; Pezzella, 2002; Potenza, 1996; Catalano, 2003; Moscati, 2005; De Biase, 2006). The repairs are also reported in the *Liber Pontificalis* (Pezzella, 2002).

The marble epigraph, 1.86 × 0.86 × 0.17 m, today is kept in the connection chamber of the Acquaro-Pelosi spring. The inscription was interpreted and integrated by Sgobbo (1938): “D(omini) N(ostri) F(flavius) C(onsul) C(onstantinus) max(is) Pius Felix Victor Aug(ustus) et F(lavius) Iul(ius) Crispus, et F(lavius) Cl(audius) Constantinus nobiles Caesaris Fontis Augustei Aquaeductum longa incuria et vetustate corruptum pro magnificentiis liberalitates consuetae sua pecunia refici iussent et usui civitatum infrascriptarum reddiderunt dedicante Ceionio Iuliano vi(ro) c(larissimo) Cons(ulari) Campaniae curante Pontiano vi(ro) p(erfectissimo) praepo sitio eiusdem aquaeductus nomine civitatum Puteolana Neapolitana Nolana Atellana Cumana Acerrana Baiana Misenum”. The epigraph reports that the repair works were directed by the *vir perfectissimus* Ponziano, in his function of *praepositus aquaeductus*, which means the curator of water and aqueducts.

Fifteen years after the construction of the epigraph, the Serino aqueduct is mentioned again in a constitution of the Onorio Emperor dating back to December, 28, 339 and addressed to the praefecto praetorio of Italy, Valerio Messala (Codex Theodosianus, XV 2.8) (Pezzella, 2002). After the fall of the Roman Empire, the Serino Aqueduct together with the major part of Roman aqueducts went out of service because of the low level of maintenance carried out as well as the devastation as a consequence of the Barbarian invasions (Pavesio, 1985; Moscati, 2005; De Biase, 2006).

In the VI centuries, in fact, Naples was invaded several times by Ostrogoti of Totila and the Serino aqueduct was one of the strategic targets destroyed in order to conquer the city. In particular, Procopio, a Greek historian tells how General Belisario ordered the aqueduct channel out of the Costantinopoli’s door of Naples to be broken. A soldier was able to enter in the city using the aqueduct channel and after him, General Belisario together with other 400 soldiers followed. Then, just like Ulysses in Troy, Belisario and his troupe opened the doors of Naples to the rest of his army. Curiously, the same technique was used several years later, in 1442, by Alfonso d’Aragona in his battle against Renato d’Angiò (Pavesio, 1985; De Biase, 2006). Therefore, the aqueduct had a black hole of a millennium in which it was out of service and completely forgotten.

In the period 1,532–1,553, during the Hispanic domination of Naples, the viceré don Pietro Toledo entrusted Pietro Antonio Lettieri (Tabularius) to investigate the way to increase the supply of drinking water for the city. Lettieri was a technician with expertise in topography and after four years of study, proposed the complete recovery of the Augustan aqueduct as a possible solution to the problem of water scarcity (Pavesio, 1985; De Biase, 2006). The report written by Pietro Antonio Lettieri was copied for the first time by Giambattista Bolvito and conserved in the archives of Real Corte, and then collected in Archives of P.P. Chierici Regolari Teatini of SS. Apostoli of Naples (Giustiniani, 1797; Pavesio, 1985). Lettieri’s project remained on the papers because of
its high cost. In that period the *Fontis Augustei* was property of the Prince of Avellino, who earned a lot from the use of water for factories, watermills and irrigation (Pavesio, 1985). Pietro Antonio Lettieri was able to describe the route of the ancient Serino aqueduct (Pavesio, 1985; Moscati, 2005; De Biase, 2006).

Three centuries after the study of Lettieri, another important investigation took place. From 1840 to 1864, architect Felice Abate, in fact, investigated the route, the works and the places interested by the ancient Augustean aqueduct (Abate, 1864). Other important source of information is the Società Veneta (1885). The Società Veneta was the enterprise entrusted to realize the new aqueduct for the city of Naples. May the 10th, 1885, in the famous Plebiscito square, was a great day for Naples: the people again had the famous water of Serino. However, the water did not come from the *Fontis Augustei* (Acquaro-Pelosi spring) but from the nearby Urciuoli Spring (324 m). This source, in the same period of the Augustean aqueduct Serino-Neapolis-Misenum, was the *caput aquae* for the aqueduct Serino-Beneventum spring (36 km long). In 1936 the water coming from the two sources was joined to significantly increase the flowrate for the city of Naples (2,000–3,000 L/s) (Potenza, 1996).

**Route**

The main channel of the Serino aqueduct in its route toward Naples and Miseno was approximately 96 km long, and had 7 main branches to towns along its trace such as Nola, Pompeii, Acerra, Herculanenum, Atella, Pausillipon, Nisida, Puteoli, Cumae and Baiae (Figure 2). The length from Serino (1) to Naples (2) was approximately 78 km long; while, the length from Naples (2) to Miseno (3) was around 18 km. Since the total length of all the branches was approximately 49 km, the Serino aqueduct complex had a length of around 145 km and therefore it should be considered the largest aqueduct system in the Roman world. In fact, the other long aqueducts are Cartagena with 132 km and the Aqua Marcia and the Anio Novus, in Rome, with 91 and 87 km, respectively (Adam, 1988). The ancient route of the Serino aqueduct can be described joining the information coming from the descriptions by Pietro Antonio Lettieri (in Giustiniani, 1797) and Felice Abate (1864).

From the Acquaro-Pelosi spring in Serino, at 370 metres above sea level, the aqueduct crossed the Sabato river on a bridge to the west to Aiello. It passed below Contrada in a tunnel, then through the plain of Forino through Petrano, Pandola, Tor di Marcello, Castel S. Giorgio and Taverna di Lazzaro to a major tunnel below Monte Paterno of 1,903 m long towards Sarno. Through Episcopio and Palma it continued to Mura d’Arce where it ran in a double section, one buried and one on arches to Vallone del Monaco where both branches joined again. The following section passed through Torricella, San Gennaro

![Figure 2 Route of the Augustan aqueduct from Serino to Miseno](https://iwaponline.com/ws/article-pdf/7/1/131/418472/131.pdf)
Vesuviano, Piazzolla, Masseria De Martino, S. Maria del Pozzo, Masseria San Sossio, Masseria La Preziosa and then over a section on arches to Pomigliano d’Arco.

Then through Casalnuovo, Afragola, San Pietro a Paterno to San Giuliano north of Naples where there are remains of an aqueduct bridge (Ponti Rossi). The aqueduct circled Naples below the hills of San Eframo, Santa Maria della Vergine, to Santangelo, where a branch went south to serve the city of Neapolis through Porta di Costantinopoli and San Patrizia. The main channel followed the route through S. Elmo and Chiaia to a tunnel to west of Naples. This is a major road tunnel, the Crypta Neapolitana, 5 m high, 4.5 m wide and 700 m long. It was built by L. Cocceius Auctus, an architect who came from this area and probably worked for Agrippa. The aqueduct does not lie in the tunnel itself, but runs parallel to it at an height of 50 cm from the base of the tunnel on its north side. On the west side of the tunnel, the aqueduct then branched; one branch went south to a junction at the coast, where a branch probably went over a bridge to the island of Nisida, while another passed parallel to but on the north side of another road tunnel, the Grotta Seiano, to serve the large imperial villa at Posilippo (Pausilippon) also known as the Villa Polii after its first owner. The main branch of the Serino aqueduct left the Crypta Neapolitana to the west with a small side branch to the large bath complex of Terme di Agnano. From there, it passed through Pozzuoli with a branch to the city, then along the via Domitiana to circle the Lake of Averno. Here a side branch passed parallel to and at the north side of another road tunnel built by Cocceius to Cuma. The main channel then follows the flank of three craters above Baiae and on the Misenum (Giustiniani, 1797; Abate, 1864; Catalano, 2003; Passchier and Schram, 2005; De Biase, 2006).

The total relief of the aqueduct is 366 m from the source (1) to the Piscina Mirabilis (2) at 10 m altitude, which gives a mean slope of 0.38% (3.81 m/km). The mean slope of the stretch from Serino (1) to Naples (2) (Ponti Rossi at 41.4 m) was 0.43% (4.29 m/km); while the mean slope from (2) to (3) was 0.17% (1.74 m/km). Along the route, the local slope varied considerably: from 0.016% to 0.73%. The specus of the aqueduct varied in size, but was mostly 0.8 m wide and 1.8 m high (Figure 3).

The maximum capacity at the upper sections can be estimated in approximately 1,000 L/s, which would be a total of 86,400 m³/d. Pompeii was one of the towns served by the aqueduct, and the capacity of the branch that ended here in the castellum aquae was 42 L/s (Passchier and Schram, 2005). Ohlig (2001) in Jones and Robinson (2005) investigated the connection of the castellum aquae with the Serino aqueduct. It was pointed out that a channel outside the town, hitherto interpreted as part of a rather
unproductive earlier water supply, was not a water conduit at all, and, moreover, it could be assigned to a more recent date than that of the main water supply channel.

On the other hand, on either side of this supply channel, two layers of lime sediment (sinter) were observed at different levels. Mineralogical and chemical analysis has proved that Pompeii received through this single channel water from two completely different sources, one replacing the other in a later period; the flow of water in the second phase was considerably less than in the first. Analysis of other lime samples, taken from sections of the Serino aqueduct both before and after the junction with the probable branch aqueduct serving Pompeii, gave the following picture. It is very likely that Pompeii first received water via her own aqueduct from the mountains due north east of Avella. The town must have had a long distance water supply, quite some time before the Augustan Age, probably around 80 BC. When the Serino aqueduct was built under Augustus, it crossed the course of the older Avella aqueduct between the Apennines and Mount Vesuvius, and both aqueducts were united into a single system. The section of the Avella aqueduct, from the point where it crossed the Serino aqueduct onward, continued to serve as a supply channel for Pompeii. The new Avella/Serino aqueduct, apart from serving the imperial fleet at Misenum, also supplied a number of other Campanian towns with water. As a result Pompeii received a smaller amount of water from the new system than it used to get from the original Avella aqueduct.

**Works and places**

During the war with Pompeius, Augustus ordered the construction of a harbour complex just west of Puteoli, named Portus Iulius, where an old Greek dam was restored to create an artificial lake, Lacus Lucrinus, which was then connected by a channel to another lake, Lacus Avernus, which was traditionally one of the entrances to the underworld. Later, this harbour was seen as less ideal, because of silting problems, and a new complex was built further west at Misenum, where two lakes were connected to become the basis of the western Mediterranean war fleet. This major naval base needed large quantities of fresh water for the base itself and for the ships, which must have been one of the reasons why Augustus had a new aqueduct built (Passchier and Schram, 2005).

The Serino aqueduct filled several cisterns in the section beyond Naples. The main cistern filled by the aqueduct is the Piscina Mirabilis in Bàcoli (Misenum) (Adam, 1988; Potenza, 1996; Catalano, 2003; Passchier and Schram, 2005).

The Piscina Mirabilis (Figures 4 and 5), situated up the hill facing the sea in order to provide the *Classis Praetoria Misenensis*, is a gigantic reservoir 72 m long and 27 m large, which derives its name from the eighteenth century antiquarian tradition, with clear
reference to the impressiveness of its plan as well as the remarkable architeconic effect. It is dug in a tufa hill and has two step entrances in the north-west and south-east corners, this latter closed. Forty-eight pillars, arranged on four rows serving as a support to the barrel vault, divide it in five aisles on the long sides and thirteen aisles on the short sides, lending to it the majestic look of a cathedral. The Piscina Mirabilis can be considered one of the biggest Roman cisterns ever known until now with a volumetric capacity of 12,600 m³ of water. The water coming from Serino flew into it near the north-west entrance. The long wall were realized in opus reticolatum (reticular work) with brick bonding courses and by the technique of the tufa stone pillars, both covered with a thick waterproof layer of opus signinum (pounded terracotta).

The seventh short aisle, just in the middle of the reservoir, appears embedded in it for about 1 m, with the plane inclined in the direction of an outlet at the south end. It was used as a Piscina limaria for the periodical cleaning of the reservoir. There is a basin of 1.10 m, probably a polishing pool, that is a waste-bath for the maintenance of the cistern, in the floor of the nave. The water, through a series of doors opening in the vault along the central nave, was raised through hydraulic engines on the covering terrace of the reservoir, which was also floored with signinum and from there, canalized towards the built-up area. Along the north-west external side, in the course of the first century AD were added twelve vault-covered little rooms in opus reticolatum with angular brick bonding courses, in the second of which is kept a signinum floor with labyrinth-shaped mosaic tesserae and a central white inlaid panel with limestone polychrome tiles, which seems to date back to a more ancient phase (Adam, 1988; Potenza, 1996; Catalano, 2003; Passchier and Schram, 2005).

Close the Piscina Mirabilis, there are two other large cisterns, probably belonging to large villas, the Grotta Dragonaria and Cento Camerelle (Nerone’s jail). In Pozzuoli, the aqueduct served several cisterns, notably the Piscina Cardito (55 × 16 m²) from the second century, and the Piscina Lusciano (35 × 20 m²) from the first century AD. In Baiae, a tunnel with two cisterns, known as the Crypta Romana, was filled by the aqueduct (Adam, 1988; Catalano, 2003; Passchier and Schram, 2005).

Conclusions
This paper presented and discussed the historical development of the Augustan aqueduct from Serino to Cape Miseno, in Southern Italy. After a brief introduction on Roman aqueducts, the paper focused on the Serino aqueduct. The topic was discussed relating to three main subjects: chronology, route, works and places. The overall conclusions from the research results can be summarized as: (a) the aqueduct was probably constructed between 33 and 12 B.C. when Marcus Vipsanius Agrippa was curator aquarum in Rome; (b) the main channel was approximately 96 km long; (c) the aqueduct had 7 main
branches corresponding to approximately 49 km; and (d) the total length of the Serino aqueduct could be around 145 km and therefore it should be considered the largest aqueduct system in the Roman world.

References


