IJEMS | SCIENTIFIC ARTICLE

Water Management and Land Defense: Roman Artificial Lake Emissaries

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This paper compares hydraulic works constructed during the Roman period for the managing of the waters of several lakes in central Italy that lack natural outlet. The lakes of Albano and Nemi, both located in the southeast of Rome – in the Castelli Romani Park – and the basin of Lake Fucino in Abruzzo (which no longer exist due to its complete drainage in the 19th century) present notable similarities: each featured an artificial outlet created through the excavation of underground tunnels, extending several kilometers in lenght. The primary objective of these works was to regulate water levels and prevent flooding in the surrounding lowland areas. By examining different construction phases and building techniques used, through the analysis of bibliographic sources and direct observation of the structures and their contexts, this study identifies both similarities and differences among the various cases. The research aims to raise awareness of these engineering works, which are of significant architectural, historical, and landscape value. Their preservation poses considerable challenges for enhancement and future use, owing to the complexity of the structures and the multidisciplinary nature of the research required.

Key Words: Roman emissaries, Lake Nemi, Lake Albano, Lake Fucino, construction techniques, accessibility

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https://doi.org/10.70908/2232-6022/18.387-402

INTRODUCTION

Among ancient water management systems, those constructed during the Roman period for lakes without natural outlets resulted in extraordinary engineering works with a dual purpose: enabling the discharge

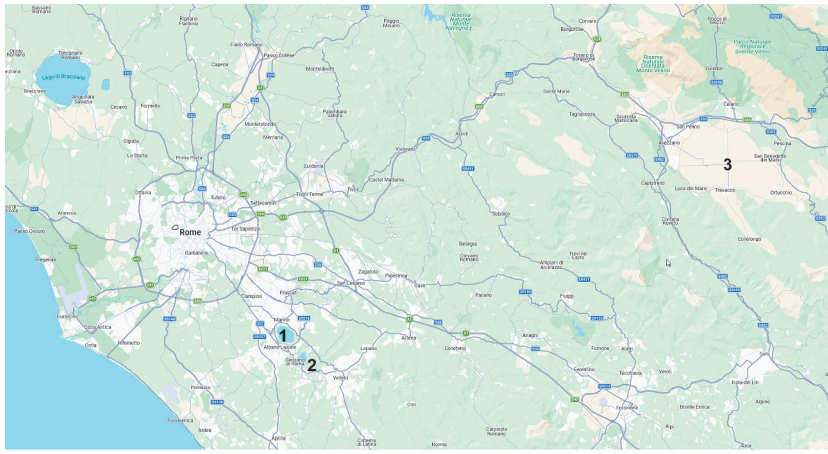

FIGURE 1 Map Showing the Locations of the Three Lakes

NOTES 1 – Lake Albano, 2 – Lake Nemi, 3 – Lake Fucino.

of excess water during flood periods to prevent inundation and lowering water levels to reclaim new land for cultivation (figure 1).

This latter objective ultimately led to the complete drainage of Lake Fucino in Abruzzo, carried out in the second half of the 19th century. This intervention occurred shortly before the hydroelectric industry began to reshape mountainous landscape by creating new artificial reservoirs.

Studies and surveys conducted since the early modern period, and more systematically between the 19th and 20th centuries, on ancient artificial emissaries provide a basis for comparative analysis. Research initially focused on the lakes of Nemi and Albano, both located southeast of Rome in the Castelli Romani park in the Lazio region (Placidi 2010; Caloi et al. 2012; Cioli and Baldi 2013; Ferri Ricchi 2015), and later extended to Lake Fucino, situated a few kilometers from the city of L'Aquila in Abruzzo. These studies allow for comparisons of construction techniques employed during the initial phases and subsequent interventions, the long-term effectiveness of these hydraulic systems, their impact on landscape, society, economy, and territorial organization, and the current condition of these works.

Although research has focused primarily on archaeological analysis, the conservation status of these structures raises significant concerns. Many of the emissaries are partially or entirely inaccessible – for example the emissary of Lake Albano remains flooded and is accessible only

through underwater cave exploration. In addition, accidental events over time have obstructed conduits, interrupting or altering their function and preventing further investigation and maintenance.

These works constitute a major component of cultural heritage, embodying both material and immaterial values values and reflecting advanced ancient knowledge of hydraulic engineering and landscape management. [389]

CONSTRUCTION TECHNIQUES

The construction of artificial emissaries resulted from complex and ambitious engineering projects. The operations required to achieve the intended outcomes can be broadly identified as follows: the excavation of underground channels deep beneath the mountains surrounding the lake basins, their connection to the surface through water-collection system (such as a spillway composed of multiple collecting basins and channels in the case of Lake Fucino, and control chambers in the Lazio examples), and, finally, the creation of a complex network of access tunnels (or 'cunicles,' *cuniculi* in Italian) and vertical wells. These vertical descents into the system were essential not only for proper ventilation but also for the removal of excavation debris and for transporting workers and materials.

The emissaries of Lakes Nemi and Albano (figure 2), located in the Alban Hills, were constructed between the 4th and 5th centuries BC Each extends for just over two kilometers beneath the surrounding mountains and includes two control chambers used to regulate the flow of water into the underground tunnels.

The emissary of Lake Nemi, whose precise date remains unknown, was designed to convey water toward the nearby Ariccia valley, where the modern town of the same name now stands. Its primary purpose was to prevent the lake level from rising high enough to damage the 1st-century BC sanctuary of Diana Nemorensis, on the lake's shore (Cappa 2002). Although Lake Nemi is relatively small, it is fed by several stream-like inlets and numerous springs that periodically increase its volume. These features, combined with episodes of heavy rainfall and surface runoff, necessitated the construction of the emissary. The tunnel, approximately 1.700 meters long, is generally passable, though in certain sections its cross-section narrows significantly, dropping to just under one meter above the ground level. A more recent obstacle to access is a metal pipe installed in 1973 to capture water from the lake,



FIGURE 2 Representation of the Emissaries of lakes Nemi and Albano
NOTES From Canina (1848).

which runs along the entire length of the emissary. Today, the lake's water level lies well below the entrance to the tunnel, rendering the conduit largely dry and accessible, except at a few localized points – particularly, about 700–800 meters from the entrance, where springs create shallow pools that are not difficult to cross.

Despite the relatively short length of the tunnel, excavation proceeded simultaneously from both the outlet point of the emissary and from the lakeside. This approach aimed to follow the course of the underlying groundwater, avoid dangerous flooding, and maintaining as constant the gradient as possible. These precautions ensured that the outlet lay approximately 12 meters below the entry point, and that the conduit followed a fairly linear trajectory, with only slight deviations in direction and elevation caused by the encounter with harder geological layers, features that were readily identified during reconnaissance and site inspections.

The emissary of Lake Albano, whose construction and design are described in several historical sources, including Titus Livius (V, 15) and Dionysius of Halicarnassus (I, 66), was built in 398 BC for military purposes. According to tradition, it served as part of a stratagem to bring the Etruscan city of Veio, besieged unsuccessfully for nearly a decade, under Roman control (Ferri Ricchi 2015). Unlike the nearby emissary of Lake Nemi, the Albano emissary was largely flooded for much of its history and, therefore, rarely visited or studied. Nevertheless, in 1762

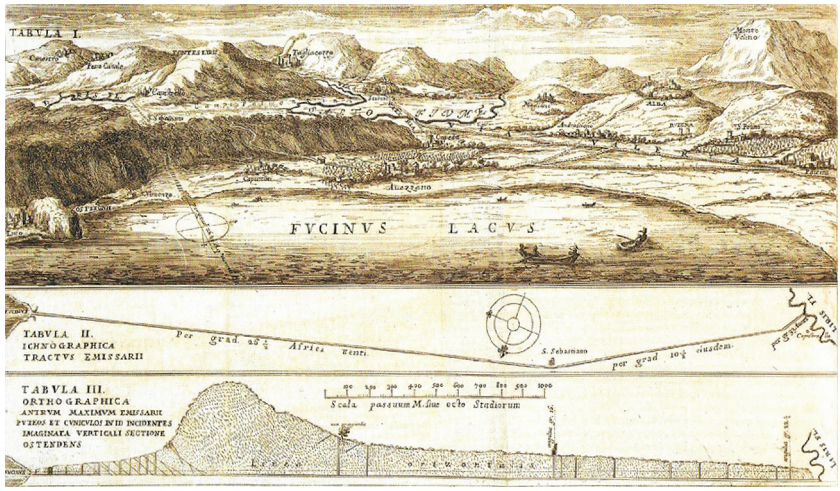

FIGURE 3 Representation of the Emissary of Lake Fucino

NOTES From Fabretti (1690).

G. B. Piranesi documented its layout in a study that also includes the emissary of Lake Fucino.

While the entrance to the Albano emissary is difficult to identify, its outlet is well-known and is located at the public washhouse in the center of Mole di Castelgandolfo district. Access to the tunnel from this point is, however, severely restricted, as the wash-house obstructs much of the conduit. Two additional potential access points, situated near ventilation shafts close to the outlet, lie on private property and are currently inaccessible (Caloi et al. 2012).

The drainage channel of Lake Fucino in Abruzzo (figure 3), also known as the 'Emissary of Claudius,' postdates the previously discussed examples and is significantly larger in scale. Construction began in 41 AD and was completed in 52 AD, before the system underwent extensive modifications in the second half of the 19th century. Numerous historical sources document its design and initial construction, including Suetonius (*Claudius* 20–1, 32), Cassius Dio (20.11.7; 20.33.6), Pliny the Elder (*Natural History*), and Tacitus (*Annals* 22.56–7). Analysis of these sources suggest that the original concept dates to the time of Julius Caesar (100–44 BC), although the project was ultimately realized under the reign of Claudius (10 BC–54 AD).

The necessity of this monumental work stemmed from the persistent flooding that affected the lakeshore areas. Lake Fucino lacked a

natural outlet and was fed primarily by the Giovenco River along with numerous seasonal torrent-like inlets, resulting in continual fluctuations in its water level. Over the centuries, destructive floods caused severe damage, inundating cultivated land and urban settlements. It is
[392] important to distinguish between the objectives of the Roman intervention which aimed at partial drainage to regulate water levels and protect surrounding land, and those of the 19th-century 'restoration,' which resulted in the complete drainage of the lake and the disappearance of its water surface.

The ancient Roman hydraulic system consisted of a long main tunnel and a collector channel extending over five kilometers. Its construction required the excavation of numerous service wells and inclined access tunnels (the so-called 'cunicles') on both sides of the mountain massif it traversed. The system was designed to divert the lake's waters into the adjacent valley, where the Liri River flows, with the outlet located near the site of the present-day town of Capistrello.

The inclined tunnels and vertical wells were necessary not only to ensure proper ventilation and aeration of the main tunnel but also to allow light to penetrate as deeply as possible. In addition to their functional purpose, they also provided access for maintenance, enabled the transport of excavation tools, and facilitated the removal of waste material, thereby supporting the work of the numerous labourers involved. By contrast, the emissaries of Lakes Nemi and Albano, owing to their shorter lengths, required only a limited number of wells and inclined passages near the entrances to safely carry out excavation and drainage operations.

Despite the considerable length of the Fucino emissary (exceeding 5 km), Romans maintained an almost constant slope along the entire tunnel, comparable to that observed in the Lazio examples. Deviations in alignment, required to overcome obstacles or penetrate harder layers of soil, were limited. Unlike the emissaries of Nemi and Albano, however, the greater length of the Fucino system necessitated the construction of a substantially larger number of vertical wells. Some sources report nearly 40 such wells (Afan De Rivera 1836), which were essential for controlling the excavation gradient and directions. Whereas excavation at Nemi and Albano proceeded simultaneously from the entrance and exit points of the emissaries, work at Fucino began from the outlet in the Liri River valley. Initially, the wells were identified and excavated, followed by the construction of the inclined tunnels, only later

was the main tunnel dug, always progressing from one well to the next, rather directly from the main exit to the main entrance. This construction sequence is evident from the fact that the descents intersecting a vertical well curve around it, indicating that the well was excavated before the conduit. These features can be clearly observed during visits [393]
to the only accessible inclined passage, known as the 'Ferraro Descent,' which is open to the public. Similar tool marks associated with Roman excavation techniques are visible here, as in the emissary of Lake Nemi.

The entry and exit points of the tunnels, as well as all intermediate sections, were determinated using the Roman technique of *coltellatio,* which, through the excavation of wells, permitted controlled gradients compatible with gravity-fed water flow. The directions of the underground excavations were managed using the Roman *Eupalinian* technique, which allowed two teams working from consecutive points to meet at the midpoint of their routes by executing curves in a predetermined direction.

The cross, the sections of the tunnels also reflect the geological conditions encountered during excavation. In the Lazio cases, builders worked primarily through volcanic formations, such as pyroclastic tuff, which is relatively soft and easy to cut. At Fucino, by contrast, the Roman builders had to cross a variety of soil types, ranging, from hard limestone to more clayey and less consolidated sediments (Burri 1994). This condition necessitated the use of wooden support structures and masonry linings in certain sections to reinforce the tunnel walls (Brisse and De Rotrou 1883; De Rotrou 1871).

By-pass tunnels also played an important role, enabling workers to move between inclined passages and to circumvent obstacles such as landslides or zones of groundwater infiltration (Placidi 2008; Brisse and De Rotrou, 1883; De Rotrou 1871).

Differences between the systems and their functional aspects

The emissaries of the three lakes exhibit significant structural differences, resulting from variations in hydrological conditions, geography, and geology. Lake Fucino, with its extensive surface area and substantial water collection capacity, required a large-scale emissary featuring a wide intake (for the captation of the water from the lake) to accommodate significant volumes of water. Today, the original Roman intake system (comprising a series of lake water-collection basins) has been

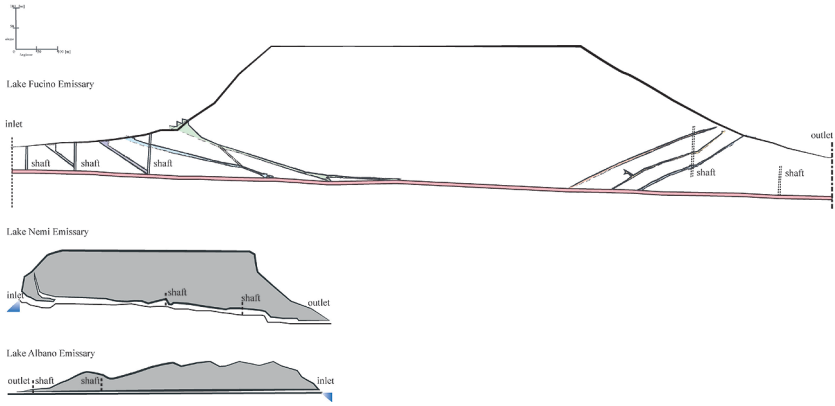

FIGURE 4 Survey Drawings of the Emissaries of Nemi, Albano, and Claudius

NOTES The figure shows the main tunnel, the intake and the outlet structures, vertical shafts and the principal inclined descents.

destroyed as a result of 19th-century modification works. Knowledge of this system survives only through contemporary written sources and visual representations, particularly those by Piranesi, which depict multiple interconnected water collection basins of varying cross-sections and connecting channels (Hind 1922). By contrast, the smaller lakes of Nemi and Albano feature a single control chamber, sufficient to regulate water flow when necessary, without requiring additional operational structures, except for perforated stone slabs placed between the chamber and the tunnel entrance to block coarse impurities. Despite the technological limitations of their time, these hydraulic works were executed with remarkable precision, attesting to the advanced skills and experience of Roman engineers in the field of hydraulic construction. Surveys conducted by modern researchers within all three systems, together with 19th-century technical treatises authored by engineers responsible for the modernization of Claudius' emissary, provide valuable insights into the layout of the tunnels. These studies also include cross sections illustrating how the conduits penetrate the surrounding mountain massifs (figure 4).

It is possible to identify similarities among the ancient sections in the different cases, as Roman practice favored a rectangular profile with barrel-vaulted ceilings that varied only according to the material being excavated. Until the end of the 18th century, environmental and landscape impact of these hydraulic structures remained relatively limited:

the emissaries of Nemi and Albano continued function, albeit with a declining level of technical knowledge regarding their construction and maintenance. The partial regulation of Lake Fucino reduced, at least until the fall of the Roman Empire, the destructive flooding of the lands adjacent to the lake's embankment. However, owing to the turbulent [395] conditions in Italy after the empire's collapse, the conduit sustained damage and blockages during the medieval and Renaissance periods, restoring the lake to its pre-emissary state. References to the system during this time are sporadic, although an imperial diploma issued by Frederick II of Swabia mentions the possibility of restoring the canal (Stile 1845; Afan De Rivera 1836). Its existence was mostly forgotten. It was only through to the rediscovery of antiquities, initiated in 1683 by Giovan Battista and Francesco Piranesi and later reinforced by the *Grand Tours* of scholars and travelers who journeyed across Europe, that the great works of the past were brought to light and reintroduced into the collective consciousness (Ciranna 2010). The long-term management of the lakes, particularly in the case of Fucino, whose size exerted a significant influence on the regional climate and biological systems, played a crucial role in preserving the millennia-old human habitat e of the region and sustaining the livelihoods of local populations over time (Burri 1994; Nardelli 1883).

The impact, however, changed markedly with the advent of the next century. The increasing population in the town of Castel Gandolfo led to the infiltration of city sewage and sludge into the Albano emissary (Ferri Ricchi 2015), rendering the conduit largely inaccessible and accelerating its degradation due to the acidity of the fluids. The complete drainage of Lake Fucino in the 19th century resulted in the near-total destruction of the Roman emissary, which was replaced by a much larger collector canal. A new intake was constructed significantly downstream from the lake's center, farther from the original Roman intake, leading to the loss of the ancient intake, and the progressive covering of many wells and drainage shafts. Specifically, the main collector canal was entirely destroyed, with only rare traces remaining where the modern conduit does not intersect and totally incorporate the Roman structure. It was replaced by a new oval-section tunnel approximately four times wider than the original Roman tunnel (figure 5).

In addition, a new water collection system, the current Monumental Intake was constructed at one of the lowest points in the Fucino basin. This monumental structure was designed to accommodate a larger,

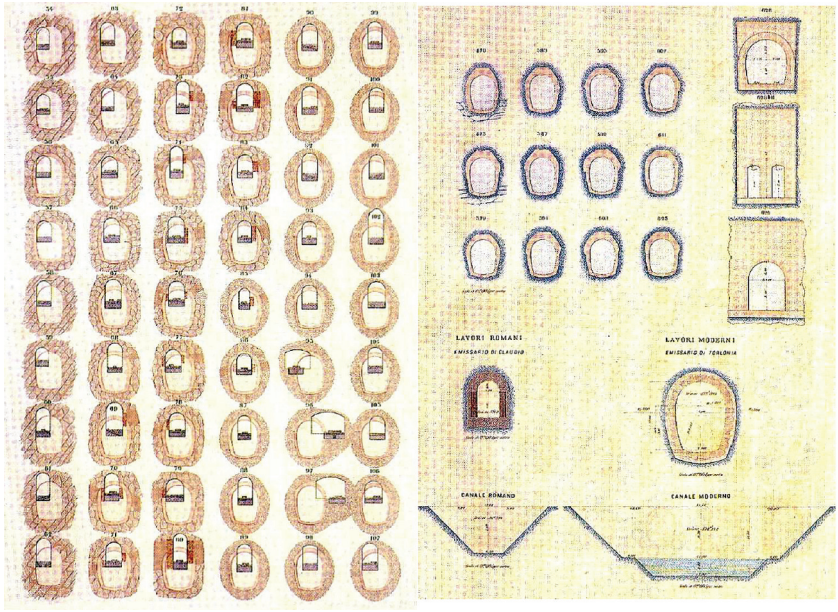

FIGURE 5 Overlay of Roman and 19th-Century Cross-Sections of the Collector Channel of the Fucino System

NOTES From Brisse and De Rotrou (1876).

modern intake, channeling all lake water into the new emissary while freeing as much land as possible for agricultural use. The rising capitalist climate following the Industrial Revolution facilitated the creation of numerous large estates on the newly reclaimed land, which in turn prompted social conflicts and agrarian reforms that continued until the mid-20th century (Furlani and Martelli 1996; Felice 2023). The landscape of the Fucino plain underwent radical transformation beginning in 1858, when construction of the new collector canal work commenced, fundamentally altering a natural system that had remained intact for millennia. Table 1 provides a comparative overview of the construction parameters and conservation issues of the three emissary systems.

CONSERVATION AND CURRENT CHALLENGES

Despite their historical and archaeological significance, analyzing the current state of conservation of the emissaries presents notable challenges, partly due to their difficult accessibility and partly because some sections are completely inaccessible.

TABLE 1 Comparative Table of the Main Construction Characteristics of the Three Systems

Characteristic	Nemi Emissary	Albano Emissary	Claudius Emissary
Construction period and main reinforcements	4th century BC; modern restorations 1927 28	4th century BC; subsequent conservations	Claudius 41–52 AD; Torlonia 1800s, later restorations
Materials and structural type	Underground tuff gallery; inlet chambers; vertical shafts	Underground tunnel in tuff and pyrolitic rock; inlet chambers; vertical shafts	Underground tunnels in heterogeneous ground; inclined tunnels; multiple vertical shafts
Emissary length	~1,653 m	~2,450 m	~6,000 m
Section, width, and height of the main tunnel	Width 0.70 1 m, limited height; section with vaulted ceilings	Imprecise data	Claudius: variable vaulted ceiling section between 2.5 and 5 m2 Torlonia: 20m2 horse-shoe section
Original function and water level management	Lake level control; prevent overflows; irrigation use	Prevent rises; controlled drainage; military use	Lake level control; drainage; agricultural reclamation
Obstructions and collapses	Partially flooded sections; passage of piping	Inaccessible sections; flooded tunnel; outlet occluded	Claudius: Blocked shafts and tunnels; accumulations
Issues	Flooding; inefficient management; intake and outlet only partially accessible	Problems with water table; loss of efficiency; lack of interventions	Climatic variations; intermittent maintenance of historic sections
Accessibility and safety	limited accessibility; not manned	Inaccessible; speleological and technical risks	New main tunnel accessible only for maintenance; one descent partially accessible for people

The emissary of Lake Nemi (figure 6) is entirely passable, though navigation is difficult in certain sections due to narrow spaces and irregular paths. Its entrance is partially hidden, and the exit is located in open countryside with no markers or protective measures. Modifications made in the early 20th century are documented only in specialized journals.

Thanks to the discovery of documents from the Uccelli archive, it is now possible to understand how the emissary was drained and made



FIGURE 6

Entrance to the Cunicolo Maggiore, Located Inside the Archaeological Park of the Cunicoli di Claudio

passable by a *deucaville* in 1928, the traces of which are no longer visible today (Cioli and Baldi 2013).

The emissary of Lake Albano, although it no longer carries sewage from nearby settlements, remains flooded and therefore only accessible for speleological and archaeological investigations (Ferri Ricchi 2015). It also suffers from collapses and blockages in both the main conduit and the wells, which impede water flow and fill sections of the tunnel.

The emissary of Fucino, still operational today, is accessible only to authorized personnel for periodic inspections of the 19th-century main channel. The extensive network of Roman tunnels and service shafts constructed for its original design is accessible only in small portions. Responsibility for managing the complex is divided: the 19th-century Monumental Intake system is overseen by the Fucino area Land Reclamation Consortium, which permits entry only in exceptional cases and in limited areas for safety reasons. Meanwhile, the Superintendence for Archaeological Heritage manages the Archaeological Park of the Claudian Tunnels (figure 7), which includes only two shaft accesses (the passable Ferraro shaft and the closed Cunicolo Maximo) and a few intermediate vertical wells. Public access is available only available by appointment, and the walkable portion of the only accessible tunnel is short and limited. Within inside the Archaeological Park, the wells and



FIGURE 7

Interior of the emissary of Lake Nemi

other tunnels on the Fucino side are visible, while on the opposite side, below the town of Capistrello, the terminal section of the Roman emissary can be observed from the outside but cannot be approached. The site is scenic and picturesque: the emissary, emerging from the rock face amid trees and vegetation, remains in operation, creating a waterfall that flows into the river. Due to Fucino's hydrological and geological characteristics (Burri 1994), the water table lies only a few centimeters below the current ground level, requiring constant diversion of this massive water volume. The water is first used to irrigate nearby field, then partially channeled in small part into the 19th-century emissary, and in larger part directed towards works that harness its energy for industrial purposes.

The expansion of industrial agriculture, which began in the 19th century with the complete drainage of Lake Fucino, profoundly altered the landscape and, in some cases, led to the destruction of the original structures. Moreover, many of the drainage shafts and underground tunnels of the system are now partially or completely inaccessible due to collapses and blockages. This inaccessibility not only limits opportu-

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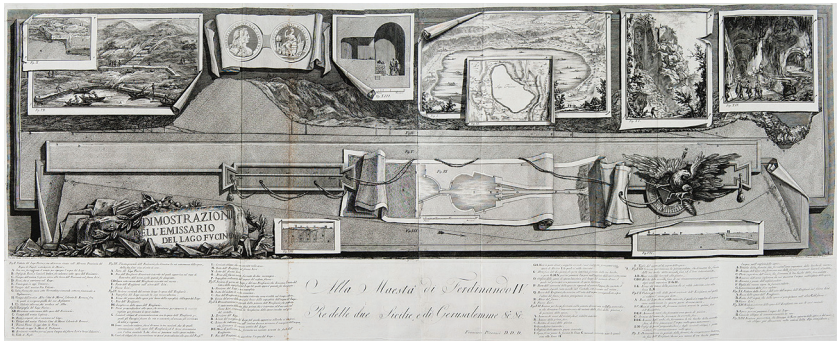

FIGURE 8 Structure of the Fucino System, Showing the Collector Channel, the Ancient Intake, the Surrounding Landscape, and Interior Views of the Tunnels

NOTES From Piranesi (1750).

nities for study and monitoring but also increases the risk of losing an extraordinary cultural heritage and of failing to recognize these sites as integrated systems rather than isolated elements. The Archaeological Park of the Claudian Tunnels appears entirely disconnected from the 19th-century Monumental Intake and, even more so, from the outlet of the Fucino emissary located on the opposite side of Mount Salviano. It is clear that without targeted conservation and enhancement interventions, there is a real risk that these structures will continue to deteriorate, ultimately disappearing from visible cultural heritage and the collective consciousness.

CONCLUSIONS AND FUTURE DEVELOPMENTS

The analysis of Roman emissaries offers valuable insights into ancient hydraulic engineering and methods of water resource management. These structures testify to the ingenuity and ambition of Roman engineers, as well as to their ability to understand and adapt to complex natural environments (figure 8).

A comparative examination of the various systems demonstrates how technical solutions evolved in response to specific local conditions, providing perspectives that remain relevant to contemporary water management strategies.

Given the difficulty of identifying and accessing many of these sites, future research should begin with the systematic georeferencing of key points of interest. The use of Geographic Information Systems (GIS)

would allow for a comprehensive analysis and management of data related to these and similar works, facilitating their documentation, accessibility, and recognition. In addition, these hydraulic systems, despite the challenges of preservation, offer insight into the technological and organizational capabilities of a civilization that knew how to [401]
harmonize technique and nature.

The large scale of these works invites reflection on the complex set of values they embody. These values are not solely architectural but also cultural, social, ethical, and environmental, representing a shift from a primarily material focus toward an immaterial one (Fiorani 2014).

The protection and safeguarding of such complex structures require an interdisciplinary approach and the recognition of values that broaden the perspective through which they are managed (Bartolomucci 2024a; 2024b). It is necessary to move beyond the concept of the single monument, broaden the scale of observation, and enter the realm of the landscape as cultural heritage, a fusion of values that transform a context into a unique and extraordinary asset that has evolved over time and therefore must be studied and transmitted to future generations.

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