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The Invisible Hydraulic Heritage of Bologna: Strategies for the Promotion and Interpretation of Its Urban Canals

Álvaro Gil-Plana *, Patricia Hernández-Lamas, Beatriz Cabau-Anchuelo and Jorge Bernabéu-Larena

Fundación Miguel Aguiló, Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos, Universidad Politécnica de Madrid, 28040 Madrid, Spain; patricia.hlamas@upm.es (P.H.-L.); beatriz.cabau@upm.es (B.C.-A.); jorge.bernabeu@upm.es (J.B.-L.)

* Correspondence: alvaro.gil.plana@alumnos.upm.es

Abstract

The city of Bologna (Italy) boasts an outstanding hydraulic heritage linked to the development of the silk industry, embodied in an extensive and valuable canal network. These public works, such as the Canale di Reno and the Canale Navile, were fundamental to the urban and economic shaping of the city from the Middle Ages onwards; however, many were concealed or dismantled from the 19th century. This article analyses recent heritage engagement and dissemination strategies regarding Bologna's historic canals and proposes new tools to overcome their spatial fragmentation and enhance their interpretation as a continuous network. The methodology combines analysis, fieldwork or valorisation of the hydraulic system, proposing two complementary promotion actions: the design of a mobile application and the development of a straightforward urban intervention consisting of linear pavement marking of the underground canals layout. The proposed operational hypotheses suggest that integrating digital resources with on-site signage brings invisible heritage to light, improves the spatial understanding of the hydraulic system, and fosters both community and tourist engagement. The study concludes that these strategies reinforce the territorial understanding and social awareness of civil engineering heritage, offering a transferable approach for the outreach of hydraulic networks.

Keywords: public works heritage; civil engineering heritage; industrial heritage; hydraulic heritage; urban canals; heritage tourism; heritage interpretation; engagement tools; Bologna

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1. Introduction

1.1. Hydraulic Public Works Heritage: Canals

The heritage interest in linear hydraulic public works generally focuses on navigable canals. This is demonstrated in documents such as the Heritage Canal Document [1], which defines assessment criteria (the technological and constructive relevance of the work), contribution to socio-economic development, outcomes of the landscape transformation dynamics shaped by the canal, associated uses and activities, etc. Furthermore, there are numerous contributions dealing with the value of navigable canals from a historical [2,3], economic [4,5], ecological [6], leisure and tourism [7,8], or industrial archaeology perspective [9–11].

However, the heritage recognition of linear works associated with water supply is more complex, whether because they remain in operation, run partially hidden along their route, and/or due to their territorial dimension [12–14]. The Bologna canals were not intended to supply human consumption, but rather the city's proto-industrial system.

Nevertheless, their process of decline and burial more closely resembles that of urban navigable canals. As occurred with the central *navigli* in Milan, once they became obsolete, they turned into inconvenient elements of cohabitation that limited the permeability of the urban fabric. Their burial process (Cerchia Interna, Milan, from 1929 onwards) or partial covering (Canal Saint-Martin, Paris, 1862/1906) prevented their interference with the city's functioning.

It is difficult to value those that are physically hidden, inaccessible to the public, or silent by design: "an «out of sight, out of mind» predicament can result that inevitably affects public consciousness, diminishes awareness of engineering and architectural significance, dampens political will, and limits funding appropriations" [14] (pp. 23–24).

Being largely buried and dispersed over vast distances, they have a fragmented territorial presence. The general public perceives a "physical disconnect between underground and above-grade components within active water systems. In addition, decommissioned elements are physically disconnected from active systems" [14] (p. 24). This reality hampers social understanding and, consequently, heritage engagement, their museumization, or the visits that so greatly aid in their dissemination.

The existing literature and studies, such as the report Water Industry as World Heritage [13], generally focus on their historical development as shapers of the modern city at the beginning of the 20th century [15–17] or their technological development [18,19]. Furthermore, this type of public works has generally been recognised in a biased manner, based on their constituent nodal elements (waterwheels, floodgates, mills, weirs, etc.).

Publications focusing on their linear or network character and their territorial extent are not as common [20]. However, it is their continuous layout that enables them to be perceived as something more than successive functional elements, allowing them to be understood from a heritage and landscape configuration perspective. Therefore, their linearity is a potential asset when it comes to their heritage enhancement [21] (p. 38).

As routes, itineraries, or paths, layouts alter the landscape's topology, articulate the territory, and establish relationships [22]. For this reason, when they can be traversed and followed on the ground, linear public works (beyond their individual elements) become experiences that forge links between the past and the present. They acquire new "cultural and social values and meanings that help us make sense of the present, our identities and our sense of physical and social place" [23]. Their capacity for reuse and renewal largely resides within these layouts.

In the specific case of Bologna, the recent resurgence of interest in its underground waters has successfully rescued numerous isolated urban landmarks from oblivion. However, considering that the true potential of this historical infrastructure lies in its spatial continuity, the following question arises: within the heritage conception of the Bologna canals, is there a territorial understanding of them as a cohesive system or network?

1.2. Origin and Evolution

Thanks to abundant water in the Po Valley, the Romans promoted the construction of navigable canals in cities such as present-day Piacenza, Parma, and Modena. They crossed urban centres and ensured their connection with the River Po and the sea. Of all these canal systems, the most important, undoubtedly, was that of Bologna. The exploitation of its water resources was crucial "for its development as a pre-industrial city and its necessary connection with other cities for trade. Between the 12th and 17th centuries, the development of a man-made water system transformed it into one of the leading industrial cities in the West" [24] (p. 9).

By the 12th century, Bologna increasingly needed water for irrigation, washing, mechanical power, leather tanning, and waste disposal. The Roman aqueduct had been

abandoned for centuries, so the adopted solution was to divert water from the two most important waterways surrounding the city, the Reno and Savena rivers (Figure 1). "The relationship between Bologna and its waters is one of artificial domestication, capable of turning the Emilian capital into a city of water, even though the urban area had never been crossed by two natural riverbeds, only brushed by them" [25] (p. 133).

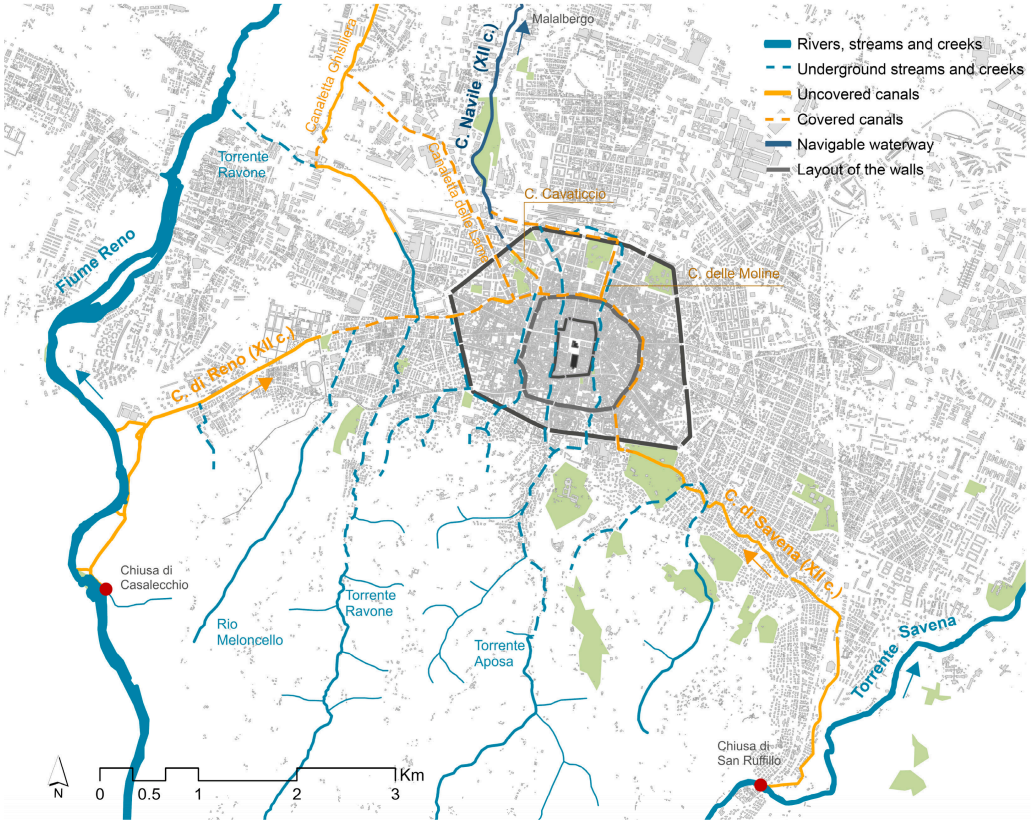


Figure 1. Relationship between Bologna's water network and its canal system. Source: The authors.

The main and the largest of the watercourses bordering Bologna is the River Reno. It rises in Tuscany, flows to the west of the city of Bologna, and turns eastwards until it flows into the Adriatic Sea. With a course of 211 km, it is Italy's tenth longest river. The second is the Savena stream, also originating in the Tuscan Apennines; it approaches the city from the east and subsequently discharges its waters into the Reno itself. It is characterised by the great variability of its flow, alternating between violent floods and droughts with a seasonal tendency [26].

In the second half of the 12th century, fundamental works began to provide Bologna with a powerful hydraulic system, the main structures of which were the artificial canals of the Savena and the Reno. To divert the flow of the Savena stream towards the urban centre, the City Council built a diversion weir (*chiusa*) in 1176, known as the Chiusa di San Ruffillo. Similarly, in 1191, the Ramisani family of entrepreneurs diverted the waters of the River Reno 5 km from the city via the Chiusa di Casalecchio, considered the oldest hydraulic work in Europe still in operation (p. 359, [27]) [28,29] (pp. 5–6, [30]).

The function of the Reno and Savena canals was manifold. On the one hand, they facilitated the water supply for the inhabitants of Bologna. On the other, they served to fill the moat of the city's second walled enclosure, the Cerchia del Mille, becoming "an integral part of the urban space enclosed between the ancient and the new city walls" (Figure 2). They also were used to supply dyeworks, paper mills, tanneries, grain mills, fulling mills, and forges. This artificial hydraulic system became the most important innovation in the

history of Bologna, and the only one "capable of marking the urban economy and society with profound originality" [27] (pp. 359–360).

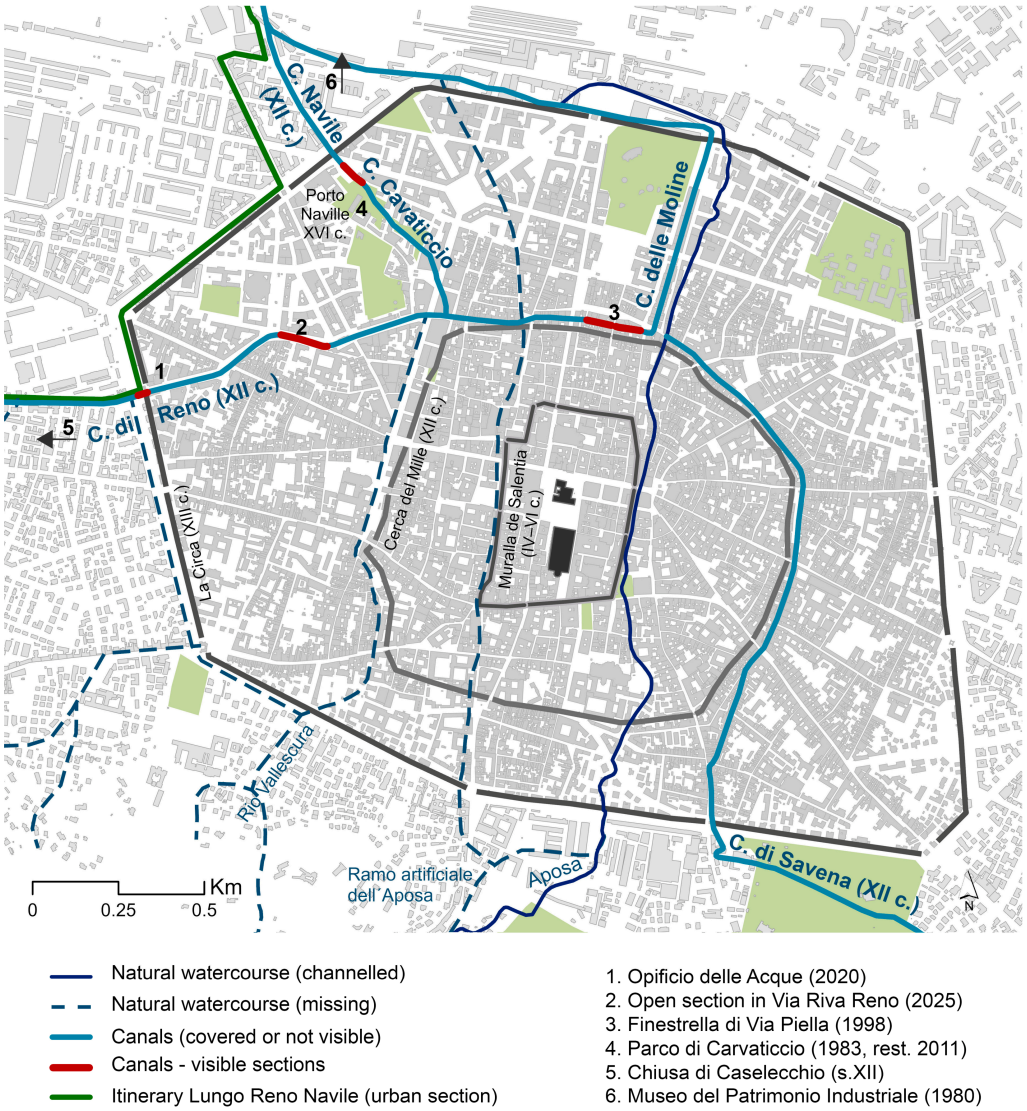


Figure 2. Bologna's three walled enclosures in relation to the natural watercourses and canals that run through the city. Source: The authors.

From the mid-14th century, a technique for twisting raw silk using the energy produced by a waterwheel had been developed in Bologna. John Lombe, whose 1717 Derby mill is considered the first successful silk factory established in England and probably the world's first fully mechanised factory, learnt the technology used in his pre-industrial establishment during his visit to Italy, in the city's hydraulic spinning mills. "The technology conceived in Bologna required little intervention from the workers and can be considered an early example of factory system [. . .] Remarkably, this automized system was in place a couple of centuries before the cotton mills that characterized the industrial revolution" [31] (p. 285).

Silk mills in Bologna achieved great success and proliferation, so much so that by 1393 there were already 50 waterwheels, and by the end of the 18th century there were 353 distributed across 119 workshops. This represented the highest concentration of urban machinery in Europe. By 1591, Bologna had over 20,000 people working on silk production, a third of its population. Regarding the hydraulic system, it should be noted that the city eventually boasted 62 km of canalisations [24,26].

Another aim of the canals was to recover the lost navigability. The landscape to the north of Bologna was dominated by a vast swamp called Padusa which, towards the sea, joined the Po River Delta. From the beginning of the 12th century, land reclamation (*bonifica*) works had been undertaken to increase the cultivation of cereals and vines and to counteract the impact of major periodic floods. Because these interventions put an end to the possibility of navigating between Bologna and the Adriatic Sea, there arose "the exigency to build artificial canals that could connect the city with the few still navigable water streams" [32] (p. 174).

Thanks, indeed, to the Canale Navile, the export of Bolognese silk could be carried out by waterway. This third canal, the origins of which also date back to the 12th century, was so named when it became navigable. This transformation was carried out in the mid-16th century by Vignola. The canal itself started from the *sostegno* (lock) della Bova, just outside Porta Lame, where it collected the waters of the Reno, Àposa, and Savena canals, to subsequently travel about 36 km through the marshy plains north of Bologna until connecting with the River Reno and then with the Po. This and other waterways were, for approximately seven centuries, rapid and secure communication routes between the city and the northern Adriatic, with Venice as the principal market from where the silk was sent to northern Europe and various parts of the Mediterranean (p. 47, [33]) [34].

In the latter years of the 18th century, a severe crisis began in the silk market, causing a significant decline in the Bolognese canals. And in the 19th century, Bologna, the most important city in the Papal States after Rome, faced the definitive decline of the silk industry (Figure 3). Nevertheless, the decline of the Bologna canals did not stem from a single cause, but rather from a confluence of technical, health, and urban planning factors. The crisis in the silk industry marked a turning point, but the abandonment of the network was accelerated by the introduction of the steam engine and, subsequently, electricity, which drastically reduced the reliance on hydraulic power. Deprived of their industrial function and, consequently, of maintenance, the canals gradually lost their relevance and were transformed into open sewers and breeding grounds for disease, radically altering their public perception [35].



Figure 3. Picturesque views of the Canale delle Moline by Antonio Basoli and Luigi Venturi from the first half of the 19th century. Sources: Accademia di Belle Arti di Bologna (CC-BY 4.0); Pinacoteca Nazionale di Bologna.

Between the late 19th and early 20th centuries, other canals in the Italian cities of the Po River valley suffered the same fate. Those in Milan were buried in 1929, with the primary aim of converting them into roads to develop a more efficient transport system.

And the Canale Maggiore in Parma was covered over from 1930 "for the sake of healthiness and decorum of the city" (p. 6752, [36]) (p. 182, [37]).

In Bologna, the first systematic burials were linked to the arrival of the railway, which necessitated the covering of the canals near the station to facilitate traffic. Subsequently, the 1889 Plan, inspired by Haussmann's Paris, entailed the burial of the northwestern sector of the city. This phase not only sought road modernisation, but was legitimised by the 1885 "Naples Law", aimed at sanitising urban areas deemed unhealthy following the recent cholera epidemics [35] (p. 57, [38]) (p. 342, [39]).

In the 1930s, the need to open large avenues and modernise the historic centre brought about a new phase of concealment. Between 1931 and 1933, the Cavaticcio canal was covered to make way for the present-day Via Marconi. Shortly after, between 1934 and 1935, a section of the Canale Navile was covered, and the city's old port was almost completely demolished, with only the Salara building (salt warehouse) being saved. The silting of the port and the disappearance of its docks caused a profound impact in the northwestern sector of the city, characterised by the historical presence of hydraulic factories and the high visibility of water. The new urban planning of the area "effectively marked the end of the Navile as a living presence in the city" [34,40].

Finally, the ill-fated canals suffered a definitive blow after the Second World War, based on four main premises: the modernisation of the road network; a health emergency; the recovery of urban spaces; and the adaptation of the sewerage network. Bologna's rapid demographic growth without a modern sewerage network turned the waters into intolerable open sewers for the residents. On the other hand, economic growth required the city to adapt to increased car traffic and imposed the creation of parking spaces. In 1956, the complex covering of the Canale di Reno began in the central Via Riva di Reno, and in subsequent years, the burial policy was extended to other areas (Via della Grada, Via Sabotino) and to Canale Navile. The dismantling of the 1950s, "which saw the locks closed to navigation and the canal downgraded to a second-class hydraulic structure, marked the end of the canal as a piece of infrastructure of importance to the city" [34,35,40] (pp. 57–58, [38]).

1.3. Citizen Awareness and Public Interest

From the 1970s onwards, greater attention began to be paid in Italy to all heritage that, until then, had been considered "minor". Thus, a movement emerged to enhance industrial and technical heritage. From that moment on, various restoration and enhancement projects and interventions for these constructions and structures were developed, generating a growing public interest in Bologna's waterways [34].

According to Carlone and Landi, although the value of Bologna's hydraulic system has shifted from being central to contextual, it remains an important heritage element for the city, around which, however, "the city's historical, cultural and/or recreational dimensions should be structured; these are underpinned by an environmental and eco-conscious ethos, to which the voluntary and non-profit sectors have contributed". Furthermore, various community groups have been working for two decades to raise awareness of the relationship between Bologna and its canal network. "These are initiatives aimed, on the one hand, at the historical, natural and landscape-based restoration of our water heritage, and, on the other, at promoting leisure activities, sustainable mobility and social interaction" [25] (pp. 138, 141).

Today, "Bologna's waterways serve as elements of urban design, recreational facilities, environmental conservation measures and a bastion of historical memory. The city's complex water system, much of which is still visible today, has never ceased to flow beneath the streets and the built environment" [25] (p. 133). For Tozzi Fontana, recent years have

seen various events in Bologna that have favoured "the renewed interest in the presence and use of water which, hidden and overlooked, flows through the city" [41] (p. 50).

The City Council is one of the stakeholders that, in recent years, has carried out valuable work in recovering and improving the hydraulic network through restorations, the design of routes, and the creation of the Museum of Industrial Heritage in 1980 (Table 1).

Table 1. Governance framework of stakeholders involved in the management and dissemination of Bologna's hydraulic heritage. Source: The authors.

Typology	Specific Agents	Roles and Functions	Inter-Institutional Collaboration
Municipal & regional administrations	Comune di Bologna, Città Metropolitana, Province of Bologna.	Executors of urban regeneration, restorations, signage, and cycle-pedestrian itineraries.	Top-down institutional support; adoption of projects proposed by grassroots citizen movements.
Canal Consortium	Canali di Bologna.	Manager of the canal system and main heritage stakeholder: archives, accessible sites, educational programs, and events.	Link between authorities, schools, and citizens; they facilitate access to restricted spaces for tourist and educational purposes.
Local associations; Community	Vitruvio, Amici delle vie d'acqua, Salviamo il Navile, Succede solo a Bologna, Ponte della Bionda.	Community activism, environmental safeguarding, and organisation of dissemination activities.	Bottom-up advocacy and promotion, raising awareness and pressuring public administrations to recover forgotten spaces.
Tourism bodies	Bologna Welcome, ExtraBo, Emilia-Romagna Tourism.	Destination marketing, creation of thematic brochures, and inclusion of the canals in leisure activities.	Inclusion of the recovered hydraulic heritage into accessible tourist products that become part of Bologna's tourism brand.
Cultural institutions	Museum of Industrial Heritage, Salaborsa Library, IBC Emilia-Romagna.	Preservation of industrial and hydraulic memory through the design and organisation of exhibitions and other educational activities.	They provide the documentary and academic foundation that validates the narratives used by tourism bodies, associations, and administrations.

Following the cleaning of the Reno and Moline canals, the council recovered one of the fundamental functions of Bologna's hydraulic network. The construction in 1994 of the Cavaticcio hydroelectric power station, the city centre "has symbolically revived the significance of water as a driving force for generating electricity". Shortly after, between 1996 and 1997, interventions were made to sanitise the Àposa stream. The discovery of the remains of a Roman bridge linked to the Via Aemilia and the *decumanus maximus* of Bononia "has aroused great interest among the public and sparked similar curiosity about Bologna's historic waterworks system as a whole". When, in 1998, the view of two uncovered sections of the Canale delle Moline was restored, including the opening of the now-famous Finestrella of Via Piella, "it was clear that the public had a keen and widespread appreciation of the quality of the rediscovered site" (p. 53, [42]) (Figure 4).

Enhancement projects continued in the ensuing years: the acquisition of the land adjacent to the Chiusa di Casalecchio, converted into a bathing area or *lido* in 1998; the nighttime illumination of the Chiusa itself; the reopening of the Canale di Reno at the Grada, just behind the 14th-century walls; and the regeneration of the porto Navile in 2011, one of the most prominent [42] (pp. 53–54).

Furthermore, the recent enhancement of the Reno and Navile canals through cycle-pedestrian itineraries has been made possible by the strong public advocacy promoted

especially by local groups and associations (Salviamo il Navile, Ponte della Bionda, etc.) that actively champion heritage and environmental safeguarding. Publications and conferences, citizen meetings, shows, walks, environmental activities, and exhibitions are activities "which have found particularly fertile ground thanks to the deep affection of residents for the canal and its historical and social heritage" [43] (p. 3).



Figure 4. Tourists in front of the Finestrella on Via Piella and views of the Canale delle Moline. Source: The authors, 2025.

In this process, the immense work carried out in recent years by the organisation Canali di Bologna, the consortium of the Reno and Savena canals, stands out. Their 2022 survey, conducted among more than 500 people linked to various interest groups in the city and its surroundings, revealed the identity and heritage significance of Bologna's hydraulic heritage. For instance, 77% of respondents strongly or somewhat agreed with the statement that the canals represent a distinctive element of the city. 71% considered them pleasant for walking and sports, and 65% believed they beautified the urban landscape, as if it were a "little Venice". Furthermore, another 65% strongly or somewhat agreed that they have a strong tourist appeal [44] (pp. 27–31).

2. Materials and Methods

The methodology proposed in this research comprised several phases (Figure 5), although not all of them are developed in this article:

A. Understanding: Inventory, selection, description, and analysis. The research combines qualitative analyses (historical, and documentary) with quantitative analyses (tourism data and user reviews) given that the system or network that comprises Bologna's hydraulic heritage is simultaneously a functional infrastructure, a historical legacy, and a tourism product. These analyses were developed in three interconnected phases:

- Historical and heritage analysis. Consultation of specialised scientific literature on the case study to establish the framework for the evolution of the Bolognese

water system (origin, development, proto-industrial function, concealment, and oblivion) and to gather testimonies and preceding studies that demonstrate the recent and growing heritage consideration and the progressive process of citizen awareness and revaluation.

- Tourism analysis. Consultation of the most up-to-date tourism data and reports available to understand the role of Bologna's hydraulic heritage within the city's tourism offering and demand, and to determine its public perception (citizen interest).
- Content and communication analysis. Evaluation of the media and communication tools utilized by public institutions, non-profit organizations and associations, and private promoters for the promotion of the hydraulic system.
    - Specific analysis of Canali di Bologna, the managing consortium of the hydraulic network.
    - General analysis of other institutions, organisations, associations, and companies: Comparative analysis of the narratives offered on websites, tourist guides, etc.

B. Territorial articulation: fieldwork to deepen the understanding of the significance and connection of the canal network with the territory. Phase extending the generic analysis to the reality of the city and its surroundings, based on in situ observation:

- Analysis of routes and itineraries, essential for the environmental and landscape enhancement of the hydraulic network, particularly in the sections furthest from the historic centre.
- Evaluation of the design and content of the outdoor signage, alongside each heritage element.
- Participative observation and content analysis of the wide range of water-themed routes and guided tours in Bologna.

C. Assessment and strategies. The information obtained from the preceding analyses and field work leaded to identify heritage assets and shortcomings, providing valid intervention and awareness strategies for local engagement and tourism promotion.

- In the process of characterising and identifying the values of the Bologna canals (Figure 6), three interrelated dimensions emerge [45] (p. 103):
    - Among the intrinsic qualities of the Bologna canals—the characteristics that define the network—are continuity (uninterrupted itineraries, even if it sometimes appears otherwise due to their burial); linear connectivity (the linking of different places on an urban and territorial scale); unity (the understanding of a system or network, a whole comprised of locks, canals, mechanisms, etc.); and human scale (the relationship of public works with citizens).
    - Among the values of the complex—aspects that make it unique—five are identified: economic (formerly industry and trade, today tourism); environmental (conservation of water and the environment); social (use and collective memory); heritage (civil engineering legacy); and landscape identity (the identification of Bologna as a "city of water", and the territorial articulation based on the canalisations).
    - Among current uses—the contribution of this built heritage to present-day Bologna—the most notable are technical water management (rainwater collection, sewerage, and clean energy production); cultural tourism (visual attractions, guided tours, etc.); education and engagement (educational programmes to reconnect with historical memory);

public space regeneration (parks or urban landmarks driven by the presence of surface or buried water); and slow mobility (pedestrian and cycling itineraries that follow the canal layouts).

- The intervention proposals are selected based on the results obtained in the understanding (analysis) phase.

D. Spatial representation and cartography: mapping the invisible infrastructure and its urban context. Superimposing the network of buried or vanished canals (Reno, Savena, Cavaticcio, Moline, Navile) and their main landmarks onto the city's current street network, creating a baseline for the design and layout of the intervention proposal.

E. Engaging the population: appropriation, use, and activation of social memory following the intervention. Applying Participatory Action Research (PAR) techniques [46] (pp. 3–5), a process of heritage engagement is initiated and evaluated, through which citizens can forge new connections with the canals, both visible and invisible. The interaction of citizens with the proposed interventions and dissemination tools serves as a key mechanism to activate a territorial reading of the hydraulic heritage.

F. Enhancement: public participation, dissemination, and education. This final phase consists of developing a strategic dissemination plan designed as a participatory teaching-learning process. Its goal is to engage the community by using Bologna's urban environment as an open-air classroom or museum in which to better understand the relationship between the city, water, and engineering. The technological and physical proposals enable a more engaging and accessible dissemination.

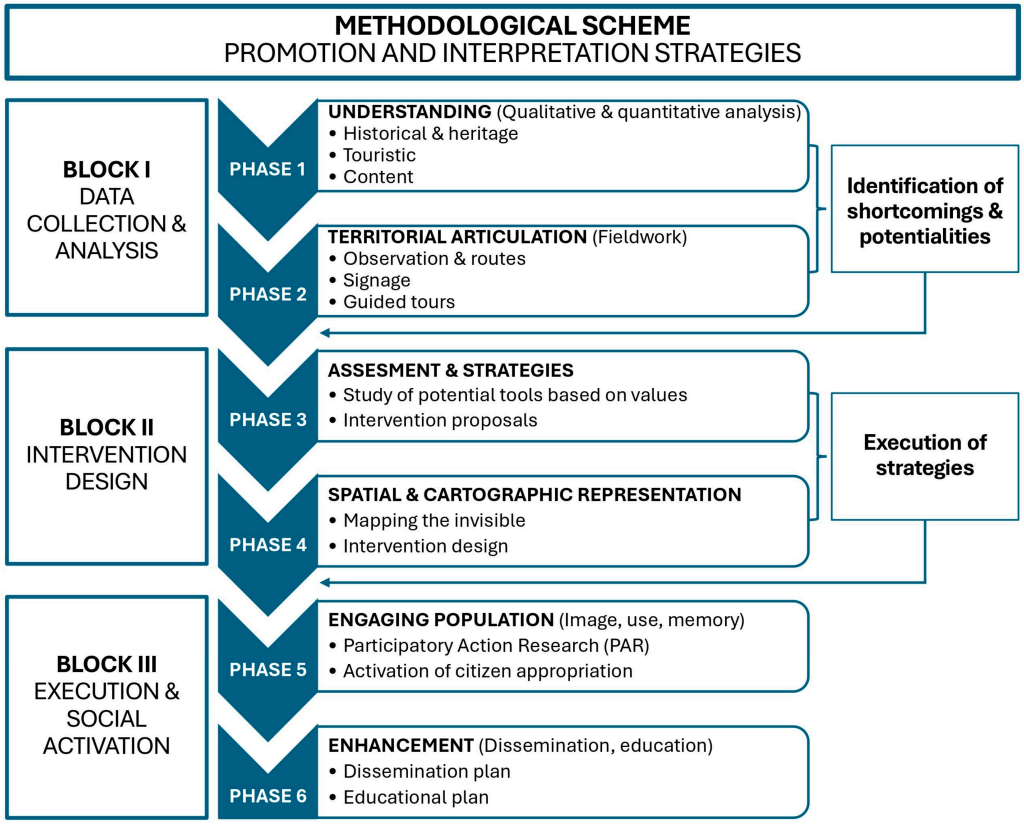


Figure 5. Scheme of the proposed research methodology. Source: The authors.

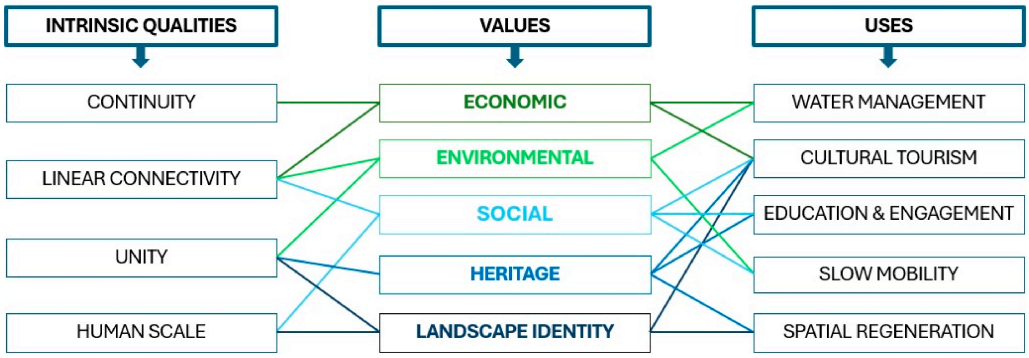


Figure 6. Scheme of the methodological phase for the characterisation and assessment of the Bologna canals. Source: The authors, based on [45] (p. 103).

3. Results

The analysis of the enhancement, promotion, and "social" management of Bologna's hydraulic heritage reflects that the Italian city's canal network has evolved from being a lesser-known heritage asset into a central element of its identity, local cultural revitalisation, and tourism development.

The results presented below are the outcome of the analysis carried out in this research, which aims to answer this question. The problem is identified in Gil, Hernández & Cabau [47] through an analysis that has been synthesised in the following tables as a preamble to the solution proposed in this article.

3.1. Main Results Obtained

A. Awareness, community enhancement, and civic relevance.

   a. Heritage enhancement. Bologna's hydraulic network, underused since the late 18th century and hidden throughout the 19th and 20th centuries, regained interest from the 1970s onwards. The growing appeal of industrial heritage and public works led various associations and organisations (City Council, tourism administrations, Museum of Industrial Heritage, Vitruvio Association, etc.) to develop various restoration and enhancement projects and interventions for these constructions and structures, generating a growing public attachment to the city's waterways.

   b. Local identity and community attachment. The hydraulic system, so relevant to the Bolognese economy and society in the past, has been recovered as an indispensable part of its inhabitants' collective memory. Its different spaces and elements cover the historical, cultural, and recreational dimensions of the city, and some of them, such as the Chiusa di Casalecchio, are genuine hallmarks of social identity, representative symbols, and urban landmarks.

B. Strategic actions and driving stakeholders. The current comprehensive and varied heritage promotion of Bologna's hydraulic network is the result of coordinated, grassroots work by several organisations:

   a. Canali di Bologna as the primary and essential driver of heritage engagement. The Consortium of the Reno and Savena canals is the main promotion stakeholder of this heritage (Table 2). Slogans such as "The history of Bologna flows through two towers and two canals" or "We conserve and enhance" perfectly exemplify this important work [48].

   b. Restoration and creation of visible landmarks. The regeneration and improvement interventions have been crucial in the cultural and identity-based en-

hancement of the system, keeping alive the purpose of unearthing these traces of the past and generating new urban landmarks designed around water.

c. Educational and civic role. The canals are a specific theme addressed in history and heritage education in Bolognese schools. Canali di Bologna and other organisations offer various educational activities for schools, most notably the Percorsi Blu programme, which combines theory with on-site exploration and the creation of communication materials by students [26].

d. Community activism. Various community groups and associations (such as Salviamo il Navile, Vitruvio, etc.) have worked for decades to promote the canal network, organising narratives of historical and landscape regeneration, as well as leisure and social activities. They are also responsible for many regeneration and enhancement projects subsequently adopted and developed by public administrations.

C. Tools and promotion channels. To publicise this heritage, organisations rely on a wide variety of physical and digital formats (Table 3):

a. Signage and open-air museumization. The Cartelli Blu urban signage project, promoted by Canali di Bologna, has led to the installation of 66 information panels with QR codes granting access to multimedia content about the canal network. These panels, alongside other qualified ones such as those on the Lungo Reno Navile itinerary, contribute to strengthening the in situ promotion of hydraulic heritage (pp. 49, 79, [44]) [49].

b. Digital resources. Canali di Bologna also offers excellent content on its website (online archive, interactive map, virtual tours, etc.). Other institutional websites (such as Origine di Bologna and Bologna Online) also provide detailed maps and digital resources about the canals [50–52].

c. Events and special tours. Canali di Bologna is also the organisation that organises the most water-related events, almost all of which have a significant social impact, especially the underground canal tours (Sotterranei di Bologna) and the Notte Blu and Effetto Blu events, featuring a diversity of cultural and recreational activities (p. 72, [44]) [48].

d. Thematic itineraries. Different cycle-pedestrian routes have been developed, such as the Lungo Reno Navile, which follow the course of one or more canals whilst highlighting their constituent hydraulic works. Furthermore, the tourism offering includes several thematic routes on urban hydraulic heritage, such as the *Circuit of Water*, and specialised leaflets like "Acque nascoste a Bologna", which propose tours covering the main points of interest [53–56] (Figure 7).

D. Tourism impact. The analysis also demonstrates that hydraulic heritage has become a differentiating attraction for Bologna's cultural tourism offering, capable of diversifying it (Chiusa di Casalecchio) and reducing its seasonality (Sotterranei di Bologna):

a. New attraction or resource. Water, vital in Bologna's past, is assuming a renewed role as a revitalising element of cultural tourism. The frequently mentioned Finestrella already ranks as the 16th most popular attraction in the city on Tripadvisor, ahead of icons such as the Fountain of Neptune.

b. Need for specialisation. The city requires a new narrative that, through its hydraulic system, uniquely identifies it in the global context and not merely as a little Venice [57].

c. Varied tourism offering. The range of guided tours is extensive, including proposals from Canali di Bologna, the Museum of Industrial Heritage, private companies (such as Arte e Musei) and cultural associations like Vitruvio, which

even offers experiences as varied as the possibility of white-water rafting on the Canale Navile [58–61].

In short, Bologna's hydraulic network has shifted from being a lesser-known heritage into an axis of urban design and collective memory, with an active and qualified multi-channel engagement that, through the physical regeneration of the canals, education, new technologies, and event organisation, has successfully engaged both citizens and tourists.

Table 2. Heritage engagement carried out by Canali di Bologna. Source: The authors, based on [47].

Areas	Media	Main Activities and Intervention Projects
Guided tours	In-house staff guiding on-site	Guided tours of floodgates, locks (Casalecchio and San Ruffillo), hydroelectric power stations, and the Opificio delle Acque museum space.
School education	Classroom materials, graphic resources, outings, and content creation	- Primary: COLORing programme (theory and drawings). - Secondary: Percorsi Blu programme (creation of videos, podcasts, and poster materials by students).
Digital promotion	Website, virtual environments, and social media	Digitised archive, georeferenced interactive map, 3D virtual tours (drone, plans of the Chiusa), and social media (Facebook, Instagram, YouTube).
Signage	Physical panels and QR codes	- Percorsi Blu: drop-shaped stickers on pavements with QR codes linking to schoolchildren's projects. - Cartelli Blu: 66 metal signs with maps and QR codes.
Publications	Books and leaflets	"Bologna città d'acque" leaflet, featuring an illustrated map inviting the discovery of hidden elements and sections.
Special events	Special openings, cultural activities	- Notte Blu/Effetto Blu: special lighting, music, gastronomy, etc. - Sotterranei di Bologna: visits to the underground canals.
Urban regeneration	Public works and landscaping	Opening of the Finestrella (1997); reopening of the Canale di Reno in Via Riva di Reno associated with an urban renewal operation (2025).



Figure 7. (**1**) Example of a City Council information panel on hydraulic heritage in Bologna city. (**2**) Cover of the leaflet "Acque nascoste a Bologna", available free of charge on the Bologna Welcome website. (**3**) Guided tour by the association Succede solo a Bologna inside the Baths of Mario. Sources: The authors, 2025; Bologna Welcome.

Table 3. Heritage engagement carried out by other stakeholders. Source: The authors, based on [47].

Media	Organisations Involved	Main Activities and Intervention Projects
Websites and interactive maps	Comune di Bologna (City Council); Bologna Welcome (Tourism); Salaborsa Library	- Blog post on "Bologna delle acque", inviting tourist discovery. - Interactive map on *condotti d'acqua*. - Interactive map with tabs for the georeferenced urban signs regarding Bologna's water.
In situ information panels	Comune di Bologna	- "Le acque a Bologna": 15 blue signs on posts dedicated to the city's hydraulic network. - Panels about the Canale di Reno (industrial and engineering content) on the Lungo Reno Navile route. - Sculpture-panel in the Oliviero Olivo park.
Routes and itineraries	Metropolitan City/Province of Bologna; Emilia-Romagna Tourism	- Lungo Reno Navile: cycle-pedestrian route of over 40 km following the layout of the Reno and Navile canals. - Hydraulic heritage routes through the urban centre.
Travel and tourist guides	Province of Bologna; Publishers (Insight Guides, Eyewitness)	- Urban guide featuring a "Circuit of the Waters" to discover hidden corners. - International mentions of the canal network and, especially, the Finestrella.
Museums	Museum of Industrial Heritage; Association of Friends of the Museum	- "Bologna of water and silk" exhibition featuring scale models. - Guided tours outside the museum and various educational projects.
Thematic leaflets	Bologna Welcome; ExtraBo (Tourism)	- "Acque nascoste a Bologna" leaflet (route featuring 10 hydraulic elements and spaces of interest). - Maps of the Cycle path associated with Canale Navile.
Guided and experiential tours	Associations and private companies (Vitruvio, Succede solo a Bologna, Emilia Romagna Segreta, Arte e Musei, etc.)	Nature trekking along the Canale Navile; visits to the Baths of Mario (Conserva di Valverde); rafting on the Navile; scholar guided tours and treasure hunts; etc.

3.2. Identified Shortcomings

Despite the intensive and ongoing heritage engagement surrounding Bologna's canals, which enjoys widespread public appreciation, this analysis reveals several shortcomings and challenges addressing the research question:

A. Shortcomings in urban integration through continuous spatial expression. A decade ago, Maldina warned how curious it was "to follow the courses of the canals at the two levels of the city and see how at road level there is no sign of what is flowing underneath" [32] (p. 182). It cannot be claimed that Bologna lacks an adequate signage system; as has been pointed out, excellent initiatives such as the Cartelli Blu have introduced numerous indicators of the canal network into the urban environment. These scattered panels provide valuable data, but they are limited to offering a

fragmented pedestrian experience. Therefore, an integrated spatial dissemination strategy is required, through which citizens and visitors can interpret the hidden canalisations as part of a continuous and unified territorial system. A consistent and potential action is to mark the invisible layout of the underground canals through permanent pavement or ground markers.

B. Shortcomings in promotion through location-based mobile apps. As mentioned, there are interactive maps that use georeferencing for heritage promotion. The websites of Canali di Bologna and Origine di Bologna offer this type of digital maps, and the 66 panels of the Cartelli Blu project, scattered throughout the city, feature QR codes allowing pedestrians to access this content. However, none of these interactive cartographies are available as a mobile application, the most useful tool for effectively connecting linear heritage with the territory in situ.

4. Discussion

4.1. Proposal 1: Pavement Intervention

There are various examples where lost heritage is showcased thanks to urban interventions. Through pavement modifications or the installation of metal plaques on the ground, the layout of old streets, buildings, or other assets that were forgotten after their destruction can be recovered. These straightforward tools capture the pedestrian's attention and, through complementary instruments (websites, mobile applications, information panels, etc.) contribute to highlight urban heritage values.

The original aim of these markers is almost always heritage promotion, aimed at preserving sites' memory. However, these urban interventions often end up becoming tourist resources, more focused on engagement through itineraries and urban walks. In any case, to ensure the success of this engaging action, the marks must be accompanied by information panels or, at least, QR codes that redirect to digital dissemination platforms.

The authors propose four levels to classify the set of heritage pavement markers:

- By scale: Urban markers can be nodal, to represent the perimeter of a building or any other nodal structure, or linear, allowing the length of a linear layout or a network or system to be reflected.
- By design: The markers themselves can be continuous or discontinuous. In most cases, metal plaques, cobblestones, or other materials placed at a certain distance from each other (in linear examples) or scattered across different parts of a city (in nodal examples) are used. In other cases, the marks are made continuous with an appropriate pavement treatment (different materials, colours, reliefs, etc.).
- By institution: There are markers planned and developed by both private organisations and public administrations dedicated to the protection and promotion of cultural heritage, but on other occasions, these interventions originate from public or private organisations dedicated to tourism promotion.
- By purpose: Whether memorial or itinerary-based.

4.1.1. Markers with a Memorial Purpose

Many urban marks are created to show a ground marker of the past, to remember a lost heritage element, or to pay homage to historical moments or prominent figures.

One of the best-known examples, due to its symbolism and historical relevance, is the Bastille fortress in Paris, France. Destroyed during the French Revolution, its location and dimensions can currently be known thanks to cobblestones and plaques placed on the ground. In the same city, a series of 135 plaques indicating the route of the Paris Meridian, dedicated to the French astronomer François Arago, can also be found.

The marker of the Berlin Wall in Germany was created between 2002 and 2006 by the German Senate Department for Urban Development. The *Berliner Mauerweg* (Berlin Wall Trail) invites pedestrians and cyclists to tour the city following the vanished border (p. 226, [62]) (Figure 8).



Figure 8. Top, different treatments of the Berlin Wall marker in the city's streets and parks. Bottom, examples of markers in Paris, France: (**1**,**2**) Metal plaques and pavement treatment to reflect the perimeter of the walls and towers of the Bastille fortress. (**3**,**4**) Metal plaque of the Meridian and continuous section in the Observatory garden. Sources: Tangopaso (Public domain); Jean-François Gornet (CC-BY 2.0); Roland.h.bueb (CC-BY 3.0); Bärbel Miemietz, Aridd, Andrzej Otrębski, Chabe01 & Mbzt (CC-BY 4.0).

4.1.2. Markers with an Itinerary Purpose

Most pavement markers are created with the purpose of generating itineraries that promote heritage through the connection of scattered elements, further fostering urban mobility (Figure 9). Two types of treatments can be applied to this type of pavement marker:

- On the one hand, a continuous line connecting the different spaces, which are marked by installing a plaque in front, can be used. A good practice example in this typology is the highly successful Freedom Trail in Boston, where red paving stones (authentic or painted on the asphalt) accompany visitors along 3.2 km. It is one of the most famous tourist-heritage itineraries in the United States and one of the first created in an urban centre [63] (p. 262).
- On the other hand, routes can be indicated with discontinuous plaques, placed at an interval of a certain number of metres or solely situated in front of the selected sites. This is the case with the red paving stones that, since 1997, have allowed the *Modernisme* Route to be followed in Barcelona, Spain; the signage installed in 2015 for the Commonwealth Walkway in Valletta, Malta; and the plaques marking the properties inscribed on the World Heritage List in the city of Nice, France, since 2024.



Figure 9. Examples of markers for tourist routes: (**1**,**2**) Metal plaque and red line of the Freedom Trail in Boston (USA). (**3**) Red paving stone of the Modernisme Route in Barcelona (Spain). (**4**) World Heritage plaque in Nice (France). (**5**) Commonwealth Walkway plaque in Valletta (Malta). Sources: The authors, 2025; Canaan (CC-BY 4.0).

4.1.3. Specific Examples: Water and Hydraulic Engineering

These interventions in pedestrian streets and pavements allow citizens to rediscover lost cultural assets or orient themselves along tourist routes. But they also serve to draw attention to what lies underground. In many cities, there are rivers, streams, canals, or water pipes that flow buried, without people knowing of their existence. Thanks to this type of marker, they can be made known, making the invisible visible.

Among the main best practices in the signage of buried natural watercourses are the Garrison Creek project in Toronto; the markers of the River Bièvre in Paris; the plaques of the River Effra in South London; and the Ghost Rivers project in Baltimore [64–69]. Regarding best practices related to urban signage allowing the discovery of the existence and layouts of underground or buried civil engineering works over time, from fountains to water supply networks (Figure 10, Table 4), the following stand out:

- The renewal in 2011 of the marker of the Caños del Peral Fountain in Madrid, Spain, during the refurbishment works of the Ópera Metro station. On this occasion, it is an intervention with a heritage objective, of nodal scale and continuous design, accompanied by the reconstruction of one of the granite spouts. Two small scale models were also installed, one of the fountain and another of the walls, and inside the station, the original remains of the fountain can be visited [70].
- Also in Madrid, the intervention carried out in 2021 in the Plaza de los Carros to mark a section of the city's oldest historical water supply system (*viajes de agua* or *qanats*) on the pavement stands out. In turn, a metal plaque featuring a map explaining the Mus-

lim period of Madrid's history and the functioning of these *qanats* was incorporated under the title "Mayrit. An Andalusian medina" [71,72].

- Equally interesting are the plaques installed in 2009 in the city of Segovia, Spain, to mark the underground section of the Roman aqueduct between the famous arches and the present-day *alcázar* (castle) [73].



Figure 10. Examples of markers regarding hydraulic heritage in Spain: (**1**) Caños del Peral fountain, Madrid; (**2**) Plaque marking the route of the *viaje de agua* in Plaza de los Carros, Madrid; (**3**) Plaque of the underground section of the Roman aqueduct in the historic centre, Segovia. Sources: The authors, 2025.

Table 4. Classification of different examples of urban markers, ordered chronologically. Source: The authors.

	By Scale		By Design		Institution (Year)	By Purpose	
	Nodal	**Linear**	**Cont.**	**Discont.**		**Memory**	**Route**
Freedom Trail (Boston)		X	X		U.S. National Park Service (1951)		X
Meridian (Paris)		X		X	City Council; Ministry of Culture (1994)	X	
Garrison Creek (Toronto)		X		X	City Council (1996)	X	
Modernisme Route (Barcelona)		X		X	City Council (1997)		X
River Bièvre (Paris)		X		X	City Council (2000)	X	
Wall (Berlin)		X	X		Senate Department for Urban Development (2002–2006)	X	X
Aqueduct (Segovia)		X		X	City Council (2009)		X
Caños del Peral (Madrid)	X		X		Madrid Metro; Madrid Region Government (2011)	X	
River Effra (Greater London)		X		X	Walking the Effra Project (2012)	X	
Commonwealth Walkway (Valletta)		X		X	Grand Harbour Regeneration Corporation; Ministry of Tourism (2015)		X
Hidden Rivers (Norwich)		X	X		City Council (2016–2017)	X	
Bastille (Paris)	X			X	City Council (2019–2021)	X	
Viaje de agua (Madrid)		X		X	City Council (2021)	X	
World Heritage (Nice)		X		X	City Council (2024)	X	
Ghost Rivers (Baltimore)		X	X		Bruce Willen (artist) and local institutions (2024)		X

4.1.4. Bologna: Current Pavement Markers

In Bologna, where there are numerous examples of signage used to promote the city's underground watercourses and canals, there are very few examples of urban interventions reflecting their layout on the ground.

One of the few examples can be found in Via Alessandro Codivilla, south of the historic centre (Figure 11). This street, built between 1854 and 1857 and known then as Via Panoramica, connects the top of the San Michele in Bosco hill with the Porta di San Mamolo. At a certain point, the asphalt strip is interrupted by a small section of cobblestone pavement, grey on the path and pink at the edges. They were installed in 1943 as additional protection for the air-raid shelter located below. But, since then, they also mark the point where the street crosses the Àposa stream via a single-arch bridge, inside which the World War II shelter was installed. Downstream, to the north, a high masonry wall bridges the drop of about 10 m.



Figure 11. The Àposa stream before entering the "intramural" city. (**1**) Orthophoto reflecting the correspondence between the watercourse and the layout of the garden. (**2**) Masonry wall of the bridge over the Àposa. Sources: Google Maps; Brunelli, M., Giordano, F. (2012). "Aposa segreto. I rifugi antiaerei". Bologna Soterranea. Associazione Amici delle vie d'acqua e dei soterranei di Bologna.

In 2013, the hidden course of the stream was also "highlighted in the paving of the small garden below", from which the buttresses of the retaining wall and the access to the interior of the arch can be observed [74,75]. It is important to note, however, that the landscaped square housing this paved path is not open to the public. In one of the guided tours on Bologna's water offered by the Amici delle Acque Association in this area of the city, it is indicated that the garden is "not open to the public except on these occasions" [76].

To the northwest of Bologna, within the third walled enclosure or *Circla*, lies the Cavaticcio park (Figure 12). Created in 1983 and restored in 2011, it is named after being located over the eponymous branch of the Canale di Reno. The path runs in a southeast-northwest direction following the layout of the buried canal, to a point where the green area gives way to an artificial pond representing the dock of the old port. This urban intervention aims to highlight the memory of the place by recovering the appearance of the Porto Navile, but both the original remains of the port and the Cavaticcio canal itself remain hidden underground [40,77,78].

As Maldina points out, the Cavaticcio garden was, within the remodelling of the Manifattura delle Arti and the MAMbo, "the centrepiece of a project with definitely pos-

itive outcomes." And yet, a unique opportunity to turn it into a pole of attraction and engagement regarding the city's hydraulic heritage was lost: "the redevelopment of a small stretch of the canal, not led, and is not intended to lead, a rediscovery of a part of the history of Bologna. On the contrary, the canal of Cavaticcio was transformed in fountain, an abstract element, a pure aesthetic gesture" [32] (p. 182).

These two Bolognese examples (Codivilla and Cavaticcio) can be considered a missed opportunity in terms of showcasing the city's historic water network. Although they are best practices in terms of paving and landscaping, due to their direct and respectful relationship with the layout of their respective watercourses, they are designs that have not taken heritage promotion into account. The urban and spatial interventions are not complemented by informative tools such as information panels or other types of signage that effectively allow the visitor to discover and understand the hydraulic heritage that justifies and gives meaning to these actions.



Figure 12. "Involuntary" markers of the Cavaticcio and Navile canals: (**1**) Hidden layout of the canals and prominent buildings. (**2**,**3**) Path over the canal in Cavaticcio Park. Sources: The authors based on Google Earth; The authors, 2025.

In 2024, Canali di Bologna carried out an urban intervention linked to the Percorsi Blu educational programme. On a temporary basis, drop-shaped stickers with QR codes were placed on the pavement. Situated on the footways, near the waterways, they allowed pedestrians to access the informative content of the consortium's website. The phrase with which they captured people's attention was: "Did you know there's a canal running underneath here?" [79].

4.1.5. Bologna: Pavement Markers Proposal

As a complement to the outstanding engagement of Bologna's hydraulic heritage, the creation of a ground marker is proposed which, under the name Il Filo Azzurro (The Blue Thread) would mark on the city's pavement the main buried sections of the rivers and canals crossing the city (Figure 13).



Figure 13. Images for the proposed urban marker in Bologna: (**1**) Map showing the layouts of the Àposa stream and the Savena, Reno, and Cavaticcio canals (light blue), highlighting the sections where it would be marked on the pavement (dark blue). (**2**,**3**) Virtual examples of how the marker would look on the city streets, including the scale model [AI-generated images]. Source: The authors, 2025–2026.

Currently, the Finestrella is the hydraulic element in the urban centre that garners the most attention. Nevertheless, its tourist success has generated a partial, even anecdotal, image that renders the rest of the network invisible. This "fragmentation" of public

perception can be corrected thanks to this continuous urban marker, capable of ensuring, as in other analysed examples, the revelation of an integral system. A coherent, continuous, and well-signposted itinerary would make the complete hydraulic network understandable.

This study proposes marking certain sections of the Àposa stream and the Savena, Reno, and Cavaticcio canals, always within the ring road corresponding to the third walled enclosure (Viali di Circonvallazione). Much of the layout runs between buildings, along secondary streets, and through private land, so the markers would only be established on main streets and parks. In short, in accessible spaces or, in any case, where the line can be perceived at a glance by passers-by.

The marker would consist of a continuous line, formed by blue paving stones or of another colour different from the current pavement, interspersed with metal plaques. These would display the logo of Canali di Bologna or the City Council, the most suitable organisations to develop the project, and a legend: Canale Nascosto/Hidden Canal or Canale Sotterraneo/Underground Canal.

As in the Madrid examples of the Plaza de los Carros and the Caños del Peral Fountain, this action could be complemented with the installation of at least one urban scale model showing the complete layout of the network as it passes through the historic centre. The most suitable locations would be Piazza Minghetti, through which the Àposa stream flows; the surroundings of Via Piella, taking advantage of the proximity of the highly successful Finestrella; Porta Galliera, next to the uncovered section of Canale di Reno; or Cavaticcio park, next to the pond representing the old dock of Porto Navile.

It should be noted that this proposal is not intended to be a reductionist exercise, limited to transferring the existing vertical signage to a horizontal format. On the contrary, the aim of Il Filo Azzurro is to foster the transition from the current fragmented communication to an integrated spatial dissemination framework. The continuous physical marker aims to function as a band connecting the landmarks and their panels (such as the Finestrella and its corresponding cartello blu) into a cohesive territorial narrative. Combined with subsequent participatory actions and educational programmes, the marker would evolve from a simple urban design intervention into an active mechanism of social engagement, enabling a dynamic and continuous reading of Bologna's hydraulic legacy (both visible and hidden).

It is worth noting that the description and visual representation of Il Filo Azzurro presented in this study are, fundamentally, a conceptual proposal. In a real-world application scenario, the boldest interventions would be conceived as temporary and reversible actions. Furthermore, should a permanent marker be installed, it ought to adopt a more discreet design (a discontinuous layout, materials integrated with the existing historic pavement, etc.), guaranteeing absolute respect for Bologna's historic centre and its aesthetic and conservation guidelines.

4.2. Proposal 2: Mobile Application with an Interactive Map

4.2.1. Original Mobile Application, 2016–2021

Although Canali di Bologna already has an interactive map georeferencing the main heritage elements of the city's hydraulic network, it is only available via its website. Between approximately 2016 and 2021, it had a mobile application which is unfortunately no longer active, but which included a map with these points of interest (Figure 14).

Its operation relied heavily on Bluetooth beacon technology. Whenever a user approached one of these points, the app automatically activated the corresponding content, acting as an interactive audio guide. This is a useful option for urban tours, since the phone informs the user automatically as they approach the included elements [80].

Canali di Bologna has not publicly stated the reasons for withdrawing the tool, possibly due to various issues. On the one hand, reliance on Bluetooth transmitters can become an obstacle due to its costly maintenance (installation, calibration, repair, etc.). Moreover, the app may have become obsolete due to a lack of necessary updates, preventing its adaptation to continuous iOS and Android changes.

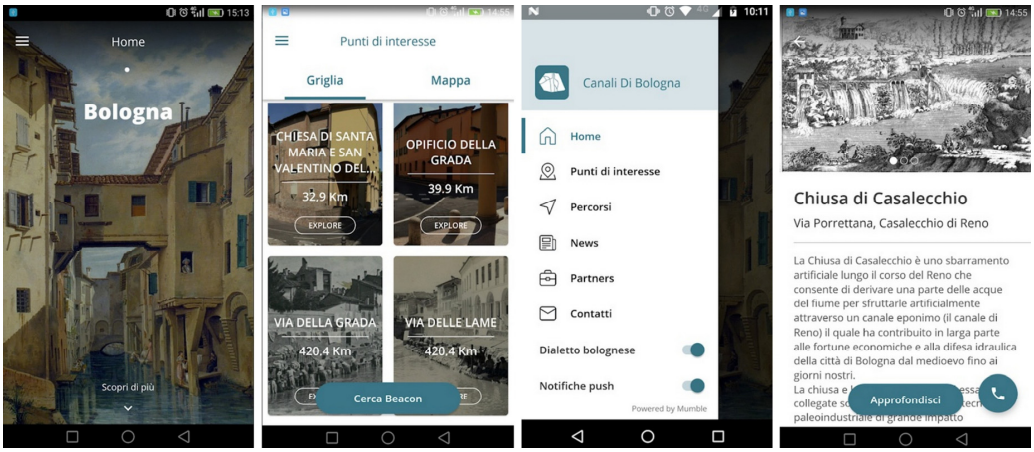


Figure 14. Screenshots of the discontinued Canali di Bologna mobile application. Source: [80].

4.2.2. Applications Concerning Hydraulic Heritage and Best Practices

Water heritage or landscapes require tools to understand the complex historical relationship between hydraulic public works, territory, and society. In this regard, digital technologies facilitate the visualization of historical scenarios, the interpretation of currently hidden elements, and the dynamic understanding of the evolution of the hydraulic landscape [81] (pp. 3717–3719).

There are very few examples of mobile applications based on interactive maps with georeferencing aimed at promoting hydraulic heritage. There are various apps on industrial heritage, and slightly fewer on civil engineering heritage [82,83]. But there are very few examples of apps on navigable canals, and even fewer specifically dealing with supply systems or other types of canalisations, like those in Bologna.

An exceptional case is the C&O Canal Explorer application, dedicated to the navigable Chesapeake & Ohio canal in the United States and designed to provide tourists with a tool to explore this important 19th and 20th-century public work more deeply [84]. Another example is the Open Canal Map application, which georeferences both the routes of the canals and the points that make them up. Among the latter, some are part of these public works (locks, bridges, tunnels, etc.) and others relate to navigation or linked tourist services (boats, fishing areas, information, picnic areas, toilets, etc.) [85].

In general, new technologies "change users' perceptions of and relationships with place and help them visualise the deep territorial significance of public works". As part of these, the features of mobile applications, perfectly detailed in 2021 by Hernández et al., make them highly effective instruments in heritage promotion. They are "essential tools that favour access to vast amounts of orderly, geolocated information", and with them "territorial scale civil engineering heritage can be more fully identified, assessed, disseminated and recovered" [83] (pp. 3, 22).

An example of best practice, although not related to hydraulic systems but to all types of civil engineering heritage, is the Spanish GOING application (Grandes Obras de Ingeniería/Major Engineering Works) (Figure 15). It stands out from a tourism perspective because its interactive map is connected to Google Maps, meaning users interested in finding a specific work are redirected to this page, where directions (on foot, by car, etc.) from their location are displayed [86].

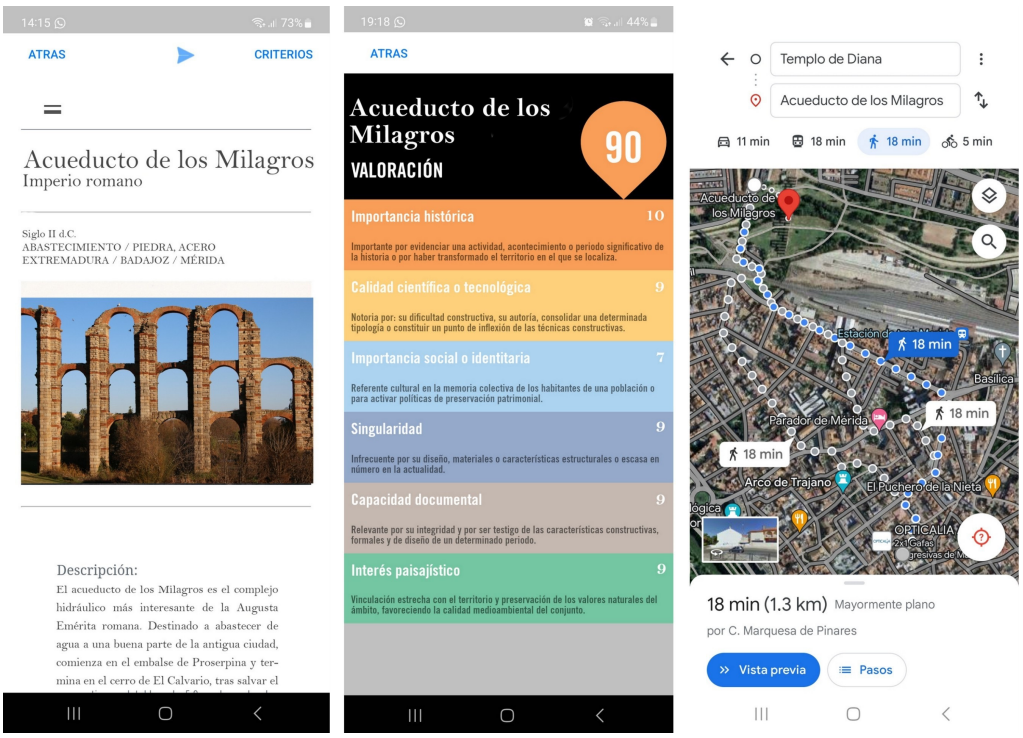


Figure 15. Screenshots of the GoING app, featuring an example of an information sheet, a heritage assessment tab, and a route provided by Google Maps. Source: [60] (p. 68).

4.2.3. Advantages of Applications over Websites

Cultural heritage can be explored online, remotely. But it can only be experienced in situ. Furthermore, promoting linear public works (such as canals and supply systems) requires itineraries that enable visitors to traverse and discover their routes and individual elements. This approach fosters a comprehensive understanding of these structures as interconnected networks within their territorial context. For this reason, the advantages of offering visitors a mobile application are considered greater than referring them to a website or online database (Table 5).

Table 5. Comparison between website and mobile application functions. Source: The authors.

Function	Websites	Apps
In situ access	No	Yes
Browsing speed	Standard	Fluid, instantaneous
Location and orientation	Remote	Real-time position
Analysis and continuous improvements	Limited in field use	Route optimisation
Geolocation	Limited	Precise, continuous
Proximity notifications	No	Yes
Offline access	No	Yes (preloaded content)
Multimedia resources	Unstable	Stable, fluid
Route customisation	Limited	Complete
Integration with sensors	Very limited	Complete
Stability for itineraries	Sometimes limited	Native and fluid
Access to native functions	Limited	GPS, camera, notifications

4.2.4. Bologna: Application Proposal

Both the interactive map on the current website and the 66 Cartelli Blu are excellent as static or blended resources, and the connection via QR codes between physical signage and digital information is a good engagement practice. However, a mobile application would

allow moving from passive interpretation to proactive mediation, accompanying the user on tours, notifying and contextualising information in situ. In this way, visits could become guided (self-guided) and personalised experiences in real time. The application, which would be available in several languages, could integrate these interpretative tools:

- Current georeferenced interactive map but allowing the user to know their real-time location relative to the different points of interest. Old maps could be georeferenced and overlaid on the main base, facilitating the comparison of the canals' relationship with the urban grid in different eras.
- Geolocated routes with different themes: Chronological (Roman, Medieval); Typological (historical, industrial, natural); and Geographical (by city neighbourhoods).
- Augmented reality to visualize lost elements, the canals in different eras, working hydraulic mechanisms, or productive buildings. For example: weirs, the Canale delle Moline waterfalls, old dyeworks, and historical machinery such as the silk spinning mechanism.
- Simplified audio guides to provide basic information without aiming to replace guided tours, which are more comprehensive and effective.

4.3. Research Limitations

The research presents a series of limitations, such as the absence of complementary qualitative and quantitative techniques (interviews, surveys, etc.) and the lack of a cost assessment. The dissemination strategies (markers and application) are treated as conceptual proposals, but they are not developed in detail, and a more in-depth study would need to be carried out subsequently. Regarding the methodology, the actual quantitative assessment of the social impact of the final Engagement and Enhancement phases cannot be measured empirically unless the institutions involved (City Council or Canali di Bologna) implement the physical or digital tools.

On the other hand, a future development of the marker will need to consider the actual layout of the canals, which runs under buildings, secondary streets, and private properties, preventing the line from being strictly uninterrupted. It will also require a detailed study of design, materials, or colour palette that is respectful of the city's historic centre. As for the mobile application, the final format requires further empirical research to assess the behaviour and preferences of potential users. Furthermore, the inactivity of the previous Canali di Bologna app serves as a reminder of the external limitations of digital tools, which require constant maintenance and funding to prevent their obsolescence.

5. Conclusions

This research set out to answer whether, within the heritage conception of the Bologna canals, there is a territorial understanding of them as a cohesive system or network. Based on the analyses, the conclusion is that such a territorial understanding is currently lacking. While the canals have successfully emerged as a key element of the city's identity, the public perception remains highly fragmented. The current promotion and engagement work, although notable, is excessively focused on specific, isolated landmarks (such as the Finestrella) and neglects the spatial understanding of the network as a whole.

It is therefore essential to connect its recognizable, visible elements with the underground, invisible ones. The proposed strategies (linear pavement signage and a new mobile application based on georeferencing) aim to address the identified shortcomings in urban and digital integration. Based on the successful implementation of similar interventions in other cities, these tools have the potential to overcome the current fragmented vision to be overcome, facilitating a continuous and spatial reading of the hidden network flowing beneath the streets.

In short, the hybrid combination of physical interventions in public space and in situ interactive technological can be an essential strategy to recover the integral memory of hydraulic engineering and foster processes of social appropriation. With these implementations, Bologna would take another step in its positioning as a cultural tourism destination and as an international benchmark for best practices in the enhancement of the heritage of public works.

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