Archaeological Heritage and subsidence-induced flood risk: the emblematic case of Santa Croce in Ravenna (Italy)

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ABSTRACT

The archaeological complex of Santa Croce, located in the historic centre of Ravenna (Italy), within the buffer zone of the world heritage site of the Early Christian Monuments, near the Basilica of San Vitale and the Mausoleum of Galla Placidia, includes a 17th-century church, the remains of the original 5th-century basilica and of a Roman domus with well-preserved mosaic floors. Over the centuries, the area has undergone several extensive architectural transformations and has been affected by intense natural and anthropogenic subsidence, which lowered the original ground surface well below the current water table. The site, after the extensive archaeological excavations, has been repeatedly flooded over the past decades — most recently in March 2025 — due to the limitations and failures of the permanent drainage system installed in the late 1970s.

In 2022, as part of the EU Horizon 2020 research project SHELTER, a comprehensive geotechnical investigation campaign was carried out, including field and laboratory tests. Based on these data, a finite element numerical model was developed to simulate current seepage conditions within the excavated area and the effect of possible interventions to mitigate flood risk and related damages to archaeological structures. Key hydraulic parameters were calibrated back-analysing measurements obtained by a purposely implemented and still operating piezometric monitoring system.

Keywords: Cultural Heritage Preservation; Land Subsidence; Shallow Aquifers; Seepage Numerical Modelling; Drainage System; Santa Croce Site (Ravenna, Italy).

INTRODUCTION

Land subsidence, the gradual lowering of the ground surface, represents a pervasive yet often overlooked geohazard with profound environmental, social, and economic implications. Once perceived primarily as a coastal phenomenon associated with relative sea-level rise, today is well established that subsidence affects a wide spectrum of urban environments—including major inland cities—undermining the stability of buildings and critical infrastructures. Its slow and often invisible progression can mask its severity; it spans administrative boundaries and rarely falls under a single institutional mandate. Consequently, it is frequently neglected until the associated damages become economically and socially intolerable (Ohenhen et al., 2025).

The origins of land subsidence are both natural and anthropogenic. Natural drivers include tectonic movements, glacial isostatic adjustment, and long-term compaction of unconsolidated sediments. Anthropogenic causes, however, dominate in densely populated and industrialized regions, where human activities accelerate ground deformation. Excessive groundwater extraction induces consolidation of compressible strata, while the cumulative load of urban construction and dewatering for foundation excavations can locally amplify settlements (Gambolati et al., 2006).

Emilia Romagna region in Northern Italy (Figure 1 A) is the most vulnerable in Italy to hydrogeological risks due to the combined effects of natural and human factors. Its steep Apennine slopes drain rapidly into a low-lying, subsiding plain (Po River plain), crossed by a dense network of rivers and artificial canals (Marchi et al., 2025). Extensive urbanization and soil sealing reduce natural infiltration, while groundwater and gas extraction have accelerated the land subsidence phenomenon, especially along the coast. However, this region hosts an outstanding cultural heritage, with approximately 23,000 buildings and historic sites, of which 8% are located in areas associated to high flood probability (HPH), 55% to medium probability (MPH) and 64% to low probability hazard (LPH), corresponding to return periods of 20–50 years, 100–200 years, and over 200 years, respectively (Figure 1 B) (ISPRA, 2021).

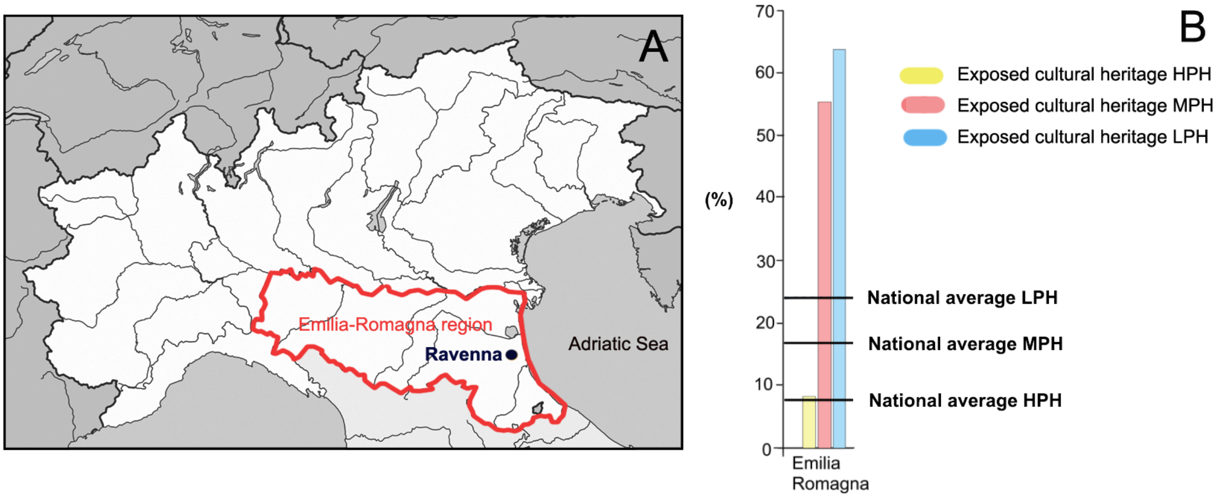

Figure 1. *A) Geographical setting of the study area. B) Percentage of cultural heritage assets of the Emilia-Romagna region located within flood-prone areas for the three flood-probability scenarios and corresponding values calculated at the national scale. Modified from ISPRA (2021).*

The city of Ravenna is located on the southeastern edge of the Po River plain, around 10 km from the Adriatic coast (Figure 1 A). The city is highly urbanized and hosts residential buildings, industrial areas, a major port and a wide range of tertiary activities, especially related to tourism. In particular, Ravenna is internationally renowned for its eight UNESCO World Heritage Sites, celebrated for their exceptional early Christian mosaics and architecture.

However, this valuable and densely developed urban setting is particularly exposed to significant hydrogeological hazards. The city faces significant hydrogeological risks due to its low-lying and subsiding ground surface, to its proximity to the Adriatic coast and to the widespread presence of rivers and drainage canals, which together increase vulnerability to flooding, storm surges and sea-level rise. Moreover, the area is historically affected by intense natural subsidence, among the highest recorded across the Po Plain. In recent decades, Ravenna and its surroundings have experienced a severe anthropogenic land subsidence, reaching up to fifty times the natural rate, essentially driven by fluid withdrawal from the subsoil (Bertoni et al., 2005). Although the problem has been more recently mitigated thanks to specific government actions, the cumulative negative effects associated with elevation loss in the area still persist (Ricceri, 1992).

This contribution presents the emblematic case study of the Church of Santa Croce in Ravenna (Figure 2 B), located within the buffer zone of the monumental complex of the Mausoleum of Galla Placidia and the Basilica of San Vitale, both recognized as UNESCO World Heritage Sites since 1996 (Figure 2 A). Although the church has not preserved its mosaic heritage like its neighbouring monuments, it remains a significant testimony to the city’s glorious past, when Ravenna served as the capital of the Western Roman Empire from 402 to 476 AD.
The paper first presents the increasing flood risks to which the Roman mosaics and the whole historic site are subjected, then it illustrates the geotechnical investigation campaigns carried out over time to ensure the site’s enjoyment and to mitigate the effects of land subsidence. It also presents selected results from in-situ tests, laboratory analyses and a preliminary three-dimensional numerical model simulating the distribution of pore water pressures in the shallow aquifer system beneath the site. The final calibrated model will support the design of a new drainage system aimed at controlling the

groundwater table and pore water pressures in the area, ultimately enabling the full preservation of the archaeological site together with a safe public access to it.

***Figure 2**. A) A bird's-eye view of the Santa Croce site and neighbouring monuments (image source: Google Earth); B) View of the Santa Croce Church and of the archaeological remains located within the excavated basin.*

HYDROGEOLOGICAL CONTEXT AND LAND SUBSIDENCE

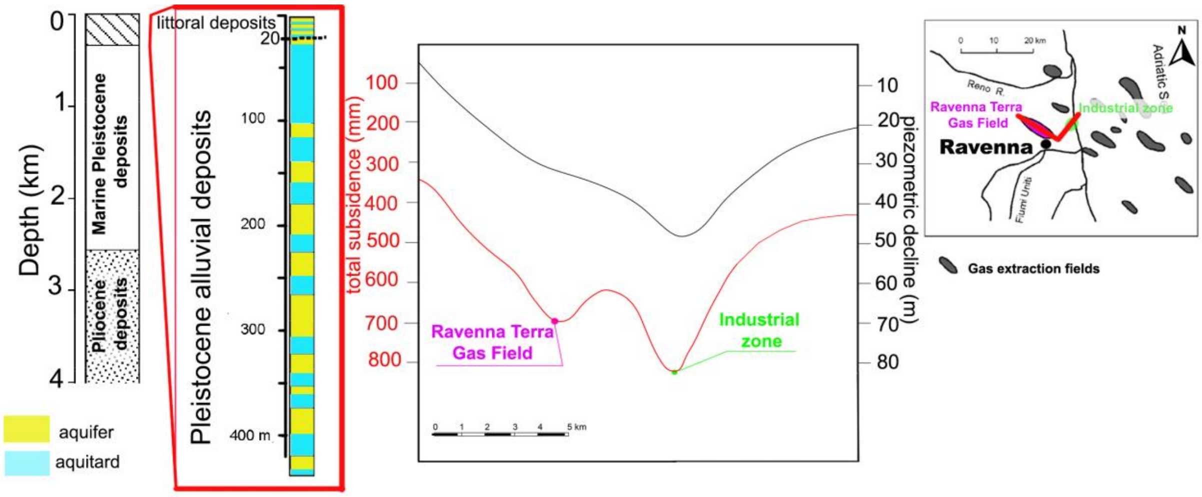

***Figure 3**. A) Stratigraphic column of the soil deposits underneath the Ravenna city centre. Modified from Carbognin et al. (1984). B) Piezometric decline and corresponding total ground-surface subsidence measured along the red section shown in the map on the right. Modified from Carbognin et al. (1984).*

The city of Ravenna lies in a geologically young and dynamic area shaped by the interplay between fluvial, marine and deltaic processes. The shallow subsoil is composed of a thick sequence of Quaternary deposits, reaching several hundred meters, and resting on Pliocene marine clays (Figure 3 A). The top of the Quaternary sequence is composed by a 0.4 km thick littoral, lagoon and alluvial Holocene and Pleistocene sediments, whose uppermost 20 m, directly interacting with the archaeological site, is characterized by Holocene sandy littoral sediments, deposited during a regressive phase of the sea that followed the Flandrian marine transgression (i.e., when the shoreline reached its maximum inland extent around 6,000–7,000 years BP) (Figure 3 A) (Teatini et al., 2005).

This geological setting, characterized by thick, relatively young and compressible sedimentary deposits, makes the Ravenna area particularly prone to land subsidence. Natural land subsidence in this area has been estimated to occur at a rate of approximately 2–3 mm/year over the last 2,500 years (Gambolati & Teatini, 1998). Starting from the 1950s, subsidence rates increased markedly in the eastern sector of the Emilia-Romagna region due to anthropogenic activities, primarily related to

intensive groundwater withdrawal from the multi-aquifer system extending to depths of about 450 m (Figure 3B), as well as gas extraction from both onshore and offshore reservoirs. This phase coincides with Italy's post–World War II economic boom.
Subsidence reached its peak between 1972 and 1973, when rates of up to 110 mm/year were recorded in the industrial area of Ravenna and about 80 mm/year in the historic city centre (Carbognin et al., 1984). From the late 1970s onward, the phenomenon progressively declined as a result of targeted mitigation measures implemented by the Italian government. These included the introduction of mandatory permits for new wells, progressive restrictions on groundwater extraction in the most critical areas (e.g., Ravenna and the coastal zone), the development of the Canale Emiliano Romagnolo for agricultural and industrial water supply, and the construction of the Ridracoli public aqueduct mainly for civil use.
The reduction in groundwater withdrawal, combined with the progressive depletion of many gas reservoirs, led to a significant decrease in subsidence rates. By the 1990s, subsidence in the historic centre of Ravenna had dropped to less than 5 mm/year (Teatini et al., 2005), approaching values comparable to those recorded before World War II.

SITE HISTORICAL EVOLUTION AND CURRENT CONFIGURATION

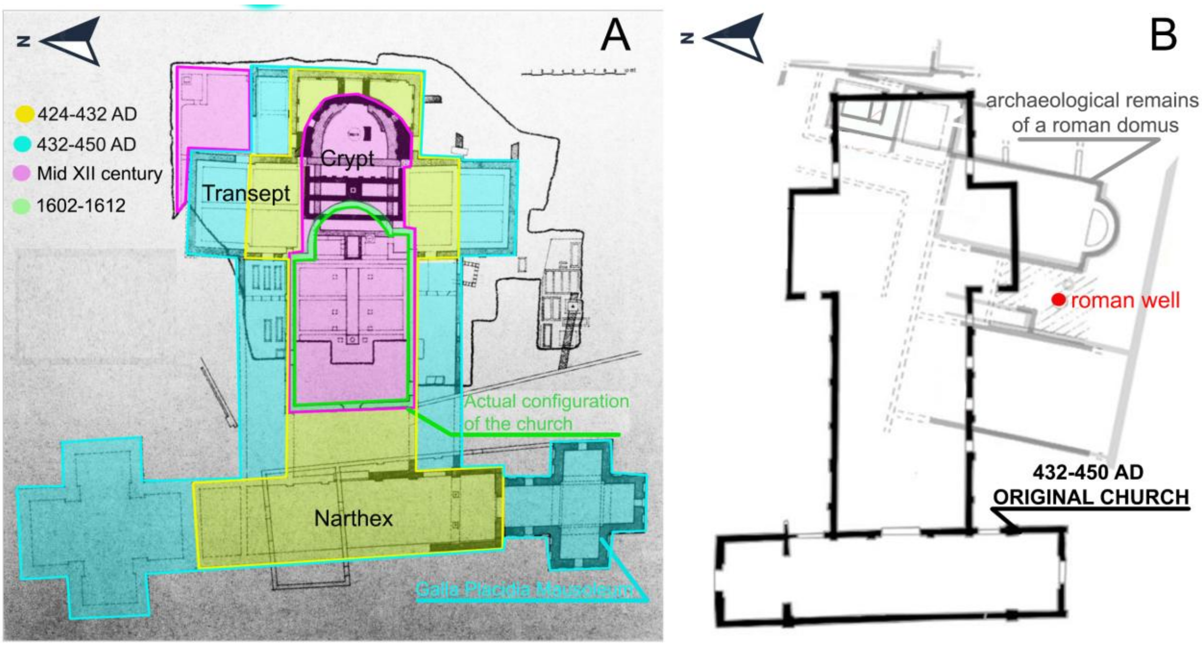

Figure 4*. A) Architectural evolution of the Church of Santa Croce; B) Superimposition of the 5th-century AD church structure (in black) onto the preceding Roman residential settlement (in gray). Modified from Verdier (2015).*

The site of Santa Croce is the result of a long and complex sequence of construction, decay, and restoration phases extending over more than fifteen centuries (Figure 4 A).
Archaeological excavations have revealed the coexistence of three major historical layers:
(i) the remains of a Roman domus dating to the late Imperial period (2nd–3rd century AD), abandoned in the 4th century (Figure 4 B);
(ii) the late-antique church of Santa Croce, erected between 424 and 432 AD by Empress Galla Placidia;
(iii) the 17th-century church, still standing today, built after the demolition of part of the original structure.

The first phase of the basilica (ii) consisted of a single-nave Latin cross plan with a rectilinear apse and a narthex. Shortly after its completion, the building underwent significant enlargement: the transept arms were extended, two side porches with mosaic pavements were added, and the southern sacellum—the future Mausoleum of Galla Placidia—was constructed (Figure 4 A) (David et al., 2013). Between 1602 and 1612 the basilica was completely transformed: the narthex was demolished, the façade set back to open a new street separating it from the Mausoleum (Galla Placidia street), and a semi-circular apse

and bell tower were added (Figure 4 A). These works marked the definitive separation of Santa Croce from the Galla Placidia complex, profoundly altering its original urban and symbolic unity.
In the 1980s, excavations were carried out around the church to uncover the archaeological remains (David et al., 2013); consolidation works and the installation of a permanent drainage systems had to be also implemented to mitigate the effects of land subsidence and maintain dry the excavated basin.

LAND SUBSIDENCE AT THE SITE AND THE DRAINAGE SYSTEM

Building on the subsidence framework described above, the cumulative settlement at the Santa Croce site can be quantified as follows. Assuming an average natural subsidence rate of about 2 mm/year, the Santa Croce monumental area is estimated to have undergone approximately 2.9 m of settlement from the time of its construction (424 AD) to 1897. An additional 1.25 m of settlement, resulting from the combined effects of natural and anthropogenic subsidence, was recorded between 1897 and 2002 by a nearby benchmark located at Porta Adriana (about 300 m away).
The total settlement affecting the area can therefore be conservatively estimated at around 4.2 m. This explains why the original ground level of the Church of Santa Croce now lies ~4 m below the present-day street level of Via Galla Placidia, which is located at approximately +1.5 m a.m.s.l (Figure 6).

Figure 5. *A) Flooding of the Santa Croce archaeological site in August 2019. From Bitelli et al. (2021). B) Map showing the layout of the drainage system operating in the area. The image also schematically represents, through a stylized eye, the perspective of the photograph shown in A.*

As a consequence of this marked elevation loss, groundwater control becomes a critical issue for the preservation of the archaeological site. In fact, in this area, the undisturbed phreatic water table lies approximately 1.5 m below the level of Galla Placidia street. However, thanks to the drainage system installed in the archaeological area, the water table is maintained below the level of the excavated basin surface (Figure 5 B). The system consists of perforated drainage pipes running along two sides of the excavation, which collect groundwater and convey it to a storage tank, from where two pumps lift and discharge it into the street sewer network (Figure 5 B).
Over time, however, the drainage system has lost efficiency due to a lack of maintenance causing the clogging of pipes by eroded soil particles. As a result, water now flows over the surface, promoting soil erosion, as evidenced by shallow slope instability and differential settlements affecting the archaeological structures near the drainage tank (Marchi et al., 2024).
Moreover, malfunctions of the pumping system occasionally cause flooding of the basin, leading to widespread degradation and biological colonization of the archaeological remains of the church and of the Roman mosaic floors preserved on site (Figure 5 A) (Ugolini et al., 2020; Giorgi et al., 2025).

FROM THE SITE INVESTIGATION CAMPAIGNS TO THE GEOTECHNICAL MODEL OF THE SUBSOIL

The first investigation campaign at the Santa Croce–Galla Placidia–San Vitale monumental complex was carried out in 1983 (Ricceri, 1992). A total of five continuous-core boreholes and five cone penetration tests (CPT) were performed (Figure 6).

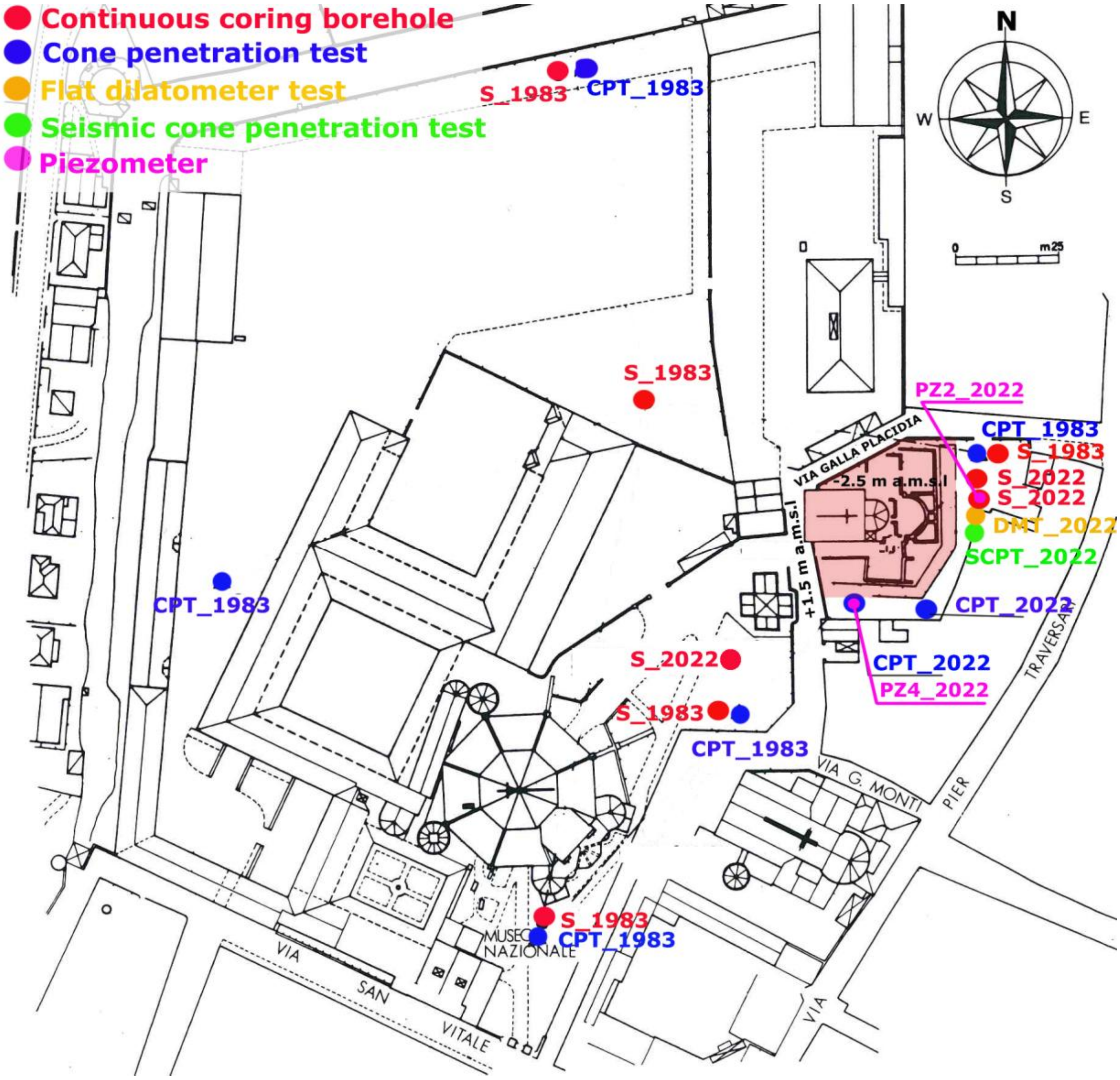

Figure 6. *Map showing the location of in situ tests carried out during the 1983 and 2022 geotechnical investigation campaigns, along with the positions of selected monitoring devices.*

In 2022, within the framework of the European H2020 SHELTER Research Project, a new investigation campaign was carried out. The activities included three continuous-core boreholes with the collection of undisturbed samples, one dilatometer test (DMT) and three piezocone tests (CPTu) - one of which seismic (SCPTu).
In addition, the piezometric levels of five piezometers and of an ancient well, located in proximity of the Church of San Vitale, were monitored. Results from the first eighteen months of monitoring are reported in Marchi et al. (2023, 2024).
The analysis of the core samples extracted during the 2022 investigation campaign, combined with the SBT Robertson's (2016) interpretation of CPT data confirmed the stratigraphic model previously proposed by Ricceri (1992).

Down to the maximum investigated depth of 40 m, the subsoil consists of five main geotechnical units—**R, I, II, III, IV, V**—which are laterally continuous across the study area, though their thickness varies locally. The interfaces between units are generally horizontal or gently inclined.
Taking the Galla Placidia street as the elevation reference, the anthropogenic layer (**R**) extends from the ground surface to about –5.4 m and consists of recent alluvial deposits mixed with man-made fill materials and archaeological remains (Figure 7). Below this layer, the natural soil sequence appears as an alternation of granular (aquifer) and more fine-grained (aquitard) layers.

- The **unit I**, extending from –5.4 m to –23 m, is composed of fine sands with interbedded silty lenses. Grain-size analyses indicate an absence of gravel, a sand content decreasing from about 60% near the top to 40% at depth, and a corresponding increase in silt content from 25% to 45%, reflecting gradual textural fining (Figure 7).
- The underlying **unit II**, of cohesive nature and approximately 6 m thick, consists of a dark grey to greenish silty clay. The sand fraction remains below 20%, while the clay and silt fractions maintain similar proportions. The clay content, varying between 10% and 55%, corresponds to a plasticity index (PI) in the range 5 to 30% (Figure 7).
- The **unit III**, a coarse-grained formation composed of grey medium-coarse sand, is consistently thinner than the overlying sandy unit I (5 m vs 16 m).
- The **unit IV**, a greenish-grey silty clay with thin sandy and silty interbeds, has its base located at 35.0 m from the ground level and a thickness of ~ 1.3 m.
- The **unit V,** a fine clean-sand aquifer, represents the lowest layer investigated.

The boundaries of Units IV and V were identified through investigations extending beyond the depth of SCPT_22, including a core drilling carried out on the north-east side of the Santa Croce site during the 2022 campaign, reaching 36 m depth, as well as continuous core drillings performed during the 1983 campaign down to 40 m.

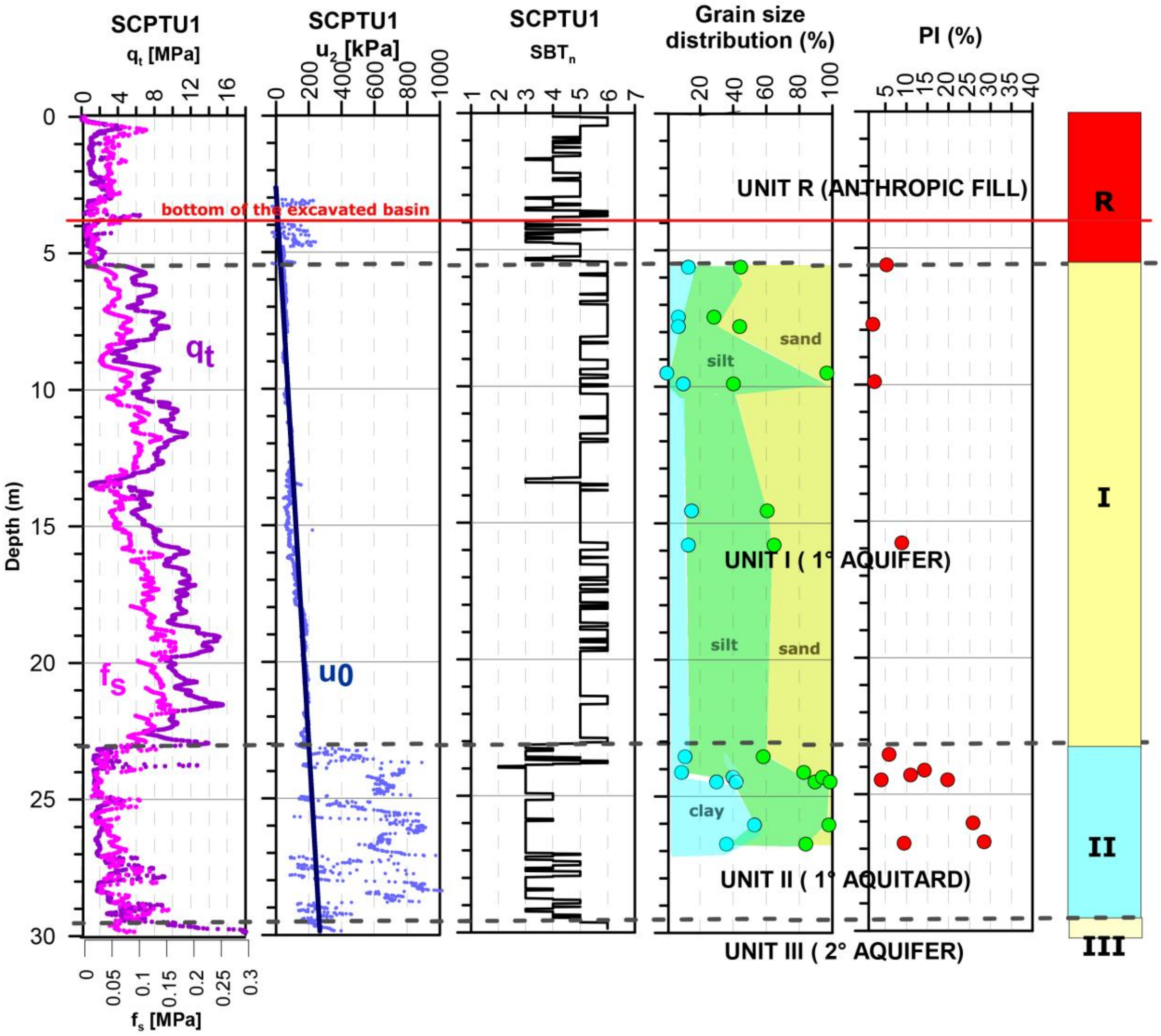

Figure 7. *From left to right, profiles with depth of corrected cone resistance (q_t) and sleeve friction (f_s); pore water pressure at the cone shoulder (u_2) and hydrostatic pressure (u_0); Normalized Soil Behaviour Type class (SBTn), all elaborated from SCPT_2022 (Figure 6); grain size distribution and Plasticity Index (PI), obtained from laboratory tests.*

THE 3D NUMERICAL MODEL OF THE TRANSIENT SEEPAGE IN THE SHALLOW AQUIFERS

Several geomatic techniques were employed to develop a high-resolution 3D model of the Santa Croce site (Bitelli et al., 2021), that supported the creation of a three-dimensional finite element numerical model in PLAXIS 3D, aimed at simulating the distribution of pore water pressures within the 3D aquifer system underlying the Santa Croce complex, as influenced by the drainage system currently in operation.
The local stratigraphy was incorporated into the numerical model using the Boreholes function of Plaxis 3D, which interpolates the stratigraphic profiles defined at the investigation points, corresponding to the CPTu tests and continuous-core boreholes carried out during the 2022 campaign.

The model domain measures 195 × 177 × 44 m (x*y*z), extending several times beyond the Santa Croce basin to ensure that the external boundaries are located where the shallow aquifer system is only marginally influenced by the drainage operation.

The bottom boundary was set within the sandy **unit V**. The domain was discretised using tetrahedral mesh elements with an average size of 2.0 m, refined to the centimetric scale near the drainage system. The simulation covers a 100-day period (from 22/03/2022 to 30/06/2022).

The hydraulic boundary conditions of the model were defined as follows:

- Upper boundary: prescribed infiltration flux (rainfall), Neumann-type boundary condition;
- Lower boundary located in unit V: constant piezometric head equal to the undisturbed water table level (measured at pumps shut down);
- Lateral boundaries: for units R and I, boundary conditions were defined based on piezometric observations from a historical well located near S_1983 (Figure 6) at the San Vitale site; for unit III, they were defined using data from a piezometer installed in this aquifer. The lateral boundaries associated with the clayey units II and IV were prescribed as a linear interpolation between the piezometric heads of the overlying and underlying units.

The drainage system has been modelled as imposed-pressure head lines lowering the phreatic water table to 0.4 m from the basin surface in the east side, and to 1 m in the south side, close to the extraction pumps, in accordance with the comprehensive survey of the entire drainage system conducted in 1995 (CMC, 1995) (Figure 8 A).

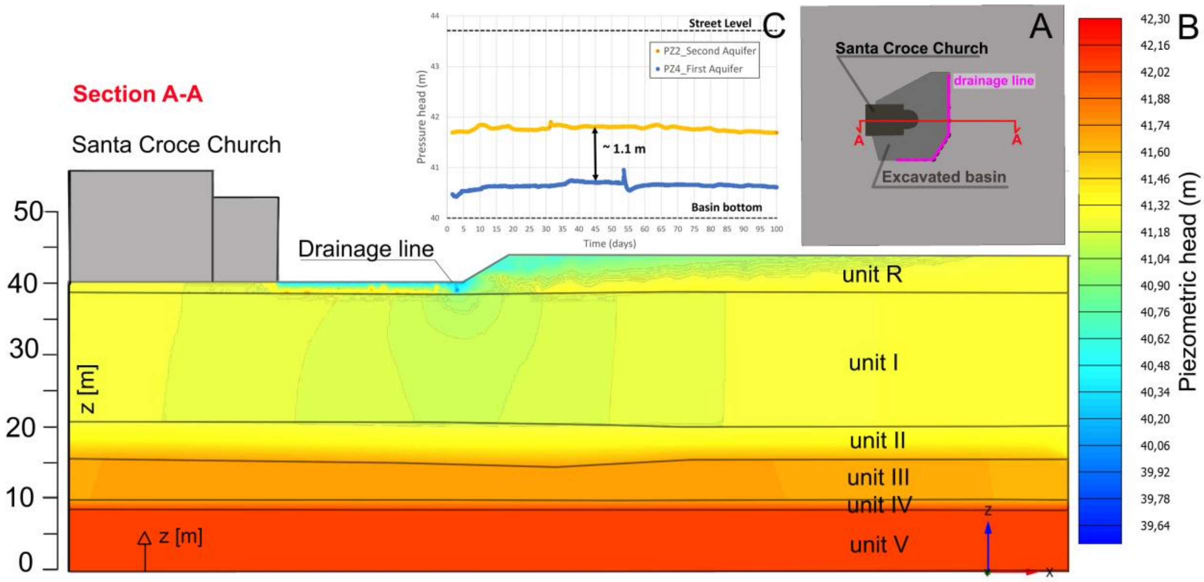

Figure 8. *A) Plan view of the 3D geometrical model developed in PLAXIS 3D, showing in red the cross-section along which the distribution of piezometric head beneath the Santa Croce site was obtained (B).*

C) Graph showing the monitoring points associated with piezometers PZ4 and PZ2, installed in the I and III units (aquifers), respectively. The location of piezometers is shown in Figure 6.

Piezometric data collected at various depths within the aquifers, together with the estimated average water flow extracted by pumps, were used to calibrate the saturated hydraulic conductivity of the shallowest geotechnical units - being the key parameters governing seepage and infiltration processes within the aquifer system and resulting in the order of 10^{-6} m/s for unit I and of 10^{-7} m/s for unit R.

The quality of the simulation was verified by comparing simulated and observed pore water pressure data in observation points corresponding to 2021 piezometers, located in the first and second aquifer. The section shown in Figure 8 B illustrates the distribution of piezometric head after a significant rainfall event that occurred on 22/04/2022 (day 31). A clear pore water pressure cone of depression can be observed within the first aquifer (I) and anthropic fill (R), induced by the drainage system, while only a limited influence is detected in the second aquifer, where piezometric height remain approximately 1.1 m higher than that established in the first aquifer close to the extraction pumps (Figure 8 C).

CONCLUSIONS

Within the framework of the European H2020 SHELTER Research Project, this study combines historical research, long-lasting monitoring, targeted geotechnical investigations and numerical modelling to address the persistent issues of recurrent flooding and land subsidence affecting the Santa Croce complex in Ravenna (Italy).
Core logging and in situ test interpretation confirm a laterally continuous but thickness-variable succession of shallow aquifers and aquitards, affected by both long-term natural and 20th-century anthropogenic subsidence.
Piezometric time series, integrated with site hydrological data, allowed the calibration of a 3D transient seepage model capable of reproducing the observed pore water pressures in the first two shallow aquifers.

From the preliminary analysis of the current drainage system, two main conclusions can be drawn from the numerical modelling:
(i) it generates significant hydraulic gradients in its proximity within the upper aquifer, while only marginally influencing the deeper one;
(ii) water head control is sub-optimal, as the system does not ensure a uniform lowering of the groundwater table across the archaeological area, particularly during intense rainfall events;
In addition, field evidence indicates that the deterioration of the drainage system contributes to localized surface erosion and differential settlements affecting the archaeological structures.

The developed model will serve as a decision-support tool for the design of a new drainage system, as well as for the development of maintenance routines and early-warning protocols, with the ultimate goal of enabling safe public access to Santa Croce while preserving its archaeological integrity.
The Santa Croce case study thus provides a replicable methodological framework for the assessment and mitigation of hydrogeological risks at heritage sites located in subsiding plains.

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REFERENCES

Bertoni, W., Elmi, C. & Marabini, F. (2005). The Subsidence of Ravenna. Giornale di Geologia Applicata, 1, 23–32.

Bitelli, G., Barbieri, E., Girelli, V.A., Lambertini, A., Mandanici, E., Melandri, E., et al. (2021). The complex of Santa Croce in Ravenna as a case study: integration of 3D techniques for surveying and monitoring of a historical site. Valencia: Editorial of the Universitat Politècnica de València.

Carbognin, L., Gatto, P., Mozzi, G. (1984). Case history No. 9.15 Ravenna, Italy. In J.F. Poland (Ed.), Guidebook to studies of land subsidence due to ground water withdrawal. UNESCO, (pp. 291–305). Michigan: Chelsea Bookcrafter.

CMC - Cooperativa Muratori Cementisti – (1995). Indagine e studio del comportamento strutturale, geotecnico, idrogeologico dell'area comprendente l'ex chiesa di S. Croce in Ravenna. Technical report (in italian).

David, M., Cassanelli, R., Cirelli, E., Crociati, E., Civiletti, J.P., Fiorini, A., Jaggi, C., Pasquini, L., Scaini, R. (2013). La Basilica di Santa Croce. Nuovi contributi per Ravenna tardoantica. Ravenna: Edizioni del Girasole (in italian).

Gambolati, G. & Teatini, P. (1998). Numerical analysis of land subsidence due to natural compaction of the Upper Adriatic Sea basin. In G. Gambolati (Ed.) CENAS. Water Science and Technology Library, 28. Dordrecht: Springer.

Gambolati, G., Teatini, P., Ferronato, M. (2006). 158: Anthropogenic Land Subsidence. In M.G. Anderson (Ed.), Encyclopedia of Hydrological Sciences. New Jersey: John Wiley & Sons.

Giorgi, E., Boschi, F., Morsiani, S., Sigismondo, G. (2025). MAPS Project: Ravenna as a case study for urban long-lasting settlement. Groma Documenting Archaeology, 9, 160-168.

ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale (2021). Dissesto idrogeologico in Italia: pericolosità e indicatori di rischio. Rapporti 356/2021. ISBN 978-88-448-1085-6 (in italian).

Marchi, M., Bertolini, I., Gottardi, G. (2023). Geotechnical investigations and monitoring of the archaeological site of Santa Croce in Ravenna (Italy). In A. Ferrari, M. Rosone, M. Ziccarelli, G. Gottardi (Ed.), Geotechnical Engineering in the Digital and Technological Innovation Era (pp. 536-543). Switzerland: Springer Nature.

Marchi, M., Bertolini, I., Gottardi, G. (2024). Endangered historic sites: the case study of Santa Croce in Ravenna (Italy). In N. Guerra, M. M. Fernanes et al. (Ed.), Geotechnical Engineering Challenges to Meet Current and Emerging Needs of Society, 1st Edition, Chapter: B – Geohazards. London: CRC Press.

Marchi, M.; Bertolini, I.; Tonni, L.; Morreale, L.; Colombo, A.; Simonelli, T.; Gottardi, G (2025). An Extensive Italian Database of River Embankment Breaches and Damages. Water, 17, 2202.

Ohenhen, L.O., Zhai, G., Lucy, J. et al. (2025). Land subsidence risk to infrastructure in US metropolises. Nature Cities, 2, 543–554.

Ricceri, G. (1992). Studi e ricerche nell'area di San Vitale, Galla Placidia e Santa Croce in Ravenna. Padova: SGEditoriali (in italian).

Teatini, P., Ferronato, M., Gambolati, G., Bertoni, W.,Gonella, M. (2005). A century of land subsidence in Ravenna, Italy. Environmental Geology, 47(6), 831–846.

Ugolini, A., Melandri, E., Agostinelli, E.R., Sericola, M., Vandini, M., Fiorentino, S. (2020). Managing water risks in archaeological sites: the flooding of the complex of Santa Croce in Ravenna.In G. Biscontin & G. Driussi (Ed.), Gli effetti dell'acqua sui beni culturali, valutazioni critiche e modalità di verifica. Proceedings of the 36th conference of international studies, Venezia, 17-19 november, (pp.163-174). Venezia, Italy.

Verdier, N. (2015). Conservazione e Valorizzazione dei ruderi del complesso dell'ex chiesa di Santa Croce a Ravenna. Master Thesis. University of Bologna (Italy) (in italian).