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Groundwater in the city of Pesaro (Marche, Italy): anthropic impact and interference with the urban environment

Le acque sotterranee e la città di Pesaro: impatti antropici ed interferenze con l'ambiente urbano

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Riassunto

Il lavoro svolto ha analizzato, nell'ambito della città di Pesaro, le diverse interferenze tra acque sotterranee ed ambiente urbano, sia rispetto ai progetti edificatori, in particolare quelli sotterranei, ma anche idraulici, geotermici e di potenziamento dei prelievi da falda. L'aspetto particolare della intrusione salina e della incidenza dei diversi siti contaminati caratterizzati da impatti sulla falda è stato considerato, in quanto pone limiti sostanziali di ordine urbanistico e pianificatorio, anche in previsione dei futuri scenari climatici. Alla luce della complessità rilevata, si individua la necessità di un rinnovato impegno per lo studio ed il monitoraggio della risorsa idrica locale, il cui utilizzo rimarrà essenziale ancora a lungo, anche al fine di promuovere una risposta culturale e di maggiore consapevolezza sia nei cittadini che nel governo locale.

Abstract

Groundwater in the urban area of Pesaro is a significant local resource, supplementing the main surface-water supply from the external Metauro watershed. Nevertheless, since Pesaro's groundwater is tapped from a coastal alluvial aquifer in a heavily anthropized environment, its use involves mutual impacts with the urban environment, which poses several constraints. Our work schematized the main interferences of groundwater with building works such as housing (i.e. foundations and underground works), hydraulic infrastructures, wells' network development, and geoexchange projects. Moreover, the presence of a seawater wedge, historically intruding the aquifer, must be taken into account, alongside its potential evolution in changing climate scenarios. Contaminated sites were also analyzed, as they represent a critical issue when further groundwater withdrawals are planned. Due to these complex interactions, there is a need for renewed commitment to studying and monitoring the local water resource. This is also essential for promoting awareness among both citizens and the local government that its use will remain crucial for a long time.

Introduction

The city of Pesaro has a long history of intense and irrational exploitation of local groundwater resources, which still serve as an important supplementary supply to the primary surface water resources from the Metauro river basin, which have been relied upon by the municipality of Pesaro referred since the late 1980s (Farina, 2013). On the other hand, the alluvial aquifer of Pesaro is subject to a significant anthropogenic pressure, impacting both its quality and quantity (Arpam, 2017). The current effects and future trends of these pressures, especially in the context of ongoing climate change, are not well understood. Pesaro is located in a particularly sensitive context, that of the "coastal, lagoon, and delta groundwater cities" (La Vigna, 2022), which will suffer a major impact from the expected increase in sea level (Marche Region, 2023). The aquifer, even before being a water resource, is a physical entity which has historically interfered with, and still interferes with the built space of Pesaro, representing a conditioning factor to building projects. At the same time, it is impacted by these human activities, becoming both a target and vehicle of several different forms of contamination linked to the urban and productive local context. For this reason, there is a need to collect the main studies developed over the years, both in academic (Elmi et al., 1983), technical-professional (Hydroco, Amga, unpublished data,1989; Gennari, 2004; Gori, 1978), and planning (Municipality of Pesaro, 2023b; Didero et al., unpublished data, Province of Pesaro-Urbino, 1990) literatures, to integrate and update our knowledge of the subject. In doing this, we focused on three fundamental aspects:

1. The interference between groundwater and the built space, also considered from an urban planning perspective.
2. The state of exposure of groundwater to actual and potential hazardous contamination caused both by anthropogenic factors (water pollution, contaminated sites) and by natural factors (sea-water intrusion).
3. The preliminary framework of the projects, both developed and ongoing, which aim at the use, recovery, and protection of the local groundwater resource, including the geoexchange use of the aquifer and artificial recharge systems.

This operation has not only a technical-scientific but also a cultural and political implication, which relates to the problematic relationship between the city and the natural environment ("The Nature of Culture" is the motto of Pesaro Italian Capital of Culture 2024).

Materials and methods

Geographical and hydrogeological framework

The analyzed area is located in the lower valley of the river Foglia, geographically included between the coastline on the Adriatic Sea and the route of the A14 motorway, which encloses most of the urbanized and residential space of the city, extending mostly to the right bank of river Foglia (Fig.1). From a hydrogeological point of view, the area includes the essentially phreatic aquifer, with an average thickness of around 25-30 m, which is located upstream of the A14. A transition zone to the two-layer aquifer (unconfined and confined aquifer) can be identified in the stretch between the motorway and the Bologna-Ancona railway line. Downstream, the two permeable saturated layers, both gravelly-pebbly-sandy, are naturally separated by a thick silty-clayey layer, with other minor silt-clay septa of more limited thickness interbedded towards the coast (Fig. 2). The overall thickness of the aquifer in this terminal portion varies mostly from about 50 to 60 m. Downstream the State Road 16 "Adriatica"/Vittoria street, the alluvial sediments of the Holocene Synthema pass to the coastal sediments, consisting mainly of fine and medium yellow-brownish sands of variable thicknesses, usually within 4-5 m. In the SE sector of the city, the alluvial deposit is interdigitated by extensive silty-sandy-clayey bodies constituting the fan of the Genica creek and those of the minor tributaries, so that the main gravel layer is located at a significant depth, up to over 20 m deep.

In this context, there are essentially two aquifers:

1. The unconfined aquifer, with a variable water table (depth mostly between -2 and -4 m deep), which is located in the sediments of the Genica fan, in the coastal deposits and in the peri-fluvial Holocene alluvial deposits (Syntema del Musone). That corresponds to the districts of Pantano, Loreto-Muraglia and Zona Mare, at altitudes mostly between 3 and 6 m a.s.l. Within the Pleistocene terrace (altitudes from about 9 to 13 m a.s.l.) on which the historic center of Pesaro is founded and the immediate suburbs to the SW (districts from Villa S. Martino to Villa Fastiggi), the water table's depth consequently increases from 6-7 to 9-10 m deep. In this sector a local shallow suspended aquifer was identified, contained in the thin silty sediments of the alluvial terrace (Figs. 2 and 3).
2. The confined aquifer, located in the thick basal gravelly-sandy level, is currently characterized by absolute potentiometric elevations that are little differentiated from those of the water table of the unconfined aquifer.

The use of groundwater for water supply has historically referred to the so-called "artesian" aquifer, even if it was only between the 1920s and the 1960s, when drilled wells were flowing, that this artesian character was manifest. The drilling of new wells then extended upstream, as the advance of the salt wedge was observed, thus leading to the salinization and subsequent dismission of the "Centrale Principale" wells (the ones close to the railway station), from which the city drew the maximum share of groundwater until the end of the 1980s.

The limit of the salt wedge was originally restricted to the sector below the historic center (within the Della Rovere city-walls), and then extended between the 1960s and 1980s to the limits of the Miralfiore Park, just beyond the railway line. The well fields used or built after the end of the 1980s are mostly located within the single-layer aquifer upstream of the A14 ("Pozzi Hydroco": A14 exit, Insala street, near the suburb

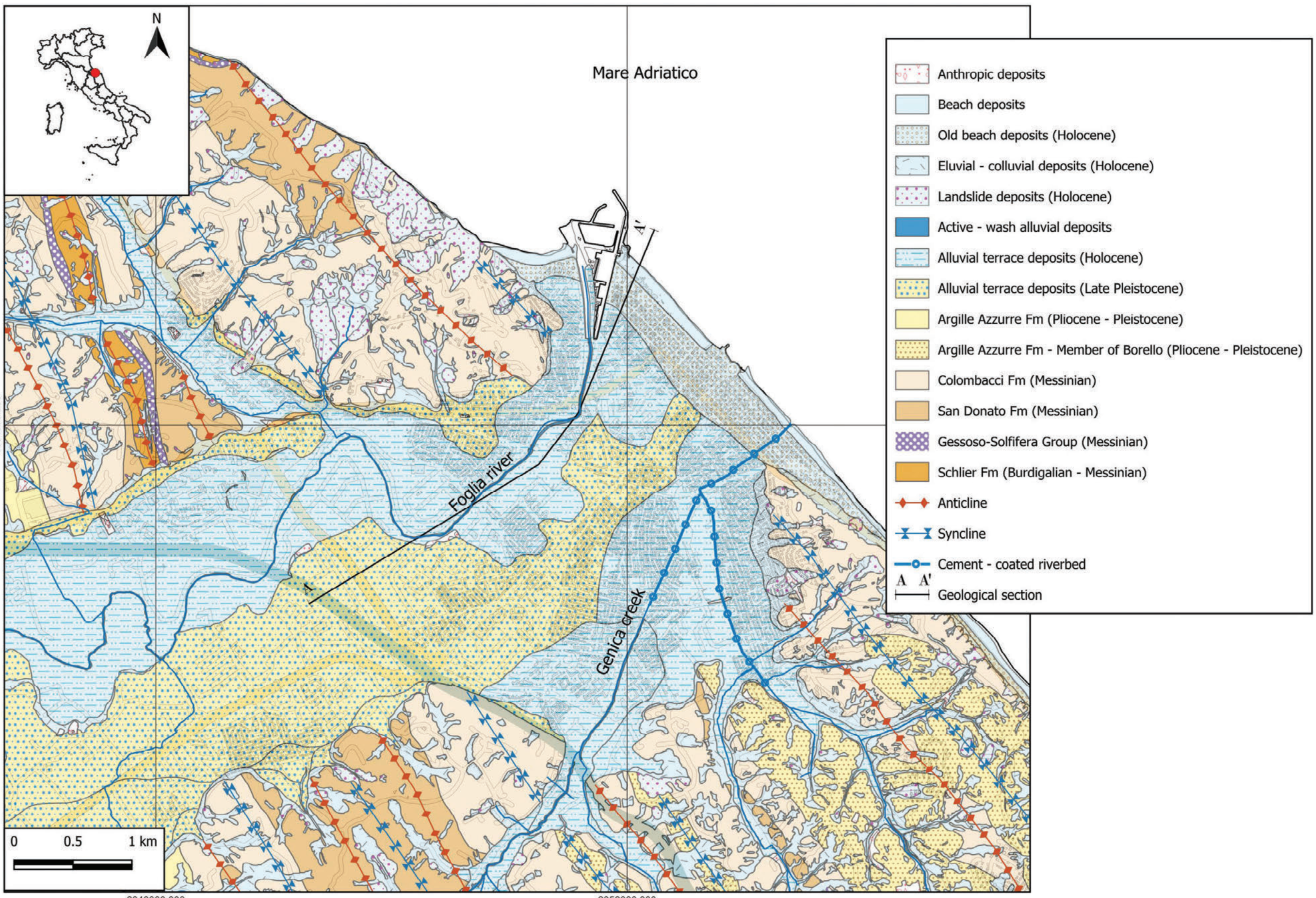

Fig. 1 - Geologic map of Pesaro (from Marche Region's geological map, modified). Grey shade: urban area and industrial areas of Pesaro.

Fig. 1 - Carta Geologica di Pesaro (da CARG Regione Marche, modificata) Aree a sfondo grigio: area urbana ed aree produttive di Pesaro.

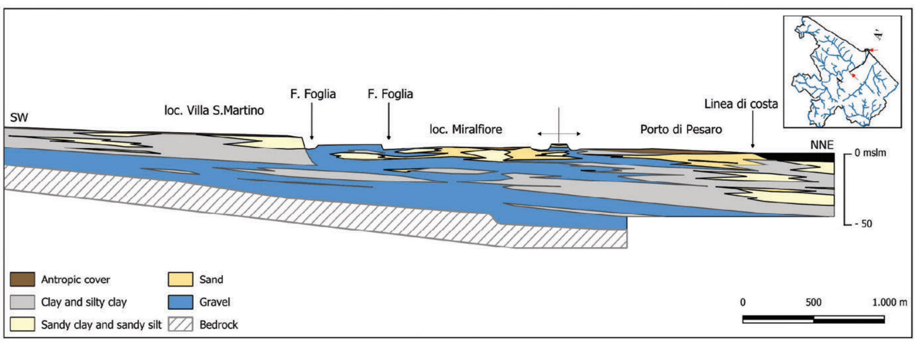

Fig. 2 - Geologic cross-section of the alluvial deposits (from Pesaro's master plan, modified).

Fig. 2 - Sezione geologica dei depositi alluvionali (da PRG di Pesaro, modificato).

of Villa Fastiggi). Currently, water withdrawals from aquifers are variable, but estimated at an average of 3.8 x 106 m^3/year, that is approximately half of what was extracted during the 1980s (Hydroco, Amga, unpublished data, 1989).

Survey criteria and methodology

In order to perform the analyses and meet the objectives listed in the introduction, the following methodology has been adopted and the following sources of data and studies have been acquired:

1. The interference between groundwater and the built space.

This phase can be conceptually assimilated to the mapping of the unconfined aquifer's water table' depth. To this end, a threshold value of the free-water table was preliminarily established as a screening criterion, referring to the height of the road surface in the flat sectors of the valley floor, determined by the average depth of all those works that involve the construction of foundations and/or splatting works or excavations up to a minimum depth of 3.5 m from the ground level. The sources of useful direct and indirect data or information that can be used as proxies are briefly listed in Tab.1

With regard to point 1), the geognostic database and the data available from the Seismic Microzonation studies for the Municipality of Pesaro (Marche Region, 2024) were acquired, examined and queried. These contain instantaneous and non-systematized potentiometric data, which nevertheless provide

Tab. 1 - Data and criteria of analysis on the interference between groundwater and built areas.

Tab. 1 - Dati e criteri di analisi sulla interferenza tra falda e spazio costruito.

Type of data	Indirect/Proxy?	Source
1) Direct data of GW depth taken from geologic/ hydrogeologic surveys (wells, piezometers)	No	Geological Database of the township of Pesaro New potentiometric data not included in Database Hydrogeologic map of Pesaro' Master Plan
2) Topographic map of the urban area and river Foglia' flood channel	Yes	Marche Region 1:10,000 map, Pesaro township 1:2,000 map
NOTE: hydraulic continuity between river and phreatic GW is assumed		
3) Geomorphologic and historical maps (alluvial and littoral terraces, river's paleochannels, alluvial fans)	Yes	CARG geologic map, geomorphologic and hydraulic risk map of Pesaro Master Plan (PAI)
4) Information and data of well-point installations	No	Geologic Reports, direct knowledge
NOTE: provides a direct knowledge of GW de-watering works		
5) Other information on problems or constraints of underground works (foundation piles, tanks, sewer pipelines, flood lamination reservoirs and similar)	No	Geologic Reports, direct knowledge
NOTE: provides a direct knowledge of GW- foundations interaction		
6) Evidence of GW-seepage and/or capillary rises in underground buildings or basements,	Yes	Geologic Reports, direct knowledge
NOTE: interference may be confirmed only if potentiometric data are available (see # 1)		
7) Information on graved/buried old hydraulic works (i.e. «Vallato Albani» Canal)	Yes	Historical ed archeological studies
NOTE: interference may be confirmed only if potentiometric data are available (see # 1)		

a first information, which can be evaluated, in relation to the characteristic seasonal oscillation of the water table, in the light of potentiometric monitoring data conducted between the end of the 1990s and the beginning of the 2000s (Farina et al., Aspes, unpublished data, 1998). These data, however, are not homogeneously distributed and refer mostly to the sector of the unconfined aquifer, while those relating to the peri-fluvial areas, and to the most coastal part of the aquifer, are much scarcer. Therefore, while the natural annual groundwater level's variation of the upstream part (up to the Miralfiore Park) is quantified at around 1.0-1.2 m, for the peri-fluvial areas it can locally reach and exceed 2 m, depending on the passage of flood waves and the local permeability of the floodplain sediments and the grain size of the unsaturated zone. In the area overlooking the coast and the estuary of river Foglia, it is estimated that the groundwater level's variation is represented by a fraction of the tidal oscillation (Meteomin, 2024), with particular regard to the periodic astronomical component. From this point of view, because of the lack of systematic potentiometric measurements, an estimate was made according to the analytical approach of Cooper et al. (1964) utilizing the hydraulic parameters of the unconfined aquifer (Farina et al., Aspes Multiservizi, unpublished data, 2003). On this base, the oscillation of the water table was assumed to be equal to half of the maximum oscillation of the astronomical tide, therefore in the order of 20-30 cm, applied to the entire sector of coastal deposits, with a linear decreasing trend toward the upstream sector. This is a largely approximate figure, but still sufficient for the purposes of the study, given the magnitude of the threshold value and the type of interference with the foundations' structures. On the other hand, as far as the areas close to the well fields are concerned, the effects in the dynamic piezometry have been studied and provide a "snapshot", depending on the pumping regime and the extent of the leakage factor of the aquitard separating the unconfined and the confined aquifer.

2. Exposure and contamination of the groundwater, framework of groundwater projects

In this case, reference was made to specific studies, commissioned in different periods by different regulators (Farina, Province of Pesaro-Urbino, unpublished data, 2011) with particular regard to the census of potentially contaminated sites, Emergency Shut Down procedures, groundwater remediation projects, aquifer's vulnerability and/or wellhead protection areas assessments. To map the area of the artesian aquifer affected by salt water-intrusion, including its diffusion border, we referred on two indicator parameters such as chlorides and sulphates and their respective drinking water limits (Italy, Legislative Decree No. 18, 2023). The sites involved in specific feasibility studies and projects on groundwater use, protection and/or modifications, we considered the following aspects: a) the aqueduct use of groundwater, b) the geoexchange use of the aquifer (with "open loop" systems), c) artificial recharge systems; d) other projects involving significant interferences between surface and groundwater, both in terms of qualitative and quantitative impact and design constraints (e.g. expansion tanks/river lamination areas).

Results and discussion

From the hydrogeological framework and the maps presented, it is clear that there is a substantial overlap between the most urbanized area of the valley and the aquifer sector that is both the most productive (in terms of saturated thickness and hydraulic parameters) and most used in the recent past. This aspect, which Pesaro shares with other towns on the Adriatic coast and in the foothills of Emilia-Romagna, is particularly pronounced due to the city's location between two coastal hills, which laterally limit the extent of the aquifer along the valley axis. Therefore, the interaction between resource and its uses, between built space and groundwater, is articulated and complex.

Groundwater and built structures interaction

Regarding the first aspect considered, related to the "depth to the water table" of the first aquifer, it can be observed that the study area can be schematically divided into two sectors (Fig.3): a) the historic city center and the sector of the watershed between the basin of river Foglia and that of the Genica creek, corresponding to the Pleistocene terrace, extended to the SW of the city, characterized by a groundwater depth more than 3.5 m (on average between 5 and 7 m deep). b) the belt of coastal deposits and areas of Holocene alluvial deposits located both to the NW and to the SE of the historic center, characterized by a depth less than 3.5 m (up to less than 2 m deep). The first sector extends around the axis of the Albani canal (whose initial construction dates back to before the 13th century). This canal, later covered, followed the ideal hydraulic profile, entering through the southwest gate of the Roveresque city walls (now Garibaldi and Lazzarini squares) to supply mills, factories, and other uses along its course, mainly directed towards the current canal harbor (Bertini & Catolfi, 2010; Spadoni, 1991).

The second sector involves different groundwater interactions with the built space, especially in the southeast sector of the city (from the Central Cemetery area to the Muraglia and Pantano neighborhoods) where any construction work (including burial grounds, foundational works, and hydraulic structures) encounters substantial constraints or limitations within the first 2-3 m below ground, due to the presence of the saturated first aquifer. In this sector, the decommissioning of some aqueduct wells ("Muraglia" wells, downstream from Case Berardi) during the early 1980s probably led to an increase in piezometry of the unconfined aquifer, thus promoting an upper leakage between the

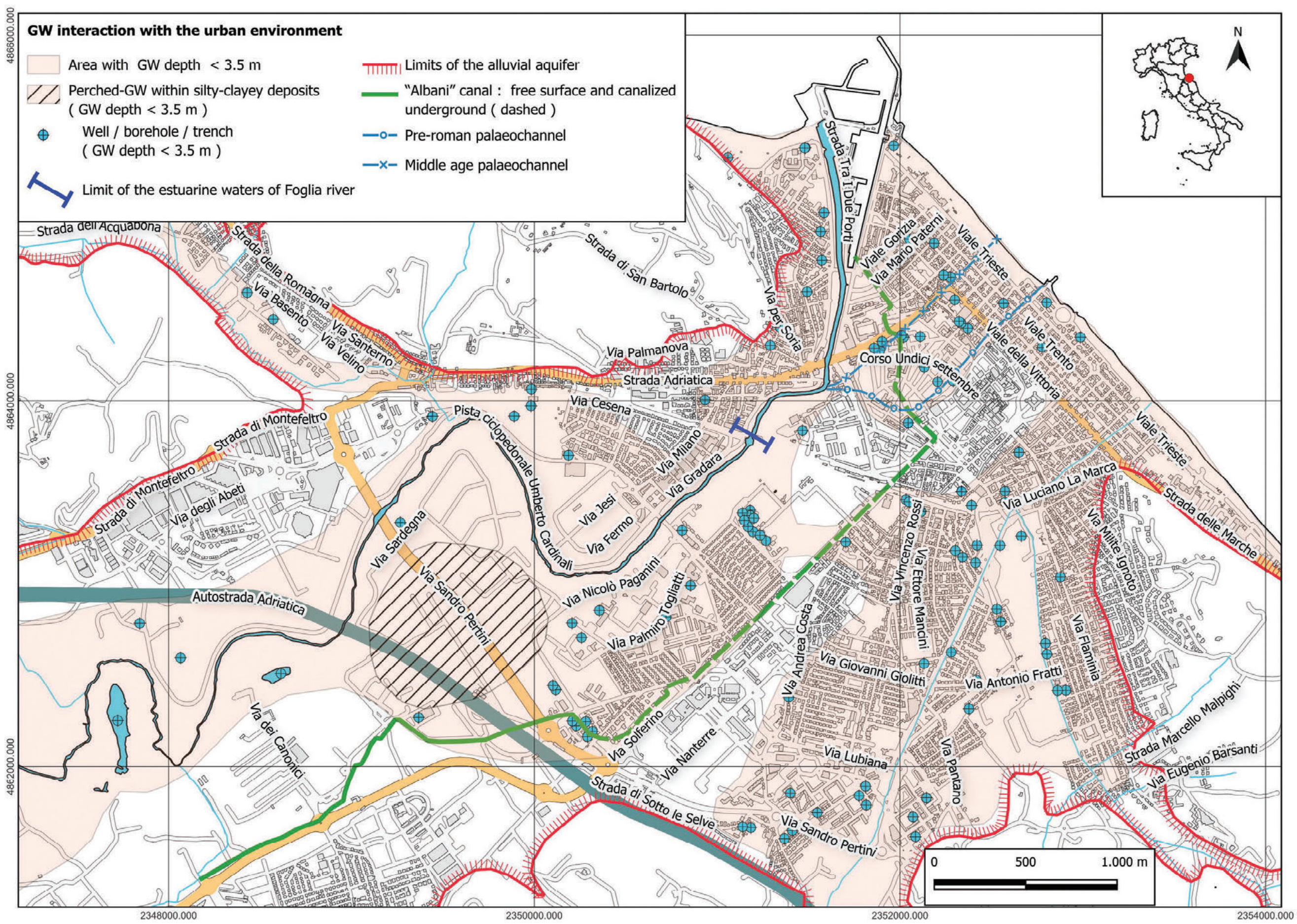

Fig. 3 - Groundwater and the city: depth of GW map, hydrogeological and historical features.

Fig. 3 - Acque sotterranee e città: carta della profondità della falda, aspetti idrogeologici e storici.

basal artesian aquifer and the surficial aquifer, through the sandy-silty covering terrains and/or the wells itself. On the opposite side, to the N-NW border of the historic center and towards the harbor, one of the problems encountered, not only in excavation work, is the drainage of the aquifer into the old brick sewer pipes, and probably into the same backfilled section of the Albani canal, with dynamics that are neither known well nor studied in detail (Amga, personal communication, 1990). In these areas, and especially in the coastal sector, where the covering sandy soils are significantly more permeable, the impact of the hydrogeological factor on the built space construction is clearly demonstrated by implementation of de-watering systems (well-points), by the problems of water infiltration into houses' basements built with inadequate techniques, by the potential subsidence of the ground due to uncontrolled pumping, by the interaction of materials with aggressive brackish water and, last but not least, by the seismic-geotechnical aspects related to the potential liquefaction of the sands.

The state of contamination of groundwater

The urban and sub-urban territory of Pesaro is affected by a level of anthropic pressure that leads to various forms of degradation of the quality of groundwater. In general, the predominant forms of contamination are directly attributable to the urban areas, while the impact of the upstream agricultural activities (e.g. contamination by nitrates or pesticides) is moderate to negligible (Arpam, 2017). The actual impact of the various hazard centers (identified by the local environmental agencies as Centri di Pericolosita' Potenziale) clearly depends on the degree of protection/vulnerability of the aquifer and varies in intensity between the peripheral sector of the single-layer aquifer and the urban area characterized by the presence of two essentially distinct aquifers. Leaving aside the forms of contamination by intrinsic natural pollutants related to the aquifer's lithology and environment (in this specific case, mainly manganese), the following features can be recognized (Fig. 4):

1. the long-standing case of saline intrusion of artesian aquifer, connected with the overexploitation of the aquifer, in particular during the thirty-year period 1950-1980: by the early 1980s the dynamic groundwater levels at Centrale Principale' wells were ranging between -10 and -15 m under sea level (Elmi et al., 1983), as a consequence of intense pumping (up to 100 L/s). Progressively, a sharp increase of certain parameters (chlorides, sulphates, magnesium and others) above the limit values for drinking water was becoming evident

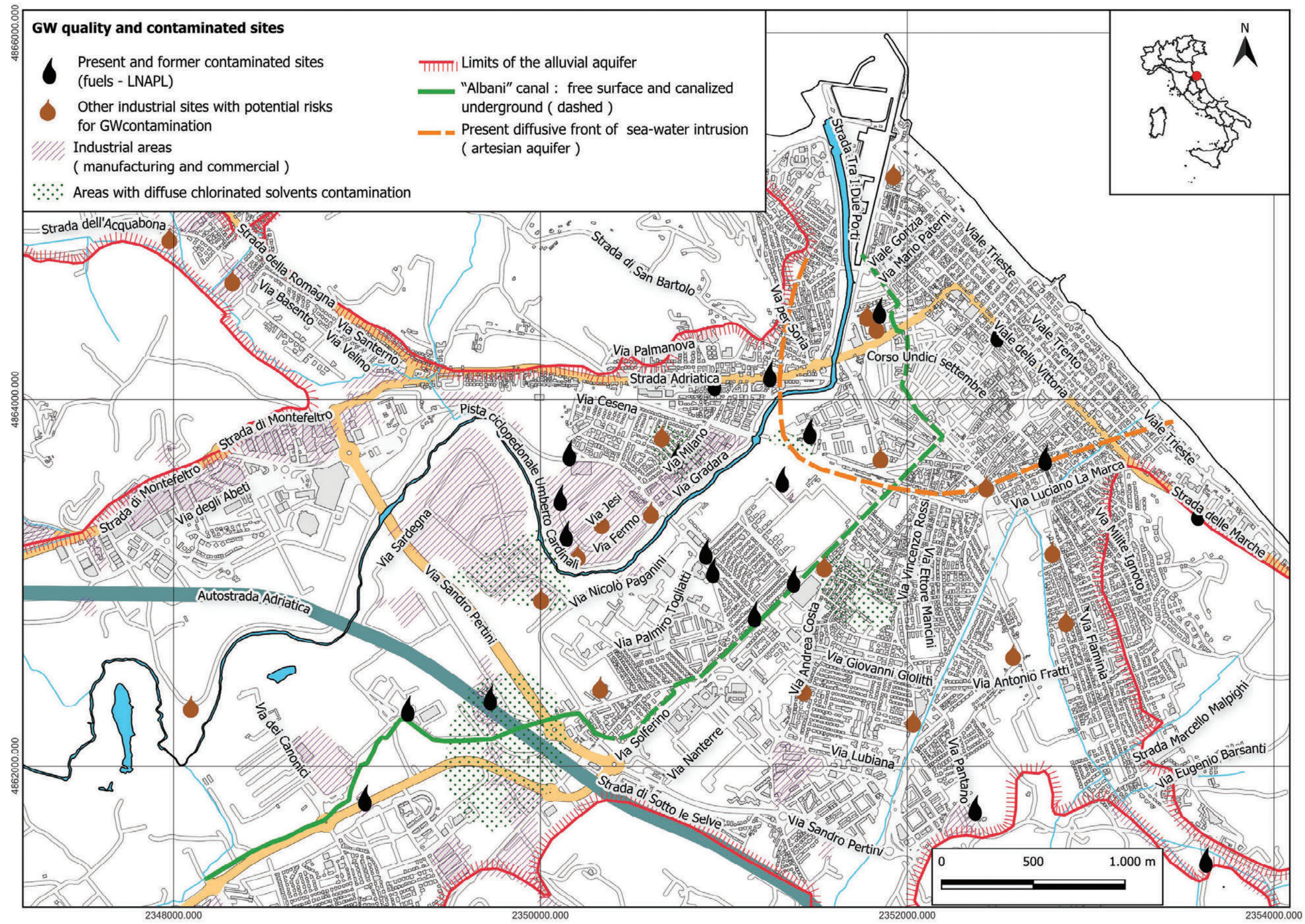

Fig. 4 - Contaminated sites, actual and potential impact on GW, sea-water wedge.

Fig. 4 - Siti contaminati, impatto reale e potenziale sulla falda, intrusione salina.

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(Didero & Salvatori, 1985). The present situation in the neighboring area of Miralfiore Park is quite similar to that depicted in the early 2000s (Fig. 5,6), suggesting an irreversible groundwater quality deterioration, compared to the previous situation, when concentrations were quite high but similar to those detected upstream the aquifer (Electric Conductivity ≤ 1300 μS/cm; Cl^- and $SO4^{--}$ < 150 mg/l; Mg^{++} ≤ 50 mg/L (Farina et al., Aspes Multiservizi, unpublished data, 2003; Italy, Legislative Decree No. 18, 2023);

2. the impact associated with more than a dozen cases of petroleum products spills, mostly from gas stations or fuel depots, resulting in exceeding the contamination threshold values imposed by Italian authorities for typical parameters associated with this type of pollution (Benzene, n-hexane, Methyl-tert-Butyl Ether, etc.). In particular, due to its mobility in the aquifer, MTBE has locally affected extensions of aquifer well outside the borders of fuel stations' areas (Farina et al., Aspes, unpublished data, 2000);
3. other typical forms of contamination from industrial activities present in the area, in particular linked to the long-standing and widespread presence of chlorinated solvents, in some cases exceeding contamination threshold values, or the presence of other pollutants associated to previous activities, as is the case of the "Ex-Amga" site (Municipality of Pesaro, 2023a) , where a Tar-products contamination of groundwater is related to a former coke coal distillation plant for city gas production during the period 1880-1950 approximately.

From the perspective of the classification of the procedures related to so-called contaminated sites (according to Legislative Decree No. 152/2006), relating to the referred contaminated sites, it is interesting to notice that almost all of these are connected to gas stations, following the widespread implementation of self-reporting procedures among operators in the national fuel distribution network. Beside those events, and with the exception of some striking cases such as the "orphan site" Ex-Amga case, the observed contamination by chlorinated solvents is rarely attributable or has been traced back to a specific manufacturing activity. In this case, it has been classified as "diffuse contamination" for several years now (Arpam, 2022; Farina, Province of Pesaro-Urbino, unpublished data, 2011) and practically leads to "no-remediation".

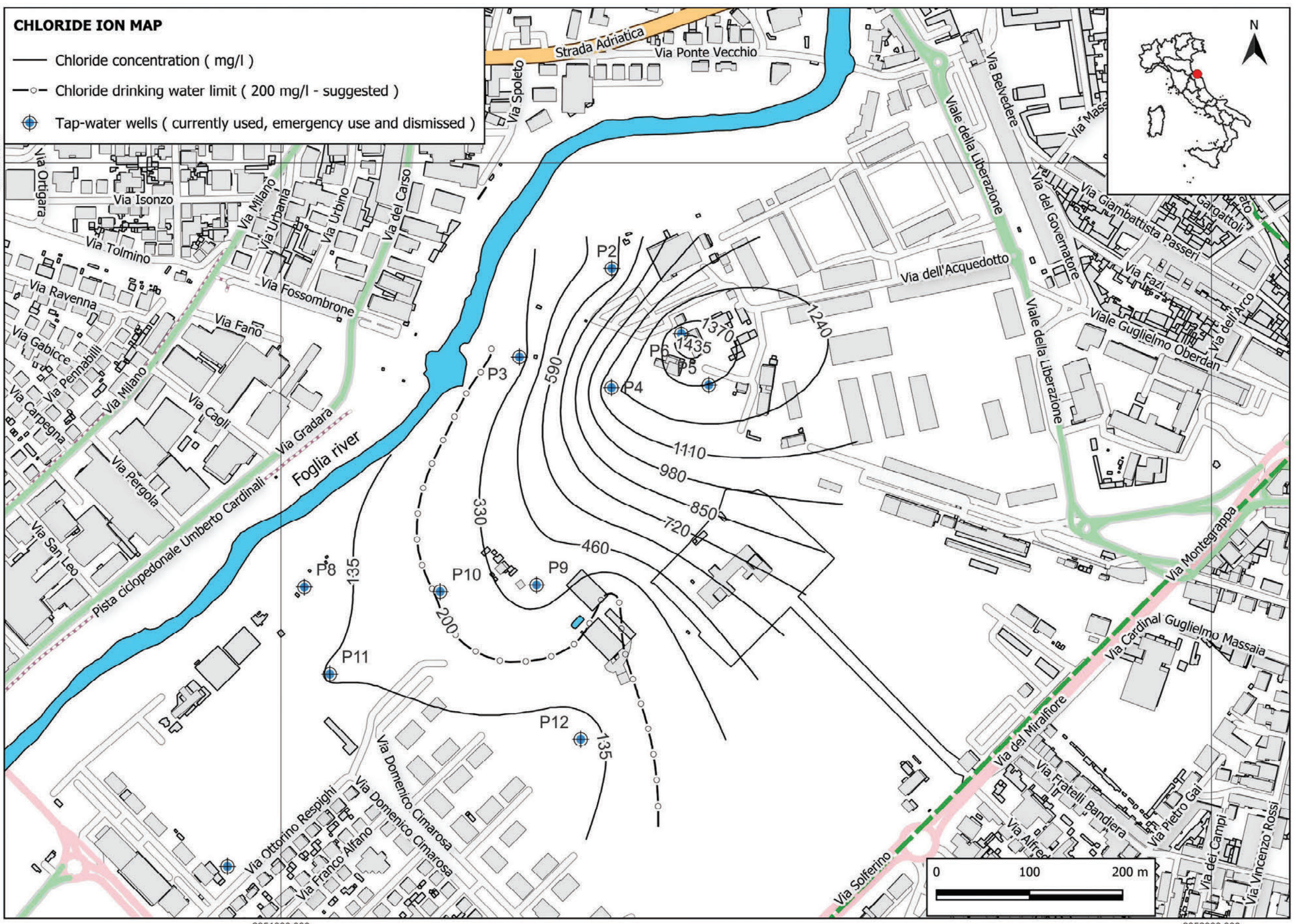

Fig. 5 - Chloride ion map (Sept. 2002).
Fig. 5 - Carta dei cloruri (Sett. 2002).

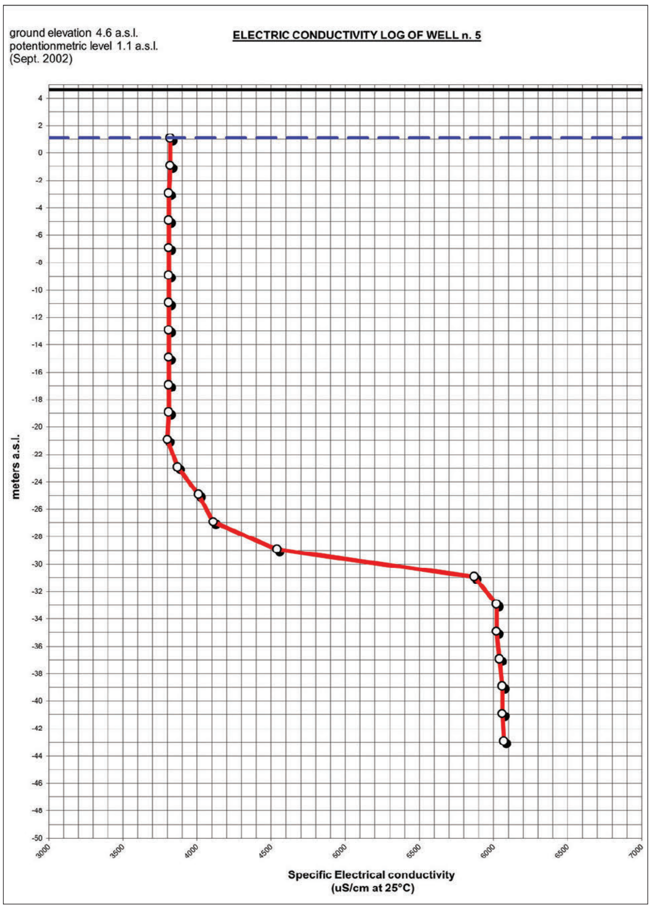

Fig. 6 - Electric Conductivity log of well n.5 (Sept. 2002).

Fig. 6 - Log conduttimetrico del pozzo n. 5 (Sett. 2002).

Interventions and projects involving groundwater

In the summary review, depicted in Figure 7, the following are conceptually distinguished:

1. Projects aimed at the use, protection or enhancement of the groundwater resources.
2. Projects or realizations that interfere with the aquifer(s), where these represent conditions of technical constraints to the project.

As for the first aspect, a project was developed in 1994 in the upstream sector of the town, along the course of the Albani canal, which allowed the functional recovery of this canal and the reuse of a quarry lake present there, together with a scheme for the phytoremediation and reuse of civil wastewater from the local treatment plant (Farina & Gerboni, 1994). The object, in particular, was that to assess the feasibility of an artificial recharge plant aimed to reduce the potentiometric drawdown, caused by the wells' pumping, which characterizes this sector during the summer season (Fig. 8).

In the sector downstream, within the Miralfiore Park, a similar feasibility project was drawn in 2003 for the artificial recharge of the aquifer through leaking canals and injection wells, designed to make supplementary withdrawals compatible with the salt wedge and its predictable future evolution (Farina et al., Aspes Multiservizi, unpublished data, 2003).

In facts, in the same sector an increase of groundwater withdrawals through some existing wells was more recently planned (Aato1, 2020). These are wells intended for emergency supply, located at the edge of the area of diffusion of the salt wedge.

The aspect of the energy use of groundwater through "geoexchange" plants such as "open loop" (pumping of the aquifer and return of water to the river) represents a type of intervention that has a potential impact on groundwater. In this case, we have mapped a recent project that involves using some old wells of the former "Centrale Principale" pumping plant, abandoned due to the progressive advancement of the salt wedge, to supply a heat pump system intended for air conditioning purposes for several utilities located in the historic center buildings. The project is still in course, and the technical data are not yet available.

Regarding the second aspect concerning hydraulic works that interfere with the water table, some projects of construction of flood expansion tanks are mapped in Fig. 7. Here, the underlying groundwater has represented a technical constraint for the construction of expansion basins. In certain types of facilities (i.e. lamination, or flood detention, areas), the volume of water held during flood conditions implies a modification of the natural recharge of the aquifer compared to the pre-construction situation. This modification must be assessed according to Environmental Impact Assessment criteria to identify its impact or synergies concerning current uses of the groundwater resource.

Conclusions

Groundwater in the urban area of Pesaro still represents an important supplementary water resource that integrates the main source of surface water supply from the nearby basin of river Metauro. In spite of the lower volumetric consistency of the withdrawals and the worse quality of groundwater tapped from the Pesaro aquifers, its importance lies in its proximity to users and its distinct origin compared to the primary extra-basin resource (groundwater versus surface water). This also includes flexibility in use, i.e., the ability to increase withdrawals up to doubling during short periods compared to the annual average withdrawal rate. However, this role, which is de facto recognized at the management level by the recent works to increase the wells operativity, does not correspond to an adequate planning action in the mid and long term: the resource-aquifer suffers from a long phase of "stasis" of studies and monitoring, apart the basic institutional one (Arpam, 2017), including that of detailed qualitative and quantitative updated surveys. Those are deemed necessary, both from a management and planning perspective, so to assess both qualitative and quantitative scenarios, in the light of the ongoing climate change, and to determine limitations on the use of the resource, both currently and in the future. Indeed these "limitations" in facts are only hypothetical but currently cannot be assessed quantitatively, while it is already evident that global climate change is already heavily impacting on the availability of surface waters, with significant consequences

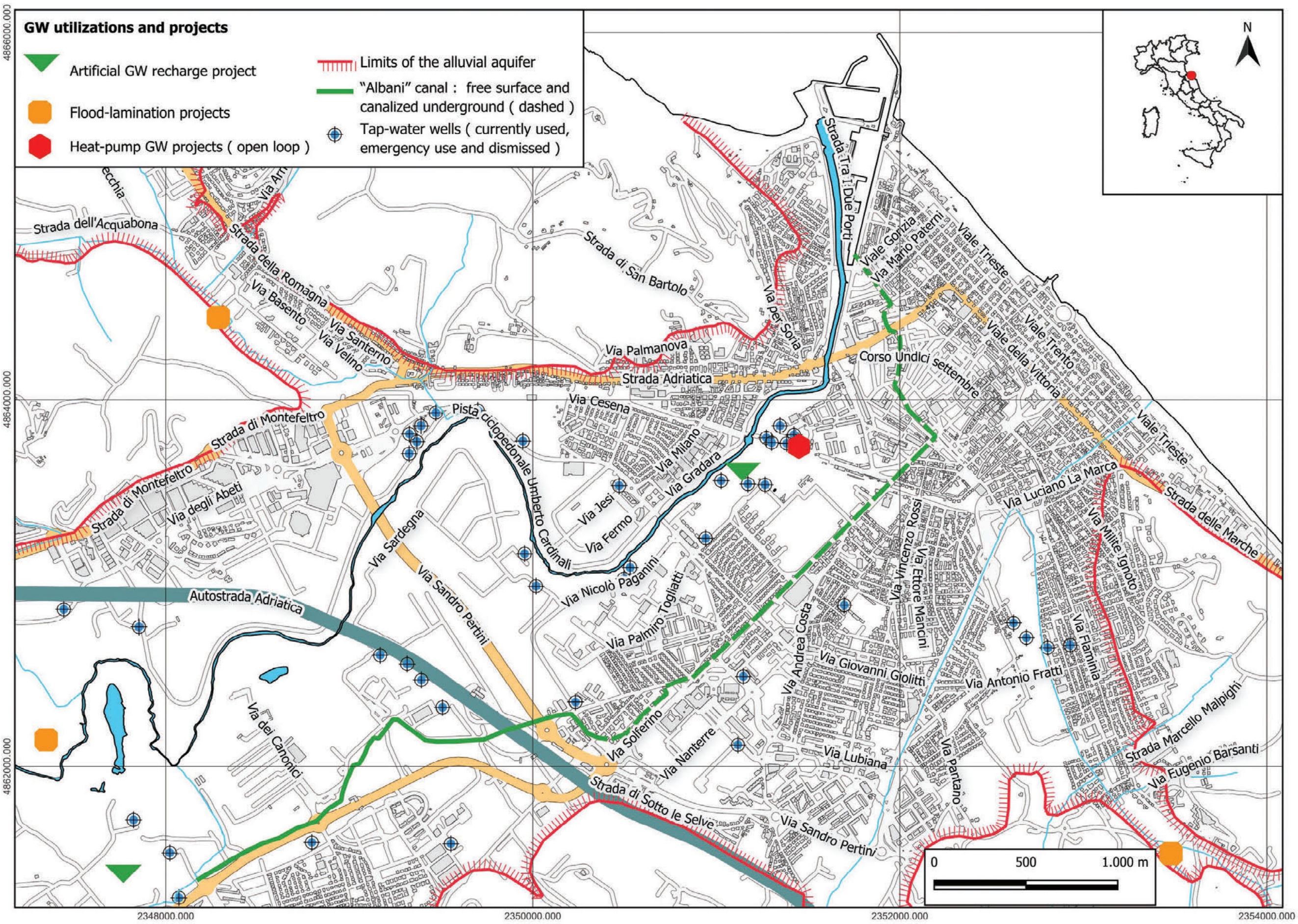

Fig. 7 - Public water wells and project showing interference with groundwater.

Fig. 7 - Rete dei pozzi acquedottistici e progetti che presentano interferenza con le acque sotterranee.

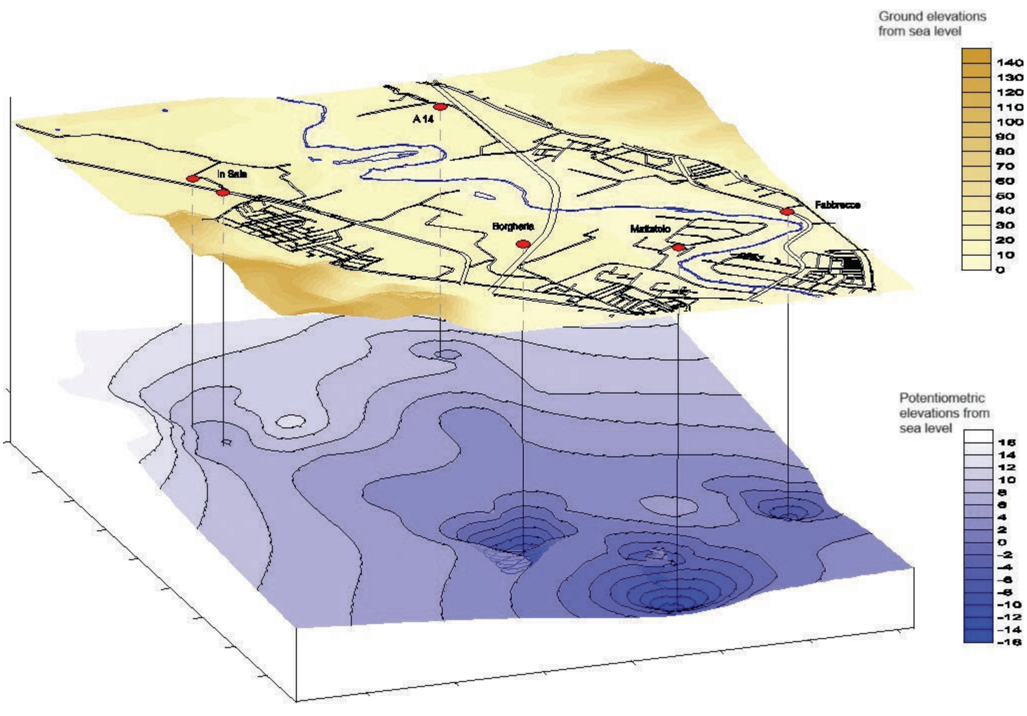

Fig. 8 - Potentiometric 3D map of the unconfined alluvial aquifer during the summer of 2002, with the principal well-fields in function (red dots).

Fig. 2 - Carta piezometrica 3D dell'acquifero freatico durante l'estate del 2002, con i principali campi-pozzi in esercizio (punti rossi).

on the water balance, Minimum Runoff constraints and the environmental status of these water bodies (ISPRA, 2023).

In face of these challenges, there does not seem to be an effective connection and collaboration among the various institutional stakeholders involved in water resource management locally (such as the Municipality, water service provider, Province, Region, and River Basin Authority). Consequently, there is a significant governance deficiency concerning the water resource.

Compared to prevailing issues such as land consumption, the water resource, especially groundwater, does not "emerge" as a physical reality and cultural entity except incidentally. It becomes noticeable mainly when assessing contamination (as seen with numerous "contaminated sites" of Figure 4) or interference with built environments during underground construction projects, or when energy utilization of groundwater is considered and assessed. The cultural challenge of groundwater " to make the invisible become visible" (theme of the 2022 World Water Day) and that of "The nature of the culture" (theme of Pesaro Italian Capital of Culture 2024) finds its maximum expression in the urban management of the city and the ecosystem services that support it and, in a word, in the very concept of sustainability, which always pertains to the future perspective: will future citizens still be able to use Pesaro's groundwater, will they ever know that it exists or that, as a resource, it has existed?

Competing interest
The authors declare no competing interests.

Author contributions
Conceptualization, data curation, formal analysis, investigation and writing of the original draft, D.F.; data curation, figures and maps' draft, review and editing, S.D-A.
All authors have read and agreed to the final version of the manuscript.

Additional information
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