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An integrated approach to the Environmental Monitoring Plan of the Pertuso spring (Upper Valley of Aniene River)

Un approccio integrato al Piano di Monitoraggio Ambientale della sorgente Pertuso (Alta Valle del Fiume Aniene)

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Riassunto: La caratterizzazione idrogeologica delle acque sotterranee e superficiali è uno strumento di fondamentale importanza per una corretta gestione e salvaguardia ambientale delle risorse idriche. Il presente lavoro illustra la pianificazione del programma di monitoraggio multi-disciplinare relativo al progetto di consolidamento della derivazione della sorgente Pertuso, nell'Alta Valle del Fiume Aniene, per il superamento delle emergenze idriche nei Comuni a sud di Roma. Alla luce di quanto prescritto dal D.Lgs. 152/2006, così come modificato dal D.M. 260/2010, la realizzazione di opere di ingegneria, interessanti il sottosuolo, non può prescindere dalla predisposizione di un Programma di Monitoraggio Ambientale, dal quale ricavare il patrimonio informativo sull'assetto idrogeologico dell'area di studio. La caratterizzazione idrogeologica, realizzata attraverso il Programma di Monitoraggio Ambientale, costituisce uno strumento utile per valutare i potenziali impatti ambientali correlabili al progetto di derivazione. Per la valutazione e la conseguente gestione sostenibile delle risorse idriche, un requisito fondamentale è la quantificazione della ricarica della falda acquifera. Per tale motivo è stata inclusa nel piano di monitoraggio una dettagliata caratterizzazione quantitativa delle acque sotterranee erogate dalla sorgente Pertuso, al fine di garantire che i lavori di derivazione non alternino il naturale equilibrio idrogeologico della falda acquifera. A questo scopo è stato redatto un Programma di Monitoraggio Ambientale delle acque sotterranee e superficiali dell'Alta Valle del Fiume Aniene, di cui il presente studio illustra nel dettaglio gli obiettivi e l'articolazione.

Parole chiave: sorgente Pertuso, fiume Aniene, acquifero carsico, Piano di Monitoraggio Ambientale.

Keywords: *Pertuso spring, Aniene River, karst aquifer, Environmental Monitoring Plan.*

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Abstract: *Quantitative assessment of groundwater and surface water is an important tool for sustainable management and protection of these important resources. This paper deals with the design of a multi-disciplinary monitoring plan related to the catchment project of the Pertuso spring, in the Upper Valley of Aniene River, which is going to be exploited to supply an important water network in the South part of Roma district. According to the Legislative Decree 152/2006, as modified by DM 260/2010, any infrastructure design should take in consideration an Environmental Monitoring Plan for the hydrogeological settings of the study area. Thus, the hydrogeological characterization combined with an Environmental Monitoring Plan provides to evaluate the potential adverse environmental impacts due catchment works. For water resources assessment and management, the quantification of groundwater recharge is a preliminary step. As a matter of fact, it has been included the quantitative characterization of the Pertuso spring, in the aim of to protect catchment area, which is directly affect by the natural hydrogeological balance of this aquifer. Thus, a multi-disciplinary monitoring plan has been set up, including quantitative and hydrogeochemical measurements, both for groundwater and surface water of the Upper Valley of Aniene River. The target of this Environmental Monitoring Plan is to set up the background framework on the hydromorphological, physico-chemical and biological properties of water resources in the water basin influenced aim by any potential environmental impact due to the construction activities. The Environmental Monitoring Plan and main features of the monitoring network will be presented in this study.*

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Introduction

Karst aquifers constitute more than 30 % of the EU land mass (Foster et al., 2013) and these groundwater resources are the most important source of water supply for world-wide (Sappa et al., 2013). The hydraulic behaviour of karst aquifers is controlled by a network of highly permeable flow features (i.e. karst conduits, rutted fields, sinkholes, cave systems and ponors) embedded in a less permeable fractured rock matrix. Depending on their sizes (hydraulic capacity) and interconnection, conduit networks are responsible of discharging large volumes of water rapidly through a karst aquifer (White, 1993). Flow velocities into well-developed karst networks range on the order of hundreds to thousands of feet per day are not uncommon (White, 1988). The hydrogeologic characteristics of these aquifers are largely controlled by the structure and development of the conduit network, which generally produces short-circuit surface drainage providing alternative subsurface flow paths that have lower hydraulic gradients and resistance (White, 1999). The heterogeneous distribution of permeability within the karst aquifer and the limited attenuation processes make them more vulnerable to pollution than porous aquifer. Due to their vulnerability, the exploitation of groundwater from karst aquifers requires special strategies for protection and management (Bakalowicz, 2005).

The Pertuso karst spring is located in the Upper Valley of Aniene River (Central Italy) westward of Filettino (FR), at an elevation of about 700 m a.s.l.. Until now, it has been one of the largest fresh water springs in Latium Region. The study area is located in the upper part of Aniene River basin, between the town of Filettino and Trevi nel Lazio (FR) and outcrops from an important karst aquifer, mainly made of dolomitic limestones and dolomites of Cretaceous age. The northern part of this basin, belonging to the Regional Park of Simbruini Mountains, the largest protected area of Latium Region, has a remarkable environmental value and belongs to Nature 2000 network as Special Protection Areas (SPAs) (Habitats Directive 92/43/CEE). The proposed environmental monitoring plan will provide water quantity and quality data useful for monitoring activities and impacts associated with the catchment project of the Pertuso spring, and will contribute useful information to (i) monitor water quantity and quality; (ii) set up monitoring methodology and identify monitoring parameters; (iii) identify any adverse environmental impact, and (iv) design the performance and effectiveness of mitigation measures proposed.

This paper presents an overview of the Environmental Monitoring Plan that will be used for the hydrogeologic investigation and characterization of the karst aquifer feeding the Pertuso spring.

Geological and hydrogeological setting

The study area is located along the SW boundary of the Simbruini Mountains, characterized by the confluence of the Fiumata Valley and the Granara Valley from which starts the Valley of Aniene River (Cipollari et al., 1995). The Pertuso spring is sited about 1 km down from the confluence of these valleys. An important carbonate karst aquifer mainly made of dolomitic limestone and dolomites of Cretaceous age outcrops in this area (Fig. 1). On the top, there are Quaternary fluvial and alluvial deposits, downward pudding and Miocene clay and shale, while the bottom of the series consists of Upper Cretaceous carbonates, made from alternating layers of granular limestone and dolomites (Ventriglia, 1990).

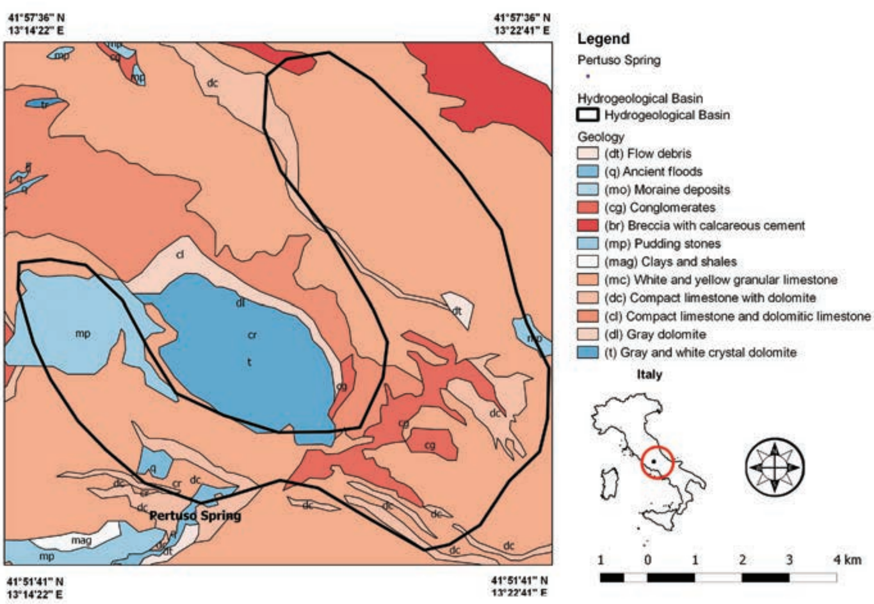

Fig. 1 - Simplified geological map of the study area.

Fig. 1 - Carta geologica semplificata dell'area di studio.

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This area is mostly made of highly permeable Cretaceous carbonate rocks, deeply fractured and mostly soluble. Due to weathering, distinctive surface and underground karst formations are developed in this area at small and large scales. The most important karst landforms are rutted fields, karren, sinkholes and swallow holes. The karst surface is very permeable and enables the rapid infiltration of rainfall into the underground system, where the carbonate dissolution makes cavities (Accordi and Carbone, 1988; Bosellini, 1989; Damiani, 1990). Dissolution conduits strongly influence groundwater flow and evolve into complex networks, often crossing several kilometres throughout the limestone matrix.

The Pertuso spring is located in the dolomite outcrop upstream the town of Trevi nel Lazio and flows into the Aniene River, close to the boundary of the carbonate hydrogeological system (Ventriglia, 1990).

The Pertuso karst spring is the natural outcrop of groundwater discharging from these conduits and it comes out when this aquifer made of this high enhanced karst network, matches topographic surface (Fig. 2).

The Pertuso spring discharges groundwater coming from an about 50 km^2 karstified Cretaceous calcareous rock area. In the Upper Valley of Aniene River the total average annual discharge amounted to about 3800 l/s of which up to 1400 l/s are referred to the Pertuso spring (Acea ATO 2 S.p.A., 2005). The discharge at this karst spring is usually rapid and displays pronounced peaks following recharge events. Unfortunately they are not available data referred to groundwater discharge more than ones represented in Fig. 3.

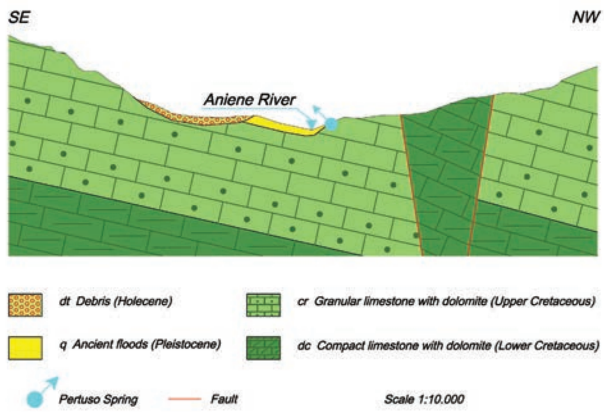

Fig. 2 - Geological cross section of the Pertuso spring.

Fig. 2 - Sezione geologica della sorgente Pertuso.

The catchment project of the Pertuso spring

On 28 June 2002, a Legislative Decree of the President of the Council of Ministers has established the drought emergency state of the municipalities in the south part of Roma district. For this reason, the Pertuso spring, currently feeding the Comunacqua hydroelectric power plant, owned by ENEL group, since 2002 also supplies the Simbrivio water supply network, for a maximum of 360 l/s, in addition to the volumes not available from Simbrivio historical springs. In order to reduce costs and make this spring independent from the plant owned by ENEL group, in the program of actions to resolve the state of drought emergency was included a catchment work project of the Pertuso spring for a maximum of

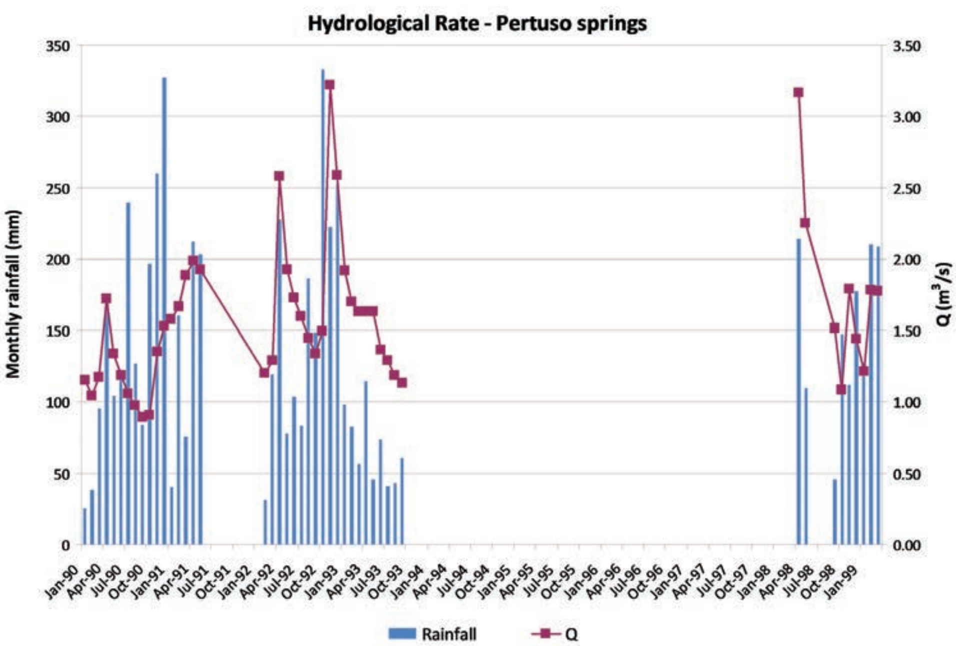

Fig. 3 - Hydrological rate of Pertuso spring in the 1990 - 1999 period (Filettino meteorological station).

Fig. 3 - Regime idrologico della sorgente Pertuso relativo al periodo 1990 – 1999 (stazione meteorologica di Filettino).

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360 l/s. The design of the exploitation project includes a first section from Pertuso Dam to Sosiglio Bridge, characterized by the excavation with TBM of a tunnel across Druni Hill (Construction site 1), and a second one, from Sosiglio Bridge to Cervinara Stream (Fig. 4), in open excavation, till the intersection with the existing water pipe which leads to the Ceraso hydroelectric power plant (Construction site 2). The primary aim of the Environmental Monitoring Plan is to ensure hydrogeological data about (i) temporal and spatial variations in groundwater and surface water levels, (ii) temporal and spatial variations in groundwater and surface water quantity and quality and (iii) impacts due to the drainage of groundwater through the Druni Hill tunnel and the interaction with surface water linked with groundwater. Thus, according to the Legislative Decree 152/2006, as modified by DM 260/2010, the Environmental Monitoring Plan suggested to characterize the major environmental components (i.e. surface water and groundwater) of the Upper Valley of Aniene River for the evaluation of the environmental parameters during survey, excavation and post-excavation phase of the project. For this reason a long-term water quantity and quality monitoring has been established in the study area.

Environmental Monitoring Regulatory Requirements

The European Union, by Water Framework Directive 2000/60/EC, identified the need to create a legal framework for sustainability and protection of all waters (surface water, groundwater, inland waters, transitional waters and coastal waters) and sets out specific objectives that must be achieved by specified dates. The Water Framework Directive aims to prevent further deterioration, protect and enhance all water resources and sustain the natural ecosystems that depend on them. The main purpose is the achievement of good status for all water bodies by 2015; and if this is not possible, aim to achieve good status by 2021 or 2027. Good status means good ecological status for surface waters up to one nautical mile from the coast; good chemical status for all territorial waters, good chemical and good quantitative status for groundwater and good ecological potential for heavily modified water bodies. Italian law system (i.e. D.M. 260/2010), in agreement with Water Framework Directive, establishes an Environmental Monitoring Plan both for protection and sustainability purposes of water resources. The Ministerial Decree D.M. 260/2010 identifies three categories of monitoring in the following: (i) Supervisory monitoring, to define the hydrogeological conceptual model of the aquifer; (ii) Operating monitoring, to measure the potential impact that could result from project operations; (iii) Survey monitoring, to assess the effectiveness of remedial measures. Through supervisory activities will be carried on the environment characterization of the study area, including the definition of spatial and temporal trends in measured parameters. This monitoring is useful to establish the baseline values for environmental quality and quantity indicators so that long-term changes can be evaluated. The operating monitoring allows the existing physical and chemical characterization, the evaluation of the environmental parameters and the examination of the potential contamination sources due to the catchment project. The monitoring plan aims to assess the status of water bodies, to check whether the environmental targets are being effectively

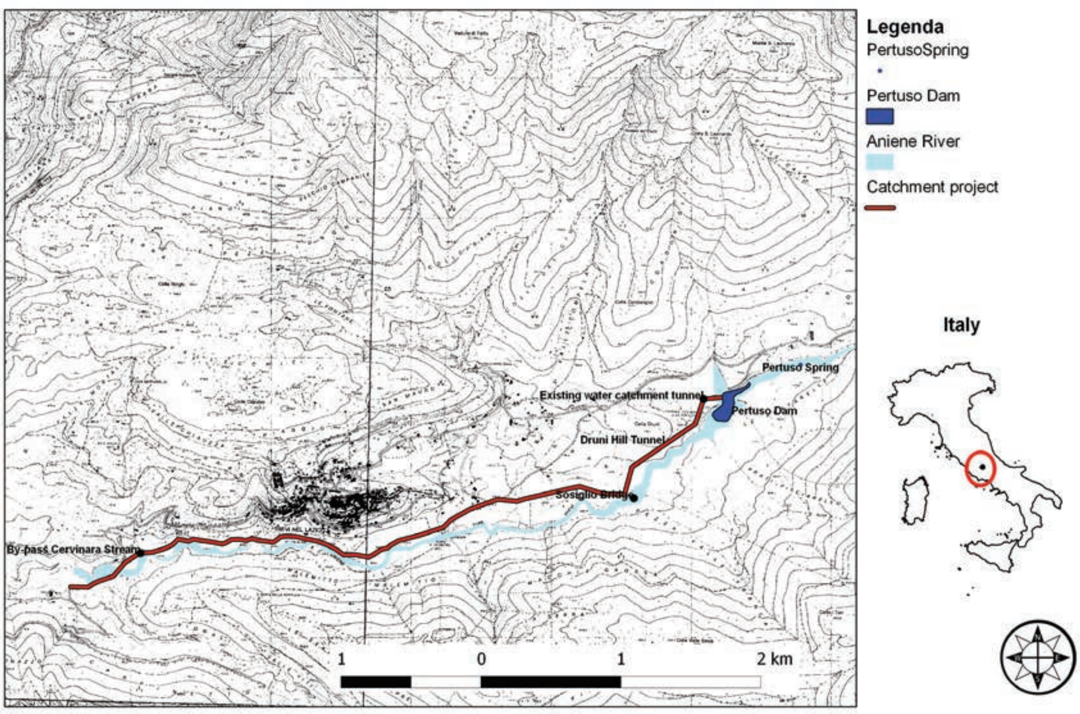

Fig. 4 - Design of the exploitation project of Pertuso spring.

Fig. 4 - Progetto di consolidamento della sorgente Pertuso.

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achieved. This approach was needed to identify the environmental status of groundwater and surface water and to localize where management action is required to achieve the purposes of the Water Framework Directive. The Environmental Monitoring Plan integrates water policy bringing together, within its framework, the actions that are required by all EU and national water legislation.

Water monitoring network design

In the study area a monitoring network has been set up to assess the karst aquifer – Aniene River hydrodynamics properties. The recommendation for monitoring in karst aquifer is to focus on the sensitive connections between surface water and groundwater. The monitoring points should be representative of the hydrogeological conceptual model, with regard to groundwater flow and its interaction with surface water.

The monitoring network will be used to provide baseline hydrogeological conditions and temporal changes in groundwater and surface water conditions prior to project development. The network will also be monitored in the long term (i.e. before, during and after construction activities) to provide ongoing measurement of quality and quantity, including temporal and seasonal changes. In addition, to providing baseline information, the results from the monitoring plan will provide a reference to measure any environmental impacts that could occur. Long-term water monitoring will be conducted at several monitoring stations, chosen according to the importance and the significance of the each environmental component, subjecting to identify the conditions for accessibility.

For the purpose of this study, the monitoring network is based on in situ gauge stations shown in Fig. 5, located along the proposed catchment project.

Four stations are located along a 2 km long Aniene River main stream (SW_01, SW_02, SW_03 and SW_04), referred each one to the two construction sites, as SW_01 and SW_03 are the monitoring stations, designed to control environmental conditions upstream each construction site, while SW_02 and SW_04 are designed to control the same conditions downstream each of them, along the Aniene River main stream.

The groundwater monitoring network includes three existing piezometers (GW_02, GW_03 and GW_04). The Aniene River basin is characterized by a complex network of catching and reservoirs, which doesn't allow a good evaluation of the average annual recharge of this system (Sappa and Ferranti, 2013). Thus, to assess quantitative and quality alterations of the karst aquifer feeding the Pertuso spring, an additional groundwater monitoring station (GW_01) will be installed in the spring to evaluate the undisturbed conditions upstream the karst aquifer. GW_02 monitoring stations were chosen as representative of aquifer conditions downstream the construction of Druni Hill tunnel, while GW_03 and GW_04 are site respectively upstream and downstream the second construction site, in order to monitor groundwater quantity and quality.

Each of the monitoring stations will be identified with a set of Global Positioning System (GPS) coordinates (Table 1).

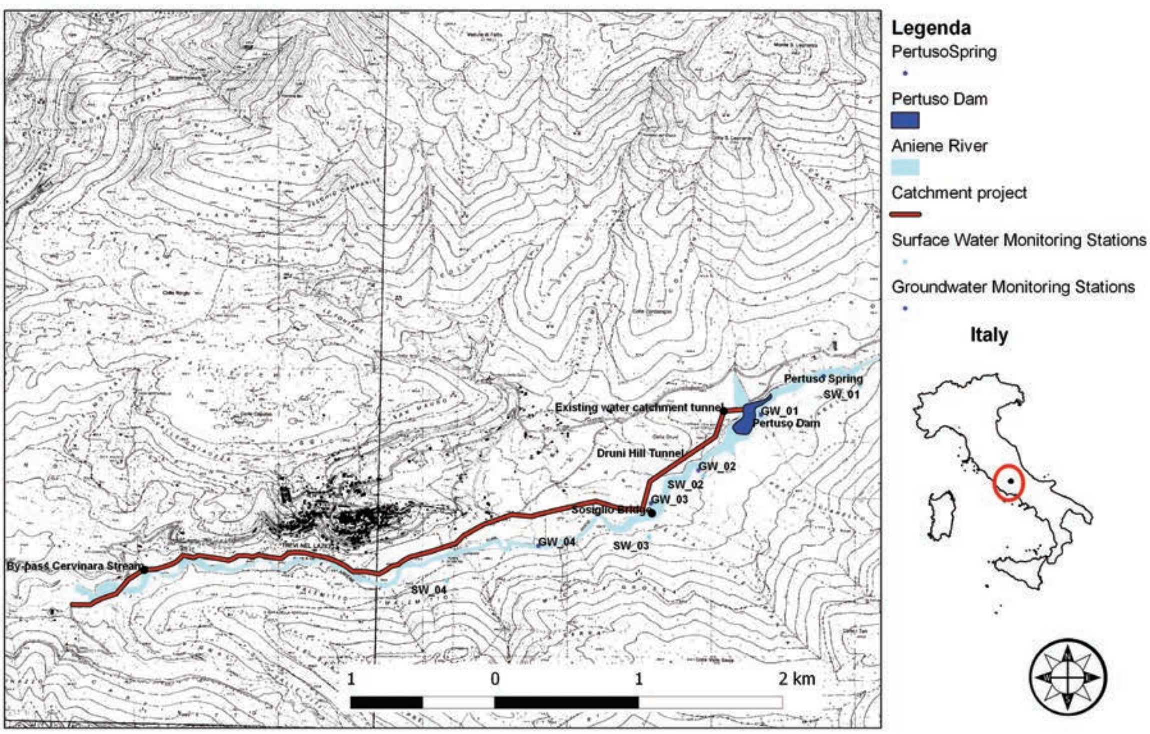

Fig. 5 - Location of monitoring stations (SW: surface water; GW: groundwater).

Fig. 5 - Localizzazione delle stazioni di monitoraggio (SW: acque superficiali; GW: acque sotterranee).

Tab. 1 - Main characteristic of the monitoring stations.

Tab. 1 - Caratteristiche principali delle stazioni di monitoraggio.

	Monitoring Station	N (m)	E (m)	Location
Groundwater	Pertuso spring	4637128.87	357846.31	Spring (Upstream 1° construction site)
	GW_01	4636860.56	357411.6	Piezometer (Upstream 1° construction site)
	GW 02	4636474.9	356977.6	Piezometer (Downstream 1° construction site)
	GW_03	4636246.5	356647.9	Piezometer (Upstream 2° construction site)
	GW_04	4635951.2	355865.5	Piezometer (Downstream 2° construction site)
Surface water (Aniene River)	SW_01	4637064.68	358097.8	Upstream 1° construction site
	SW_02	4636437.2	357012.9	Downstream 1° construction site
	SW_04	4636013.5	356634.9	Upstream 2° construction site
	SW_03	4635706.8	355230.9	Downstream 2° construction site

Methodology

Because of the interconnection between matrix, fractures, and conduits network, karst aquifers are extremely heterogeneous and have hydraulic and chemical properties that are highly scale dependent and temporally variable (Toran et al., 2007). For this reason, the Environmental Monitoring Plan involves collecting samples of surface water and groundwater for quantitative and quality characterization of the karst aquifer feeding the Pertuso spring.

The Environmental Monitoring target is to set up the environmental state and quantitative and quality analysis of temporal water trends for the evaluation of potential interactions between project design and karst aquifer. The aim of this monitoring plan is to build a background framework on the hydromorphological, physico-chemical and biological properties of groundwater and surface water resources in the aim to prevent and evaluate any potential environmental effect coming from the construction activities.

Samples of surface water and groundwater for major dissolved species and trace elements will be collected using standard techniques (Brown et al., 1970; Wood, 1976) that include field filtration using a 0.45 µm membrane filter for major ions and trace elements. Laboratory analysis will be carried on by a certified water testing laboratory for chemical-physical, organic, inorganic, and microbiological parameters, following DLgs. 152/06 prescriptions (Tab. 2). Properties such as temperature, electrical conductivity, pH, dissolved-oxygen, oxidation-reduction potential, static water level and stream flow can be measured directly in the field before the water sample collection. The choice of measures equipment depends on several factors including the accuracy of measurement required and the type and accessibility of well (monitoring or water supply).

All field instruments will be calibrated according to manufacturer's recommendations prior, to be taken into the field. Calibration standards will be selected based on historic data for best instrument accuracy.

Surface Water Monitoring

Stream discharge and water quality parameters such as turbidity, dissolved oxygen, water temperature and electric conductivity monitoring is important to have a referring trend, along the year, of these values range and to be ready to evaluate potential modifications due to construction activities.

Stream discharge will be indirectly estimated by the calculation of discharge from the in situ measured data set. Seasonal measurements of Aniene River water stream, along with periodical measurements of cross-sectional area, water surface width, flow velocity, bed channel depth will be started on August 2014. These measurements will be made with conventional measurements methods such as reels current meter method for discharge. Thus, the Aniene River flow will be measured using a current-meter (SEBA F1 - Seba Hydrometrie) which, combined with SEBA Z6 pulse counter, allows to measure velocity between 0,025 m/s and 10 m/s.

The current U.S. Geological Survey (USGS) procedure for gagging discharge in rivers is to measure stage and then to calculate discharge from an empirically generated stage discharge relation (rating curve) (Chow, 1964 and Rantz, 1982). In natural river systems a common approach is to build the stage–discharge relationship with the help of several segments only valid for a given range of stages. For this reason, flow measurements will be collected at a number of equally spaced verticals (N), inside the river cross section, at multiple depths at each monitored vertical. The rating-curve will be regarded as a relation fitted to N points (h_i, Q_i), i=1,2,…,N, the measured stage hi and corresponding measured discharge Q_i recorded on N occasions.

Groundwater Monitoring

The groundwater monitoring network is made on the first by the GW_01 station (Pertuso spring), where will be placed a multiparameter probe, connected to a data logger to collect daily time series of temperature, electrical conductivity, pH, dissolved-oxygen, oxidation-reduction potential and water

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Tab. 2 - Water Quality Monitoring Parameters.
Tab. 2 - Parametri oggetto del monitoraggio.

Tipology	Parameter	Unit	Surface water	Groundwater
In Situ Parameters	Water Temperature	°C	x	x
	Dissolved Oxygen	mg/l	x	x
	Conductivity	µS/cm	x	x
	pH	-	x	x
	Flow	m^3/s	x	x
Laboratory Parameters	Turbidity (Residue At 105 ° C And 550 ° C)	(mg/l)		x
	Total Suspended Solids	mg/l	x	
	Total Hardness	mg/l $CaCO_3$	x	x
	Bicarbonates (Temporary Hardness)	(mg/l)		x
	Bicarbonate Alkalinity	(mg/l)		x
	Carbonate Alkalinity	(mg/l)		x
	Bicarbonate Ion	(mg/l)		x
	Total Nitrogen	N µg/l	x	
	Ammonia Nitrogen	N µg/l	x	x
	Nitrate Nitrogen	N µg/l	x	x
	Nitrous Oxide	µg/		x
	BOD5	O_2 mg/l	x	
	COD	O_2 mg/l	x	
	Orthophosphate	P µg/l	x	
	Total Phosphorus	P µg/l	x	x
	Chloride	Cl^- µg/l	x	x
	Nonionic Surfactants	µg/l		x
	Anionic Surfactants	µg/l		x
	Color	µg/l		x
	Odor	µg/l		x
	Sodium	µg/l		x
	Calcium	µg/l		x
	Potassium	µg/l		x
	Magnesium	µg/l		x
	Sulphates	SO_4^{2-} µg/l	x	x
	Boron	µg/l		x
	Free Cyanide (	µg/l		x
	Fluorides	µg/l		x
Metals	Cadmium	µg/l	x	x
	Total Chromium	µg/l	x	x
	Chromium Vi	µg/l		x
	Mercury	µg/l	x	x
	Nickel	µg/l	x	x
	Lead	µg/l	x	x
	Copper	µg/l	x	x
	Zinc	µg/l	x	x
	Aluminum	µg/l		x
	Antimony	µg/l		x
	Silver	µg/l		x
	Arsenic	µg/l		x
	Beryllium	µg/l		x
	Cobalt	µg/l		x
	Iron	µg/l		x
	Selenium	µg/l		x
	Manganese	µg/l		x

belows Tab. 2 - Water Quality Monitoring Parameters.
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Tipology	Parameter	Unit	Surface water	Groundwater
Organic Compounds	Aldrin	μg/l	x	
	Dieldrin	μg/l	x	
	Endrin	μg/l	x	
	Isodrin	μg/l	x	
	DDT	μg/l	x	
	Benzene	μg/l		x
	Ethylbenzene	μg/l		x
	Styrene	μg/l		x
	Toluene	μg/l		x
	Para-Xylene	μg/l		x
	Hexachlorobenzene	μg/l	x	
	Hexachlorocyclohexane	μg/l	x	
	Hexachlorobutadiene	μg/l	x	
	1,2-Dichloroethane	μg/l	x	
	Trichloroethylene	μg/l	x	
	Trichlorobenzene	μg/l	x	
	Chloroform	μg/l	x	
	Carbon Tetrachloride	μg/l	x	
	Perchloroethylene	μg/l	x	
	Pentachlorophenol	μg/l	x	
	Hydrocarbons C> 12	μg/l		x
	Hydrocarbons C <12	μg/l		x
	Total Hydrocarbons	μg/l		x
	BTEX Hydrocarbons	μg/l		x
	Methyl Tert-Butyl Ether MTBE	μg/l		x
	Total Polycyclic Aromatic Hydrocarbons	μg/l		x
Microbiological Parameters	Escherichia Coli	UFC/100 ml	x	x

level, starting from September 2014, till one year after construction activities end. All these data will be sent daily to a PC station, to control every day groundwater spring properties, and they will be display on a website.

Spring discharge will be indirectly evaluated, at the Aniene River cross – section shown in Figure 6, by the calculation of discharge from the in situ water level data set, in order to evaluate the contribution of the Pertuso spring to Aniene River flow.

Seasonal sampling will be carried out on August 2014 and groundwater samples will be taken directly from each monitoring stations (boreholes and spring). Boreholes are GW_02, GW_03 and GW_04, placed, respectively, downstream of the first construction area, GW_02, upstream and downstream of the second construction area, GW_03 and GW_04.

The target of groundwater sampling is to have a water sample that represents the groundwater properties, in the area under study, in any season, as a reference database to relate the results of analysis carried on during construction activities. To obtain a representative sample it is necessary to remove the stagnant water from the well before a sample is taken. Before collecting a groundwater sample, the boreholes will be purged to remove any stagnant water in it and to ensure that the water sample is representative of the aquifer being sampled: so, a minimum of three to five well volumes of water will be purged.

Purging must continue until temperature, electric conductivity, and pH level readings stabilize. The readings will be taken and logged every few minutes and recorded in a field log book together with the pumping method and the volume of water pumped.

The water level will be measured using a probe attached to a permanently marked polyethylene tape, fitted on a reel. The probe detects the presence of a conductive liquid between its two electrodes, when contact is made with water; the circuit is closed, sending a sound back to the reel. The water level is then determined by taking a reading directly from the tape, at the top of the well. Some physico-chemical parameters cannot be reliably measured in the laboratory as their characteristics change over a very short time scale. Parameters that will be measured in the field include pH, electrical conductivity, temperature, dissolved oxygen and redox potential. The field parameters will be reliably measured using a multiparameter probe—usually with an electrode for each parameter.

Sampling frequency

The sampling frequency depends on the monitoring purposes, established by the Environmental Monitoring Plan (DM 260/2010). However, for surface water a more detailed sampling frequency is required for supervisory and operating monitoring, while a low sampling frequency (1/year) could be enough for survey monitoring, if any trouble would have

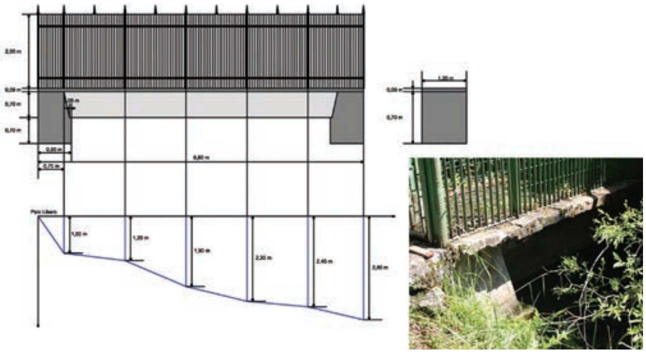

Fig. 6 - Detail of the Pertuso spring monitoring station (GW_01).

Fig. 6 - Particolare della stazione di monitoraggio in corrispondenza della sorgente Pertuso (GW_01).

come out during previous monitoring phases. The groundwater frequency sampling is related to the aim of set up the hydrogeological conceptual model of the karst aquifer. Thus, groundwater will be monitored monthly (12/year), in the whole monitoring network, for supervisory and operating monitoring, to assess seasonal and natural groundwater fluctuations, while annual sampling (1/year) will be carried out for survey monitoring. Water measurements at the Pertuso long-term monitoring station (GW_01) will be collected one time daily.

The Environmental Monitoring Plan will be reviewed annually, according to the monitoring results and ongoing of the catchment project of the Pertuso spring. The review of the monitoring plan will upgrade the potential environmental impacts and will adapt the monitoring to the updated risk rating. It will evaluate the effectiveness of each monitoring station, to assess where new locations and modifications to the monitoring network may be needed, and evaluate any impacts that may be occurring. An additional monitoring plan will be considered in case of a sensitive environmental accident. The annual review of the monitoring plan, including analysis of results, will be submitted to the authorities for review.

Conclusions

This study presented the Environmental Monitoring Plan of groundwater and surface water in the Upper Valley of Aniene River, in southern part of Latium Region. The purpose of this work is to outline the key monitoring requirements to control the environmental performance of the catchment project of the Pertuso spring. The Environmental Monitoring Plan is a formal and approved document for project execution management. The plan set up the monitoring methodology and the actions needed to evaluate the potential environmental impacts, due to the catchment works. The Environmental Monitoring Plan will be updated elaborated by updates, throughout the project ongoing with the purpose to support the implementation of environmental remediation works as part of the project.

The Environmental Monitoring Plan, combined with the implementation of measures designed to reduce the potential adverse effects of the proposed project on the karst aquifer feeding the Pertuso spring, is crucial to evaluate the environmental sustainability of the catchment project. The monitoring plan provides that, in the event of environmental impact, construction activities will stop and remediation measures will restore the environment status of the hydrogeological system.

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