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ScienceDirect

Procedia Engineering 209 (2017) 100–103

Procedia Engineering

www.elsevier.com/locate/procedia

Urban Subsurface Planning and Management Week, SUB-URBAN 2017, 13-16 March 2017, Bucharest, Romania

Management of the groundwater resource beneath the city of Ljubljana

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Abstract

Ljubljana is the capital and largest city of Slovenia. It has been developed in the vicinity of the Sava River on an alluvial plain that for more than a century has been used as a local resource for drinking water. Thanks to the natural hydrogeological conditions and protection measures, the groundwater beneath the city is still the city's main resource of drinking water. The city's growing energy demands initiated the search for new alternative sources of energy which could contribute to the reduction of CO_2 and other health hazardous emissions. In this respect, the ground beneath the city, the groundwater especially, offers favorable conditions for the implementation of ground-source heat pump systems, which represent one of the key technologies of renewable energy for heating and cooling. The city's future challenges regarding the subsurface will be related to the sustainable and efficient use of all resources and the avoidance of conflicts in their mutual use, in which drinking water resources will be of paramount concern.

Peer-review under responsibility of the scientific committee of the Urban Subsurface Planning and Management Week.

Keywords: groundwater management; shallow geothermal energy; urban area

1. Introduction

The city of Ljubljana, the capital of Slovenia, has a central position within Slovenia (Fig. 1). It is located on an alluvial plain, which is part of the Ljubljana Basin, formed by tectonic subsidence and the gradual filling with material that the Sava River transported from the alpine periglacial areas. The sediments, forming layers up to 100 m thick, are mostly composed of highly permeable gravel and sand beds that are partly lithified. The basement of the Quaternary aquifer consists of Carboniferous and Permian rocks of which hills and hilly hinterland are mainly composed.

The hydrogeological conditions in the area are characterized by strong interactions between the groundwater and the Sava River. The unconfined aquifer is recharged from the Sava River and rainfall, percolating through an unsaturated zone, which is on average 25 m thick. Approximately 1 m^3/s of the groundwater is abstracted from this highly productive aquifer for drinking water, which represents roughly 90 % of all the water in the system, supplying some 300 000 people with drinking water.

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Peer-review under responsibility of the scientific committee of the Urban Subsurface Planning and Management Week.
10.1016/j.proeng.2017.11.135

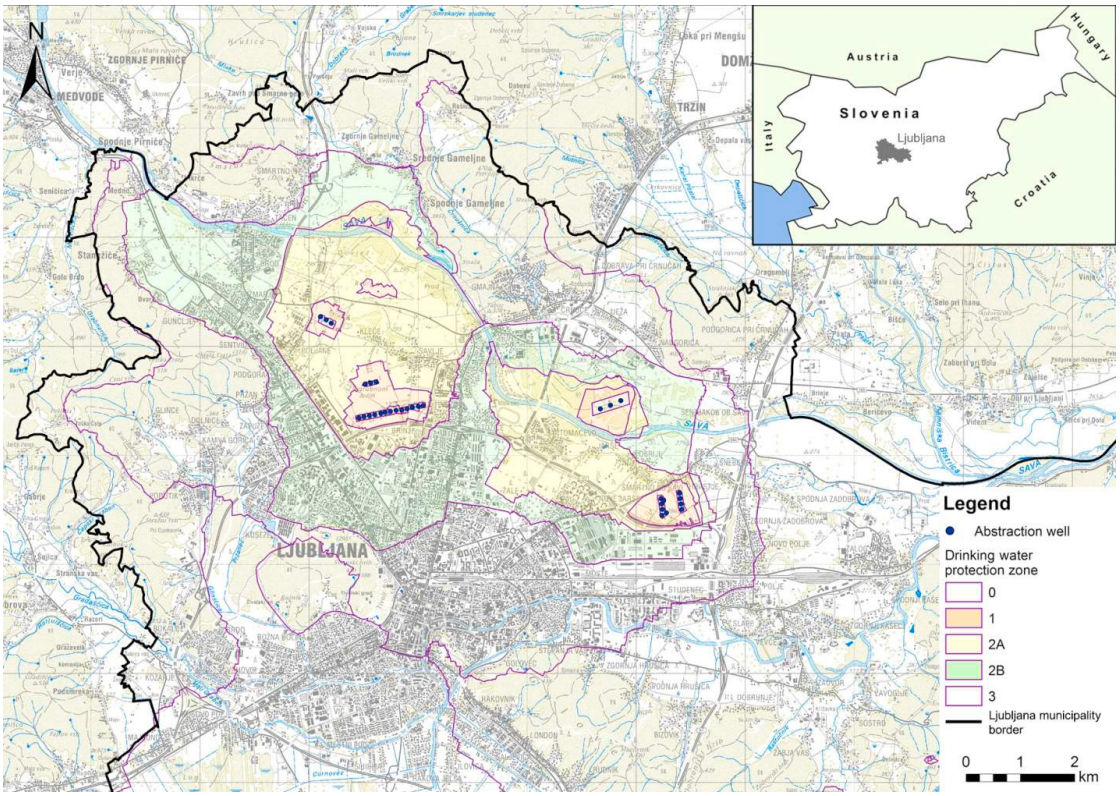

Fig. 1 Map of the city of Ljubljana with drinking water protection zones.

2. Drinking water resource

The drinking water supply of the city has relied on the above-mentioned aquifer for more than a century, thus the concept of groundwater management has been developed during this time. A basic protection of the catchments of abstraction wells is provided by drinking water protection areas. The delineation of the protection areas (Fig. 1) is based on groundwater residence time and the hydrogeological characteristics of the aquifer.

The integration of protection areas into the city's spatial planning documents has a preventive role and reduces the risk of pollution of the groundwater. Human activity and land use within these areas that can have an unfavorable impact on groundwater quality are restricted.

The implementation of drinking water protection areas has influenced the spatial development of the city. The protected areas represent two of five green wedges, which link the city center with the hinterland and are a key macro spatial component section of the urban space, as well as important climate corridors for the city (Fig. 2).

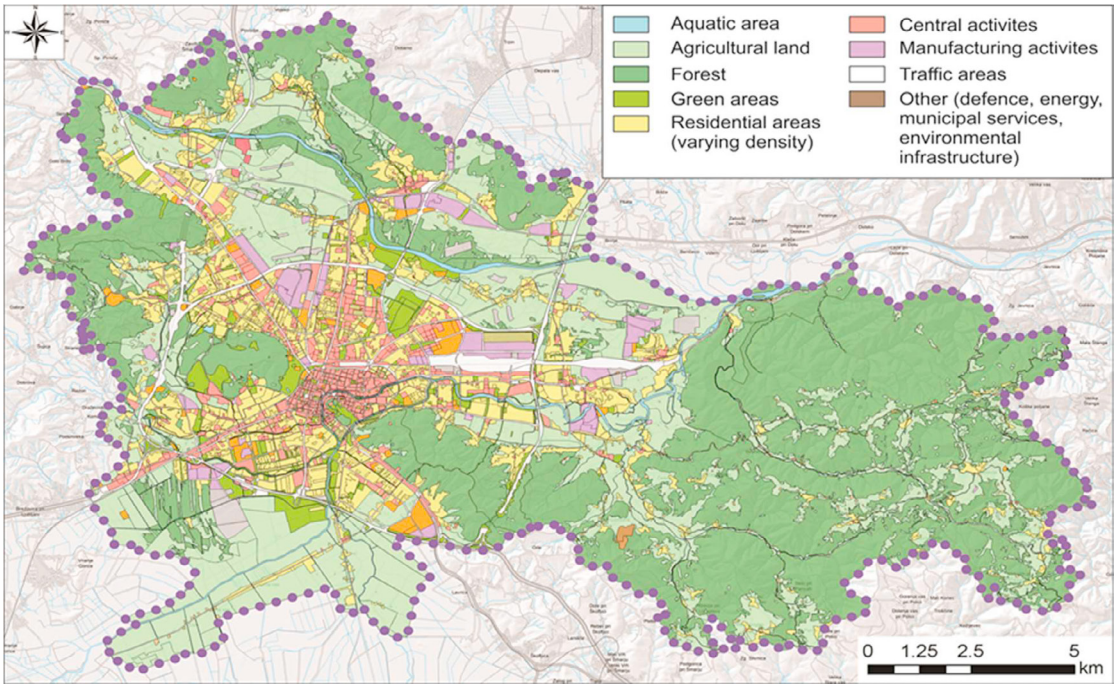

Fig. 2. Land use map of the Municipality of Ljubljana [1].

Despite the implementation of protection zones, certain risks related to unusual events or accidents that can frequently occur in a highly urbanized area still remain. To handle these risks of groundwater pollution, a form of decision support system was developed [2]. The developed system is an interactive computer system that utilizes: a database, hydrological modeling and knowledge of the experts/stakeholders (decision model). It links logically related activities, such as, the detection of pollution in the groundwater, the simulation of pollution propagation, and decision making, into a common system, which enables fast and easy access to supporting information in the case of the detection of groundwater contamination, thus significantly improving the response time and the mitigation capacity of drinking water management.

3. Shallow geothermal energy

At the moment, a coal and biomass powered district heating system covers most of the densely populated area and distributes heat to 74 % of all households. Natural gas is the complementary source of heating. The share of geothermal energy use for heating and cooling is very low (few percent).

To preserve its green identity and to follow the energy policies of the European Union the city of Ljubljana set in its Sustainable Energy Action Plan, the following goals to be achieved by the year 2020 (baseline year 2008):

- substitution of fossil fuels with renewable energy sources (25 % share of renewable energy in the final energy consumption),
- improvement of the energy efficiency (20 % less energy use),
- reduction of the greenhouse gas emissions by 35 %,
- intensification of research and the introduction of new technologies for the utilization of renewable energy sources.

The local heat/cold production is the sector in which is expected the largest share of greenhouse gas emissions reduction (65 %). In this respect, shallow geothermal energy will have an important role. There is a need for an integrative development and management strategy to foster the use of shallow geothermal energy.

One of the important reasons for the low share of geothermal energy in energy consumption is a lack of information on the shallow geothermal potential and the barriers for its utilization. Providing this information in a quantified form that can be used as a solid base for planning and designing geothermal systems is a great challenge. Especially when taking into account the conflicts arising from the multiple use of the subsurface in this densely populated area and the use of the groundwater below the city as a main drinking water resource.

To enhance the awareness on shallow geothermal potential and boost its utilization, the city of Ljubljana has been included as the pilot area in the project GeoPLASMA-CE, which addresses shallow geothermal utilization and intends to foster the market share of these techniques for heating and cooling in Central Europe.

The objective of the planned project activities is to quantify the spatial distribution of the shallow geothermal potential for the utilization of ground source heat pumps, primary for heating but also cooling purposes. Based on existing data, including results of hydrological model [2], and new measurements, a 3D geothermal model will be developed to support the elaboration of thematic maps and other information that will be integrated into the development and management strategies of the city with a goal to foster the use of shallow geothermal energy and to meet the environmental objectives: to reduce gas emissions hazardous to climate and air quality and to increase the share of renewable energy in the final energy consumption.

Acknowledgements

The presented work was supported in part by the Slovenian Research Agency under the Research program Groundwater and geochemistry (P1-0020), COST action Sub-Urban (http://sub-urban.squarespace.com) and the Interreg CENTRAL EUROPE project GeoPLASMA-CE (http://www.interreg-central.eu/Content.Node/GeoPLASMA-CE.html).

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