Mapping of low enthalpy geothermal resources. The example of Parma

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STUDY AREA

We study the area of the city of Parma in the Emilia-Romagna Region, located in the flood plain at the foot of the Apennine chain (Figura 2).

The city of Parma has a population of about 180,000 people and is the second city after Bologna.

In recent years the urban area have been authorized and carried out various low enthalpy plants both open and closed loops.
**GEOMORPHOLOGICAL FRAMEWORK**

The study area including the portion of high and medium padan plain. The quote is reaching higher in south with about 75 m a.s.l. while toward north the surface degrade to about 40 m a.s.l.. The entire area is drained by the Parma and Baganza river.

**GEOLOGICAL FRAMEWORK**

In surface the geological units belong to Higher Sintema of Emilia-Romagna (AES). The subsintema outcropping is the Ravenna Unit (AES8) and Modena Unit (AES8a). These geological units are characterized by alluvial deposits both coarse (gravel and sand) that fine (mud and silt).
The exploitation of low enthalpy geothermal reservoir

In the city of Parma is spreading the practice of conditioned buildings through the heat pump system using geothermal energy. From the technical point of view the geothermal reservoir can be exploited by means of:

1. Extraction of groundwater through wells and sending the fluid to the heat pump – refrigerator unit. The system with water with drawl is called open loop.

2. Heat exchange with the geothermal reservoir through fluids circulating in closed loop pipes cemented in to the ground, without the taking of groundwater. The system without water withdrawal is also called closed loop.
In recent years have been installed, in the urban area, some geothermal plants. Today were approved 5 open loop plants that reached the total power of about 800 KWt and the wells have an average depth of about 30-35 meters.

The plants approved with heat exchange in the underground (closed loop) are 6 and reached a total installed capacity of about 3500 KWt. The average depth of geothermal probe is about 120-130 meters.
POSSIBLE IMPACTS ON THE TERRITORY

GEOTHERMAL PLANTS APPROVED AND ZONE OF PROTECTION OF GROUNDWATER RESOURCES
THE PHENOMENON OF THERMAL SHORTING

Vertical section and plan view diagram of a doublet geothermal wells without thermal interference (Banks, 2009).

Vertical section and plan view diagram of a doublet geothermal wells with potential thermal interference (Banks, 2009).
CURRENT STATE OF KNOWLEDGE

Example of mathematical model of open loop geothermal system serving a spa-hotel.

Open loop system type consisting of 2 drawing wells and 2 restitution wells.
Heating Power Peak 1043 KW
Cooling Power Peak: 668 KW
Flow rate instant peak: 40 liter/second

Plume of cold water after 20 years of operation and areas of influence of withdrawal and restitution
EXAMPLE OF GEOLOGICAL SECTION WITH THE PRESENCE OF GEOTHERMAL SYSTEMS AND THE LIMITS OF PROTECTION AREA OF WATER WELLS
PURPOSE OF THE PROJECT

The main purpose of the study is the creation of thematic maps aimed at zoning of the territory according to the sustainability of hydrogeologic system for heat exchange with the subsurface.

The cartographic maps will be operational tools for the industry, both public and private.

For the achievement of this objective is necessary to develop a mathematical flow and heat transport 3D model in steady state.

The software to be used is the finite element code «FEFLOW 6» (WASY).
METHODOLOGY OF WORK

The work methodology is based on three phases:

I) On an accurate reconstruction of the 3D subsurface stratigraphic model with the mapping of the main stratigraphic surface (bases of different aquifers complex) that will identify the different layers of the model and the mapping of isopercentual of coarse deposit (gravels and sands - aquifers) compared to fine deposits (clays and silts – aquiclude) within the different layers.

II) Input of stratigraphic and hydrogeological data in the mathematical model and setting of the boundary conditions of the flow model.

III) Run and calibration of the mathematical flow model in steady state.

IV) Input of physical data related to sedimentary deposits and to open and closed loop system in the model and setting the boundary condition of heat transport model.

V) Run and calibration of the flow and heat transport model in steady state condition in order to simulate the different operating condition, both open and close loops system, in the different aquifer complexes in the study urban area and falling within the physical domain of the model.
Before carrying out simulations will be established hydrogeological constraints the main ones are:

- the maximum variation in temperature between extraction and re-entry
- The maximum distance, with respect to the points of disturbance, that is considered acceptable for a given thermal variation

The mathematical model simulates the formation of thermal plume in groundwater and soils caused by the use of geothermal heat pumps both in closed and open loops system. In this way the maps will be zoned to give the limits of sustainability in relation to the density of existing hydrogeological constraints. Infact the environmental impact and efficiency of these system depend mainly on the density of the plants on certain portion of the urban area.

The maps will be used to estimate both the environmental impact of possible geothermal plants to protect the efficiency of the same, in order to avoid thermal interference.
FIRST PHASE– PARMA URBAN AREA PROJECT

SUMMARY OF MAJOR ACTIVITIES HELD DURING THE FIRST PHASE OF THE PROJECT.
REFERENCE PERIOD OCTOBER 2011 – MAY 2012
The activities during the first phase of the project had as main purpose the reconstruction of a three-dimensional model of the hydrogeological system in the urban area. This goal has been achieved through the development of bathymetric GRID of the main hydrostratigraphic surfaces that have been identified in the physical domain of the model.

In Emilia-Romagna region exist a reference hydrostratigraphic model (RER-ENI, 1998).

The physical domain of the model will include the aquifers complex A0, A1 and A2 belonging to Group Aquifer «A». The base of the model coincide with the base of aquifer Complex «A2».

The choice of the physical model domain is due to the fact that in the urban sector the major aquifers complex exploited, especially for aqueduct purpose, are precisely the aquifer system A1 and A2.

In the study area the base of aquifer complex A2 reaches the maximum depth of about 140 meters. This means that most of the geothermal power plants already made and future hardly exceed the order of 150 meters depth.
GEOGNOSTIC DATABASE

ABOUT 500 BETWEEN WATER WELLS, SONDAGGI E POVE PENETROMETRICHE

NETWORK OF 18 HYDROSTRATIGRAPHIC SECTION
I STEP - HYDROSTRATIGRAPHIC SECTION

Review and geometry control of hydrogeological sections regarding the study area, on which were highlighted four main stratigraphic surfaces:
- Surface P1: base of Unit Aes8 (A0)
- Surface P2: base of Unit Aes7b (A1sup)
- Surface P3: base of Unit Aes7a (A1inf)
- Surface P4: base of Unit Aes3 (A2)

In addition, are also highlighted two surfaces of activation of river systems called respectively:
- Surface P1r
- Surface P2r

MAIN STRATIGRAPHIC SURFACES OF THE MODEL

- Base of Aquifer Complex A0
- Base of Aquifer Complex A1-sup.
- Base of Aquifer Complex A1-inf.
- Base of Aquifer Complex A2

Silt and clay
Gravels and sands
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Using the wells point in the hydrostratigraphic sections and the points of intersection of the sections have been created shape file for each surface of the model.
Using geostatistical methods, in particular the Kriging, was analyzed the spatial distribution of the quoted points in order to obtain the bathymetric GRID related to the principal stratigraphic surfaces of the model.

Kriging is a moderately quick interpolator that can be exact or smoothed depending on the measurement error model. It is very flexible and the flexibility of kriging can require a lot of decision-making. Kriging, like most interpolation techniques, is built on the basis that things that are close to one another are more alike than those farther away.

Global Neighborhood = exact interpolator

Order of trend = second

It is a parabolic algebraic function that best approximates the behavior of model surfaces.
The semivariogram that best fitting with the data spatial distribution of our data is Spherical: $Y = \frac{1}{2}(P_{x1} - P_{x1-h})^2$

The semivariogram depicts the spatial autocorrelation of the measured sample points. The empirical semivariogram is a means to explore this relationship. Pairs that are close in distance should have a smaller difference than those farther away from one another. The extent that this assumption is true can be examined in the empirical semivariogram.

The Semivariogram that best fitting with the data spatial distribution of our data is Spherical: $Y = \frac{1}{2}(P_{x1} - P_{x1-h})^2$
Cross-validation uses all of the data to estimate the trend and autocorrelation models. It removes each data location, one at a time, and predicts the associated data value. This procedure is repeated for a second point, and so on. For all points, cross-validation compares the measured and predicted values.
OUTPUT OF GEOSTATISTICAL ANALYSIS: P1 SURFACE ISOBATH GRID

ISOBATHS OF P1 SURFACE (m a.s.l.)

P1 SURFACES: BASE OF AQUIFER COMPLEX "AO"

High: 66 m a.s.l.
Low: 12 m a.s.l.
OUTPUT OF GEOSTATISTICAL ANALYSIS: P4 SURFACE ISOBATH GRID
Base of the physical model domain
THE NEXT PHASES OF THE PROJECT ARE WORK IN PROGRESS........

THANKS FOR YOUR ATTENTION