New geothermal targets in the Paris basin

Olivier Grière[1], Christian Boissavy[2].

[1] G2HConseils –- 29 rue B. Hottinguer 77600 Guermantes France

[2] Cabinet BOISSAVY – 35, Boulevard de Magenta 75010 Paris France

g2hconseils@sfr.fr

Keywords: low temperature geothermal DH, lower cretaceous, fine grained sandstones doublet completion, heat pump, injection

ABSTRACT

Experiences from the petroleum and geothermal energy industry indicated, that reinjection of the cooled geothermal water into a sandstone aquifer often leads to a reduction of the permeability of the formation .The reinjection pressure has to be increased in order to maintain the injection rate. The phenomenon can be attributed to various reasons: microbiological effects, water sensitivity of sandstones, suspended solids, fine migration in the reservoir, trapped gases, air contamination… Numerous geothermal doublets in Europe faced this type of problems and consequently have been abandoned in France, Hungary, Germany and Romania. Two recent operations in the Paris area have proved that in non-saline environment this type of geothermal doublet should be a success using simple methods.

1. GEOLOGICAL AND GEOTHERMAL POTENTIAL IN THE PARIS BASIN:

The basin is large and covers around 100000 km2 from the Vosges mountains to Britannia (east-west) and Belgian border to Massif Central (north-south). The maximum thickness of sediments is known in the eastern part of Ile de France and amounts about 2500 m from Permian layers to quaternary deposits without lacuna (Figure 1 Geological cross section). The basement has been drilled in a very few numbers of oil and gas exploration wells and if the topography of these formation has been mapped very few details are available regarding the petro- physical nature of these rocks.

From the bottom to the top of the section several aquifers are considered as geothermal potential targets (figure 2):

Triassic layers: made of detrital sediments with alternance of sandstones and clays. They are exploited for oil and gas in the eastern part of Ile de France and average permeability usually low. Two attempts of geothermal exploitation have been performed in Melleray to heat greenhouses in the 80's, the production rate was good but the injection become quickly impossible due to the pressure increase and the operation has been performed during some tears with discharge to the Loire river. The second attempt was in Achères, west of Paris and the plant never been put into operation because the index of injectivity is too low to operate commercially the doublet scheme.

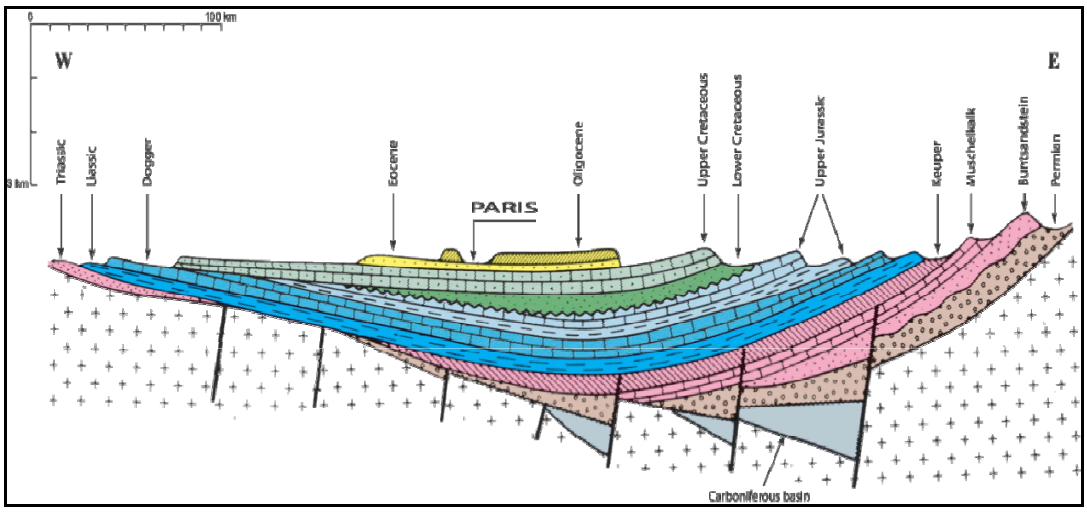

Figure 1: The geological cross section (east-west)

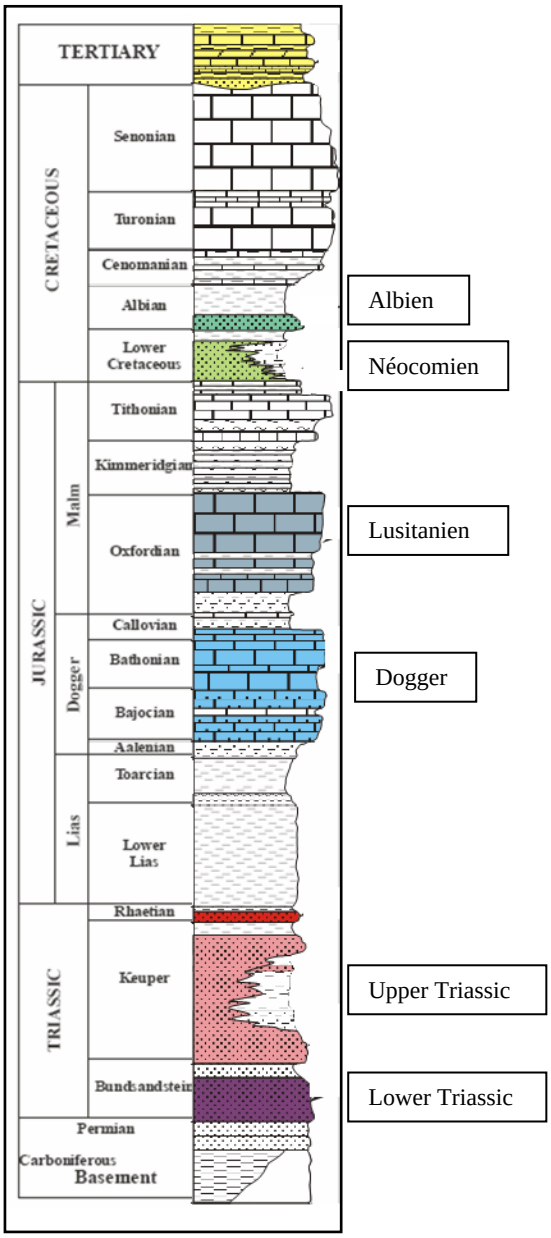

Figure 2: Lithostratigraphic section with the 6 main deep aquifers present in the basin

Dogger limestone: This aquifer is the main geothermal target in Ile de France with an installed thermal capacity of more 270 MW than and a yearly production of 1200 GWh. Out of the 57 doublets that were drilled in the Paris basin, 34 are still active. There are 29 geothermal production plants exploiting the Dogger aquifer for district heating. Each plant operates with double or triple wells systems ("doublet" or "triplet"). Only 27 plants show brine temperature higher than 65°C but no energy decline has ever been reported.37 wells were abandoned mainly for technical (corrosion or scaling) or economic reasons (low profitability of geothermal operations compared with fossil energies when the oil barrel fall down to 12US$). The vast majority of abandoned operations lie in the North West Part of the basin. New operations restarted in 2007 and about 20 operations are in the pipeline.

Oxfordian limestone (Lusitanian) has been tested in Orly with a flow rate comparable to the Dogger aquifer and a temperature 15°C lower. This aquifer is a good alternative in the department of Val de Marne (SE of Paris) where the highest density of doublets could prevent the development of new projects.

Lower Cretaceous detrital formations: The Albien sands have been exploited for drinking water purposes since 150 years in Paris area. This aquifer has been exploited for geothermal use (heating and cooling) since 1960 in La Maison de La Radio with a single well and discharge to the river. A doublet is exploited since 20 years in two towers of the Front de Seine for heating and cooling uses with a reversible system (the production well, in winter, is exploited as injector during the summer period).

The Néocomien sands have been drilled and are exploited in two operation one in CEA (Bruyères le Chatel) for water and heating purposes with a single well and one in Corbeil for industrial use (pure water for electronic devices manufacturing).

2. DESCRIPTION OF THE LOWER CRETACEOUS AQUIFERS

The sedimentary sequence is made of Albien, Aptien, Barremien, Hauterivien, Valanginien which are the 5 layers bearing the two aquifers called Albien and Néocomien Sandstones. The geographical extension is shown on the figure 3 with Albien (green dark) and Néocomien (green).

The Albien contains three main sand layers intercalated with argillaceous formations. The Néocomien is composed by a multilayer made of sands and clays. The aquifer is separated from Albien by a compact intercalation of plastic clays. The two aquifers could be locally connected but in the centre of the basin the reservoir pressures are different with an overpressure for the deepest.

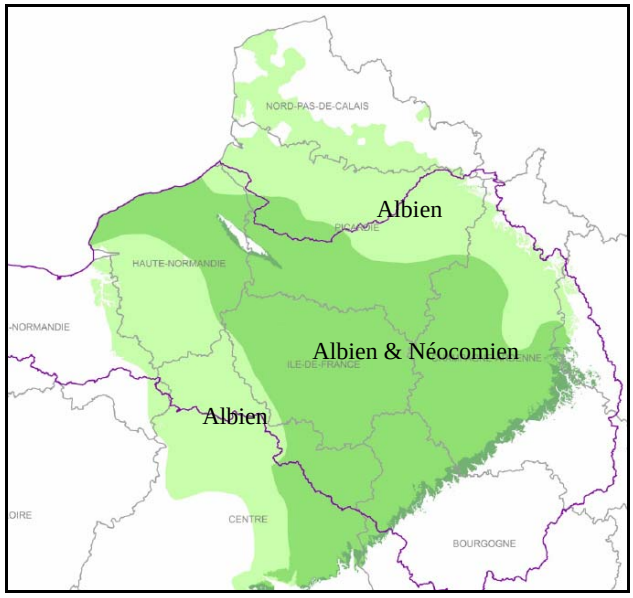

Figure 3: Geographical extension of the two geological formations

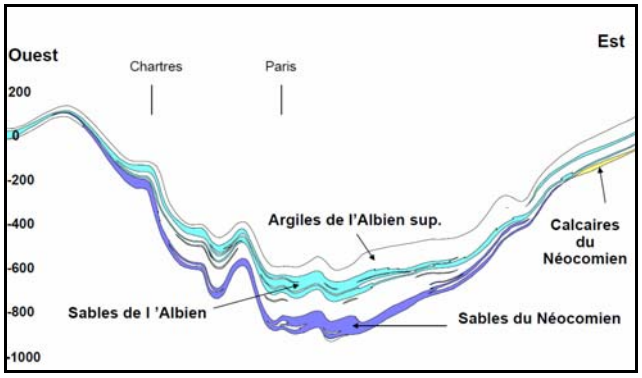

Figure 4: Cross section east-west with the position of the aquifers and connected zones in the shallower positions

The thickness of the two reservoirs is similar (in yellow and redder), it is measured from 55- 60 m to 110-130 m for both aquifers. With average porosities from 10 to 20% in clean sands layers, the total amount of water reserves is estimated at 655 billion of m^3.

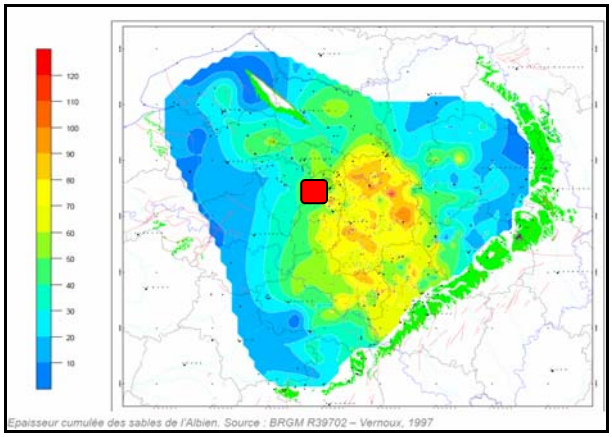

Figure 5: Cumulative thickness of the Albien reservoir made of sands

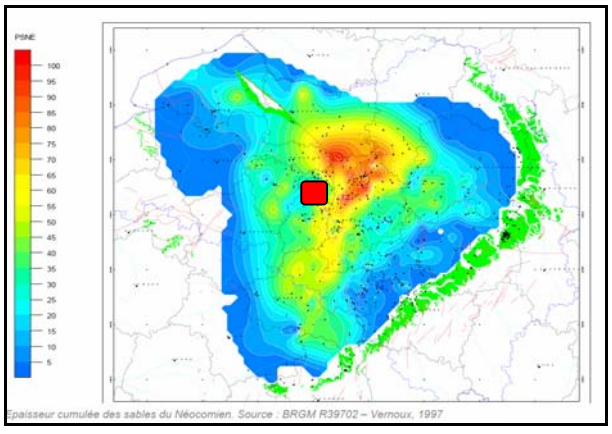

Figure 5: Cumulative thickness of the Néocomien reservoir made of sands

The two reservoirs are captive and very well protected from the surface and sub-surface pollutions. The transmissivity for Albien is excellent (10^{-2} to 10^{-3} m^2/s) and smaller for Néocomien at 2.10^{-3} m^2/s. This type of transmissivity can give productivities in between 3 to 10 $m^3/h/m$ of drawndown. On the contrary the clayish levels (argiles du Gault, clay or Aptian argillaceous levels) have permeabilities from 10^{-7} to 10^{-9} m/s. The Néocomien reservoir is practically untapped for water production but Albien sands are exploited. From the beginning of pumping before 1900 to 1980 the hydrodynamic pressure was strongly decreasing but since now 20 years the phenomenon has been stopped and year by year the reservoir is recovering 0, 5 m each two years.

Figure 6: Albien level indicator which is calculated by DRIEE Ile de France in charge of deep reservoir management and control (Bureau of Mines).

The recharge of the Albien reservoir is achieved by the outcrops on the border of the basin and also from the Neocomien reservoir. The salinity is very low < to 1,5g/l on the whole basin. The circulation speed of the water has been calculated at 5m/year. A ^{14}C dating gives an apparent age of the water of 30 000 years under Paris.

33 wells are exploiting the Albien reservoir and 75% of the total amount of water pumped yearly in the aquifer is concentrated in the centre of the basin. This aquifer is considered as strategic for human consumption in case of heavy pollution at the surface and a network of emergency distribution fountains already exists in the city of Paris.

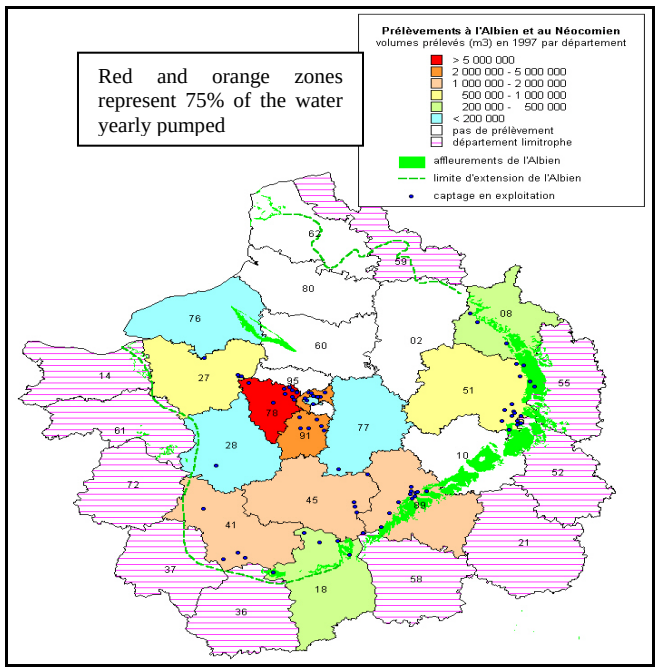

Figure 7: Map of the basin (in green outcrops, blue points show the position of existing wells)

3. RECENT PROJECTS IN ILE DE FRANCE

Two recent geothermal doublets have been drilled in the department des Hauts de Seine (locations are in the red mark on figures 4 and 5). The cretaceous has been selected because the shallow geothermal resource does not exist in a plateau area at170 m of altitude, 140 m above the Seine river level. The deeper resources in the Dogger are too high in term of thermal power (8 to 10 MWth) compared to the size of the two districts which represent needs of 4 to 5MWth. The two plants has been built by DALKIA (VEOLIA Group) which has financed 100% of the investment secured by a 25 years contract exploit the geothermal district heating network and sell the heat to all the consumers connected.

The Issy Les Moulineaux plant is a based on the construction of a new district (1600 dwellings with 9 collective housings) in a zone occupied before by the French army. It is based on a cold loop at 27°C with centralized back up based on natural gas and decentralized heat pumps.

3.1 Albien Geothermal plant in Issy les Moulineaux

The geothermal doublet is based on one vertical production well and one deviated injection well. This system has been implemented to create a sufficient spacing of around 600 m in between the two impacts at the reservoir level in order to prevent cold water recycling between the two wells.

The geometry and technology of the reservoir completion has been conventional due to the long experience gained in Ile de France to drill water well for tap water and also due to the fact that the size of the sands is already well known. Nevertheless, as for the doublet of le Plessis Robinson the deviated injection well has been fitted with pre-gravel packed reinforced screens in stainless steel (304L) in 8''5/8. The pumping test of 72 hours demonstrated a flow-rate of 216 m^3/h at 29, 2°C with a correlative drawdown of 21,44 m giving a productivity index of 10,1 m3/h/m. The transmissivity is 5-6.10^{-3} m^2/s.

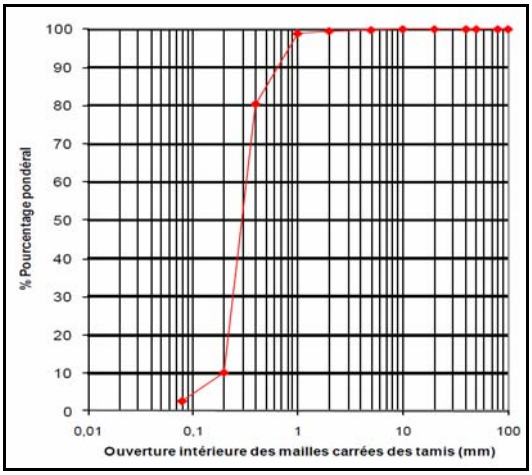

Figure 8: Granulometry of the Albien sands at 550m depth (70% between 0, 2 and 0,4 mm)

Figure 9: Checking of the solid content during the pumping test using Ihmoff cone

The wells have been tested and the plant will start for the heating season 2013-2014.

3.2 Neocomien Geothermal plant in LE plessis robinson

The doublet has been drilled as in Issy les Moulineaux with one vertical production well and one deviated injection well in order to obtain a sufficient spacing.The Plessis Robinson plant, it is just a transformation of an existing small district heating of 1800 dwellings of collective housing. The heat pump system is centralized. In this case, the geothermal reservoir is known only from cuttings and geological logging (mainly gamma Ray) of deeper wells down to the Dogger, for example, the wells drilled at Chatenay Malabry, but the first exploited well for tap water is located at 35 kilometres). The permeability prognosis was lower compared to Albien sands in correlation with the extreme fine grained sands which were expected.

Figure 9: The drilling rig (Cofor company) close to one of the building connected to the network

The production well is cased in 0,273 m (9”5/8) at 887 m depth, the reservoir is drilled down to 991 m in 0,381 m (15’’) and equipped with stainless Johnson screens of 0,194 m (8’’5/8) placed with liner hanger and gravel packed with a calibrated sands. The injection well is deviated and the equipment different because the screen used are pre gravel packer with glass balls.

Figure 10: Pre-gravel packed screens Munipack@

Figure 11: Detail of the screens (glass balls 0,3 to 1,4 mm) can be seen in the slit

The two wells has been air lifted at 250 m^3/h after completion in order to develop the reservoir and avoid small particles to be produced during exploitation. Very long pumping test has been carried out (more than 100 hours) and a final production test has been performed with a submersible pump in the two wells preceding a production-injection test at real scale to measure the capacity of the doublet.

The recapitulative results of the production well are very similar to the injection one. The temperature of the geothermal water at the suface is 38,7 °C and as expected for a geothermal gradient of 3°C/100 m. The salinity is below 1g/l and the water as a content of oxygen bof 0,03 mg/l with a pH of 7,6. The water is of bi-carbonaceous type (calco-magnesium).The analysis shows very similar value compared with the two existing wells located at more than 25 kilometres to the south.

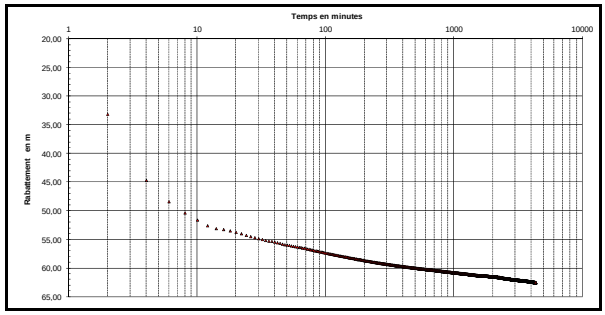

Figure 14: Drawdown in the production well at 180 m3/h with a correlative drawdown of 62m.

The calculated transmissivities from drawdown and build up of the long trem pumping test is between 1,32 to 2,53.10^{-3} m^2/s and the storage factor (S) is 7,82.10^{-2}.

The value of transmissivities are sligtly better compared to those of the geothermal well drilled in 1981 in Bruyères Le Chatel of 4,9.10^{-4} to 1,7.$10^{-3}$$m^2$/s.

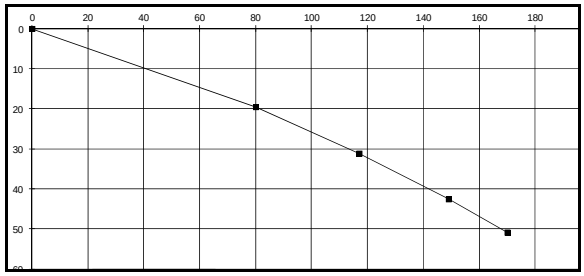

Figure 12: Caracteristic curve of the well which shows that at 170 m^3/h the critic flowrate is not attained

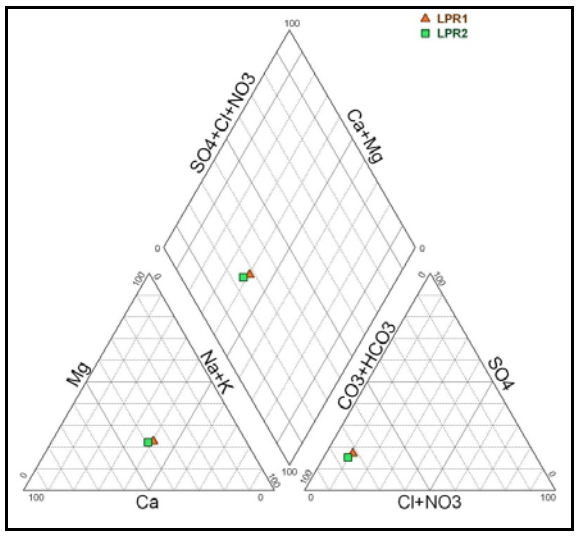

Figure 13: Piper Diagramme (LPR1 is the producer) the two analysis very similar

The wells have been tested 72 h at real scale with injection of the produced water. The final equipment performed in February 2013 and the production has started.

3. CONCLUSIONS

The plant built in Issy-Les-Moulineaux address to the geothermal reservoir of the Albian sands. The formation is well known since 1850, the date of the first deep well drilled in Paris. A first attempt in Front de Seine, demonstrated 20 years ago that the doublet concept is possible in clastic formations with high permeability but only with a reduced injection flow rate.

The new doublet will be capable to produce 200 m^3/h at 30°C with injection at 10°C giving a geothermal installed power of 4, 7 MWth, has been equipped with special screens which allow a good injectivity index.

The second geothermal doublet has been installed in Le Plessis-Robinson (2012), 5 kilometers away, but in this case the geothermal reservoir was unknown, the permeability prognosis was lower compared to Albian sands in correlation with the extreme fine grained sands expected.

This doublet in a new reservoir which has been never exploited for geothermal purposes with re-injection of the water in the same reservoir is successful because of large drilling diameters, pre-gravel packed screens, long stimulation with air lift with the highest testing flow-rate and high grade filtration in order to avoid particles in the injection well. This new doublets open an alternative in the Paris basin for using geothermal energy in two additional reservoirs covering each a surface of 4000 square kilometers.

The two plants are going to use heat pumps decentralized for Issy and centralized in Le Plessis Robinson in order to supply 4 to 6 MWth each corresponding to annual energy saved of about 50 GWth for heating purpose and sanitary hot water.

REFERENCES

Bel. A (BRGM) Les nappes profondes de l'Albien et du Néocomien dans le bassin de Paris –Etat des connaissances en 2012 - 20 slides CFGI Novembre 2012;

G2H Conseils - Dossier des ouvrages exécutés Opération géothermique d'Issy Les Moulineaux (2013)

G2H Conseils - Dossier des ouvrages exécutés Opération géothermiques du Plessis Robinson (2013)

G2H Conseils, BRGM, DALKIA France- Etude de l'injection dans les aquifères sableux- Novembre 2010