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WATER SAMPLING IN LOW PRODUCTIVE BOREHOLES: HOW TO ENSURE OF THE REPRESENTATIVENESS OF SAMPLING?

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ETABLISSEMENT PUBLIC DU MINISTERE DU DEVELOPPEMENT DURABLE

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A CHALLENGING TASK

Because you often have little information on low productive boreholes especially on deep ones.

It's well established that the common way – *wellbore purging by pumping* – may induce drawbacks – *flow-weighted averaged samples*.

Deep sampling

What to do then?

Perform low-flow sampling!

- But this can also give flow-biased samples in long-screened boreholes where vertical gradients exist…

So what's next?

Perform deep sampling!

- This allows discrete sampling at selected intervals.
- Unless you know some information about the borehole (*e.g.* CTD logging).

What will you discover when browsing poster?

- A comparative study (deep sampling vs. pumping) in South France…
- And especially some benchmarks on how low productive boreholes produce water and how confusing results of pumping may be.

1.2 *Liter of fluid per 100 m of borehole lenght*

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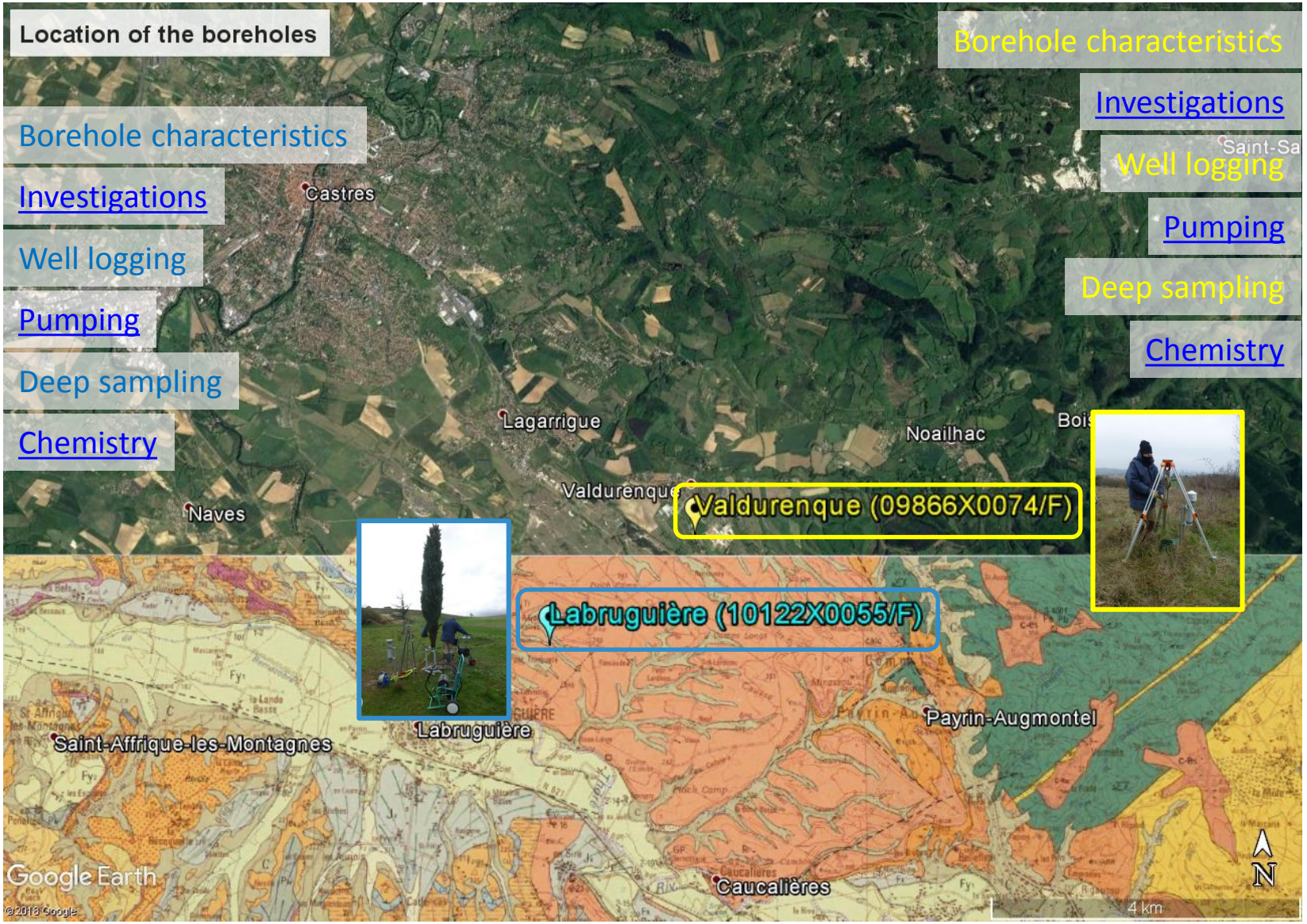
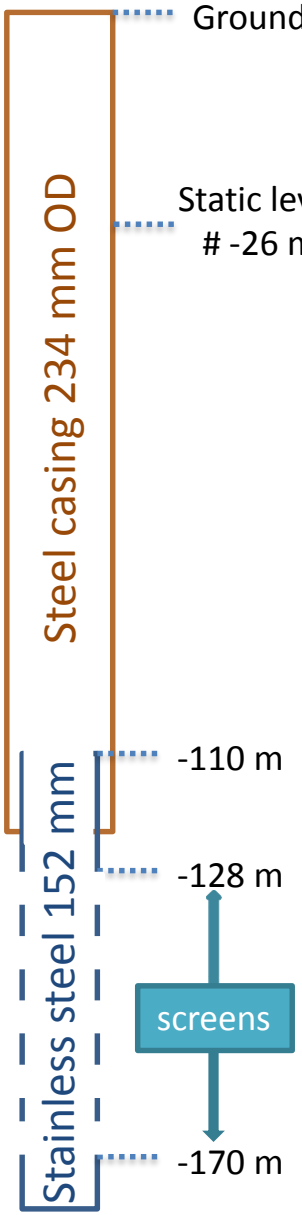
WATER SAMPLING IN LOW PRODUCTIVE BOREHOLES: HOW TO ENSURE OF THE REPRESENTATIVENESS OF SAMPLING?



Conclusions



LABRUGUIÈRE

Borehole characteristics.

Geology

- Sandy and clayey horizons under limestone and marly limestone cover.
- Former drinking water supply water well, now used for groundwater level monitoring.
- No frequent monitoring for water quality.

Other

- Depth: 170 m.
- Groundwater level: close to -26 m (bgl).
- Stainless steel casing: only for the screened section.
- Screens from -128 to -170 m (bgl) = more than 40 m.
- No information on possible heterogeneity in the water column.

WHAT HAS BEEN DONE?

Detailed investigations under a cyclic mode (repeated 3 times):

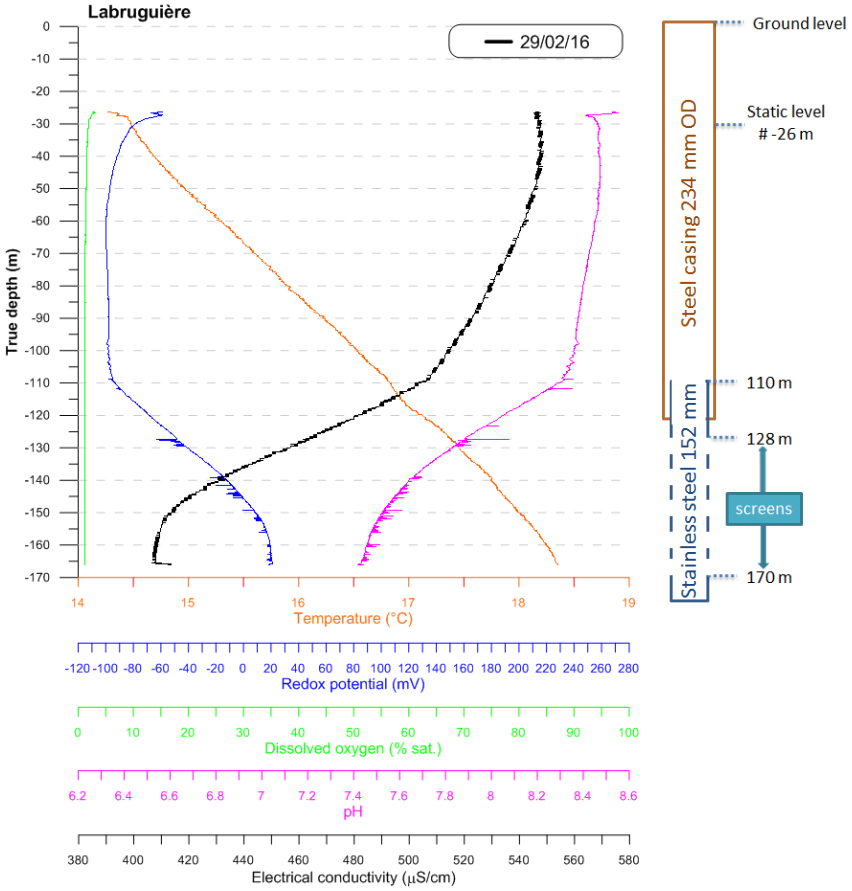
1. **Well logging (T°, EC, pH, ORP, dissolved O_2);**
2. **Deep sampling at selected depths (as learned from chemical logging);**
3. **Pumping with pump set at 45 m depth (high drawdown of the water table).**

Day	Investigation	Depth (m bgl)	Duration
	Logging	-26 to -170	0.5 h
	Deep sampling	-130, -150 and -163	3 h
	Pumping	-45	3.5 h

Typical schedule of intervention

WHAT HAS BEEN MONITORED?

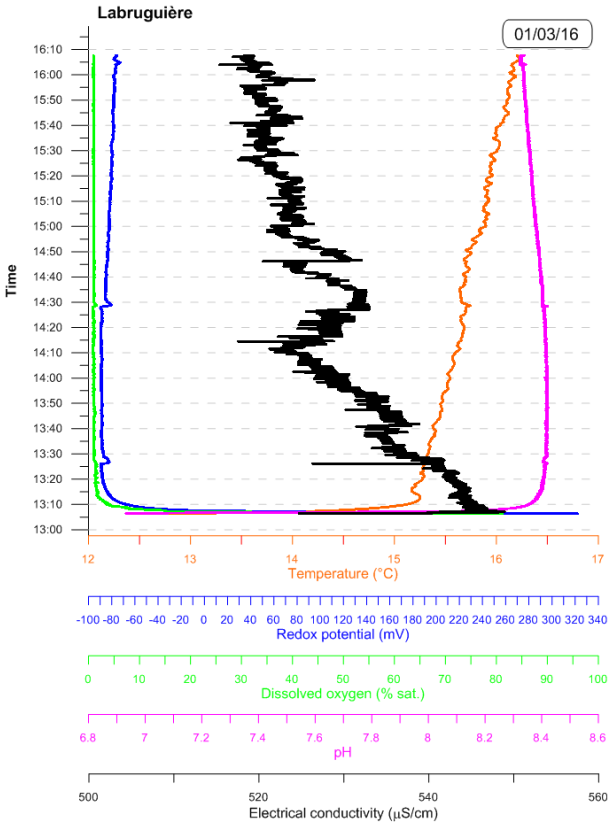
Well logging before pumping



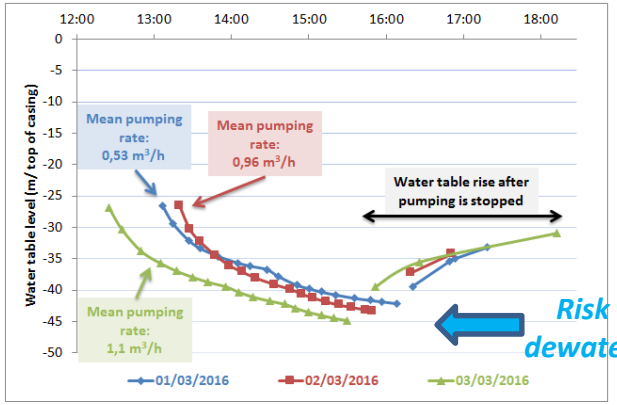
- Borehole has been logged close to nominal depth.
- Temperature evolution close to that of mean geothermal gradient (29.7°C/km) + 13.5°C (yearly mean surface temperature).
- No interaction with oxygenated waters (borehole preserved from infiltration of recent waters).
- EC, ORP and pH values are clearly different in the cased part and in the screened section:
  - Stagnant water in the cased part (interaction with steel casing);
  - Progressive variation at the top of the screens and more stable parameters in the last 10-15 m of the screens): this suggests supply of water is more likely in the deepest part of the screened section.

WHAT HAS BEEN MONITORED?

Pumping sequences.



- Using MP1 pump set at 45 m depth – 3 pumping sequences.
- Monitoring of physico-chemical parameters at the drainage of the pump.

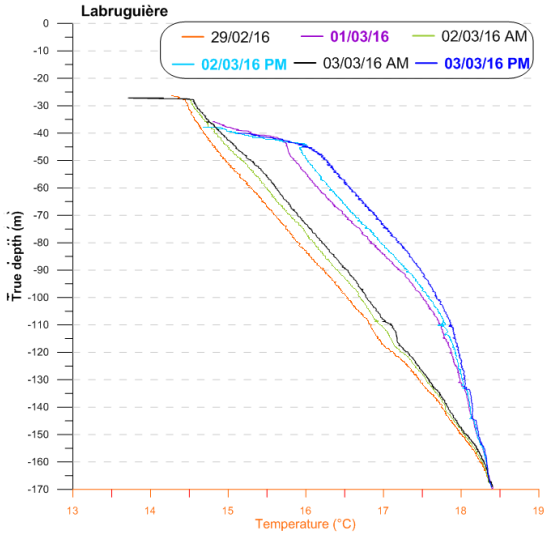


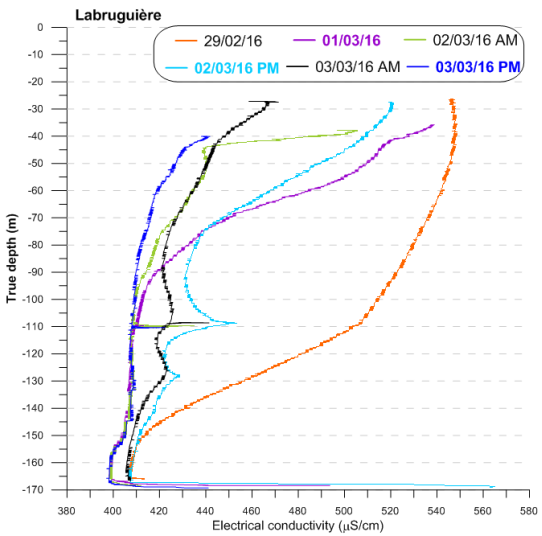
	Volume pumped
01 March	1600 l
02 March	2400 l (4000 l)
03 March	3300 l (7300 l)

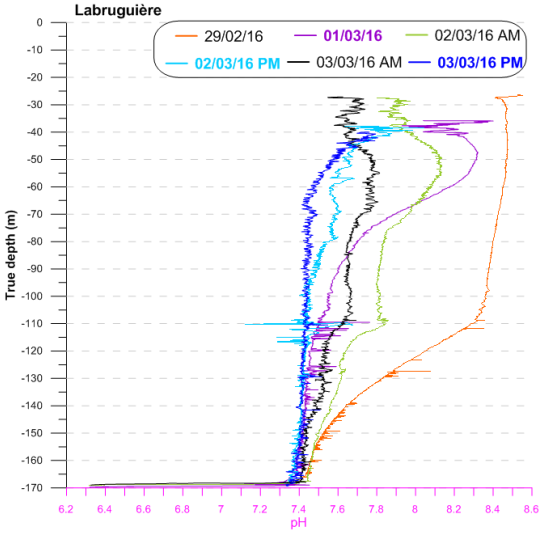
Borehole volume # 4600 l

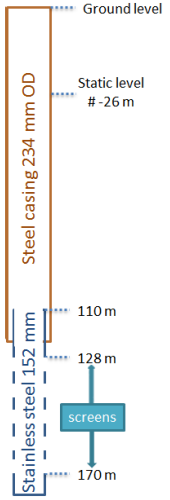
WHAT HAS BEEN MONITORED?

Well logging – Evolution through time.









- Recovery of water table level within a few hours.
- As may be expected, strong influence of pumping on temperature distribution – but quick vanishing of the anomaly (reequilibration).
- Progressive homogeneization of the EC in the water column to the value measured at bottom at rest.
- Same statement for the pH.
- *BUT the water that may be sampled by pumping at 45 m depth has not the characteristics of the water produced through the screens even after the pumping of 1.6 times the volume of water in the borehole!*

	Volume pumped
01 March	1600 l
02 March	2400 l (4000 l)
03 March	3300 l (7300 l)

Borehole volume # 4600 l

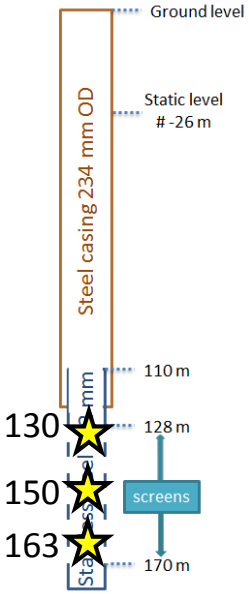
WHAT HAS BEEN MONITORED?

Deep sampling before, in between and after pumping phases.

- Done using BRGM system (patent FR1259214).
- One drive leg with inert gas pressuring, the other drive leg used to sample fluids at a selected depth and to collect them at surface. Virtually unlimited volume of sample (max. volume of fluid retrieved at surface: 1.2 l per 100 m of water column).
- Several depths can be investigated without the need to retrieve the system at surface.
- Allows the collection of water and also of dissolved gases (such as noble gases).

WHAT HAS BEEN MONITORED?

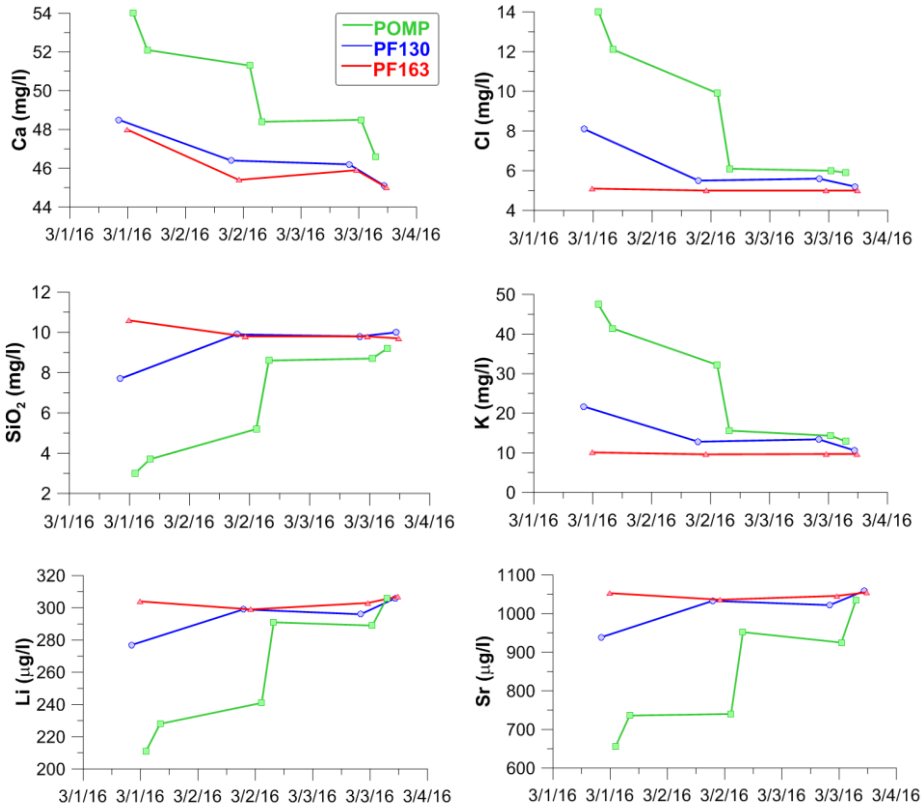
Deep sampling before, in between and after pumping phases.



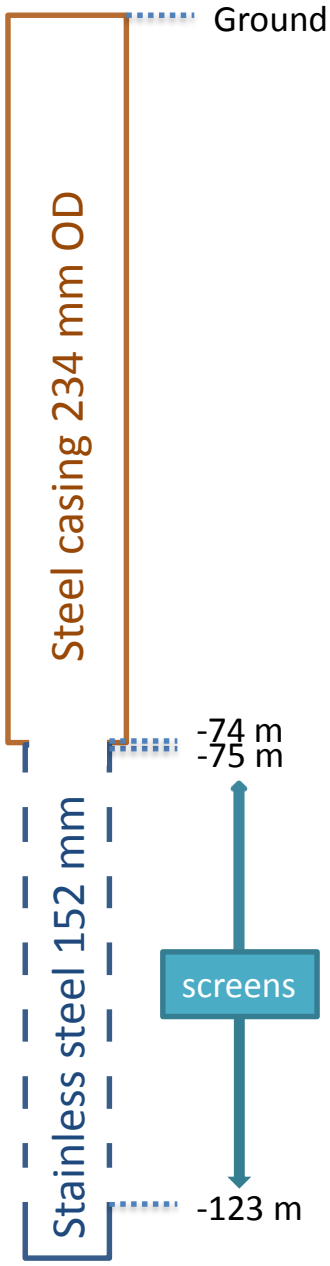
- 3 depths.
- 3 runs for purging the system + 1 run to sample (*i.e.* purge of 3.6 l to 4.8 l depending on the depth).
- Comparison with chemical logs:
  - EC: difference < 2.5%;
  - pH: difference < 0.2 pH units;
  - T°: bias linked to the time needed to get water back to surface;
  - Dissolved O_2 and redox can suffer from contact with atmosphere (measurements done without flow-through cell).
- But, mostly important:
  - No difference in noble gas concentrations when comparing sampling during pumping and sampling by deep sampling;
  - Accurate evaluation of the dissolved chemical elements.

WHAT HAS BEEN MONITORED?

Water chemistry: pumping vs. deep sampling



- Comparison between samples obtained by pumping (green), by deep sampling at 130 m (blue) and at 163 m (red).
- Concentrations in major or trace elements have little variability with time at 163 m even when considering first sample (no purge) → water producing horizon.
- Variability with time is slightly higher at 130 m (progressive purge of the borehole as a result of pumping) but a slight purge (35% of the borehole volume) leads to better evaluation of the water chemistry.
- Concentrations of samples obtained by pumping may not reach the concentrations observed at depth – a large volume of water needs to be pumped to reach this situation.



VALDURENQUE

Borehole characteristics.

Geology

- Sandy and clayey horizons under limestone and marly limestone cover.
- Former drinking water supply water well, now used for monitoring of water table level.
- No frequent monitoring for water quality.

Other

- Depth: 123 m.
- Groundwater level: close to -10 m (bgl).
- Stainless steel casing: only for the screened section.
- Screens from -74 to -123 m (bgl) = close to 50 m.
- No information on possible heterogeneity in the water column.

WHAT HAS BEEN DONE?

Detailed investigations under a cyclic mode:

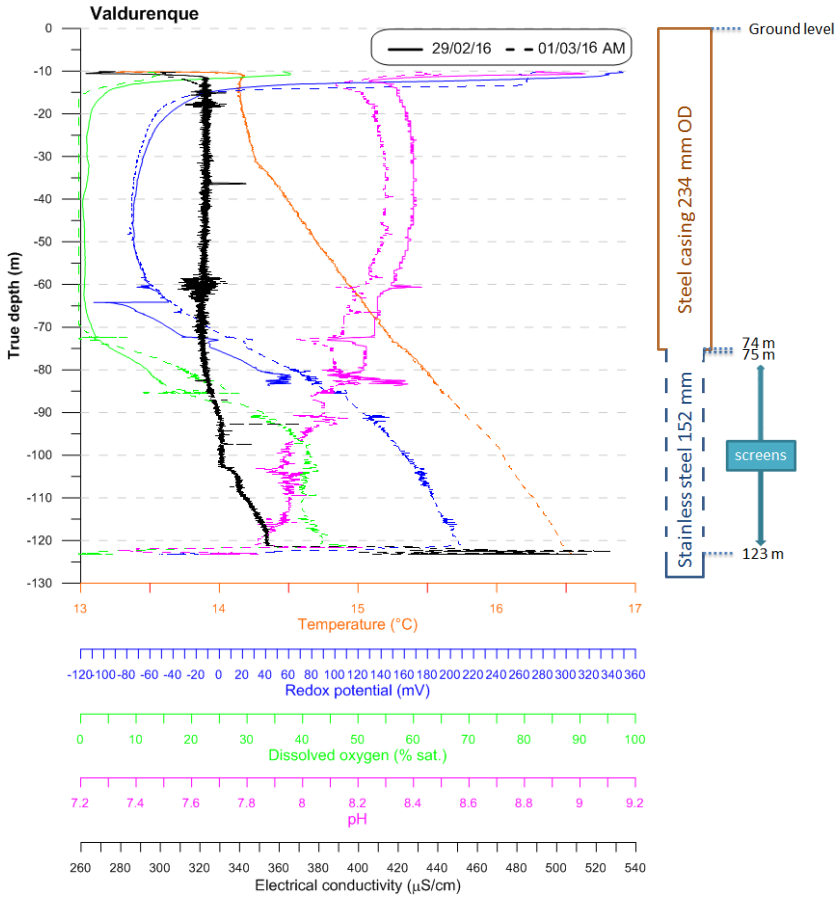
1. **Well logging (T°, EC, pH, ORP, dissolved O_2);**
2. **Deep sampling at selected depths (as learned from chemical logging);**
3. **Pumping with pump set at 45 m depth (drawdown of the water table smaller than the one of Labruguière).**

Day	Investigation	Depth (m bgl)	Duration
	Logging	-10 to -85 m (day 1) -10 to -123 m (vase plug flushed during pumping)	0.5 h
	Deep sampling	-81 and -119 (when possible)	3 h
	Pumping	-45	3.5 h

Typical schedule of intervention

WHAT HAS BEEN MONITORED?

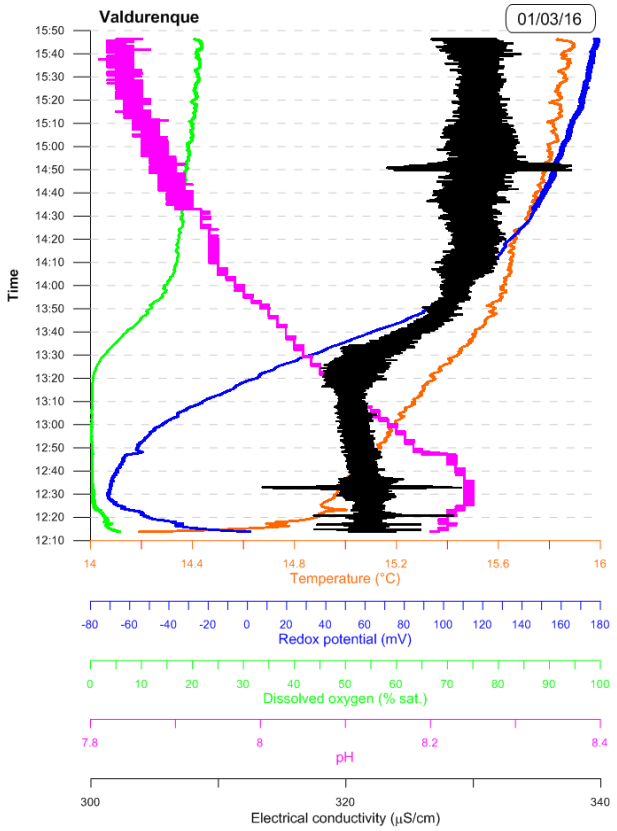
Well logging before pumping.



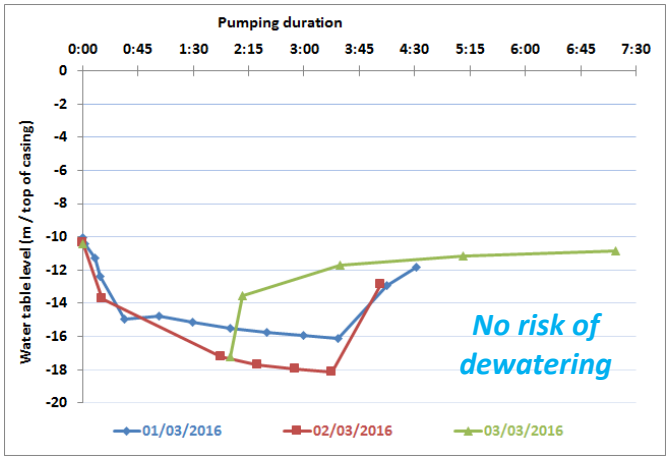
- Borehole logged to 85 m depth on the first day (plugged) – plug flushed during first pumping session.
- Temperature gradient (25.4°C/km) lesser than that of mean geothermal gradient + 13.5°C (yearly mean surface temperature) – nearly no T° change in the first 20 m.
- Dissolved O_2 is present in the screened section (ORP values vary accordingly).
- EC and pH values are slightly different in the cased part and in the screened section:
  - Stagnant water in the cased part (interaction with metal casing);
  - Variation only at the base of the screens with no stable value reached: this suggests supply of water is more likely in the deepest part of the screened section but the aquifer seems to be heterogeneous.

WHAT HAS BEEN MONITORED?

Pumping sequences.



- Using MP1 pump set at 45 m depth – 3 pumping sequences.
- Higher productivity compared to Labruguière.
- Monitoring of physico-chemical parameters at the drainage of the pump.

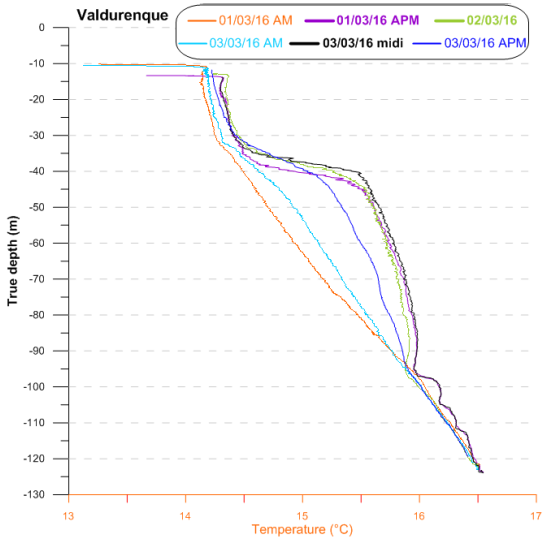


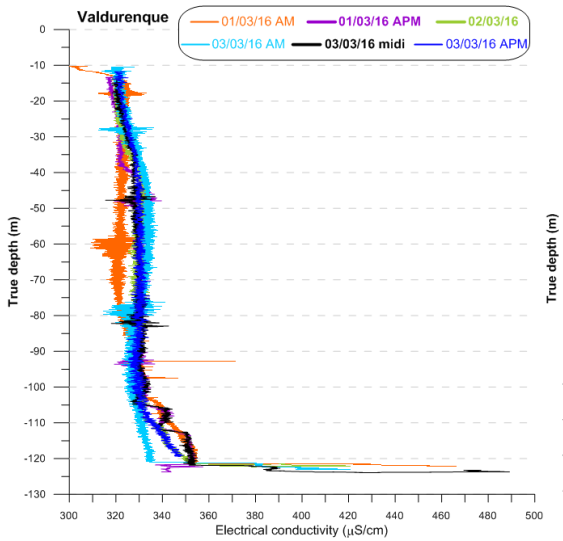
	Volume pumped
01 March	5000 l
02 March	5700 l (10700 l)
03 March	3900 l (14600 l)

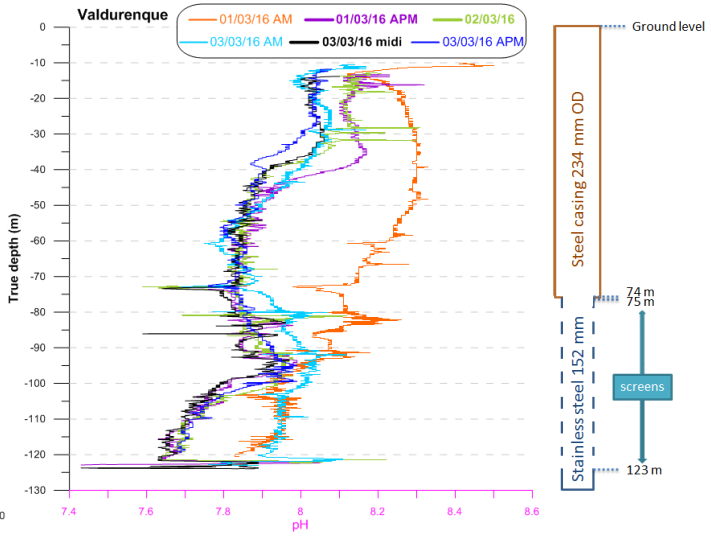
Borehole volume # 4000 l

WHAT HAS BEEN MONITORED?

Well logging – Evolution through time.







- As may be expected, strong influence of pumping on temperature distribution – but quick vanishing of the anomaly (reequilibration).
- Existence of temperature anomalies in the screened section after pumping: existence of several productive horizons?
- Low variability of the EC in the water column (but with some heterogeneity due to different levels at depth).
- pH values during pumping different than values at rest.
- *Here, no difference between sampling by pumping and direct sampling of water produced through the screens.*

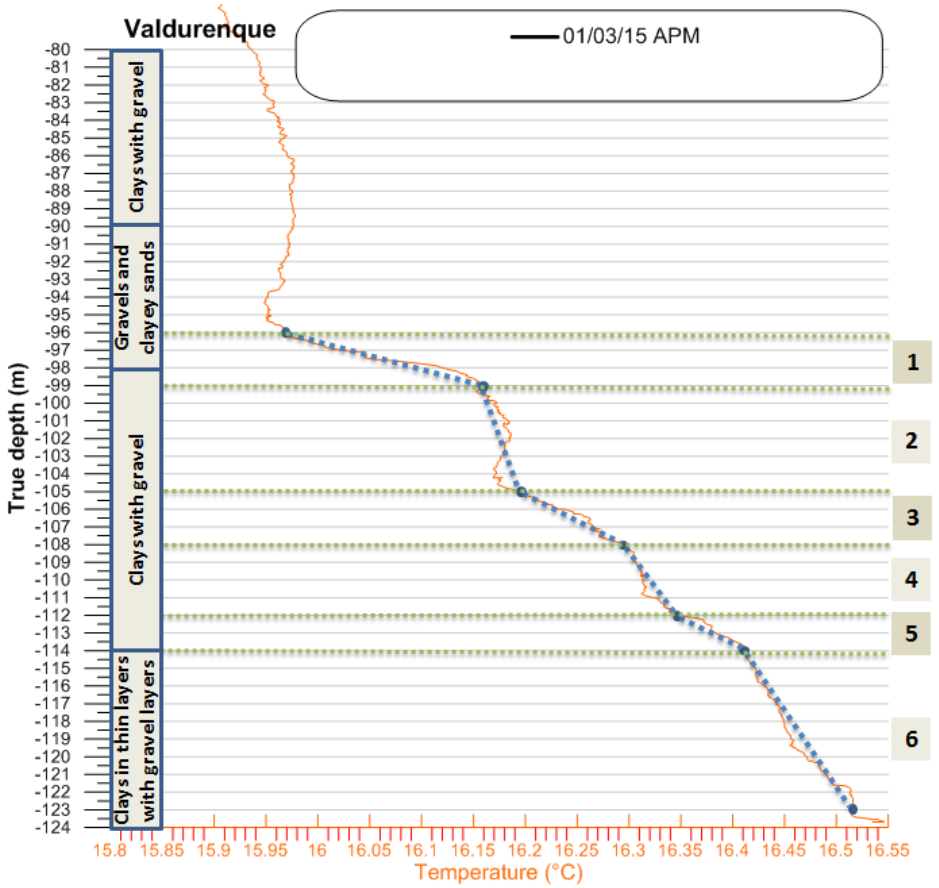
	Volume pumped
01 March	5000 l
02 March	5700 l (10700 l)
03 March	3900 l (14600 l)

Borehole volume # 4000 l

WHAT HAS BEEN MONITORED?

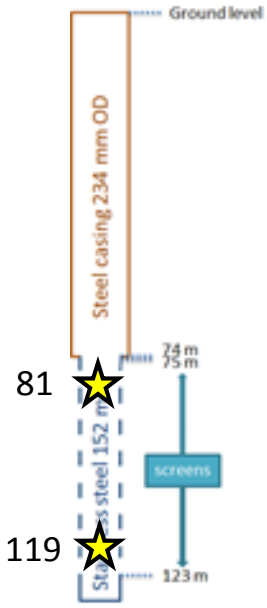
Well logging – Evolution through time – detail of T° evolution

- Several temperature levels in the screened section, noticed after pumping:
  - Zones 1, 3 and 5: T° gradient >> geothermal gradient;
  - Zones 2, 4 and 6: T° gradient close to geothermal gradient;
- Zones of high gradient are supposed to be zones of low permeability where fluid circulation is low and does not allow thermal homogeneization at short time scale (horizons likely to be clay-rich).



WHAT HAS BEEN MONITORED?

Deep sampling.



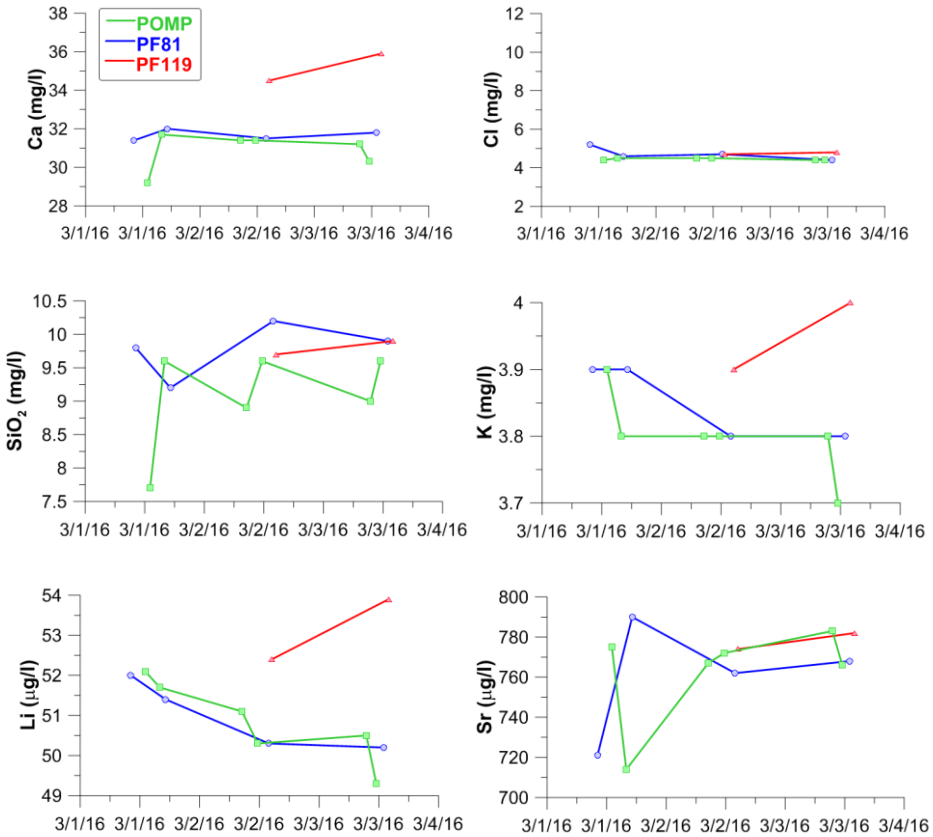
- 2 depths.
- 2 runs for purging the system + 1 run to sample (*i.e.* purge of 1.7 l to 2.6 l depending on the depth).

- Comparison with chemical logs:
  - EC: difference < 2.5%;
  - pH: difference up to 0.4 pH units; attributed to possible rapid modifications on the water characteristics during water ascent in the tube (high content in particulate material).
  - T°: bias linked to the time needed to get water back to surface;
  - Dissolved O_2 and redox measurements also possibly modified by deep sampling.

- But, mostly important:
  - Accurate evaluation of the dissolved chemical elements.

WHAT HAS BEEN MONITORED?

Water chemistry: pumping vs. deep sampling



- Comparison between samples obtained by pumping (green), by deep sampling at 81 m (blue) and at 119 m (red).
- Less discrepancy between pumping and deep sampling: pumping conditions are good here.
- Concentrations in major or trace elements may have higher variability by comparison to what was observed at Labruguière:
  - Here several horizons contribute to water chemistry;
  - At 119 m only one productive layer;
  - At 81 m up to 3 productive layers can contribute to the chemistry.

GENERAL CONCLUSIONS

- *In the case of boreholes of good discharge capacity,* pumping methods and deep sampling methods well compare to characterize the chemistry of an aquifer – albeit deep sampling may not be as representative for getting information on physico-chemical parameters.

- *In the case of low productive boreholes,* pumping may not allow to draw water from the productive level to the pump – worse, false positives may be recorded as some parameters may reach stability but at values that are not those of the productive level.

- In such case, **deep sampling is a good alternative**:
  - Reliable information (dissolved elements) can be obtained without any purging – but knowing some information on the water column (EC…) is of value to help in locating the sampling;
  - Better characterization can be obtained by coupling water column logging, slight sollicitation of the borehole by pumping (if technically feasible) and then deep sampling at one or several depths as suggested by previous investigations.
  - Application is not restricted to boreholes of 100 to 200 m depth, and much more deeper boreholes can be investigated!

- *Want to learn more* about this study?
  - See http://infoterre.brgm.fr/rapports/RP-65934-FR.pdf (in French...).
- *Want to see an application case* on deep boreholes?
  - See PICO poster 7172!