Shallow Geothermal Energy: Mapping of the potential of a specific area in Brussels

Master thesis submitted under the supervision of
Prof. dr. ir. Bertrand FRANCOIS
In order to be awarded the Master's Degree in
Civil Engineering, option constructions and geomaterials

November 6, 2014

METTENS Sybille

Table of contents

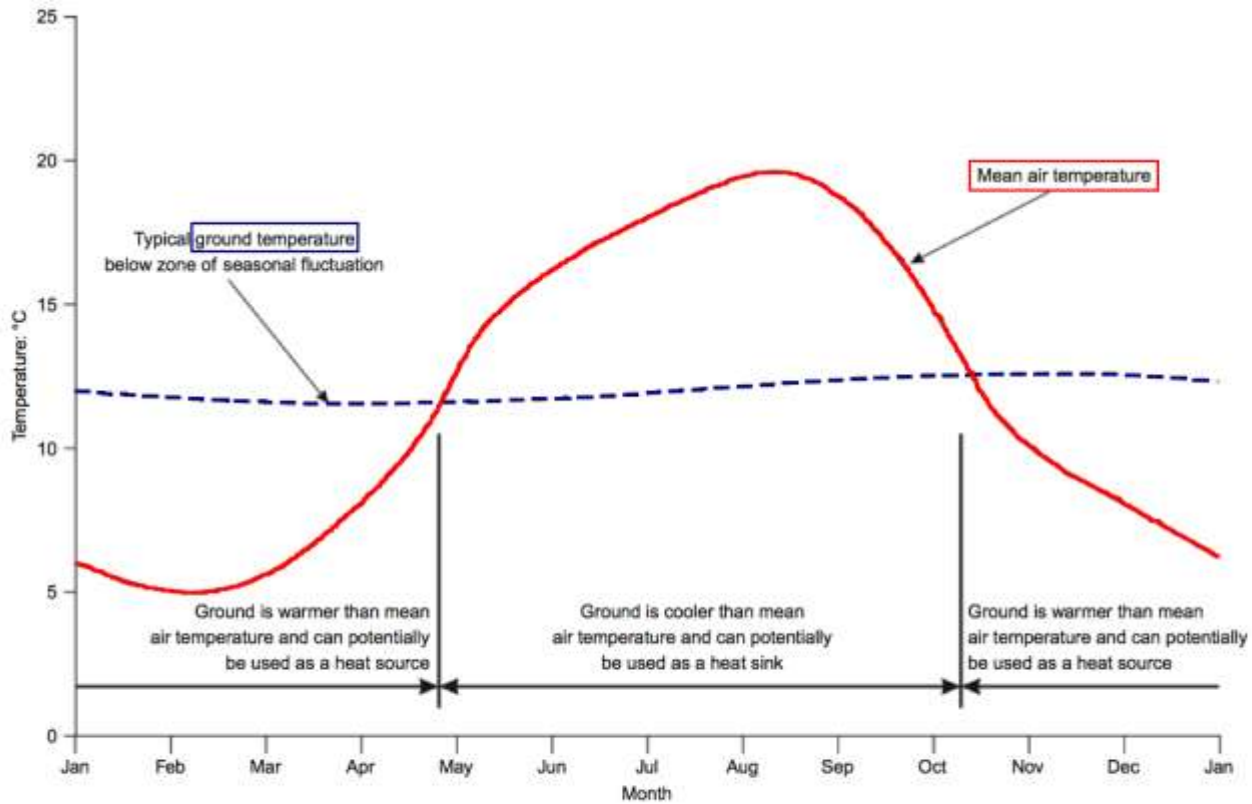
I. Introduction

- Heating & cooling: CO_2 ↗
  → Brussels: PEB
- Study low carbon emission technologies
- Use ground

- Aim of the work:
  - Describe constraints of GSHP project
  - Estimate geothermal potential of a specific area

II. Geothermal energy

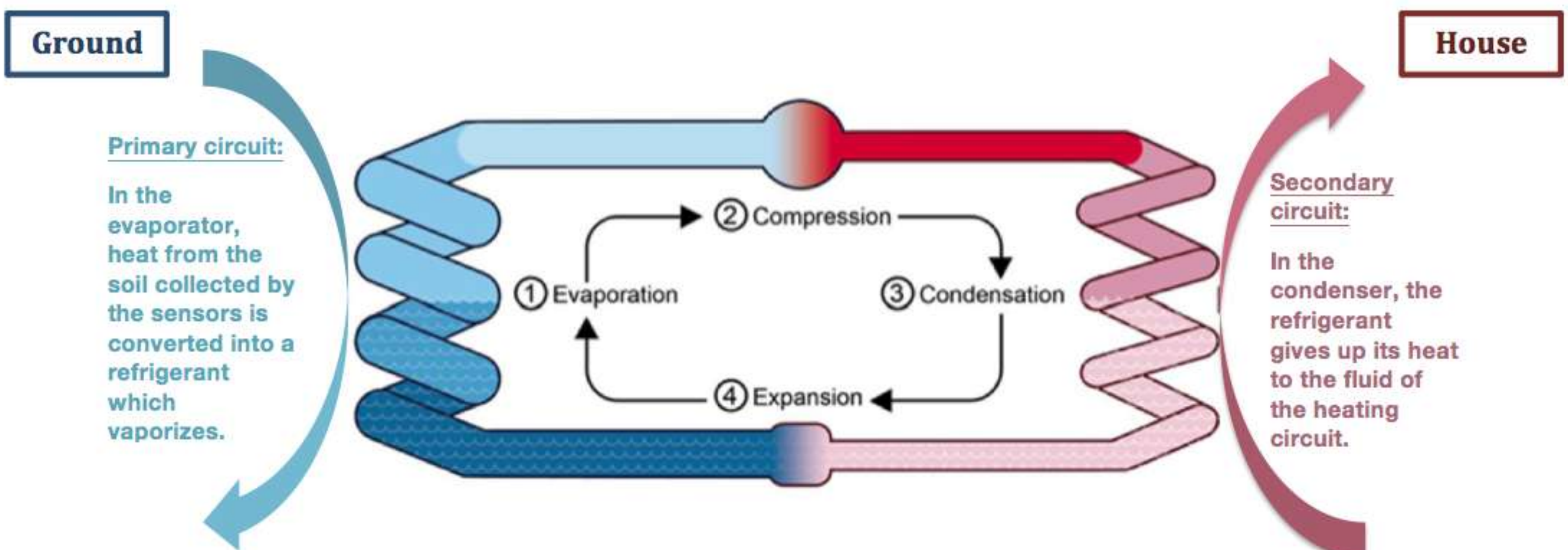
- Shallow geothermal energy (0 to 200 m)
- Ground = thermally stable mass



PREENE, M., & W. Powrie. (2009). Ground energy systems: from analysis to geotechnical design. Géothec- nique, 59(3), pp. 261-271

II. Geothermal energy
1. GSHP system

- Heat to or from the ground:
  - Primary circuit
  - Secondary circuit
  - Heat Pump $COP = \frac{Q_{out}}{P_{el}}$;



JOHNSTON, I.W., G.A. NARSILIO & S. Colls. (2011). *Emerging geothermal energy technologies.*

II. Geothermal energy

2. Borehole Heat Exchanger

Open-loop	Closed-loop
Groundwater extraction	Fluid through absorber pipes
Good water-bearing	Usable for each soil
High permeability	Vertical:
Less authorizations	- Depth: 50 - 150 m
	- 5-10m from each other
	Horizontal:
	- Depth: 1.5 - 2 m
	- $\pm$ 2 X S_{heated}

Choice of a specific area

Are there areas in Brussels more suitable to accommodate a GSHP system?

III. Choice of a specific area

1. Aim of this choice

Bruface
Brussels Faculty of Engineering

- Important: method
- Purpose of the choice:
  - Not too much constraints
  - Achieve the goal

III. Choice of a specific area

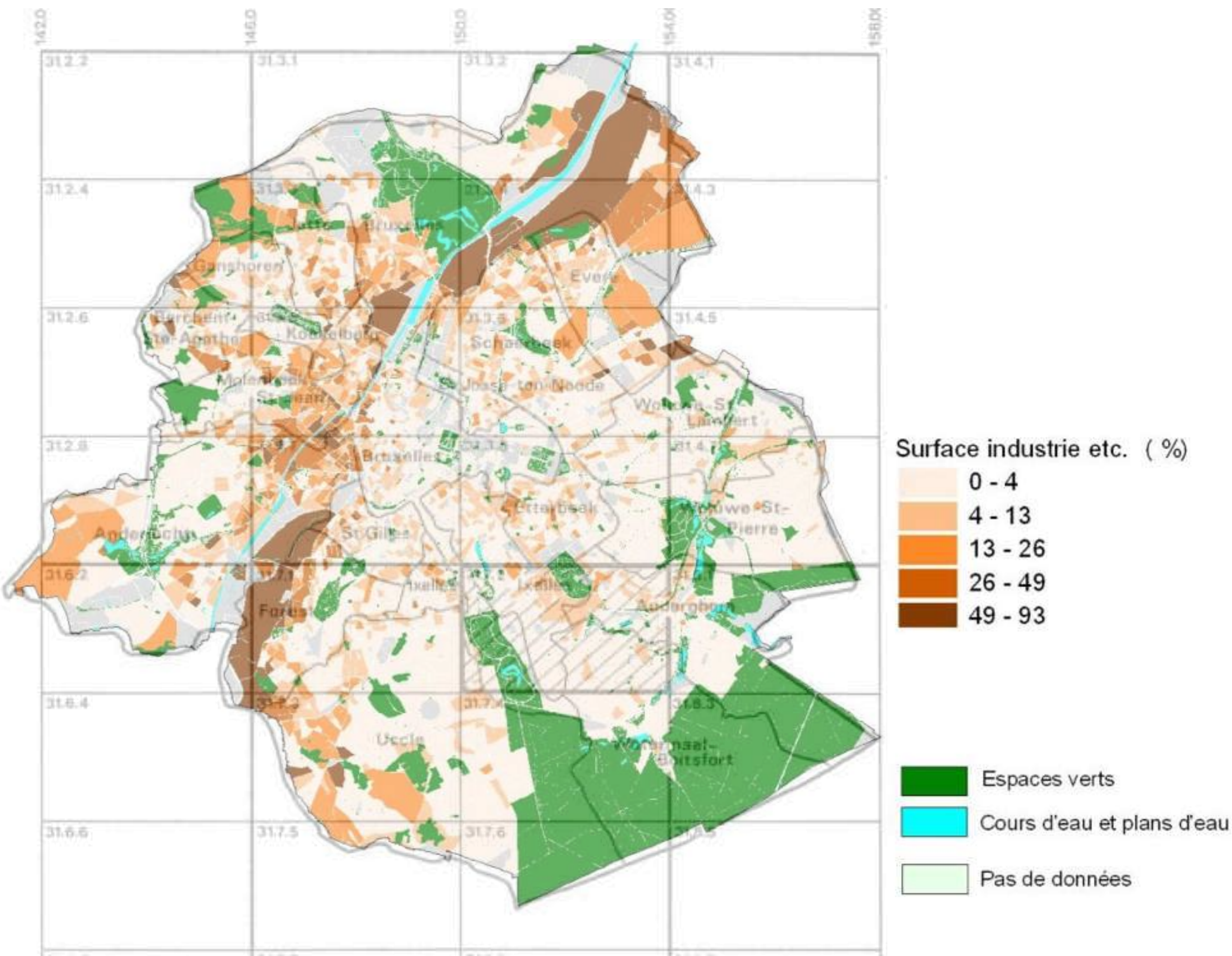
2. Method

- Geotechnical maps
- Constraints:
  - Space
  - Accessibility
  - Building needs
  - VITO

	Favorable for geothermy	Houses with 3 or 4 fronts	Varied types of buildings	Low portion of old buildings	Varied population density	Portion of built-up area	City blocks	**Average**
31.2.2	/	/	/	/	/	/	/	/
31.2.4	+ -	+ -	+ -	+ +	+ -	+	+	+/-
31.2.6	+ -	+ -	+ -	+ +	+	+ -	+	+/-
31.2.8	- -	+ +	+ -	+	- -	+	+	+/-
31.6.2	- -	+ +	/	+	- -	+	/	/
31.6.4	/	/	/	/	/	/	/	/
31.6.6	/	/	/	/	/	/	/	/
31.6.8	/	/	/	/	/	/	/	/

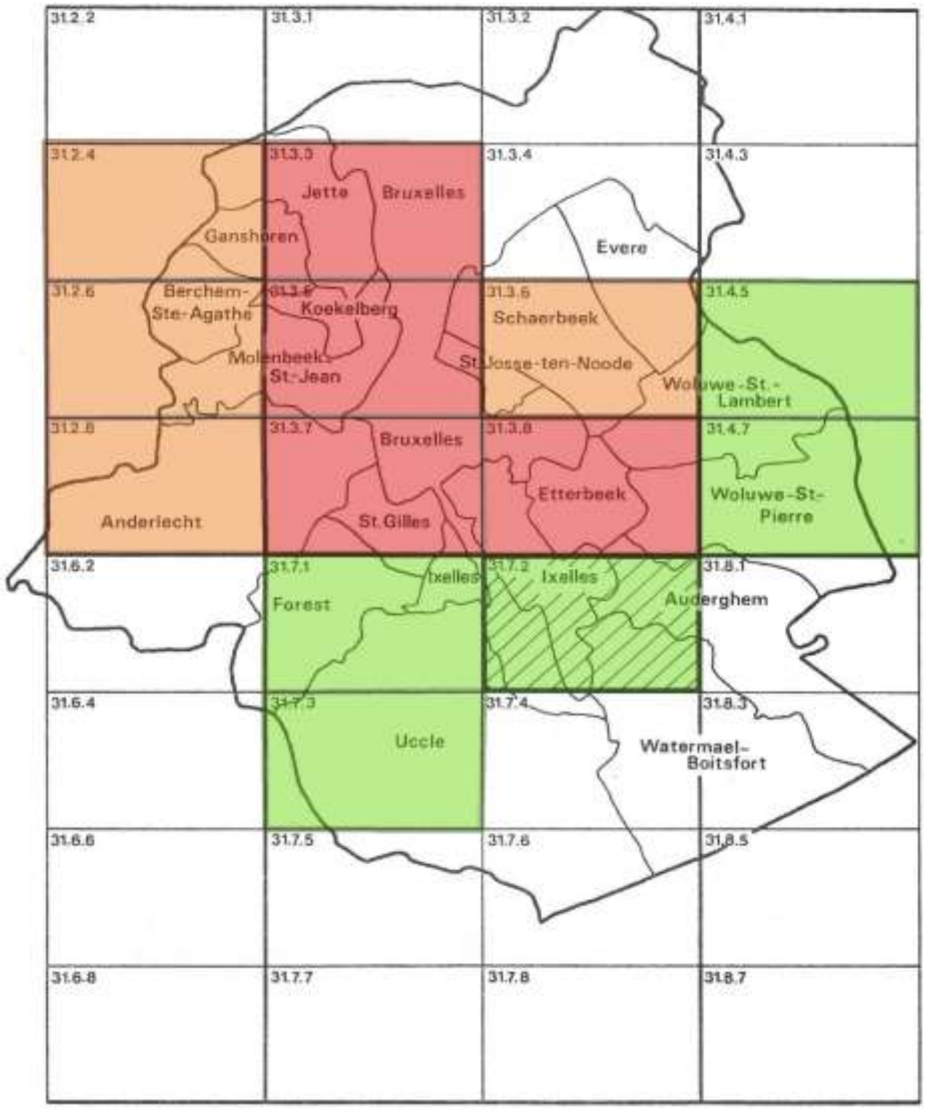
III. Choice of a specific area

2. Method



III. Choice of a specific area

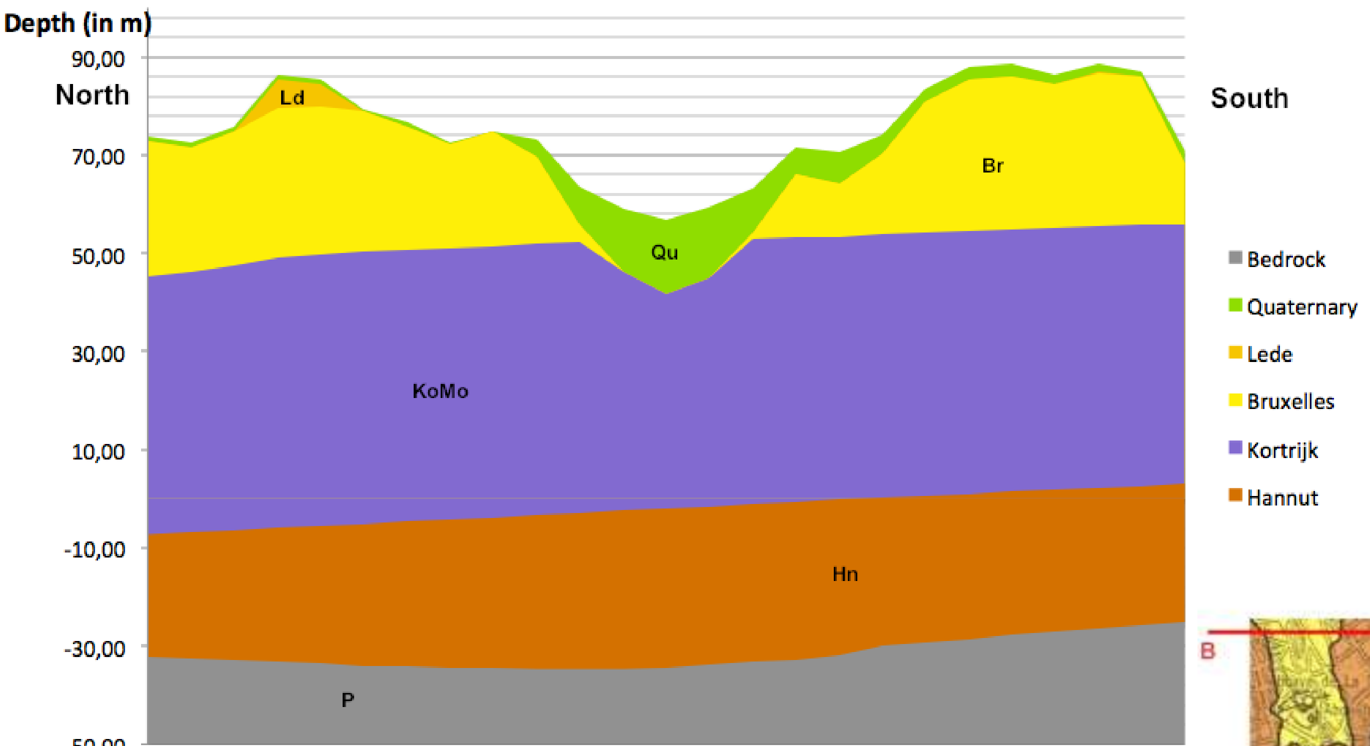
2. Summary



Analysis of the chosen zone

What prevents me from having a GSHP system in this area?

IV. Soil properties



Cross-section A-A'

BUFFEL, P. & J. MATTHIJS. (2001). Planche 31-39: Bruxelles - Nivelles. Carte Géologique de Belgique: Région de Bruxelles-Capitale.

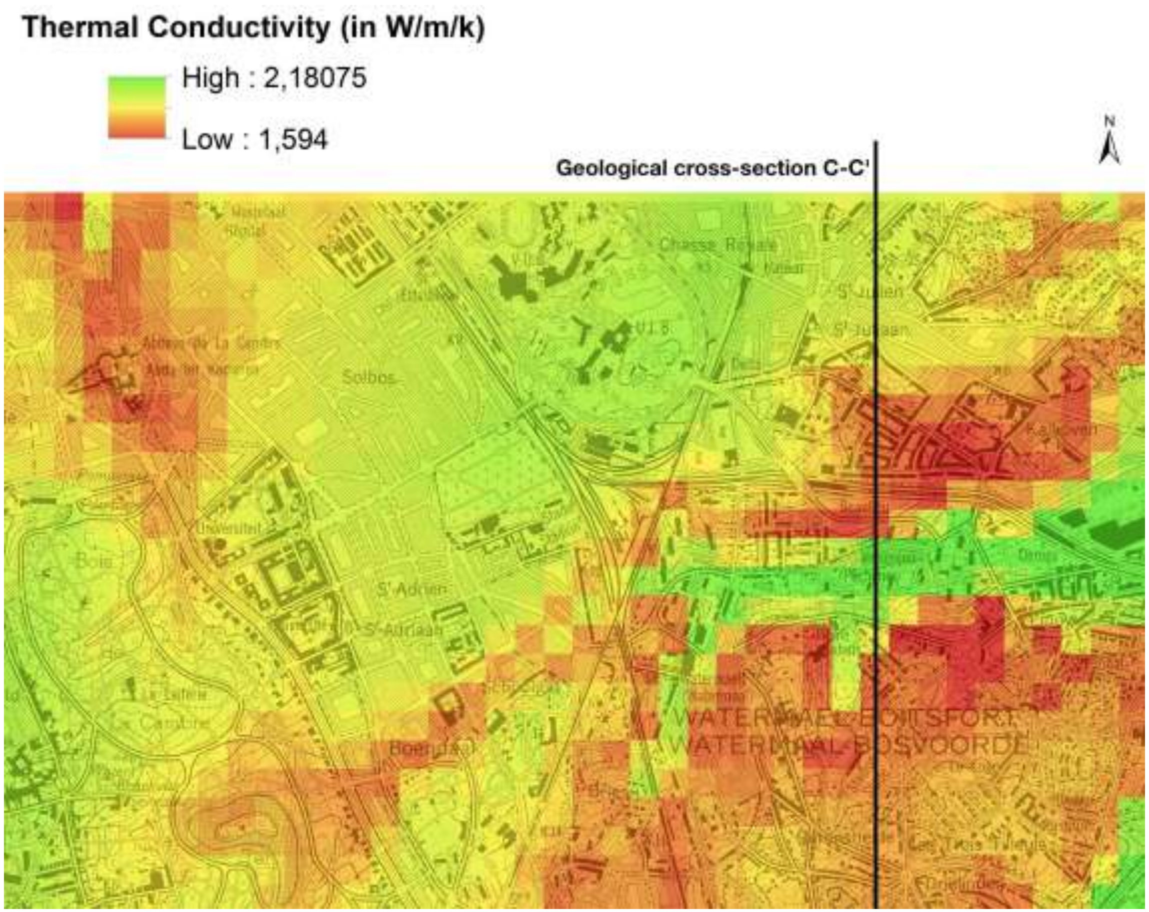
IV. Soil properties

- Smart Geotherm: from Thermal Response Tests
- Tertiary:

Formation	Minimum thermal conductivity (in W/m/K)	Average thermal conductivity (in W/m/K)
Maldegem	1.4	1.7
Lede	1.9	2.3
Bruxelles	1.9	2.3
Kortrijk	1.2	1.5
Hannut	1.2	1.5

- Bedrock: 4 W/m/K
- ~~Quaternary~~

V. Detailed analysis
1. Geothermal energy



Thermal conductivity of a geothermal probe with a depth of 100m

$$\lambda = \frac{\sum \lambda_n t_n}{\sum t_n};$$

V. Detailed analysis
1. Geothermal energy

$$\eta = 9.0375\,\lambda_{av} + 29.058\;;$$

$$\eta = \frac{Q_{ground}}{L_{tot}}\;;$$

$$Q_{out} = \frac{COP}{COP-1}\,Q_{ground}\;;$$

Heat supplied (W/BHE/year):

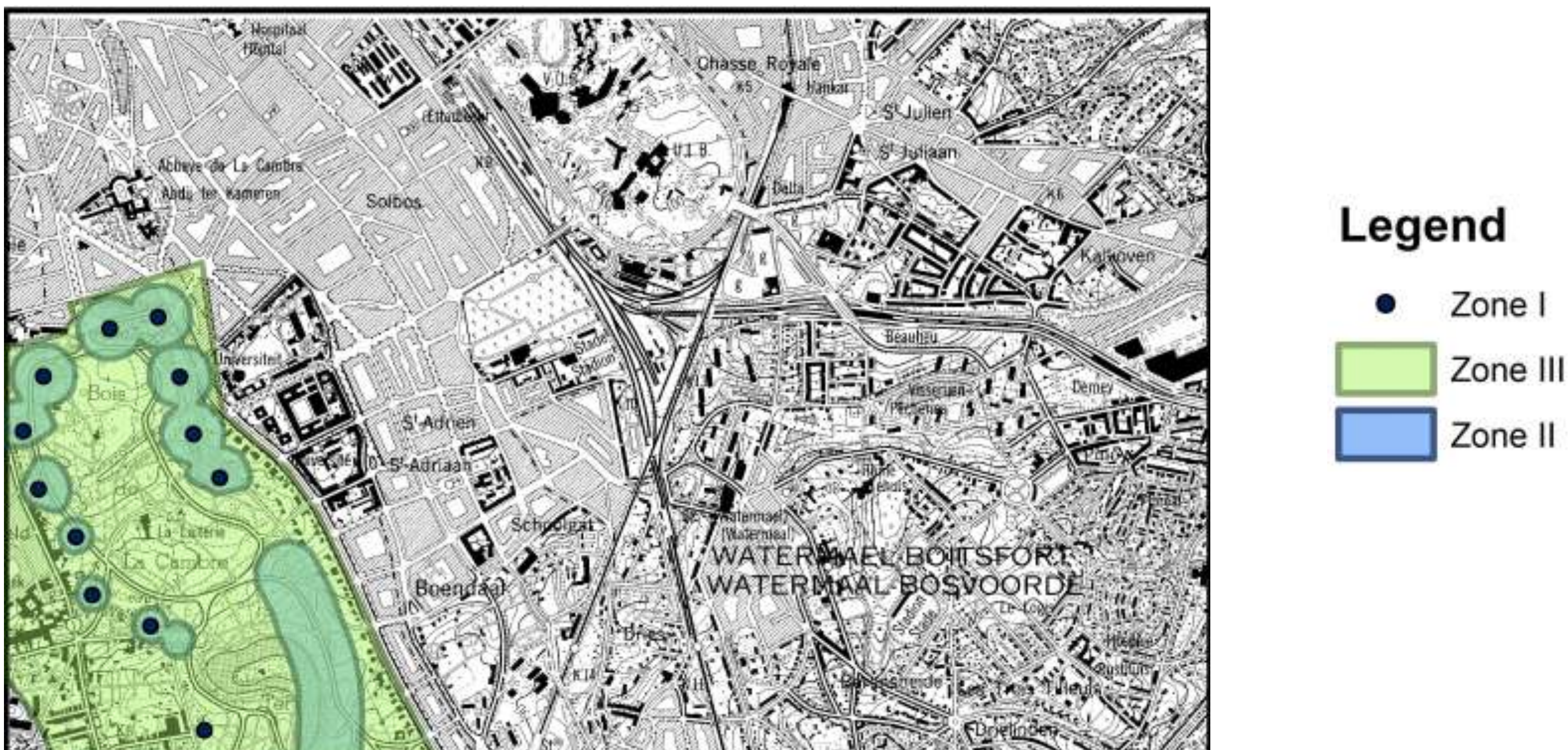
Apartment with 3 living areas of 80 m^2 & Q_{out}= 6200 W/BHE/year:

	Recent construction	House built up between 1975 & 1985	House built up before 1975
Required energy (W/m²/year)	50 to 70	100	120 to 150
Number of BHE	2 to 3	4	5 to 6

V. Detailed analysis

2. Brussels regulations

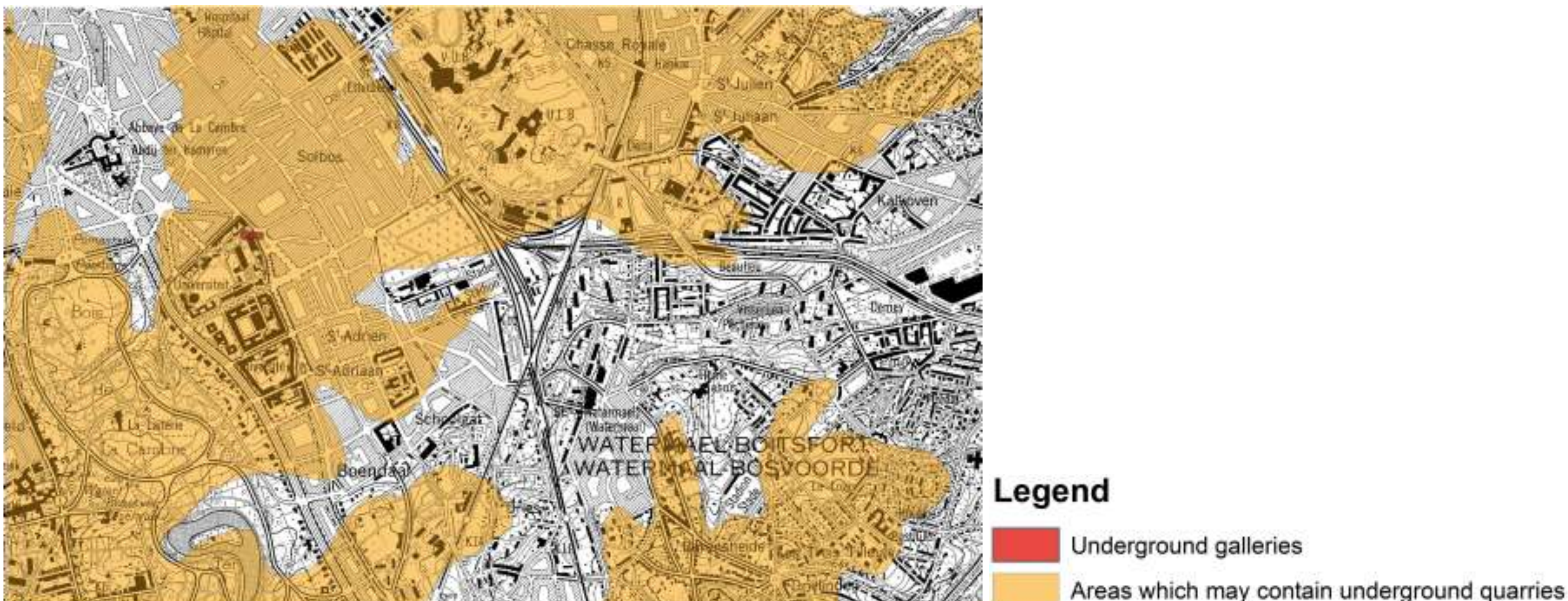
- Impossible to forecast a refusal
- Except: groundwater catchment zone



V. Detailed analysis
3. Geotechnics

Galleries:

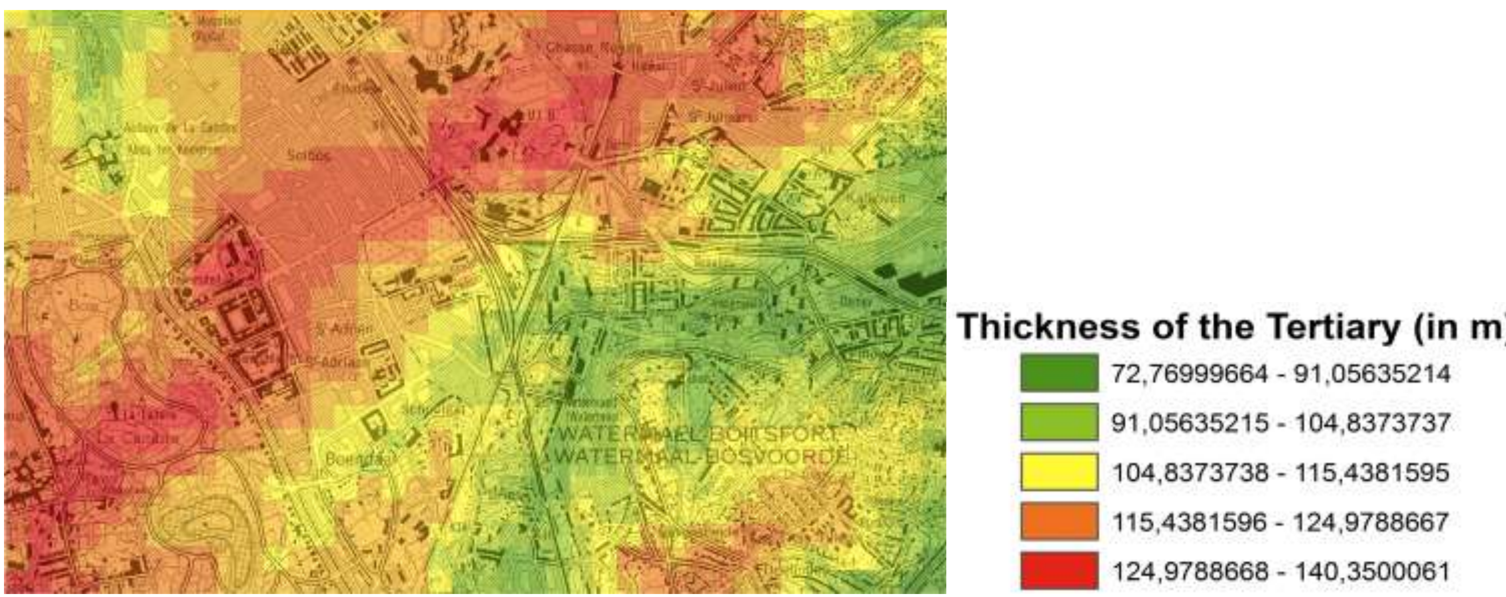
- Water & grouting flowing → danger
- NOT impossible !



V. Detailed analysis
3. Geotechnics

Bedrock:

- Hard → Drilling difficulties
- NOT impossible !
- High price (>< High conductivity)
  - Equipment
  - Not enough knowledge



VI. Detailed analysis

5. Attempt to study price

Assumptions:

- **Installation:**
  - Drilling:
    - 30 €/m in soft ground
    - 50 €/m in bedrock
  - Probes: 10 €/m
  - HP: 600 €/kW
  - Bounty: 25 %
- **Dwelling (80 m²):**
  - Electricity: 0.17 €/kWh
  - Gas: 0.08 €/kWh
  - Q_{out}= 8 kW/year

Equations:

- **Variation of L_{ter}**

$$Q_{ground} = \frac{COP - 1}{COP} Q_{out} ;$$

$$\eta = \frac{Q_{ground}}{L_{tot}} ;$$

$$L_{tot} = L_{bed} + L_{ter} ;$$

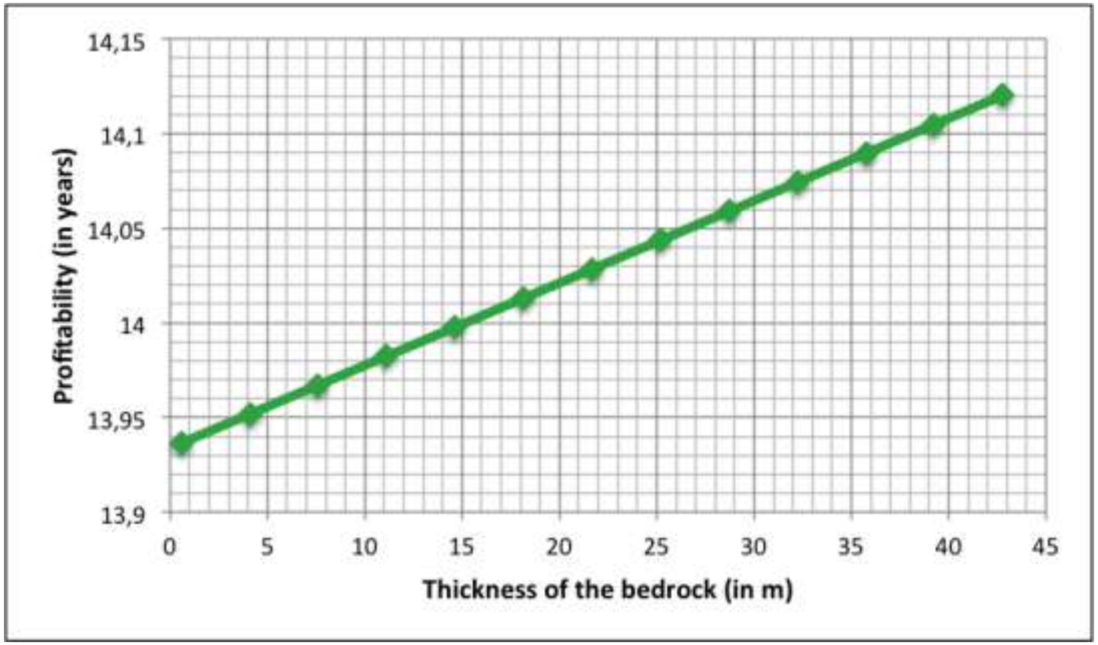
$$\eta = 9.0375\, \lambda_{av} + 29.058 ;$$

$$\lambda_{av} = \frac{\lambda_{ter} L_{ter} + \lambda_{bed} L_{bed}}{L_{tot}} ;$$

$$\lambda_{ter} = \frac{\lambda_{Mal} + \lambda_{Led} + \lambda_{Bxl} + \lambda_{Ko} + \lambda_{Hn}}{5} ;$$

VI. Detailed analysis

5. Attempt to study price



- Hypothesis based on basic information
- Best solution:
  - Sharing
  - New construction

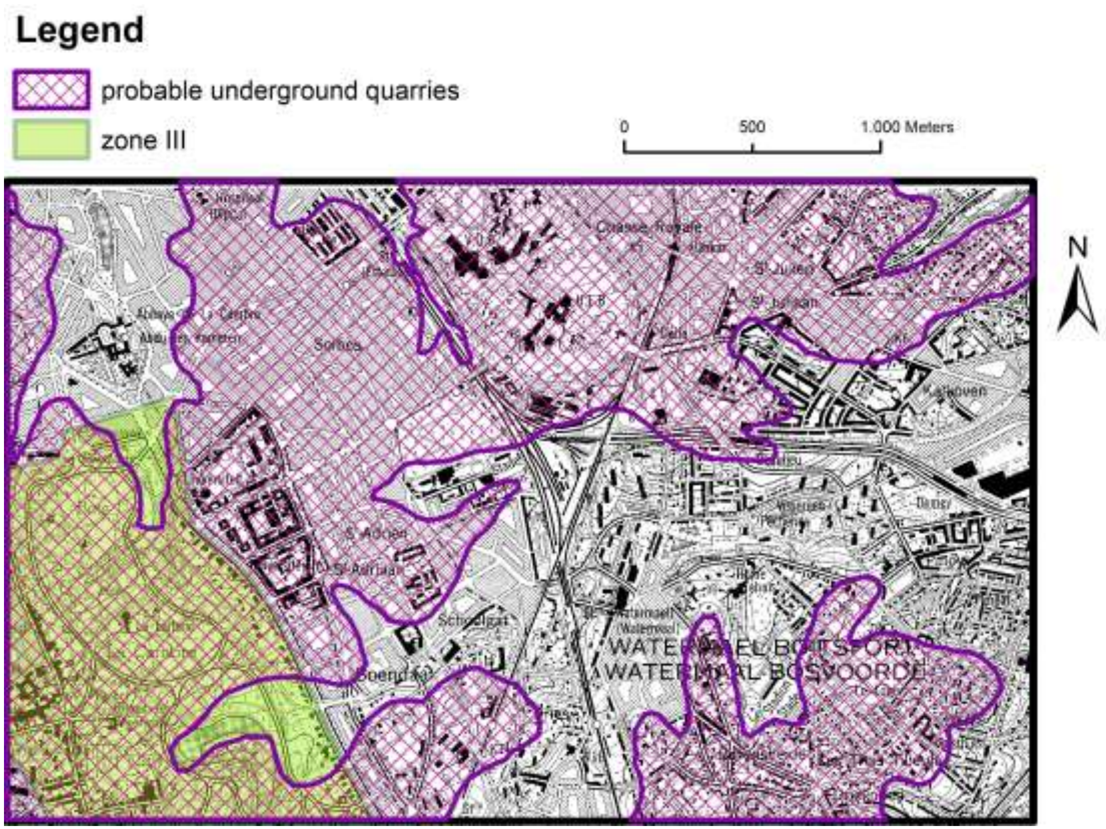
L_{ter} (m)	L_{tot} (m)	$Price_{installation}$ (€)
130	130.57	10034.22
125	129.09	10045.24
120	127.60	10056.27
115	126.12	10067.29
110	124.64	10078.31
105	123.16	10089.33
100	121.67	10100.35
95	120.19	10111.38
90	118.71	10122.40
85	117.22	10133.42
80	115.74	10144.44
75	114.26	10155.46
70	112.77	10166.49

Conclusions

Conclusion of analysis? Long-term prospects?

VI. Conclusion
1. Reminder

- Categorical refusal: groundwater catchment
- Problem: galleries & bedrock (financing)



VI. Conclusion
1. Reminder

- Quite good thermal properties: 43.4 – 49.7 W/m

VI. Conclusion

2. Perspectives of the method

- Not a substitution for fieldwork !
- Maps → decide if it is reasonable to make further investments

- Usable at larger scale?
  - Conceivable
  - Necessary to have access to data on the entire zone:
    - Reproduction of the underground
    - Banned drilling areas
    - Databases
    - Thermal conductivity
    - Drilling capacity

Thank you for your attention !