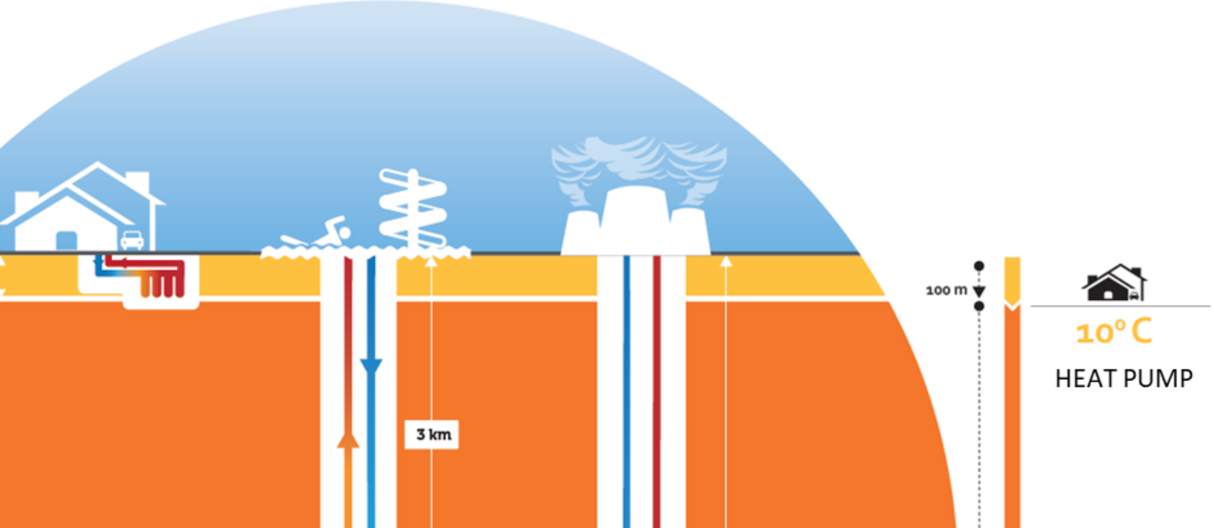
Laboratory Measurements of soil and rocks' Thermal Properties for Shallow Geothermal Potential Mapping



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International Summer School in Thermogeology
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Serial laboratory measurements of thermal conductivity of soil and rocks - methodology

- **PB-102/CBGS** Thermal propierties of cohesive soils
- **PB-103/CBGS** Thermal properties of non-cohesive soils
- **PB-104/CBGS** Thermal properties of rocks

Based on:

- IEEE 442-2017 - IEEE Guide for Thermal Resistivity Measurements of Soils and Backfill Materials;

- ASTM D5334-14 - Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure

energies MDPI

Article

Serial Laboratory Effective Thermal Conductivity Measurements of Cohesive and Non-cohesive Soils for the Purpose of Shallow Geothermal Potential Mapping and Databases—Methodology and Testing Procedure Recommendations

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Abstract: The article presents the methodology of conducting serial laboratory measurements of thermal conductivity of recompacted samples of cohesive and non-cohesive soils. The presented research procedure has been developed for the purpose of supplementing the Engineering–Geology Database and its part–Physical and Mechanical Properties of Soils and Rocks (abbr. BDGI-WFM) with a new component regarding thermal properties of soils. The data contained in BDGI-WFM are the basis for the development of maps and plans for the assessment of geothermal potential and support for the sustainable development of low enthalpy geothermal energy. Effective thermal conductivity of soils was studied at various levels of water saturation and various degrees of compaction. Cohesive soils were tested in initial moisture content and after drying to a constant mass. Non-cohesive soils were tested in initial moisture, fully saturated with water and after drying to a constant mass. Effective thermal conductivity of non-cohesive soils was determined on samples mechanically compacted to the literature values of bulk density. Basic physical parameters were determined for each of the samples. In total, 120 measurements of thermal conductivity were carried out, for the purposes of developing the guidelines which allowed statistical analysis of the results. The results were cross-checked with different measuring equipment and with the literature data.

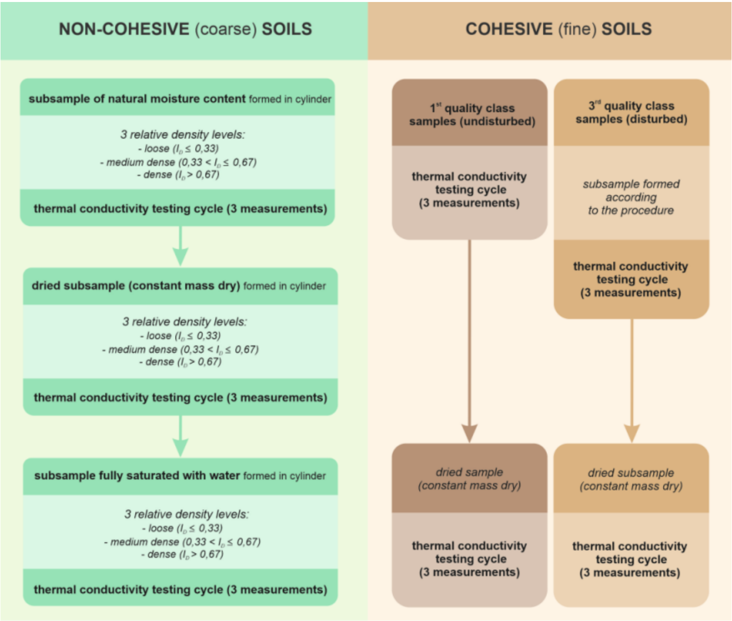
Keywords: thermal properties of soil; transient line source method; ground source heat exchangers; geological mapping and databases; low enthalpy geothermal energy

1. Introduction

Thermal conductivity coefficient values of soil are useful in many subjects connected with energetics. Dynamic development of renewable energy sources and increasing awareness of necessity to reduce the use of fossil fuels are main trends that drive rising interest on thermal parameters of soil and rocks. Recognition of soil's thermal properties and parameters is essential when it comes to proper designing and building installations that use geothermal heat for energetics purposes, e.g., ground source heat pumps, [1–3]. At the same time, incorporating into the buildings thermally active construction elements that use thermal potential of a soil–rock medium and exchange heat between the ground and building is getting more and more popular. Few examples of those constructions are thermoactive foundations, foundation piles or tunnel walls [4–6].

Thermal properties of soil play key role also in determining possibilities of heat transfer in case of underground transmission infrastructure like high-voltage cables or district heating systems [7] as well as in terms of radioactive waste storage [8].

Laboratory measurements of thermal properties of soil and rocks - methodology

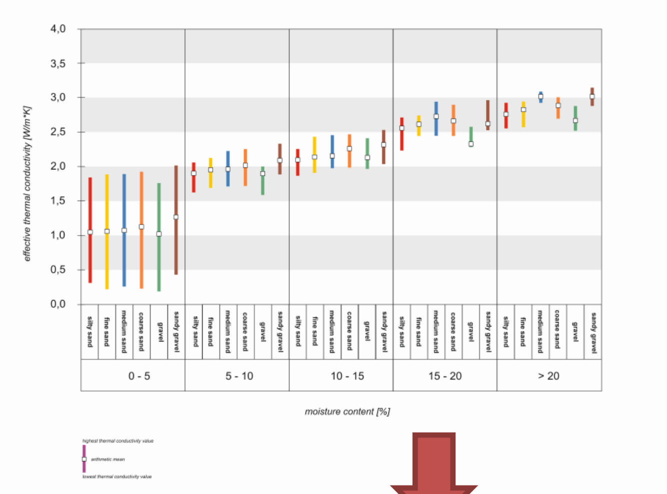


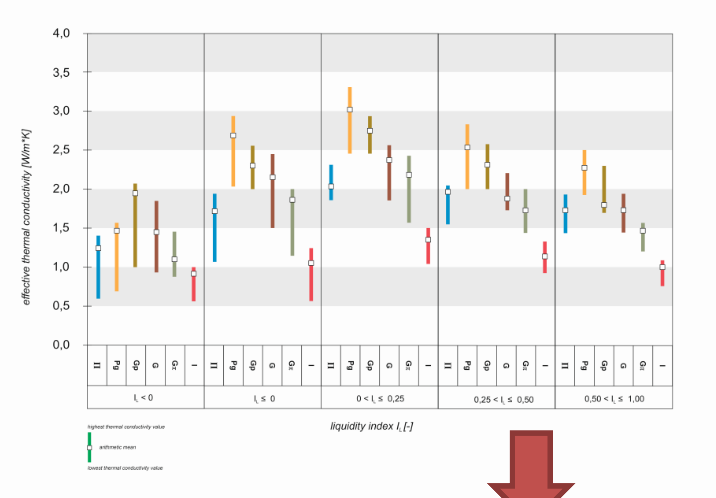
+ **set of tests for physical properties, including:**

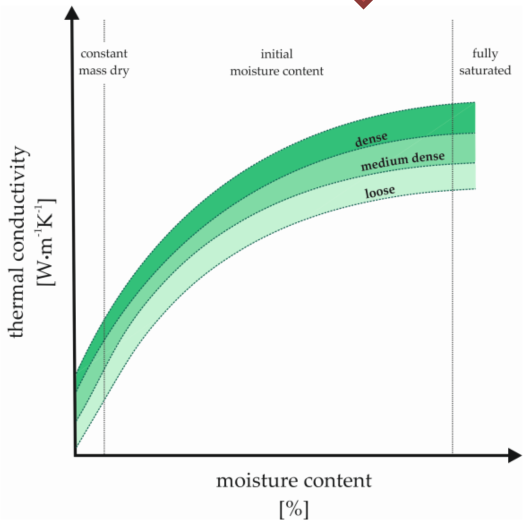
moisture content,
particle size distribution, bulk density, mineral composition

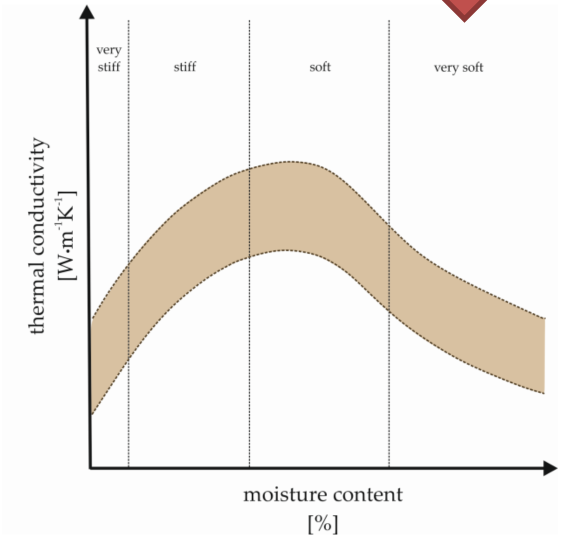
Thermal properties of soil

- **thermal conductivity** — **K** [W/m·K]
- **thermal resistivity** — **Rho** [K·m/W]
- **heat capacity** — **C** [mJ/m³K]


effective thermal conductivity [W/m*K]
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
silty sand
fine sand
medium sand
coarse sand
gravel
sandy gravel
0 - 5
5 - 10
10 - 15
15 - 20
> 20
moisture content [%]
highest thermal conductivity value
arithmetic mean
lowest thermal conductivity value


effective thermal conductivity [W/m*K]
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
Π
Pg
Gp
G
Gπ
I
I_L < 0
I_L ≤ 0
0 < I_L ≤ 0,25
0,25 < I_L ≤ 0,50
0,50 < I_L ≤ 1,00
liquidity index I_L [-]
highest thermal conductivity value
arithmetic mean
lowest thermal conductivity value


constant
mass dry
initial
moisture content
fully
saturated
dense
medium dense
loose
thermal conductivity
[W·m-1K-1]
moisture content
[%]


very
stiff
stiff
soft
very soft
thermal conductivity
[W·m-1K-1]
moisture content
[%]

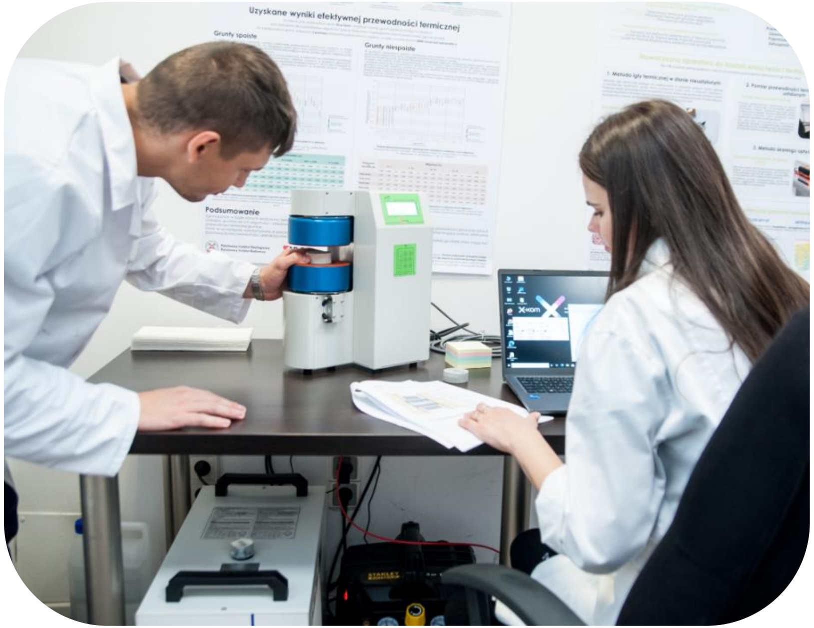
Soil and Rock Testing Centre - geothermal laboratory

Transient line heat source method

TK04 Thermal Conductivity Meter

TEMPOS Thermal Properties Analyzer

Soil and Rock Testing Centre – geothermal laboratory

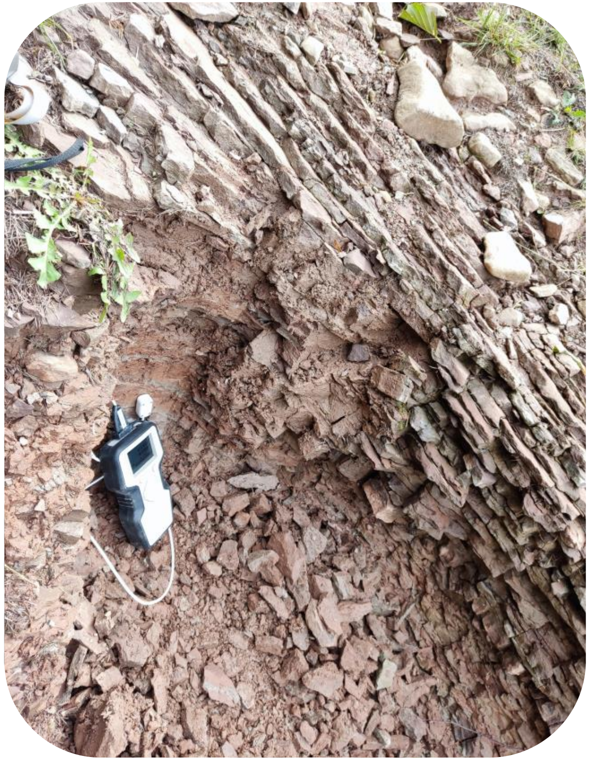


FOX50 Heat Flow Meter

- guarded-hot-plate method
- determination of **steady-state** thermal resistivity of soils and rocks

Field measurements

TEMPOS Thermal Properties Analyzer



Field measurements

Hukseflux Field Thermal Needle System

- soil thermal conductivity and resistivity measurements from the surface down to a depth of 1.5 m

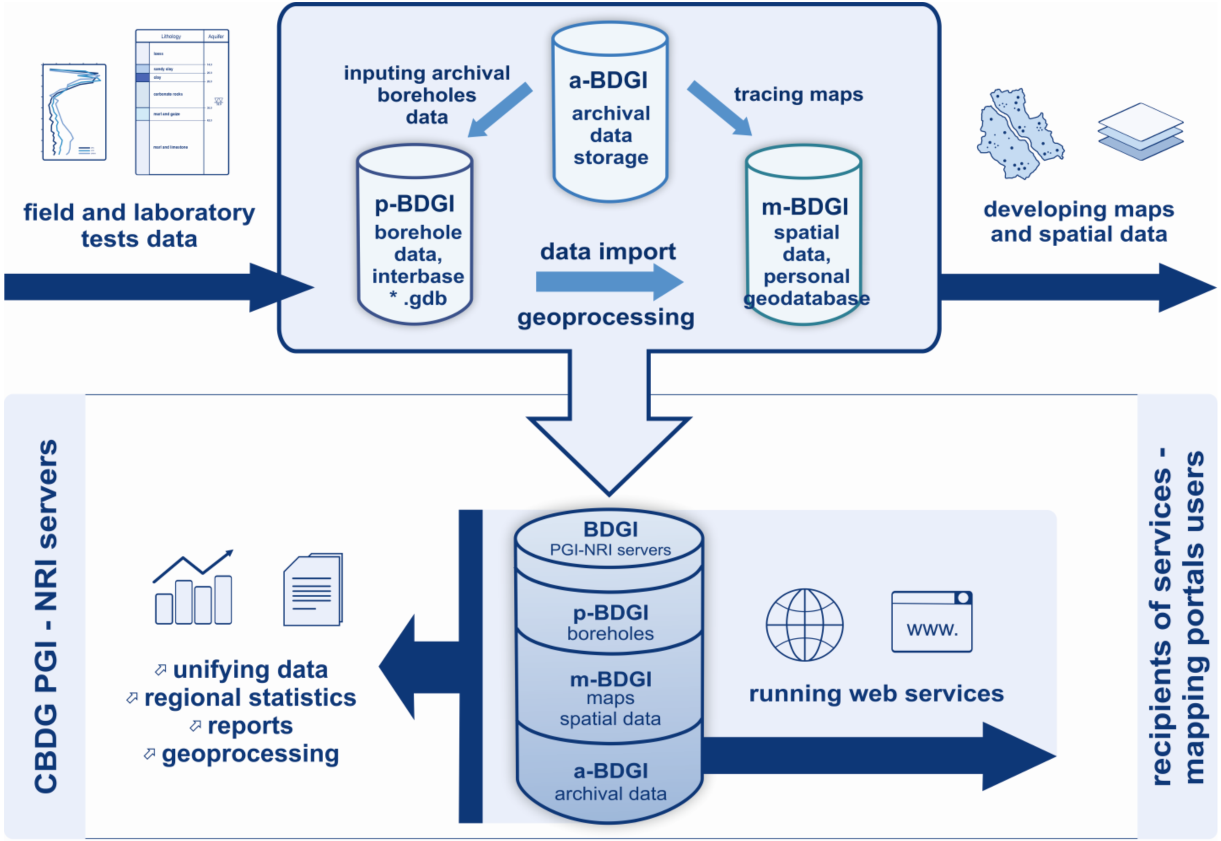
Field measurements

Profiling temperature in wells and heat exchangers

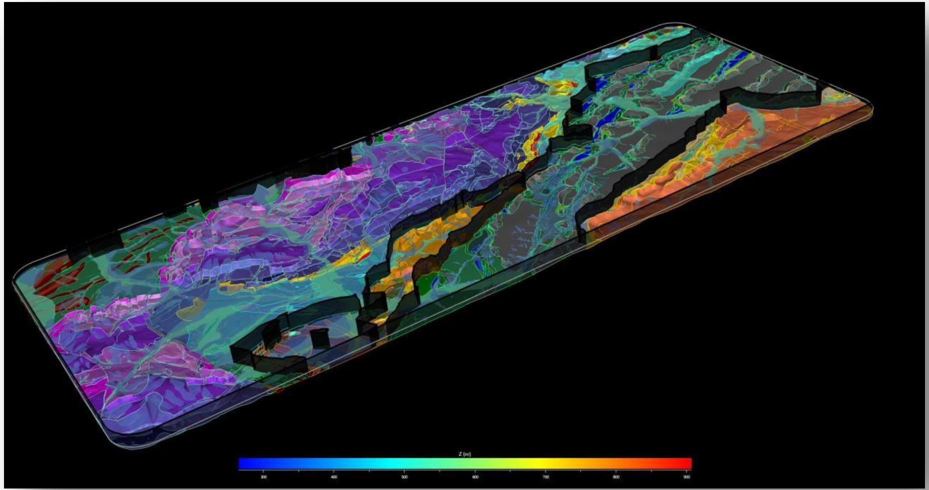
Thermal Response Test (TRT)

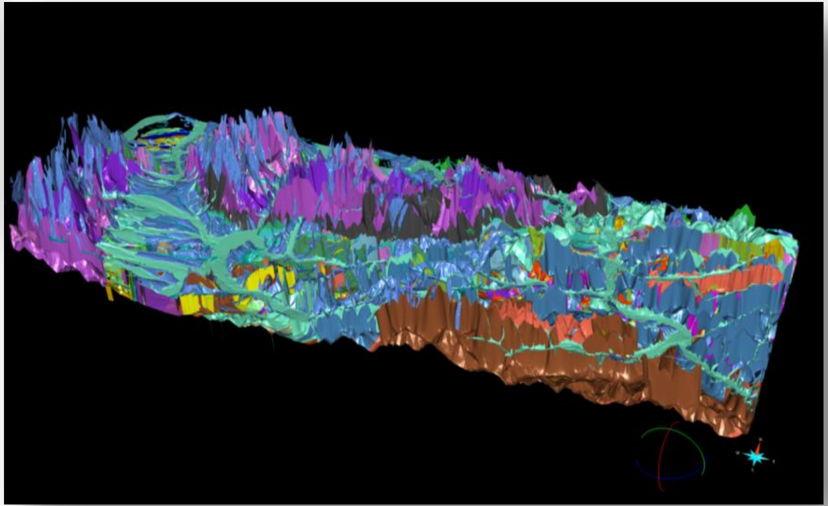
Water Level and Temperature Meters

Thermal Parameters of Soil and Rocks PGI-NRI's Database

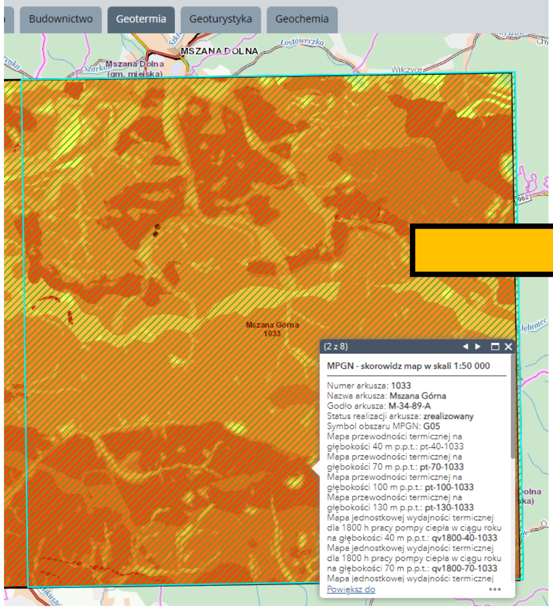


Geothermal potential 3D models

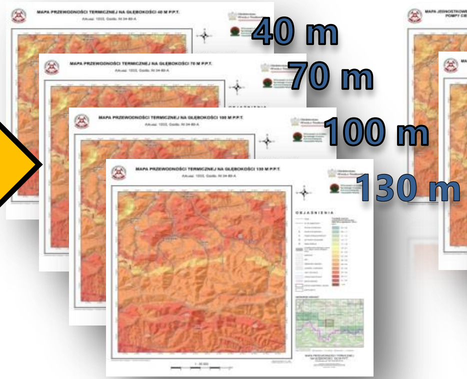




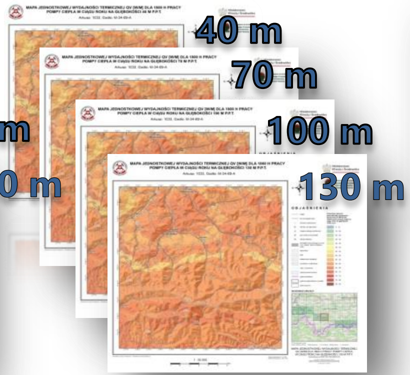
Shallow Geothermal Energy Potential Maps



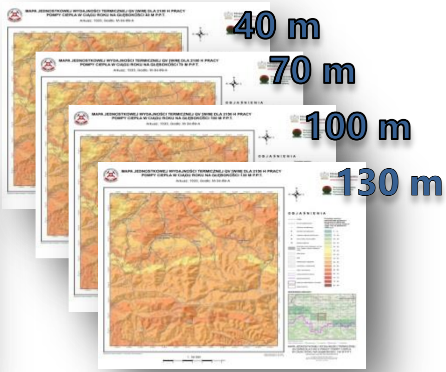
Thermal conductivity [W/m*K]

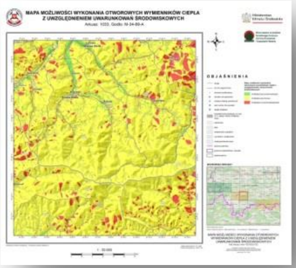


Heat extraction rate 1800 h [W/m]



Heat extraction rate 2100 h [W/m]



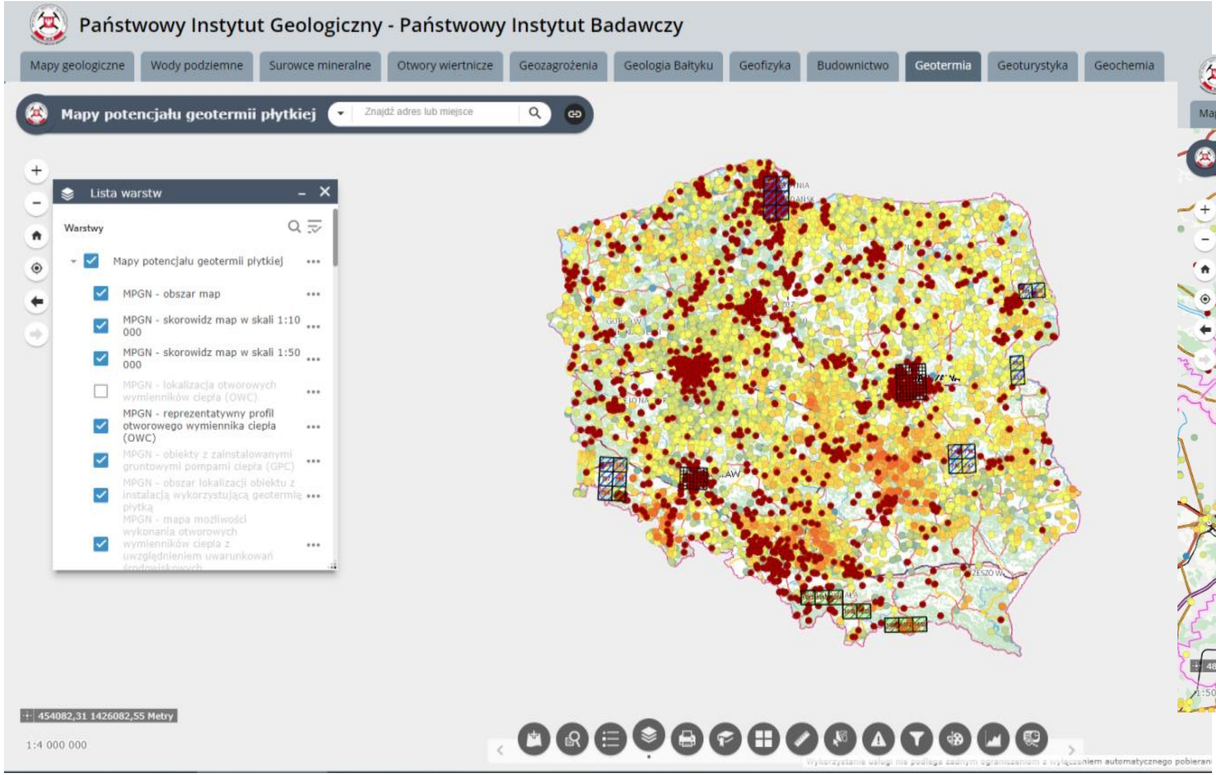


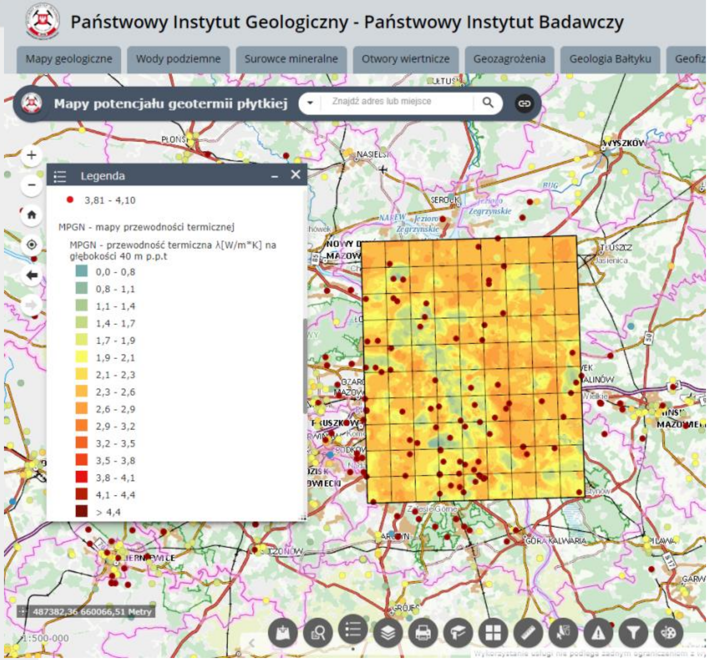
CONFLICT MAP

existing BHEs
landfills,
landslide and flood hazard,
national parks and reserves,
mining areas, etc.

MPGN

www.pgi.gov.pl/geotermia





Scale 1:50 000

Thank you ☺