Managing Urban Shallow Geothermal Energy

Project number GeoE.171.006

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The involved MUSE team

Royal Belgian Institute of Natural Sciences – Geological Survey of Belgium (P108 RBINS-GSB)	David Garcia Moreno (preparation of contents, layout)
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Bureau de Recherches Géologiques et Minières	Harri Williams (preparation of contents, editing)

General description of the deliverable according to the application form

The methods, workflows and concepts, developed in WP2 and WP3 will be linked to the joint GeoERA knowledge infrastructure (e.g. project vocabulary).

Version

Version	Description
22-07-2021	Final version

List of abbreviations

Abbreviation	Full name
EGDI	European Geological Data Infrastructure
GeoERA	Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe
GIP-P	GeoERA Information Platform project
MUSE	Managing Urban Shallow Geothermal Energy
SGE	Shallow geothermal energy
WMS	Web map services
WFS	Web feature services

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1 INTRODUCTION

The MUSE project is one of the projects inside the Geo-energy theme of the multidisciplinary GeoERA project. GeoERA contributes to the optimal use and management of the subsurface, by maximising its added value for energy, raw materials, and groundwater, while minimizing environmental impacts and footprint. In this context, MUSE produces data describing resources, possible conflicts of use and limitations to the use of shallow geothermal energy (SGE) in 15 European urban areas, which were selected as pilot areas to serve as role models for the implementation of similar web platforms for other European regions.

In MUSE, we aimed at implementing efficient and user-friendly web services for planning and managing the use and installation of shallow geothermal energy systems. With that purpose, a series of web pages and services have been created in the framework of the project. The web services have been created by the GIP-P, which has undertaken an extension of EGDI to house data that will be generated by the different GeoERA projects (including MUSE).

This extension comprises:

- *A document repository to archive non-spatial data,*
- *Project vocabularies to define specific concepts and terms non-existent in current standardized vocabularies (e.g., INSPIRE),*
- *An update of EGDI metadatabase,*
- *Modules to upload data to EGDI 2D and 3D databases that are adapted to the different datatypes that will be produced by the GeoERA projects,*
- *Additional EGDI MapView interfaces to properly visualize and share the data created in the framework of MUSE and other GeoERA projects,*
- *Search engines to facilitate finding data, metadata and documents stored at EGDI.*

The spatial data produced in the framework of the MUSE project have been uploaded into EGDI and (hyper-) linked with documents, metadata and vocabulary, providing information about their origin, structure, etc. The interconnected data, metadata, documents and vocabularies will thus function as a knowledge base in EGDI, being part of the GeoERA knowledge infrastructure.

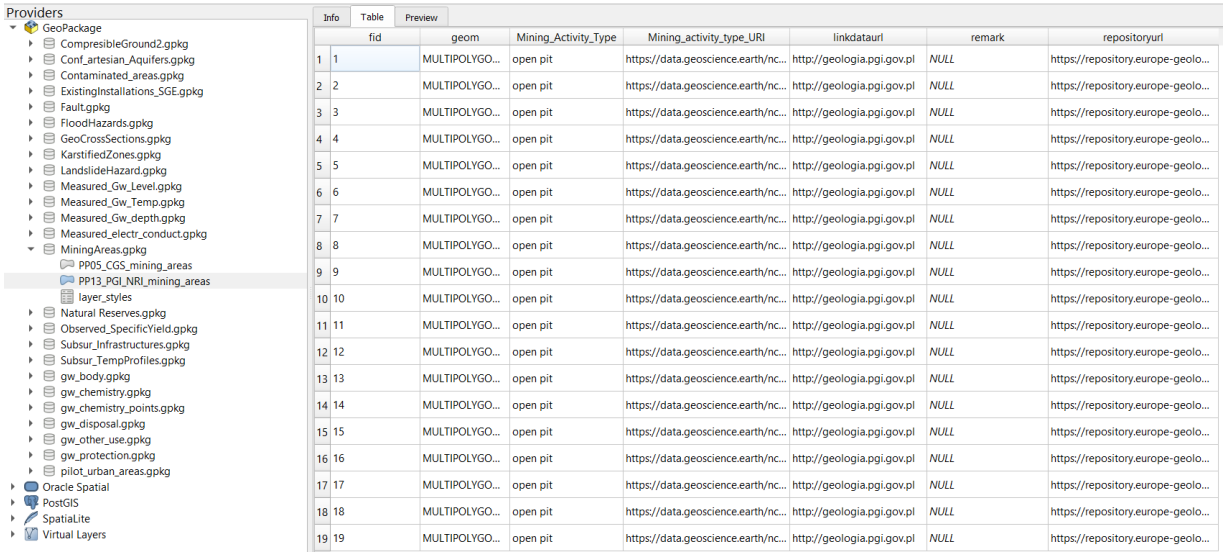
The present deliverable provides an overview of the knowledge infrastructure created for MUSE within EGDI.

2 MUSE DATA

MUSE data comprises the following datatypes:

- *2D vector data, which are uploaded into EGDI spatial database as multi-layered GeoPackages (Figure 1)*
- *Raster graphics, which are uploaded into EGDI spatial database as single GeoTIFFs*
- *Factsheets, images/figures and reports, which are uploaded into EGDI document repository as PDFs and JPGs*

Vector data comprise a number of attributes, containing specifications about the data. Every vector and raster dataset is accompanied by a factsheet, providing information about their source, the data owner, construction methods, etc. (for more information, see MUSE deliverable D 5.5).



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2	2	MULTIPOLYGO...	open pit	https://data.geoscience.earth/nc...	http://geologia.pgi.gov.pl	NULL	https://repository.europe-geolo...
3	3	MULTIPOLYGO...	open pit	https://data.geoscience.earth/nc...	http://geologia.pgi.gov.pl	NULL	https://repository.europe-geolo...
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11	11	MULTIPOLYGO...	open pit	https://data.geoscience.earth/nc...	http://geologia.pgi.gov.pl	NULL	https://repository.europe-geolo...
12	12	MULTIPOLYGO...	open pit	https://data.geoscience.earth/nc...	http://geologia.pgi.gov.pl	NULL	https://repository.europe-geolo...
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19	19	MULTIPOLYGO...	open pit	https://data.geoscience.earth/nc...	http://geologia.pgi.gov.pl	NULL	https://repository.europe-geolo...

Figure 1. GeoPackages created to archive vector data in MUSE. The layers included in each GeoPackage are the datasets produced by each partner for each parameter. The layers within a GeoPackage have the same structure and attributes, where links are provided to definitions, national databases and factsheets archived in EGDI document repository.

3 METADATA

WP5 has created 61 metadata entries in the EGDI metadatabase (http://www.europe-geology.eu/metadata/), one for every output parameter created in the framework of the MUSE project (Figure 2). These metadata entries were entered manually into the EGDI metadatabase. Note that the same metadata applies to all layers (one per pilot area) of the same dataset. An example of the information provided in the metadata of MUSE parameters can be consulted at https://egdi.geology.cz/record/full/60216646-bee8-4fc6-8fac-4fd20a010833.

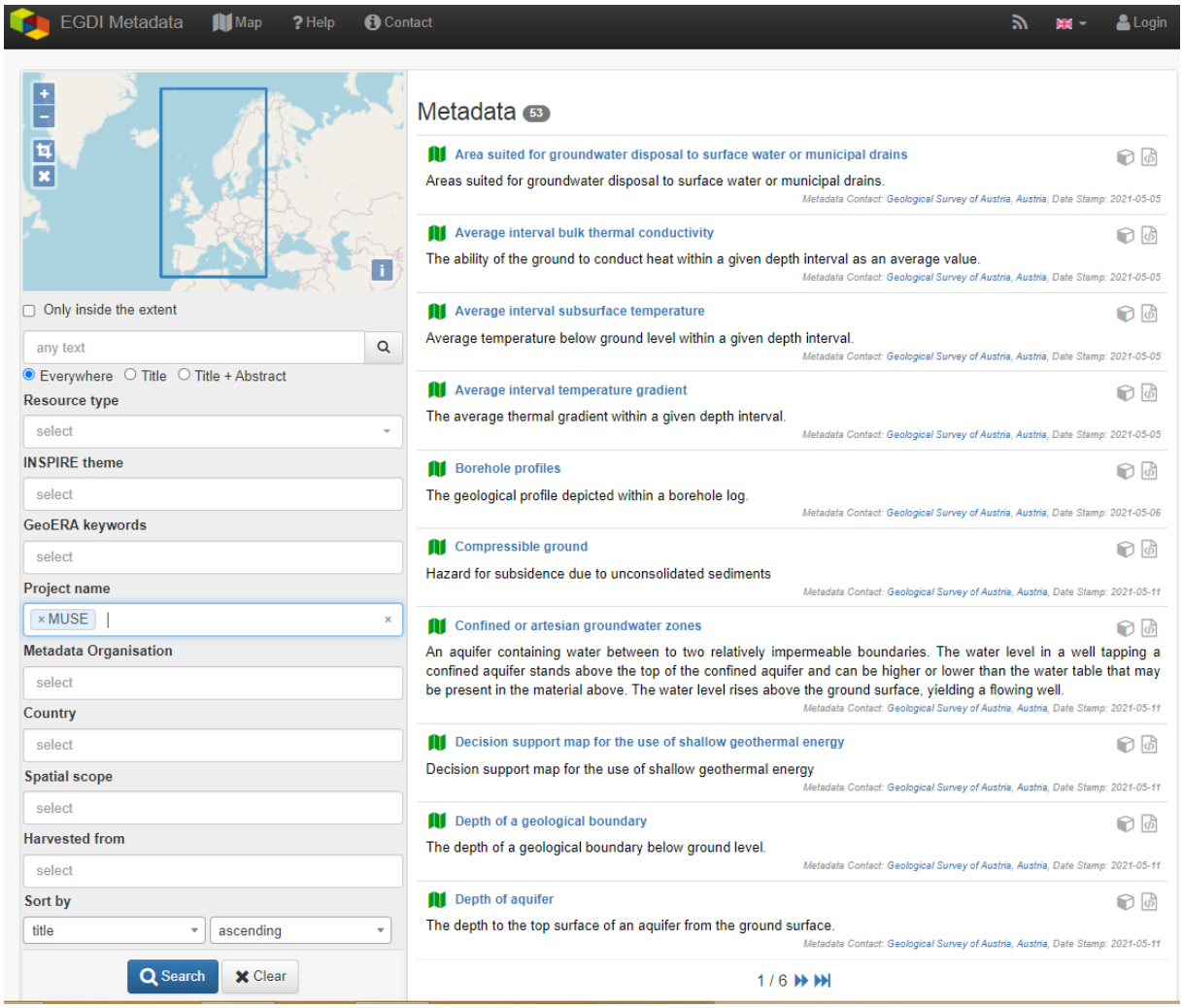

Figure 2. Print-screen of the metadatabase and search engine of EGDI, showing some of the metadata entries existing for the MUSE project.

4 PROJECT VOCABULARY

In MUSE the project vocabulary comprises the terminology we used in the project. For shallow geothermal energy a harmonized international language is still missing and therefore the project team considered it crucial to further build on the harmonization efforts that started for example in the GeoPLASMA-CE project (https://portal.geoplasma-ce.eu/glossary).

The project vocabulary of MUSE includes definitions and bibliographic citations of all our output data sets and their sub-categories if applicable in English language. The descriptions are linked to the data sets on EGDI for additional information to the user of the web platform. WP5 defined 106 terms in EGDI project vocabulary, for which the GIP-P generated permanent URIs (see Figure 3). These URIs were included in the attributes of the pertinent datasets. They were also linked to the pertinent concepts and terms included in the factsheets of each layer.

In the beginning, the project team assumed to use definitions already available in INSPIRE. However, it turned out at the beginning that there were almost no terms in INSPIRE available related to shallow geothermal energy. We took only a few definitions directly from INSPIRE, the majority of the parameters in the project vocabulary were defined for MUSE directly. The definitions were kept as general as possible, in order to facilitate an implementation into INSPIRE later on, or at least to enable their use in other projects.

The MUSE project vocabulary is based on the structure of the INSPIRE definitions, where a broader scheme consists of multiple concepts, which are structured hierarchically. Each concept has a definition in English and at least one bibliographic citation. In case the definitions could have been taken directly from INSPIRE or another database, the URI links were stated in the table as “exactMatch”. For some of the MUSE parameters a close match was identified with an existing definition, this was stated accordingly as well as “coseMatch”.

In the MUSE project we aimed at many output data sets. To arrange them more clearly inside the project vocabulary, we classified them in three top concepts:

1. Concepts in the field of shallow geothermal energy
    a. Decision support map for the use of shallow geothermal energy
    b. Possible limitations of shallow geothermal energy use
    c. Resources for shallow geothermal energy
    d. Geothermal energy (includes the different shallow geothermal energy systems)
2. Concepts in the field of shallow geothermal energy related to Geology
3. Concepts in the field of shallow geothermal energy related to Hydrogeology

The entire project vocabulary is included as annex 1 to this report.

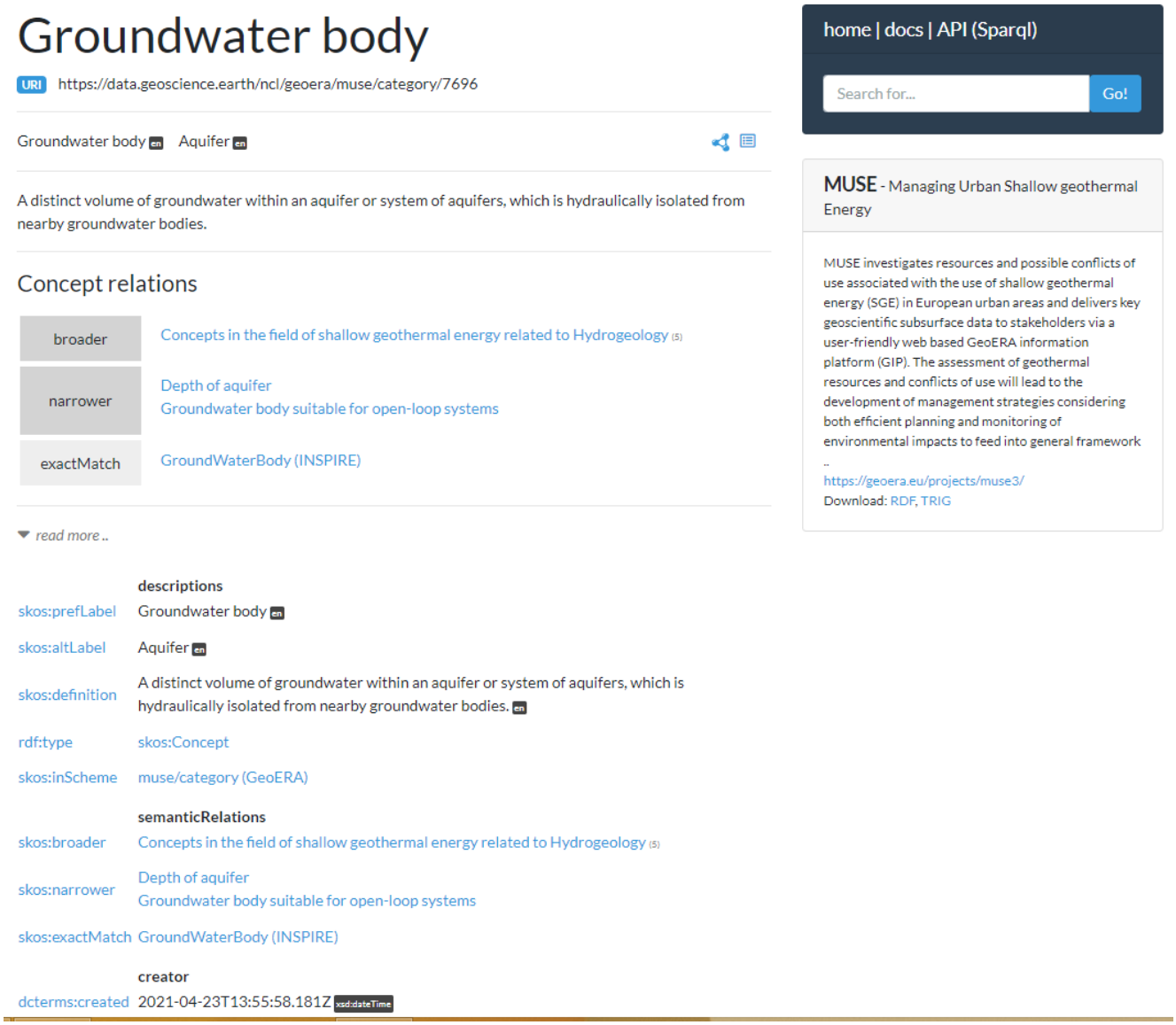

Figure 3. Print-screen showing an example of one of the concepts defined in the MUSE project vocabulary.

5 MUSE KNOWLEDGE INFRASTRUCTURE

5.1 Achievements

All products (data, documents, metadata, definitions, etc.) are interconnected in EGDI. Links among products are established as follow:

1. Links to metadata are automatically established anytime a dataset is uploaded into the EGDI database.
2. Links to the URLs created by EGDI document repository for factsheets and pertinent documents providing information about vector data are included in the attributes of the data. Links to those documents are also provided in the text that appears when users activate the layers containing those datasets in EGDI MapViewers. Note that vector data also contain (when available) links to national repositories and databases, where users can consult the original datasets and get detailed explanations about them. Those links are also provided in the documents uploaded to EGDI document repository.
3. Links to the URLs created by EGDI document repository for factsheets and pertinent documents providing information about raster graphics are provided in the text that appears when users activate the layers containing those datasets in EGDI MapViewers. Links to national repositories and databases from where users can consult the original datasets and get detailed explanations about them also provided in the documents uploaded to EGDI document repository linked to raster graphics.
4. The links between the specific terminology used to create the attributes of the spatial data and that are included in factsheets and reports are established by adding hyperlinks to the pertinent URIs of MUSE project vocabulary.

Therefore, data, metadata, documents and vocabulary are interlinked in a way that, no matter how users consult MUSE datasets, they will have access to all the available information.

5.2 Outlook

In the framework of the MUSE project, we introduced the new portfolio of terms and concepts related to the use of shallow geothermal energy. We applied a bottom-up approach for identifying relevant contents from the point of view of the involved 17 Geological Survey Organizations. The developed knowledge infrastructure allows for future adaptation and expansion in follow-up initiatives of EuroGeoSurveys. Future activities might cover:

- Update of concepts and terms in line with the future state of the art and regional hydrogeological requirements of countries not participating in MUSE,
- Expansion of concepts towards new technological utilization concepts, such as underground thermal energy storage linked to shallow geothermal energy use.

6 ANNEX

Annex 1 – MUSE project vocabularies

name of vocabulary topic; uppermost hierarchy label. --- **Mandatory**	labels (in English) of concepts in hierarchical order, where the uppermost concept label (top concept) is inserted in the first concept column, the second hierarchy level (narrower concept) is inserted in the second column, etc. **--- Mandatory**				altLabel@en = Concept's synonyms in English. Only one synonym is allow per column. If multiple synonyms, add columns to the right. **--- Optional**		definition@en = formal definition of the concept. **Definitions cannot exceed 500 characters, better below 300 characters due to web services limitations --- Mandatory**	A note or example showing the use of the concept in non-English languages **--- Optional**	A note or example showing the use of the concept in English **--- Optional**
scheme	**concept**	**concept**	**concept**	**concept**	**altLabel@en**	**altLabel@en**	**definition@en**	**example@**	**example@en**
geothermal energy					geothermal heat exchangers		Exploration pertaining to the utilization of geothermal energy resources and design of geothermal heat pumps.		
	shallow geothermal energy						Energy stored underground in a depth of up to 400 meters.		
		shallow geothermal energy system			ground source heat pump system		Installations that enable the use of the energy stored underground in a depth of up to 300 to 400 meters.		
			open loop system		groundwater heat pump	open loop geothermal system	A shallow geothermal open loop system extracts energy of a waterbody (usually ground water or surface water) to use it for heating and or cooling, domestic hot water or energy storage.		
				surface water heat exchanger			A surface water body provides energy for heating or cooling either directly (free cooling) or with a heat pump.		
				ground water heat exchanger			Groundwater provides energy for heating or cooling either directly (free cooling) or with a heat pump.		
			closed loop system		closed loop geothermal system		A heat carrier fluid circulates in horizontally or vertically installed pipes to harness from or store heat into the underground. The system provides heating and cooling, domestic hot water or energy storage.		
				Borehole heat exchanger	vertical heat exchanger		A heat carrier fluid circulates in vertically installed pipes in a borehole to harness from or store heat into the underground.		
		Resources for shallow geothermal energy					Thermal energy supply for the use of shallow geothermal energy		

			Resources for open loop systems				Shallow geothermal energy supply for open loop systems		
				Thermal productivity			The maximum temperature shift between the production and the injection well that is possible with regards to legal or ecological limitations.		
				Maximum groundwater temperature			Annual maximum groundwater temperature.		
				Minimum groundwater temperature			Annual minimum groundwater temperature.		
				Specific thermal capacity - open loop systems			Thermal capacity of a well doublet for heating and/or cooling depending on the hydraulic productivity and the thermal productivity.		
				Specific annual thermal load - open loop systems			Energy content available per year in a defined volume of a groundwater body for heating and/or cooling applications.		
				Specific hydraulic productivity			Maximum yield or pumping rate of a groundwater well doublet per square meter at a given location.		
			Resources for closed loop systems				Shallow geothermal energy supply for closed loop systems		
				Formations suitable for borehole thermal energy storage (BTES)			Geological layers that are well suited to store thermal energy in the ground with borehole heat exchangers.		
				Thermal conductivity at a specific geological unit			Thermal conductivity of a geological unit relevant for shallow geothermal energy use (e.g. bedrock).		
				Land surface temperature			Temperature of the land surface on the top canopy layer		Luo, D., Jin, H., Marchenko, S.S., Romanovsky, V.E. (2018): Difference between near-surface air, land surface and ground surface temperatures and their influences on the frozen ground on the Qinghai-Tibet Plateau. Geoderma 312, 74 - 85
				Average interval bulk thermal conductivity			The ability of the ground to conduct heat within a given depth interval as an average value.		
				Average interval subsurface temperature			Average temperature below ground level within a given depth interval.		
				Average interval temperature gradient			The average thermal gradient within a given depth interval.		
				Heat transfer rate			Maximum heat transfer rate (heating, cooling) related to borehole heat exchangers (BHE) for a defined depth interval.		
				Annual thermal load - closed loop system			The annual amount of thermal energy available to be used with a specified closed loop system.		
				Specific annual thermal load - closed loop system			Specific annual thermal energy content for heating and / or cooling referring per surface area for borehole heat exchangers at a defined length.		

				Specific thermal capacity - closed loop system			Specific thermal capacity per surface area unit for borehole heat exchangers of a defined length.		
		Possible limitations of shallow geothermal energy use					Areas where the use of shallow geothermal energy might be limited, due to geological, hydrogeological conditions or conflicts of use.		
			Traffic light map for closed loop system				Overall evaluation of possible limitations and restrictions to the installation of closed loop systems based on a 3 colour schemes (pink: no installation allowed, yellow: installation based on case to case decision, green: no restrictions known)		
			Traffic light map for open loop system				Overall evaluation of possible limitations and restrictions to the installation of open loop systems based on a 3 colour schemes (pink: no installation allowed, yellow: installation based on case to case decision, green: no restrictions known)		
			Contaminated area				Sites with confirmed or suspected waste, landfills and/or underground pollution generated from domestic, construction and/or industrial activities that may have an impact on the installation of shallow geothermal energy systems.		
				contaminated site			Site with proven contamination of the underground		
				potentially contaminated site			Site which due to its use bears the risk of potentially contaminating the underground.		
			Aquifer Type				Types of aquifers		
				Confined artesian			An aquifer containing water between to two relatively impermeable boundaries. The water level in a well tapping a confined aquifer stands above the top of the confined aquifer and can be higher or lower than the water table that may be present in the material above. The water level rises above the ground surface, yielding a flowing well.		
				Confined subartesian			An aquifer containing water between two relatively impermeable boundaries. The water level in a well tapping a confined aquifer stands above the top of the confined aquifer and can be higher or lower than the water table that may be present in the material above it. The water level does not rise above the ground surface.		
			Groundwater protection				Areas dedicated to drinking water or curative water supply, which migh limit the use of shallow geothermal energy		

			Potentially karstified zones				Areas with rocks susceptible to karstification		Bakalowicz, M. (1979). *Contribution of water geochemistry to the knowledge of the karst aquifer and karstification* . PhD thesis in Natural Sciences. Dynamic Geology Laboratory, CNRS Underground Laboratory. University P. and M. Curie, Paris.
			Compressible ground				Hazard for subsidence due to unconsolidated sediments		
			Faults		fault zone	faulted contact	A contact separating two bodies of material across which one body has slid past the other.		
			Mining Activity Type				The type of mining activity, processing activity, or production.		
				Open pit			An open-sky excavation (also open-sky mine) for the extraction of metallic ores and /or commodities.		
				Open pit and underground			Covers both the open pit and underground mining activity		
				Subsurface mining			Mining beneath the surface of the earth.		
			Critical chemical composition of groundwater				Groundwater zones of problematic chemistry related to shallow geothermal energy		
				no chemical risk			No groundwater risks associated with manganes and iron scaling; carbonate scaling; metal and concrete corrosion.		
				risk of manganese and iron scaling			Where precipitation of manganese and iron is likely in the presence of oxygen.		
				risk of carbonate scaling			Usually results from the precipitation of carbonates, principally calcium carbonatre (lime scale) from groundwater in the proximity of the well screen.		
				risk of metal corrosion			Acid conditions generally lead to corrosive attack on metallic objects places in groundwater. Susceptible metals include iron, steel, galvanized iron and brass.		

				risk of concrete corrosion			Where the risk of concreter corrosion is likely.		
				multiple risks			Multiple risks associated with manganes and iron scaling; carbonate scaling; metal and concrete corrosion.		
				lack of chemical analysis of groundwater			Lack of data available to analyse the chemical properties of the of groundwater.		
			Flood hazard				Zones possibly affected by periodic flooding		
				Flooded area in a 100-year-flood			Zones possibly affected by a flood that statistically occurs once every 100 years		
				Flooded area in a 300-year-flood			Zones possibly affected by a flood that statistically occurs once every 300 years		
			Nature protection				area which relates to the protection of nature		
			subsurface infrastructure				Any subsurface installations which might lead to conflicts with well drilling and borehole heat exchangers.		
				unspecified			Unspecified subsurface infrastructure		
				tunnel (underground road or railway)			A passage built underground, for example to allow a road or railway to go through a hill, under a river, etc.		
				electric lines			A utility link or link sequence used to convey electricity from one location to another		
				gas lines			A pipeline used to transport natural gas		
				district heating			The distribution of thermal energy in the form of steam, hot water or chilled liquids, from a central source of production through a network to multiple buildings or sites, for the use of space or process heating or cooling		
				water and sewage infrastructure			Areas used for the extraction, collection, purification storage and distribution of water, collection and treatment of sewage (including the pipelines).		
				telecommunication			Telecommunications networks.		

				underground car park			Underground car parking facility.		
			Landslide				Processes of downhill slope movements of soil, rock, and organic materials related to different types of ground failure.		
		Decision support map for the use of shallow geothermal energy					General map evaluating the suitability and preference of open loop and closed loop shallow geothermal systems.		

bibliographic references. Add as many as pertinent --- Mandatory				URI link to an existing concept scheme (vocabulary) to which you want to relate the concepts. The ones below are examples, add as many as necessary. **--- Optional**		if the concept meaning is the same as the one to which we are linking it --- **Optional**	if the concept meaning is similar but not exactly the same as the one to which we are linking it --- **Optional**
bibliographicCitation_1	**bibliographicCitation_2**	**bibliographicCitation_3**	**bibliographicCitation_4**	**INSPIRE_Mapping URI**	**geosciml_Mapping URI**	**exactMarch**	**closeMatch**
				http://inspire.ec.europa.eu/codelist/BoreholePurposeValue/geothermalEnergy			http://inspire.ec.europa.eu/codelist/BoreholePurposeValue/geothermalEnergy
Garcia-Gil, A., Goetzl, G., Klonowski, M., Borovic, S., Boon, D., Abesser, C., Janza, M., Herms, I., Petitclerc, E., Erlström, M., Holecek, J., Hunter, T., Vandeweijer, Cernak, R., Moreno, M. M., Epting, J. (2020): Governance of shallow geothermal energy resources. Energy Policy 138.							
Sass, I., Brehm, D., Coldewey, W.G., Dietrich, J., Klein, R., Kellner, Tö, Kirschbaum, B., Lehr, C., Marek, A., Mielke, P., Müller, L., Panteleit, B., Phol, S., Porada, J., Schiessl, S., Wedewardt, M., Wesche, D. (2015): Empfehlungen Oberflächennahe Geothermie - Planung, Bau, Betrieb und Überwachung - EA Geothermie. Wilhelm Ernst & Sohn.	Garcia-Gil, A., Goetzl, G., Klonowski, M., Borovic, S., Boon, D., Abesser, C., Janza, M., Herms, I., Petitclerc, E., Erlström, M., Holecek, J., Hunter, T., Vandeweijer, Cernak, R., Moreno, M. M., Epting, J. (2020): Governance of shallow geothermal energy resources. Energy Policy 138.	Lund, J., Sanner, B., Rybach, L., Curtis, R., Hellström, G. (2004): Geothermal (ground-source) heat pumps a world overview. GHC Bulletin					
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