EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

COST is supportrd by the EU Framework Programme Horizon 2020

Sub-Urban

TU1206-WG2.5-006

Geotechnical Modelling and Hazards

TU1206 COST Sub-Urban WG2 Report

G. Ryżyński, B. Mozo, A.Toumazis, I. Vergauwen, G. van Alboom, M. Van Damme, V. Van-wesenbeeck, K. Majer, D. Entwisle, A. Ustun, I. Peshevski, M. Jovanovski & M. S. Serbulea

Foto: Statens vegvesen

COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

COST is supportrd by the
EU Framework Programme
Horizon 2020

Sub-Urban

TU1206 COST Sub-Urban Report
TU1206-WG2.5-006

Published 2017

Author: G. Ryżyński (PGI), B. Mozo (GSI), A.Toumazis (), I. Vergauwen (Geotechnics, BE)), G. van Alboom, M. Van Damme, V. Vanwesenbeeck, K. Majer, D. Entwisle, A. Ustun (Engineering Faculty, Selcuk Univ.), I. Peshevski (Univ. Cyril and Methodious), M. Jovanovski & M. S. Serbulea (UTCB)

Editor and layout : Guri Venvik (NGU)

Cover photos: Statens Vegvesen (Norwegian Public Roads Administration)

COST is supportrd by the
EU Framework Programme
Horizon 2020

Acknowledgements

This report is based on work from COST Action TU1206 Sub-Urban, supported by COST (European Cooperation in Sciences and Technology), and itself a component of the European Union's Horizon2020 programme. Sub-Urban is a network to improve understanding and the use of the ground beneath our cities (www.Sub-Urban.eu).

Many participants of the Sub-Urban COST Action have contributed to this report and to the Action as a whole, each with their own experience and expertise. This evaluation would not have been the same without their presentations, comments, and discussions; they are all thanked for their contributions.

Contents

Executive Summary

The rapid growth of urban areas, and the constant development of city infrastructure, necessitates better understanding of the underground space. Across Europe, the urban subsurface is usually taken into consideration in the planning process, but awareness of the importance of knowledge about the geotechnical data and geohazards among city planners and stakeholders, still needs to be increased. This includes the need for a greater consideration of the subsurface information in the City Master plans, if geological and geotechnical problems are to be anticipated, and more realistic construction timeframes and budgets are to be developed.
In the presented report the main goal was to emphasize the geotechnical data and geohazards importance in the city subsurface management. The report summarizes in sections 1-4 the issue of geotechnical databases, geotechnical data availability and geotechnical data exchange frameworks using selected best practices provides by COST Sub-Urban Action Members. Section 5 is focused on geohazards in the urban environment and their importance in the city planning process.

The report addresses geotechnical databases, models and geohazard inventories in relation to urban planning and management of the urban subsurface. The main questions and knowledge gaps that are flagged in the report include:

- How to increase the awareness among city planners and stakeholders of the importance of geotechnical modelling and geohazards inventories
- How to incorporate geotechnical modelling and geohazards data into the early stages of spatial planning
- How to encourage private companies to share their geotechnical data with Geological Surveys and municipalities and public organizations in between themselves Legal enforcement may be one option, but cooperation may be equally effective or even preferable (cf. ASK Network)
- What framework/standard should be the best for the integration of 2D/3D geotechnical models (site specific) within the city-scale 3D models

The report provides an overview of geotechnical databases, which are a key to effective parameterising of 3D models. As geological 3D models contain basic geological information on lithology, more pertinent parameterisation is needed in order to influence construction-related decision-making. This requires access to a range of geotechnical data. Both physical and mechanical parameters from the geotechnical databases can be used for 3D model parameterisation. Key parameters include: bulk density, moisture content, grains size distribution, friction angle and cohesion, oedometric modulus, etc... Such parameterised models can help to fill the gap between city scale data (1:10 000), which provides the geotechnical component to sites, and site-specific data (1:500). Spatial planning and feasibility studies for new large construction projects should use such parameterised 3D models as a starting point in their geological risk assessment and planning of site investigation.

Also, it is necessary to allow the implementation of geohazards risk assessment and mapping on a city scale. A multi-hazard and multi-risk approach is needed. All types of

natural hazards should be analysed and identified. The list and the examples of geohazards (landslides, land subsidence) are presented in section 5 of the report.

1. Introduction

G Ryzynski, B Mozo

1.1 Rationale

The rapid growth of urban areas, and the constant development of city infrastructure, demands a better understanding of the underground space. Across Europe, the urban subsurface is usually taken into consideration in the planning process, but awareness of the importance of knowledge about the subsurface and geohazards among city planners and stakeholders still needs to be increased. This includes the need for greater consideration of subsurface information in City Master plans, if geological and geotechnical problems are to be anticipated, and more realistic construction timeframes and budgets are to be developed.

Geotechnical data is vital when dealing with construction in urban areas. The access to outcrops in cities is very limited and geotechnical data helps in the characterization of the soils and or bedrock that are in the area. By getting a better knowledge of the physical and chemical characteristics of the soils, a better approach can be taken when designing the construction.

Across Europe, there is a large heterogeneity of geotechnical datasets, both in how the data is collected and how it is stored. Also, the lack of legislation in some European countries makes more difficult the access to the data.

European landscape and geological environments are very different, this is the reason for geo-hazards like landslides to be included in this report.

Landslides are a major geohazard that can cause substancial damage in cities, infranstructures and loss of life in those areas in Europe that have a hilly landscape. They can be trigged by earthquakes, volcanic eruptions, heavy rainfall, or man-made activities like building in urban areas.

The aim of this report is:

- To give an overview of the collection, storage and usage of the geotechnical data across Europe
- To highlight the importance of geotechnical databases and geohazards inventories to establish an efficient management of the city subsurface
- To identify good practices/ best efforts in the storage and usage of geotechnical data and management of geohazards based on real cases

2.1 Knowledge base

This report has been compiled by a consortium of researchers and city partners from 8 countries within the COST Sub-Urban Action, and the report presents existing knowledge from universities, Geological Surveys and city municipalities.

3.1 Report structure

Geotechnical data and geohazards are very important elements in city subsurface management. The report provides an overview of the best practices in the above mentioned topics across Europe.

The report summarizes the issue of geotechnical databases; geotechnical data availability and geotechnical data exchange frameworks using selected best practices provided by COST Sub-Urban Action Members (presented in Chapters 2, 3 and 4). Chapter 5 focuses on geohazards in the urban environment and their importance in the city planning process.

The report has 3 Appendixes. Appendix 1 is a set of 22 filled geotechnical data availability questionnaires. Appendix 2 consists of three case studies; best practices of geotechnical databases (2.1 – DOV database from Belgium, 2.2 – The National Geotechnical Borehole Database from Ireland, 2.3 – PGI-NRI Engineering-Geological Database from Poland). Appendix 3 is a report on geohazars from Romania.

The report is a part of a general WG 2 report of Sub Urban COST Action (TU-1206-WG2), available at the action's website: http://sub-urban.squarespace.com/

The report is the starting point for a COST Sub-Urban Action's TOOLBOX, which will provide further guidance and examples. The Sub-Urban TOOLBOX is also available at Action's website.

2. Geotechnical data availability

G Ryzynski, B Mozo, A Toumazis

Key words: geotechnical data in Europe, databases, data re-use, data availability

2.1 Introduction

The data from geotechnical investigations improve and extend the geological interpretations, and helps in the modelling of urban subsoil for construction purposes. Geotechnical boreholes and cone penetration tests (CPT being one of the most popular geotechnical field tests) are mostly shallow, down to an average of 30 m below surface. Therefore, the geotechnical characterisation of the soils only occur in the uppermost layers of the borehole. The geotechnical boreholes in combination with the field and laboratory tests are very useful for the creation of parametric 2D and 3D models of the urban subsurface that has being affected by man-made activities.

Because geotechnical data is collected mostly during private projects, it is not easily available for Geological Surveys or municipalities. The legal regulations referring to the ownership and legal status of the geotechnical data (stating whether geotechnical data should be archived or not in the national databases of Geological Surveys or their equivalent institutions) is different in each country. This is one of the reasons why geotechnical data is not stored in databases and it is more difficult to use it in the urban planning process. Construction conditions maps at given depths, used for spatial management are a good example of practical use of geotechnical boreholes databases.

The specifics of geotechnical data is connected with certain problems. The main problems are:

- Large heterogeneity of geotechnical datasets. The geotechnical data is gathered by a large number of different organisations, including public institutions, private companies, Geological Surveys, and municipalities. Often there is a lack of information about what sort of data they have and in what format are stored (paper/pdf/editable). There are cases of duplication of data as there is no sharing of it between the companies or organizations. Also, due to national legislation, sometimes different institutions collect the same geotechnical data.
- Availability of geotechnical data. Geotechnical data is generally stored in two ways:
    - Kept for reference only and may be obtained only in paper format or non-editable digital version (pdf/tiff)
    - Archived in digital format for databases creation. This data are often a subset of a larger dataset (for example only the geological description is digitised but the test are not included). In many cases the maintenance of large geotechnical databases is

done with public funding. The data are free only for public projects (spatial management, municipality services, public information, construction of public infrastructures, etc...). In the case of private projects, the geotechnical data has to be bought.

- Legal framework. Who owns the geotechnical data? Who can use and re-use geotechnical data? In many cases there is no legal framework in place, so private site investigation companies don't have to share their data. Only legislation can solve this problem. There are some cases of re-using of geotechnical data. Only the interpretation of data is shared, but not the raw data. From the point of view of managing and modelling the subsurface only the raw data is useful.

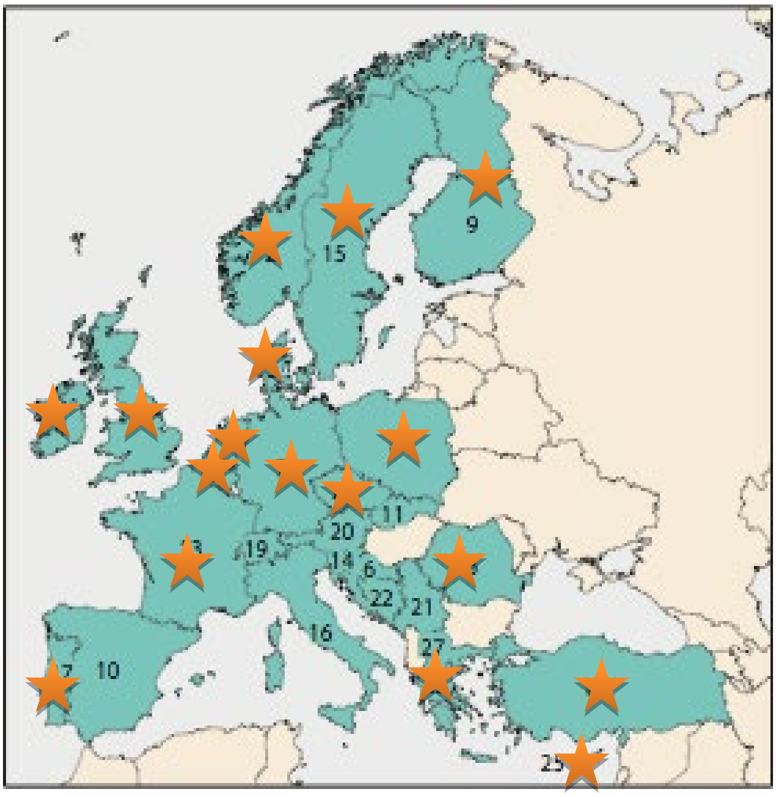
2.2 Availability of geotechnical data – an European overview

The need to extend and intensify the usage of geotechnical data for suburban space management in city areas has increased. The efficient use of geotechnical data is often limited by its availability. This type of subsurface data is collected mostly by private companies and it is not easily available for Geological Surveys and municipalities .The main purpose of this report is to present an overview of the situation with geotechnical data in the COST Countries.

To obtain a real picture of the availability of geotechnical data in the COST countries some questionnaires were done. The questionnaire included questions about the organisations that collect the geotechnical data, the availability of geotechnical data, data format and usage across COST countries. Legal framework was also covered, especially with regard to two questions: Who owns the geotechnical data? and who can use and re-use geotechnical data?

The format of the questionnaire was developed to allow a qualitative evaluation of results.

The geotechnical questionnaire was sent to all 27 countries participating in COST Action SubUrban (state for September 2014). The feedback was monitored and finally 22 completed questionnaires from 17 countries were sent back, (as seen on the figure 1 and figure 2). Most of those sent 1 questionnaire. Turkey, UK and Ireland sent more than one (4 from Turkey, 2 from UK and 2 from Ireland) 4 countries (Romania, France, Belgium and Sweden) sent their questionnaires for the whole country or for an specific region. **Questionnaires are included in Appendix 1.**



Country	City/Region
Belgium	Flanders
Cyprus	Nikosia
Czech Rep.	Ostrava
Denmark	Odense
Finland	Helsinki
Germany	Hamburgh
Ireland	Dublin, Naas
Netherlands	Rotterdam
Norway	Oslo
Poland	Warsaw
Portugal	Leiria
Turkey	Konya, Bursa, Denizli, Kayseri
UK	Glasgow, Belfast
Macedonia	Skopje
France	
Romania	
Sweden	

Fig. 1. COST Countries that completed the geotechnical questionnaire

In both Turkey and Ireland, the availability of the data is different depending on the city. This is an example of how the collection of geotechnical data is closely related to the projects. This means that depending on the project and where the data is collected, its availability might change.

In these cases, developing a geotechnical data exchange between private companies and public databases (like Geological Survey's) should be promoted by municipalities and goverments.

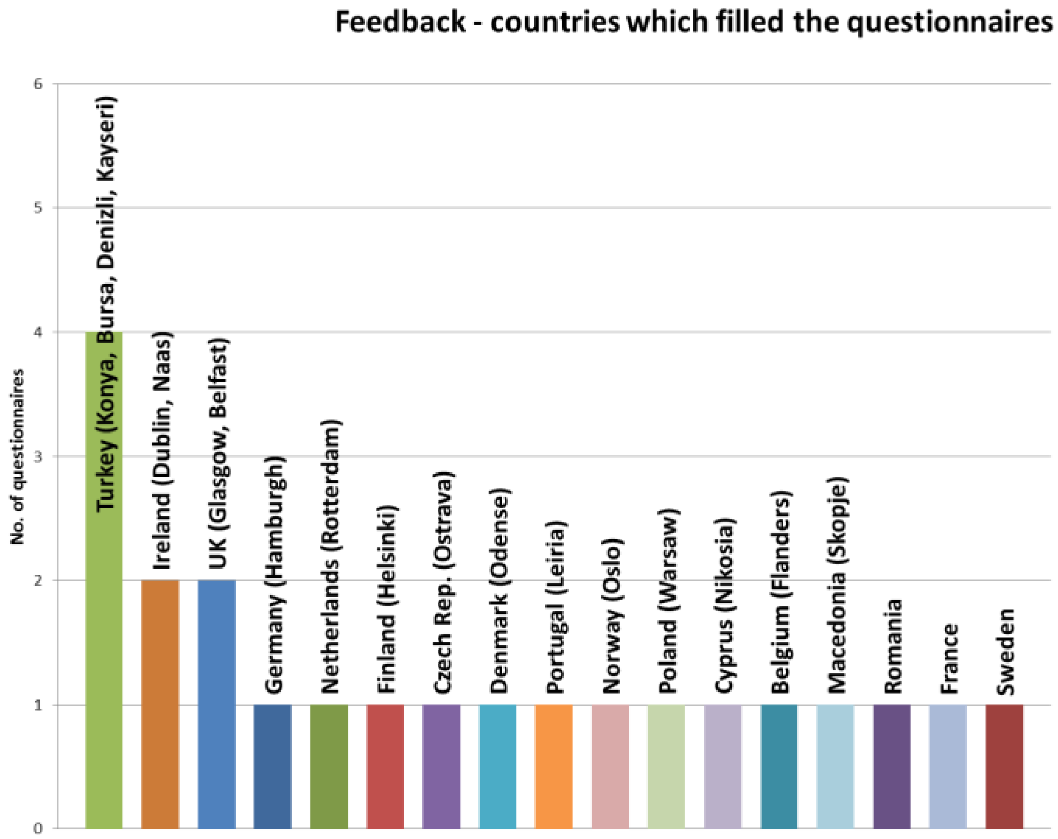


Fig. 2. Feedback from COST countries.

The questionnaires included information about who filled them. On figure 3 there is a summary of the organizations. They are mostly Geological Survey, municipalities and other public organizations. Also universities, private companies and consultants. The occupation of those who filled out the questionnaire was grouped and included: Geologists, Engineers, Geotechnical advisors, Mining Engineers, Information Officers, Data Managers, Project Managers, Professors and Heads of Divisions. Such response gave us a broad overview of the data availability within those countries but also made more difficult to evaluate the results.

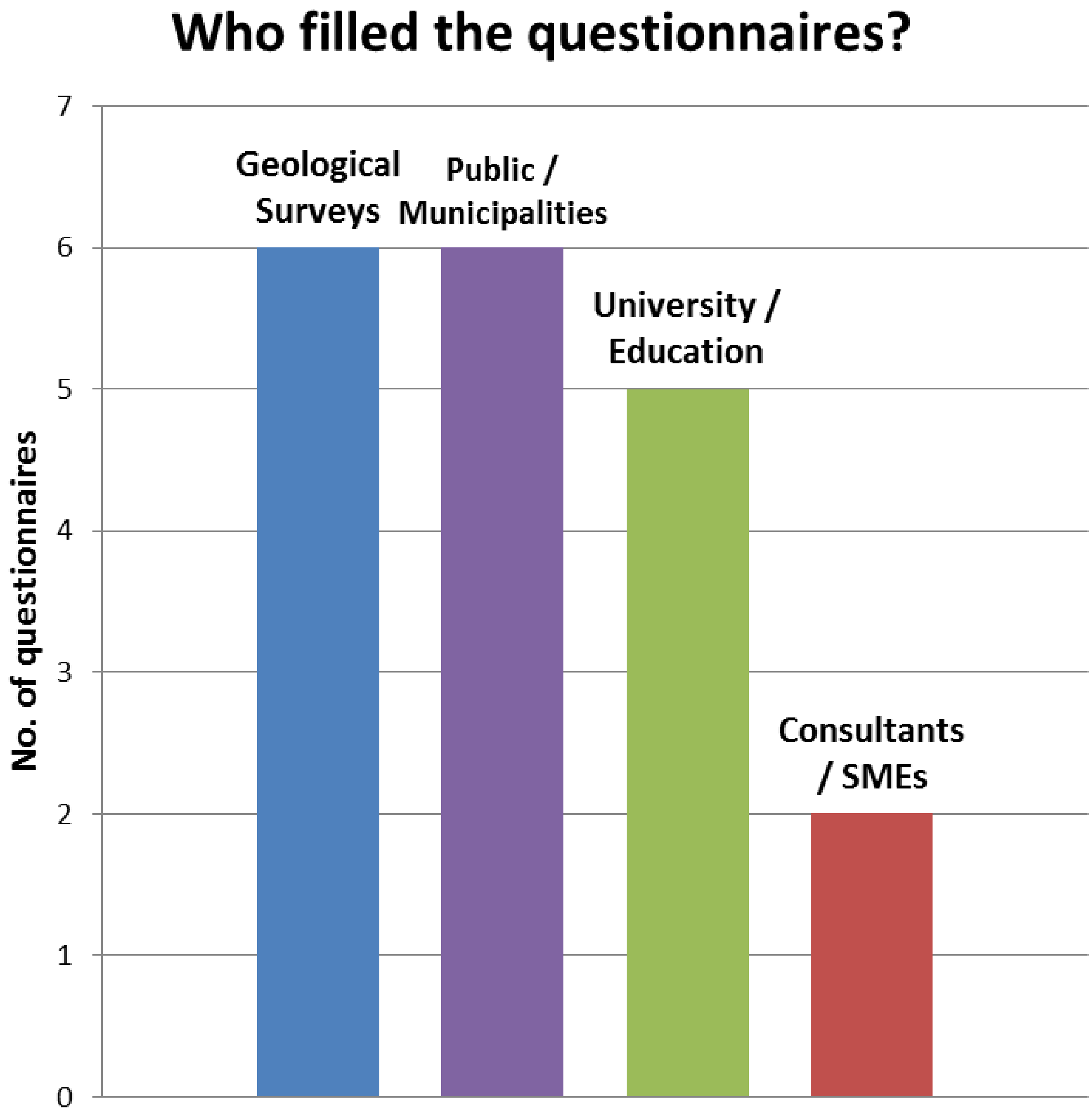


Fig. 3. Organizations that completed the geotechnical questionnaire

The questionnaire was designed to address the problem of geotechnical data availability discussed during COST Sub Urban Meeting in Santiago de Compostela in September 2014. The evaluation of the questionnaires was made in a qualitative way, which allowed us to have an overview of the data availability in the COST countries. Answers for each question were classified into 3 or 2 categories and then presented in form of a graph. The graphs are presented on the figures 4 to 7. With this approach it was easier to generalise the conclusions obtained from the completed questionnaires. The questions asked were:

- Who owns the data? What kind of geotechnical data is collected by public and private organizations? What type of geotechnical data is collected: in-situ test, laboratory test, geochemical laboratory test, borehole log description, ground water level measurements, hazards, etc...?

- Which format is the data collected (digital or paper)?
- Is geotechnical data available for the public for free or does it cost ?
- How is the data used? Is data kept for reference or used to build databases, is it shared with other companies, organizations?
- Is there any legislation regarding the collection of geotechnical data?
- The detailed answers for other questions, listed below could be found in filled questionnaires attached to this report.
- Is geotechnical data used by the owners/designers/contractors only?
- If geotechnical data is submitted to licensing authorities as part of license application, how is this data used by the licensing authority?
- Who owns geotechnical data? Are there any legal provisions regarding the depth of drilling?
- Who owns the underground resources (soil, rocks, water, etc.) in a private property? Up to what depth and what characteristics?

The questionnaire also included a request for persons who answered them to write any comments/ suggestions/ regarding the collection and use of geotechnical data at city level.

Note: If in the evaluation graphs any country is missing, this means that that field in the questionnaire was left empty or the answer given was difficult to evaluate.

Who owns the data? Organization types.

Geotechnical data is owned mostly by public bodies and private companies. In France and Cyprus (Nicosia) the geotechnical data is owned mostly by pubic bodies whereas in Ireland and Turkey is the private companies who own most of the data.

From these results we can conclude that geotechnical data is very heterogenic and is kept in different places (archives, repositories and local databases), therefore to access it can be very time consuming. This can impact in its use and re-use for large scale analyses (like city scale 3D parameterized models and maps). Also the incompatibility of the geotechnical data is one of big barriers towards the widespread use of geological and geotechnical 3D data within BIM (Building Information Systems) and GIS systems.

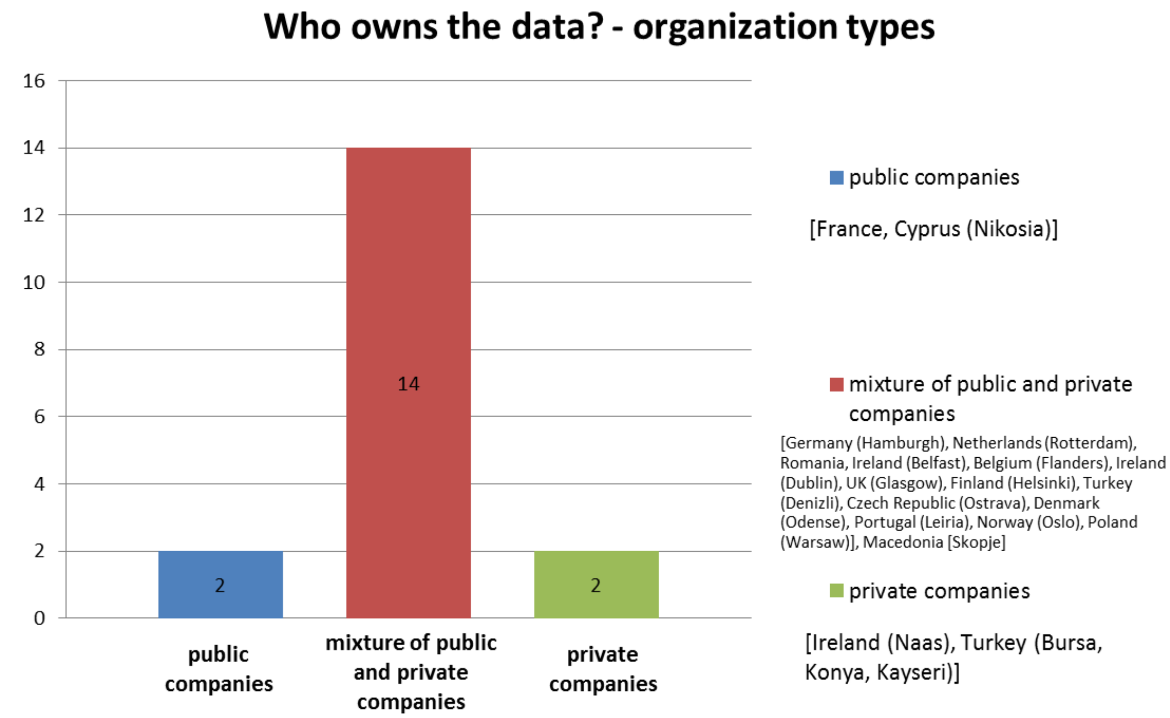


Fig. 4. Who owns the data? – organization types.

Type of geotechnical data – Paper or digital?

The results of the questionnaire show, that the most common way of collecting geotechnical data is in a mixed format. Data is collected both in paper and digital format (see Fig.5). Six countries have their geotechnical data collection mainly in digital format (Netherlands, Belgium, Ireland, Finland, Denmark, Portugal, Norway and Sweden). In some countries (Romania, Turkey, Cyprus) geotechnical data is still collected mostly in paper. There is a tendency towards the full digitalization of collected data. A lot of the digital data in the geotechnical archives is non editable pdf/tiff (scans) documents. It is essential the development of efficient tools and workflows for the digitalisation of archived borehole logs, geotechnical soundings logs and laboratory tests reports.

New geotechnical boreholes and soundings should have their exchange standards (like AGS format) implemented. Only digital, interoperable format should be used for the collection of new geotechnical data. For example in Belgium (Flanders) and in the Netherlands there are exchange standards (xml for Flanders and xml BRO for the Netherland). They are not the same, therefore Flanders could not use the Dutch exchange standards because they have different ways of documenting geotechnical data.

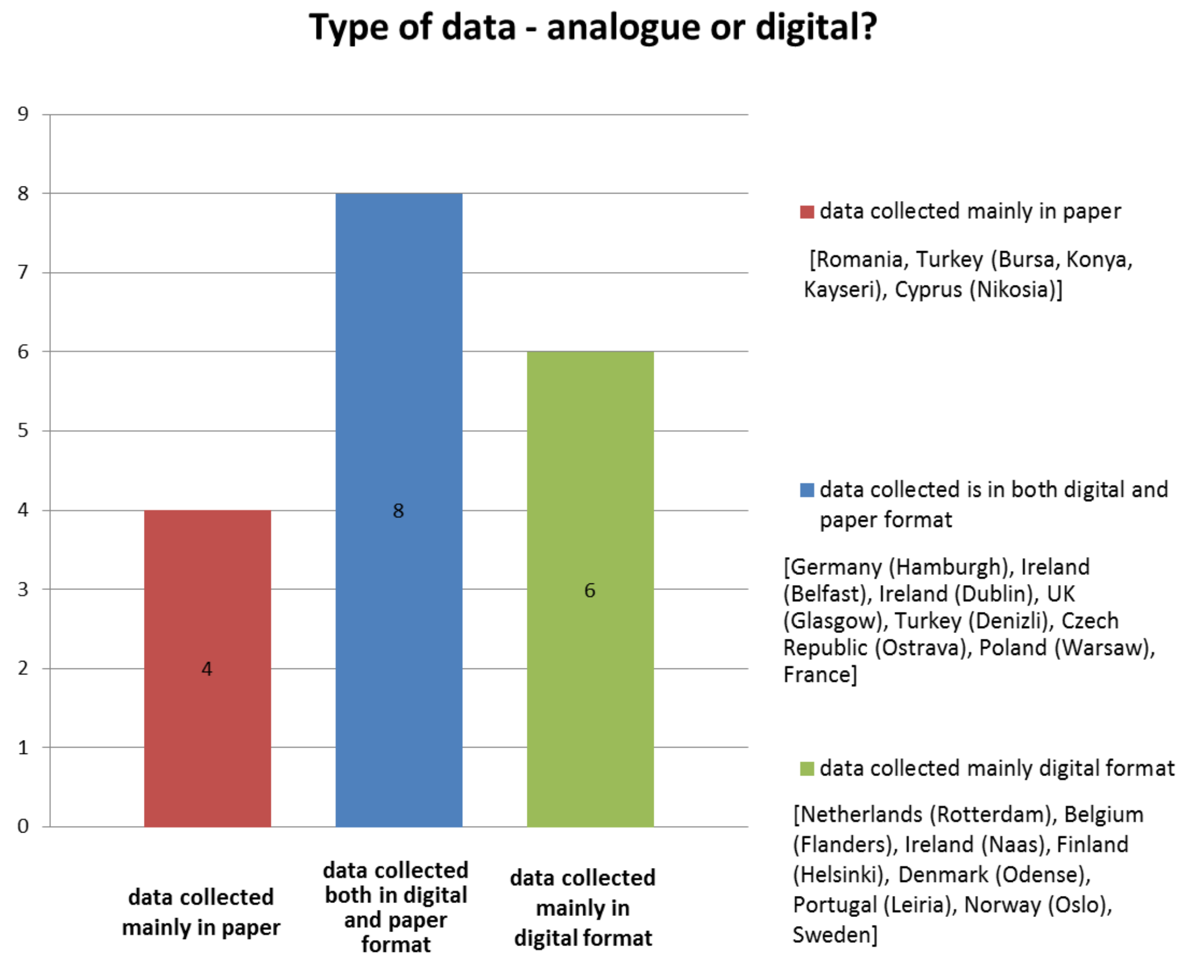


Fig 5.Type of data – paper or digital?

Use of data – for free or for a fee?

The results shows that in some countries the data is free, in others you have to pay. In Netherlands, Denmark, Sweden, Romania and France the geotechnical data stored in public databases are available for free. On the other hand, in many cities, geotechnical data is kept for reference only and not free.

There is a tendency towards the open data policy. To make this approach a standard in many countries a lot has to be done, starting from the creation of a legal framework that will help in the data sharing between private companies, Geological Surveys and municipalities. Database management requires a lot of maintenance costs, so probably some payment for geotechnical data will always exist to cover these costs. If database's maintainance is public funded , then the data is often for free for public projects.

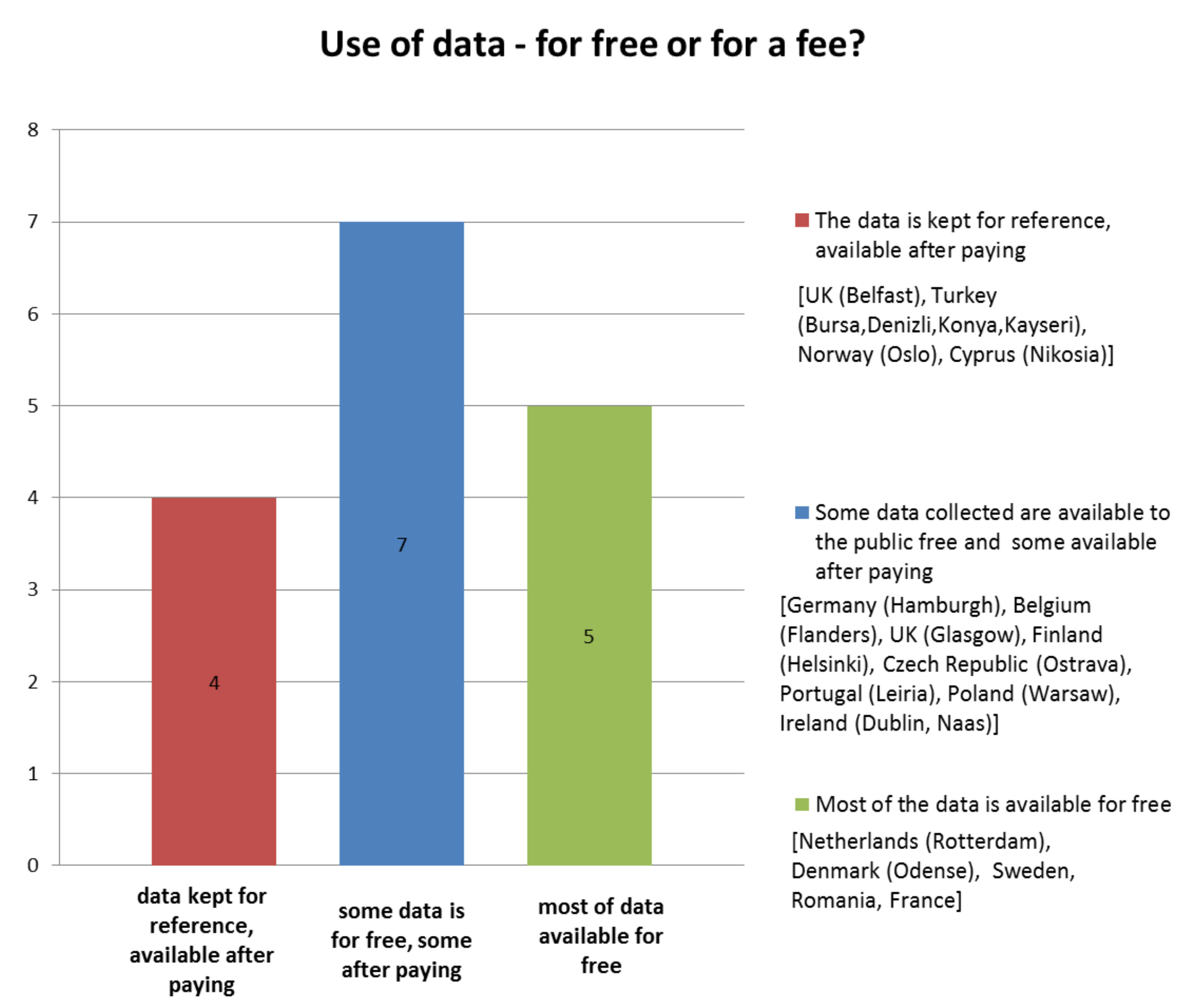


Fig. 6. Use of data – for free of for a fee?

How geotechnical data is used?

The results shows, that data is used in most cases to build databases, however keeping data only for reference and only in archives is still persistent. The databases are built mostly by Geological Surveys and or by municipalities departments or public organisations. A lot of private companies have their own databases and archives.

Building centralized and interoperable geotechnical databases is necessary. Without centralized databases further processing and analyses for the city needs will not be effective and even possible. This brings a big need for guidelines and set of good practices on topics such as:

- Tools and workflows for digitalisation of analogue data
- Management of controlled glossaries of soil/rock symbols, stratigraphy, etc...,

- Data interoperability standards (like AGS format)

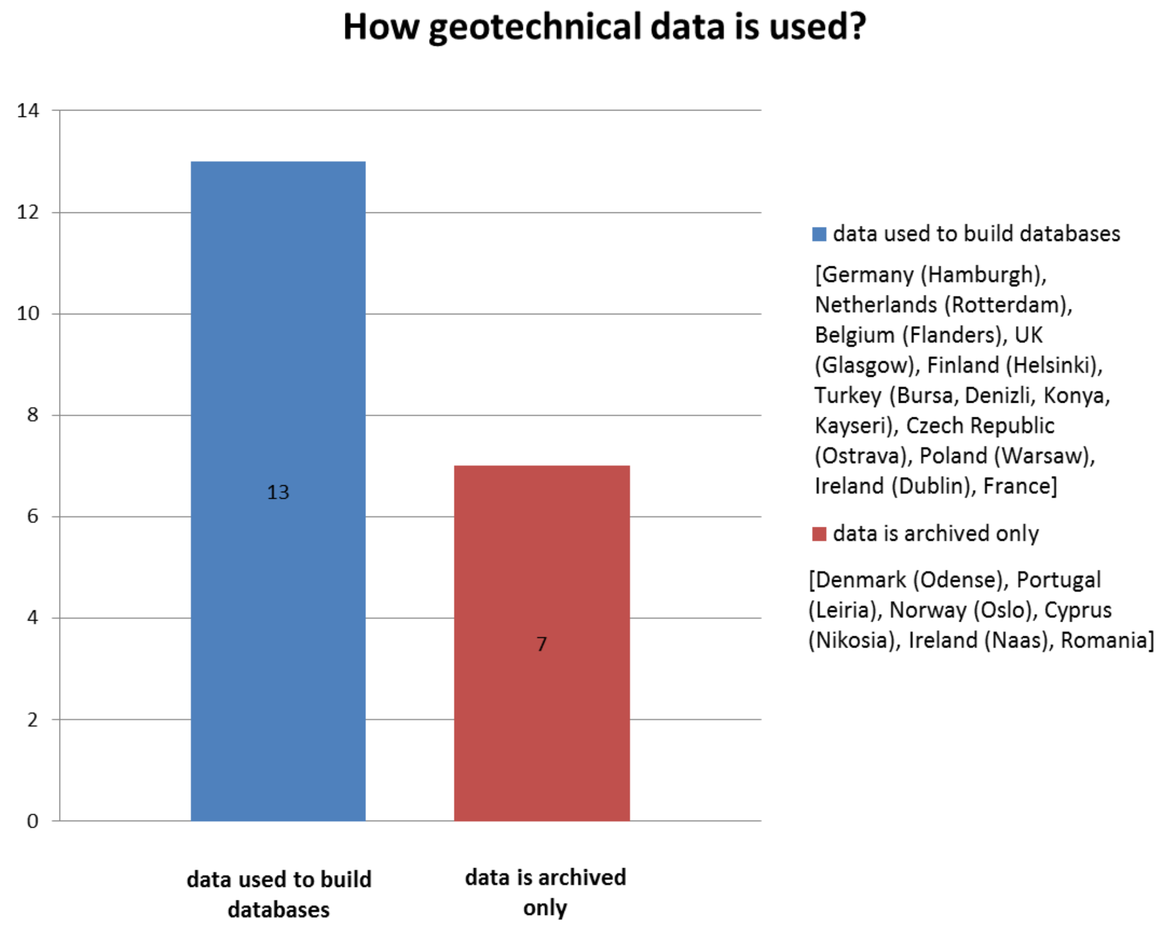


Fig. 7. How geotechnical data is used?

Legal framework for geotechnical data collection

The results show two tendencies about regulation of geotechnical data collection:

- Those who have a legal framework regarding the collection of geotechinical data. The regulations given for geotechnical borehole data collection often give requirements of depth (for example >10 meters in France) or size of construction projects (for example on the basis of III geotechnical category, and in some cases II category, according to Eurocode 7 – this type of approach is used in Poland). This means, that even with the legal regulations still only part of geotechnical data is being archived by Geological Surveys databases and their equivalent public organizations (like DOV database in Belgium/Flanders).

The legal regulations often cover only borehole data, as for other geotechnical data (like cone penetration data or laboratory tests results) there are no regulations. As a result of this a lot of useful geotechnical data remains unavailable for the municipality, Geological Survey and public projects.

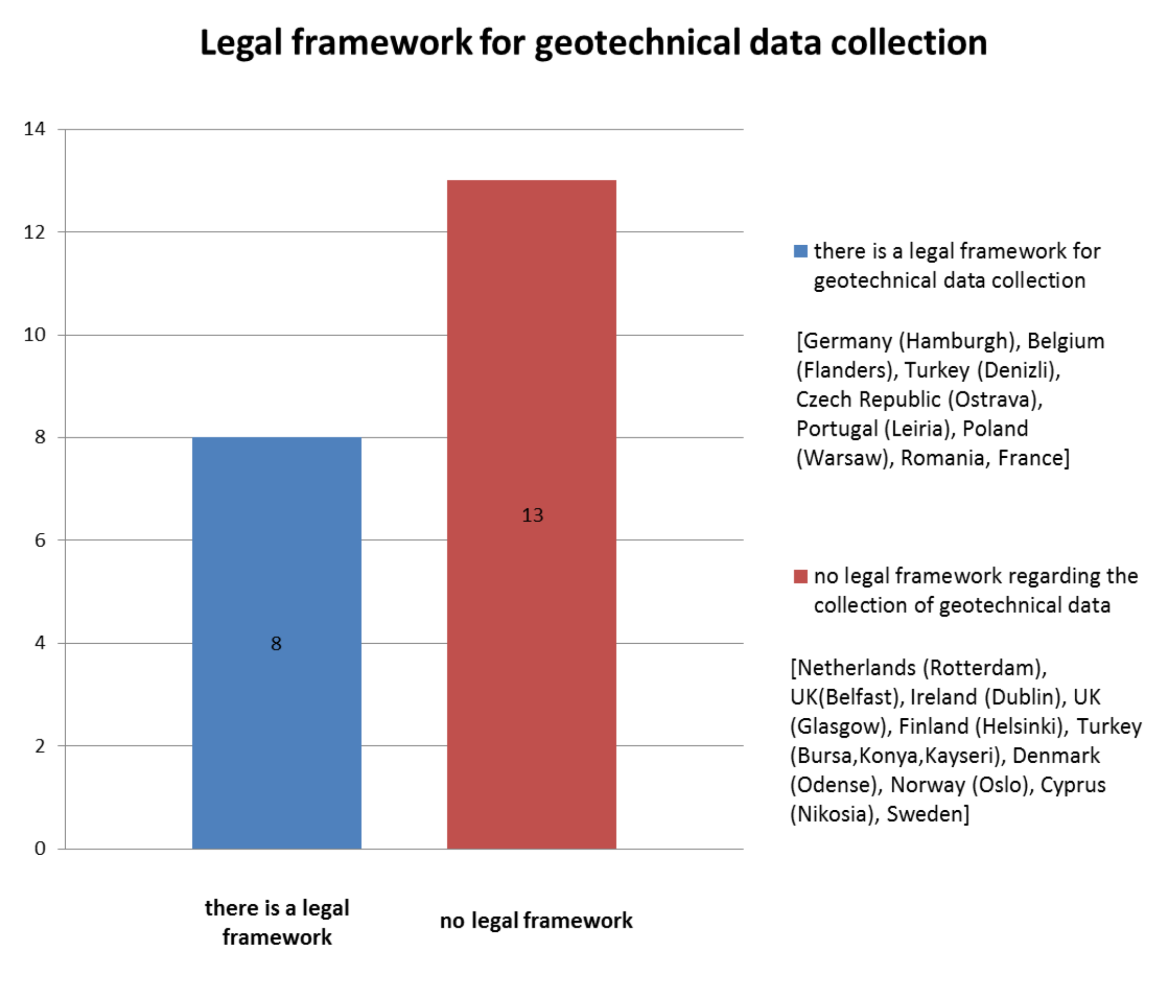


Fig. 8. Legal framework for geotechnical data collection.

- Those who don't have a legal framework regarding the collection of geotechnical data. All geotechnical data is coming mostly from private companies and is stored in public databases only as a "good practice" between the private companies and the Geological Surveys, or other public organizations. Good example of data exchange can be seen in Glasgow where the ASK network (Accessing Subsurface Knowledge) was developed to connect private companies, municipality and the British Geological Survey (BGS). Companies can use and re-use the geotechnical data stored in the BGS's database and the derived products from the database processing. There is still a lot to be done to improve the cooperation between private companies and public organizations in regard to the collection of geotechnical data and data exchange.

Summary and recommendations

From the results of the questionnaires we make some general conclusions and recommendations in relation to geotechnical data availability:

- Open data policy is the right direction, access to geotechnical data should free, geotechnical data exchange frameworks should be developed
- Geotechnical investigation results are very valuable for companies and investors therefore the approach of a free access to processed data seems the most reasonable solution. Processed geotechnical data can include: maps, regional statistics or 3D models. Raw geotechnical data for individual processing (including detailed borehole profiles and geotechnical soundings readings and logs) would be kept by the owners
- Development of geotechnical databases is needed. Without such databases future implementation of widespread use of GIS and BIM systems would be limited
- Development of geotechnical databases brings the urgent need for the implementation of geotechnical data exchange standards and controlled glossaries of certain database fields (e.g. Eurocode/ISO soil and rock classification, stratigraphy, genesis, etc.)
- Geotechnical data exchange formats should be disseminated in form of specifications (for example AGS format)
- Data gathering tools must be developed in order to minimize transcription errors in databases. Databases need to have quality assurance in order to be effectively used for further GIS/BIM analyses or 3D geotechnical modelling
- Geotechnical databases can help to fill a gap between city scale data (1:10 000 scale) and site specific data (1:500 scale)
- Legal regulations are the main driver for geotechnical data to be storaged in geotechnical databases. If there is no national legislation for geotechnical data, then solutions for data exchange between private sector and public databases holders (Geological Surveys) and municipalities is needed.

Current State	Desired State	Gap Description	Gap Reason	Remedies
There is a large heterogeneity of geotechnical data sources. Many private companies and public organizations collect geotechnical data on their fields of activities (water services, railway and road infrastructure, etc...). Geotechnical data kept in many different and often isolated and incompatible places (archives, repositories and local databases)	Geotechnical data should have the same unified format and content. Procedures for geotechnical data collection and storage should be unified. All data should be kept in structured databases and in digital and editable format.	Legal framework for geotechnical data collection is different in all questioned countries. The owners of most geotechnical data are mostly private companies and investors, who are not interested in sharing the data.	Companies and investors see no profits in sharing their data. Companies and city planners are often not aware of the benefits of sharing the geotechnical data.	Solutions like ASK Network. Exchange of data between companies – city authorities – geological surveys. Knowledge exchange. Legal regulations. Publication of freely available data models and exchange standards.
Lots of geotechnical data is archived in paper format or is just scanned and stored as a non-editable pdf files. This situation limits the usability of geotechnical data gathered in public and private archives.	All available data should be in an editable format, stored in database. Such state would allow reprocessing the geotechnical data and would shorten the time needed to access the necessary information for the planners and for investors for the feasibility studies for new projects. Implementation of unified, open geotechnical data model would allow the use of importing applications for the borehole data, soundings and lab tests.	As geotechnical data is mostly site-specific and generated by the private companies, the integration of information on the city scale level is difficult. Archival data is mostly mixed format, paper and digital.	Companies use different software and methods to create their site investigation reports and borehole logs. The data is reported for the clients often only as hard copy or pdf and MS_Office files, with no source and editable data. In most countries there are no guidelines for geotechnical database structure standards and geotechnical data exchange standards.	Toolbox: Workflow for digitalization of geotechnical data. Standard exchange format for geotechnical data Geotechnical data models

3. **Geotechnical databases**

I Vergauwen, G Van Alboom, M Van Damme, V Vanwesenbeeck, B Mozo, K Majer, G Ryzynski

Key words: geotechnical databases, 3d models, geotechnical data, geotechnical parameters, data sharing and exchange.

Introduction

Main sources of information about the city subsurface are the databases, maps and geological models maintained mainly by Geological Survey Organisations. Other sources of relevant information include archives held by municipalities, some of which have their own borehole records, maps and databases. In city areas, there is also a considerable volume of data about underground space held in form of geotechnical data. The geotechnical data are typically “site specific”, and are gathered for specific construction projects. This type of subsurface data is collected mostly by private companies, is generally not readily available to meet the needs of municipalities (e.g. for master planning, cultural heritage, road- and railway building) and/or Geological Survey Organisations (e.g. for the development of maps and geological models). Efficient use of geotechnical data for city scale modelling is often prevented by its restricted availability.

Geotechnical data is very important for modelling and managing the subsurface in cities. It includes boreholes and numerous amounts of geotechnical soundings and laboratory tests. These huge array of geotechnical testing methods (including most common field tests such as: CPT, DMT, SPT, DP, PMT, FVT as well as specific laboratory tests: for ex. TXT, OED, BET, permeability and organic content) give us a number of parameters to fully characterize the subsoil. The most common interpretation of geological structures, based only on lithology and stratigraphy is not sufficient for modelling of construction subsoil. The character of the geotechnical data is “site specific”. Geotechnical boreholes and cone penetration tests (CPT) are mostly shallow, down to average 30 m and cover only top layers of the geological borehole, but due to associated geotechnical data including in-situ and laboratory parameters, they are very valuable for parametric 2D and 3D modelling of the zone of construction and soil-structure interaction in city areas.

Geotechnical data are key to effective parameterising of 3D models. Geological 3D models contain mostly basic geological information on lithology and stratigraphy. More pertinent parametrization is needed in order to influence construction-related decision-making. This requires access to a range of geotechnical data. Both physical and mechanical parameters from geotechnical databases can be used for 3D model parameterization. Key parameters include: bulk density, moisture content, grains size distribution, friction angle and cohesion, oedometric modulus, etc.. Such parameterized models can help to fill the gap between city scale data (1:10 000), which provides the geotechnical context to sites, and site-specific data (1:500). Spatial planning and feasibility studies for new large construction projects should use such parameterized 3D models as a starting point in their geological risk assessment and planning of site investigation.

Geotechnical models and databases can be of significant use for:

- Preliminary investigation of the subsoil/soil prior to in situ testing (desk studies, geological risk analysis)
- Planning and interpretation of in situ tests (and subsequent lab tests)
- Reporting of raw data (for modelling and implementation in GIS and BIM systems)
- Advanced use of data and policy making (by experts and city planners)
- Communication and increased understanding of the importance of city subsurface

Good practices

To present examples of good practice in the use of the geotechnical models and databases in relation to city subsurface management, the DOV database from Belgium has been chosen.

The mission of DOV (Databank Ondergrond Vlaanderen / Regional database of the subsoil/soil of Flanders) is to structure and manage all data and information concerning the soil and subsoil of Flanders and make them widely available (see database website http://dov.vlaanderen.be). DOV is a geotechnical database intended as a platform to foster for cooperation between partners. The data and information concerning the soil and subsoil of Flanders are made available in an integrated way, and are supported by controls and reporting on their quality.

The data in DOV originate from the activities of DOV's private sector partners. The data relate to geology, geotechnics, groundwater and soil. Since 2013, geothermal data have been added to DOV.

The geological information in the database include drillings, lab tests, geological interpretations (Quaternary, Neogene-Paleogene (Tertiary), Cretaceous, faults), 3D mapping (see Figure 9), related drill logs and lab test data, etc. The geotechnical information in the database include drilling data, cone penetration tests, geotechnical laboratory tests, and other geotechnical interpretations, thematic maps, etc.

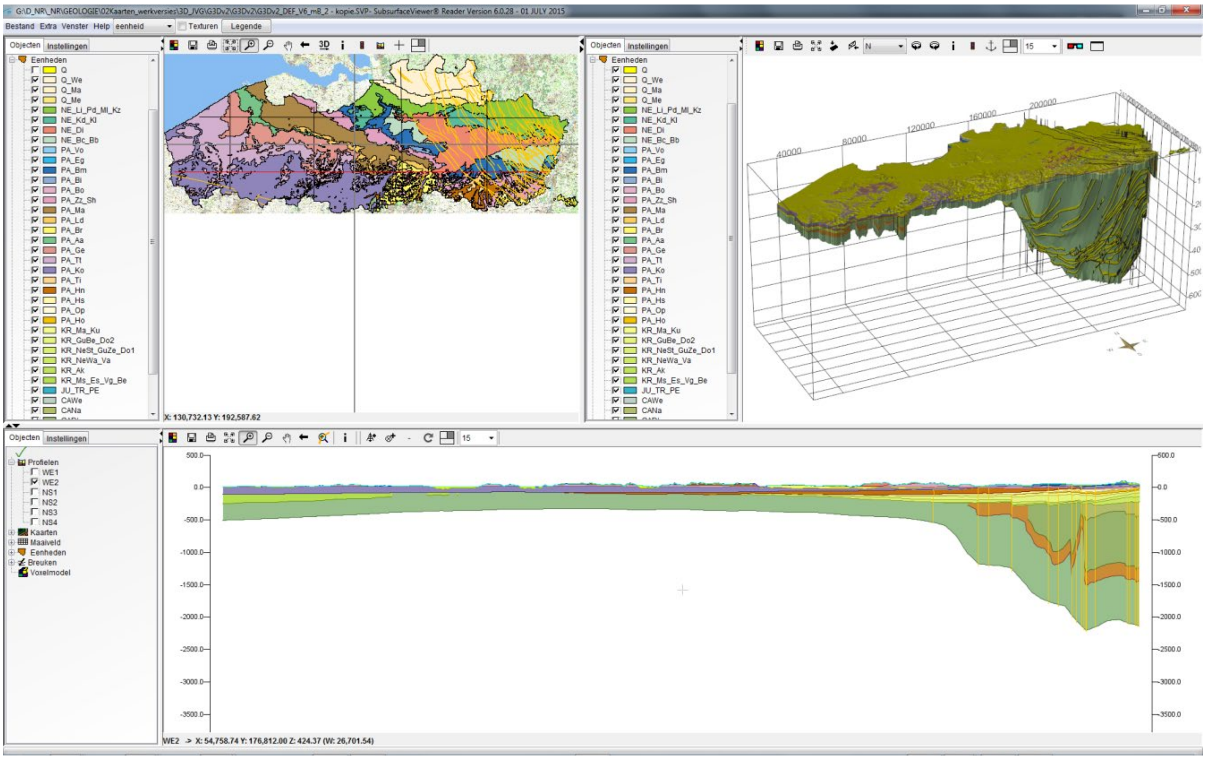


Figure 9. Impression of geological 3D model in the 3D SubsurfaceViewer® with a) 2D map, b) 3D view, c) cross section generated from the model. Geological 3D Model (Matthijs et al., 2013) published at http://dov.vlaanderen.be

The main advantage of bringing all the data from the different sources together in DOV is that they can be consulted and re-used by DOV's partners and other interested parties. The reuse of these data is not without problems. The data are not a substitute for ground investigation on current projects, and data should only be used as reference data in a geotechnical setting, mainly because of the inaccuracy, particularly in older data, of the location of observations, drill sites, and in situ tests.

DOV is multidisciplinary, and offers subsoil/soil information for a wide range of applications: geotechnical design, environmental studies, geological mapping, groundwater modelling, groundwater policy, and scientific research. Therefore, users of DOV can be found within a wide range of organizations, such as governmental institutions, universities, consultancy firms, the wider private sector, municipalities and even the public.

DOV database applications are divided into internal and external applications. Internal applications are available only to DOV partners; more than 300 partners can log into DOV to use these. The external applications are available on the internet (http://dov.vlaanderen.be) and can be used by anyone free of charge. The daily monitoring of the applications indicates an average of 250 users per day.

Among several other geotechnical databases, with similarities to DOV are the Geological Survey of Ireland's (GSI) National Geotechnical Borehole Database (see http://spatial.dcenr.gov.ie/GeologicalSurvey/GeoTechnicalViewer/index.html) and Polish Geological Institutes (PGI) Engineering-Geological Database (see http://atlasy.pgi.gov.pl).

More details for good practices of geotechnical databases can be found in Appendix 2.

Geotechnical databases can be used to generate a wide range of 2D and 3D outputs that can be applied directly to urban needs. Examples of such outputs include the foundation conditions map (1:10 000 scale) prepared directly for city spatial planning in the city of Łódź in Poland, and a 3D model of the Quaternary cover for the city of Dublin (Ireland) presented in figures 10 and 11 respectively.

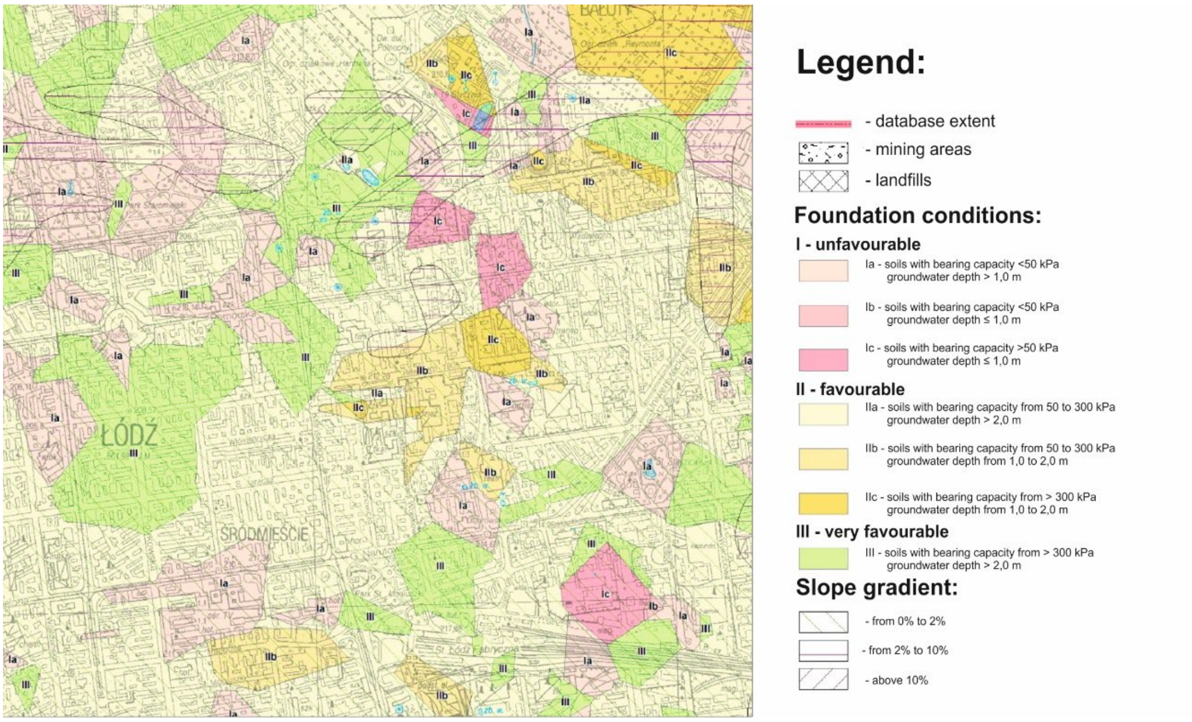


Figure 10. "Traffic-light" map with foundation conditions (based on soil type and ground water depth) at the 2,0 meters below ground level. An example of geotechnical database processing 2D product oriented for city master planning (for the city of Łódź in Poland).

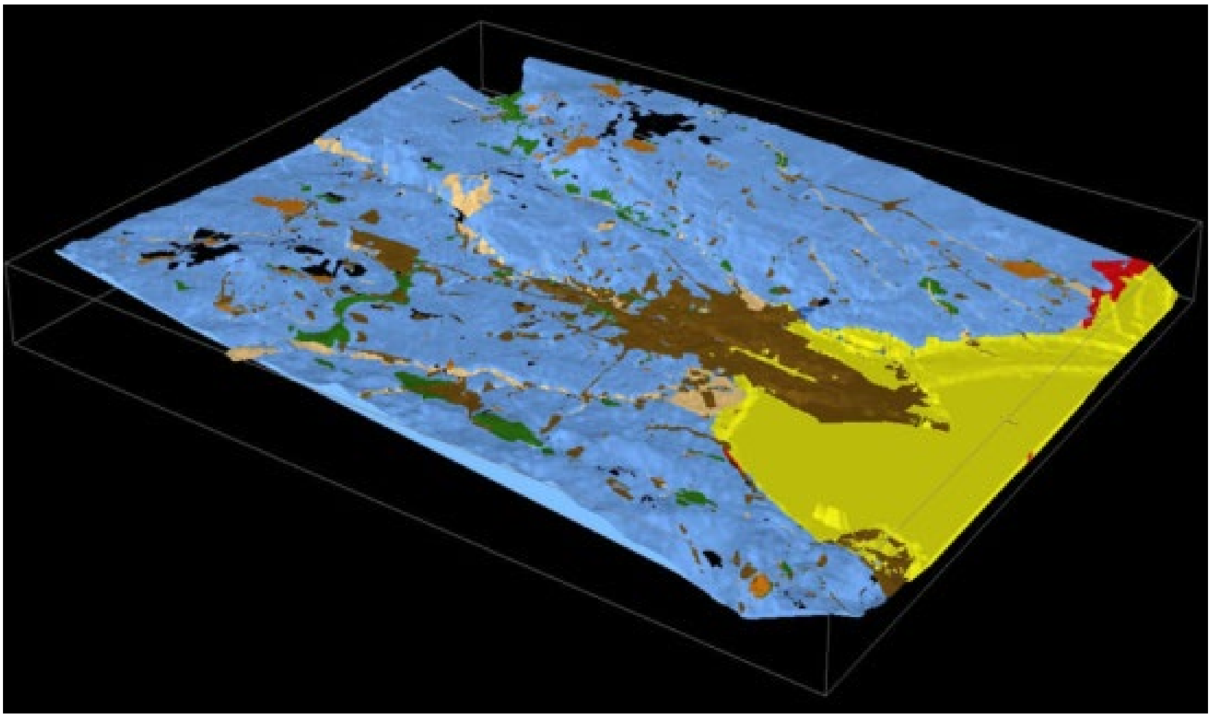


Figure 11. 3D model of the Quaternary Geology in Dublin City, Ireland (blue is glacial till, red is estuarine sediments, yellow is marine sediments, green is glaciofluvial sand and gravels, brown is made ground, orange is top soil and light cream is alluvium)

Knowledge gaps

Current State	Desired State	Gap Description	Gap Reason	Remedies
Availability of geotechnical data is limited due to legal framework. As private companies own most of the geotechnical data the use and re-use geotechnical data is limited. Geological Surveys archive only part of available geotechnical data.	Cooperation between private companies, city planners and Geological Surveys. The Geological Survey takes the role of geotechnical information storage, both city planners and private sector benefit from that solution. The Geological Survey can develop a data importing/exporting application so geotechnical exchange formats can be implemented. The processing of data is made by the Geological Survey. Integration of site-specific geotechnical data allows preparation of city scale products (maps, 3D models, WFS and WMS GIS services), that are then used by private sector and city planners. This approach, based on mutual benefit cooperation should also be supported by legal regulations.	There are specific conditions of geotechnical data re-using, that allow to share only the interpretation of data, but not the raw data. From the point of view of managing and modelling the subsurface only the raw data is useful.	Geotechnical data is gathered during mostly private projects. Geotechnical laboratory and in-situ tests are expensive and their results are valuable for the companies. Companies must see the benefit of sharing their data with geological surveys and city planners.	Presentation of good practices (benefits) of geotechnical data sharing. Legal regulations.
Geotechnical data is essential for parameterization of 3D models. Geological 3D models contain mostly basic information (lithology and stratigraphy). More parametrisation is needed and this can be provided by the use of geotechnical datasets.	The physical and mechanical parameters from geotechnical databases can be used for 3D model attribution. Such parameters should include (bulk density, moisture content, grains size distribution, friction angle and cohesion, oedometric modulus, etc.). Such parameterized models can help to fill a gap between city scale data (1:10 000) and site specific data (1:500). Spatial planning and feasibility studies for new big construction projects should use such parameterized 3D mode as a starting point for geological risk analyses and further site investigation planning.	Databases of geotechnical data and geological databases of geological survey that create 3D models and maps are not integrated. Geotechnical databases use Eurocodes and national standards, geological databases use their own developed glossaries. Another issue is data quality – as geotechnical data sources are of different quality creation of large scale geotechnical 3D models is very difficult task.	Geotechnical data is gathered during mostly commercial projects. Geotechnical laboratory and in-situ tests are expensive and their results are valuable know-how of companies. Companies must see the benefit of sharing their data with geological surveys and city planners.	Presentation of good practices (benefits) of use of parameterized 3D models for spatial planning and geological risk analysis and site investigation planning.

References

DOV - original database of subsoil for Flanders (Belgium); Cooperation between three divisions within the Government of Flanders:•The 'Land and Soil Protection, Subsoil and Natural Resources Division' of the Department of Environment, Nature and Energy, The 'Operational Water Management Division' of the Flemish Environmental Agency, The 'Geotechnics Division' of the Department of Mobility and Public Works. (http://dov.vlaanderen.be)

Geological Survey of Ireland GSI, Department of Communications, Energy and Natural Resources - Online mapping (http://www.gsi.ie/Mapping.htm)

Polish Geological Survey, Engineering-Geological Database (http://atlasy.pgi.gov.pl).

Polish Geological Survey Landslide Inventory "SOPO" - http://geoportal.pgi.gov.pl/portal/page/portal/SOPO/Wyszukaj3

Boel K., De Nil K., De Rouck T., De Schrijver P., Uitdewilligen D., Van Damme M., Vanthournout L., Vanwesenbeeck V., Vergauwen I. (2007). 10 jaar Databank Ondergrond Vlaanderen - Jubileumverslag 2006. Departement Leefmilieu, Natuur en Energie, Directoraat-generaal, Brussel, 67 pp.

Boel K., De Nil K., De Rouck T., Van Damme M., Vanthournout L., Vanwesenbeeck V., Vergauwen I. (2011) . Databank Ondergrond Vlaanderen - Jaarverslag 2010. Departement Leefmilieu, Natuur en Energie, Directoraat-generaal, Brussel, 34 pp.

Boel K., De Nil K., De Rouck T., Van Damme M., Vanthournout L., Vanwesenbeeck V., Vergauwen I. (2012) . Databank Ondergrond Vlaanderen - Jaarverslag 2011. Departement Leefmilieu, Natuur en Energie, Directoraat-generaal, Brussel, 39 pp.

Algoe C., Boel K., De Nil K., De Rouck T., Van Damme M., Vanthournout L., Vanwesenbeeck V., Vergauwen I. (2013). Databank Ondergrond Vlaanderen - Jaarverslag 2012. Departement Leefmilieu, Natuur en Energie, Directoraat-generaal, Brussel, 52 pp.

Van Alboom G., De Schrijver P., Vergauwen I. (2007). The regional geotechnical database "Databank Ondergrond Vlaanderen-DOV" as a powerful tool for consultation of subsoil information. In: Proceedings of the 14th European Conference on Soil Mechanics and Geotechnical Engineering, Madrid, Spain, 24-27 September 2007, p.1757-1764.

4. **Framework of geotechnical data transfer to increase the knowledge of the city subsurface Accessing Sub-surface Knowledge (ASK) network**

David Entwisle

Key words: geotechnical data exchange, specification for data capture, geotechnical GIS

Introduction

There is a great need to extend and intensify the use of geotechnical data for modelling and management of suburban space. The impingement of new on existing city infrastructure (tunnels, metro lines, underground car parks, and high-rise buildings sub levels) is becoming more and more commonplace, and therefore, the use of geotechnical data and consideration of geohazards on a city scale geological modelling is increasingly necessary.

Geotechnical data are collected mostly during commercial/private projects, so they are often not readily available for use by the municipality, unless there is legislation in place to require the data to be made available (e.g. in relation to the National Key Register (BRO) in the Netherlands, and in national/state legislation in Germany) or there is a prevailing culture of data sharing (e.g. the ASK network in the Glasgow area (UK)). Also, as geotechnical databases are often hosted by widely differing entities (public bodies such as Geological Survey Organisations, or private sector construction, industry and infrastructure companies) the data are likely to be kept in many different locations (archives, repositories and local databases) and in formats which are not interoperable. Another barrier towards greater use of geotechnical data for modelling purposes is the basis of ownership and legal status of the geotechnical data. Hence, many important geotechnical data are not available for wider use/re-use.

Effective use of geotechnical data and geotechnical models will require robust solutions for enabling data exchange between the data providers (private companies), and those who need access to the data (e.g. municipalities and geological surveys). Such solutions must bring mutual benefits to all interested parties, as geotechnical laboratory and in situ tests are expensive and their results represent valuable intellectual property of the companies. Companies must therefore see the benefit of sharing their data.

Framework of geotechnical data exchange

Establishing a framework for geotechnical data exchange between private companies, geological surveys and municipalities is a vital step in improving knowledge of the urban subsurface. Such a task has been undertaken in Glasgow (UK). The primary objective was to develop a network – ASK (Accessing Subsurface Knowledge) – to change the culture of subsurface (geoscience) data and knowledge exchange in the Glasgow conurbation, and beyond. Greatly increasing the impact of geological 3D data and knowledge will be a key result. Also incorporating the clients, consultants and contractors (the private sector) into the data exchange network, and sharing with them the benefit of access to the geological/geotechnical database and related 3D geological models, is an essential step in convincing them, that they can derive a direct benefit from sharing their data with a geological survey organization and local municipality.

The generalized information flow in ASK network is shown in Figure 24. A key aim of ASK is to improve the basis for decision-making, as well as lowering development and regeneration costs, within the Glasgow area, and possibly through expansion of the ASK approach, to other UK cities and city-regions. The ASK network partnership is a mechanism to provide data and exchange knowledge between the public and private sectors. It was initiated by the British Geological Survey (BGS) and Glasgow City Council (GCC), with support from other partners in the public and private sectors (ASK Network).

The ASK network website provides further information:

http://www.bgs.ac.uk/research/engineeringGeology/urbanGeoscience/Clyde/askNetwork/home.html.

The primary objective is to develop a network – ASK (**A**ccessing **S**ubsurface **K**nowledge) – to change the culture of subsurface (geoscience) data and knowledge exchange in the Glasgow conurbation, and beyond. Greatly increasing the impact of geological 3D data and knowledge will be a key result. The intention is to improve the basis for decision making and lower development and regeneration costs within the Glasgow area and possibly other UK cities. The ASK network partnership is a mechanism for the provision of data and knowledge exchange between the public and private sector. It was developed by the British Geological Survey (BGS) and Glasgow City Council (GCC) as the major partners, with support from other partners in the public and private sectors (ASK Network).

History

The British Geological Survey and Glasgow City Council (GCC) have been working together for mutual benefit for over 30 years. BGS produced a series of maps and a report on environmental geology of Glasgow in the 1980’s funded by central Government (Browne and Hull, 1985, Browne et al. 1986). In the 1990’s BGS was contracted to provide a GIS application using a combination of GCC- and BGS-supplied data (Mellon and Frize, 2006). Glasgow was selected by the BGS for 3D geological modelling partly because it is Scotland’s largest city but also because of the relationship between the Council and the Survey (Merritt et al. 2006).

The 3D geological model

The 3D geological models contain anthropogenic deposits (one unit), superficial deposits (30 main units and 18 subunits or lenses) and bedrock (6 units) with a number of major faults.

Accessing Subsurface Knowledge (ASK)

The 3D models were provided as a resource to the Council. An innovation agreement was drawn up to provide the basis for improving knowledge exchange, primarily the models, and the flow of data and information between organizations involved in the use of ground investigation data. This was done with particular reference to the acquisition, interpretation, reporting and recycling of site investigation data. For information and data flow ASK required input and use by the private, public, research sectors with the BGS. For this to happen a network was required that allowed the free flow of data within the various organisation. The ASK network was initiated with launch on the 16th November 2012. Sixty two delegates attended from the public and private including local authorities, geotechnical and civil engineering consultancies and universities (see ASK Network launch 2012, Baron and Campbell 2013 and ASK Network workshop 2014). The ASK Network.

ASK Network Innovation agreement

The ASK network partnership agreement contains the case for the flow of data and information, the aims of the agreement and BGS making the Draft 3D geological model and exports available to the ASK Network Partnership signatories. Restriction on the use of the subsurface information (and data) are to work in connection with Glasgow City Council and other local and regulatory authorities who have signed up to the agreement and that it cannot be used for commercial use outside the ASK Network Partnership without the further permission for the BGS.

Currently, there are 24 organisations that are part of the Network including consultants, contractors, local authorities, regulatory authorities and universities.

Site investigation data and GSPEC

The agreement does not include how the data is to be provided to the BGS. However, all site investigation contracts issued by GCC DRS specify Association and Geotechnical and Geoenvironmental Specialists (AGS) digital data transfer format (Mellon and Frize, 2006).

Glasgow SPEcification for data Capture (GPEC)

To ensure that the data can be accessed and used, the AGS digital data format (Bland 2014, Bland et al. 2014), needs to follow a specification. The GSPEC (Glasgow SPEcification for data Capture) was developed by GCC and BGS. The main requirements of GSPEC are that:

- The AGS data transfer files should follow the rules and conforms to the requirements of the format;
- All point data (trial pits, boreholes and sample) should have British National Grid Reference (x and y) and Ordnance Datum (z).
- AGS data transfer format files are deposited with GCC via a web portal.

The GSPEC data is initially validated by an automated validation process developed by the BGS and is triggered by an online submission to the ASK network portal. This is the responsibility of GCC, as the client. Files that pass the initial validation checks are then sent to the BGS. Only compliant data is added to the NERC databases.

Currently, the geotechnical data is not yet made available to the ASK Network. A tool to extract data from the National Geotechnical Properties Database for an area to prove this concept has been developed for a limited suit of parameters and tables. Further development of this tool along with a web portal could allow the signatories of the ASK Network to access the site investigation data, for planning and desk study purposes. Figure 12 shows the flow mode of geotechnical data, dashed lines are not yet in place.

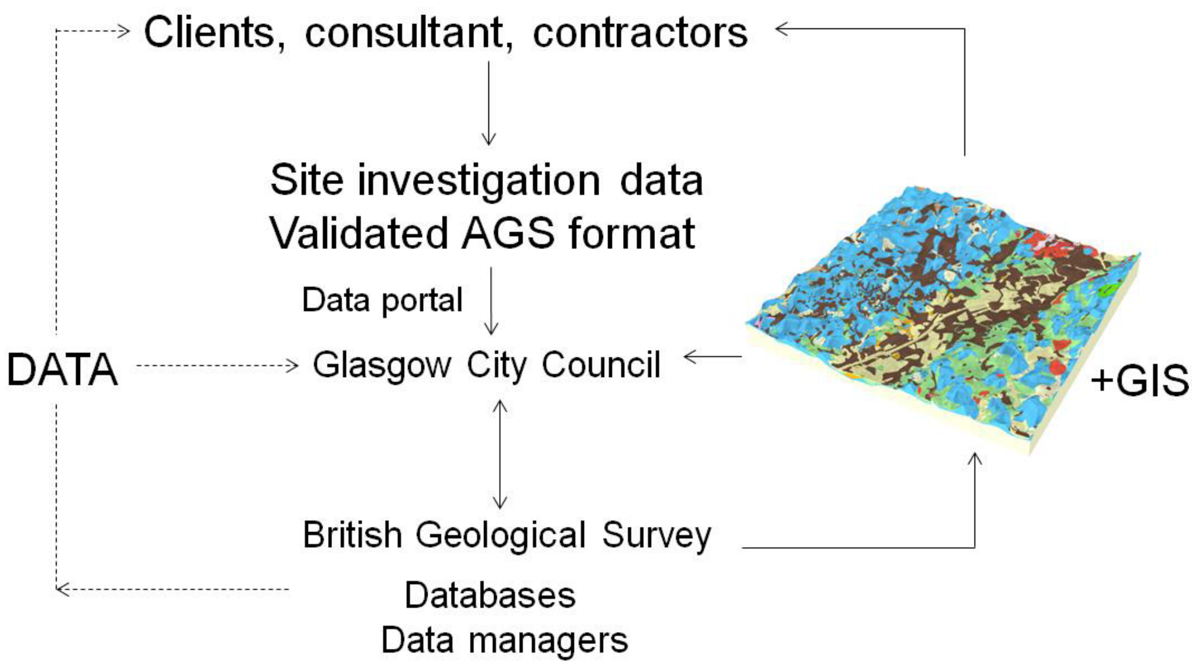


Fig. 12. Geotechnical data and information flow.

Geotechnical GIS

The Geotechnical GIS is a spatially defined geotechnical information system designed to provide geological and geotechnical data and information for Glasgow City Council (Entwisle et al. 2008) and for the ASK network. The GIS (ArcGIS) covers a 10 km square and contains:

- The position and depth of the trial pits and boreholes (data resources);
- The modelled geological units (bedrock, superficial and anthropogenic deposits (shp files), and thickness and tops of bases metres Ordnance Datum (OD) or depth from surface (grid files)
- Information on the legacy of undermining of Glasgow (.shp files)
- A geotechnical and geoenvironmental database, containing data from selected commercial site investigations
- Tools developed:
    - To show pre-drawn summary graphs for the geological units and cross-sections
    - Interactive tool to show cross-plots of data from the database

The geotechnical parameters presented for engineering soil: Water content, bulk and bulk density, undrained shear strength, consolidation parameters, engineering chemistry (solid and water pH, total sulfate, aqueous soluble sulfate, water sulfate, solid and water chloride).

For engineering rock: Bulk and dry density, point load index uniaxial compressive strength.

For *in situ* tests: Standard penetration test, rock quality designation.

The interactive tool allows the user to specify a geological unit from the GIS or from a dropdown list in the table associated with the tool. The database table containing the parameter, as listed above, is then selected and the parameters are chosen from a dropdown list, which includes depth below ground level and height metres OD. An extra classification can be added for the lithology or the Ordnance Survey quarter sheet (5 km x 5 km). The cross plot shows all the data of the parameters. A sub-set of the data can then be selected from the cross-plot or from an area on the map.

The GIS tools have been rewritten several times as the versions of ArcGIS have been changed. It has been rewritten using a different programming language and sit outside the GIS so it is now independent of the GIS version and, with some minor changes should, will be used in other platform perhaps including web applications.

References

Barron, H and Campbell S D G. 2013. Ask Network Partnership. Presentation at Scottish Water, Shieldhall, Glasgow, UK, 30th August 2013. http://www.bgs.ac.uk/research/engineeringGeology/urbanGeoscience/Clyde/askNetwork/docs/BGS_ASK_Network_ScottishWater.pdf (accessed 25/02/2015).

Bland, J. 2014. AGS data transfer format. Ask Network 2, Glasgow City Chambers, Glasgow, Scotland, UK, 4th March 2014. http://www.bgs.ac.uk/research/engineeringGeology/urbanGeoscience/Clyde/askNetwork/docs/Jackie_Bland_ASKNetwork2.pdf (accessed 24/02/2015).

Bland, J, Walthall and Toll, D. 2014. The development and governance of the AGS format for geotechnical data. Advances in Soil Mechanics and Geotechnical Engineering, volume 3, Information Technology in Geo-Engineering. In: Proceedings of the 2nd International Conference (ICITG), editors D G Toll, H Zhu, Ashraf, W Coombs, X Li and M Rouainia. Durham University, 21 to 22 July, 2014. 67-74. IOS Press EBooks.

Browne M A E and Hull , J H. 1985. The environmental geology of Glasgow, Scotland – a legacy of urban surface and subsurface mining. In: Proceedings of the twentieth Forum on the Geology of Industrial Minerals, editors J D Glaser and J Edward Jr. Maryland Geological Survey Special Publication 2, 141-152

Browne, M A E, Forsyth, J H, McMillan, A A. 1986. Glasgow, a case in urban Geology. Journal of the Geological Society 143, 509-520.

Entwisle, D C, Wildman, G, Campbell, S D, Merritt, J, Self, S, Monaghan, A and Reeves, H J. 2008. 3D geological modelling and geotechnical GIS for planning and development: an example from Glasgow, UK. In European conference of the International Association for Engineering Geology, Madrid, Spain, 15 – 20 September 2008. http://nora.nerc.ac.uk/4991/ (accessed 24/02/2015).

Mellon, Paul and Frize, M. 2006. A digital geotechnical data system for the City of Glasgow. In: Engineering geology for tomorrow’s cities, Nottingham, UK, 6th to 10th September, 2006. Editors M G Culshaw, H J Reeves, T Spink and Ian Jefferson. IAEG2006 Paper number 346. http://iaeg2006.geolsoc.org.uk/cd/PAPERS/IAEG_346.PDF (accessed 24/02/2015).

Merritt, J, Entwisle D C and Monaghan. 2006. Integrated geoscience data, maps and 3D models for the City of Glasgow, UK. In: Engineering geology for tomorrow’s cities, Nottingham, UK, 6th to 10th September, 2006. Editors M G Culshaw, H J Reeves, T Spink and Ian Jefferson. IAEG2006 Paper number 394. http://iaeg2006.geolsoc.org.uk/cd/PAPERS/IAEG_394.PDF (accessed 24/02/2015)

5. Geohazards in the urban environment, why planners should take them into account

Igor Peshevski, Milorad Jovanovski

Key words: geohazards, landslides, spatial planning

Introduction

City spatial planning must also take into account areas of existing and potential geohazards. Areas with geological instability have a tendency to reveal themselves during the construction process or during ground investigation. Overlooking the potential for geohazards during spatial planning may lead to serious repercussions (e.g. large material losses, damage to city infrastructure and even injuries and death). The destructive force of geohazards can be extremely very high, although their occurrence is local and often periodic.

There is often considerable information and knowledge about geohazards available in the databases and inventories of national Geological Survey Organisations, and this should be taken into account during spatial planning. However, the awareness of the potential impact of geological hazards amongst planners and stakeholders is often relatively low, so that city plans often fail to take account of this issue or cover it only in a limited way.

Therefore, incorporating geohazards into mapping and 3D modelling is one of the most important issues to address if safe and effective urban development/planning are to be achieved. Since there are already existing recommendations, methodologies and tools for dealing with geohazards, it is rather the intention of this report to bring to the attention of urban planners, the importance of geohazards during urban spatial planning.

Another key issueto assure safe and smart city development is to identify **the full scope of geohazards** and consider them in city planning and geological modelling, to increase public awareness.

A natural hazard is a natural process or phenomenon that may cause loss of life, injury or other impacts, property damage, lost livelihoods and services, social and economic disruption, or environmental damage. The Council of the European Union – Commission Staff Working Paper – Risk Assessment and Mapping Guidelines for Disaster Management defines two basic terms:

- Geohazard (Geological hazard) - A geological process with the potential to cause harm.
- Risk - The likelihood that the harm from a particular hazard will be realised.

To allow practical implementation of geohazard risk assessment and mapping on a city scale, a multi-hazard and multi-risk approach is necessary. All types of natural hazards should be analysed and identified. The comprehensive list of geohazards (according to PanGeo Project 7FP, 2013) is shown in Figure 13. Also, geohazards such as flash flood and groundwater flooding areas should be taken into consideration.

City planners can utilize this information to properly manage city infrastructure development. Spatial plans concerning geohazard areas can give citizens and investors valuable information on their occurrence. This information could be of considerable value to developers at very early stages in their planning of developments for example, but it could also affect the value of land, and existing houses. Such information would though enable more informed choice of design methods and monitoring systems for construction activities.

Considerable opportunities for geohazards identification are provided by remote sensing methods, including satellite imagery (Landsat, Iconos, etc.) and satellite interferometry (e.g. InSAR – interferometry satellite aperture radar).

1	**Deep Ground Motions**	1.1	Earthquake (seismic hazard)
		1.2	Tectonic Movement
		1.3	Salt Tectonics
		1.4	Volcanic Inflation / Deflation
2	**Natural Ground Instability**	2.1	Land Slide
		2.2	Soil Creep
		2.3	Ground Dissolution
		2.4	Collapsible Ground
		2.5	Running Sand / Liquefaction
3	**Natural Ground Movement**	3.1	Shrink-Swell Clays
		3.2	Compressible Ground
4	**Man Made (Anthropogenic) Ground Instability**	4.1	Ground Water Management Shallow Compaction
		4.2	Ground Water Management Peat Oxidation
		4.3	Groundwater Abstraction
		4.4	Mining
		4.5	Underground Construction
		4.6	Made Ground
		4.7	Oil and Gas Production

Figure 13. Geohazards inventory according to the PanGeo Project, http://www.pangeoproject.eu (PanGeo 7FP 2013)

Eventually, geohazard identification will lead to better management of the hazard and risk and planners/decision makers will be able to decide whether to block developments in selected areas, to mitigate the risk, which will enable safe construction, or to prepare early warning systems for specific situations, where higher level of risk can be accepted. In following sub-chapters is discussed the problem of landslie hazard as one of the most pronounced in many European countries.

Landslides in urban environment

The term landslide, as defined by Cruden (1991) for the Working Party on World Landslide Inventory, denotes "the movement of a mass of rock, debris or earth down a slope". Varnes (1978) defined a landslide as "a downward and outward movement of slope forming materials under the influence of gravity".

Landslides can occur in natural ground and in manmade slope, due to natural processes (gravitation, precipitation, earthquakes, etc.), during the process of excavation/ construction, and also in the process of exploitation of structures in an urban area.

Landslides are complex phenomena that affect urban settlements, infrastructure and agricultural and environmentally valuable land in many sloping areas in Europe. There are large number examples for landslides that have caused billions of Euro's for remediation of some urban area. Nowadays, landslide risk is substantially increasing in these areas as a result of growing urbanization and associated infrastructure together with increasing or changing precipitation trends. In Europe, geological, morphological and other geo-environmental settings and conditions are greatly variable, as are the main natural landslide triggers (e.g. rainfall, seismicity and rapid snowmelt). It is generally recognized that mapping landslide distribution (i.e. inventorying) and susceptibility (basically "where" landslides may occur in the future), hazard (basically "where and when or how often") and risk (potential damage or losses) are challenging tasks (Hervás J. 2007). On European scale there is a well-established network of geoscientists who work in the field of landslide hazard and risk. Many projects have been realized on European scale (ZERMOS project, 1970 (Humbert 1972, 1977, Antoine 1978). EPOCH Project 1993, SafeLand 2009, PanGeo 2011) and many others. Numerous congresses, symposiums and workshops are being organized on annual level. All publications have shown that landslides in urban areas are one of the most common natural hazards in many of Europe's cities or villages. Therefore, we found necessary to incorporate the landslide hazard as one important obstacle in the urban development/planning, and it is included in this TU1206 Suburban cost action.

Since there are already existing recommendations, methodologies and tools for dealing with the landslide hazard, our intention is only to brought the attention of the urban planners, and to have them think of the landslide hazard during the process of urban planning. The idea is to get them interested to take a look in existing maps of landslide inventories, landslide hazard and landslide risk wherever they are available / or to follow the recommendations for preparation of such maps, for which that they would ask from the consultant specialist who works in the field of landslide hazard (in most cases experts in Geosurvey of certain Country). Eventually, this will lead to better management of the landslide hazard and planners/decision makers will decide whether to prohibit certain development, to mitigate the risk which will enable safe construction, or to prepare early warning systems for specific situations, where higher level of landslide risk can be accepted.

It should be mentioned however, that landslide distribution on European scale in not equal, and some countries don't have this problem at all. For others, it is the most common, when speaking of natural hazards.

Landslide data - general description of the best practice

Speaking of available landslide data (database, inventory, susceptibility, hazard and risk maps), it can be noted that most countries in Europe have some type of database for landslides (in paper or digital format). Some databases have old and un-updated data and some have very fresh with advanced way of presentation in GIS software. The databases in some cases are established and developed by Governmental institutions, and in some established by the local authorities, or in frame of certain Projects (for example the IFFI project in Italy). However, the existing data is usually with restricted access, but can be found in cooperation with the specialists from this field. Our free estimation is that there are at least 800.000 registered landslides in databases and thematic maps across Europe, which is probably only half of the real number of landslides. Most affected countries are the ones in the Alps: Switzerland, Italy, France, Austria; Spain, Balkan countries, and those on the far East and North of Europe.

As one of the most affected countries, Italy has one of the most advanced database of landslides in Europe. It was prepared in frame of the IFII project (Inventory of Landslide Phenomena in Italy- http://193.206.192.136/cartanetiffi/). It consist of inventory of all registered landslides in Italy with clear distinction of the landslide mechanism, marked zones in which a landslide can progress on to, information for performed investigations on a certain landslide etc. It is web based and easy to use service.

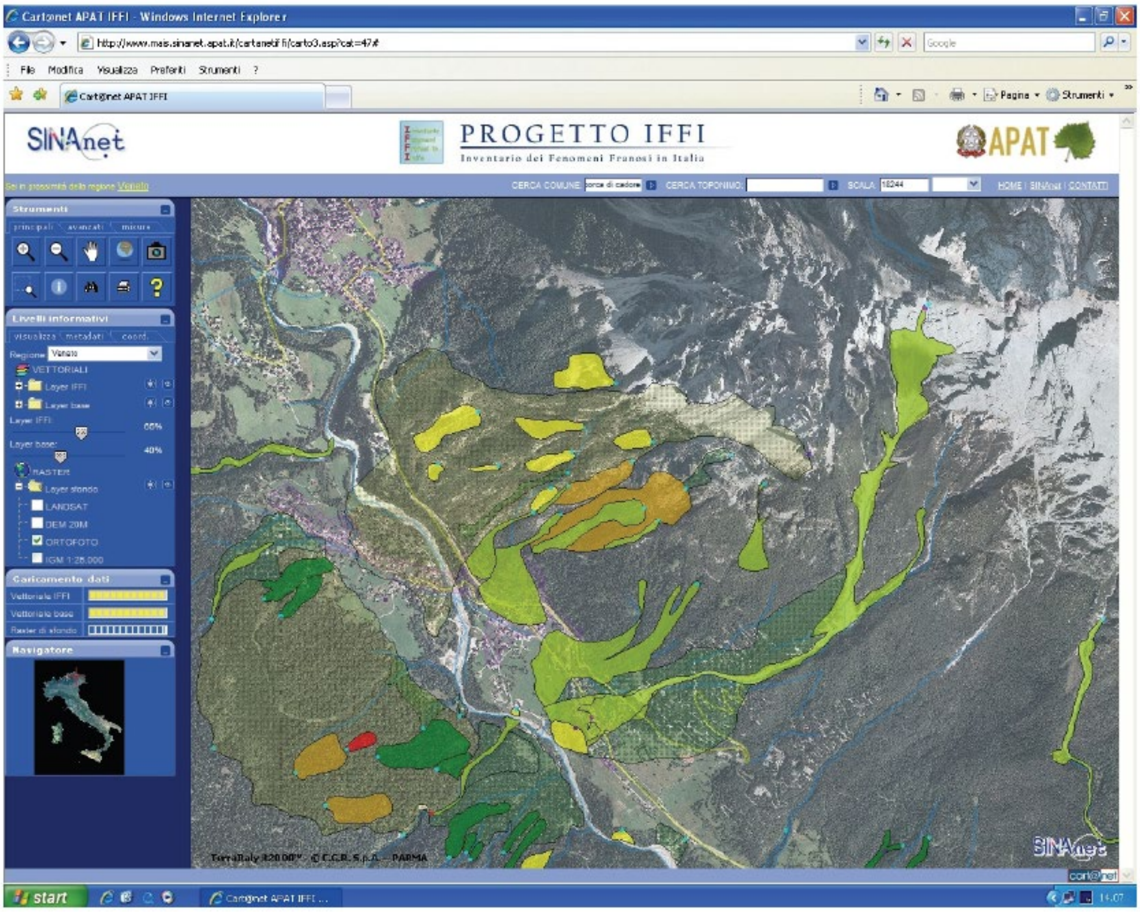


Fig. 14 IFII WebGIS interface.

Other examples of very advanced databases are those of the British geological survey and the Czech Geological survey, available in GIS and web based format as the one presented above. Hyperlinks to these databases (http://www.bgs.ac.uk/landslides/nld.html, http://mapy.geology.cz/svahove_nestability/index_EN.html?config=config_EN.xml). Some of the databases (for example of Croatia) enable that companies and citizens can notify the institution which maintains it, if they notice some new landslide.

Examples of landslide database for urbanised areas

One example of a landslide database is for the City of Belgrade in the Republic of Serbia. It is called BeoSLIDE consisting of modern landslide inventory in a GIS oriented software for Belgrade General Plan area (approx. 360 km^2 with more than 1,2 mil. population). All noted landslides were categorized by level of hazard and risk of their activation. This information system and landslide database should enable continuous monitoring of the landslide processes and possibility of early warning system development. Such information should be at disposal to: **planners, investors and builders**. Basic goals for creating a new inventory were: to archive all documentation of Belgrade landslides in one place and to make data publically available; to collect data in digital form (database) in order to have them continuously updated during time; to make a database searchable by various parameters which are crucial for city governance (by municipality location, different urban zones, infrastructure locations etc.); to generate full .pdf or .doc format reports with quality data about inventoried landslides (with included maps, diagrams, laboratory data, core sampling etc); to provide local decision makers with information on priorities in landslide investigations for civil engineer projects or for landslide prevention and remediation, in different stages of project design. Digital landslide inventory with database and information system for Belgrade General Plan area was made during 2008-2010 yr. 1150 individual landslides were registered and for each of them the following information has been added to the database: location, geological conditions, existing exploration works and their results and works on prevention and stabilization (http://rgf.bg.ac.rs/is/BeoSlide.html). Beside geological and engineering-geological data, various datasets important for decision makers and City Government branches have been inputted in the database.

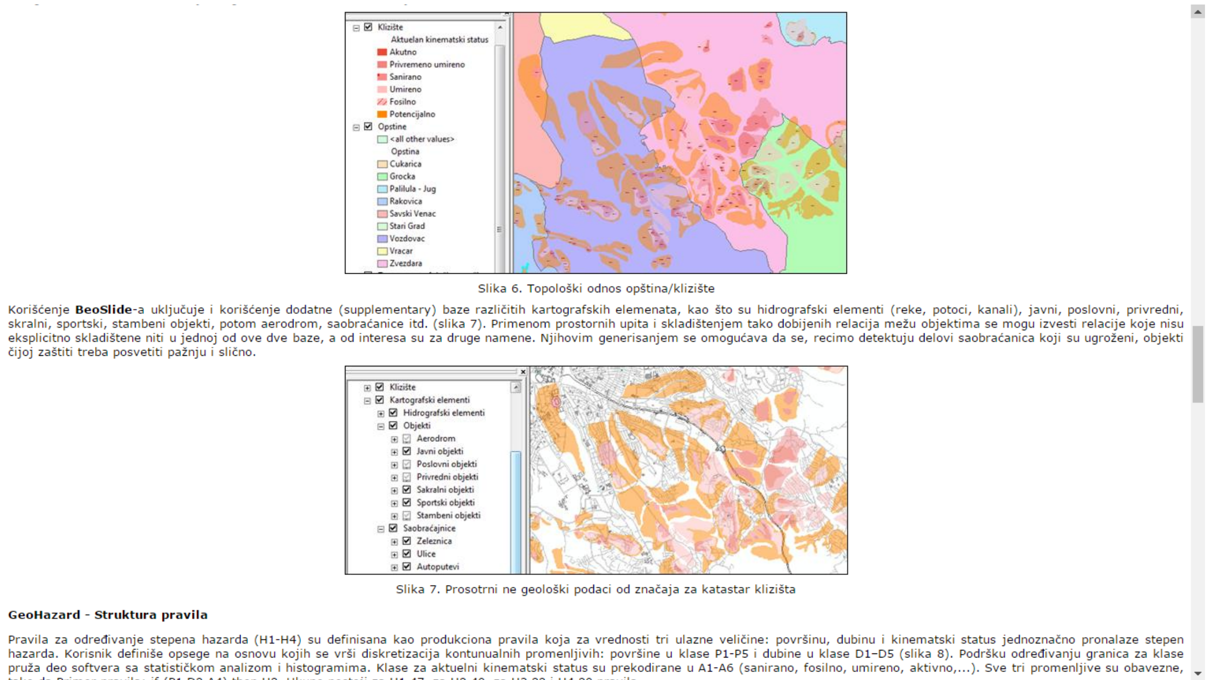


Fig. 15 Beoslide landslide database. Avalilable at http://rgf.bg.ac.rs/is/BeoSlide.html

One specific case of landslide database for urban areas is the post-event landslide database related to the high yield rainfalls and floods that hit Serbia and neighbouring countries in May 2014. The database was created in the frames of the project "BEWARE" that had overall aim "to standardize post-event landslide database and closely involve local community of 27 municipalities affected by May 2014 events in Serbia, and prepare them to cope with catastrophic events in the future." The total number of verified landslides in the

BEWARE database is 1885 (Fig. 16). The total damage related to the May 2014 flood and related landslides.

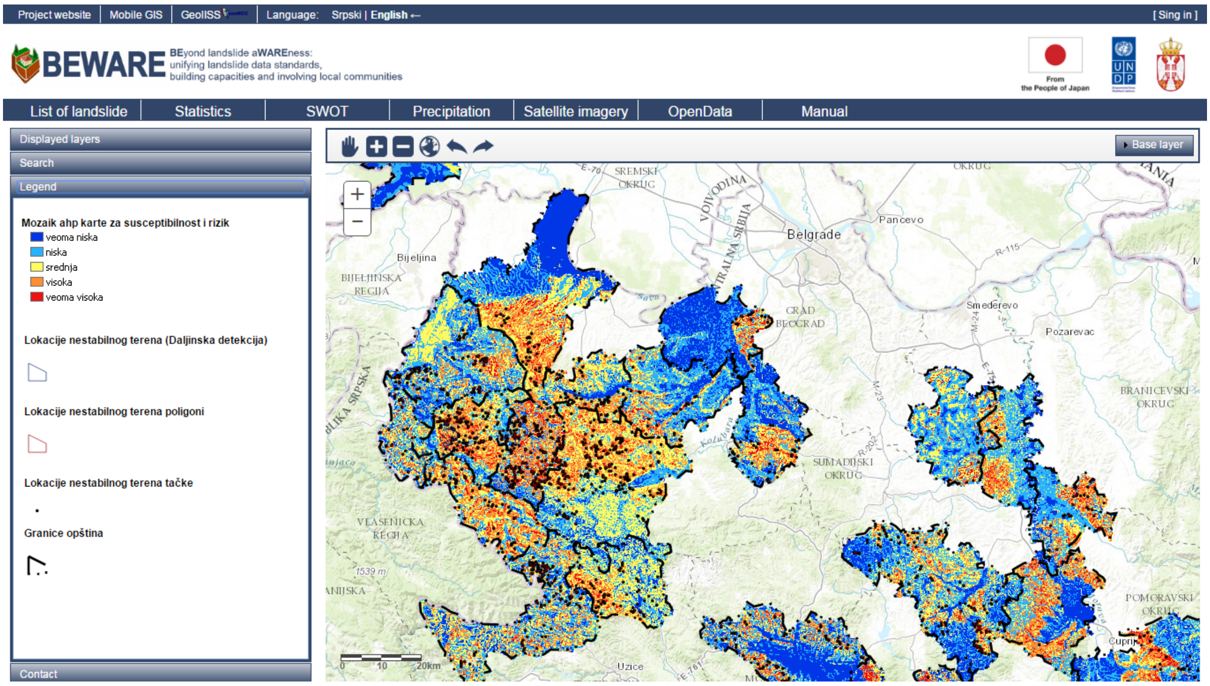


Fig. 16 Landslide susceptibility map generated in frames of the BEWARE project with position of landslides in 27 municipalities. Source: http://geoliss.mre.gov.rs/beware/webgis/?lang=2

Among the other benefits from the BEWARE project for the municipalities we note the following: Enhancing municipal capacities/Civil Protection offices in 27 municipalities in Serbia with necessary equipment for effective landslide event reporting.; Building capacities among the regional/local authorities/Civil Protection staff for landslide event reporting; BEWARE (GIS) web portal as a platform for interactive landslide event reporting, and unifying landslide data records.; Improving land use planning documents of each municipality – SWOT analysis of each municipality for justifying landslide hazard, vulnerability and risk analysis; Identifying critical sites for landslide rehabilitation; Improvement of governmental agencies practice in building/updating national landslide database from BEWARE itself, but also form general crowd sourcing approach. More on this specific project can be found on the web page: http://geoliss.mre.gov.rs/beware/

Example of landslide hazard in an urban environment

Landslide Ramina is located in municipality of Veles (Republic of Macedonia). It has reactivated several times, first in the 19th century, and then in 1963, 1999 и 2002. In the 20th century the landslide was forested and construction in the area was not allowed, but people begin to build illegally and a new neighborhood was born in short period. The landslide is long around 500 m, and width of 100 m, the thickness is 20 m. Hydrogeological conditions show that the sliding is probably be connected to the zone of high moisture. After small earthquake in 1999, reactivation created a lot of damages on existing houses and infrastructure. In total 120 houses are directly exposed and additional 500 more indirectly. Big project for remediation and re-settlement of the population was undertaken which cost a lot of money. The landslide is now stabilized with geotechnical interventions and monitored on regular basis.

This is only one simple example, and many larger or smaller landslides in urbanized areas have caused problems throughout Europe in the past.

a)

b)

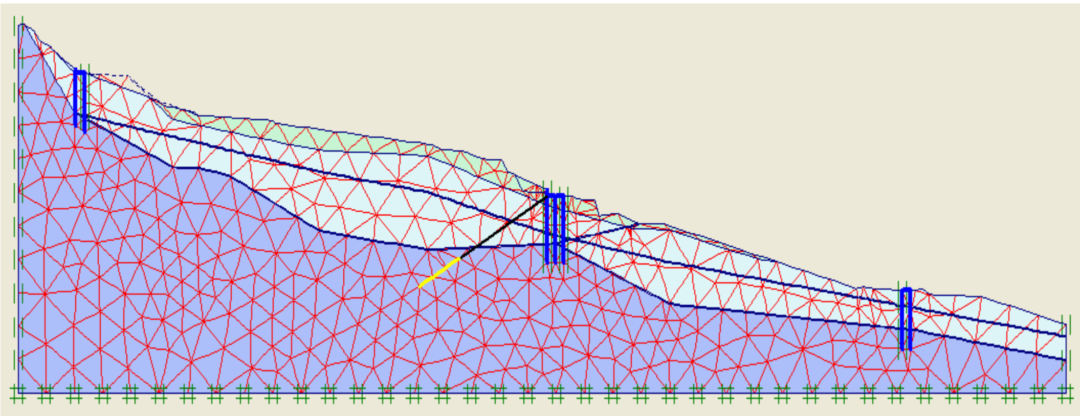


Fig. 17 (a) Some of the consequences of the last reactivation of landslide Ramina in 1999, and (b) geotechnical modelling for remediation design purposes (prepared by J Josifovski 2014).

Landslides and Planners

Regarding landslides in the toolbox, it is most important to stress to the city planners to at least use landslide inventory maps, when they plan/develop a new/existing urban area. It is important that a planner or planers teams have access to the landslide database - maps, and they always should consult with the specialist/experts to better assess the landslide hazard in an area, and what consequences they might have on the new development.

Geohazards – Landslide inventories

With regard to landslide data (database, inventory, susceptibility, hazard and risk maps), most countries in Europe have some type of landslide database (in paper or digital format). The quality of data they hold, and the frequency of update varies greatly however, as does their ability to present data in a GIS (e.g. the SOPO Landslide Database of the Polish Geological Institute - http://geoportal.pgi.gov.pl/portal/page/portal/SOPO/Wyszukaj3).

Landslide databases are established and maintained, mainly on a national or regional basis by Governmental institutions and in some cases by local authorities. In other instances, the databases are linked to specific Projects (for example the IFFI project developed by ISPRA, the Italian National Institute for Environmental Protection and Research). However, existing data are often restricted in access; access may require cooperation with specialists in the field.

Working group 2.5 has estimated that there are at least 800.000 registered landslides in databases and thematic maps across Europe. This may be a significant under-estimate, however. Those countries most susceptible to landslides are typically those with the extreme topography (e.g. Switzerland, Italy, France, Austria, Spain, France, Slovenia, Poland, Slovakia, Bulgaria, Romania, Bosnia and Herzegovina, and Macedonia) and therefore those with the most landslide data.

As one of the most affected countries, Italy has one of the most advanced databases of landslides in Europe. It was prepared within the framework of the IFII project (Inventory of Landslide Phenomena in Italy - http://193.206.192.136/cartanetiffi/). This consists of an inventory of all registered landslides in Italy, with clear distinction of the landslide mechanism, demarcation of zones through which a landslide is likely to travel, and site-specific information from landslide investigations. It is a web-based and easy to use service.

Fig.18. SOPO (Landslide Conteraction System) Polish Geological Survey web browser application. An example of landslide inventory. Map presents identified landslides with relation to their Landslide Registration Forms. (http://geoportal.pgi.gov.pl/portal/page/portal/SOPO/Wyszukaj3).

Summary

When speaking of urban planning, depending on the region, the landslide hazard problem can be treated as very important or secondary (depending of regional settings) in relation to other geohazards. At least Landslide inventory maps should be considered in the process of urban planning. Wherever available, susceptibility, hazard and risk maps should also be considered. In cooperation with specialists, planners can suggest preparation of such maps if they think that the landslide problem is not well managed in some areas. From their cooperation and proposals, decision makers can decide for performing of projects to assess the landslide susceptibility/hazard/risk in an area. Recommendations and methodologies (tools) exist and can be taken from above/similar sources. Specialists in the field should perform such assessment.

References

M.V.D Eeckhaut and J. Hervás (2012) Landslide inventories in Europe and policy recommendations for their interoperability and harmonization. A JRC contribution to the EU-FP7 SafeLand project. European Commission Joint Research Centre Institute for Environment and Sustainability

Cruden, D.M., (1991). A simple definition of a landslide. Bulletin International Association for Engineering Geology, 43: 27-29.

Varnes, D. J. (1978). Slope movement types and processes. In: Special Report 176: Landslides: Analysis and Control (Eds: Schuster, R. L. & Krizek, R. J.). Transportation and Road Research Board, National Academy of Science, Washington D. C., 11-33.

Hervás J. (2007). Guidelines for Mapping Areas at Risk of Landslides in Europe. Proceedings of the Experts Meeting held on 23-24 October 2007 Institute for Environment and Sustainability. Joint Research Centre (JRC), Ispra, Italy Edited by Javier Hervás) EUR 23093 EN - 2007.

EPOCH (1993). The temporal occurrence and forecasting of landslides in the European community (Ed: Flageollet, J. C.). Contract No. 90 0025, 3 Volumes.

http://www.pangeoproject.eu/

Humbert, M. (1972). Les Mouvements de terains. Principes de réalisation d'une carte previsionelle dans les Alpes. Bulletin du BRGM. Section III, n°1 : 13-28.

Humbert, M. (1977). La Cartographie ZERMOS. Modalités d'établissement des Cartes des zones exposées à des riques liés aux mouvements du sol et du sous-sol. Bulletin du BRGM, Section III, n°1/2 : 5-8.

Antoine, P. (1978). Glissements de terrains et aménagement de la motagne. Bullettin de la Société vaudoise des Sciences Naturelles. n. 353, 74(1): 1-14.

Lokin, P., Pavlović, R., Trivić, B., Lazić, M., Batalović, K., Đurić, U., (2012). Katastar klizišta Beograda (Belgrade Landslide Cadastre); Zbornik radova XIV Simpozijum inženjerske geologije i geotehnike, Društvo geoloških inženjera i tehniĉara Srbije, Komitet za inženjersku geologiju i geotehniku, str. 389-403. ISBN 978-86-89337-01-3. http://cobiss.izum.si/scripts/cobiss?command=DISPLAY&base=COBIB&RID=193445132

Josifovski J. et al. (2014). Landslide Ramina From Natural hazard to Remediation. Landslide and flood hazard assessment. Proceedings of the First Regional Symposium on landslides in the Adriatic-Balkan region, Zagreb 2014, pp.165

Appendix: 2. Geotechnical databases case studies

2.1 DOV - original database of subsoil for Flanders (Belgium) (http://dov.vlaanderen.be)

DOV - Databank Ondergrond Vlaanderen (or Regional database of the subsoil/soil of Flanders) (http://dov.vlaanderen.be)

Vergauwen Ilse, Van Alboom Gauthier[1]

Van Damme Marleen, Vanwesenbeeck Veerle[2]

About DOV

Since 1996 DOV or Databank Ondergrond Vlaanderen is cooperation between three divisions within the Government of Flanders:

- The 'Land and Soil Protection, Subsoil and Natural Resources Division' of the Department of Environment, Nature and Energy
- The 'Operational Water Management Division' of the Flemish Environmental Agency
- The 'Geotechnics Division' of the Department of Mobility and Public Works.

The cooperation was renewed in 2006 and is open to new partners (Boel et al., 2007; Algoe et al., 2013). The aim of DOV is to structure, manage and provide subsoil/soil data of Flanders through one portal (figure 1). This implies that all subsoil/soil data and/or information on the data can be found in the database. Today, all data of the DOV partners are made available in DOV. In the future, subsoil/soil data of other sources should also be known in DOV and can be distributed, or redirected by DOV (Boel et al., 2011).

In doing so, DOV keeps up with the developments in technology and IT so the most suitable tools to structure, manage and make subsoil/soil data accessible are used. The amount of subsoil/soil data within DOV continuously increases and the quality of the data and metadata is brought to a higher level.

MISSION Structure and manage all data and information concerning the soil and subsoil of Flanders and make them available.

VISION DOV is a cooperation of partners that mobilizes data and information concerning the soil and subsoil of Flanders, guards and reports on their quality and makes them accessible in an integrated way, DOV works according to Flemish decrees and international agreements, in the most effective, efficient and flexible way.

---

[1] Geotechnics Division - Department of Mobility and Public Work - Government of Flanders

[2] Land and Soil Protection, Subsoil and Natural Resources Division - Department of Environment, Nature and Energy - Government of Flanders

DOV also supports the business processes of the partners involved in the cooperation. DOV gives support along seven pillars (figure 2), focused on all stakeholders involved, in a service oriented architecture (Algoe et al., 2013). These seven pillars are:

1. Preliminary investigation of the subsoil/soil prior to in situ testing

2. Administrative aspects related to in situ tests

3. Planning of in situ tests

4. Execution of in situ tests (and subsequent lab tests)

5. Reporting of raw data

6. Data management

7.Advanced use of data and policy making

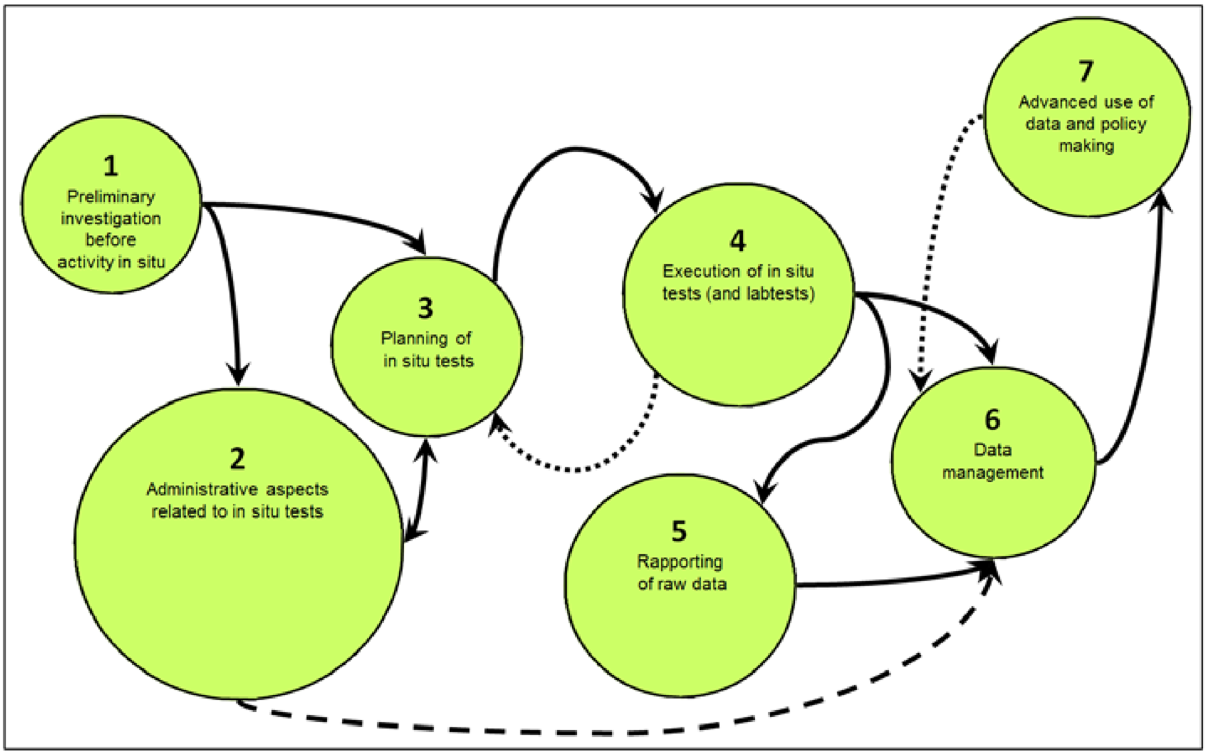


Figure 1: Supported business processes in DOV (Algoe et al., 2013).

Data in DOV

The data in DOV originate from the business processes of the partners involved in DOV (Boel et al., 2007). Data are covering the themes of geology, geotechnics, groundwater and soil. Since 2013 the new theme geothermic is added to DOV (Algoe et al., 2013).

Data of the theme geology include drillings, lab tests, geological interpretations, Quaternary, Neogene-Paleogene (Tertiary), Cretaceous, 3D mapping, faults, loggings, etc. (figure 3).

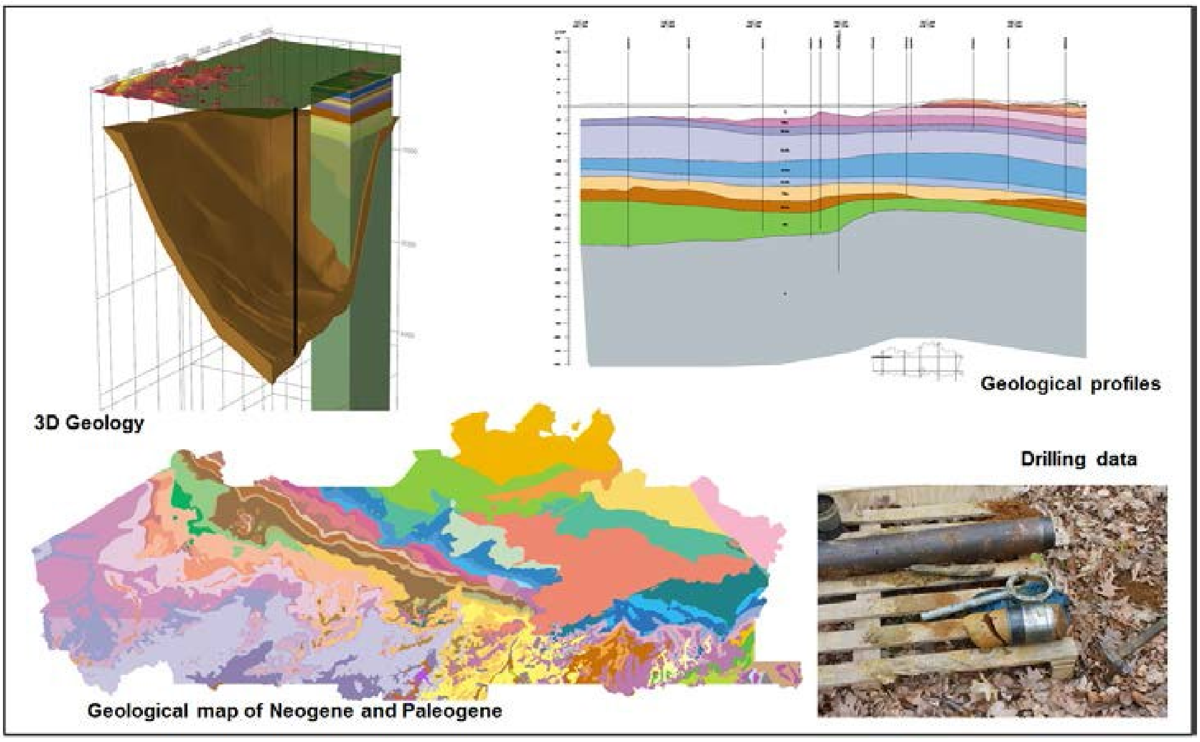


Figure 3: Examples of geological data

Data of the theme groundwater are the drilling data, groundwater monitoring network, groundwater abstraction permits, groundwater quality measurements, groundwater level measurements, abstraction wells, observation wells, groundwater capture zones and protection areas, nitrate sensitive areas, groundwater vulnerability map, HCOV-boundaries (hydrogeological coding of the subsoil of Flanders), groundwater bodies, etc. (figure 4).

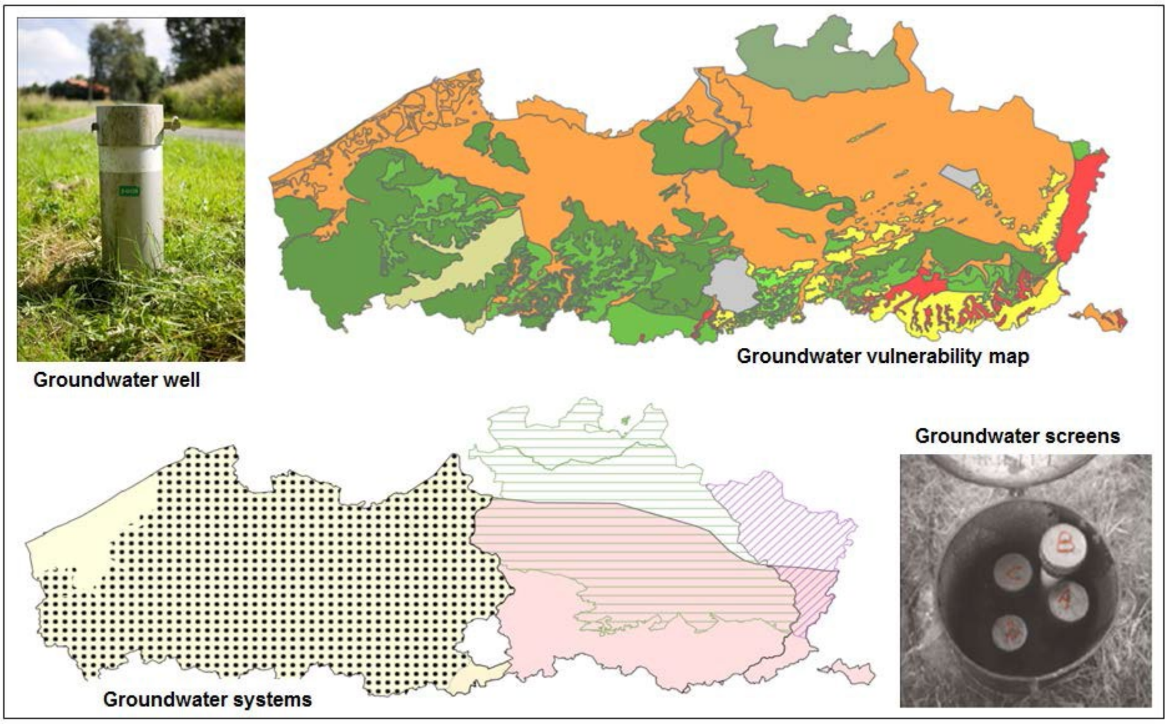


Figure 4: Examples of groundwater data.

Geotechnical data also include drillings and cone penetration tests, and geotechnical laboratory tests, geological and geotechnical interpretations, thematic maps, etc. (figure 5).

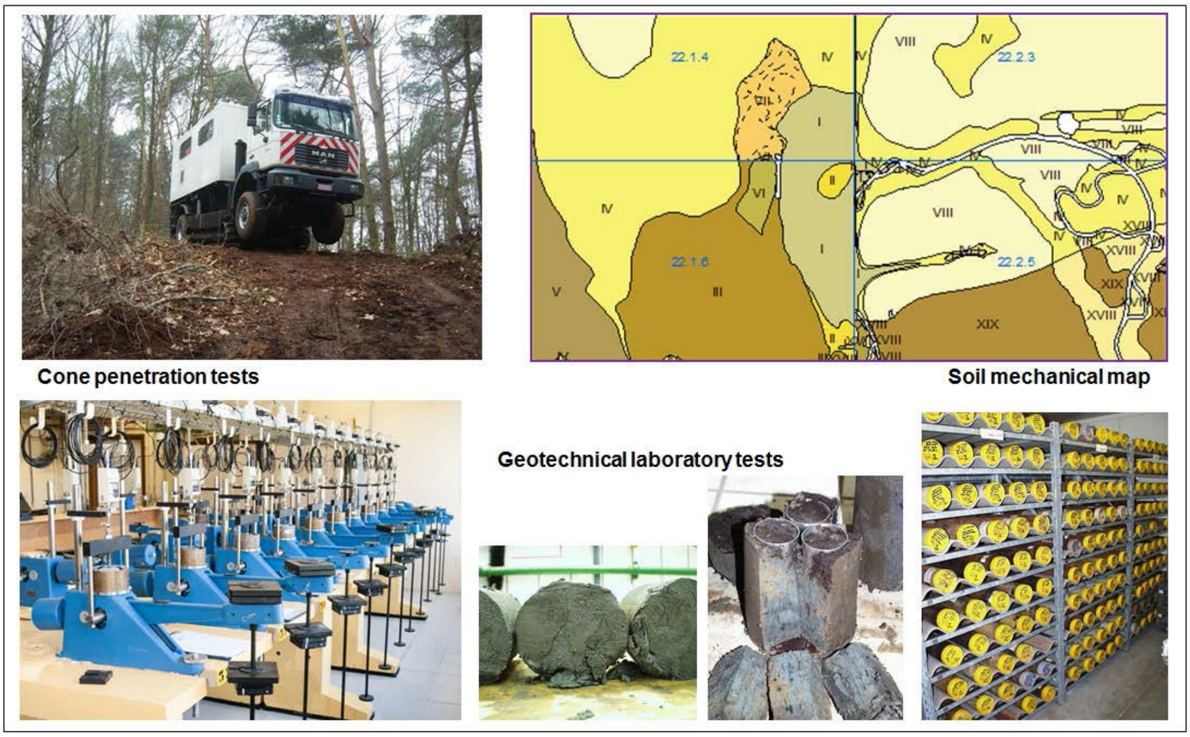


Figure 5: Examples of geotechnical data

Soil data consist of soil profiles and samples, soil maps, soil association map, erosion data, landslide data, pedological heritage, etc. (figure 6).

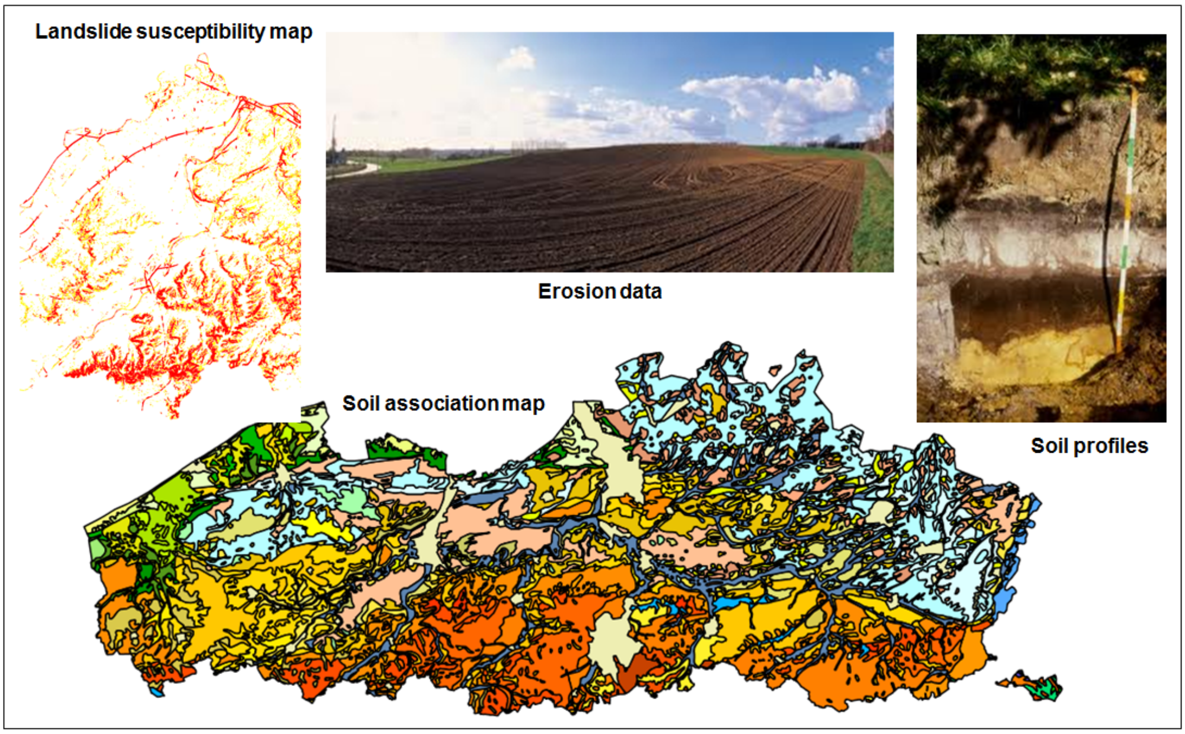


Figure 6: Examples of soil data.

DOV contains a vast amount of data derives from various sources.

Figure 7 gives an overview of the increasing number of objects in DOV. For example, the drilling data from the archives and the day to day work of the DOV partners. This implies that drilling data collected for different goals come together in the database (Boel et al., 2007).

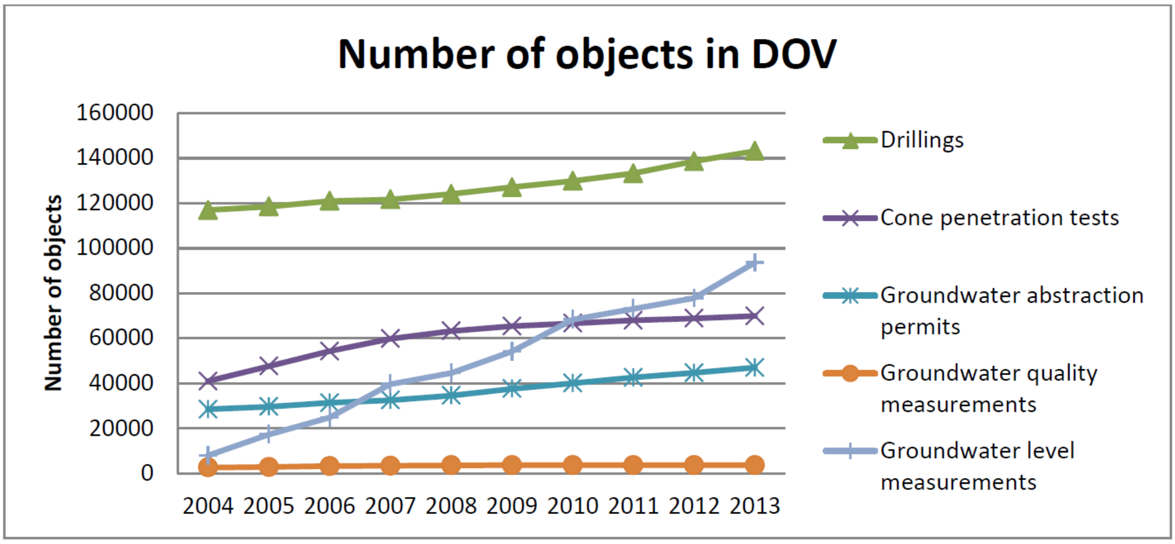


Figure 7: Number of objects in DOV.

The drilling data provided by the Geotechnics Division, one of the DOV partners, are collected in geotechnical studies. These drilling data consist of the technical drilling data, a very precise geographical location, a description of the lithology and a geological interpretation by an experienced geologist. During the drilling, samples for geotechnical laboratory testing can be taken. Within the area of investigation several cone penetration tests (CPT) are executed, comprising a CPT in the immediate vicinity of each boring.

Based on the results of the laboratory tests, CPT and drilling data the geotechnical engineers also add a geotechnical interpretation to the bore hole logs. In this geotechnical interpretation primary concern is given to the soils with a geotechnical impact.

The DOV partner, Operational Water Management Division assembles drilling data in their daily work and studies as well. In these the focal point is groundwater, therefore the interpretation of the drilling data is more or less directed towards the groundwater models. Their typical data hold the technical data coupled with the installation of wells, the geographical location, a description of the lithology and hydrogeological interpretations by an experienced hydrogeologist and the hydrogeological scheme of the subsoil. The Operational Water Management Division also uses the data for mapping and modelling.

The Land and Soil Protection, Subsoil and Natural Resources Division has digitized a huge amount of drilling data out of the archives. They use these data in combination with the data of the other DOV partners to make geological (soil) maps and models. If necessary they improve the existing geological interpretation of bore holes in DOV or add new interpretations to DOV.

From the 1st of January 2015 on, a new legislation concerning drilling data will enter into force. As a consequence all drilling data will be supplied to DOV. Which data are obligatory depends on the objective of the drilling. So, other data will be mandatory for a drilling carried out in a geotechnical, hydrogeological, geothermal context. Data will have to be delivered in the XML-format of DOV, which is the standard in Flanders for the exchange of drilling data. All information concerning the standard XML-format of DOV is explained on the website of DOV (Algoe et al., 2013).

The main advantage of bringing all the data of the different sources together in DOV is that the data can be consulted and re-used by the DOV partners or other interested parties. At the same time this collection of data imposes certain problems when the data is re-used. For instance, drilling data gathered for geological purposes in past tenses can only be used as reference data in a geotechnical setting, mainly because of the inaccuracy in the geographical location. After all, on a construction site the exact position of the in situ tests and the geotechnical conditions at that proper location are essential.

This plain example indicates on the one hand the importance of the quality of the data, on the other hand that the demands of the quality of the data differ with the purpose for which the data is used. Therefore it is not merely a question of good or bad data. Data must be documented extensively, so users are able to evaluate whether the provided data can be of use in their projects. Metadata is a key issue for DOV and all partners are putting a lot of hard work in it (Boel et al., 2011; Boel et al., 2012; Algoe et al., 2013).

Users of DOV

DOV is multidisciplinary, and offers subsoil/soil information for a wide range of applications: geotechnical design, environmental studies, geological mapping, groundwater modelling, groundwater policy, scientific research. Therefore the users of DOV can be found within several organizations such as governmental institutions, universities, consultancy firms, private sector, etc.

The DOV applications are divided into internal and external applications.

- The internal applications are available to the users of the DOV partners. More than 300 unique users can log on to these internal applications.
- The external applications are available on the internet (http://dov.vlaanderen.be) and can be used by anyone free of charge. The daily monitoring of the applications indicates an average of 250 users a day (figures 8 and 9).

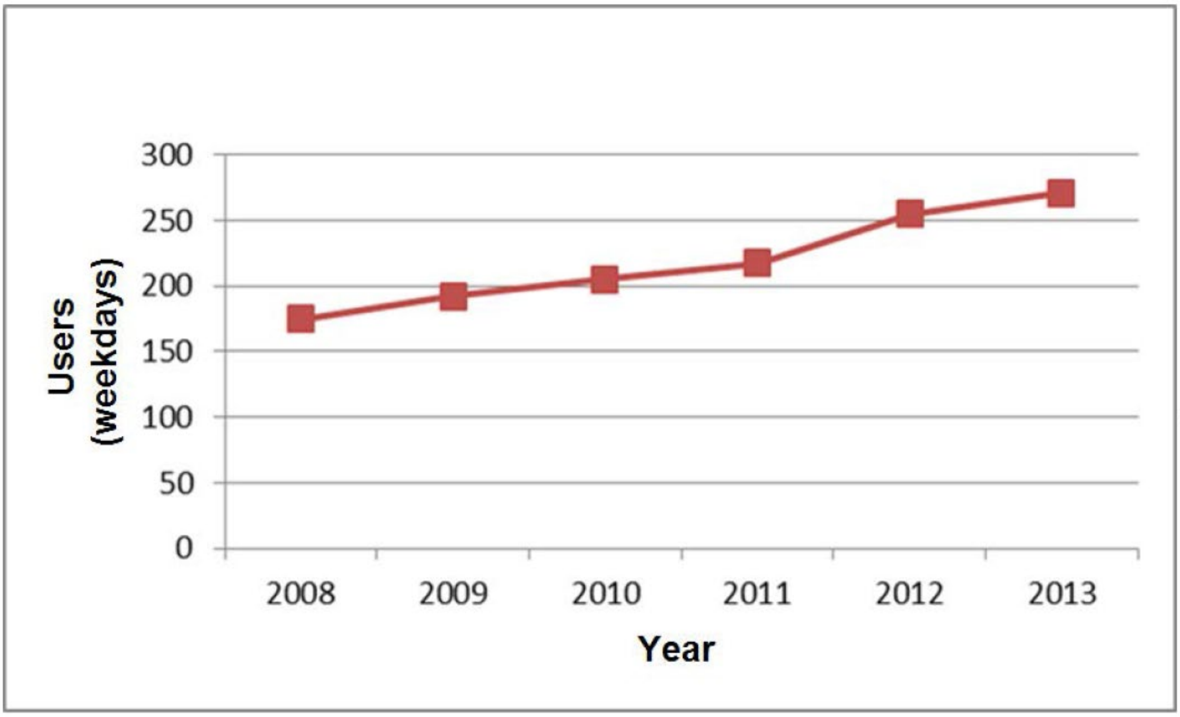


Figure 8: Evolution of the number of users of the DOV website between 2008 and 2013.

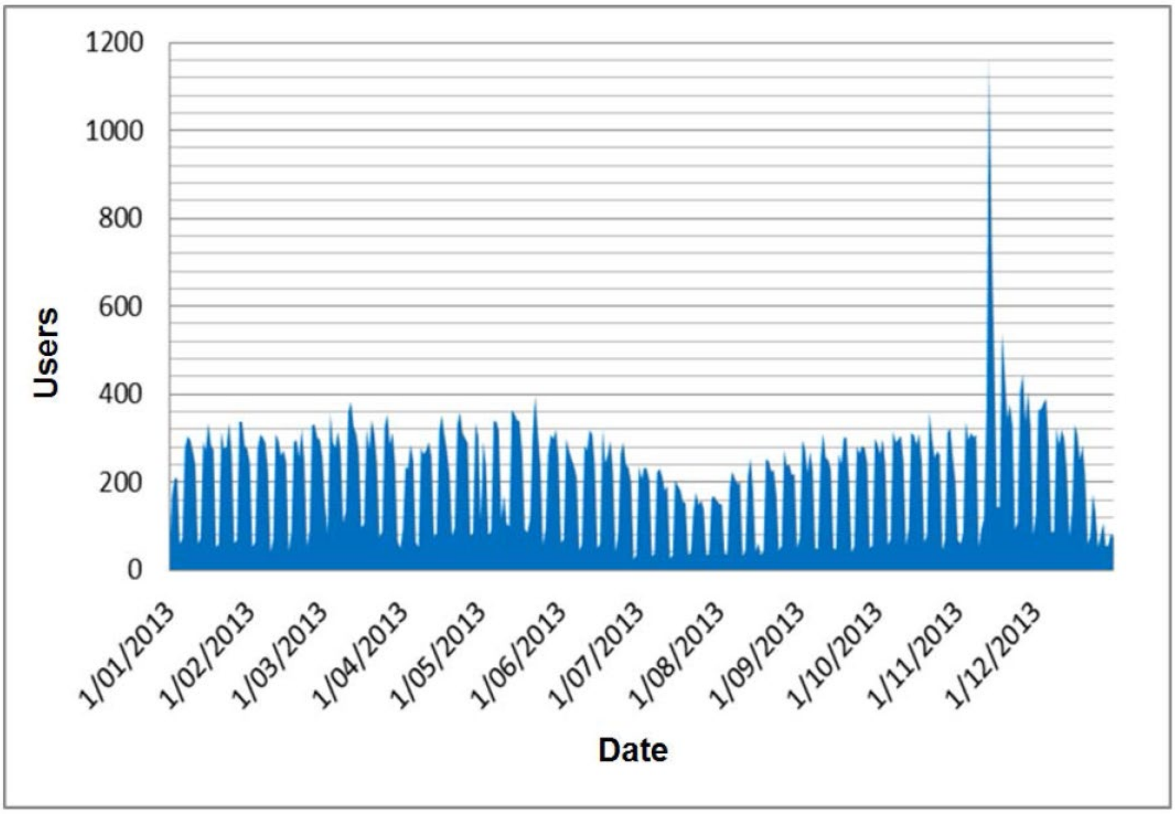


Figure 9: Number of users of the DOV website in 2013.

Architecture of DOV

Since 2002 the website of DOV http://dov.vlaanderen.be is online. On this site the DOV viewer with all subsoil/soil data can be consulted. This viewer is based on ArcIMS (ESRI) technology and communicates with an ArcSDE/Informix database that contains all subsoil/soil data. This technology is more or less outdated, so DOV recently decided to improve its architecture and to migrate the old DOV Viewer to a new technology. This migration process is currently in progress.

The new architecture of DOV had to satisfy the following demands:

- All business processes of the DOV partners founded on DOV must be supported.
- The new architecture must meet the requirements and needs of Flemish, Belgian and European legislation. In particular the Flemish SDI-decree and INSPIRE Directive were taken into account.
- The new geodata infrastructure must be open to any user of DOV. The technology must be easily accessible, extendable, broadly supported and reusable.

The partners of DOV have engaged in European projects, such as GS Soil, OneGeology and eWater, where the use of open source software was strongly stimulated. In the GS Soil project the DOV partner 'Land and Soil Protection, Subsoil and Natural Resources Division' took the lead in order to learn more about recent evolutions in the open source GIS software. Internal projects gave more insight in the pros and cons of several software alternatives. The whole lead to the establishment of the new DOV infrastructure (Boel *et al.,* 2011; Boel *et al.,* 2012; Algoe *et al.,* 2013).

The new architecture consists of three main settings.

- In the first, each DOV partner has its own working environment where the partner data are managed and the business processes take place. Applications to support this work can be created by one or more DOV partners together. Each partner is responsible for its own environment and can build it out according to its own needs. However, in doing so, certain rules imposed by DOV must be fulfilled, so that the connection between the partner environments and DOV is insured at all time.
- All partner environments transmit their validated data to the heart of DOV, which is the second setting. In here all subsoil and soil data come together and can be redistributed again.
- Data are provided back to the partner environments and also to the publication environment where all interested parties can find and use the data.

The technologies used to set up this architecture for the Publication-environment are the open source products PostgreSQL/PostGIS, GeoServer and GeoNetwork; and for the internal- and partner-environment a mixture of ESRI software and the previously mentioned open source software is used. GeoNetwork is the discovery service, allowing tracing data and offering a vast amount of metadata of the data. GeoServer, an open source Java-based server, is equipped to display all sorts of geographical data and maps, and is flexible in handling different kind of web services (Web Map Service - WMS; Web Feature Services - WFS; etc) (Boel *et al.,* 2011; Boel *et al.,* 2012; Algoe *et al.,* 2013).

Legal framework of DOV

DOV is a governmental project and thus bound to the Flemish, Belgian and European legislation. DOV follows the open data policy of the Government of Flanders. In this policy, open data are the rule within Flanders and the open data must make use of open standards.

Legislation that paved the way for the current open data policy started years ago. Two important conventions dealing with the public access to environmental information are:

- The Convention of Aarhus of 1998 and the Directive 2003/4/EC on public access to environmental information of 2003. As DOV includes a lot of environmental data, these directives immediately had an impact on the work of DOV. The environmental data had to be made available and disseminated to the public authorities and to all citizens.
- In 2003 the Directive 2003/98/EC, also known as the PSI Directive, entered in force. It was revised in the 2013 Directive (2013/37/EU). This directive provides a legal framework for the re-use of public sector information and focuses on the re-use of information rather than on the access to information (Boel *et al.,* 2011; Boel *et al.,* 2012; Algoe *et al.,* 2013).

In 2007 Europe established an Infrastructure for Spatial Information within the European Community (INSPIRE). INSPIRE supports environmental policies and activities and makes sure that spatial data are compatible and usable in the European Community (Directive 2007/2/EC). In Flanders the cooperation SDI-Flanders was established in 2009. All public bodies of the Flemish region are incorporated in this cooperation and its aim is to manage, use and exchange geographical information between the participants and also to provide data to INSPIRE.

DOV is of course one of the participants and provides the soil and subsoil data to the SDI-members and to Europe.

DOV data are part of the INSPIRE annexes II and III. So far, DOV has been able to fulfil all deadlines imposed by INSPIRE concerning discovery, view services, download and transformation (figure 10) (Boel *et al.*, 2011; Boel *et al.*, 2012; Algoe *et al.*, 2013).

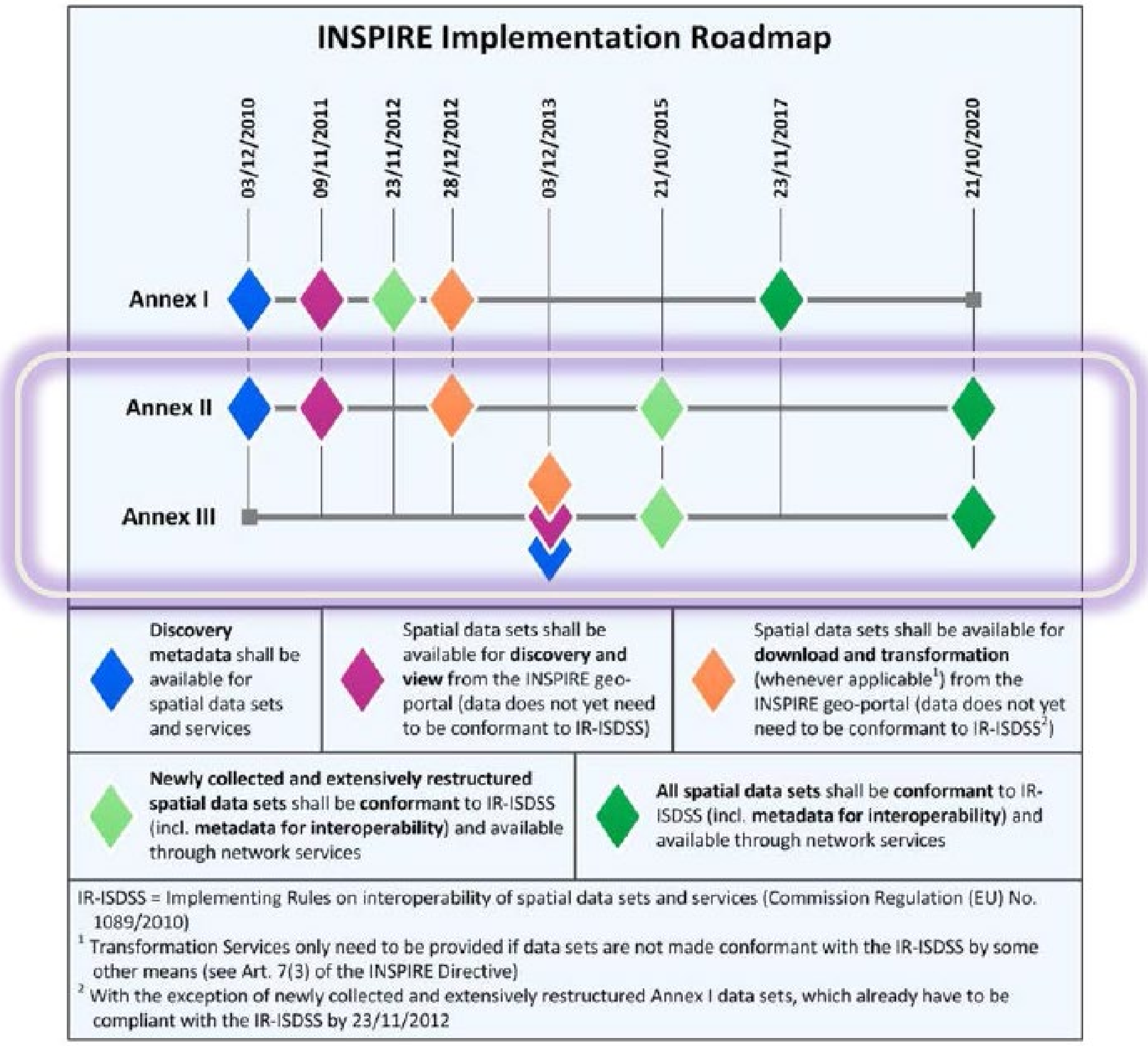


Figure 10: INSPIRE implementation Roadmap.

DOV puts several applications at the disposal of external and internal users.

- The internal applications allow internal users to key in data, to manage data, to search and query for data, to extract and transfer data and to make advanced analyses. For the internal users, DOV is a powerful tool that supports many business processes. For instance, the Geotechnics Division uses DOV to collect data, to make global inventories, to plan new in situ tests, to analyze the geotechnical parameters, etc. for major infrastructure project. In urgent or hazardous situations the data in DOV can even be used to undertake short time actions based on engineering judgment. Permanent, well-considered solutions can then be worked out gradually (Van Alboom et al., 2007).
- The external users can make use of all the applications and data available on the website of DOV free of charge (figure 11). The applications open to the public are:

Figure 11: Start page of the DOV website.

General DOV viewer

In the general DOV viewer most of the subsoil and soil data available in the databases of DOV can be consulted (figure 12). The viewer has advanced tool, so users can search for the data, query the data, retrieve reports of the data, combine data and extract data. The general DOV viewer is appreciated by the majority of the external users, because of its advanced tools. However the technology of this viewer is more or less outdated. New web service based viewers are in development and will replace the old general DOV viewer.

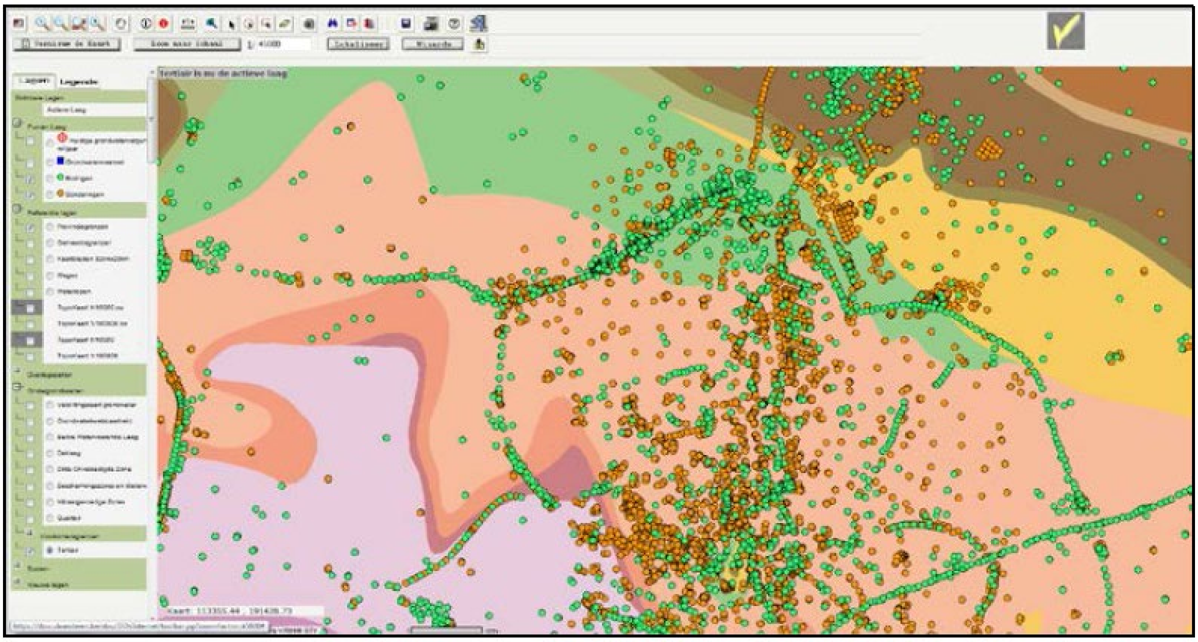


Figure 12: Impression of the general DOV viewer - the Neogene-Paleogene (Tertiary) geological map near the town of Ghent and the locations of drillings (green dots) and cone penetration tests (orange dots).

Soil viewer

The soil viewer already partly replaces the old DOV viewer (figure 13). The thematic soil viewer is emanated to meet the needs of the soil data stakeholders. Certain soil data were supplied in formats that were not compatible with the technology used in the older DOV viewer. However, these data can easily be managed in a service orientated environment.

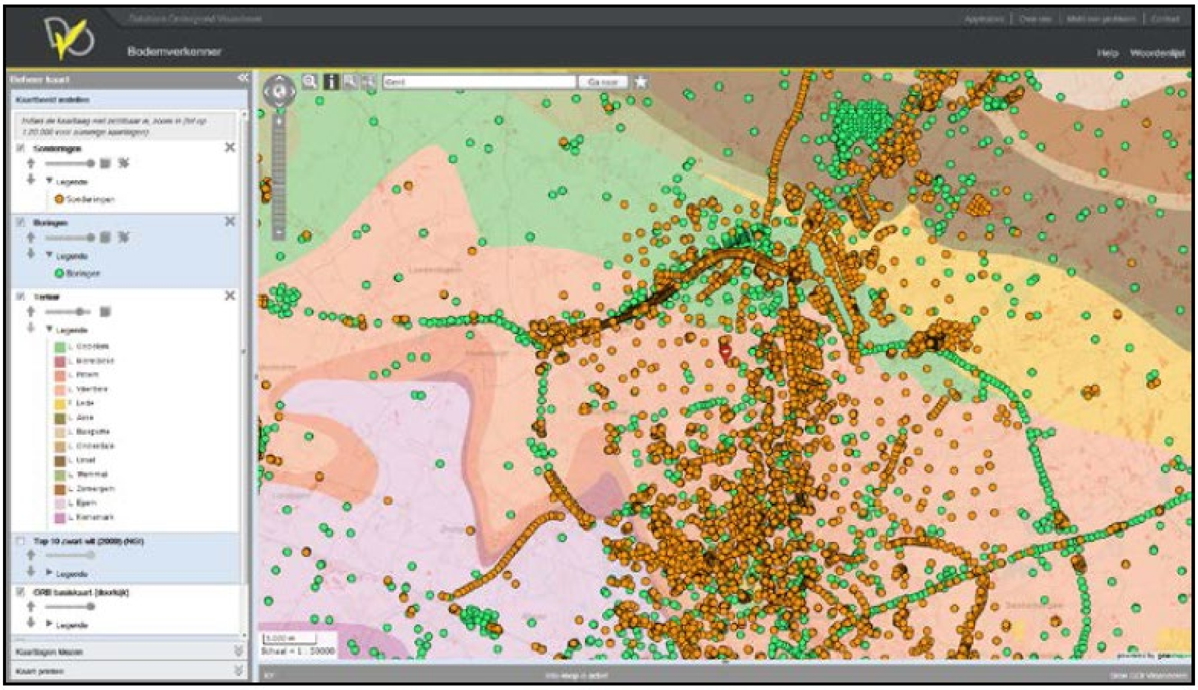


Fig 13: Impression of the soil viewer - the Neogene-Paleogene (Tertiary) geological map near the town of Ghent and the locations of drillings (green dots) and cone penetration tests (orange dots).

The newest soil data are handled in the new service based soil viewer. The soil viewer is capable to display all web services. All DOV data are provided to the soil viewer as web services, but the emphasis in the soil viewer is put on the soil data (figure 14). Services from other sources can also be integrated in the soil viewer. Other thematic viewers, each focused on another target group, will be developed in the near future.

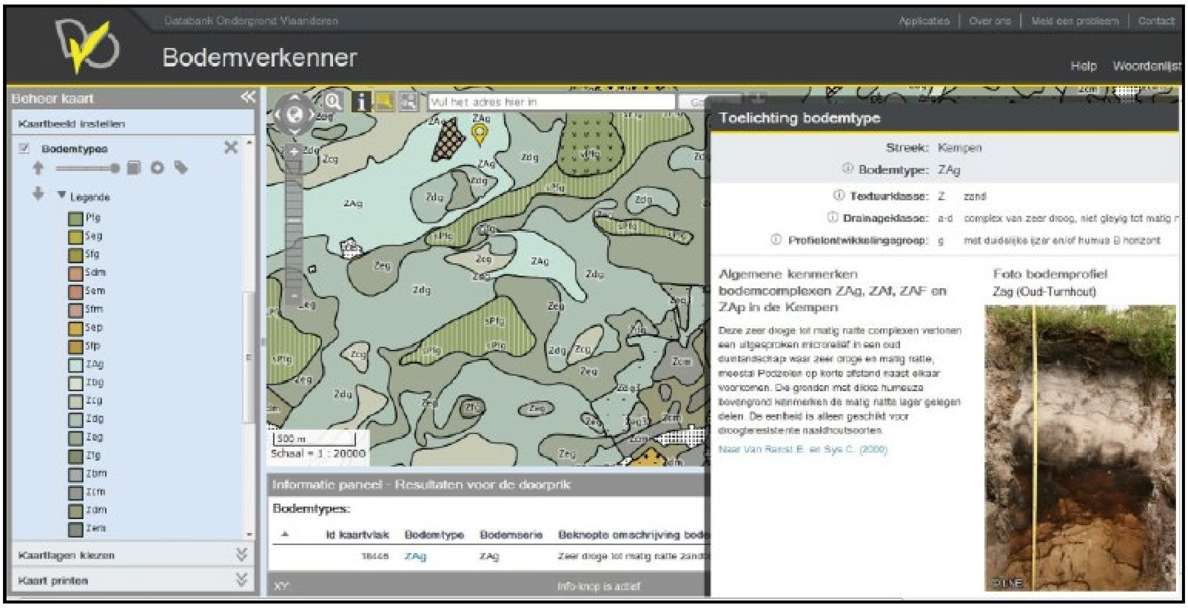


Fig 14: Impression of the soil viewer with soil data.

Geological 3D Model

The DOV partner 'Land and Soil Protection, Subsoil and Natural Resources Division' was responsible for the development of the geological 3D Model of Flanders. The model is based on the data in DOV. The 3D model can be viewed with the SubsurfaceViewer® of van INSIGHT GmbH (http://www.subsurfaceviewer.com). The SubsurfaceViewer® Reader and the data can be downloaded from the DOV website, installed and used on your own PC. The software allows the users to display the 3D model, to make cross-sections, to make related maps, etc. (figure 15).

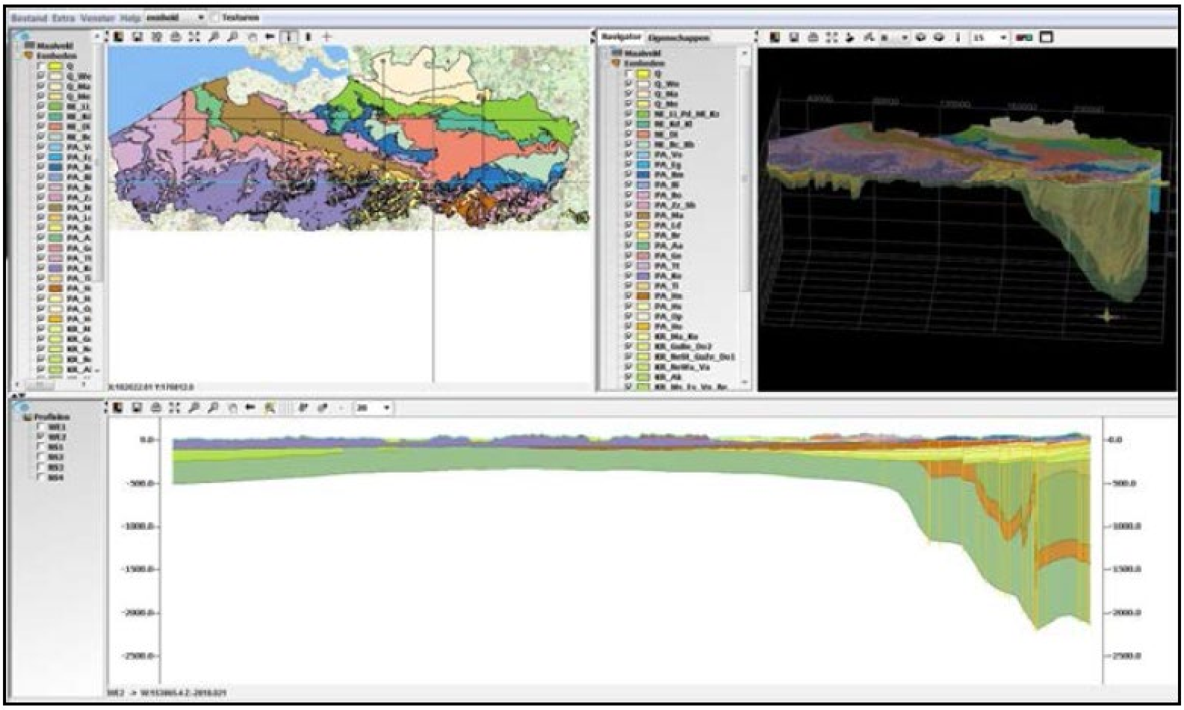


Figure 15: Impression of geological 3D Model in the SubsurfaceViewer®
(http://www.subsurfaceviewer.com)

Viewers VLAREM section 55.1 and VLAREM section 53.8

In Flanders, the VLAREM legislation deals with the environment. Any interference in the environment is strictly regulated by VLAREM. DOV offers two viewers to the public in order to accommodate two small sections in this vast legislation. VLAREM section 55.1 and section 53.8 basically prohibit any activity that can result in the contamination or disturbance of groundwater reservoirs. Anyone who's planning activities that reside under VLAREM section 55.1 or section 53.8 can consult the DOV viewers to find out which legislation is applicable to their situation (figure 16).

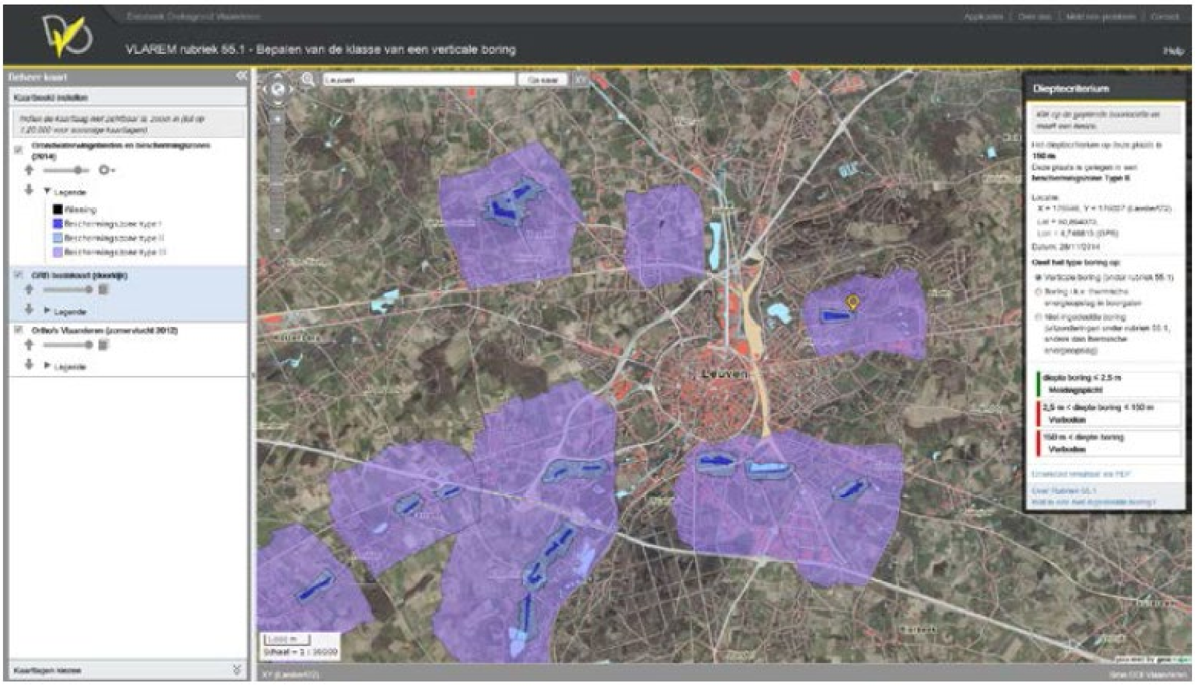


Figure 16: Impression of the viewer VLAREM section 55.1

Operational network services

Since 09/05/2011 DOV is offering network services. The data and services are defined as part of the Spatial Data Infrastructure (SDI) of Flanders since 19/09/2012. The data are available for (commercial) re-use based on the Free Flanders open data license since 18/09/2013. The services are INSPIRE compliant and are continuously monitored with the open source software SESAM (Service Endpoint Security And Monitoring, https://github.com/tvgulck/sesam) of the Government of Flanders. DOV has been able to fulfil all deadlines imposed by INSPIRE concerning the availability of the services. All information on the DOV network services can be found on the DOV website https://dov.vlaanderen.be/dovweb/html/services.html (figure 17).

The DOV network services consist of:

- Catalog service (CSW): metadata of 228 datasets

The catalog services are available on https://www.dov.vlaanderen.be/geonetwork (figure 18)

- View service (WMS): 390 layers
- Download service (WFS): 298 layers
- Download service (WCS): 92 layers
- Predefined downloadable datasets for all datasets

The view and download services for each dataset are available on the DOV website https://dov.vlaanderen.be/dovweb/html/services.html (figure 17)

Figure 17: Information page on the DOV network services on the DOV website https://dov.vlaanderen.be/dovweb/html/services.html

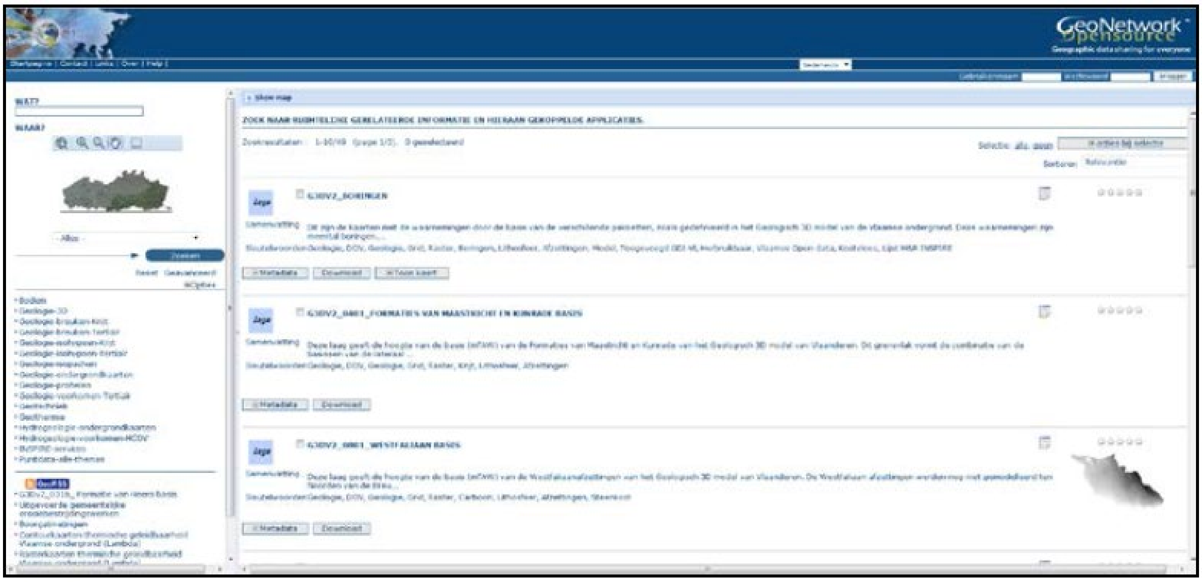


Figure 18: The DOV catalog services on GeoNetwork https://www.dov.vlaanderen.be/geonetwork

Conclusions

DOV is a cooperation that exists since 1996. It offers data covering the themes geology, geotechnics, groundwater, soil and geothermic to all stakeholders.

The DOV data can be consulted by making use of the DOV applications. But the use of the DOV services is also strongly promoted. These web services are designed according to the open standards and can be integrated in any geographical information system. Users can combine their own data with data collected out of web services, thus creating their own tailor-made geographical environment. To re-use DOV data, an enhanced knowledge of the data is required. They must be documented in such a way that users are able to evaluate whether the provided data are meaningful for their projects. Therefore, the importance of metadata can hardly be underestimated. Metadata is and will always be a key issue for all partners. In the future DOV intends to expand its cooperation so that the amount and types of subsoil/soil data, and the metadata continuously increase.

References

- Boel K., De Nil K., De Rouck T., De Schrijver P., Uitdewilligen D., Van Damme M., Vanthournout L., Vanwesenbeeck V., Vergauwen I. (2007). 10 jaar Databank Ondergrond Vlaanderen -Jubileumverslag 2006. Departement Leefmilieu, Natuur en Energie, Directoraat-generaal, Brussel, 67 pp.

- Boel K., De Nil K., De Rouck T., Van Damme M., Vanthournout L., Vanwesenbeeck V., Vergauwen I.(2011). Databank Ondergrond Vlaanderen - Jaarverslag 2010. Departement Leefmilieu, Natuur en Energie, Directoraat-generaal, Brussel, 34 pp.

- Boel K., De Nil K., De Rouck T., Van Damme M., Vanthournout L., Vanwesenbeeck V., Vergauwen I. (2012). Databank Ondergrond Vlaanderen - Jaarverslag 2011. Departement Leefmilieu, Natuur en Energie, Directoraat-generaal, Brussel, 39 pp.

- Algoe C., Boel K., De Nil K., De Rouck T., Van Damme M., Vanthournout L., Vanwesenbeeck V., Vergauwen I. (2013). Databank Ondergrond Vlaanderen - Jaarverslag 2012. Departement Leefmilieu, Natuur en Energie, Directoraat-generaal, Brussel, 52 pp.

- Van Alboom G., De Schrijver P., Vergauwen I. (2007). The regional geotechnical database "Databank Ondergrond Vlaanderen-DOV" as a powerful tool for consultation of subsoil information. In: Proceedings of the 14th European Conference on Soil Mechanics and Geotechnical Engineering, Madrid, Spain, 24-27 September 2007, p.1757-1764.

APPENDIX: 2 Geotechnical databases case studies

2.2 Geotechnical Data Management - From data acquisition to 3D modelling

Beatriz Mozo Lopez, Michael Sheehy

Introduction

Geological Survey Ireland (GSI) maintains the Irish National Geotechnical Borehole Database. The database holds over 7500 ground investigation reports with data on more than 92,000 boreholes and trial pits. It contains the reports of site investigation works undertaken to determine the ground conditions at the location of proposed development projects. The reports typically contain a text report and borehole, trial pit and probe logs, as well as field tests and laboratory sample analyses and site maps.

The database is currently held in both hard copy (databank) and digital format in corporate Oracle databases named Geodata and Goldmine. The data are accessed by interested parties by visiting the GSI, using Geological Survey Ireland Spatial Resources Viewer (Geotechnical tab) or GSI online archive services (GOLDMINE).

The primary purpose of maintaining the database is to provide geological information to GSI stakeholders. These data provide information on ground conditions to developers and act as both an enabling resource towards better environmental decisions and an aid to reduce development costs.

The database also acts as an important information source which contributes to GSI maps and 3D models of the surficial geology. In urban centres, traditional field methods are difficult to deploy and often prohibitively expensive so site investigations (SI) are one of the very few windows available into the subjacent geology and are used to develop insights into this otherwise inaccessible target.

The reports held in the database come from a mix of **Public (like road, rail, water, sewerage and gas pipeline infrastructure) and private sector projects (like residential, commercial or industrial developments).** The data is acquired by the GSI on an ad hoc, best effort, basis built on the good standing of the database and the good will of the data providers (public clients and private engineering/ site investigation companies).

End user support for the maintenance and expansion of the database is well established however the absence of legislative support for the management of subsurface data necessitates ongoing efforts to attract new data contributions. Most reports submitted to GSI are paper copies but in increasingly data is now provided in digital formats. In future GSI will respond to demand for the provision of data in AGS format, which is growing.

Geotechnical Database and Viewer

The database structure is a relational database held in an Oracle environment. The database structure can be seen in Figure 1.

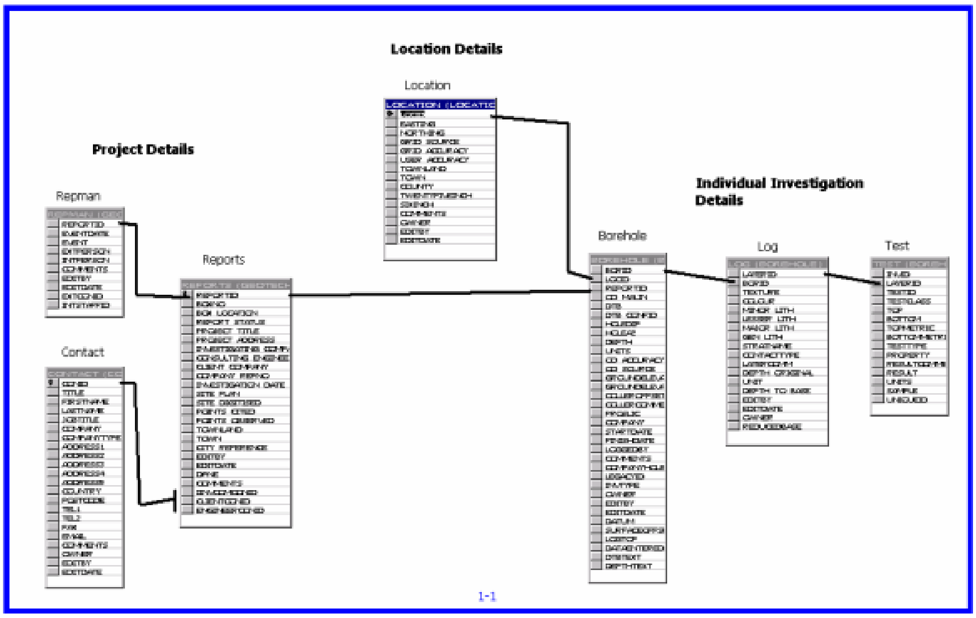


Figure 1: Structure of the database

Manual data input is controlled using a custom interface application called Geodata (Figure 2).

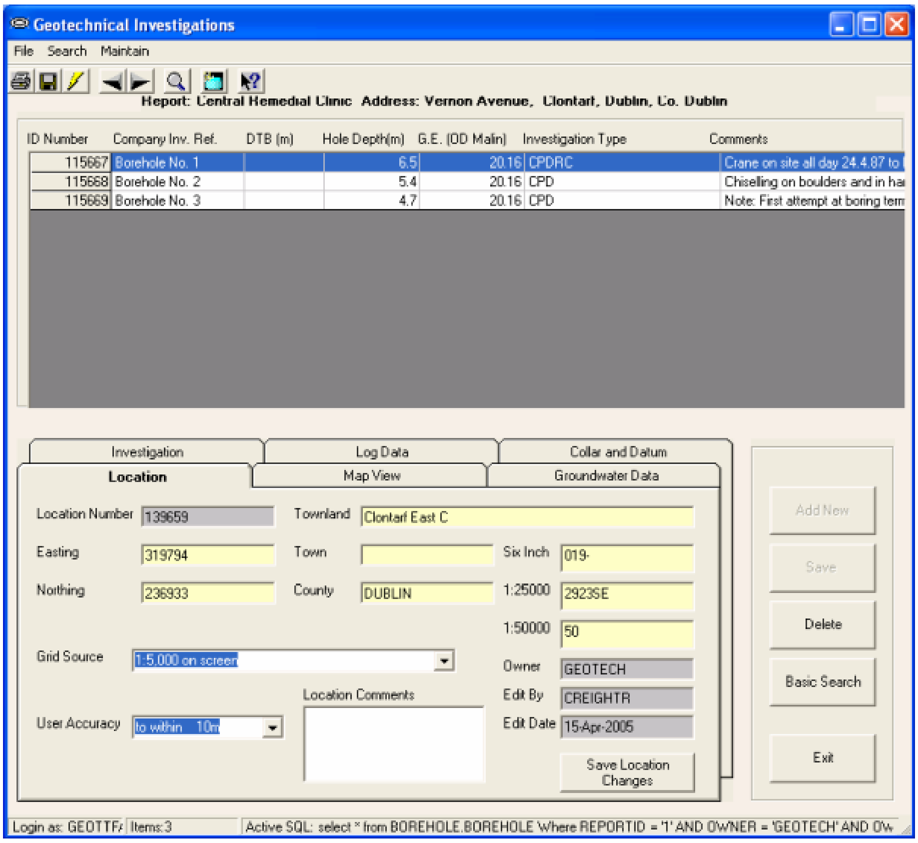


Figure 2: Location tab of a site investigation

Investigations that have a known location (X and Y coordinates), are digitised in a separated web application called the “Production Digitizer” (Figure 3).

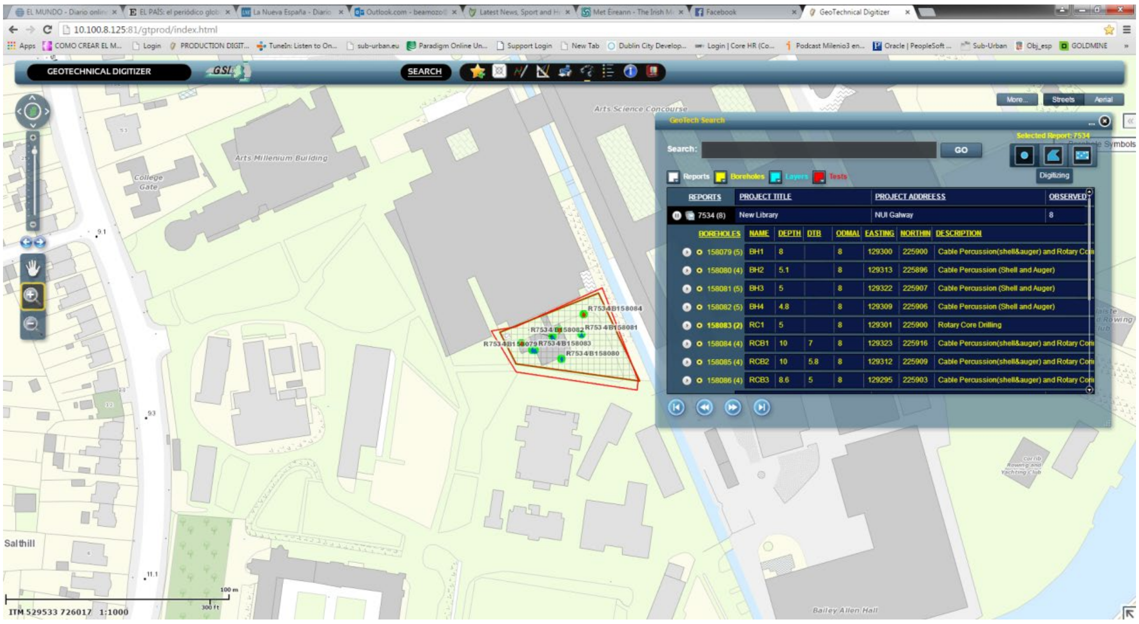


Figure 3: Production digitizer

All the data stored in Geodata and digitized in the Production Digitizer are immediately available in the Geotechnical Data Viewer which is available from the Geological Survey Ireland Spatial Resources Viewer web page (Geotechnical tab). Therefore quality control is of great importance in the inputting process. To ensure consistency and fidelity there is a detailed inputting manual as an instruction resource for data entry personnel and a quality control protocol for supervisors.

The quality control protocol:

- The inputter sends weekly reports to supervisors detailing progress
- Supervisors carry out weekly checks on the new data added to the database

The facility provides users with access to detailed information on geotechnical borehole/trial pit investigations and test results via an easy to use map-centric interface (Figure 4).

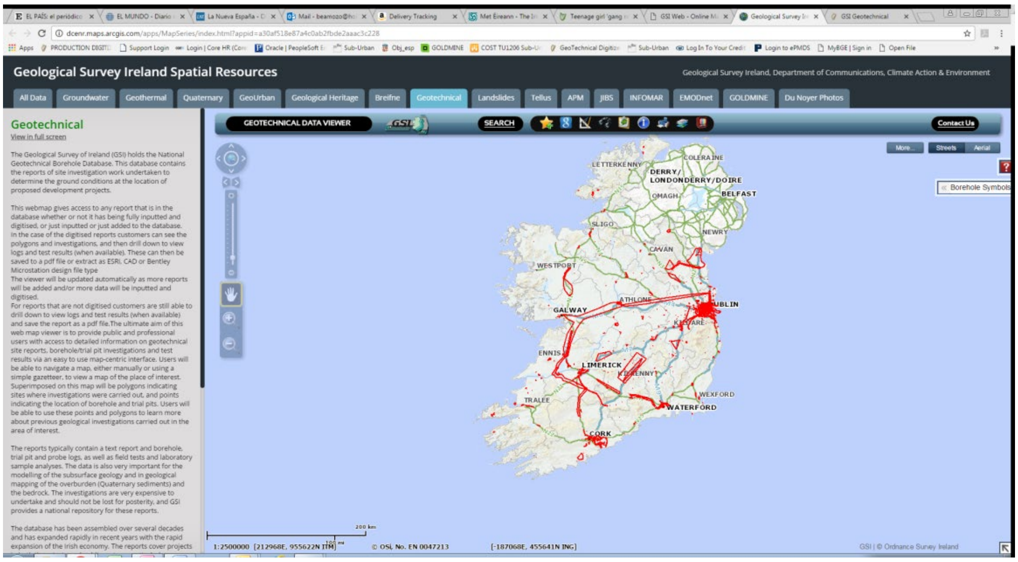


Figure4: Geotechnical Data Viewer

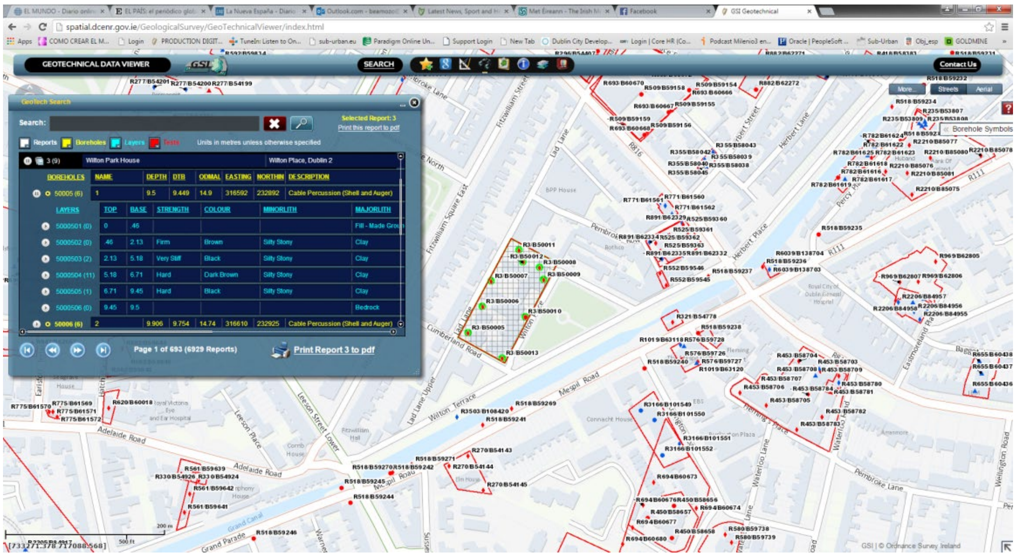


Figure 5: Search option

In the geotechnical data viewer, the data can be viewed, queried (Figure 5), printed or extracted to GIS formats or saved as a PDF file (Figure 6)for example.

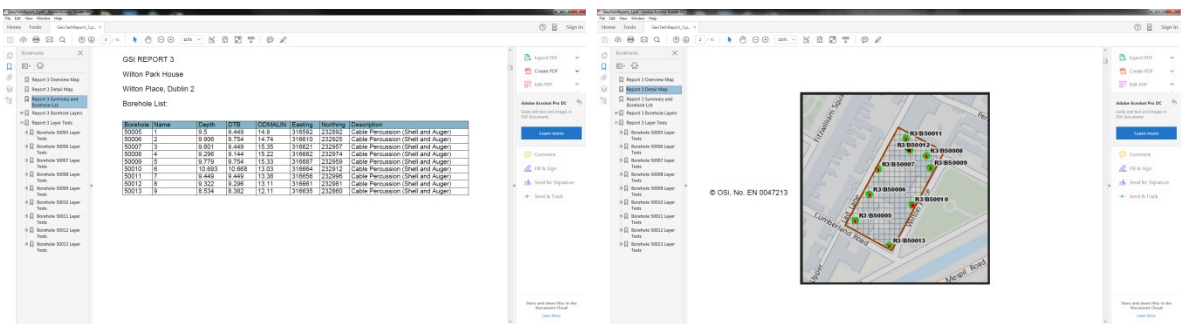


Figure 6: PDF export of a report selected in the viewer

In some cases, the reports registed in the database don't have the data inputted yet. In those cases, customers can contact the GSI staff and have access to the data they are looking for or access the data through The GSI online digital archive – GOLDMINE .

Outputs

Sustained gathering and entry of SI data into the Irish National Geotechnical Borehole Database (NGBD), over the past decades, has provided the requisite density and redundancy of data to enable 2D & 3D modelling of the subsurface in the urban centres of Dublin. These models allow new insights into the nature and distribution of the geological units that underpin some of Ireland's most important infrastructure.

- **Outputs 2D**
  As the amount of site investigations digitised increases ever year, Depth to bedrock contour maps, Rockhead OD maps, and 3-D models of the bedrock topography have been generated for Dublin.

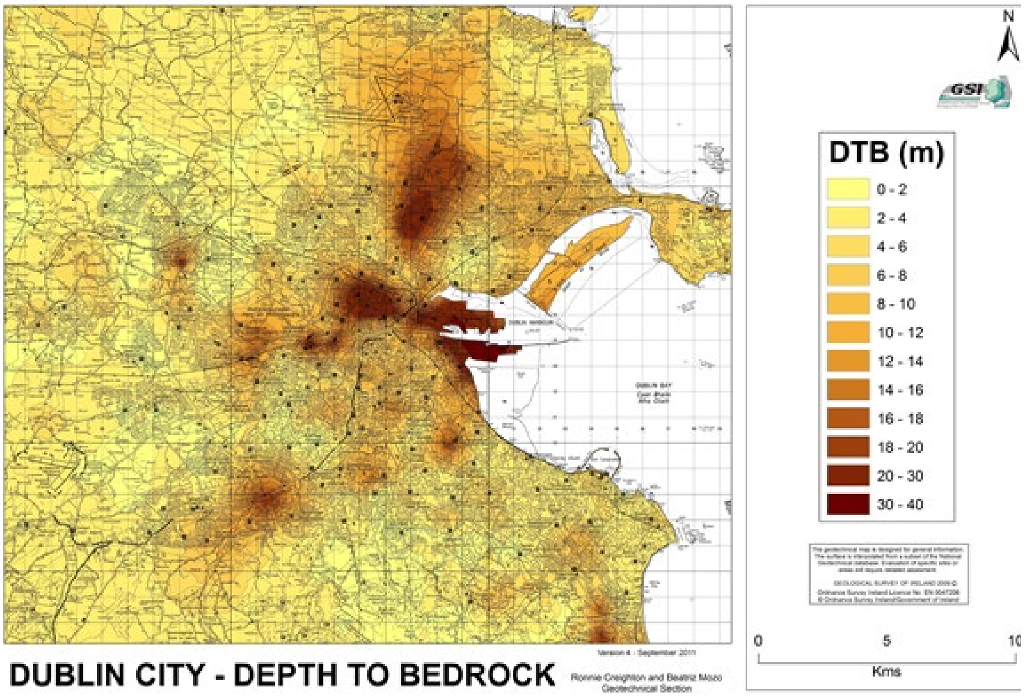


Figure7: Depth to Bedrock in Dublin City

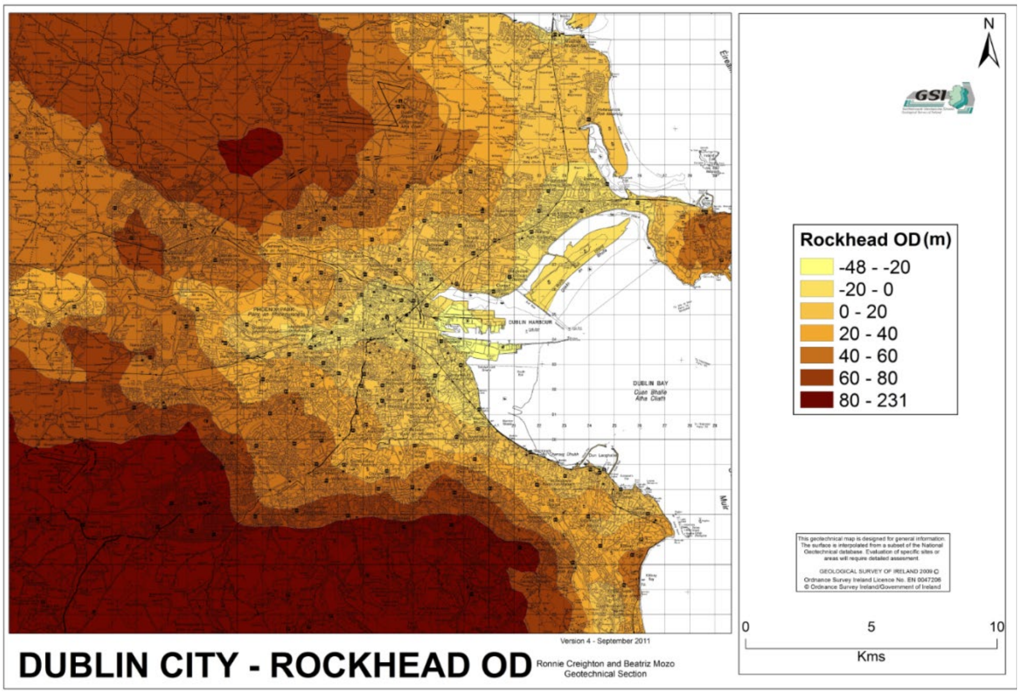


Figure8: Rockhead OD in Dublin City

- **3D outputs**

  The modelling was done using Subsurface Viewer is a methodology and associated software tool for 3D geological modelling.

  The models are constructed by creating fence diagrams of cross sections and the software interpolates between them.

  The availability of high quality and quantity georeferenced data constrain the model's accuracy.

  A 3D model has been created for Dublin.

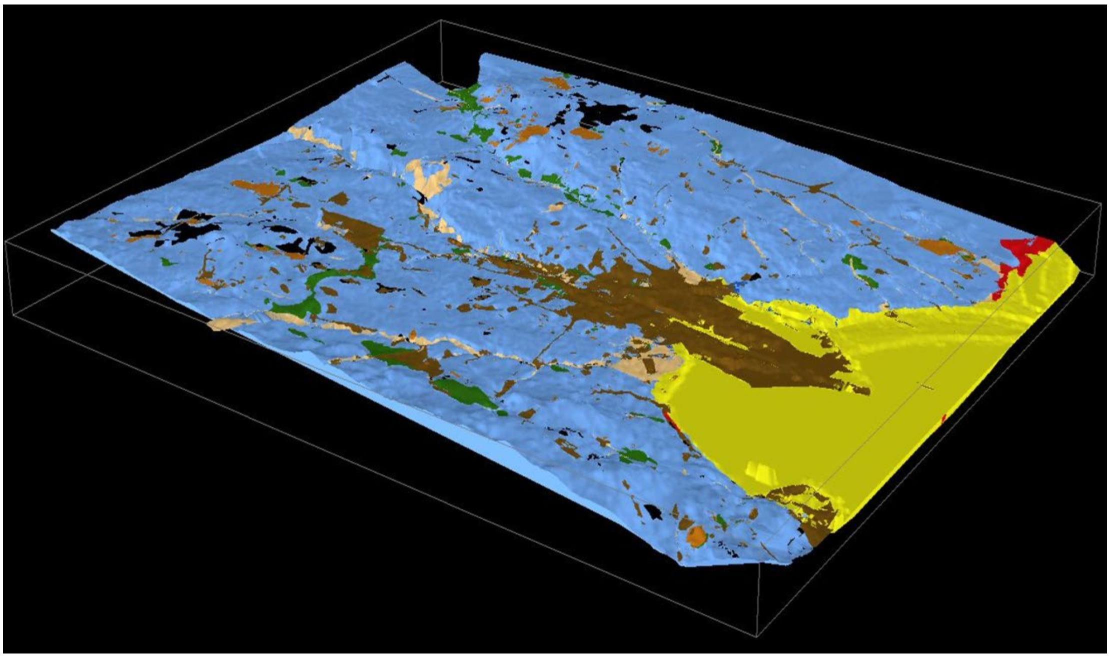


Figure9: 3D model of the Quaternary in Dublin City

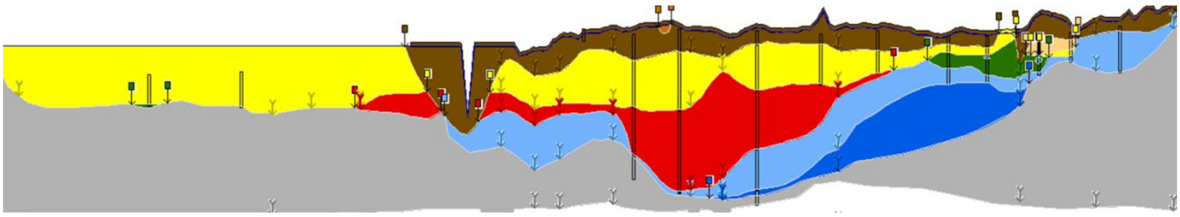


Figure10: EW cross section in Dublin Port

This model is now available for downloading for free from [3D Quaternary model of Dublin City](#).

There are detailed instructions on how to download the reader version of the Subsurface viewer and how to view and query the model by creating synthetic boreholes and cross sections.

The model can be downloaded in two different formats:

- 3D pdf
- Subsurface Viewer file type

APPENDIX: 2 Geotechnical databases case studies

2.3 PGI-NRI Engineering-Geological Database

Grzegorz Ryżyński, Krzysztof Majer

Engineering Geological Database project (BDGI)

The idea of creating modern engineering-geological studies which might be useful, inter alia, in the spatial planning and crisis management, was founded in 1998, when the project "Engineering-geological atlas of Warsaw" started. This prototype project resulted in creating 8 atlases for subsequent urban areas over the years 2003-2012. PGI-NRI, participated in their development (except Poznań atlas agglomeration) either as a consortium member or a co-operator.

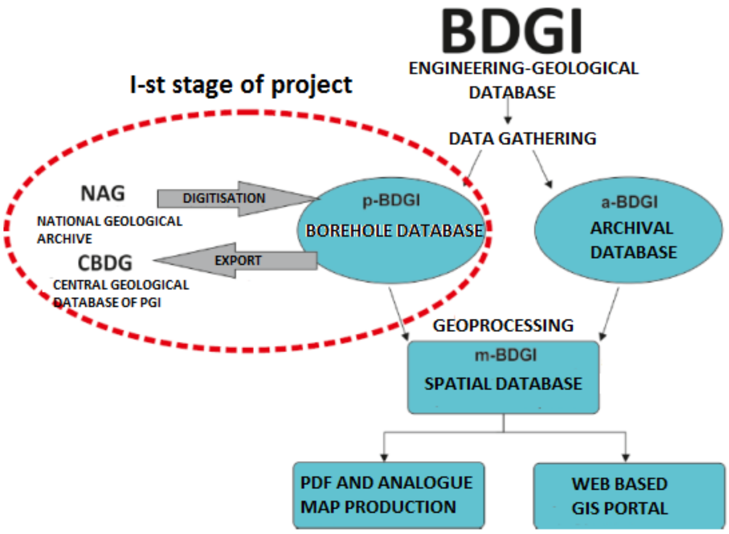
In 2013 PGI-NRI was entrusted to carry out the theme "Maintaining and updating the Engineering-Geological Database (BDGI), together with the preparation of engineering-geological atlases of selected areas of the country on the 1:10 000 scale ". It is a direct continuation of the previous studies and it is a part of the tasks of the Polish Geological Survey for the years 2013-2016 (according Geological and Mining Law).

During the task one “Engineering Geological Database (BDGI)" will be created. The database will merge and unify the bases of earlier atlases. It will be also supplemented with archive data from the geological documentation and continuously updated by the data from studies carried out for the BDGI project. As a part of the task, 6 new engineering-geological atlases will be developed on 1:10 000 scale (Bydgoszcz and Koszalin city, Plock and Piaseczno district, Gdynia and Kashubian cliffs). Previous engineering-geological atlases of urban areas will be updated. Feasibility study for 2 engineering geological atlases (for Lublin and Szczecin) will be developed as well. In addition, in terms of the popularization of the knowledge of engineering-geology the publication in the series of "Guidelines of engineering-geological documentation" will be released and the website about engineering geology will be continuously updated.

Introduction

Engineering geological atlases of urban agglomerations are the largest and unique digital collection of such data in Poland. They include detailed information obtained from an engineering-geological, geotechnical, hydrogeological documentations and borehole profiles.

Thematic maps included in atlases are graphical synthesis of information, based on engineering-geological data contained in the CBDG. They allow evaluating engineering-geological conditions in the areas of urban agglomerations, inter alia, for the purpose of spatial planning. They also enable decision making related to the design of detailed ground studies, minimizing damage to the environment. They may be used for the preparation of forecasts as well as for the assessment economic aspects of the investment. Analysis of information layers about geological and economic risks enables the risk assessment maps composition.



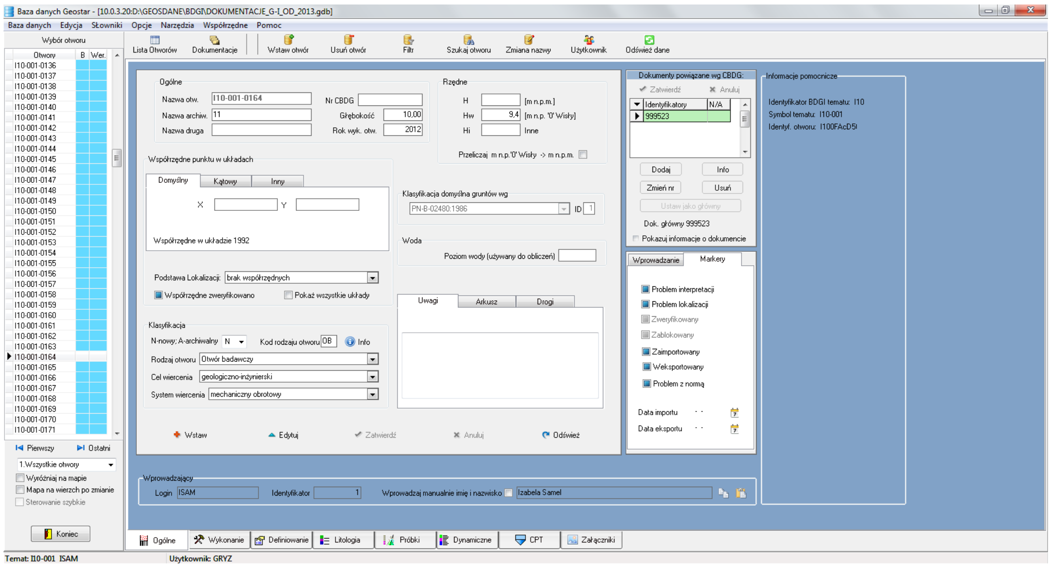


Fig2. Borehole Data Management interface (Geostar7BDGI Sotware)

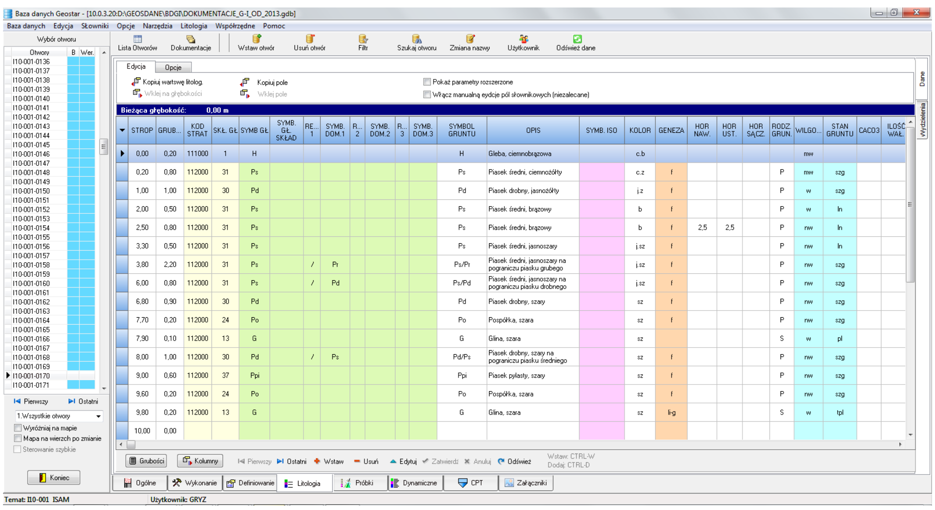


Fig. 2. Interface for data input.

Engineering Geological Atlases

Engineering geological atlases of urban agglomerations are the largest and unique digital collection of such data in Poland. They include detailed information obtained from an engineering-geological, geotechnical, hydrogeological documentations and borehole profiles.
Maps included in atlases are graphical analysis of the information obtained from the synthesis of engineering-geological data. The use of digital methods on a huge data collection allows to asses engineering-geological conditions, especially for the purposes of spatial planning. The information included in atlases enable decision making related to the design of detailed ground studies, minimizing damage to the environment. They may be used for the preparation of forecasts as well as for the assessment economic aspects of the investment. Geological and economic risks information layers analysis enables risk assessment maps composition.

Data management

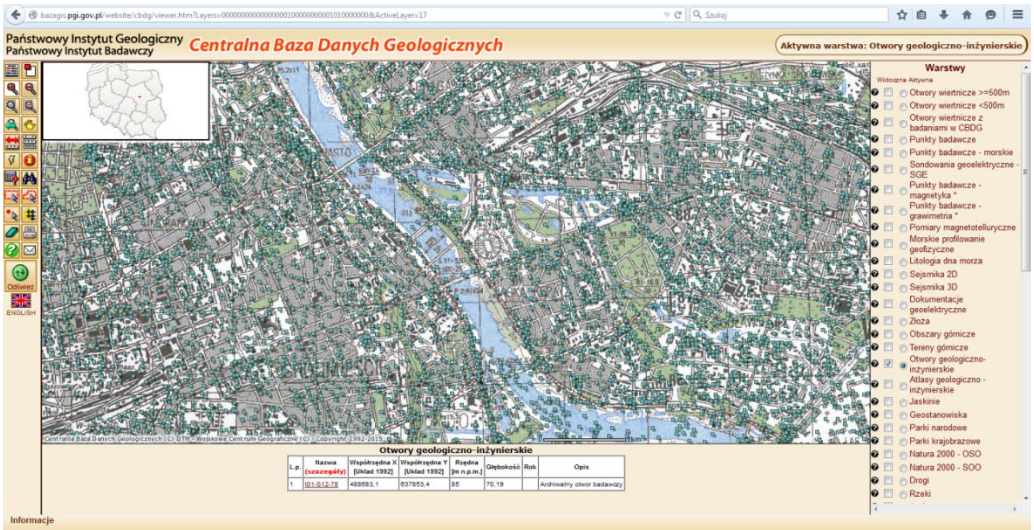


Fig. x. Spatial data viewer. (Version v.1.0.) New version is currently developed.

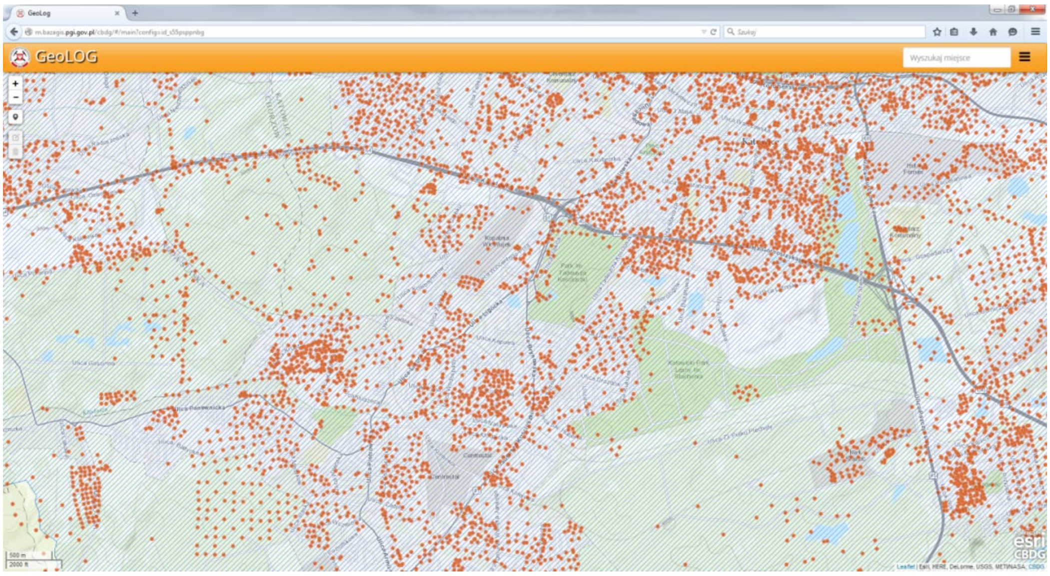


Fig. x. Spatial data viewer. (GEOLOG) This browser is dedicated mostly to be used on mobile devices.

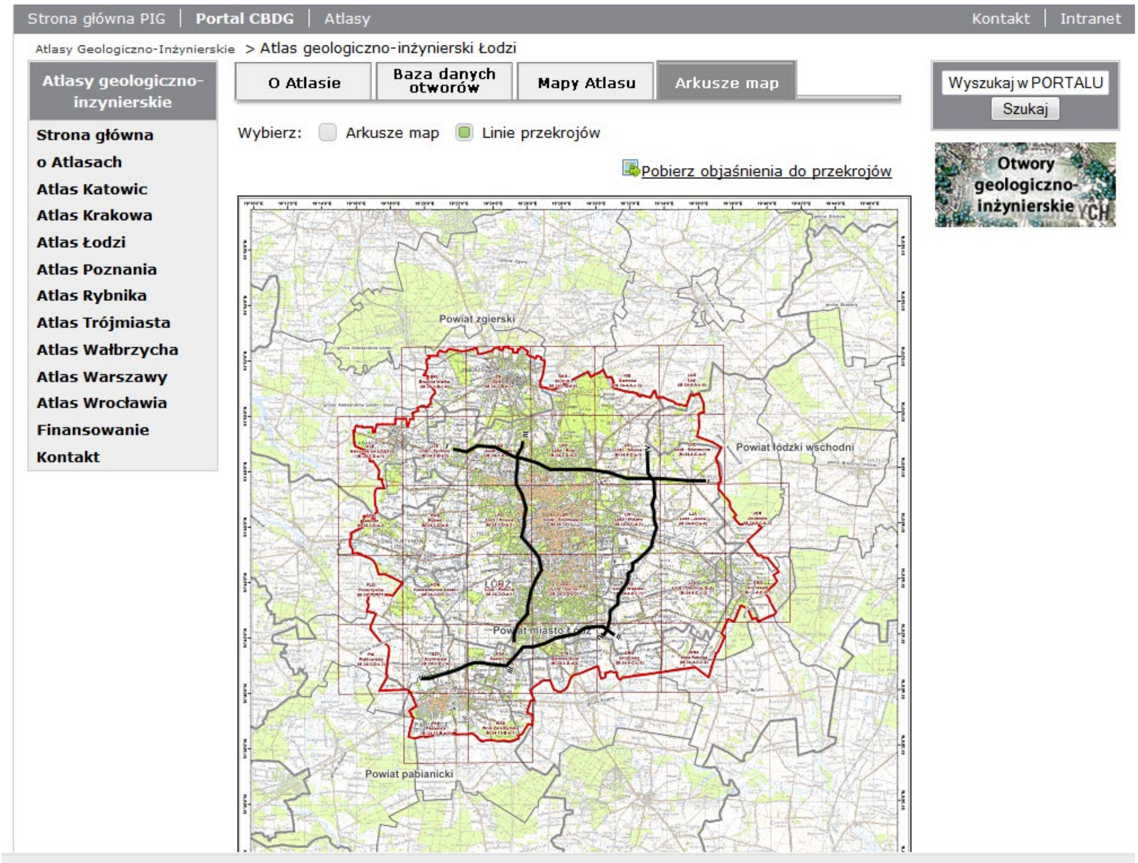


Fig. x. The map and cross sections download utility.

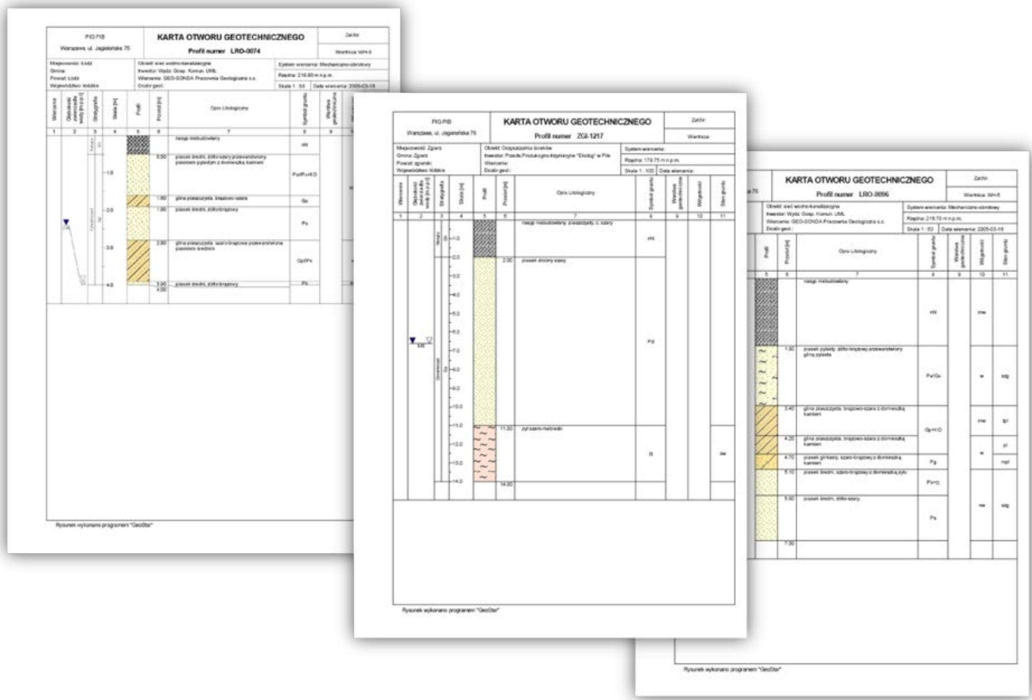


Fig. n. Borehole logs generated from the database. The pdf-generator software is provided by GeoStar.

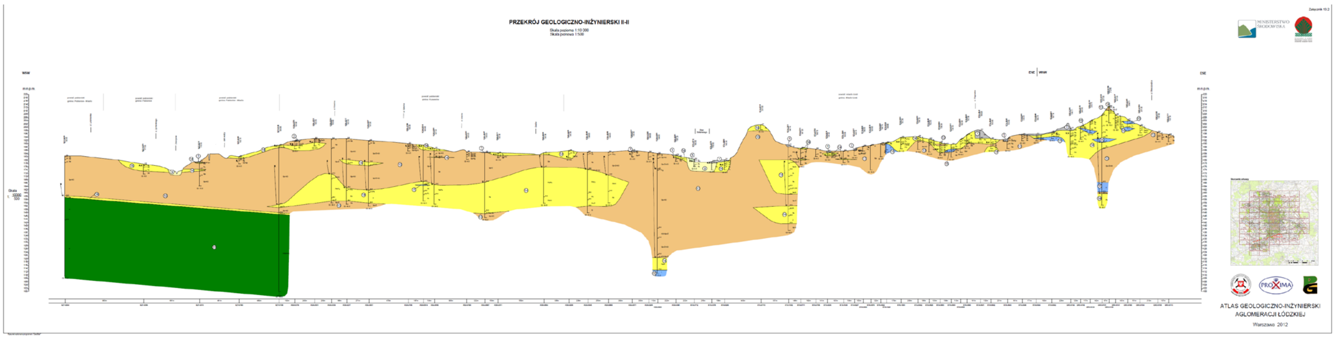


Fig. x. Engineering-geological cross section.

The main objective of creating engineering-geological atlases

Considering (the fact) that the environment is a complex and interconnected system, all changes must be considered carefully.
As far as the study and design work for investment in urban areas is concerned it is necessary to have a large amount of different information, both concerning natural engineering-geological conditions as well as infrastructure, land use, ownership relations etc. It is also crucial to have the possibility of varied processing of such data.
Properly prepared spatial information allows evaluating engineering-geological conditions in urban areas for the purpose of spatial planning, for example, for the choice of location for residential, planning surface and underground transport infrastructure, including different variants. They also

enable decision making related to the design of detailed ground studies, minimizing damage to the environment. They may be used for the preparation of forecasts as well as for the assessment economic aspects of the investment. Combined analysis of geological and economic risks information layers, enables risk assessment maps composition.

Methodology of creating engineering-geological atlases

Engineering-geological digital databases are the base for the preparation of engineering-geological atlases. They are created on the basis of engineering-geological, geotechnical, hydrogeological documentation and borehole profiles. Not only documents archived in a National Geological Archive (NGA) PGI- NRI, but also materials stored in the archives of state-owned enterprises, municipal offices as well as data obtained from field mapping are used for this purpose.

A prepared database is used as a rich reference material for analysis in GIS technology. Precise quantitative and qualitative geostatistical analyses are carried out together with defining the relations between the data sets. The creation and connecting different digital layers prepared using GIS methods allow to perform so-called thematic maps depicting and synthesizing information contained in the database. This enables the presentation of the factors influencing the construction conditions in the ground.

Development of the atlas includes activities of: gathering, archiving, analyzing, processing and data visualization, which is a tedious and complicated process. Therefore, the main elements of the methodology and procedures of digital engineering-geological atlases creating is included in "Engineering Geological Atlases of Urban Agglomeration on 1:10 000 scale - Instructions for executor".

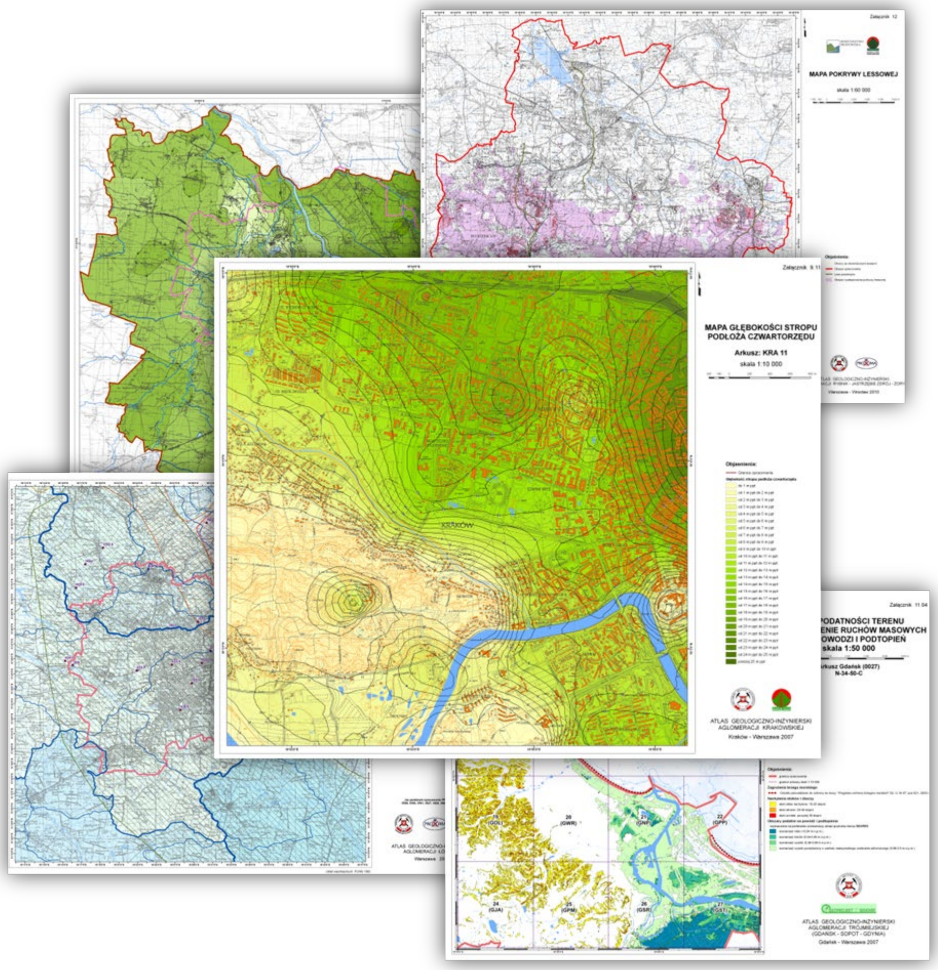


Fig. x. Set of engineering-geological and thematic maps.

Atlas' maps

Thematic maps were created automatically, based on representative archival boreholes collected in a computer database. For the purpose the following programs were Arc/Info (ArcViev 3.2) and Surfer 6, working both in vector and raster format.
For Katowice urban agglomeration most maps were prepared and printed in 1:10 000 scale. The only exception was: locality maps in 1: 150 000 scale and geomorphological map in 1: 50 000 scale.

The following maps were created:
1. Division of the Katowice urban agglomeration in the sheets – at a scale 1: 150 000
2. Documentation map – at a scale of 1:10 000
3. Map of anthropogenic ground - at a scale of 1:10 000
4. Map of ground at a depth of 2m - at a scale of 1:10 000
5. Map of ground at a depth of 4m - at a scale of 1:10 000
6. Map of the Triassic deposit level - at a scale of 1:10 000
7. Map of the Carboniferous deposit level - at a scale of 1:10 000
8. Map of the depth of groundwater - at a scale of 1:10 000
9. Map of construction conditions - at a scale of 1:10 000
10. Map of mining conditions - at a scale of 1:10 000

11. Map of areas for further evidence - at a scale of 1:10 000
12. Map of information useful for the classification of urban area - at a scale of 1:10 000
13. Geomorphological map - at a scale of 1:50 000

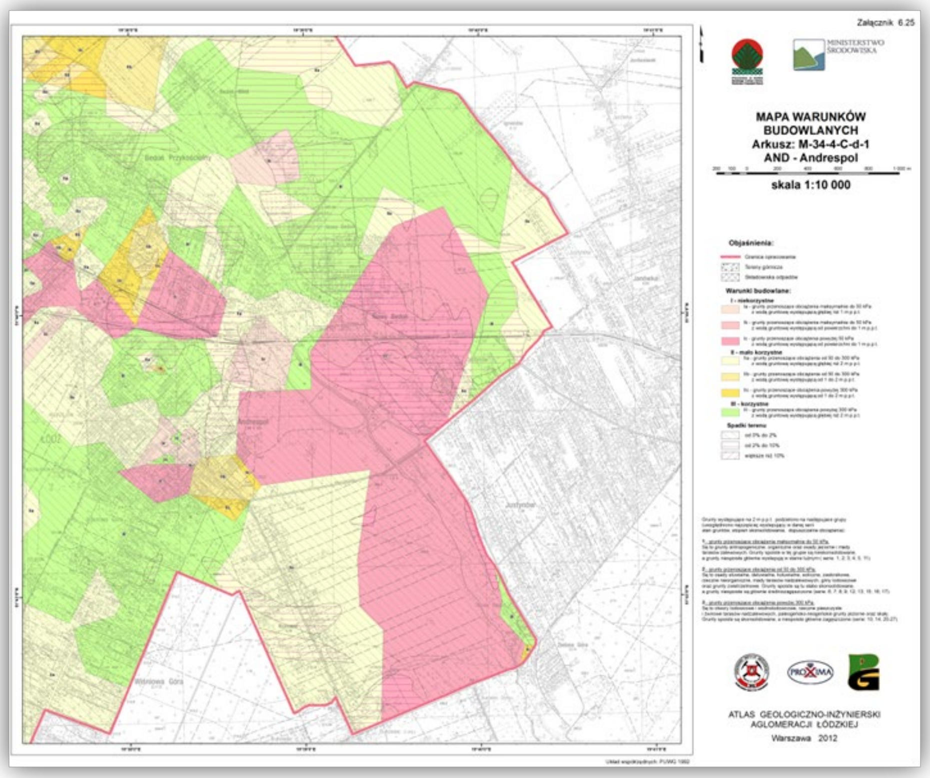


Fig.7. Example of an engineering-geological conditions map.

- 3D outputs

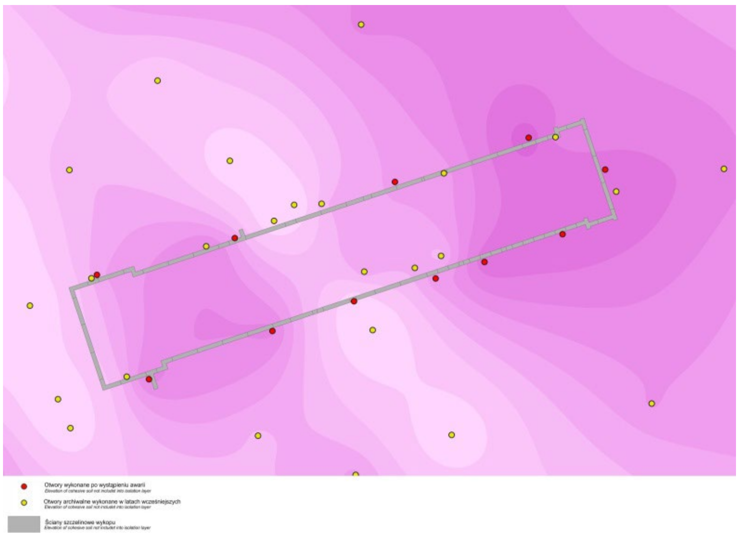


Fig. 2. Part of isolation layer elevation map, based on archive boreholes and those drilled after the accident

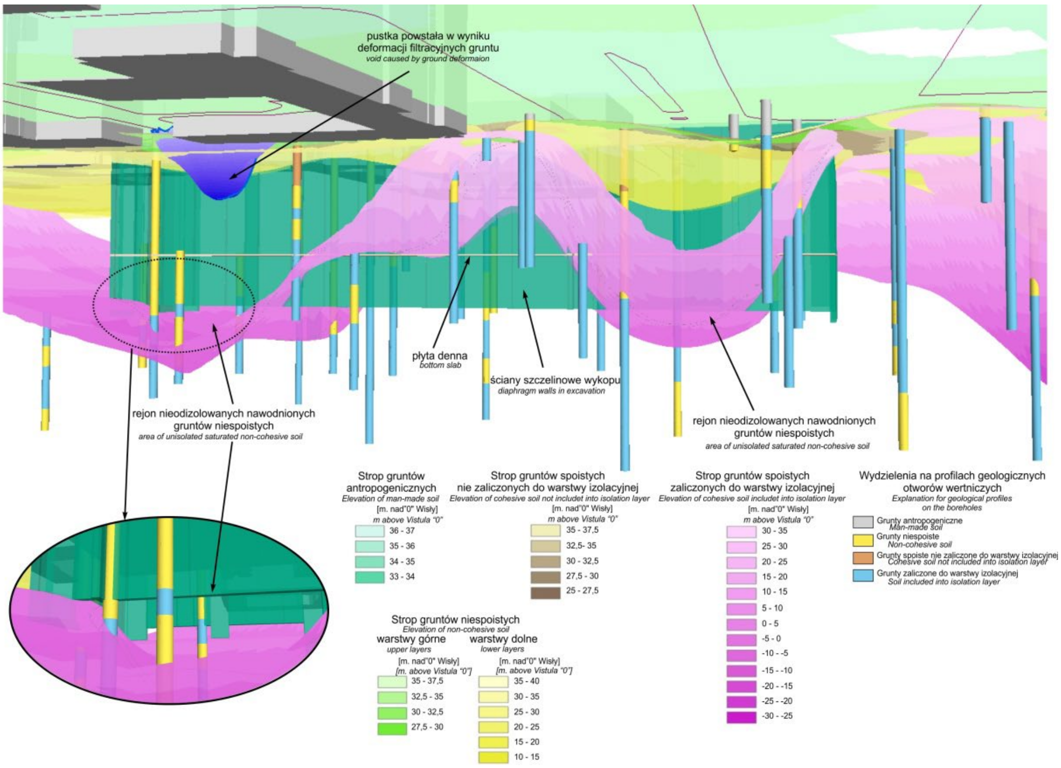


Fig.4. Fragment of geological 3D model in the area of ground works

Appendix 3. Geohazards. Case studies

3.1 Geohazards – Country report: Romania

Manole Stelian Serbulea

Current State

According to Eurostat, Romania is the seventh largest country in EU in terms of population (~20milion people) and twelfth largest in terms of surface (238,391km2), being in all accounts the largest in the South-Eastern Europe. The total built area is 2,454km2 (sixth in the EU), however, to a road network of 85,362km only 710km are motorway.

It is clear that in the conditions briefly described above the top priority of development should be infrastructure. In the past years, most of the local and European funded projects encountered difficulties regarding the geotechnical and hydro-geological conditions that stalled the works on sites even if at the present time all the Eurocode package is enforced, most of the National Annexes are issued detailing the local conditions along with revising the Technical Norms for Eurocode compliance.

The rising question is what must be the reason for technical difficulties in an industry fully regulated according to the EU norms, with experienced EU and local companies openly tendering for works under international FIDIC type of contracts?

There are here several reasons, out of which, the most important are:

- a. lack of information and transparency;
- b. special underground conditions over wide areas;
- c. excessive continental temperate climate, strong seismic zone;
- d. superficial technical approach of companies resuming to the strict compliance with the norms leaving aside the good practice principles.

The clause a. in the list hereinbefore may be readily understood by reading the Geotechnical Questionnaire forwarded to the COST Action TU1206 Sub-Urban, where the answer to most question regarding the collection of geotechnical information is “Yes – paper” and the availability for access, even for a fee is “No”.

The issue of sharing geotechnical information has been heavily debated during the National Conferences of the Romanian Society for Geotechnical and Foundation Engineering along with the possibility of creating an entity for certifying/authorising the companies that produce geotechnical reports.

So far, the conclusion is that the geotechnical information is private and proprietary and its sharing may lead to a decrease in the volume of new investigations and, regarding the certification/authorisation entity, it is unnecessary since there is already enforce the authorised checking of the geotechnical reports.

Clause b. shall be detailed hereinafter, c. is self-explanatory and being mitigated by technical regulations while d. is detailed in chapters 2 and 3.

Known and regulated geotechnical issues in Romania

Collapsible soils

The collapsible soils, also known as “macro-porous soils”, “loess” or “loessial soils” are Aeolian deposits of silts and silty soils (seldom with variation between sands to silty clays) that developed soluble mineral bonds between the solid grains leading to the preservation of the loose structure from the moment of sedimentation even after thick layers of soils settled on top. As long as the material remains dry, it has a very good mechanical behaviour, its only peculiarity being the failure mechanism that occurs through the crushing of the structure (known as “punching”) rather than the classical general failure by shearing.

If the soil moist, the soluble bonds dissolve and soil subsides. Depending on the collapsible soil layer thickness, it may collapse under its own weight (class “B”) or a surcharge (such as the one from a building) is necessary (class “A”). According to the norm NP125:2010 (replacing the pre-Eurocode norm P7/200), the distribution of collapsible soils in Romania is approximately the one given in Fig. 1. This norm is not only used for identifying the loessial soils, but is also a design code for all the structures built on them.

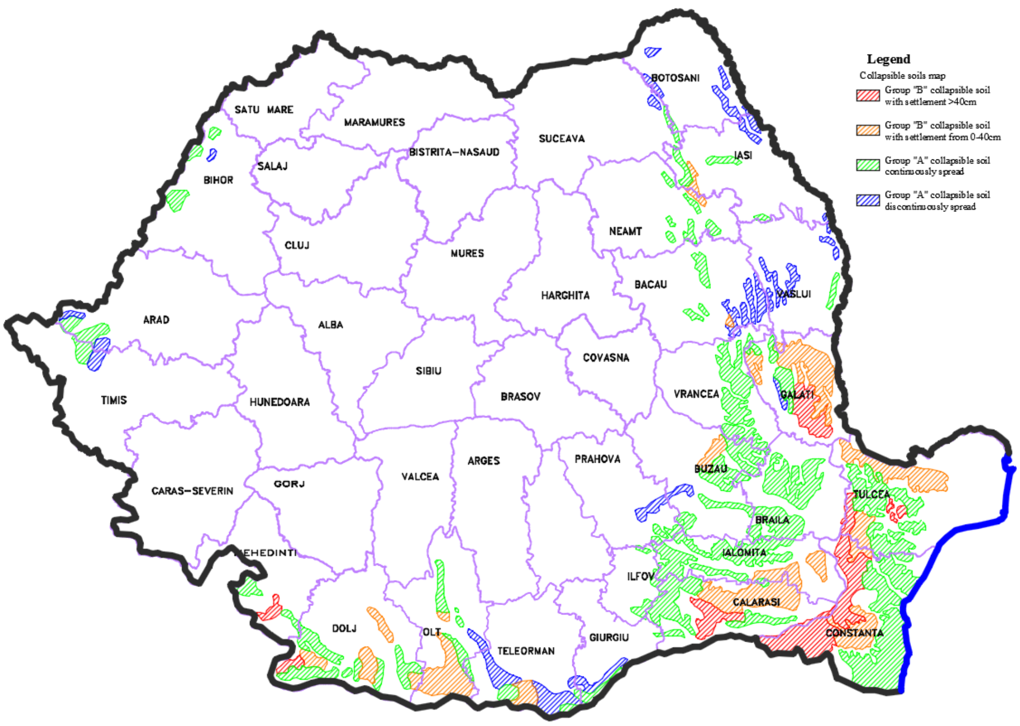


Fig. 1: Collapsible soils (according to NP125:2010)

Most of the times the water wetting the collapsible soils has anthropogenic origin (water supply, sewer or thermal network breaking, excavations left open over winter when rainfall regime is elevated and so on), affecting mostly the urban communities, but the natural ground water level increase appeared as a reason for collapse in few cases.

Out of the total surface covered by collapsible soils: ~17% (~40,000km^2), the different types of loessial deposits are:

Class “B” with subsidence when flooded, under the own weight larger than 40cm	2.0%
Class “B” with subsidence when flooded, under the own weight from 0 to 40cm	4.1%
Class “A” with no subsidence when flooded under the own weight, continuously spread	8.7%
Class “A” with no subsidence when flooded under the own weight, discontinuously spread	1.8%

The map included herein is a reproduction after the one given in the new NP125:2010, that is reported as being at a scale 1:800,000 and is a weak reproduction from the previous norm (where “Yugoslavia” is depicted as a neighbouring country!). In this conditions it is quite obvious that an update for the possible areas where collapsible soils may be encountered is necessary and would be facilitated by the construction of a national borehole database.

Even if there are no recorded data concerning the damage induce by loess associated subsidence, in several major cities of Romania, especially in the Eastern and South-Eastern side of it, losses were reported both by public and private civil engineering structures owners.

Expansive soils

As defined by the norm NP126:2010, the expansive soils are soils with an important content of active clay leading to swelling pressures that act on the foundation structures. The medium active to active soils have 15-30% clay and induce 50-200kPa swelling pressure, while the very active ones have more than 30% clay and exert more than 200kPa upon the foundations.

The norm gives sufficient methods both to identify and to mitigate this type of soils, but just like the case of the collapsible ones, the distribution map, reproduced herein as Fig. 2 is even less accurate than the previous one.

Since the effect of the expansive soils is subtle and less obvious than the one induced by collapsible soils there are seldom cases when it is identified as a problem per se, usually being associated with frost heave, improper waterproofing, water network leakage and so on.

Over-conservative design approach when mat foundation is used when it is not necessary diminishing the pressure driven by the superstructure of a building under the swelling pressure is the most common cause of foundation cracking since it is subjected to a upwards pressure it was not designed against (main reinforcement being on the opposite side).

In the case of transportation infrastructure design, the earthworks standard STAS 2914-84, the clays are classified in the worst group of soils (4 out of 4) being recommended removal or improvement by mixing with sand or lime. Unfortunately, since in this type of works the soil volumes necessary to be processed are large, some contractors try to avoid these costly procedures and leave the material in its natural condition leading to various types of superstructure decay, the most common being longitudinal cracking of the carriageway.

By a rough approximation from the map (Fig. 2), the total surface covered by expansive soils with medium to very high activity is ~29% (~69,000km^2), out of which:

Very expansive soils	13.1%
Medium expansive soils	15.8%

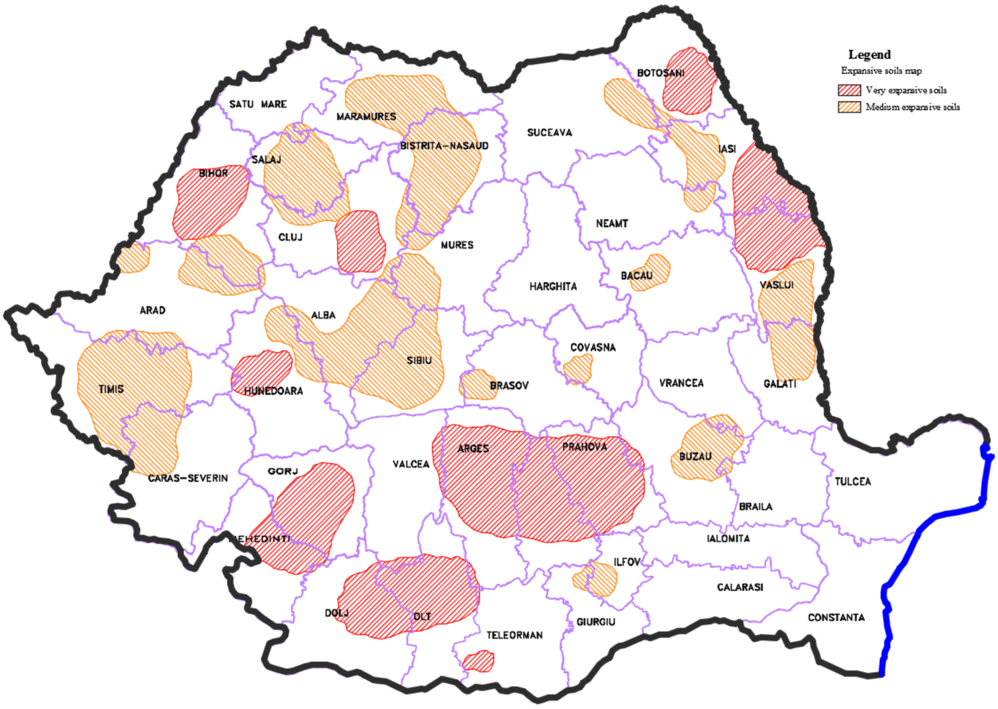


Fig. 2: Expansive soils (according to NP126:2010)

Proper mapping should be compiled for the distribution of this type of soil, too. An important remark is that in some cases the soil may be both collapsible and expansive, when we deal with macro-porous silty clays.

Unstable soil mases (landslides)

According to the values reported by the Natural Disasters Insurance Pool (PAID, Romanian acronym), in 2015 there have been opened 100 claims of landslide damage. The compulsory insurance policy covers three natural disasters, namely landslide, earthquake and flooding in a quantum of €20,000 per dwelling.

Since the landslide effect is immediately obvious, this type of geotechnical problem was the most studied, the guideline hazard map (Fig. 3) being defined by the Law 575/2001. It also decreed at the clause 7 that in maximum three years from the date the law was enforced, the counties *"shall detail identify, mark geographically and declare the natural risk areas [...] and compile data banks regarding these areas that are periodically updated and integrated in tha national monitoring system"*.

This important operation started, demonstrative maps have been compiled, however at present time they were not generalized and are completely forgotten due to the lack of funding.

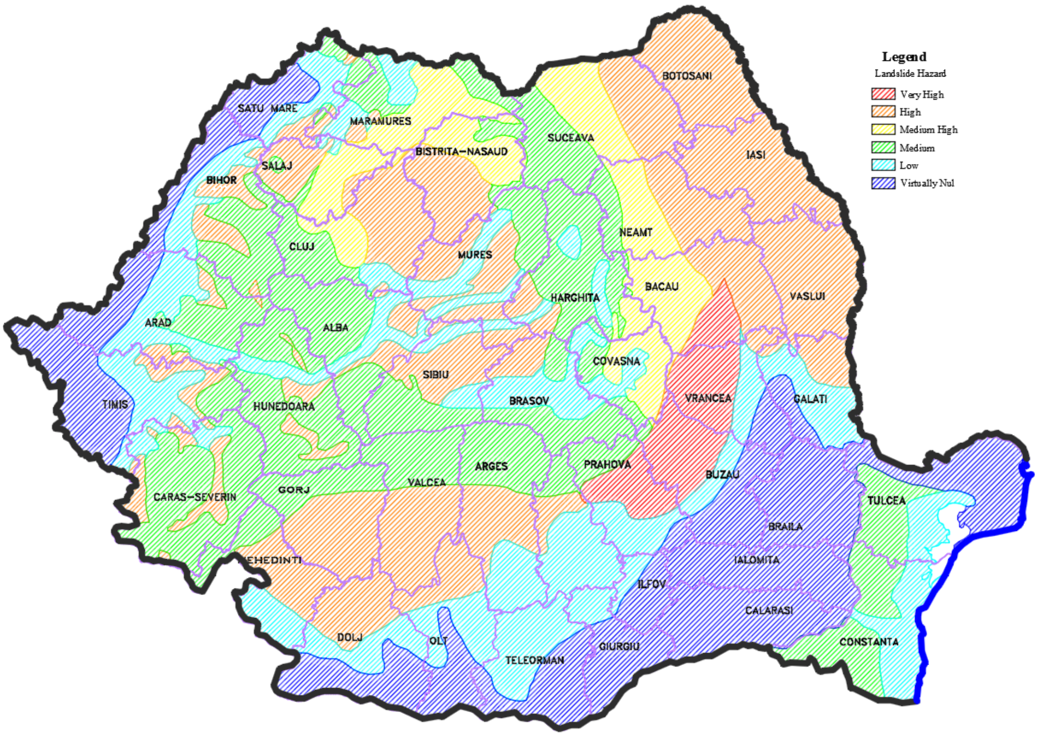


Fig. 3: Landslide hazard zones (according to Law 575/2001)

Technically, more than 60% of the territory is prone to landslide:

Very high hazard	3.5%
High hazard	27.6%
Medium-high hazard	7.5%
Medium hazard	24.4%
Low hazard	18.0%
Virtually null hazard	19.0%

Suggested good practice/´best practice´

Good practice

For issuing the Construction Permit of all the civil engineering structures in Romania, according to the Law 50/1991 and its following amendments states that the Geotechnical Report is compulsory for all buildings in urban environment and for the ones in rural regions that have more than one storey. Moreover, all the Geotechnical Reports must bear a third-party verification of an authorised checker that proves the compliance with all technical regulations. Each checker has to forward periodically all the reports they sign to the Ministry of Public Works, so the full list of all authorised persons works may be controlled.

The norm regulating the content of Geotechnical Reports, NP074:2014 has been revised and includes references to all the possible problems that may occur. This norm is compliant with Eurocode 7.2 and it gives supplementary requirements for the local conditions of Romania along with the content for each type of geotechnical documentation.

The content and shape of the report and its basic reference information such as the borehole record with synthetic data, the amount of testing and the type are regulated. The same applies to the in-situ tests such as CPT.

Basically, all the documents mentioned here have to be issued on paper, so there is no possibility of indexing, recording or searching any significant information even after several years. The checker themselves is not supposed to / allowed to keep a copy of the document submitted for verification, but the document is null without their original stamp.

Best practice

Probably the best practice would be to have all issued verification report updated online on the Ministry site in order to avoid loss of information along with a minimum set of information such as the borehole records with the complete set of synthetic data that are required by law along with the position of the investigation point.

The problem of data security, validation and storage remains, along with the means of using all the data remains a key to this issue.

Highlights of key technical requirements for the future

Also the gap analysis was performed in the table below:

Current State	Desired State	Gap Description	Gap Reason	Remedies
Standard exchange formats for geotechnical data in use in a small number of cities	Common standards used across all dataset themes identified as high priority by city partners	i. Many cities who could benefit from AGS for geotechnical data are not using it.	Some cities are simply not aware of the standard, whilst others may consider it an unnecessary expense.	Provide free and open case studies which illustrate the cost-benefit of implementing such a standard and provide guidance for interested parties as part of WG3 toolkit.
		ii. No common data exchange formats for groundwater data, tunnels, utilities, pollution data, land use or surface features.	Either they were never created or where they do exist the potentially users are unaware they exist	*WG3 could investigate best candidates for standards for each priority?*

3.2 Web based GIS project for land subsidence monitoring in Konya Basin, Turkey

Aydin Ustun

Introduction

Web-based mapping services which lead to manage, view and share spatial information with public and autohized users by means of custimized map interfaces is a way of reducing costs of a GIS project using standardised map infrastructures.

A GIS project launched for developing a geovisual analytics environment with map mashups aims to investigate the vertical displacements in Konya Closed Basin. The concept of web mashups has arised as a result of the widespread use of internet and developments in web technologies for the last decades. A web mashup is an application that uses content from more than one source to create a single new service displayed in a single graphical interface. The term implies easy, fast integration, frequently using open application programming interfaces (API) and data sources to produce enriched results that were not necessarily the original reason for producing the raw source data.

The main data sources of the temporal and spatial subsidence detection in Konya Basin are GPS campain measurements, InSAR images, geotechnical data from the inclinometer and magnetic settlement observations in drilled boreholes, monthly groundwater level observations, time series data of precipitation and tempurature, topographical, geological and hydrogeological maps of different scales and purposes, as well.

The map mashups which combine data from different sources in a single web application provide an effective geographic information system (GIS) functionality to analyse the correlation patterns between land subsidence and groundwater levels, meteorological, hydrogeological and geological data in the region using The Google Maps API infrastructures.

Study Area and Web Mashup Application

Konya Closed Basin is the largest closed basin located in the inner part of Anatolian peninsula, covering an area about 54000 km2 including the provinces of Konya, Karaman, Nigde and Aksaray (Figure 1). In order to monitor the height changes in the basin, a GPS network which contains 27 stations has been established and 10-period measurement campaigns have been carried out with the intervals of 3-4 months. The GPS analysis results reveal vertical deformations (subsidence) about 2--40 mm/year, which have a strong correlation with the groundwater level observations. In addition, Differential InSAR analysis indicate maximum subsidence rates of 33 mm/year, and verify the GPS estimates. The vertical deformations obtained from both InSAR and GPS are located mostly within urbanized areas and green land which are used for agriculture.

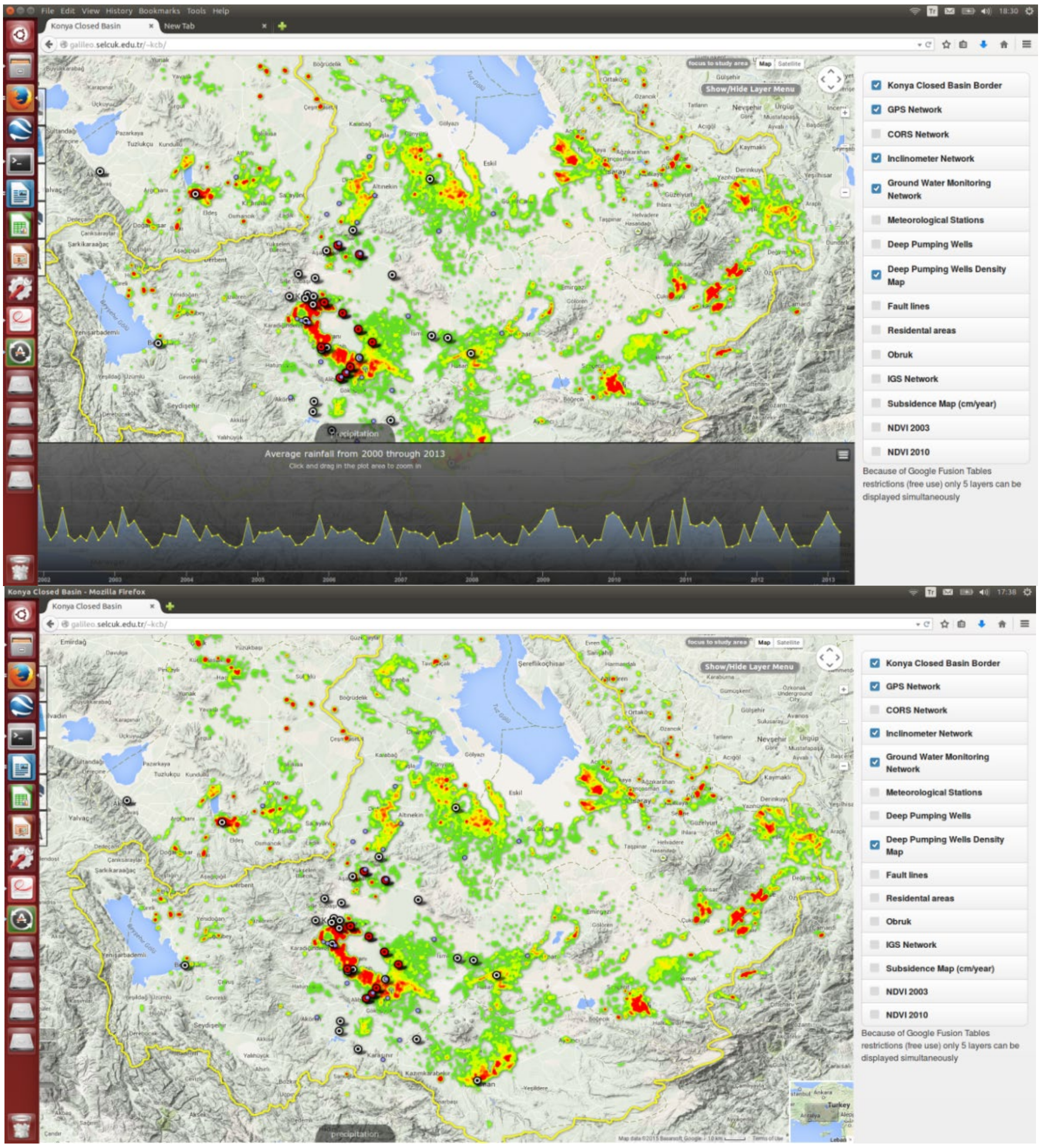


Figure 1: Subsidence monitoring project in Konya Closed Basin and web mashup GIS application

The Web mashup application for visualization of the data were constructed by Google Maps API, Google Fusion Tables API and Highcharts API. For storage and management of the collected data, the Google Fusion Tables have been used and it is a cloud-based service for data management and integration. Fusion Tables enables users to upload tabular data files (spreadsheets, CSV, KML). The system provides several ways of visualizing the data (i.e., charts, maps, and timelines) and the ability to filter and aggregate the data.

It supports the integration of data from multiple sources by performing joins across tables that may belong to different users. Individual users can keep the data private, share it with a select set of collaborators, or make it public and thus crawlable by search engines. By the Fusion Tables API, users can copy a small fragment of JavaScript code into the source of their page (e.g., a blog entry) and the visualization will be displayed there, with a live link to the data. That is, when the data is updated in Fusion Tables, the visualization is also updated.

It provides client-side visualizations through the Google Visualization API. This is a well established framework for visualizing data on the client. The visualization is rendered on the browser using JavaScript or Flash, and the data required by the visualization is obtained from a data source interface. A large collection of visualizations has already been created by Google and the community.

The point dataset of the study area has prepared within a single Fusion Table with fields name, class, class code, longitude, latitude and icon style (left panel in Figure 2). Fusion Tables also provides visualization of the data as maps and charts. The right panel in Figure 2 shows the point dataset map view visualized by icon style column. By using standard Google maps marker names, points can be visualize by its name. The created web page of mashup application can be splitted to the different frames for map, chart and legend (see Figure 1). The chart frames can be used to display horizontal and vertical displacements at GPS observation points respectively (Figure 3).

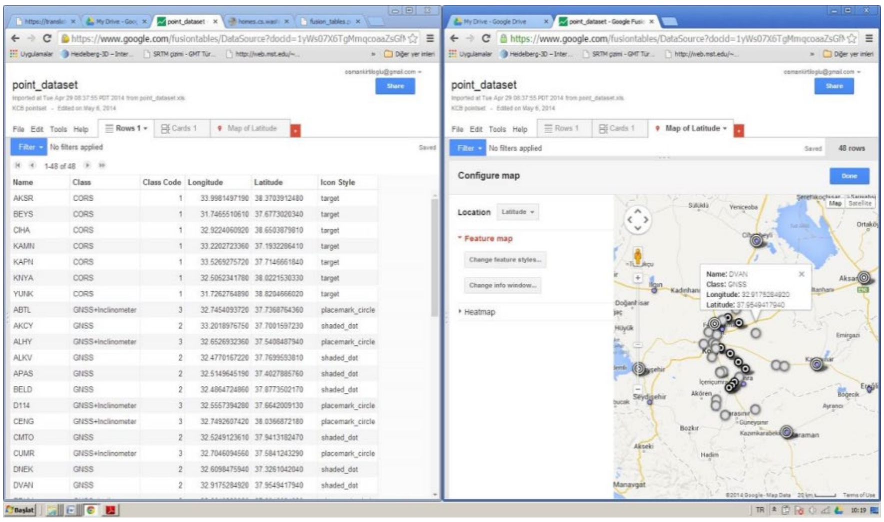


Figure 2: Point dataset in Google Fusion Tables (left) and its map view (right)

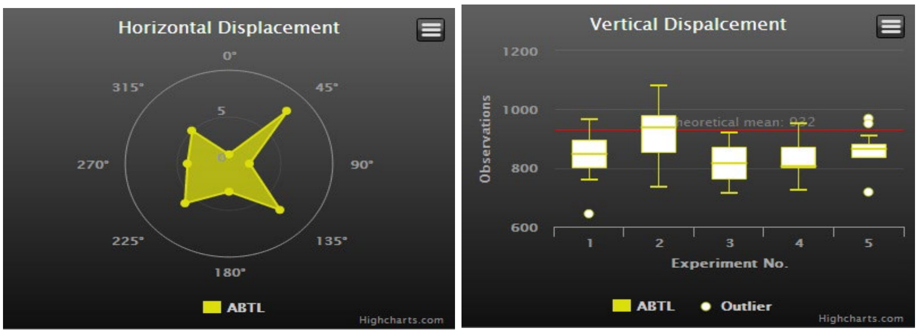


Figure 3: Different chart types for visiualizing horizontal and vertical displacements at GPS stations

The GIS environment has provided to capture the causes of land subsidence occurrences using spatial correlation analysis (Figure 4). The GIS portal of the project has been published from the url address http://galileo.selcuk.edu.tr/~kcb.

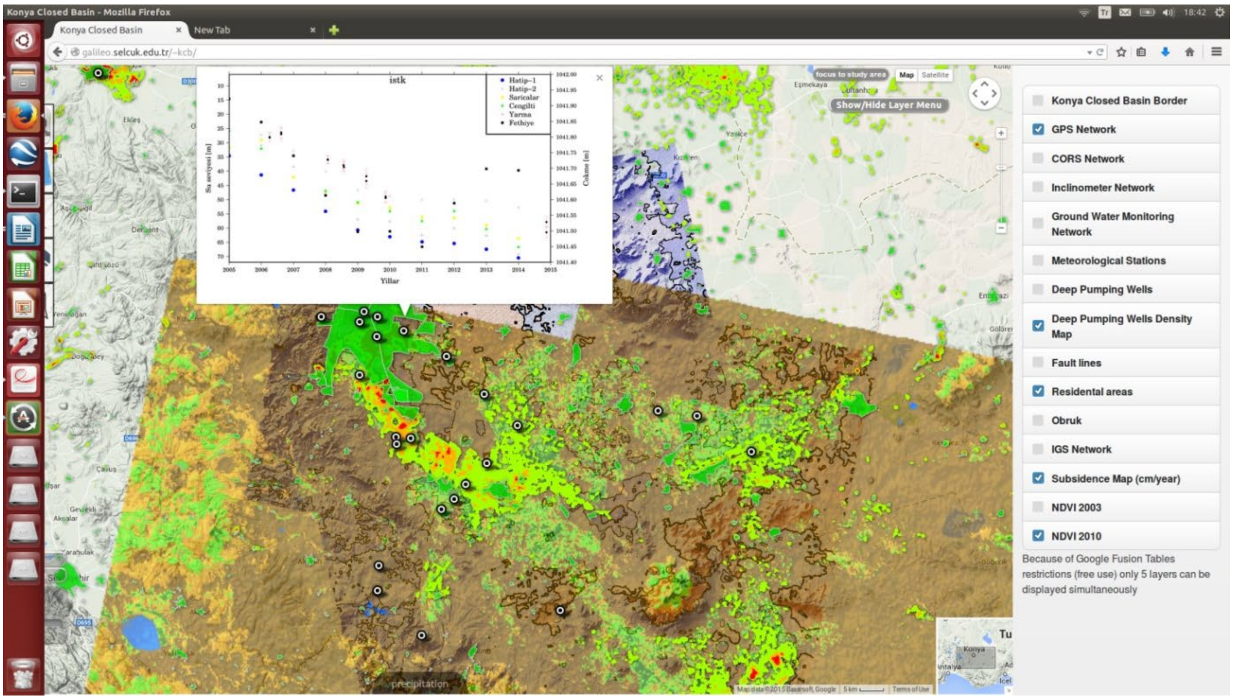
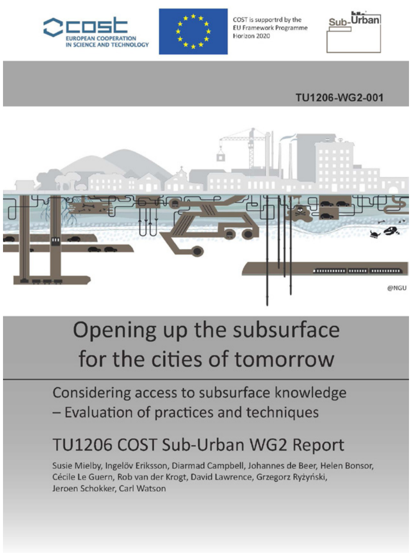
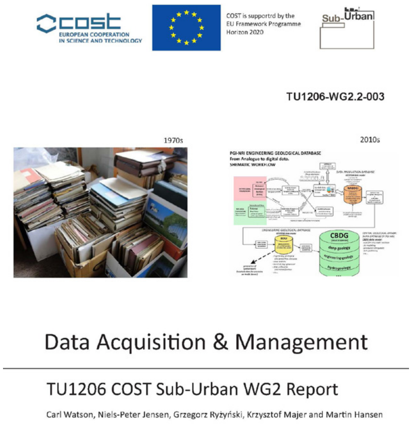
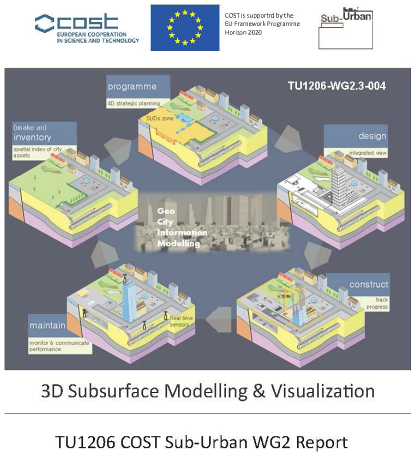


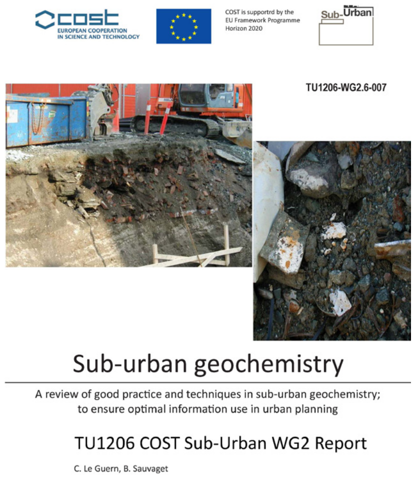
Figure 4: Land subsidence occurences caused by groundwater and land use in Konya Basin

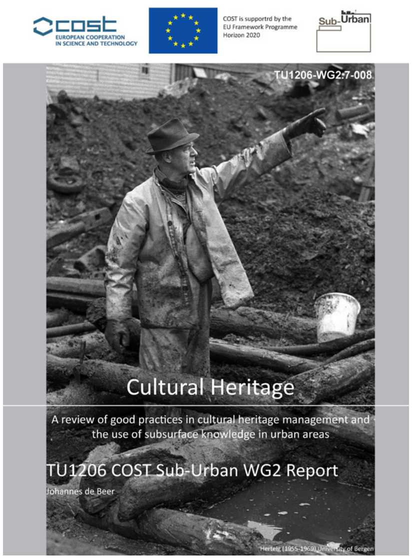
COST is supportrd by the
EU Framework Programme
Horizon 2020











www.sub-urba..eu

www.cost.eu