3D spatial planning of the Dutch subsurface : why is it so vital for society?

Swiss Bull. angew. Geol. Vol. 24/1, 2019 S. 7-11

3D Spatial Planning of the Dutch Subsurface: Why is it so vital for society?

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Keywords: geological data, geological 3D model, key register, data access, subsurface legislation, subsurface land-use planning

1 Introduction

The Netherlands are a country characterized by high population density, ensuing high land-use intensity and a high degree of urbanisation. These are not the easiest circumstances for exploiting the countries underground resource such as gas, groundwater, construction materials, salt and silica sand, as they easily get in conflict with each other and the surface usages. Nevertheless, there is a lot of activity in the Dutch subsurface (Fig. 1). The main driver for activities in the Dutch underground is to make profit in the deep subsurface (gas fields or coal mines) and to avoid costs in the shallow subsurface (housing foundations or ground water).

The geology of the Netherlands is complex. Much more complex than one might imagine of such a flat country. The piece of lands nowadays known as the Netherlands has been shaped by dynamic process within the earth's crust, by millions of years of climatic and environmental change and by human activity. In the past, the area has experienced ice ages and periods of tropical climate. It has sometimes been land and sometimes lain beneath the sea. In warm, moist periods, it has been covered by dense vegetation, leading to the formation of thick deposits of dead plant material. In warm, dry periods, the shallow seas have evaporated to form salt deposits surrounded by desert.at our times, rivers have transported large quantities of sand and clay into the region from newly created mountains further inland. And when the Netherlands was covered by sea, thick layers of clay and chalk have built up.

2 Urgent need for action

For all the human activities in the subsurface, a sectorial approach with light coordination was the standard until recently. For example, Groningen gas field is a giant natural gas field in the northeastern part of the Netherlands. Discovered in 1959, it is the largest natural gas field in Europe. The gas extraction from the Groningen field led to seismic tremors damaging building infrastructure, ultimately leading to the drastic political decision to stop the production of onshore gas on 17 January 2014. Those affected by the earthquake received a compensation worth of 1.2 billion Euro, spread over a period of 5 years.

Another example: the groundwater extraction for an industrial plant in Delft, which was going on for more than one hundred years, was stopped and the ensuing raise in

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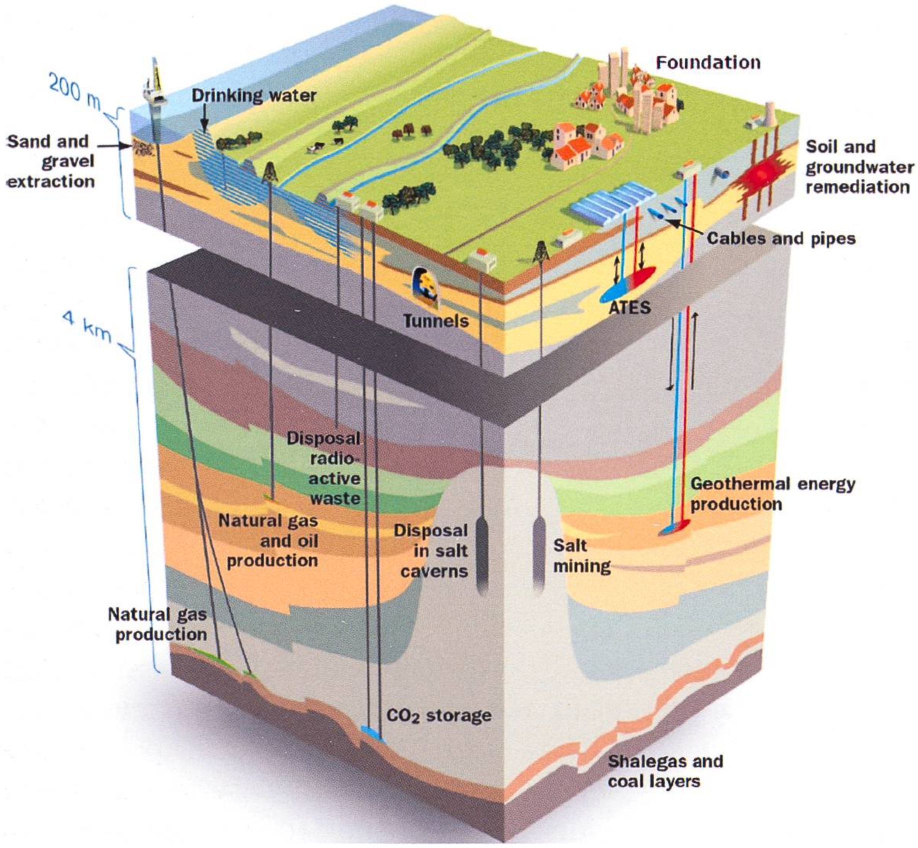

Fig. 1: Human activities in the deep and shallow subsurface of the Netherlands.

the groundwater table by up to 10 m flooded numerous basements. The houses were built after the start of the extraction at low groundwater levels and the design of the basements neglected the temporary nature of this low groundwater table.

These two cases-studies are compelling examples for the need of a good understanding of the subsurface and sustainable planning and coordination of its use. The foundation of this is reliable data. The decision makers recognised this and the Geological Survey of the Netherlands TNO was enabled to collecting all relevant subsurface data in a so called key register which is for a big part open for public access. What helped convincing the policy makers where studies which tried to monetarise the value and societal benefit of freely accessible subsurface data.

3 Evolving regulatory context and data registers

Reliable subsurface data are crucial to making well-founded decisions about the land-use planning of the underground. Data on the deep subsurface (deeper than 500 m) tend to derive from petroleum, natural gas, mineral salt or terrestrial heat exploration. Companies are obliged by the Mining Act (2003) to make their data available to the Geological Survey of the Netherlands. The information remains confidential for a period of five years. All the information, from century-old drilling data to recent geophysical research are stored in the digital archive DINO (Data and Information of the Dutch Subsurface. DINO contains information that had previously been stored in a series of independent archives, some of which were more than 100 years old. These old analogues archives are already history. Since the 1980s and 1990s they have become digitised and standardised within DINO. The main data come from drillings, groundwater levels and data that are contained within the Mining Act. All this information is accessible for third parties, specialist or applied research. The only archive that the Survey cannot digitize is the large collection of drilling samples in the Central Core sample Storage which is kept in its analogue form.

Most of the knowledge of the composition of the shallow subsurface (up to 500 m deep) derives from drillings and cone penetration tests on-shore and off-shore (Dutch North Sea zone). The most important component if a drilling is the description of the sediments bored and this information is also contained in DINO. The database for the shallow subsurface also contains geophysical recordings like geoelectrical measurements, seismic and side-scan sonar.

With the creation of a Key Register of the Subsurface BRO (2012), the government strongly improved the accessibility of the subsurface information (Fig. 2). This was achieved by standardizing public information and making it available to both governmental and other parties. The BRO is part of the national key register system and is the continuation of the existing registers «Data and Information of the Dutch Subsurface» (DINO) of TNO and the «Soil Information System» (SIS). Later on, data on the environment quality of the subsurface will be added to the BRO. All the geological data are managed in one location (TNO) and are available for subsequent multiple use.

In the deep subsurface (making profit), the cumulative maintenance value of the BRO data collection is 10s of millions Euros. The values of the assets collected in the data collection is in the 10s of billions Euros. The database helps in securing 100s of billions state revenue from all the subsurface activities (royalties, tax, etc.). This is a good cost to value ratio. In the shallow subsurface (avoiding costs), a study shows that 70% of public projects were delivered late and 73% were over the tender price. 37% of these costs overrun where blamed on ground problems as a major contributor. It is estimated that the Key Register of the Subsurface BRO could reduce these cost overruns by 2-5% saving up to 128 Mio € of tax payers money in 10 years. This are just the cost savings for the public sector alone. Such numbers convinced policy makers of the value of a better understanding of the subsurface by having the necessary data widely available and the necessary laws were formulated and the budget reserved.

The key success factors enabling this where the recognition that subsurface data is a valuable resource and that there is great value in «recycling» this data, the information as well as the concepts derived from them also for other uses than the original purpose of it's acquisition.

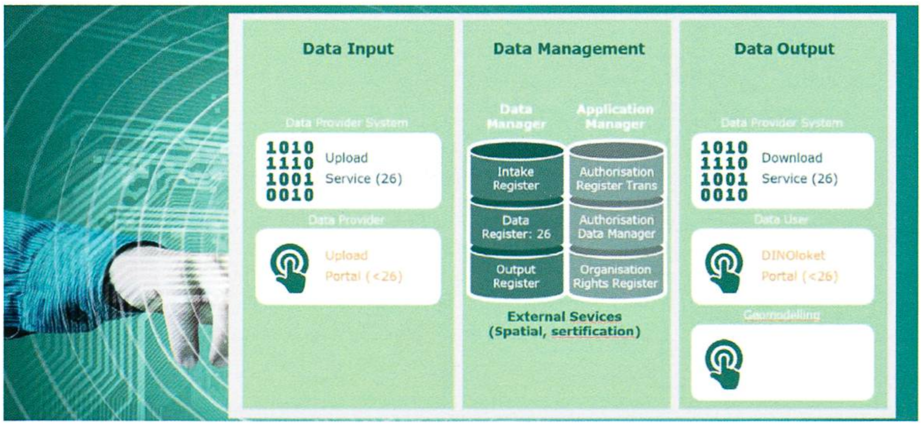

Fig. 2: Building the new Key Register of the Subsurface (2012).

4 Subsurface geological 3D models

The Geological Survey of the Netherlands systematically constructs 3D models based on the hundreds of thousands of borehole data and cone penetration tests held in the DINO database and decades of geological mapping experience. The models predict the geometry and occurrence of unconsolidated sediments, such as sand, clay and peat in the subsurface. The models can be used as a starting point for e.g. groundwater surveys and the forecast of subsidence. The models also contribute to the insight in the geological development of the Netherlands and they are important building blocks for further geoscientific research.

For the shallow subsurface (to a depth of 500 m) the Geological Survey has developed three models: the Digital Geological Model (DGM), the Hydrogeological Model (REGIS II) and GeoTOP. All three models are freely available via the internet: www.dinoloket.nl. They also offer the opportunity to create synthetic boreholes and geological cross sections at any location and view maps of properties of the modeled geological units.

The Digital Geological Model (DGM) is a regional-scale layer model of the subsurface of the Netherlands to a depth of 500 meters. The geological layers in this depth interval consist mainly of unconsolidated sediments such as clay, sand and gravel. They have been classified into lithostratigraphic units on the basis of their lithology and other rock properties. The DGM provides insight into the stacking and spatial relationships of these lithostratigraphic units. In this model the base and top of the units are displayed by depth maps. The thickness of the units is derived from the grid maps of the surface and the base.

The regional hydrogeological model REGIS II, in grid files at 100 x 100 x to a depth up to 500 m, is serving for further subdivision of the modelled geological units into hydrogeological units, aquifers and aquitards. Using the lithological information from boreholes and additional hydrological data such as hydraulic heads and pumping tests, the hydrogeological units are characterized in terms of their hydraulic conductivity, transmissivity and vertical resistivity, vertical flow resistance.

The 3D voxel model GeoTOP (Fig. 3) schematises onshore Netherlands in millions of vox-

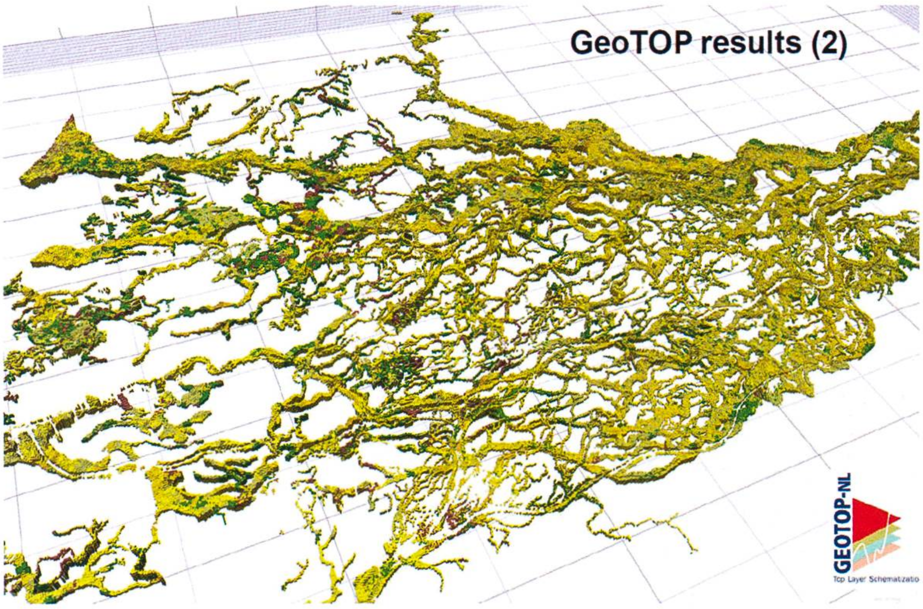

Fig. 3: The 3D voxel model GeoTOP (100 x 100 x 0.5 m) to a depth of 50 m.

els, each measuring 100 x 100 x 0.5 m, to a depth of 50 m below NAP (Dutch Ordnance Level). Each voxel in the model contains information on the lithostratigraphy and lithological classes, including the probability of occurrence for each lithological class. GeoTOP has been constructed per region from the available digital borehole logs stored in the DINO database, which contains some 430,000 borehole logs.

The Digital Geological Model-deep (DGM-deep) is a regional subsurface layer model covering the on- and offshore of the Netherlands. Twelve geological horizons, ranging from Carboniferous to Neogene in age, are the constituents of this stacked grid model. The model is based on interpretations of publicly available 2D and 3D seismic survey data, combined with a variety of well data, supported by biostratigraphical, petrophysical and chemical analysis. The DINO database contains over 135 3D seismic surveys covering around 99.900 km^2 and more than 577.000 km 2D seismic lines (analogous- & digital lines). The number of non-confidential wells is around 5800. All non-confidential 3D-surveys and 1305 wells have been used to stratigraphically constrain the modelling process. 2D Seismic data has been used to fill in areas not covered by 3D seismic surveys.

5 What are the future challenges in the subsurface?

The future exploitation of the underground for mineral and energy resources, for waste storage, for construction of infrastructures and for groundwater management has the potential for social and political tensions. In a country progressly under development, the pressure of urbanisation exists in all directions and increasingly involves the subsurface as well. Faulty planning (first come – first serve) as well as unanswered questions concerning underground property rights lead to conflicts. Subsurface land-use planning is a major challenge for all those involved. Particularly in large densified urban agglomerations, it is crucial to have quick and easy access to relevant data. Linking basic geological data with civil engineering information – such as Building Information Modeling (BIM) or the cadaster – make high-quality 3D spatial land-use planning cost-effective and sustainable.

Thanks to geological data and 3D modules provided by the Geological Survey of the Netherlands, conflicting uses can be identified at an early stage and suitable and acceptable solutions can be found.