THE KINDRA NATIONAL WORKSHOP ON HYDROGEOLOGY IN THE NETHERLANDS

KNGMG - Koninklijk Nederlands Geologisch Mijnbouwkundig Genootschap

Jan Stafleu, December 1, 2016

* *KINDRA has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 642047.*

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1. Introduction

Practical and scientific knowledge related to groundwater research and innovation is scattered amongst various actors throughout Europe. KINDRA (Knowledge Inventory for Hydrogeology Research) is developing an inventory of this groundwater knowledge-base, following a new Harmonised Research Classification System (HRC-SYS).

An European Inventory of Groundwater Research (EIGR) is being compiled, including survey results and research activities, projects and programmes, all of which are essential to identify and determine future trends, critical challenges and research gaps. The objective is to improve management and policy development for groundwater resources on a EU level coherently with the Water Framework Directive (WFD) and the Groundwater Directive (GWD).

KINDRA counts on the direct involvement of the European Federation of Geologists (EFG), which will provide the technical expertise of its national members actively cooperating within the project. In case of the Netherlands, the national member is KNGMG.

An important task in the KINDRA project is the organisation of a National Workshop on Hydrogeology in each of the 20 participating countries. KNGMG (Royal Geological and Mining Society of the Netherlands) and NHV (Hydrological Society of the Netherlands) co-organised the Dutch workshop on November 10, 2016. Venue was the office of TNO – Geological Survey of the Netherlands and Deltares in Utrecht.

The workshop was aimed at identifying research gaps in the field of hydrogeology. Research gaps may include missing scientific knowledge about the groundwater system, but also missing information or lack of knowledge of existing information. A second goal of the workshop was to discuss possible solutions to bridge the research gaps.

This report includes the programme of the workshop (Chapter 2), a summary of the presentations (Chapter 3) and a summary of the two discussion round on research gaps (Chapter 4). Chapter 5 lists the participants as well as the professionals who were interested in the workshop but were not able to attend.

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2. Programme of the National Workshop on Hydrogeology

12.00: Arrival and Lunch

13.00: Welcome by Jan Stafleu, secretary of the board of KNGMG

13.05 Introduction and presentation of the KINDRA project (Jan Stafleu)

13.25 Introduction to the programme by chairman Gé van den Eertwegh

13.30: Keynote by Roelof Stuurman (Deltares)

14.00: Discussion round 1: identifying research gaps

15.00: Tea break

15.15: Keynote by Hans Peter Broers (TNO – Geological Survey of the Netherlands)

15.45: Discussion round 2: possible solutions for the research gaps

16.30: Plenary discussion and wrap-up

17.00: Drinks

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3. Summary of the presentations

3.1. Introduction to KINDRA

After welcoming the participants on behalf of KNGMG and NHV, Jan Stafleu gives an introduction to both the programme and the KINDRA project.

Start of the programme.

KINDRA (Knowledge Inventory of Hydrogeology Research) is an EU project and part of the EU's Horizon 2020 research and innovation programme. The project aims at creating an inventory of the European knowledge on hydrogeology and disseminating this inventory via a newly developed online database. The inventory will be used to identify hydrogeological research gaps on a European level. In addition, the project aims at increasing the public awareness of the importance of groundwater in the daily life of the general public.

The three most important work packages are:

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- **WP1**: developing a new Harmonised Research Classification System (HRC-SYS) for hydrogeological research and building an online database EIGR in which knowledge and information on hydrogeology can be stored. This work package is carried out by Sapienza, the University of Rome.

- **WP2**: loading information from 20 European countries into the newly developed database and organising National Workshops. This work package is carried out by the 20 national member associations supervised by EFG.

- **WP3**: collecting, analysing and consolidating all information in order to identify research gaps on an European level and to propose a research agenda. This work package is carried out by GEUS, the Geological Survey of Denmark and Greenland.

In **WP1**, Sapienza developed a **classification system** with 200 key words relating to hydrogeology. The keywords were selected from groundwater related scientific literature, EU policy documents and Scopus. The keywords were then grouped into three main groups: Societal Challenges, Operational Actions and Research Topics. The first group encompasses the societal trends and challenges that are identified in the Horizon 2020 programme, like for example energy, climate change and health. Operational Actions include, amongst other topics, monitoring, mapping, and modelling. The idea behind the three groups is that they allow for the keywords to be organised in a 3D matrix.

The second step in WP1 is the development of an online database in which the information on hydrogeology from the 20 countries can be stored and disseminated. The database is called EIGR – European Inventory of Groundwater Research. The main window in an Internet browser shows a list of documents that were found based on a search on key words or geographical location. To date, the database is only available with user-id and password, but will become public next year (2017).

In **WP2**, Robert Warmer was responsible for **filling the database** with information from the Netherlands. Robert did an internship at Deltares, gathered the information, classified the the documents according to the new system and stored the results in the database. An internship report is available. The next step in WP2 is the **National Workshop**, which is the subject of this report.

Finally, in **WP3**, GEUS will consolidate the research gaps identified in the 20 countries. GEUS will pay special attention to those gaps that are most important to the Water Framework Directive (WFD) and the Groundwater Directive (GWD). They will also recommend a research agenda.

In summary, the project results in an European classification system, an online database dedicated to hydrogeology research and an inventory of the research gaps in the 20 participating countries.

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3.2. Keynote lecture by Roelof Stuurman

Roelof Stuurman, senior hydrogeologist at Deltares, introduces the first discussion round by showing numerous examples of what goes wrong when the subsurface is ignored. The title of his presentation was ***"Subsurface Disaster Projects: Can we learn from our mistakes?"***

Roelof Stuurman answering questions after his presentation.

Roelof's expertise is often asked when it is too late: the disaster has already taken place. But when he investigates the "crime scene" he often discovers that the cases could have been prevented very easily.

Nassim N. Taleb is often quoted for his notion of "black swans": a metaphor describing an unexpected event that comes as a surprise, has a major effect, and is often inappropriately rationalized after the fact with the benefit of hindsight. The term is based on an ancient saying which presumed black swans did not exist, but the saying was rewritten after black swans were discovered in the wild (Wikipedia The Black Swan (Taleb Book)).

Before discussing several cases, Roelof first wetted our appetite with some examples of what can go wrong:

- The first example dates back to the 17th century when a mansion was damaged due to rot of the wooden piles on which the mansion was built. The piles started to rot unexpectedly after lowering the groundwater level in the surrounding area. The famous Dutch artist Jacob van Ruisdael painted the restoration of the damage.

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Jacob van Ruisdael, repairs on the mansion of Kostverloren, 1659 – 1664 (© Rijksmuseum Amsterdam).

- An example that received a lot of attention in the Dutch media was the failure of a secondary dike in the village of Wilnis, flooding a residential area.
- In road construction works, costs are often higher than anticipated because the complexity of the subsurface is underestimated or even ignored.
- An example outside the Netherlands comes from Nassau county on Long Island: when the treatment of wastewater started and cesspits were closed, recharge of groundwater decreased and groundwater levels dropped approximately 8 feet.
- Smaller incidents include the death of horses drinking from ditch water that was polluted by high concentrations of iron; swimming pools that were unexpectedly pushed up after heightening ground water level in the surrounding area; trees that are destabilized and finally fall over due to heightening ground water level in the forest.

Next, Roelof presented 7 cases with their lessons learned. Below follows a summary of 5 of these cases.

Case 1 – Swelling Earth in the town of Staufen, Germany. In Staufen, groundwater was extracted from an aquifer below a thick layer of evaporates (anhydrite, or $CaSO_4$). Leaking of groundwater in the anhydrite layer unexpectedly led to the formation of gypsum ($CaSO_4 \cdot 2H_2O$). The accompanying increase in volume caused uplift in the village and severe damage to the buildings.

The **lesson to learn** here is that groundwater extraction is not just an engineering project, but should also involve the expertise of geologists and hydrogeologists.

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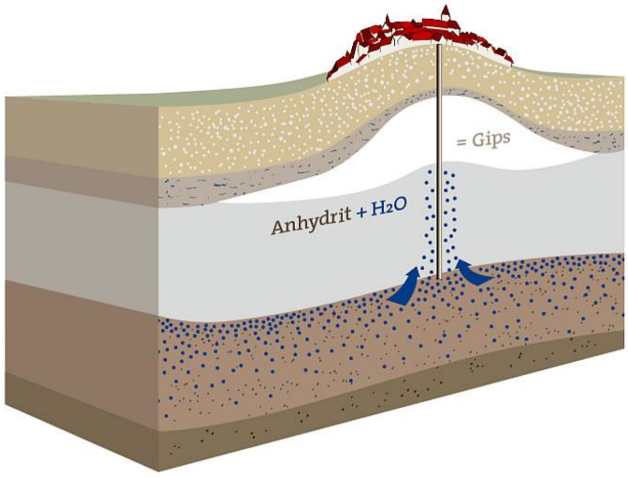

Uplift of the town of Staufen, Germany, due to unexpected formation of gypsum (© Staufenstiftung).

Case 2 – Reinforcing the North Sea coast in Delfland caused unexpected groundwater rise, pollution and salinization. New dunes were created along the coast using wet sand from the North Sea. For every m^3 of sand, 3 m^3 of sea water was supplemented to the coast. This large amount of water led to a temporary high groundwater level with salt water. Basements and a graveyard nearby were flooded and the local drinking water supply was put at risk. Furthermore, the beach was widened causing an extended distance (“L” in hydrogeological calculations) between the inland polder canal and the high tide line. This increased distance caused a structural increase in groundwater level and a seaward shift of the groundwater divide. Because of this shift, a preexisting pollution source became drained and threatened public water supply. After the damage occurred, a solution was provided using hydrogeological expertise which could of course also have prevented the damage if applied earlier in the project.

Lessons learned are: the focus was on sand and marine ecology, groundwater was ignored; available information on the preexisting pollution was overseen or ignored; the type of shoreline reinforcing chosen is not very suitable for the area at hand, other solutions may have worked better.

Case 3 – Bursting clay layers in Nieuw Vennep, Western Netherlands. In Nieuw Vennep, ponds were created in landscaping a new residential area. Digging the ponds destroyed the clayey cover layer and caused upwelling of iron-rich groundwater into the ponds, which in turn causes the formation of iron slags. The water of the ponds turned completely red.

Lessons learned are: groundwater issues were completely ignored during project preparation; both the city council and the contractor lacked the necessary expertise. A factor that might have played a role here is that due to EU regulations on public procurement, local authorities are often forced to hire the contractor with the lowest bid. If the contractor only has experience in other subsurface settings and lacks knowledge of the local geological configuration, unexpected problems may occur.

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Case 5 – Blow-out of a gas exploration well. A classic example in the Netherlands is a blow-out that occurred in 1965 when an exploration well for gas penetrated a shallow aquifer. The blow-out caused the 50 m tall derrick and several portable buildings to completely disappear into the subsurface.

Lesson learned: Exploration for gas not only requires geological knowledge about the deep subsurface, but also needs expertise about the local, shallow aquifers to determine the risks involved in the drilling.

Case 7 – "Sand piles" caused 50 million euros of damage in a road construction project. In the 1960s, plans were developed for a new motorway in the Western Netherlands. In the preparation phase, a number of "sand piles" were constructed in order to drain the area. The construction was subsequently decommissioned for several decades until the project was recently revived. Meanwhile, information of the existence and location of the sand piles was lost causing unexpected ground water effects during road construction.

Lesson learned in this case is that we need to better document our subsurface interventions to prevent problems in the future.

We can learn a lot from examples and cases like the ones presented by Roelof. However, we often fail to do so. Some organizations even tend to keep the mistakes for themselves in order to avoid bad publicity.

Roelof's main take-away message was that we need to respect the professionals in their own area of expertise: engineers and even geologists have insufficient hydrogeological expertise to foresee effects on groundwater and hydrogeologist are too often doing geological work.

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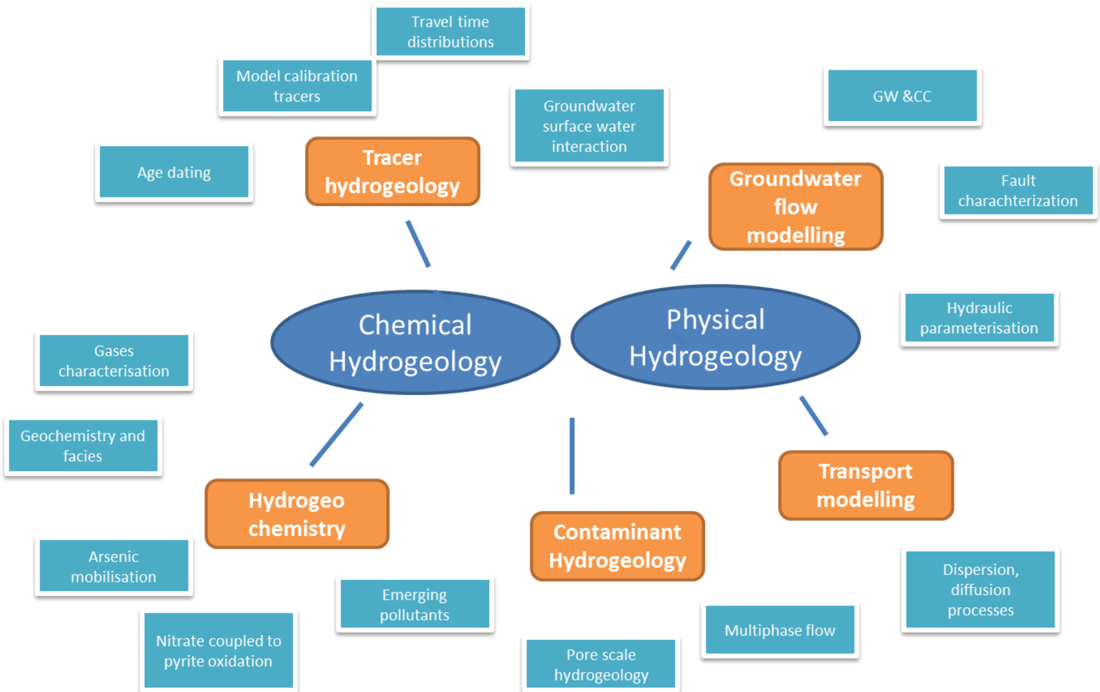
3.3. Keynote lecture by Hans Peter Broers

Hans Peter Broers, senior hydrogeologist at TNO – Geological Survey of the Netherlands, introduces the second discussion round by showing numerous examples of what goes wrong when the subsurface is ignored. The title of his presentation was ***"Putting Hydrogeology on the agenda – an Earth Sciences view on groundwater"***.

Hans Peter Broers answering questions from the audience.

Hans Peter started his presentation with a mind map of hydrogeology in a broader sense:



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In 2006, the Water Framework Directive (WFD) and the Groundwater Directive (GWD) created a new challenge to create an integrated protection approach of the whole soil-groundwater-surface water system and the corresponding monitoring network.

Societal challenges affecting hydrogeology include:

- **Secure water supply** at all times for all human and ecological uses:
    - CC and water shortage, droughts.
    - Mining of the resource.
    - Sustaining base flow to rivers.
- **Secure sources of potable water and safe exposure to water** for human and ecological users:
    - Water quality status of the resource (in relation to diffuse and points sources (macro chemistry, pesticides, organic contaminants).
    - Durability of the resources (developments in the water quality evolution in relation to travel times and subsurface reactive transport).
- **Find a balance between interests of multiple users of the subsurface:**
    - Users of water for production (farmers, consumers, industry).
    - Usages of the subsurface for storage, mining, infrastructure etc.
    - Strategies to deal with potential conflicting human uses in time and space.

Trends in hydrogeological research can be characterized as:

- More complex and more integrated.
- Higher resolution in both time and space.
- Deeper and deeper into the subsurface.

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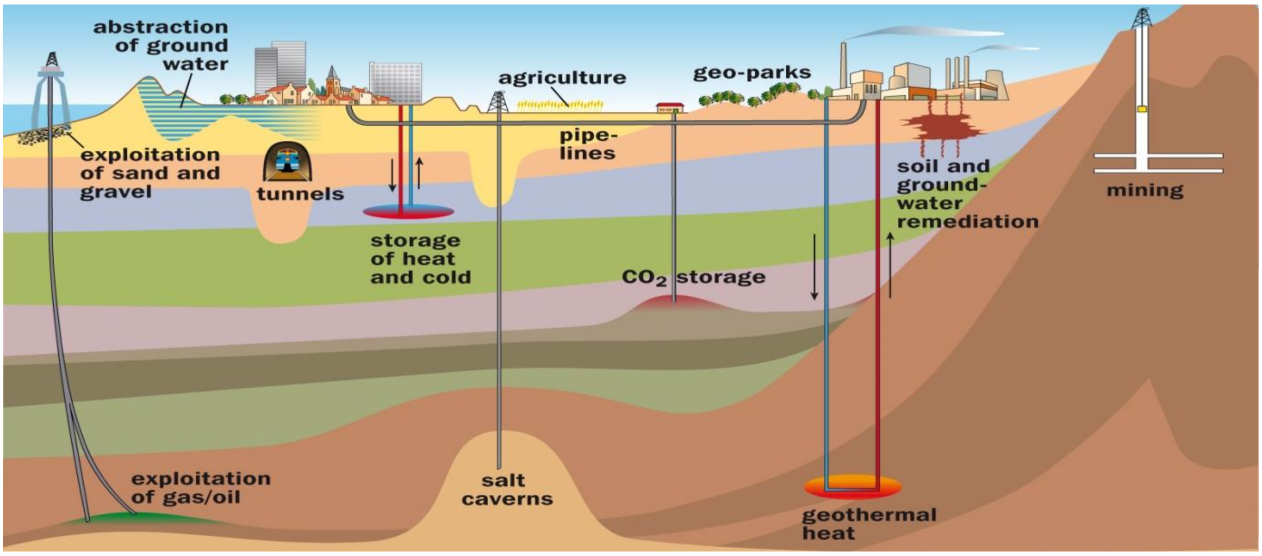

Examples of subsurface operations involving hydrogeology and requiring subsurface spatial planning(© TNO).

After this introduction, Hans Peter continues with showing examples of new trends and developments in hydrogeology.

Trend: More complex and more integrated:

- **Transboundary** – An example is the cross-border cooperation between the Netherlands and Belgium in which two different hydrogeological models were reconciled into a new, single model.
- **Integration of models and data** – The new Atlas of Groundwater Quality of the Netherlands, based on an integration of the national hydrogeological model and the national groundwater quality database.
- **Mapping of groundwater nutrients using geological constraints** – In the Netherlands, the geological configuration of the subsurface has a large effect on the nutrient concentrations. For example, high NH_4 and P concentrations occur in the coastal zone where thick sequences of Holocene deposits are present.
- **Integration of groundwater and surface water** – Groundwater adds substantially to exceeding WFD standards in surface water. Especially sulfate reduced groundwater exhibits high NH_4 and P concentrations: mineralization of subsurface organic matter. Reduction of sulfate may even lead to locally high levels of H_2S in the air, at one time causing a boy becoming nauseous.

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- **Newly emerging problems** – For example veterinary antibiotics can be measured in groundwater below livestock farms. What will be the effect of this problem on drinking water and ecosystems?

- **Technological developments** – Better tools to measure the age of drinking water include istopes and noble gases, for example ^{4}He, ^{13}C, ^{14}C, $^{18}O/^{2}H$, $^{3}H/^{3}He$, $^{13}\delta CH_4$.

- **More integrated assessments are needed** – For instance, we need to acknowledge that mining of groundwater not only results in dropping groundwater heads due to continuous extraction, but also leads to the substitution of old groundwater by young, human influenced (often polluted) water.

Trend: Higher resolution in both time and space:

- **Higher resolution in hydrogeological models** of both groundwater and surface water: from 1 km cell size to 250 m, 100 m to as small as 25 m. Surface features can be mapped out using laser altimetry surveys with even higher resolutions of for instance 5 m.

- TNO produces a nationwide **high resolution 3D voxel model** (100 x 100 x 0.5 m) attributed with geological and hydrogeological properties, with applications in for instance a brine injection project in the greenhouse complex in the Western Netherlands.

- Ongoing research is concerned with **parameterization** of the voxel model with **hydraulic parameters**. These parameters are measured in the laboratory using small samples from cores, but the measured values need to be up-scaled to the much larger voxels in the model.

- Similar research focusses on the **geochemical parameterization** of the voxel model with parameters such as S and FeO_x in order to better understand groundwater transport of nutrients and pollutions.

- **High frequency water quality monitoring,** measuring ^{18}O, ^{2}H, $^{13}C_{CH4}$, P, NO_3, NH_4, ^{222}Rn.

- **Very detailed studies** of for example time-changing groundwater outflow to a stream.

Trend: larger depths:

- **Deep shale gas exploration** competes/conflicts with shallow fresh water groundwater resources.

- **Methane in the shallow subsurface** possibly originating from a deep thermogenic source.

- Analysis of the **life cycle of geothermal installations**: risks for fresh water resources above the geothermal source (leakage) as well as clogging, corrosion, weathering and mobilization processes that occur at high temperatures.

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- Suitability of clayey formations in the subsurface for the disposal of nuclear waste: what is the travel time of groundwater from the disposal site to land surface?

Hans Peter concluded with the following remarks:

- Important trends are: more integration, higher resolution and larger depths.
- There is a lot of inspiring new research going on.
- Hydrogeology is alive:
  - There is a clear road ahead for at least 10 years.
  - However, there is an urgent need for young Earth Sciences-driven hydrologists and hydrochemists.
- An Earth Sciences approach and geoscientific data collection are key:
  - Complementary to an engineering approach.
  - Working with and collecting data crucial for scientific progress.

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4. Discussion

4.1. Introduction

Discussions took place in three groups of 12 – 15 persons each. After each of the two discussion rounds, the groups reported their findings back in the plenary session. Discussion leaders of the three groups were Gé van den Eertwegh, Erik Simmelink and Jan Gunnink, respectively.

Discussion in separate groups.

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4.2. Discussion round 1: inventory of research gaps

Discussion round 1 followed the presentation by Roelof Stuurman. Remarks made by the participants included:

Organizational:

- Data and knowledge about the subsurface is very often present, but not used by stakeholders / users. Data and knowledge resides in different institutes and organisations / individuals, which is not always known to the potential users.
- Judicial: contracts are sometimes inhibiting free flow of data and information between partners in a project, especially after the potential contractor made a detailed estimate of the work ("bestek"). The contractors see their estimate as intellectual property.
- The client (often a regional or a national authority) should have sufficient expertise to judge aspects that are related to the subsurface and to instigate additional research if necessary.
- Political choices at national level (a smaller government and more private enterprises involved in public works) have led to declining expertise at the client.
- Clients (often governments) do not promote employees to develop experience in the subsurface, due to high rotation rates of the employees.
- Subsurface related research: has it been carried out at the appropriate scale? Subsurface issues are very often scale dependent and information that is available on a certain scale might not be suitable on another scale.
- To increase awareness, the relation between the cost additional research and costs of potential failure and remediation should be stressed.
- Heat storage in the subsurface leads to conflicts between the different functions of the subsurface, e.g. between sustainable energy vs. drinking water.
- MKBA (Maatschappelijk Kosten Baten Analyse) is necessary to convince the client to pay for and insist on proper researching the subsurface.
- It is extremely important to properly translate data via information to advice for policy makers and operations.
- Cross-border issues: on either side of the Dutch_belgium and Dutch-German borders different hydrogeological models are used, each with their own schematization of the subsurface in aquifers and aquitards. There are also different approaches to the availability of both data and models; in some countries these are public, in other countries access are restricted. These issues should be resolved in a European context.
- A similar 'border' exists between the shallow and deep subsurface: data, properties and methods of the shallow subsurface is not used in the deep world and vice versa. Crossing this subsurface border is important; for instance drinking water companies want to extract deep, salt groundwater which is free from man-made pollutants.
- We need to digitize paper archives before it is too late. Due to the merging of small organizations into big ones a lot of paper archives are at risk.

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- In the ‘paper age’ more attention was paid to the data, we used to think more, nowadays we take the data for granted and put them in a model.
- We pay insufficient time to acknowledge and apply the uncertainties that are present in both data and predictive models.
- The boards of research and operational organizations consist of professional managers rather than technicians. Management should pay more respect to the position of the technicians in the organization.

Research-oriented:

- We lack knowledge on the dynamics of salt / fresh groundwater:
  - At what the time-scales does salt and fresh water transport occur?
  - What is the geometry and behavior of small-scale fresh-water lenses in a salt groundwater environment?
- What are the effects of groundwater heat pumps (using closed loops) on the subsurface?
- What are the effects of (future) shale gas exploitation on groundwater?
- What are the effects of deep geothermal energy on groundwater and how effective are these energy sources?
- We know too little about the depth levels in between those of groundwater extraction (0 – 500 m) and hydrocarbon exploitation (> 2000 m).
- What are the effects of perforation by boreholes made for geothermal energy? Are regulations being followed adequately, and If not, do authorities intervene appropriately?
- We need more control on subsidence due to lowering of groundwater level (peat consolidates and oxidizes above groundwater level).
- We need a better understanding of the recharge of our drinking water sources.
- We need more monitoring networks to support, validate and ground truth conceptual and predictive models and simulations.
- In the 1980’s and 1990’s we were used to gather a much larger number of borehole measurements, geo-radar surveys, high resolution seismic surveys, geo-electric surveys etc. than we do nowadays.
- We need a better understanding of the very shallow subsurface which is influenced by man. The very shallow subsurface is very heterogeneous and contains many unexpected features such as old ditches, abandoned sewer systems and cellars, old quay walls and sheet piles etc.
- The same applies to the very shallow subsurface of natural areas.
- We should investigate if there are non-destructive ways to measure groundwater level (without monitoring wells).

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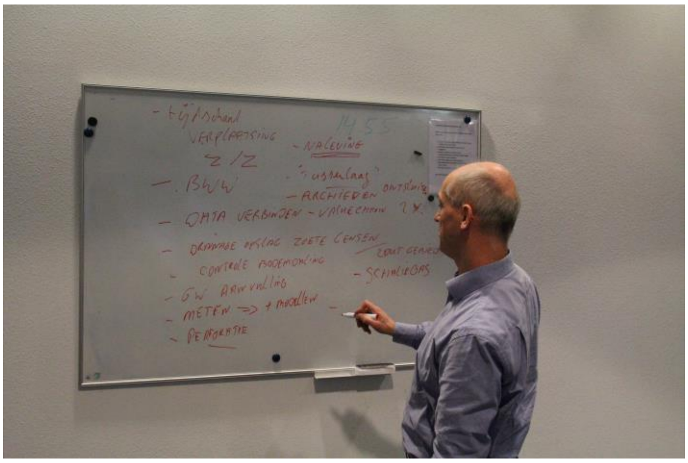

Erik Simmelink taking notes during the discussion.

Discussion continues during the tea break.

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4.3. Discussion round 2: possible ways to bridge research gaps

Discussion round 2 followed the presentation by Hans Peter Broers. Remarks made by the participants included:

Organizational:

- We need a broader network of organizations / institutes to be present at this meeting. Research gaps and ongoing research is not fully covered at this meeting.
- Both client and contractor need to be aware of the uncertainties that are inherent in subsurface data and models. It needs to be formulated and as far as practical, be quantified. Guidelines can be helpful.
- Large spatial 3D models are sometimes difficult and time-consuming to use. There seems to be a need for "simple" models for a first estimate.
- There is no barrier between sub-disciplines, although researchers sometimes act like it is. Cross-discipline data and research is needed and needs to be promoted.
- Promote scientific research.
- Before a full-scale experiment, try to sort things out in a small and simple manner.
- At an early stage, the client should formulate and articulate the terms of reference for a project together with a knowledge institute.
- We need to inform the public at an early stage in order to have the support and also be able to tap into the knowledge of the public.
- At a client's office (national authority for public works), the contracts are signed off by numerous people, it is sometimes difficult to cast doubt at the end of that line.
- Avoid duplication of workshops on hydrogeology, for example see the recent workshop on fresh water resources of STOWA

Research-oriented:

- Develop more knowledge about natural leakage (background values) of hydrocarbons to the shallow subsurface.
- Develop more knowledge about the influence of natural gas on the shallow groundwater.
- Develop more knowledge about the behavior of phreatic groundwater.
- Store information on man-made operations in the subsurface (including the potential effects of these operations) in a knowledge database.

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Chairman Gé van den Eertwegh during the wrap-up.

One of the plenary sessions.

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5. List of participants

5.1. Participants

Nbr.	Name	Affiliation
1	Anouk Creusen	
2	Bert de Wijn	
3	Brigitte Vlaswinkel	
4	Edvard Ahlrichs	Deltares
5	Erik Simmelink	TNO
6	Gé van den Eertwegh	KnowH2O
7	Gerrit Rot	Stichting BodemvochtBelang
8	Hanneke Verweij	TNO
9	Hans Doornenbal	TNO
10	Hans Peter Broers	TNO
11	Hans van Rheenen	Eijkelkamp Soil & Water
12	Harry Boukes	
13	Henk Kooi	Deltares
14	Jan Gunnink	TNO
15	Jan Hoogendoorn	Vitens
16	Jan Hummelman	TNO
17	Jan Stafleu	TNO
18	Jerney Judell	
19	Jeroen Prins	Gemeente Rotterdam
20	Jos van Oijen	
21	Jurgen Foeken	

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Nbr.	Name	Affiliation
22	Konstantina Katsanou	
23	Leon van Hamersveld	Eijkelkamp
24	Mariëlle van Vliet	TNO
25	Mark Bakker	TU Delft
26	Okke Peijters	Rijkswaterstaat
27	Patrick Kiden	TNO
28	Peter Veenhof	Nail Resources Denmark BV
29	Philip Nienhuis	Waternet
30	Pieter Pauw	Deltares
31	Robert Warmer	TNO
32	Roelof Stuurman	Deltares
33	Ronald Harting	TNO
34	Ronnie Hollebrandse	Provincie Zeeland
35	Stèphanie de Hilster	Deltares
36	Victor Bense	WUR
37	Vince Kaandorp	Deltares
38	Wilbert Berendrecht	Berendrecht Consultancy
39	Willem Jan Zaadnoordijk	TNO

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5.2. Interested professionals, not able to attend

Nbr.	Name	Affiliation
1	Almer Bolman	Waterschap Vallei en Veluwe
2	Arnaut van Loon	KWR Watercycle Research Institute
3	Bram Bot	NHV
4	Co de Vries	
5	Erik Heskes	Provincie Brabant
6	Harry van Manen	Rijkswaterstaat
7	Jacco Hoogewoud	Deltares
8	Jan Huinink	Min EZ, Directie Agro en NatuurKennis
9	Janet Hof	Provincie Drenthe
10	Jelte Stam	TNO
11	Paul Schot	Universiteit Utrecht
12	Pieter Doornenbal	Deltares
13	Teffie Schneider	

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