GeoERA RESOURCE GROUNDWATER

Resources of groundwater, harmonized at Cross-Border and Pan-European Scale

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EXECUTIVE SUMMARY

This deliverable describes the progress made towards the criteria for harmonisation over the Dutch-Flemish-German border in the work package H3O-PLUS. This particular work package of the project builds further on previous cross-border initiatives where the first step - 3D harmonization of the extension and depths of shallow and deep aquitards and aquifers – has already been accomplished. The work package takes the harmonization a step further, developing common standards to harmonize data on hydraulic properties, groundwater quality, groundwater age, hydraulic heads, groundwater fluxes and depletion patterns, This deliverable describes the outcomes of Task 3.1 s, which sets common criteria for this further harmonization, analyzing and re-interpreting tools and methods that have been applied previously on both sides of the bordering regions and countries.

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1 EXECUTIVE SUMMARY

The present document is deliverable D3.1 " Report describing the criteria set for cross-border harmonisation of groundwater data" of the project RESOURCE: "RESOURCEs of groundwater, harmonized at Cross-Border and Pan-European Scale" .

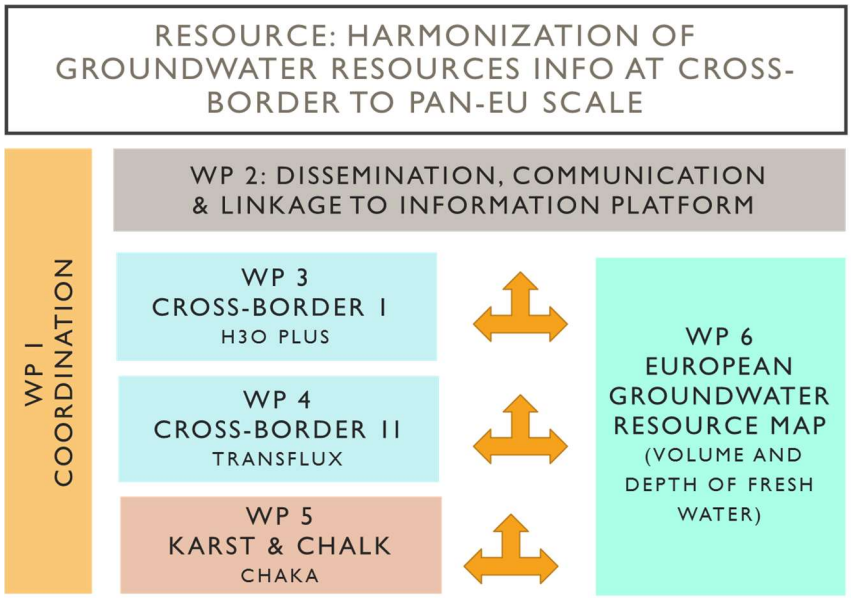

Figure 1 Overall structure of the RESOURCE project

The RESOURCE project aims at demonstrating the potentials of the harmonization of information about Europe's groundwater resources through cross-border demonstrations projects, through harmonized characterization approaches for Karst and Chalk aquifers and through a first information product at Pan-European scale where available data is compiled and integrated to produce a map of the fresh groundwater resources of Europe. The set of deliverables of the RESOURCE project will provide good practices in providing harmonized data and information across borders for assessments of the 3D structure of aquifers, the water volumes available, and the water fluxes and water quality of the resource. Harmonization of such hydrogeological information is a prerequisite for any transboundary groundwater management. A range of regional and national stakeholders are currently involved in the work in order to ensure both interaction with authorities that manage and protect groundwater resources and end-users. The RESOURCE project maximizes the dissemination of the results and provide stakeholders and end-users with easy-access tools through the cooperation with the GeoERA Information Platform Project, jointly prioritizing the information products that are most beneficial for society. The information products to be delivered will serve as a first prototype example of information to be accessible within a Geological Service for Europe.

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fluxes and depletion patterns, This deliverable describes the outcomes of Task 3.1 s, which sets common criteria for this further harmonization, analyzing and re-interpreting tools and methods that have been applied previously on both sides of the bordering regions and countries.

2 INTRODUCTION

This document summarizes the results of 'Task 3.1-Harmonization criteria' of WP3 "H3O-PLUS" of the RESOURCE project. The overall motivation for the RESOURCE project is that only limited data on hydrogeology and groundwater are available at EU scale, besides the IHME maps (International Hydrogeological Map of Europe 1:1,500,000[1]), but these contain only limited information (e.g. only 2D) and do therefore not enable more complex hydrogeological assessments such as the calculation of water balances. The general rationale of the project is that the harmonization of (hydro)geological information and harmonized 3D characterization of aquifers and aquitards is a prerequisite for transboundary groundwater management.

The RESOURCE project is built around 4 technical work packages (Figure 1), two of them relating to cross-border demonstration projects (WP3 and 4), one consisting of a methodological demonstration project on Karst and Chalk aquifers (WP5) and one pan-EU mapping effort (WP6). One additional work package is directed to creating a strong link with the Information Platform Activity (GIP) under GeoERA and includes tasks for dissemination and communication of the project results (WP2). Coordination of the work is done in WP1.

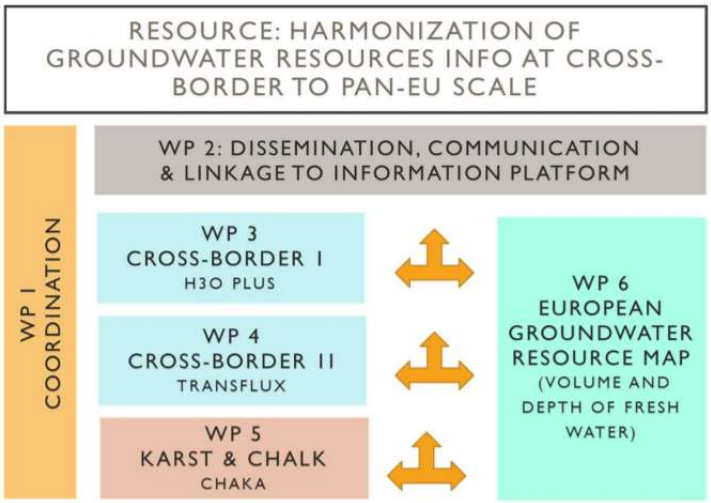


Figure 1: Overall structure of the resource project

The two cross-border demonstration projects may set a new standard for harmonization across borders, not only for hydrostratigraphy but also for hydrological data such as groundwater heads and groundwater quality. The intention is to find similarities and differences of approaches tested and needed in the two areas and to use the mutual inspiration for harmonizing the project deliverables and to use it as learning material for further harmonization at the larger EU scale and intermediate supra-national scales.
The H3O-PLUS work package (WP3) aims to be an advanced demonstration of a transboundary assessment of groundwater resources. It is 'advanced' in the sense that it builds on and extends previous work, trying to make it more useful for groundwater policy and management and for

[1] https://www.bgr.bund.de/EN/Themen/Wasser/Projekte/laufend/Beratung/Ihme1500/ihme1500_projektbeschr_en.html

subsurface spatial planning. A 3D hydrogeological model has been developed in a series of so called 'H3O' projects in the transboundary region around the Roer Valley Graben, comprising parts of Germany, the Netherlands and Belgium. The model contains 3D maps of the top, base and thickness of aquifers and aquitards (*Figure 2*). H3O-PLUS aims to add attribute data to these maps to facilitate the use of the maps in decision making processes. Note that the project does not aim to produce new maps or spatial delineations. The objective is to characterize units on existing maps and hence support the interpretation and use of those existing maps.

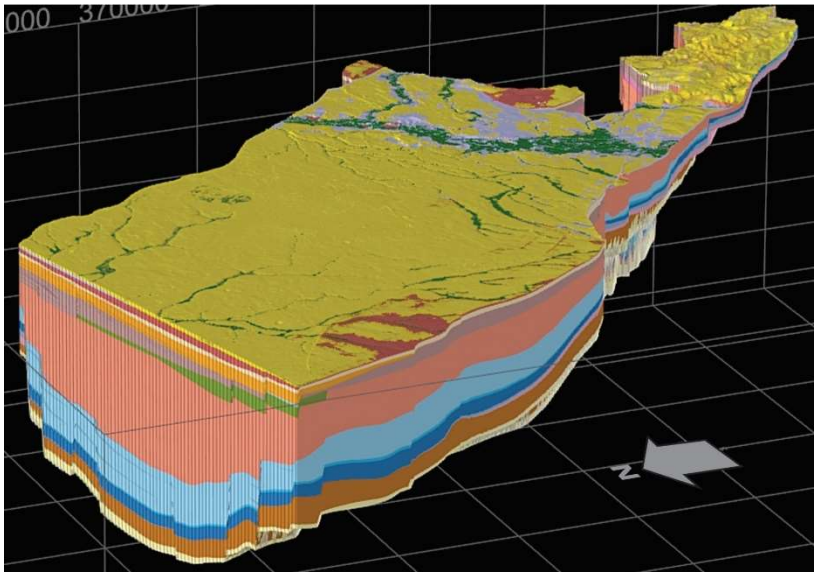


Figure 2: Example of an existing 3D geological model in the H3O-PLUS project area

This document is the first step towards this aim. It should be considered as a methodological document. It describes the 'harmonization criteria' that will guide future work in tasks 3.2 (hydraulic properties of aquifers and aquitards), 3.3 (groundwater quality and age distributions), 3.4 (volumes, water balances, recharge, discharge) and 3.5 (groundwater depletion patterns). The objective is to set common criteria for the cross-border harmonization of these attribute data. The harmonization will not start from scratch but will build on existing experience and practice by analyzing and reinterpreting tools and methods that have been applied previously in the study area.
This document discusses some methodological issues that are relevant for all considered tasks (3.2, 3.3, 3.4 and 3.5) and specifies the scope, expected outcome and approach ('harmonization criteria': what the harmonization entails and how it will be attained) for each of those tasks. It thus contains the starting points for the methodology sections in later task reports of tasks 3.2 to 3.5. Parts of that text may be repeated and/or reworked in those reports. This documents ends with a preliminary outline of the way project results can be interpreted and disclosed for real-world applications in groundwater protection and management in the transboundary region.
Figure 3 gives an overview of the planning of the project.

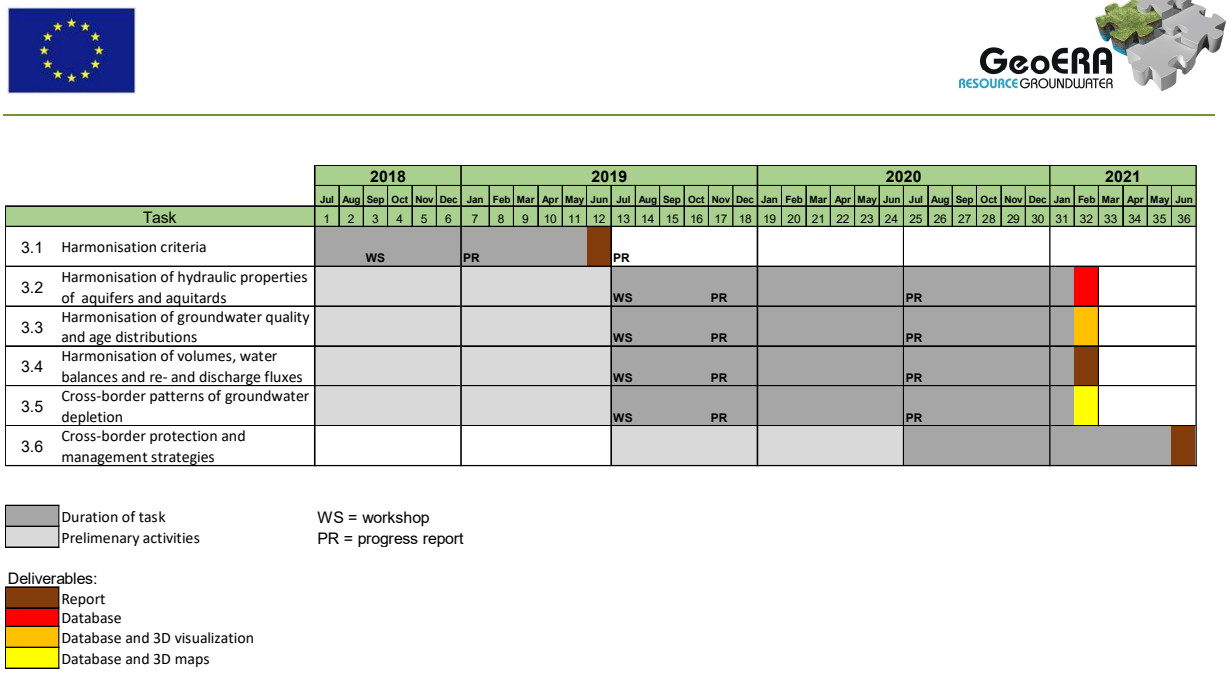


Figure 3: Planning of tasks and deliverables in the H3O-PLUS project

3 GENERAL METHODOLOGICAL ISSUES AND CONCERNS

3.1 Delineation of the study area

The overall study area coincides with the study areas of previous H3O projects (*Figure 4*). For most topics, the entire study area will be covered. For others, the analysis might be limited to part(s) of the overall study area because of practical concerns. In the last case the extent of the study area and the motivation for choosing that area will be explained in the methodology section of that topic.

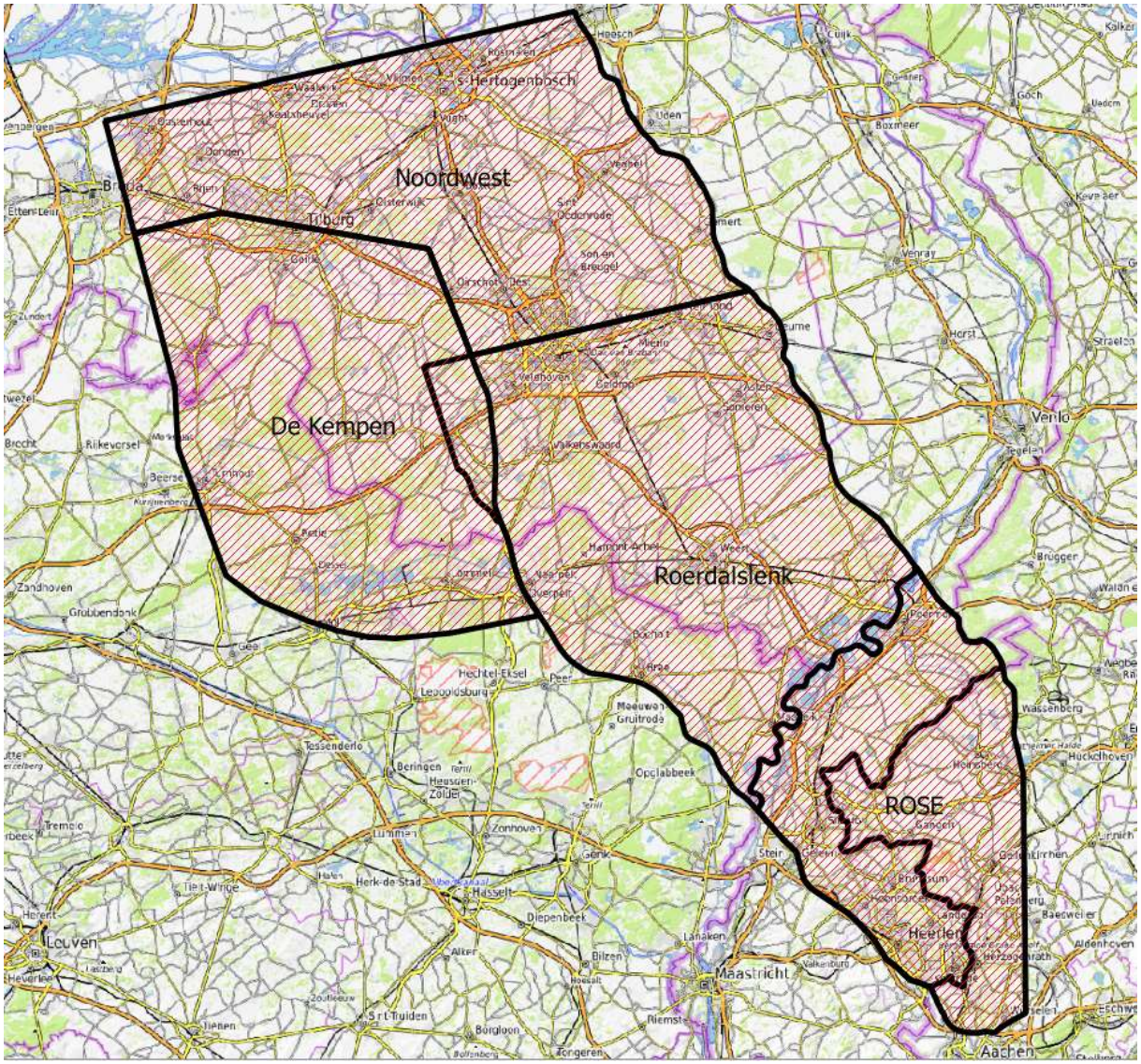


Figure 4: Study areas of previous H3O projects (note the label "Roerdalslenk" can be translated to "Roer Valley Graben")

3.2 Vertical delineation

Vertically, the study is limited to the clastic (hydro)geological layers of Cenozoic age or younger. This coincides with the vertical scope of the recently developed transboundary 3D

(hydro)geological models of the H3O projects. The base of the models is thus located at the top of the Chalk aquifer (Formation of Houthem or Maastricht) or the top of the Carboniferous deposits.
Appendices 1, 2 and 3 show the correlation tables that have been made in earlier H3O projects to establish a relation between existing hydrogeological units in different countries. The units mentioned in these tables will form the basic units for the data that will be gathered in the RESOURCE project: all attribute data that will be inventoried will relate to one or a group of units of these tables.

3.3 Coordinate system

Because there is only point data involved, transformation between coordinate systems is relatively easy to carry out. It seems therefore logical to add coordinates from the system used in all partner countries: the Netherlands (RD), Belgium (Lambert) and Germany (UTM). However, the GIP uses another coordinate system. The question is whether it is better (1) to store the data in the EU coordinate system used by the GIP and then transfer to local systems or (2) to use local coordinates and later transfer these to the ones used in the GIP. The advantage of using local systems is that these are the ones that our stakeholders use. The advantage of using the EU system is that only one system is used in the entire transboundary area.
The only coordinate system that is used in all H3O projects is that from the Netherlands (RD). Therefore, it is logical to use this as a common system during the H3O-PLUS project. Another reason for choosing RD is that the visualization tool for water quality data of TNO works with RD. Water quality data of other regions will be built in in this tool during H3O-PLUS.
The Dutch partner, TNO, is responsible for transforming coordinates in WP3 to RD of all data that are shared by the project partners. All shared GIS data should thus at least contain RD coordinates. The final result should be published in UTM coordinates. Transformation to UTM coordinates will be carried out at the end of the project.
The reference level for elevation will also be based on the system that is used in the Netherlands (NAP). Belgian data will be provided to TNO in m TAW and TNO is responsible for converting this to NAP level. For exchange with Germany, no conversion is required as the offset with the Netherlands is only one centimeter (Figure 5).

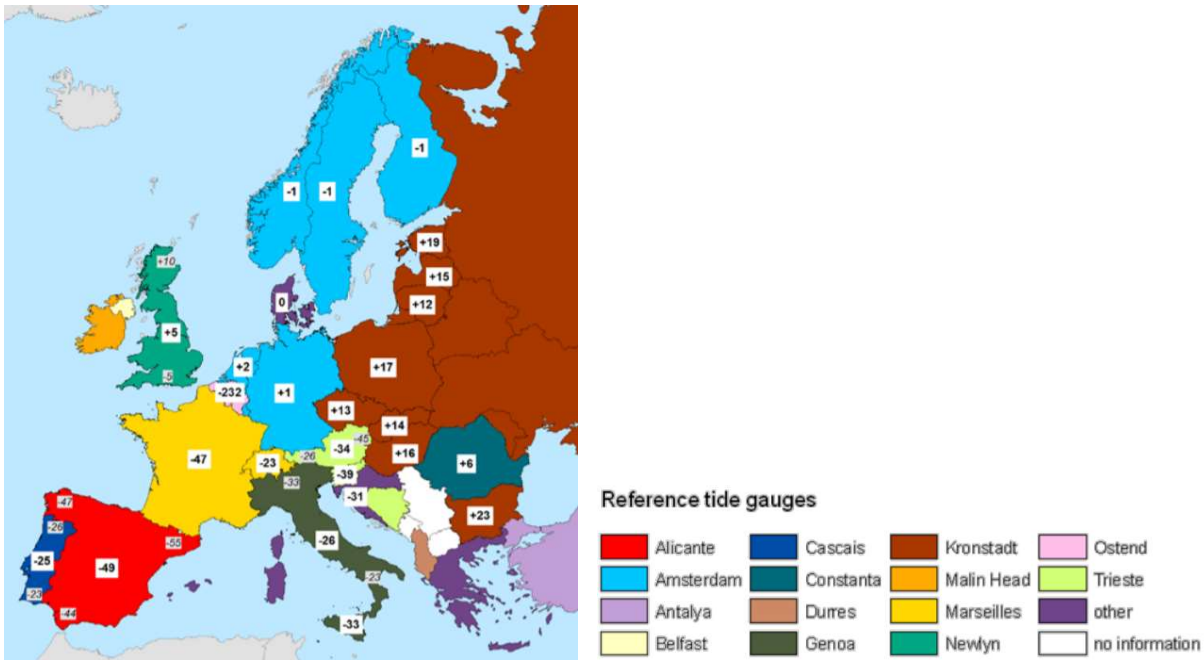


Figure 5: Datum offsets (cm) between national vertical reference frames and EVRF2007 (after http://www.euref.eu/documentation/Tutorial2015/t-04-01-Liebsch.pdf) .

4 TASK-SPECIFIC ANALYSIS

4.1 Harmonization of hydraulic properties

The second task of WP3 (3.2) aims to add information on hydraulic properties to the H3O model. The format of the 'database' is an excel sheet.

The procedure for data collection of hydraulic properties is as follows: a first round of data gathering based on an initial template developed by one project partner (TNO) was completed before the WP3 meeting in February 2019. It was discussed during that meeting, focusing on the structure of the data sheet (Which fields are useful? Which are less useful? Which data are lacking?) rather than on the collected data content. The discussion lead to several modifications of the sheet. A second round of data gathering - with an adjusted sheet – will be performed mid 2019. As soon as all data are collected, the range of values for the same hydrogeological unit and parameter (but provided by different partners) will be analyzed. If the parameters are within the same order of magnitude, they can be used directly in H3O-PLUS. If there are important differences for a given hydrogeological unit, the data should be interpreted in more detail to assess the reason for the difference and the way it should be dealt with in H3O-PLUS.

Regarding the faults, there is a link with the GeoERA project HIKE, which aims to make a generic database of faults (e.g. not 3D) based on the input from project partners. HIKE will not store data about hydraulic properties of faults directly, but might include links to literature about that topic. So HIKE will not provide data to RESOURCE, but data from RESOURCE might be imported in HIKE. Furthermore, there is also a link with the GeoERA project VoGERA, in which two pilot studies are addressing the hydraulic functioning of Roer Valley Graben faults (Rauw Fault and Peel Boundary Fault) (down to 600m). At the stakeholder workshop, the drinking water sector expressed specific interest in hydraulic properties of faults.

The entire study area will be considered in terms of hydraulic properties, including all H3O project areas.

Which hydrogeological units should be considered? In any case, it is not the intention to go deeper than the units that were modelled in 3D within the H3O projects. Units can also be grouped vertically. This will be decided while making the inventory.

Concerning the considered parameters: hydraulic conductivity is the most important, but transmissivity, resistance and porosity might also be considered. However transmissivity and resistance can be deducted from hydraulic conductivity and (saturated) thickness of the units. Also important to consider is the way the parameters are derived (cores, regional estimates, …), the number of measurements/data points and the scale at which they can be used.

We intend to produce a table mentioning (ranges of) parameter values for each (group of) hydrogeological unit(s) that is (are) distinguished in the H3O models. That table can provide information about regional differences and trends in parameter values which could be used for making maps, but it is explicitly NOT the objective of H3O-PLUS to produce such maps. Instead, the goal is to gather data from different regions and explain cross-border differences in inventoried parameter value ranges should they occur.

How can the spatial variation in parameter values be recorded in the database in a more simple way without making new maps? One option is to distinguish between values for different H3O subregions. This is a practical way to deal with spatial variation. It would also solve the problem with the lack of unique correspondence for the Kieseloolite Formation between the H3O units and the hydrogeological code of Flanders (HCOV) (which is unique within a H3O subregion). Which boundaries should be taken for the subregions? There is some overlap between H3O subregions: between ROSE and Roer Valley Graben (here we take the Meuse as boundary) and between De Kempen and Roer Valley Graben. However, the overlap is small. If the overlapping region would contain parameter values, then these will be used for both regions.
A field 'known spatial trends' will be added to the excel where we keep descriptive information about spatial variations in parameter values within the region.
We discussed whether metadata should be included in the excel table: literature source, method (type of test, type of interpretation, …), … This seems to be difficult, because one parameter range can be derived from different literature sources. A comment field is included in the excel table where arguments (and literature sources) can be inserted for setting the range to certain values (see further).

A distinction is made between the 'absolute' min-max range that includes the extremes (at the stakeholder workshop, some people argued against throwing away 'extreme' data) that can be found in literature and the 'likely' range that a modeler or other expert would use. Here, we add a 'representative' value that we would recommend to use. A field will be added to the excel table to write a motivation for using certain parameter values as a 'likely' or 'extreme' range or as representative. This might become lengthy and difficult to handle, so later on we might change the way we keep that info depending on how it works out in practice.
Furthermore, should a distinction be made between the uncertainty on properties of aquifers (usually smaller uncertainty) and aquitards (usually larger uncertainty) and the way we deal with that in setting the range? It could be argued that it does not make sense to mention 'representative values' for aquitards with very uncertain characteristics. In that case, one should leave the 'representative value' column blank.
Information about thickness of layers can be derived from the H3O models, so it is not really necessary to include this in the excel file. It might however be insightful to include a histogram of thickness values, eventually a separate graph per H3O subregion. If feasible, the histograms will be included in a (digital) appendix to the report of 3.2.

The 'Lithofacies' column is often difficult to complete because lithology shows a significant spatial variation. It is possible to include info about the spatial variation in that column (text field). However, partners are requested not to extend too much on this topic, because it is at the limit of the scope of our project.

The excel table with the completed list of attribute data is the output of task 3.2 of our project and this will be provided to the GeoERA GIP. The H3O models are needed to use these data but it is not our task to deliver this to the GIP.
In the proposal for Task 3.2, it was also proposed to assess the resistance of aquitards based on the analysis of the correlations between groundwater head series above and below clay layers. This is methodological research that will be handled in a later phase of the project (detail of the analysis depends on available time).

4.2 Groundwater quality and groundwater age

A Dutch groundwater quality tool is under construction where transects of groundwater quality data can be visualized. It is also possible to select a formation and make plots of water quality (e.g. boxplot, frequency plots) per formation. The objective is to feed this system with Flemish and German data. In this way, a tool will be set up to visualize cross-border variation in groundwater quality.

The visualization tool offers a 'static' view on groundwater quality, showing average concentrations. Time series and trends are not considered, only average properties. That implies that exchange of data via webservices to get the most actual data is not required. We need to export the validated water quality data from German and Flemish databases and import these into the tool. There is no continuous update of data needed.

The considered study area is the entire H3O project area. In vertical direction all H3O model units will be considered.

The considered parameters encompass macro-chemistry but trace metals might also be included. Derived information e.g. water type and redox class could also be considered. TNO will make a list of mandatory and optional parameters. In case of problems with (differences in) definitions of parameters by different partners arise when collecting and merging the data these issues will be solved ad hoc.

There are some automatic data quality checks in the tool: ion balance, pH versus Al, pH vs Zn, pH vs Cd, pH vs Cu, pH vs Ni, pH vs As and Fe vs NO3 (to be incorporated). These checks are at the level of the individual sample. Users of the tool will be able to choose whether or not the less reliable data are shown.
When reading each dataset, a number of automatic checks are performed by the tool:

- Check on mandatory metadata (coordinates, well name, screen number, screen depths, sampling date)
- consistency checks (coordinates, surface level, screen depths)
- screen depths checks (screen depths below surface levels, top screen above bottom screen)
- duplicates (same well-screen-date)

These checks are also performed when merging datasets from different stakeholders.
Besides, each project partners has its own data validation procedure. A comparison of these procedures will be made later on in the project.
Concerning data availability by the project partners:

- In Germany, a water quality database is available, but this is not managed by GD NRW. The owner of the data does not allow the publication of raw data but, it is possible to include the data in the tool and show processed (averaged) info.
- In Flanders, all data collected by VMM are publicly available and downloadable at dov.vlaanderen.be, even the raw data can be found there.
- Groundwater quality data provided by SCK can be disclosed as averaged data in the tool, but the underlying raw data should not be accessible for end-users.
- At the stakeholder workshop, the Flemish drinking water comparny agreed to provide groundwater quality data if the raw data are not disclosed.
- In the Netherlands, groundwater data are publicly available and downloadable at dinoloket.nl. More recent data are available at the provinces.

Concerning groundwater age, data from isotope analysis are available at TNO and some local measurements are also available at SCK. The question is whether ages determined by flowpath modelling can be useful here. We will make an inventory of the approaches used for age determination by the project partners and summarize the results of these analyses. In task 3.6, we can then analyze how these data are used in the regions for policy support.

The topic of groundwater age is also part of the GeoERA 'HOVER' project. In that project, groundwater age data of several GeoERA partners will be collected. It is not clear yet how in the HOVER project the data will be gathered. Therefore, we will start to think independently about our own approach and will adjust our method so that it fits with the HOVER methodology as soon as more info is available. Most probably, there will be differences in approach between HOVER and RESOURCE given the scale and problem setting: our transboundary study will most probably work with more detailed data than the EU scale assessment of HOVER.

4.3 Volumes, fluxes, balances, trends

In this task, the entire H3O area is considered.

Considered variables: water fluxes and ages (how does age distribution change when pumping increases/decreases?).

Two approaches can be followed:

- Approach 1: Based on the H3O model, the total volume of water per aquifer and aquitard can be estimated, based on some assumptions of the hydraulic properties of these layers (porosity, eventually also groundwater level).
- Approach 2: There are several groundwater flow models available for the study region. We could use these models to estimate the volumes, fluxes and balances.

Assessing differences between these two approaches could be interesting.
Calculations should ideally be made with groundwater flow models (approach 2). Only existing models will be used. There is no model that covers the entire project area. So we will have to use multiple models. It is not feasible in the timeframe and budget of this project to make a new model. If multiple models are available, a pragmatic approach will be followed e.g. define units where you want to know balances and fluxes and then examine whether there are differences in calculated fluxes. If so, look for possible reasons. Theoretically, it would be better to first compare the model structure, but this is less likely to deliver useful results within the timeframe of the project.
At the stakeholder workshop, an inventory of large-scale models that overlap with the study region was made. Model owners will be asked to assess the fluxes/balances/ages that are envisaged in this task, e.g. fluxes through clay layers with their models. The selection of models and variables wstill has to be made. If this is completed, the spatial distribution of the modelled fluxes and ages will be assessed and an interpretation of their uniformity will be made. Groundwater volumes and extraction rates will also be calculated.
At the stakeholder workshop, a third approach was proposed: why not make a simple, conceptual model of the entire project area? This is not that much work, only a little more complex than approach 1 (calculations based on H3O model). It was also emphasized that fluxes are more (or at least as) important for practical questions than the volumes. Volumes are only a starting point. The H3O model is not well suited for assessing fluxes.

4.4 Depletion patterns

The term 'depletion' patterns in the project proposal is too limited. The study not only considers regions with declined heads, but aims to map trends in groundwater heads in a more general way. The trends can be downward or upward or absent.

The tools for analyzing groundwater head time series will be harmonized, for a consistent cross border determination of the trends. A first step towards this goal was the organization of an expert meeting, which was hosted by SCK·CEN in Mol on 16th May 2019. Experts from the involved regions presented the groundwater head data that are available in their region and the methods that are typically used for assessing trends.

A short report of the expert workshop can be found in appendix 4.

The second step will be the selection of groundwater head time series that represent the major dynamics of the groundwater system. Criteria will be established to select these series from the existing databases. At the expert meeting, some preliminary criteria and questions that still need to be answered were formulated:

- Can we define a minimum measurement frequency ?
  - Twice a year may be enough for some areas (for example for areas without seasonal fluctuations)
- Can we define a minimum measurement period? (and then taking into account the whole time series)
- Only monitoring sites which are still active should be considered
- Screen-depth should not cross different H3O-units

For the selected series, trend assessments will be available from the methods used by the responsible organization. Where possible, these will be complemented by trend assessments with one or more methods used by the partners.

This will aid the comparison of trend assessment methods used in the Netherlands, Germany and Flanders. Based on this comparison, harmonized trends will be determined. Preliminary output will include maps (point-based) with the meteorological response and/or residuals, data about land use change and an interpretation of abstraction data. Also, the trends will be mapped.

4.5 Link with groundwater policy and management

This analysis will be limited to themes not covered by HOVER: no discussion of threshold values and qualitative status and trend assessment, but focus on groundwater protection, link with drinking water policy and quantitative status.

Two groups of stakeholders can be distinguished:

- EU and other international institutions
- Local or regional organizations that are responsible for one or more water management aspects in different parts of the project area: water boards, drinking water companies, local authorities responsible for groundwater pumping licenses etc.

Whereas the first group is mainly interested in the general approach and methods used in H3O-PLUS, the second group is primarily interested in practical applications of the H3O-PLUS approach and the concrete results.

Stakeholder meetings that are part of WP3 are oriented towards the second group. The first stakeholder workshop is organized on the 17th of June 2019 in Maastricht.
The notes and discussions of the stakeholder meeting can be found in appendix 5.

At the stakeholder workshop in Maastricht, the following policy topics were put forward:

- Licensing of abstractons
- Licensing of geotermal projects
- Protection zones

The approaches of the partner regions to these policy topics will be assessed and compared.

Who must be involved in this comparison?
In the Netherlands the provinces are responsible for groundwater protection. The Ministry of Infrastructure and Waterworks (I&W) gives the national point of view. For some abstractions the Ministry of Econimics Affairs is responsible.
In Gemany the communities are responsible for the small abstractions. The 'Bezirksregierung' carry out the groundwater protection policy of the Ministry. For geothermal questions it depends on the depth. For deep the mining authority, otherwise the local authority must be involved.
In Flanders, VMM advise the province and the Ministry.
Also the drinking water companies must be involved: de Watergroep, WML, Brabant Water and , if possible, the german drinking water supply companies (many small companies). Although they don't make policies, we must also take their point of view into account.

VMM will compile a list of contact persons for each of the three identified topics (abstractions, geothermal, protection). Each of the contact persons will be asked to send information regarding the topic (how it is handled in their region) to VMM and VMM will compare and summarize that information. Based on that comparison and summary, a discussion will be organised with the contact persons of the themes. These meetings will either be organised per theme (if contact persons are different) or for a combination of themes (in case the contact persons are the same). We can start this process in autumn 2019 (gathering information), so that the meetings and discussions can be organised in 2020.

Next to the discussion of the three themes, this tasks also deals with how the results of other tasks can be used in policy and for other practical questions.

How to proceed?
In each case, there will be a stakeholder workshop at the end of the project (mid 2021). The stakeholders would like to have an additional mid-term meeting (June 2020).

APPENDIX I : CENOZOIC CORRELATION CHART FOR PROJECT H3O – ROER VALLEY GRABEN (ROERDALSLENK)

Correlation table H3O-Roerdalslenk van de geologische en hydrogeologische modeleenheden (Deckers et al., 2014)

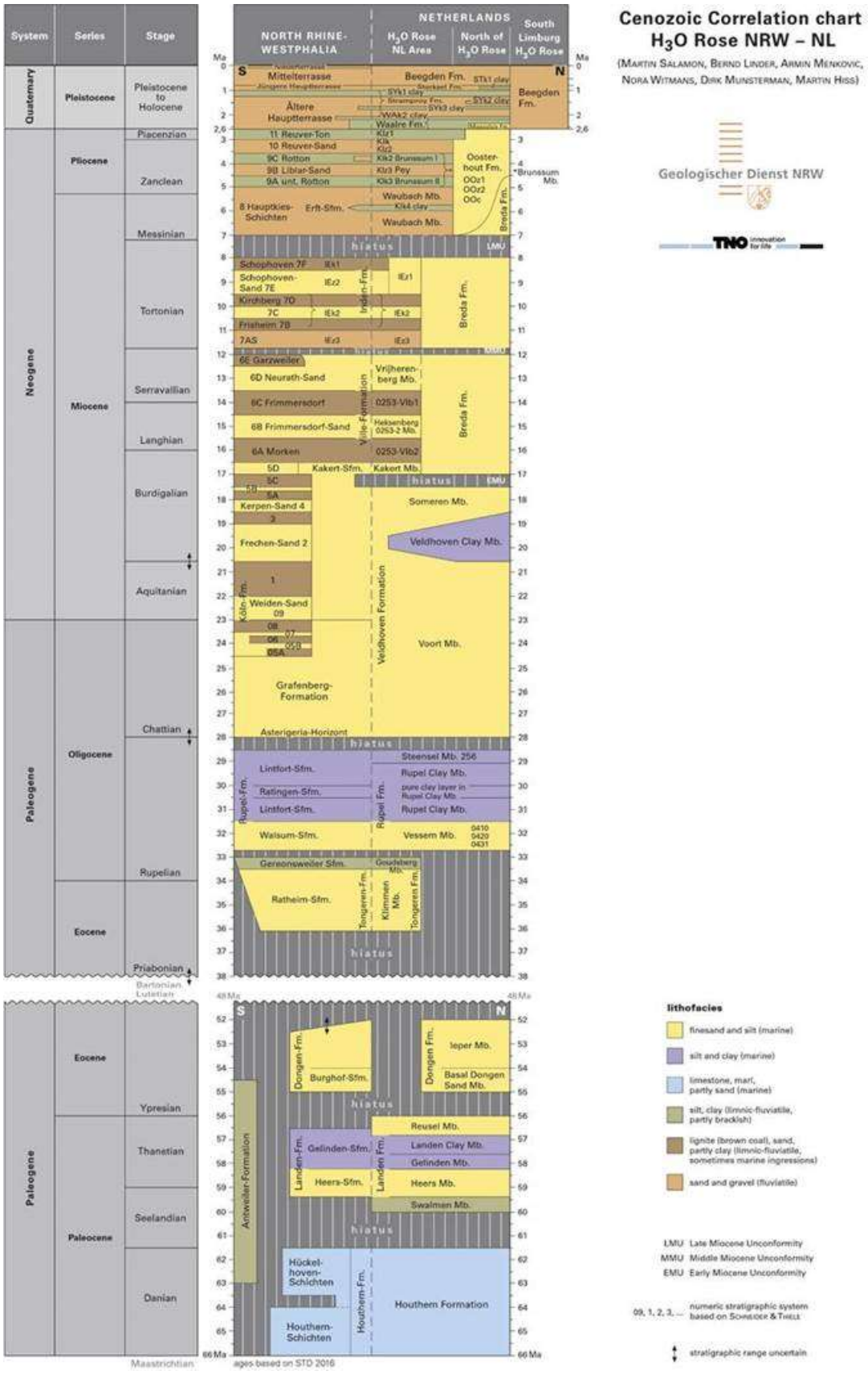
Nederlandse stratigrafische eenheid (formatie - laagpakket)	Nederlandse hydrogeologische eenheid (cf. REGIS II.2)	Vlaamse stratigrafische eenheid (formatie - lid)	Vlaamse hydrogeologische eenheid (cf. HCOV kartering)			Resultaat: H3O Modeleenheid Geologisch model	Resultaat: H3O Modeleenheid Hydrogeologisch model
Antropogeen - opgebrachte grond	HL-c	(Antropogeen)	0110		Ophogingen	HL	HL-c
Nieuwkoop - Griendtsveen		niet aanwezig					
Boxtel - Singraven		Singraven	0140		Alluviale deklagen		
Boxtel - Schimmert	BXSC-k-1					Boxtel	BXSC-k-1
	BX-z-2	Bouwel + Hechtel + Wildert	0150	0151+0152	Zandige deklagen		BX-z-2
Boxtel - Liempde	BX-k-1	Kinrooi / Molenbeersel B		0152+0153	Zand-lemige deklagen + Lemige deklagen		BX-k-1
	BXLM-k-1						BXLM-k-1
	BX-z-3	Diisen		0151	Zandige deklagen		BX-z-3
Boxtel - Best	BX-k-2	Kinrooi / Molenbeersel A herwerkt Maas-Rijn	0100	0152+0153	Zand-lemige deklagen + Lemige deklagen		BX-k-2
Boxtel ongedifferentieerd	BX-z-4			0151	Zandige deklagen		BX-z-4
	HL-c	Leut (Hepppeneert + Mullem)	0140		Alluviale deklagen	HL	HL-c
Beegden ongedifferentieerd	BE-z-1	Lanklaar / Stokkem + Geistingen	0170	0173	Afzettingen Maasvlakte	Beegden	BE-z-1
	BE-k-1	Kinrooi / Molenbeersel B + A					BE-k-1
	BE-z-2	Lanklaar / Maasmechelen + Elsden		0172	Afzettingen Tussenterrassen		BE-z-2
	BE-k-2						BE-k-2
	BE-z-3	Lanklaar / ouder grind Zutendaal Zutendaal - Winterslag		0172	Afzettingen Tussenterrassen		BE-z-3
Sterksel ongedifferentieerd	ST-z-1	Sterksel - Lommel		0171	Afzettingen Hoofdterras	Sterksel	ST-z-1
	ST-k-1	Sterksel - Hamont					ST-k-1
	ST-z-2	Sterksel - Bocholt					ST-z-2
Stramproy ongedifferentieerd	SY-z-1	Kiezeloöliet - Jagersborg (boven Reuver-klei)	0210			Stramproy	SY-z-1
	SY-k-1						SY-k-1
	SY-z-2			0211	Zandige eenheid boven de Brunssum I-klei		SY-z-2
	SY-k-2						SY-k-2
	SY-z-3						SY-z-3
	SY-k-3						SY-k-3
	SY-z-4						SY-z-4
Waalre ongedifferentieerd	PZWA-z-1	Kempen Groep	0220	0221-0223	Kiel-zand-complex van de Kempen	Waalre	PZWA-z-1
	WA-k-1						WA-k-1
	PZWA-z-2						PZWA-z-2
	WA-k-2						WA-k-2
	PZWA-z-3						PZWA-z-3
	WA-k-3						WA-k-3
	PZWA-z-4						PZWA-z-4
Maassluis	MS-z-1					Maassluis	MS-z
	MS-k-1						
	MS-z-2						
	MS-c						
	MS-k-2						
	MS-z-3						
Kiezeloöliet - onbenoemd	KI-z-1	Kiezeloöliet - Jagersborg (vanaf Reuver-klei)	0200			Kiezeloöliet	KI-z-1
Kiezeloöliet - Brunssum	KI-k-1		0210				KI-k-1
	KI-z-2						KI-z-2
	KI-k-2	Kiezeloöliet - Brunssum I		0212	Brunssum I-klei		KI-k-2
	KI-z-3	Kiezeloöliet - Pey		0213	Zand van Pey		KI-z-3
	KI-k-3	Kiezeloöliet - Brunssum II		0214	Brunssum II-klei		KI-k-3
Kiezeloöliet - Waubach	KI-z-4	Kiezeloöliet - Waubach		0215	Zand van Waubach		KI-z-4
	KI-k-4						KI-k-4
	KI-z-5						KI-z-5
Oosterhout	OO-z-1 + OO-z-2	zie bufferzone				Oosterhout	OO-z-1 + OO-z-2
	OO-c						OO-c
Inden ongedifferentieerd	IE-z-1	Inden (+ herwerkt Breda) (nieuw)	0210/0230	0234/0215	Zand van Poederlee en/of zandige top van Kasterlee of Zand van Waubach	Inden	IE-z-1
	IE-k-1						IE-k-1
	IE-z-2						IE-z-2
	IE-k-2						IE-k-2
	IE-z-3						IE-z-3

APPENDIX II: CENOZOIC CORRELATION CHART FOR PROJECT H3O –DE KEMPEN

Correlatietabel H3O-De Kempen van de geologische en hydrogeologische modeleenheden (Vernes et al., 2018)

Nederlandse stratigrafische eenheid (formatie - laagpakket)	Nederlandse hydrogeologische eenheid (cf. REGIS II v2.2)	Vlaamse stratigrafische eenheid (formatie - lid)	Vlaamse hydrogeologische eenheid (cf. Meyus et al., 2000)				Resultaat: H3O lithostratigrafie	Resultaat: H3O hydrogeologie
Antropogeen - opgebrachte grond	HLc	(Antropogeen)	0100	0110	/	Ophogingen	Antropogeen - opgebrachte grond	HLc
Boxtel - Singraven		(Singraven)		0140	/	Alluviale deklagen	Boxtel - Singraven	
Boxtel - Kootwijk	BXz2	Hechtel - Kalmthout		0150	0151	Zandige deklagen	Boxtel - Kootwijk	BXz2
Boxtel - Wierden / Boxtel - Delwijnen		Gent - Wildert			0151	Zandige deklagen	Boxtel - Wierden / Boxtel - Delwijnen	
Boxtel - Liempde	BXLMk1	Gent - Sint-Lenaarts			0152 + 0153	Zandhoudende deklagen + Lemige deklagen	Boxtel - Liempde	BXLMk1
	BXz3				/	/		BXz3
Boxtel - Best	BXk2				/	/	Boxtel - Best	BXk2
Boxtel - ongedifferentieerd	BXz4	(Complex van Meer) / (herwerkt Maas - Rijn)			0151	Zandige deklagen	Boxtel - ongedifferentieerd	BXz4
Sterksel - ongedifferentieerd	STz1	Sterksel - ongedifferentieerd		0170	0171	Afzettingen Hoofdterras	Sterksel - ongedifferentieerd	STz1
	STk1							STk1
	STz2							STz2
Stramproy - ongedifferentieerd	SYz1	Ravels + Mol partim (Stramproy)		0230	0232	Zand van Mol	Stramproy - ongedifferentieerd	SYz1
	SYk1							SYk1
	SYz2							SYz2
	SYk2							SYk2
	SYz3							SYz3
Waalre - ongedifferentieerd	PZWAz1	/		/	/	/	Waalre - ongedifferentieerd	PZWAz1
	WAk1	Weelde		0220	0221-0223	Kiel van Turnhout + Zand van Beerse + Kiel van Rijkevorsel		WAk1
	PZWAz2	Malle		0230	0231	Zanden van Brasschaat en/of Merksplas		PZWAz2
	WAk2							WAk2
	PZWAz3	Merksplas						PZWAz3
	WAk3							WAk3
	PZWAz4							PZWAz4
Maassluis	MSz1	/		/	/	/	Maassluis	MSz1
	MSk1							MSk1
	MSz2	Merksplas		0230	0231	Zanden van Brasschaat en/of Merksplas		MSz2
	MSk2							MSk2
	MSz3	Lillo - ongedifferentieerd			0233 / 0234	Zandige top van Lillo / Zand van		MSz3
Kiezeloöliet - onbenoemd	Klz1	/		/	/	/	Kiezeloöliet - onbenoemd	Klz1
Kiezeloöliet - Brunssum	Klk1	Mol	0200	0230	0232	Zand van Mol	Kiezeloöliet - Brunssum	Klk1
	Klz2							Klz2
	Klk2							Klk2
Kiezeloöliet - Waubach	Klz3						Kiezeloöliet - Waubach	Klz3
	OOz1	/		/	/	/	Oosterhout	OOz1
Oosterhout - Wouw	OOk1	Lillo - ongedifferentieerd + Poederlee + Kattendijk + Kasterlee (zand)		0240	0241	Kleilig deel van Lillo en/of van de overgang Lillo-Kattendijk		OOk1
Oosterhout - ongedifferentieerd	OOz2			0230 / 250	0234 / 251	Zand van Kattendijk en/of onderste zandlaag van Lillo / Zand van Poederlee en/of zandige top van Kasterlee		OOz2
	OOc							OOc
Breda - ongedifferentieerd	Niet gedefinieerd	Kasterlee (klei)		0240	0242	Kleilige overgang tussen de zanden van Kasterlee en Diest	Kasterlee (klei)	0242
	BRz2	Diest		0260	0252	Zand van Diest	Diest	0252
Breda - Vrijherenberg		Berchem / Bolderberg - Genk			0253 + 0254	Zand van Bolderberg + Zanden van Berchem en/of Voort	Vrijherenberg	0254
Breda - Heksenberg	BRz3	Bolderberg - Genk					Bolderberg - Genk	0253
Breda - Kaikert	BRz4	Berchem / Bolderberg - Houthalen					Bolderberg - Houthalen	0253
Veldhoven - Someren	VESOc	Voort - Someren			0254	Zanden van Berchem en/of Voort	Voort - Someren	0254
Veldhoven - Kiel van Veldhoven	VEWIk1	Voort - Veldhoven			0255	Kiel van Veldhoven	Voort - Veldhoven	0255
Veldhoven - Voort	VEVOc	Voort - Voort			0254	Zanden van Berchem en/of Voort	Voort - Voort	0254
Rupel - Steensel	RUz1	Eigenbilzen			0256	Zand van Eigenbilzen	Eigenbilzen	0256
Rupel - Rupel klei	RUBOk1	Boom - Boeretang	0300	/	0301	Kleilig deel van Eigenbilzen	Boom - Boeretang	0301
		Boom - Putte			0302	Klei van Putte	Boom - Putte	0302
		Boom - Terhagen			0303	Klei van Terhagen	Boom - Terhagen	0303
		Boom - Belsele-Waas			0304	Klei van Belsele-Waas	Boom - Belsele-Waas	0304
Rupel - Vessem	RUz2	Bilzen - Berg	0400	0430	0431	Zand van Berg	Bilzen - Berg	0431
Tongeren - Kilmmen	TOz2	Sint-Huibrechts-Hern - Neerrepen		0460	0451	Zand van Neerrepen	Sint-Huibrechts-Hern - Neerrepen	0451
		Sint-Huibrechts-Hern - Grimmertingen			0452	Zandklei van Grimmertingen	Sint-Huibrechts-Hern - Grimmertingen	0452
Tongeren - Zelzate - Ruisbroek		Zelzate - Ruisbroek		0430	0435	Zand van Ruisbroek	Zelzate - Ruisbroek	0435
Tongeren -Zelzate -Basseveide	TOz3	Zelzate - Basseveide		0450	0453	Kleilig zand van Basseveide	Zelzate - Basseveide	0453
Dongen - Asse	DOz1	Maldegem - ongedifferentieerd	0500	/	/	Bartoon Aquitaniasysteem (ongedifferentieerd)	Maldegem - ongedifferentieerd	0500
	DOA3k1							
Dongen - Brussel	DOz2	Maldegem - Wemmel	0600	0610	0611	Zand van Wemmel	Maldegem - Wemmel	0611
		Lede			0612	Zand van Lede	Lede	0612
		Brussel		0620	/	Zand van Brussel	Brussel	0620
		Gentbrugge-Vlierzele		0640	/	Zandige afzettingen van het Onder-Paniseliaan	Gentbrugge-Vlierzele	0640
Dongen - Ieper	DOIEk1	Gentbrugge-Pittem	0700	/	0701	Klei van Pittem	Gentbrugge-Pittem	0701
		Gentbrugge - Merelbeke			0702	Klei van Merelbeke	Gentbrugge - Merelbeke	0702
		Tielt - Egem	0800	/	/	Iepertaan Aquifer (ongedifferentieerd)	Tielt - Egem	0800
		Tielt - Egemkapel	0900	0910	/	Slit van Kortemark	Tielt - Egemkapel	0910
		Tielt - Kortemark					Tielt - Kortemark	
		Kortrijk - Aalbeke		0920	0921	Klei van Aalbeke	Kortrijk - Aalbeke	0921
		Kortrijk - Roubaix			0922	Klei van Moen	Kortrijk - Roubaix	0922
		Kortrijk - Mons-en-Pévèle			0923	Zand van Mons-en-Pévèle	Kortrijk - Mons-en-Pévèle	0923
		Kortrijk - Orchies			0924	Klei van Saint-Maur	Kortrijk - Orchies	0924
		Kortrijk - Mont-Héribu			0925	Klei van Mont-Héribu	Kortrijk - Mont-Héribu	0925
Dongen - Basaal Zand	DOz4	Tienen - ongedifferentieerd	1000	1010	1012	Zandige afzettingen van Loksbergen en/of Diormaal	Tienen - ongedifferentieerd	1012
Landen - Reusel	nog in te delen	Hannut - Grandglise			1013	Zand van Grandglise	Hannut - Grandglise	1013
		Hannut - Lincent			1014	Kleilig deel van Lincent	Hannut - Lincent	1014
Landen - Kiel van Landen		Hannut - Haien		1020	1021	Siltige afzetting van Haien	Hannut - Haien	1021
		Hannut - Waterschei			1022	Kiel van Waterschei	Hannut - Waterschei	1022
Landen - Gelinden		(Hannut - Maaseik)					(Hannut - Maaseik)	
		Heers - Gelinden			1023	Slecht doorlatend deel van de Mergels van Gelinden	Heers - Gelinden	1023

APPENDIX III:CENOZOIC CORRELATION CHART FOR PROJECT H3O – ROSE (DRAFT)


Cenozoic Correlation chart
H3O Rose NRW – NL
(Martin Salamon, Bernd Linder, Armin Menkovic, Nora Witmans, Dirk Munsterman, Martin Hiss)
Geologischer Dienst NRW
TNO innovation for life
System
Series
Stage
NORTH RHINE-WESTPHALIA
NETHERLANDS
H3O Rose NL Area
North of H3O Rose
South Limburg H3O Rose
Quaternary
Pleistocene
Pleistocene to Holocene
Neogene
Pliocene
Piacenzian
Zanclean
Miocene
Messinian
Tortonian
Serravallian
Langhian
Burdigalian
Aquitanian
Paleogene
Oligocene
Chattian
Rupelian
Eocene
Priabonian
Bartonian
Lutetian
Eocene
Ypresian
Paleocene
Thanetian
Seelandian
Danian
Maastrichtian
Mittelterrasse
Beegden Fm.
Ältere Hauptterrasse
Waalre Fm.
11 Reuver-Ton
10 Reuver-Sand
9C Rotton
9B Liblar-Sand
9A unt. Rotton
8 Hauptkies-Schichten
Erft-Sfm.
Waubach Mb.
Oosterhout Fm.
Breda Fm.
Brunssum Mb.
hiatus
LMU
Schophoven 7F
Schophoven-Sand 7E
Kirchberg 7D
7C
Friatheim 7B
7AS
Indeni-Fm.
6E Garzweiler
6D Neurath-Sand
6C Frimmersdorf
6B Frimmersdorf-Sand
6A Morken
Vrijheren-berg Mb.
Ville-Formation
0253-Vlb1
Heksenberg 0253-2 Mb.
0253-Vlb2
5D
Kakert-Sfm.
Kakert Mb.
EMU
5C
5B
5A
Kerpen-Sand 4
3
Frechen-Sand 2
1
Weiden-Sand
09
08
07
06
05B
05A
Köln-Fm.
Someren Mb.
Veldhoven Clay Mb.
Veldhoven Formation
Voort Mb.
Grafenberg-Formation
Asterigeria-Horizont
Steensel Mb. 256
Lintfort-Sfm.
Rupel Clay Mb.
Ratingen-Sfm.
pure clay layer in Rupel Clay Mb.
Rupel-Fm.
Walsum-Sfm.
Vessem Mb.
0410
0420
0431
Gereonsweiler Sfm.
Goudsberg Mb.
Ratheim-Sfm.
Tongeren-Fm.
Klimmen Mb.
Tongeren Fm.
48 Ma
S
N
Dongen-Fm.
Burghof-Sfm.
Ieper Mb.
Basal Dongen Sand Mb.
Reusel Mb.
Landen Clay Mb.
Gelinden-Sfm.
Gelinden Mb.
Landen-Fm.
Heers-Sfm.
Heers Mb.
Swalmen Mb.
Antwerpen-Formation
Hückel-hoven-Schichten
Houthem-Fm.
Houthem Formation
Houthem-Schichten
66 Ma
ages based on STD 2016
lithofacies
fine sand and silt (marine)
silt and clay (marine)
limestone, marl, partly sand (marine)
silt, clay (limnic-fluviatile, partly brackish)
lignite (brown coal), sand, partly clay (limnic-fluviatile, sometimes marine ingressions)
sand and gravel (fluviatile)
LMU Late Miocene Unconformity
MMU Middle Miocene Unconformity
EMU Early Miocene Unconformity
09, 1, 2, 3, ... numeric stratigraphic system based on Schneider & Thiele
stratigraphic range uncertain

APPENDIX IV: REPORT OF THE H3O-PLUS EXPERT MEETING ON TREND ASSESSMENT OF GROUNDWATER HEADS

Thu. 16 May, 10-14h, Mol
Jelle Buma (TNO-GSN), Willem Jan Zaadnoordijk(TNO-GSN), Renate Jaritz (Erftverband), Jasper Claus (IMDC), Bart Rogiers (SCK●CEN), Koen Beerten (SCK●CEN), Bob Peeters (VMM), Griet Heuvelmans (VMM), Cis Slenter (VMM)

Purpose of the meeting
The meeting was organized for the GeoERA groundwater project RESOURCE, and specifically for task 3.5 (cross-border patterns of groundwater trends) within work package 3 (H3O-PLUS concerning groundwater in the Roer Valley Graben and adjacent areas). The purpose of this meeting is (1) to inform each other about how we monitor groundwater heads and which methods each country uses for trend calculations, and (2) to prepare input for the H3O-PLUS stakeholder meeting in Maastricht (June 17th 2019).

Resource WP3: H3O-PLUS
VMM gives a short presentation about the content of H3O-PLUS. The presentation is attached to these minutes (Annex 1).

Task 3.5: cross-border patterns of groundwater trends
TNO gives a short presentation about the content of task 3.5. The presentation is attached to these minutes (Annex 2). Three aspects were discussed specifically, terminology, deliverables and relation to the EU Water Framework Directive (WFD):

- Terminology
  Proposal: replace depletion by trends. This term covers more the load.
  The term depletion has been used in the project proposal. But the proposal makes sense. Depletion points to a problem, but the groundwater heads may also rise again.
  → Agreement: in an official document we will still use depletion in the title, but in the texts we will use trends.
- Deliverables
  According to the DoW: Database and 3D maps of cross-border patterns of groundwater depletion and recharge. To be delivered in Month 32 of the project (= February 2021). The required methods of analysis and visualisation are to be elaborated by the Task partners.

- Relation to WFD
  RESOURCE Task 3.5 wil consider trends in time and in space (laterally, especially across faults, and vertically). We will not limit ourselves to the methods used in the WFD, but will make use of the WFD information where appropriate (monitoring, preliminary work, etc.).

Stakeholder meeting 17th of June Maastricht
The GeoERA projects are designed to "the development of knowledge and services aimed at European, national and regional policy makers, industry and other stakeholders". Therefore, we think it is important to have guidance from stakeholders in shaping and developing the project. The stakeholders of RESOURCE are no trend specialists, but they can tell us what they want/need and in which way they want it.

Country presentations

Germany: Erftverband (+input from LANUV)

- Erftverband is responsible for the regional water management, including groundwater.
- The brown coal mining sites are within the study area.
- 17000 wells/screens in an area of approximately 100 * 150 km.
- Owners of the screens vary, but the data is collected in one database.
- 1 measurement per month.
- Many old measurement series from the 1950s.

Four different methods are available for trend calculation. The statistical test and notably the Multichannel Wiener-filter analysis are preferred nowadays. The latter is further outlined below:

- Three time series without anthropogenic influence are compared with the time series that you want to investigate
    - Difference between what it is now and what it should be like:
        - The direction of the trend may be good, but perhaps not increasing enough.
        - The effect of compensation measures becomes visible.
        - The last drought period (more drought than ever) has been calculated fairly well.
- 12 reference points (nearby, but not too close)
    - The influence of the brown coal mining is everywhere.
    - In the north the influence is less, but the reference points must be a bit spread out over the study area.
    - These point have long time series, from the 1950s.
- A lot of expert knowledge about the study area is needed (a bit trial and error is needed for the calibration)
    - The influence of the mining has slowly shifted to the West since the 1980s.
    - Infiltration facilities have been implemented as compensation measures; sometimes, these added too much water.
    - There is a difference in groundwater heads inside and outside wetland areas.

➔ The time series are partly public and can be consulted at ELWASWEB (https://www.elwasweb.nrw.de/elwas-web/index.jsf)

➔ Erftverband / LANUV would like to exchange groundwater data with The Netherlands.

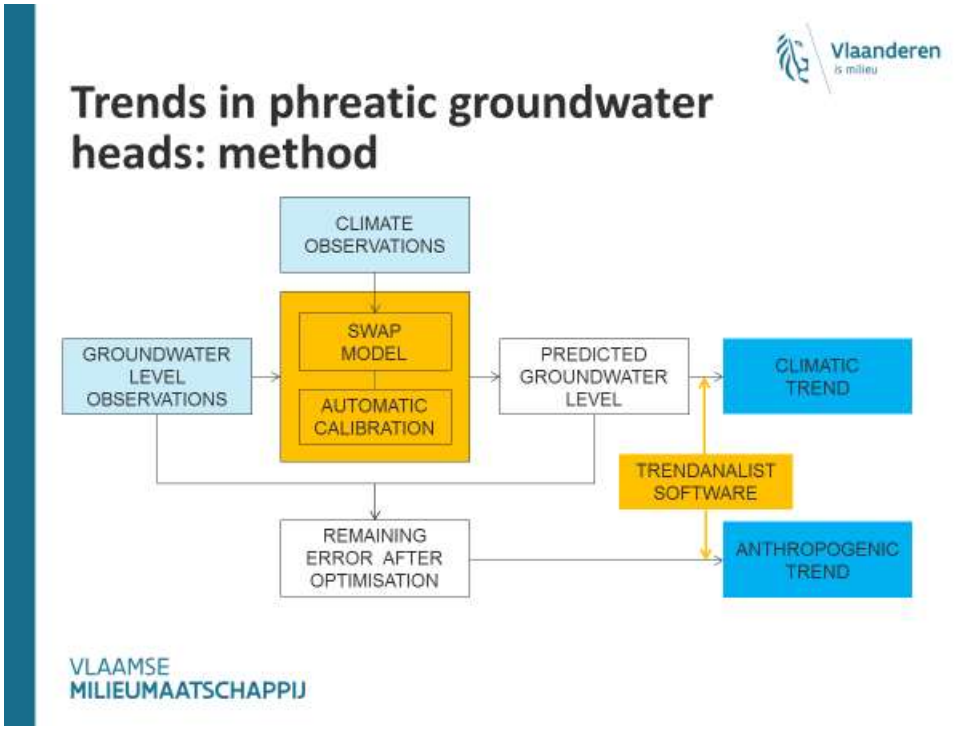
Flanders: VMM and SCK●CEN

VMM

- VMM is responsible for the groundwater management in the study area
- phreatic groundwater network
    - 174 wells, 493 screen in the study area
    - Monitoring frequency: 2 times a year
- primary groundwater network
    - 53 wells, 122 screens
    - Monitoring frequency: monthly, by hand
- There are some longer times series, but most start from the late 1980s, early 1990s

Trends in the groundwater heads:

- For the phreatic layers:
  - SWAP model
  - trendanalist on the residu



- For the confined layers:
  - statistic approach
  - preprocessing for filling gaps and removing outliers
  - trend assessment

➔ Data is public and can be found at https://dov.vlaanderen.be .

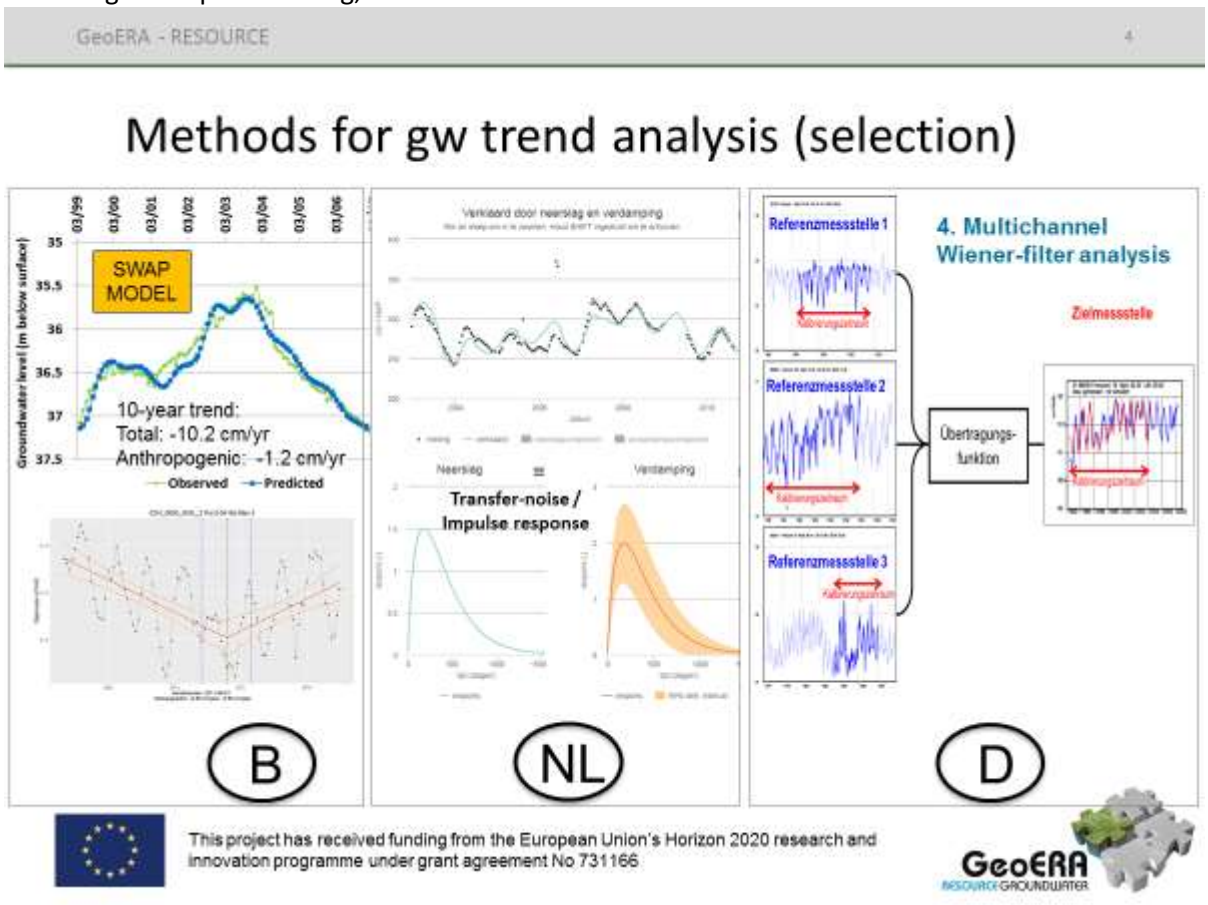
SCK●CEN

- Monitoring:
  - regional network (deep aquifer model)
  - subregional network (neogene aquifer model)
  - local network (local model)
- Methods used for time-series analysis
  - Impulse-response function modelling
    - More basic than SWAP-model, but looks like it
    - Errors: research on human impact
  - Time series decomposition
  - Break detection

The Netherlands: TNO-GSN

- GSN does not monitor groundwater heads, only provides monitoring data in public national database (https://www.dinoloket.nl/ondergrondgegevens)
    - Typical frequency twice per month for manual measurments, daily for automatic pressure transducers with data loggers
    - Some long series (starting in 1950s or even before)
- Time series models on https://www.grondwatertools.nl/grondwatertools-viewer
    - Transfer noise models with Impulse response functions for:
        - Precipitation
        - Evapotranspiration
    - daily update: a program detects whether there are new measurements, if so, it recalculates the time series model for the last 8 years of data
    - 5 calibrated parameters in time series model (3 for precipitation impulse response function, 1 for evapotranspiration response relative to precipitation, 1 decay parameter in noise model)
- Since the 1950s general downward trend +/- 30cm in The Netherlands
- Around 2000 a programme started to restore the original higher groundwater heads in nature preserves.

Following the expert meeting, TNO has made an overview of the methods:



Discussion: necessities and perspectives for harmonization of groundwater trend assessment

- Deliverables: we all have a lot of time series, but we also want to produce maps. How are we going to do this?
    - Due to time and money, we cannot work in great detail
      For example: global/regional maps
    - Point maps, the stakeholder may use the point data to make interpolations by herself (which is a lot of work, see the maps shown in the PPT of the Netherlands)

Which data can be used for cross-border relations?

- What is the impact of using different networks&installations (for example screen length), monitoring, methods on the results?
- How are we going to harmonize the data?
    - What are the criteria?
    - Phreatic and confined?
    - Should we take wetland data into account or not? They influence the image of the regional pattern
- Which aquifers should be taken into account?
    - Which hydrogeological units from H3O are we taking into account?
        - H3O-Rose: probably delivered end of 2019
- Which are the minimum requirements to use groundwater head data?
  We still have to define the criteria for this, for example:
    - Can we define a minimum measurement frequency ?
        - Twice a year may be enough for some areas
          (for example for areas without seasonal fluctuations)
    - Can we define a minimum measurement period? (and then taking into account the whole time series)
    - Only monitoring sites which are still active
    - Screen-depth should not cross different H3O-units

➔ Agreement to create a dataset of selected time series from all three countries for use in the project.

➔ Not feasible to apply all methods to all of these selected time series so work out different ways of detecting systematic differences in results.

➔ Use the H3O-Rose model to assign piezometers to hydrogeological units.

Actions

- Jelle and Willem are going to make a template table “network&installation, monitoring, methods”.
  To clearly compare the differences and similarities between the different countries.
  They will send it to the other partners, and they will complete the schedule a week later.
- TNO will make a short presentation for the stakeholder meeting about task 3.5 summarizing the results of this workshop, others will provide feedback:
    - Differences and similarities between countries;
    - Proposed approach for task.
- Create dataset of selected time series
    - TNO will send around a proposal for selection criteria and a template table in June
    - Finalize criteria in July (all)
    - October 2019: complete dataset (all)

APPENDIX V: NOTES AND CONCLUSIONS RESOURCE STAKEHOLDER MEETING MAASTRICHT 17TH JUNE 2019

Introduction

- Welcome (Eric Castenmiller, Provincie Limburg, Nederland)
- Introduction to the GeoERA initiative, RESOURCE and H3O-PLUS (Griet Heuvelmans, VMM)
- Role of the stakeholders, todays program, tour de table (Cis Slenter, VMM)

Task 2: Hydraulic properties

Presentation: Ronald Vernes (TNO)
Notes: Koen Beerten (SCK)

- Simon Six (De Watergroep) asks if the median value is the representative - and how to honour spatial variation. This is done through tackling the separate H30 areas (ROSE, De Kempen...)
- Willem Jan Zaadnoordijk (TNO) says that spatial trends need to be analyzed between the subproject areas (4), whether due to analysis method or real spatial trend?
- From what source are the data coming from? This is done through a comment field (type of data, number of points)
- Willem Jan Zaadnoordijk (TNO) advises against throwing away extreme data. From min-max, to likely range (expert judgement) to 'most representative value'
- Ksat is horizontal (aquifers) and vertical (aquitards), Ksat of faults is not very well known. All information is welcome. First focus is Kiezeloöliet because it is present in three countries. Simon Six (De Watergroep) is very interested in hydraulic properties of faults. There will be information from VoGERA project on properties of faults. Down to 600 m.
- Are you going to use information from groundwater calibrations? In any case it is not included for the test case (Kiezeloöliet). But Ronald Vernes (TNO) would include it because it might give additional information.

Task 3: Groundwater quality and age

Presentation: Mariëlle van Vliet (TNO)
Notes: Koen Beerten (SCK)

- GW quality tool: work plan (see presentation Marielle van Vliet)
- interface will be translated into English, it will be an open database, not a project database
- how many groundwater age data is available in Belgium and Germany? not for Germany in any case, for Belgium only through modelling of De Watergroep (10x10 km), some data at SCK
- GW tool has two time periods: before 1980 and after 1980, it operates through depth (not layer)
- which parameters does Marielle van Vliet needs for the tool? Anything, any information is important, but most important is nutrients and metals. Best case is a total analyses to be able to calculate the charge balance.
- also data from De Watergroep will be incorporated - it's closed data but they can deliver what we need.
- It will be possible to include data that will not be disclosed but ARE used in the spatial and temporal analyses

Task 4: Harmonization of volumes, balances and fluxes

Presentation: Ronald Vernes (TNO)
Notes: Griet Heuvelmans (VMM)

Approach 1: Based on the H3O model, the total volume of water per aquifer and aquitard can be estimated, based on some assumptions of the hydraulic properties of these layers (porosity, eventually also groundwater level).
Approach 2: There are several groundwater flow models available for the study region. We could use these models to estimate the volumes, fluxes and balances.
Assessing differences between these two approaches could be interesting.

Questions:

- Do you agree with the general approach?
- Which groundwater flow models to consider? How can we cooperate with the owners of the models?
    - See slide with model areas. There is no model that covers the entire project area. So we will have to use multiple models. It is not feasible in the timeframe and budget of this project to make a new model.
    - Pragmatic approach if multiple models are available: define units where you want to know balances and fluxes and then examine whether there are differences in calculated fluxes. If so, look for possible reasons. Theoretically, it would be better to first compare the model structure, but this is less likely to deliver useful results within the timeframe of the project.
    - Why not make a simple, conceptual model of the entire project area? This is not that much work, only a little more complex than approach 1 (calculations based on H3O model).
    - Contact persons for NL known by TNO, for Germany: LANUV, for Flanders: VMM and/or SCK
- Which administrative and hydrological boundaries to consider?
    - Examples: flux across fault, fluxes from and to rivers (especially Meuse)

Remarks:

- Fluxes are more (or at least as) important for practical questions than the volumes. Volumes are only a starting point.

Task 5: Trends and groundwater depletion patterns.

Presentation: Willem Jan Zaadnoordijk (TNO)
Notes: Matej Gedeon (SCK)

- A lot of data on groundwater levels available in project countries
- Different purposes and already trend assessment according to EU requirements;
- Various method to link heads to prec. and evap. (B: SWAP model, NL: transfer noise, DE: statistical tools using a reference piezometer);
- Different visualization tools to present (areal coverage (interpolation) or piezometer level)
- Plan:
    - Stakeholder involvement;
    - Criteria for selecting the public data for analyses;

- Database building;
- Various methods to analyse the trends (including other driving forces than atmospheric input);
- Visualisation;
- Recommendations to Task 6 -> management strategies

Discussion:

- What about the data – only public DB or there are more sources?
  - In NL -> Dino loket
  - DOV Vlaanderen
  - Industry data? Are there some other interesting data? Maybe there are some data on extractions. Probably important data are delivered to Dino loket? Not sure. We need to check.
  - Other input series as precipitation and evaporation?
    - Extractions, river discharge, mining re-watering
    - It can be very tedious to clean the data up
    - Depends if applicable
    - Limburg province can provide data for abstractions (after 1990)
  - What are the recommendations for methodology of the trend analysis?
    - Need for a comparison and insight onto the used methods;
  - What is the timeframe?
    - Not yet decided, looking at various scales and period lengths.
    - It is about the long-term trend analysis
    - Looking at the trends in deep system
  - Are other stakeholders prepared to deliver abstraction data?
    - Brabant has data from approx. 70ies
    - Complete datasets are only available from 90ies, agricultural data from 2000
    - For agriculture – indirect calculation according to the water shortage
    - German part: big abstractions available from 1975, small abstractions from after 1990 on, but is not public.
    - VMM – DOV has values for abstractions, including big agricultural abstractions
    - Watergroup has detailed data – on a yearly bases in DOV, monthly data available.
    - Statistical modelling does not really take into account the distance between piezometers and pumping, but the correlation is stronger if the abstraction is close. The approach should start with only precipitation and add abstractions if the oscillations are not explained.

Task 6: Groundwater policy

Presentation: Griet Heuvelmans (VMM)
Notes: Mariëlle van Vliet (TNO)

Main questions for the session of today:

1) Which policy/management topics do we need to consider in task 6
2) How do we proceed :
   a. Who must be involved?
   b. How will we organize information exchange?

The important topics to consider are:

- Licensing of abstractons (the idea of licensing of abstractions is the same, but pratical it is different)
- Licensing of geotermal
- Protection zones

Who must be involved?
In the Netherlands the provinces are responsible for groundwater protection. The Ministry of Infrastructure and Waterworks (I&W) gives the national point of view. For abstractions >500 m the Ministry of Econimics Affairs is responsible.
In Gemany the communities are responsible for the small abstractions. The 'Bezirksregierung' carry out the groundwater protection policy of the Ministry. For geothermal questions it depends on the depth. For deep the mining authority, otherwise the local authority must be involved.
In Flanders, VMM advise the province and the Ministry.
Also the drinking water companies must be involved: de Watergroep, WML, Brabant Water and , if possible, the german drinking water supply companies (many small companies). Although they don't make policies, we must also take their point of view into account.
VMM will compile a list of contact persons for each of the three identified topics (abstractions, geothermal, protection). Each of the contact persons will be asked to send information regarding the topic (how it is handled in their region) to VMM and VMM will compare and summarize that information. Based on that comparison and summary, a discussion will be organised with the contact persons of the themes. These meetings will either be organised per theme (if contact persons are different) or for a combination of themes (in case the contact persons are the same). We can start this process in autumn 2019 (gathering information), so that the meetings and discussions can be organised in 2020.

Next to the discussion of the three themes, this tasks also deals with how the results of other tasks can be used in policy and for other practical questions.
In this task we should also think about the way that we want to collect and harmonise the data (which data, how should we come to a continued harmonisation and data exchange after the project?) and about a monitoring strategy (what are the differences in monitoring set-up between the regions?).

How to proceed with the project: In each case, there will be a stakeholder workshop at the end of the project (mid 2021). The stakeholders would like to have an additional mid-term workshop e.g. in a year we will organise another meeting to discuss the project results (June 2020).