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

Deliverable 4.2

Integration of data in a common dataset

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1 INTRODUCTION

This document is the deliverable for task 4.2 of work package 4 of the TRANSFLUX work package which involved the “Integrated evaluation and harmonization of the hydrogeological data set for modelling purpose“. The current document presents the scope of data that were provided by participating parties in order to develop GIS layers for groundwater hydrodynamic numerical model purposes. The groundwater model will cover the Polish-Lithuanian cross-border area. In order to eventually derive a harmonized hydrogeological dataset as deliverable 4.3 of the work package, we first developed a template that can be used by the transboundary partners for collecting the data and to develop the harmonized dataset.

In this document the general idea behind the template is explained, as well as the thought of some of the choices, that were made based on agreements made during the Groundwater RESOURCEs GeoERA workshop, that was hosted in the headquaters of the Hungarian Geological Survey in Budapest on March 20th – 21th 2019, as well as arrangements, that were established during the WP4 TRANSFLUX Polish-Lithuanian working meeting, that took place in the headquaters of the Polish Geological Institute-National Research Institute in Warsaw on May 30th 2019.

2 WORK FLOW

2.1 General idea and aims

The general idea behind the work package 4 (WP4) Groundwater RESOURCE "*TRANSFLUX: Harmonization of data, monitoring and modelling in a transboundary setting*" is to develop a numerical hydrodynamic model for the Lithuanian-Polish cross-border area, that will cover the Quaternary multi-aquifer system for the selected parts of the transboundary river basins.
The project has two major research goals: the verification and determination of the transboundary groundwater flow directions in the cross-border area and the estimation of the volume of groundwater, which flows through the state border between Poland and Lithuania. The crucial part of the project, which focuses on the numerical model development was preceded by the comparison of the scope of data, that are available in each institution involved in the WP4 and can be used for hydrodynamic modelling purposes for cross-border areas. Task 4.1 of WP4 (*Comparison and unification of methods for groundwater modelling in Poland and Lithuania*) is connected with task 4.2 and it was carried out between July 1th 2018 and the end of December 2018. The deliverable for task 4.1 covered the comparative tables of data review, that can be used for groundwater hydrodynamic numerical modelling purposes. The tables were prepared and provided by all participating institutions in the WP4: Polish Geological Institute-National Research Institute (PIG-PIB), Lithuanian Geological Survey (LGT) and Geoinform of Ukraine. The comparative tables allowed to realize the similarities, as well as obstacles in a common works aimed at development of numerical hydrodynamic models, which will cover cross-border areas in this part of Europe. Some materials need further clarification in detail among involved cooperators, as well as some data need to be standardized or adjust for the transboundary use.

2.2 Workshop on model choices

The first workshop of the WP4, was hold in Sidorówka hydrogeological station of the Polish Geological Institute-National Research Institute on October 16th 2018. In this meeting representatives of the Polish Geological Institute-National Research Institute (PIG-PIB) and the Lithuanian Geological Survey (LGT) attended. At the working meeting, a proposal for the GIS layers was presented with boundary conditions for the modelling area, covering the Polish-Lithuanian cross-border zone. Discussions also aimed at the issues related to the transboundary spatial extent of model layers. It was decided, that numerical model will be developed in Groundwater Vistas software, operating in the Microsoft Windows environment. In terms of the organization of the calculation process, GW Vistas is a interface on the ModFlow group calculation moduls. The program is used to solve the filtration equation using the finite difference method. The main function of GW Vistas is the use of a graphical interface to enter input data, control the calculation process, analyze the results and communicate with other applications used in hydrogeological tasks. Due to the fact that the ModFlow modules are used to solve filtration equations using the GW Vistas program, detailed descriptions of the numerical algorithms of

solutions of the filtration equation will not be presented in this report. Numerical calculations are subject of the solution of a different equation in which the hydraulic height is unknown. In order to achieve a properly calibrated model, knowledge about piezometric pressures in the modeled aquifers is necessary. During the meeting in Sidorówka experiences referring to already existing numerical models, developed in Poland and in Lithuania were compared.
Task 4.2 of WP4 (*Integrated evaluation and harmonization of the hydrogeological data set for modelling purposes*) was conducted since January 2019. Participants of the project were obliged to provide: geological, hydrogeological and other data useful for groundwater modelling purposes. In this stage of the project cooperating parties of the project made attempts aimed at adjusting data (that are partly available in analog form or in .pdf files) to the requirements of GIS environment. The raw data were processed to the common projection in the GIS environment. The jointly agreed geographic coordinate system used is PUWG-1992. System WGS-84 is used to share data between the cooperating parties. To carry out modelling investigations the study area was discretized, the model boundaries were defined, and the boundary conditions were determined. Collecting of the rest of necessary data and preparation of GIS layers for modelling purposes is in progress.

2.3 Workshop on harmonized data collection

The second workshop of the Groundwater RESOURCE WP 4 was held on May 30th 2019 in the headquarter of the Polish Geological Institute-National Research Institute in Warsaw. The leader of the project presented schedule and milestones of the project, as well as discussed project progress. Participants of the workshop from the Polish Geological Institute-National Research Institute (PIG-PIB) and from the Lithuanian Geological Survey (LGT) discussed the issues related to the development of GIS layers (aquifers and aquitards). The project partners from Lithuania decided to verify and modify boundary conditions of the model within the Lithuanian border area.

Currently the team continues works on the determination of the top and the bottom, occurrence and spatial extent of each model layer. Aforementioned activities will finally result in the schematization of hydrogeological conditions. There are some gaps of data on the contact surface within the cross-border area between Poland and Lithuania, that need to be filled and GIS layers should be unified and merged in these parts. Moreover, the distribution of the hydrogeological parameters within the modelling area (in the cells of the discretization network) should be determined.

2.4 Hydrometric measurements for model calibration purposes

Furthermore, it was decided to carry out hydrometric measurements of surface water discharge within the cross-border area in following rivers: Szeszupa (Šešupė), Szelmentka, Wigra, Marycha (Seina), Biała Hańcza (Baltoji Ančia), Hołnianka (Alna), Dziedziulka (Didžiulė), Potopka, Gazda, Kirsna, Raišupis, Uide, Zapse, Nieda, Šlaventėlė, Morkauas, Seira, Krūčius, Bilsinyčia, Igara, Mara

and in their tributaries, using handheld electromagnetic water flow meter with automatic discharge calculation. The measurements were conducted between July 29th 2019 and August 2nd 2019 by the representatives of the Lithuanian Geological Survey and the Polish Geological Institute-National Research Institute. The bilateral field surveys were a continuation of cooperation conducted between the Institutions, including among others implementation of the arrangements concluded during the Polish-Lithuanian hydrogeological workshop, which was organized in the Polish Geological Institute - National Research Institute in Warsaw on May 30th 2019.
Hydrometric measurements were taken at low states of surface water in rivers, after a long-term period of lack of atmospheric precipitation, which allows to consider flow of surface water in individual river basins as the equivalent of recharge, that originated from groundwater. The results of hydrological measurements will be used for development of a hydrodynamic numerical model in the further stages of the project.

Photo. 1. Biała Hańcza river (Lith. Baltoji Ančia) in the proximity of Sventijanskas village, Lithuania (Photo. M. Galczak)

Photo. 2. Hydrometric measurements in Marycha river (Lith. Seina) close to the bridge in Babańce, podlaskie voivodeship (photo. T. Gidziński)

3 DEVELOPING THE TEMPLATE

3.1 Data collection structure

A joint data set has been developed in the GIS environment, using the ArcGIS software for the management of the archive hydrogeological data and results of field works. For modelling purposes the following raw data of the Polish Geological Institute-National Research Institute and the Lithuanian Geological Survey were collected:

- litho-stratigraphic profiles of hydrogeological objects (hydrogeological boreholes, piezometers and drilling wells)
- data related to hydrogeological parameters of aquifers (hydraulic conductivities *k* values from the pumping tests, accessible in the Central Hydrogeological Data Base of the PIG-PIB)
- layers of the Geological Map of Poland 1:50 000 (of Quaternary sediments)
- layers of the Hydrogeological Map of Poland 1:50 000
- hydrometeorological data
- Digital Model Terrain layers
- various data essential for the project needs.

All the data mentioned above need to be processed, transformed and adopted to the GIS layers, in order to import them later to the modelling software. The ArcGIS environment was used for the management of the field works data and archive geological and hydrogeological data.
The structure of resulting data set is illustrated In the scheme of Fig. 1.

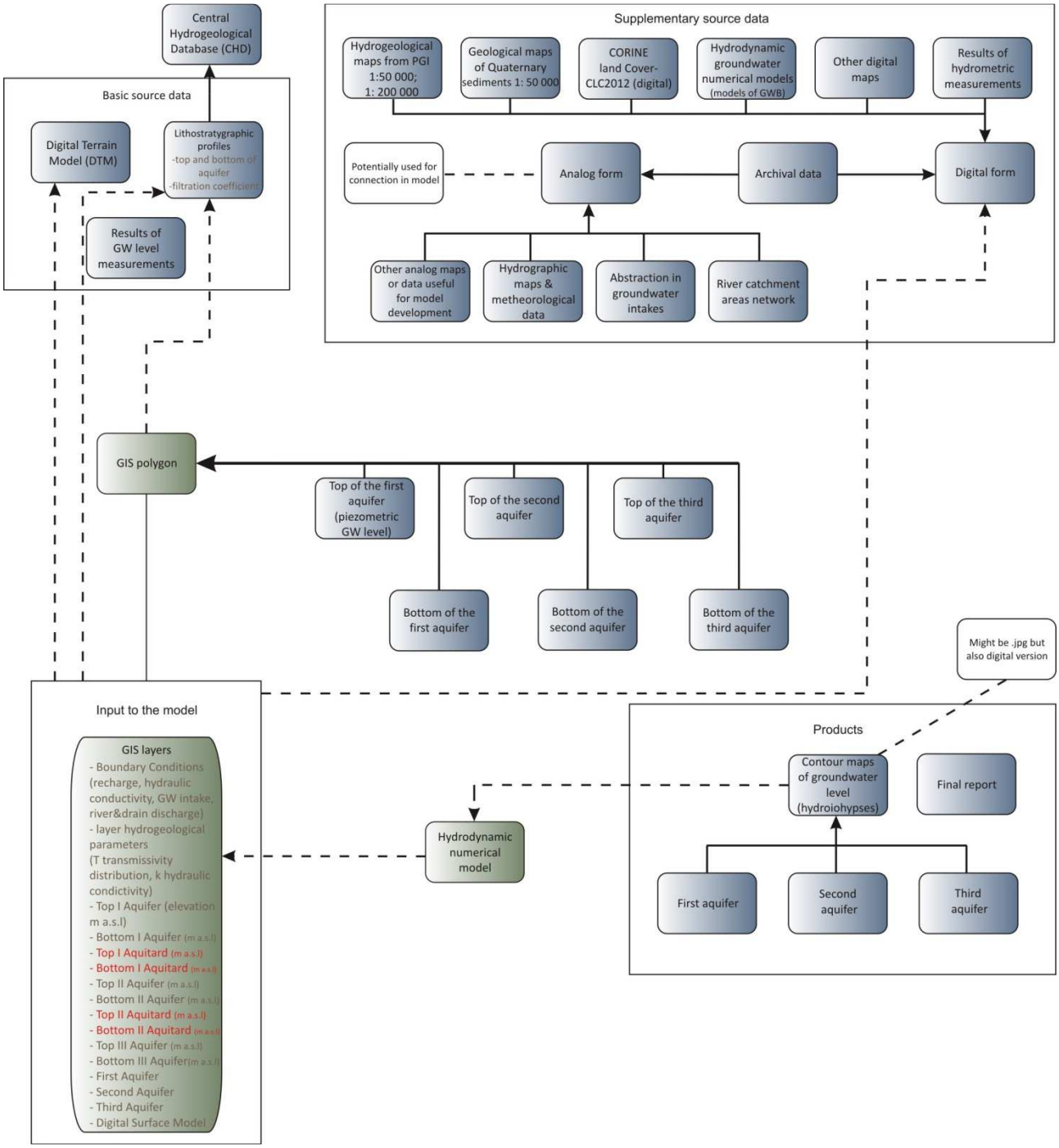

Fig. 1. Scheme of data set of the Polish Geological Institute – National Research Institute usable for numerical modelling within Polish-Lithuanian cross-border area (Lewandowski P., Gidziński T., 2019)

3.2 Model boundaries and grid discretization

To carry out modelling investigations the study area was discretized, the model boundaries were defined and the boundary conditions were determined. The major area of transboundary river basins within the Polish-Lithuanian cross-border area are on the Lithuanian territory. The model boundary conditions were defined mainly as a *no flow* (2nd type) boundary, and as a 3rd type boundary along rivers and creeks. The river level values were determined on the base of the topographic maps as well as Digital Terrain Model. Only small parts of model borders were defined as 1st type (constant head) boundary condition. The groundwater recharge and well pumping rates were defined as the 2nd type boundary conditions. The square of model cell is 500 m by 500 m. On the base of the hydrogeological conditions within study area were distinguished three productive aquifers of Quaternary age. The first aquifer from the ground surface is unconfined and locally confined, built of sands and gravels of Holocene and Plejstocene age. This layer occurs in the northern part of investigated area. The first aquifer is recharged by the infiltration of the water originating from precipitation. The second and third aquifers are important in drinking water supply. The second aquifer is the main usable aquifer in study area.

The hydrogeological scheme was supplemented by the following assumptions:

- Bottom of the third aquifer is non permeable,
- Flow field is steady-state,
- Vertical groundwater flow is neglected,
- Aquifers are hydraulically connected to the rivers and creeks,
- The distribution of spatial model parameters and the heterogeneity of the aquifer are taken into account by differentiation of the parameters in the discretization grid,
- it is assumed isotropicity of the aquifer in individual calculation block.

In software for numerical modelling the properties of aquitards will be presented as parameter of "*leakance"*.

The steady-state groundwater flow in numerical model will be solved using the finite difference method for the rectangular regular mesh with the constant spatial step 500 m by 500 m. The applied calculation procedure will require input of individual aquifer top and bottom elevations and permeability values for each node of the finite difference mesh. For the unconfined parts of the aquifer its top is equivalent to the calculated elevation of groundwater table. The aquifer top and bottom elevations will be input by the import of the files generated in the ArcGIS for the Polish and Lithuanian models, using the interpolation procedure. Close to the border line, where accuracy of data provided by each party is not good enough, data will be reprocessed using GIS tools e.g. interpolation.

The interpolation will be carried out using the Inverse Distance Weighting procedure in the Geostatistical Analyst module. The preliminary distribution of the aquifer permeability values on the Polish side will result from the interpolation of the "k" values, determined from the pumping tests, that are accessible in the Central Hydrogeological Database of Polish Geological Institute-National

Research Institute. Final distribution will be confirmed in the model calibration process (solution of reverse task).
The infiltration recharge distribution will be assessed on the base of measured and evaluated water discharge value in individual river basins and geology of surface sediments from the detailed geological maps 1: 50 000.

3.3 Model Calibration

The principle calibration criterion will be to minimize the difference between the groundwater table elevations measured in the field and calculated in selected observation wells by the groundwater flow simulations.
Numerical model always constitutes the simplification of the real hydrogeological conditions. This is why model simulations results include certain error, which results from the never full knowledge of the investigated hydrogeological system and necessary simplification made during the construction of the model.
Factors limiting the model reliability:

- Small number of piezometers and observation wells with the possibility to measure water level in the investigated area,
- Mosaic distribution of the permeability values,
- Differences in archive hydrogeological data (parameters) provided by project partners,
- Small number of reliable data from hydrogeological database in low populated cross-border areas.

In the map (Fig. 2) are presented differences of infiltration recharge distribution in the GIS layer, for the second (main usable) aquifer. The mosaic distribution of infiltration recharge on the Lithuanian and Polish cross-border territory reflects differences in determination of this parameter.

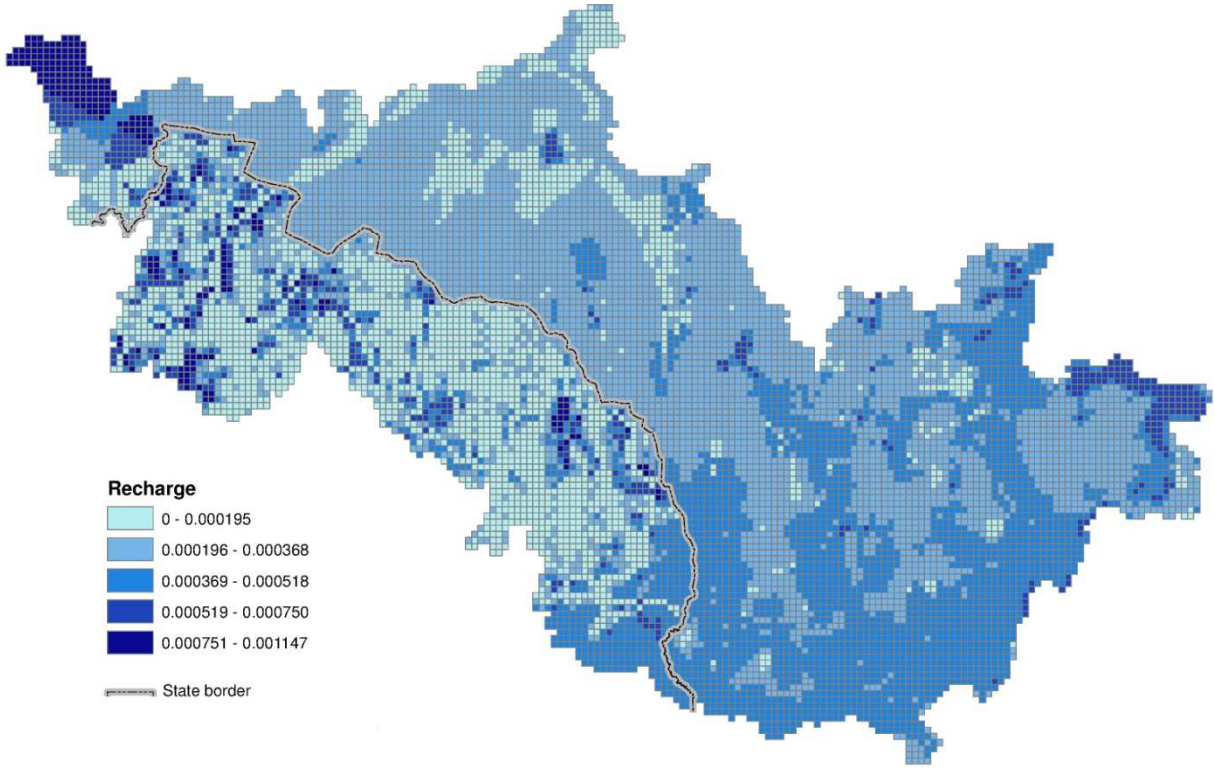

Fig. 2. Distribution of infiltration recharge in the GIS layer, second (main usable) aquifer

Project partners consider solving of reverse task, in order to obtain real distribution of infiltration recharge in comparable scale, in the modelling area. One solution is the constant volume transformation allowing to calculate the distribution of the long term mean groundwater recharge which generates the groundwater runoff with the known long term mean value. Other approach is that recharge depends only on the distribution of the lithology of surface sediments and precipitation. The algorithm is based on the assumption of the equality between this recharge and this groundwater runoff for the given budget area. The outcome of the calculations will allow to determine the most accurate distribution of the recharge in study area (Śmietański L., 2012).

3.4 Cross-border harmonization

In the contact surface of GIS layers developed and provided by both parties of the project consortium form the Polish Geological Institute – National Research Institute (PIG-PIB) and the Lithuanian Geological Survey (LGT) were identified following cases, that should be considered and unified for development of hydrodynamic numerical model.

1. GIS layer, that corresponds to the aquifer from one side of the border line does not touch the GIS layer from the other side, within the territory of another country. Therefore, the GIS layers should be analyzed, in order to fill the gaps and harmonize and join individual layers. This process will require interpolation and aggregation of accessible data, taking into consideration reliable data and information and finally an expert interpretation. As the advantage of developing of transboundary layers is access to the geological and hydrogeological information from the border territory of neighboring country. In result the data within the study area, instead of extrapolated can be interpolated, based on reliable data.

2. The second example is related to the GIS layers, that overlap each other. Thickness of individual layer, aquifer hydraulic properties and parameters of aquitards differ in some parts of study area. The cross-border zone within the numerical model area is low populated, thus number of drilled wells, investigative boreholes and piezometers is low. The layers should be harmonized, using more reliable data from profiles of existing hydrogeological objects.

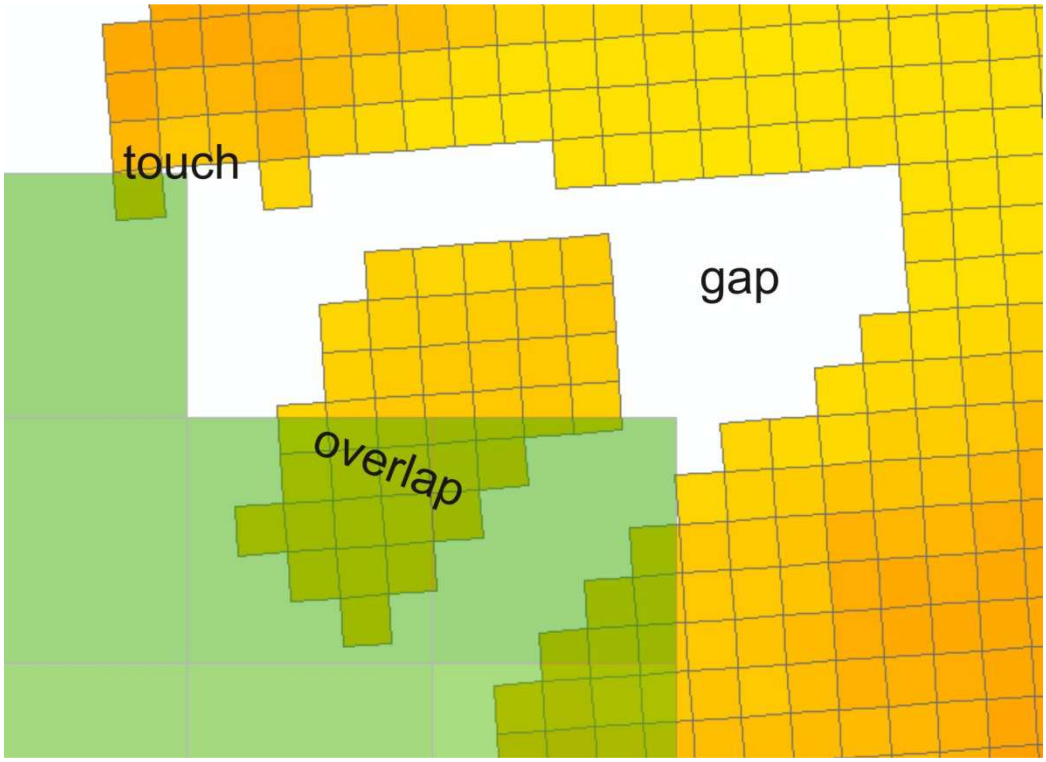

Fig. 3. Differences in GIS layers, that were developed by representatives from the Polish Geological Institute-National Research Institute (PIG-PIB) and Lithuanian Geological Survey (LGT). First aquifer

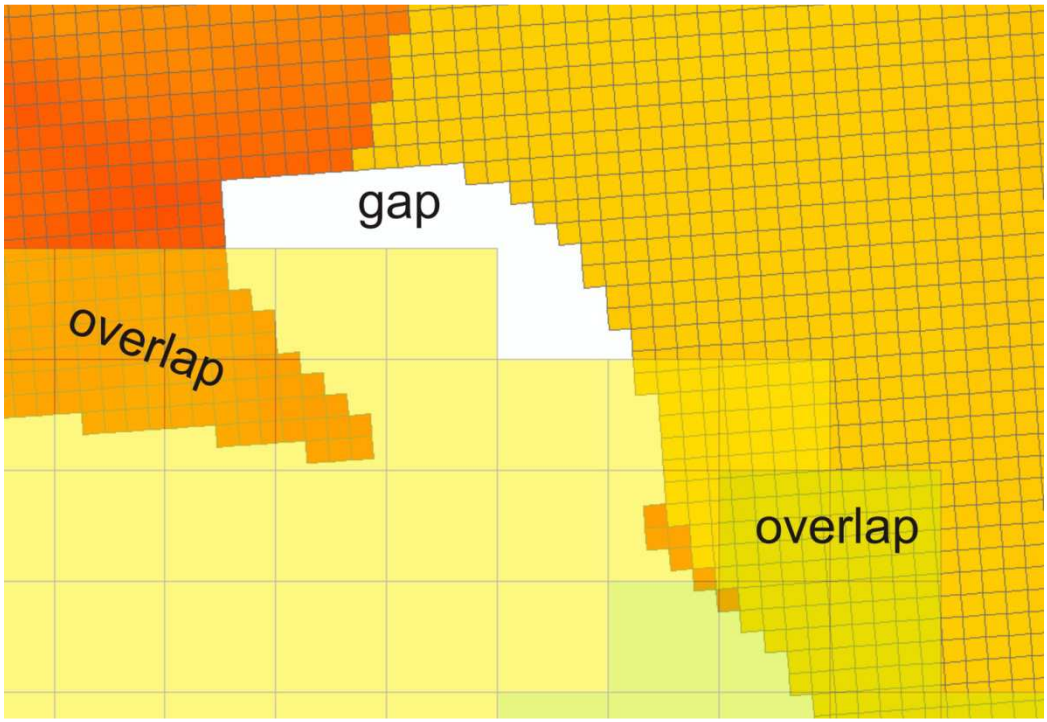

Fig. 4. Differences in GIS layers, that were developed by experts from the Polish Geological Institute-National Research Institute (PIG-PIB) and Lithuanian Geological Survey (LGT). Second aquifer

GIS layers, that touch on contact surface along border line, but there were distinguished differences in parameters of layers. The elevations of the top and the bottom of individual layers occur on different levels [m a.s.l]. Thickness of individual layer, aquifer hydraulic properties and parameters of aquitards differ in some parts of study area. The cross-border area is low populated, thus number of drilled wells, investigative boreholes and piezometers is low. The layers should be harmonized, using reliable data from profiles of existing hydrogeological objects. Sharing data from the territory of another country is an opportunity to fill or verify hydrogeological information in transboundary scale.

4 NEXT STEPS

The next step in the TRANSFLUX project is unify and further harmonize the hydrogeological dataset with data on thickness, depth of the top and the bottom of model layers of the multi-aquifer system and the hydraulic parameters of the layers distinguished.