# Application of Conceptual Hydrogeological Site Model Basing on GIS Database for the Area of Mine Waste Rock Pile

Karol Kura [a)], Marek Korcz [b)], Jacek Długosz [b)], Grzegorz Gzyl [a)], Magdalena Odrzywołek [b)]

*[a)]Central Mining Institute, Pl. Gwarkow 1, 40-166 Katowice, Poland, e-mail: karkura@gig.katowice.pl*
*[b)] Institute for Ecology of Industrial Areas, Kossutha 6, 40-844 Katowice, Poland*

## Abstract

The site is located in Upper Silesian Coal Basin, Southern Poland in Silesian Voivodeship, Gliwice County, municipality Sośnicowice, village Trachy. The main object of the site is composed from big heap in the valley of Bierawka River, one of the main tributaries of Upper Odra River. The site is located in about half of Bierawka River length. Two smaller landfills – municipal waste and post galvanic waste are located at the north-eastern and north-western edges of the heap. Whole area is drained by natural and artificial tributaries of Bierawka River.

Following existing information on site; site topography, land use, ownerhip, surface geology, soil texture, catchments and drainage scheme, climate (including annual rainfall), location of existing piezometers, deep geology (based on well and piezometer logs) location of existing surface water monitoring points, were collected. Then, this data were structured, controlled, processed and visualized to achieve a reliable data basis for planning and hydro-geological modeling.

The conceptual hydrogeological model of Trachy site was set up on the base of information gathered in GIS database. In this model, the basic groundwater aquifer is Quaternary, build of glacio-fluvial deposits, mainly sands and gravels. Thickness of this aquifer is very variable. The recharge of aquifer is mainly through infiltration of precipitated water. Drainage is mainly through Bierawka River and some extent via western side of the Quaternary valley. Development of described conceptual hydrogeological model is the prerequisite for the development of a numerical groundwater model.

**Key words:** GIS, conceptual model, rock pile

## Introduction

The development of the conceptual model is one of the most important steps within the investigation of potentially contaminated sites. The landfill sites, especially created under regime of old legislation are example of problematic areas that have to be investigated to verify the hypothesis about contamination and about the link between source and recognized chemical state of soil and water. The following paper presents this first step of work on example of a study site selected for an international project “MAGIC”- Management of Groundwater at Industrially Contaminated Areas under the INTERREG IIIB CADSES Neighbourhood Programme. The integral groundwater investigation, which is proposed by the MAGIC project seems to be a promising concept for solution of identification, assessment and management of contaminated groundwater bodies.

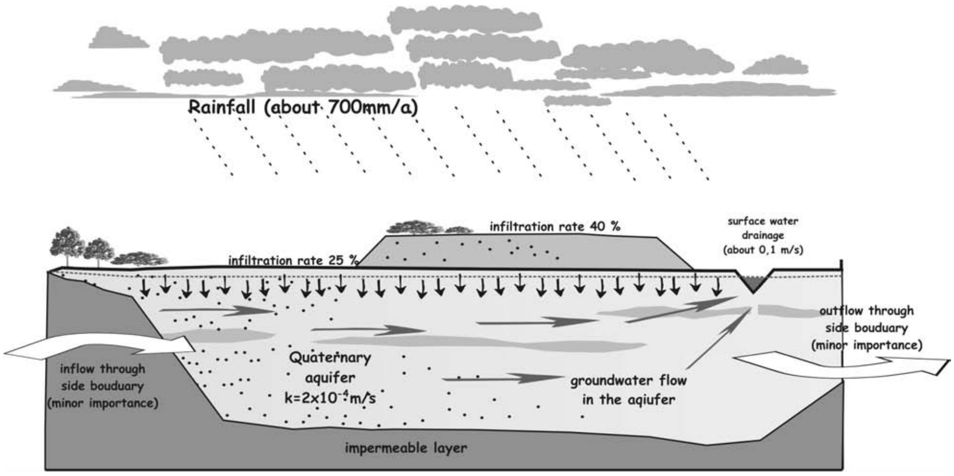
## Site description

The site is located in Upper Silesian Coal Basin, Southern Poland in Silesian Voivodeship, Gliwice County, municipality Sośnicowice, village Trachy (Figure 1). The main object of the site is composed from big heap in the valley of Bierawka River, one of the main tributaries of Upper Odra River. The site is located in about half of Bierawka River length. Two smaller landfills – municipal waste and post galvanic waste are located at the north-eastern and north-western edges of the heap. Whole area is drained by natural and artificial tributaries of Bierawka River. The valley of Bierawka is filled with Quaternary sediments with dominant of sands and gravel layers. This formation create an aquifer of Quaternary waters (Figure 2), generally unconfined, with local wells. Below these Quaternary formation impermeable Tertiary (Neogen) formation of clays of variable thickness are located. Below this layer Tertiary aquifer is located, which is an important source of potable water.

The surface is covered by forest owned mainly by the state, agriculture (individual farmers) as well as by built-up areas of Trachy village. In the vicinity is lack of other than mentioned serious groundwater contamination sources. The potable water for these villages is provided from the out-site sources.

***Figure 1*** *Trachy site localization*


***Figure 2*** *Conceptual model of Ttrachy site*




**Data collection and the compilation of a GIS database**

The data collection is the first basic step before further investigations start and new data is gained. Existing information on the project area are retrieved and collected from various sources. The plausibility check and the structured preparation helps to identify incorrect data, over aged data, data gaps and requirements for further investigation. Additional easy field measurements are necessary to verify and complete the knowledge base.The collected data contains manifold information which has to be structured and visualised to receive a picture of the contamination situation. A geographical information system (GIS) gives the opportunity to pool and illustrate a large number of spatial information. The GIS description of the site was carried out in few steps. These kind of steps is undertaken always independently from local situation. First step encompassed gathering of local and regional information that help to improve understanding of existing ecological dependences between structural elements of the site and its neighbours. In case of the "Trachy" site nearly all available information and data were in analogue form. So the next steps comprise digitalisation and vectorisation of these analogue materials. The digitised materials were verified and actualised during site visits (borehole locations – x,y and z coordinates). This step is very important because small differences in coordinates can give unexpected errors during archival data integration. The collection and evaluation of existing data is the first step to check the plausibility and the quality of data on the one side, on the other side to identify information gaps and requirements of further data collection. Within this step the data of two scales were gathered. The regional data that allow to assess the importance of the site for whole Bierawka catchment and more detail data that are limited to the direct neighbourhood of the site.In the example area at first basic spatial data had to be collected for the mining waste dump site and its surrounding area before hydro-geological information could be combined with the geographical information. The data was integrated within ad hoc designed GIS called "Trachy site" composed from two geodatabase "Chemia" and "Geodatabase". The first base contains results of water quality measurements and second contains all information layers necessary to develop a site conceptual model.

Following existing information on site; site topography, land use, ownership, surface geology, soil texture, catchments and drainage scheme, climate (including annual rainfall), location of existing piezometers, deep geology (based on well and piezometer logs) location of existing surface water monitoring points, were collected. Then this data were structured, controlled, processed and visualized to achieve a reliable data basis for planning and hydro-geological modeling. The development of GIS was carried out with application of ArcGIS® of ESRI Inc. The expected result of this step is a first conceptual model of the site. In some situation the necessary information to conduct this step is existing and gathered by proper authorities In some cases it is necessary to collect, assess and incorporate the information into databases.

**Conceptual model**

The first conceptual model comprise – sources (3 waste landfills) and two receptors (groundwater and Bierawka River). At present people are considered as hypothetical receptors only. The groundwater is not used and water in Bierawka River is polluted by sources located upstream that the use of water is forbidden. The following potential migration pathways were indicated:

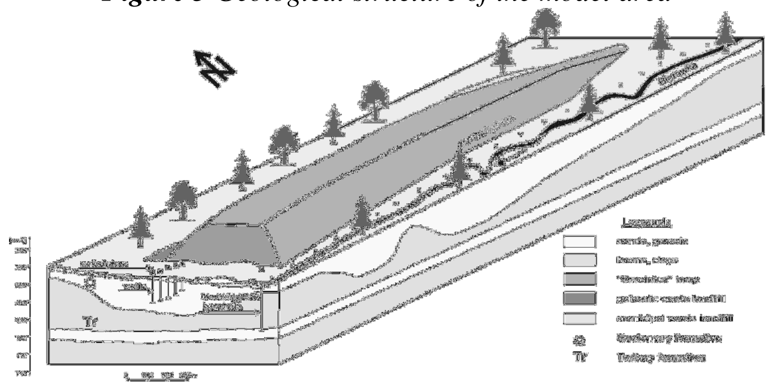
- migration of contaminants from landfills along with surface runoff (this pathway is partially controlled by dewatering ditches;
- migration of contaminants from landfills with infiltrating by waste water and further to the groundwater (this pathway is probably controlled at postgalvanic waste landfill and municipal waste landfill, it is not controlled at mining waste landfill);
- migration of contaminated groundwater into the Bierawka River (highly probable, the groundwater table is situated above the bottom of the mining waste landfill);
- the probability of migration of contaminated groundwater from the shallow horizon into the Tertiary horizons is low but should be verified by direct geological investigation;
- the migration of contaminants with dust emitted by Aeolian processes is negligible;
- the possibility of waste selfburning high in case of waste aeration.

The conceptual hydro-geological model of the Trachy site was set up on the base of information gathered in GIS database. In this model, the basic groundwater aquifer is Quaternary, build of glaci-fluvial and fluvial deposits, mainly sands and gravels. Thickness of this aquifer is very variable, from few meters up to 25 meters. Highest thickness is in the Bierawka river valley, where buried valley runs, cut within underlying Tertiary clays. Average conductivity of this aquifer is about $2 \times 10^{-4}$ m*s$^{-1}$. The recharge of this aquifer is mainly through infiltration of precipitated water. Some amounts of water may as well flow into investigated area along the buried valley of Bierawka River (from upstream – from the East). Drainage is mainly through Bierawka River and to some extent via western (downstream) side of the Quaternary valley. Existing data do not give a clear answer what is the relation of Quaternary aquifer with deeper Tertiary aquifer, but it is expected that the pressure in deeper aquifer is higher than in the shallow one. The second aquifer is formed by quite thin layers of well conductive sands intercalated with thick layers of impermeable clays. The shallowest sandy layer is expected at the depth of about 25 meters (185 m above sea level), so it is possible that the aquitard comprising clay layer is eroded in the very deepest parts of buried valley. Development of described conceptual hydrological model is the prerequisite for the development of a numerical groundwater model. Due to that fact it was recommended to install an investigation borehole 30 m deep in order to verify vertical geological profile of the site (Figure 3) and to compare groundwater pressure in the different aquifers. The investigation has shown that the pressure in the deeper aquifer is higher, so there are no possibilities for the water to flow downwards from the Quaternary aquifer.

**Conclusion**

GIS and the conceptual model enabled an overview of the site conditions. As information gaps were identified following field investigations could be defined in a most economic way. Both tools have to be updated by future results from drilling and pumping tests to guarantee a good working and evaluation basis for future projects. Due to this conclusion it was recommended to install an investigation borehole 30 m deep in order to verify vertical geological profile of the site and to compare groundwater pressure in the different aquifers. The investigation has shown that the pressure in the deeper aquifer is higher, so there are no possibilities for the water to flow downwards from the Quaternary aquifer.

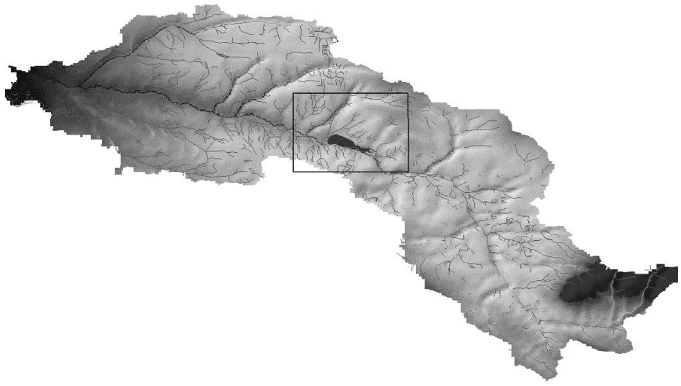
***Figure 3*** *Geological structure of the model area*



Although the working step of the data collection and GIS database creation seems to be time consuming it is the only way to get a reliable working basis to plan further field investigation in the most efficient way. In all four project areas the control planes could be defined on the reached knowledge bases.

The use of a GIS including a stable database enables a holistic view on the characteristics and the interactive system of given site. It facilities of combination of different information from data collection and identifies areas with a lack of data or insufficient data. The analysis of existing data and results of supplementary field investigation together with first GIS information enables an understanding of the hydro-geological conditions of this area.

***Figure 4*** *Digital Model of Bierawka River catchment*



During the investigation two from three sources were recognized as irrelevant (galvanic and municipal waste landfills), therefore most of the activities focused on the "Smolnica" heap (the waste from hard coal mining).

The "Smolnica" heap has negative influence on ground and surface water quality by transporting significant pollutants loads. The contamination forms one plume of pollution. The plume is very wide (around 3 km), but relatively short (several dozen meters), because it sinks in nearby the Bierawka River.

Further activities of the project allowed for precise deliniation of migration paths using numerical modeling. The initial parameter values for the models were assumed based on the data compiled in GIS database presented in this paper.

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