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# CASE OF THE ENVIRONMENT RECLAMATION IN THE REGION OF KALINA POND IN ŚWIĘTOCHŁOWICE

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**Abstract**. The pond Kalina is a natural water reservoir situated in an interior basin in the southeastern part of the city Świętochłowice. The water in Kalina pond is heavily polluted. According to the conducted research the main source of the pond's pollution has been the industrial waste tip. Water in the pond is highly alkaline and deprived of oxygen. At the bottom of the reservoir lies a 20–40 cm thick layer of a dense medium. This medium is also highly alkaline (pH = 8.5–10.2) and contains volatile phenols in concentration of a couple of hundreds to a couple of thousands mg/dm$^3$ as well as proves the COD values over 10,000 mg $O_2$/dm$^3$. Several concepts for the disposal possibilities of this sediment have already been discussed.The very complicated geological and hydrogeological structure in the concerned area needed some modelling to be performed, before any of the considered remediation options could be accepted and applied. Digital simulations were indispensable to describe the predominant water flow directions, which as a result allowed predicting the migration of pollutants assuming an increased water intake from the Kalina reservoir. A spatial model of the geological structure as well as the hydrogeological modelling were based upon the results of measurements in 139 boreholes. The digital geological model (Earth Vision software) of the area of the chemical plant as well as the waste tip and the pond let us analyze the geological conditions and identify the regions endangered by the penetration of contaminations from the waste tip. Modelling with the Modflow software has allowed describing the hydrogeological conditions in the Quaternary formations and hydraulic relations between water-bearing layers. In addition the streamline flow modelling and digital simulations for the dispersion of pollutants in case of the increased water consumption from the pond or refilling of its basin have been conducted.

**Key words**: reclamation, geological modelling, groundwater modelling, contamination, phenols, waste dump.

**Abstrakt**. Staw Kalina jest naturalnym zbiornikiem wodnym położonym w bezodpływowej niecce w rejonie Świętochłowic. Woda w stawie jest silnie zanieczyszczana. Badania wykazały, że głównym źródłem zanieczyszczeń była hałda odpadów poprodukcyjnych. Woda w stawie jest pozbawiona tlenu i ma silnie alkaliczny odczyn. Na dnie stawu zalega warstwa gęstego osadu o miąższości od 20 do 40 cm. Osad ten ma odczyn alkaliczny (pH = 8,5–10,2), zawiera fenole lotne w stężeniu od kilkuset do kilku tysięcy mg/dm$^3$ i ChZT powyżej 10 000 mg $O_2$/dm$^3$. Rozważano kilka koncepcji unieszkodliwienia tego osadu. Skomplikowane warunki geologiczne i hydrogeologiczne tego rejonu wymagały wykonania badań modelowych przed przyjęciem którejkolwiek ze zgłoszonych koncepcji. Konieczne było zastosowanie symulacji komputerowych określających dominujące kierunki przepływu wody, co pozwoliło w efekcie na określenie zachowania się ładunku zanieczyszczeń przy zwiększonym poborze wody ze stawu. Przestrzenny model budowy geologicznej oraz modelowanie hydrogeologiczne wykonano na podstawie 139 otworów wiertniczych. Geologiczny model cyfrowy (program Earth Vision) pozwolił na analizę warunków geologicznych oraz wydzielenie rejonów zagrożonych przenikaniem zanieczyszczeń z hałdy. Modelowanie programem Modflow pozwoliło określić warunki hydrogeologiczne w utworach czwartorzędowych oraz związki hydrauliczne pomiędzy poszczególnymi warstwami wodonośnymi.

**Słowa kluczowe**: rekultywacja, modelowanie geologiczne, modelowanie hydrogeologiczne, zanieczyszczenie, fenole, składowanie odpadów.

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## INTRODUCTION

Kalina pond is natural water basin, which was heavily contaminated by industrial factors. The researches and measurements proved that the main source of pond contamination was (and partially still is) the industrial waste dump of HAJDUKI S.A. chemical plant.

The plant was built in 1888 as high-temperature tar distillery (Cenowski *et al*., 1992; Kamiński *et al*., 1998). At first following chemicals were produced: benzol, crystalline naphthalene, anthracene, wash oil, impregnating oil, tar and pitch. The department of tar preparation and also first in Poland phenol station were started in fifties. The plant then treated the carbolic oil and phenolans (from wastewater phenol removal) becoming from all cookeries in Poland.

Till 1990 technological wastes and furnace cinder were put on the dump located in southeastern part of Świętochłowice, on Chorzów district border. The dump adjusts to Kalina pond (Fig. 1). It is estimated that annual stream of wastes deposited on the dump was 25,000 ton and included approximately 13,000 ton of calcareous sludge arising from soda causticization and resin production, approximately 6,000 ton of post-refining acids arising from benzol and naphthalene refining, and approximately 5,000 ton of wastes arising from machinery, and also tar tanks and containers cleaning (Oczko, 1991).

Technological wastes of semi-liquid consistence were transported via pipeline to the mud boxes on the waste dump. The boxes' banks were successively raised with cinder from the chemical plant. After a time the dump has been formed. It covered 5.1 ha and was 23–25 m high. The wastes' effluents and precipitation both contaminated by carbon compounds (esp. phenols) and infiltrating from the dump became the cause of strong contamination of Kalina pond.

In 1990 the operation of the waste dump was stopped and prevention actions were undertaken as following (Jackowicz-Korczyński *et al*., 1994; Szalapski, 1994):

- installing the watertight screen around the dump,
- installing horizontal drainage system, which collects the precipitation and groundwater; system included drainage ditch around the dump,
- pumping the drained water to the waste water treatment facility.
- so-called "mały staw" (small pond) was filled with neutral material and than covered with humus with plants' seeds and cuttings,
- the dump was re-shaped and covered with humus and plants.

The dump reclamation activities finished in 1995.

Kalina pond lies in the insulated trough in southeastern part of Świętochłowice City (Kamiński *et al*., 1998). The basin is natural drainage area and its surface equals 138.1 ha whilst the pond surface equals 53,000 sqm. The pond has diversified depth, from 3.4 m at eastern part to 1.5 m at western part. The pond is a drainage factor for groundwater and precipitation.

There is no oxygen in the pond's water and it has strong alkalic reaction. Most of contaminations occurring in the pond are toxic.

There is the layer of dense medium on the bottom. Its thickness equals 20–40 cm. Assuming the average sludge layer

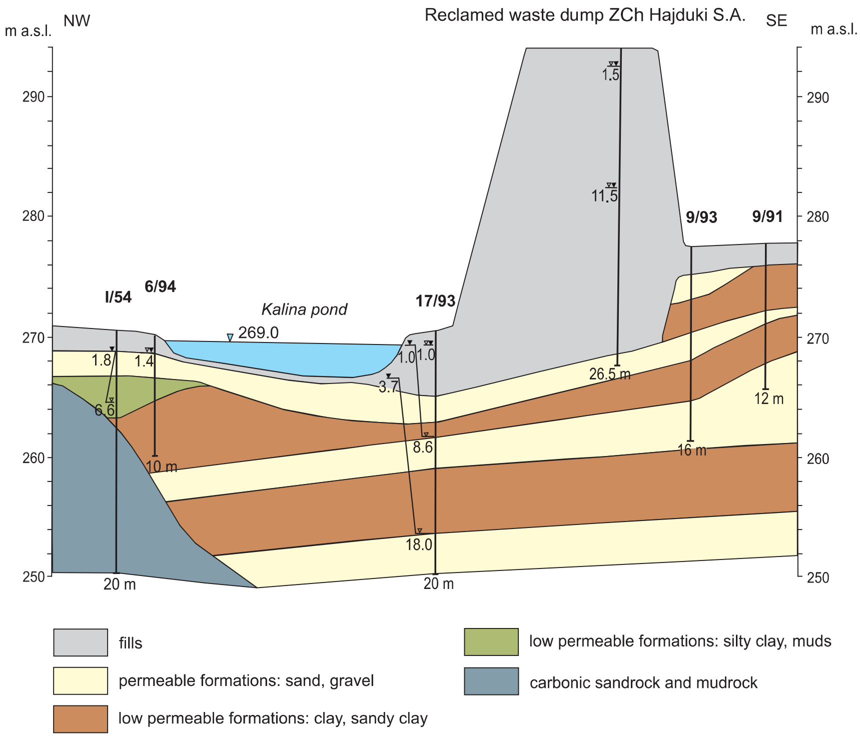


**Fig. 1. General cross-section of the Kalina pond and waste dump**

thickness as 30 cm and the pond surface as 50,000 sqm, it is estimated that there is approximately 15,000 cbm of the sludge/sediment on the pond bottom.

This medium has alkaline reaction (pH = 8.5–10.2). It contains volatile phenols of concentration level from few to few thousands of mg/dm$^3$ and also ChZT (COD — chemical oxygen demand) on the level above 10,000 mg $O_2$/dm$^3$. Dry residue equals 150–200 mg/dm$^3$ and volatile compounds levels are not higher than 30%.

Designing complex final solutions, which would prevent the impact of Kalina pond to the environment, turned out to be necessary despite of the actions that had been undertaken (screen around the waste dump, ordering the wastewater sewage system of the pond basin, cleaning of pond's water). Few options of pond noxiousness reduction were proposed in the documentation till now (Kamiński *et al.*, 1998):

**Option 1**

— pumping out all the water off the pond and removal the bottom sludge;
— putting the sludge (dangerous waste) into the specially constructed tomb-chamber on the waste dump or next to it;
— installing the drainage well system in the area and filling the pond trough with permeable material;
— constructing the impounding reservoir where through the pressure pipelines contaminated water would be pumped to;
— successive discharging water to Klimzowiec sewage treatment plant;
— filled and cleaned area would be covered with humus layer and planted with reed and willow.

**Option 2**

— pumping maximum possible volume of water out of Kalina pond, till the sludge layer on the bottom is reached, and cleaning it in Klizowiec sewage treatment plant;
— constructing kind of bank across the pond from north to south;
— excavating the sludge layer from the western part of the pond and moving it to the eastern one;
— rising the embankments around the pond;
— filling up the eastern part of the pond with permeable material, which would be natural drainage of this part of pond; this material, with relevant development, would enable water transporting through the cross-bank to western sector of the pond;
— leaving the western sector of the pond as impounding reservoir for whole basin/trough with no outlet; the pond will work with Komandra pumping station and Klimzowiec treatment plant via existing hydro-technical development;
— growing plants and trees on eastern sector of the pond.

**Option 3**

— covering the pond bottom with permeable material (filtration factor k = 10exp-4) layer of approximate thickness equal 0.5 m; the small lots of material should be lain successively on to the bottom in order to obtain the best possible mixing with the bottom sludge and not to cause pushing the sludge up the applied material;
— laying the drainage system, which enables controlled pumping the heavy contaminated (phenols) bottom water of Kalina pond to the treatment plant;
— monitoring and maintaining the level of water table in the pond;
— aeration the groundwater using the existing monitoring wells located along the west side of the dump screen (outside of it).

Due to complex geological and hydrogeological conditions of the area modeling researches were necessary prior to selecting any of proposed options. They were to describe hydrogeological conditions in Quaternary formations and hydraulic relations between particular water-bearing horizons and also between Carbon and Quaternary. Digital simulation of groundwater flow directions was necessary so it finally allowed for determination of contamination charge distribution in conditions of increased water consumption from Kalina pond.

## SIMULATION WORKS

### STAGE I — DETERMINATION OF GEOLOGICAL STRUCTURE

Geological model was done using Earth Vision 4 (Dynamic Graphics, INC.-Almeda, California 1997) software, which is the most advanced instrument for visualization and analyzing three dimensional geological structures. The experience from similar activity allows to say that this is the best way of presenting geological data, verifying the geological information from different sources, and analyzing the medium's features (like filtration ability, etc.). The layers were correlated on the basis of following features in general: soil lithology and its filtration factor, archival geological, hydrogeological and geological-engineering cross-sections. The stratygraphy of particular soil types was neglected almost at all (Wilimborek, Tarlaga, 1994; Chmura, Wagner, 1997) (Fig. 2).

Due to designing the model as preprocessor for hydrogeological simulation, numerous simplification of both structure of particular layers and also their number were made (Fig. 3, 4). The number of layers were reduced from nine to four and divided to complexes of permeable and non-permeable formations. Thus the layers directly imported to Modflow software generated:

I layer — non-permeable base — included carbon formations, till, silty clay and silt occurring in Quaternary bottom;

II layer — 2nd water-bearing horizon — included sandy formations containing second water-bearing horizon. Due to the very small number of boreholes penetrating the second water-bearing layer its thickness is difficult to estimate so was represented very approximately in the model;

III layer — non-permeable formations — consisted of clayey-sandy complexes, which divide both occurring water-bearing horizons;

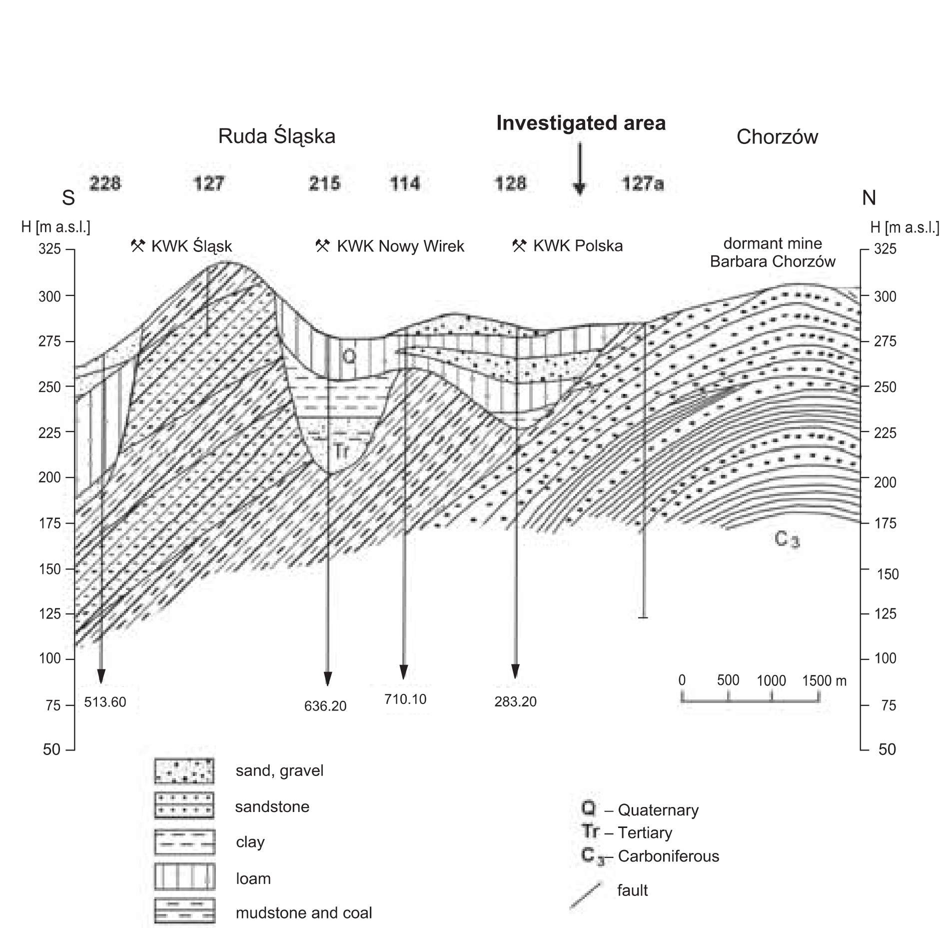


**Fig. 2. Regional hydrogeological cross-section (Chmura, Wagner, 1997)**

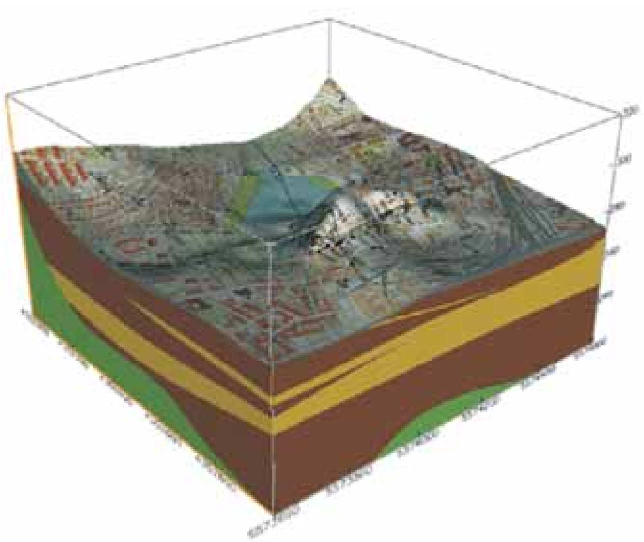

**Fig. 3. General view of geological structure model with the terrain map overlain**

IV layer — 1st water-bearing horizon — consists of sandy Quaternary formations and also anthropogenic fills that 1st water-bearing horizon occurs in.

## STAGE II — ANALYSIS OF HYDROGEOLOGICAL CONDITIONS

Three-dimensional three layer filtration model was generated in Modflow software on the basis of data concerning water-bearing layers geometry (Tkaczyk *et al.*, 2001):

— 1st Quaternary water-bearing horizon,

— non-permeable formations — the layer splitting the 1st and 2nd Quaternary water-bearing horizon,

— second Quaternary water-bearing horizon.

Modflow simulation allowed for description of hydrogeological conditions in Quaternary formations, and hydraulic relations between particular water-bearing horizons and Kalina pond. During calibration process, performed using method of successive approximations, final result was obtained as interpreted hydraulic pressure distribution in Quaternary water-bearing horizons (Fig. 5). It was concerned being consistent to the reality enough.

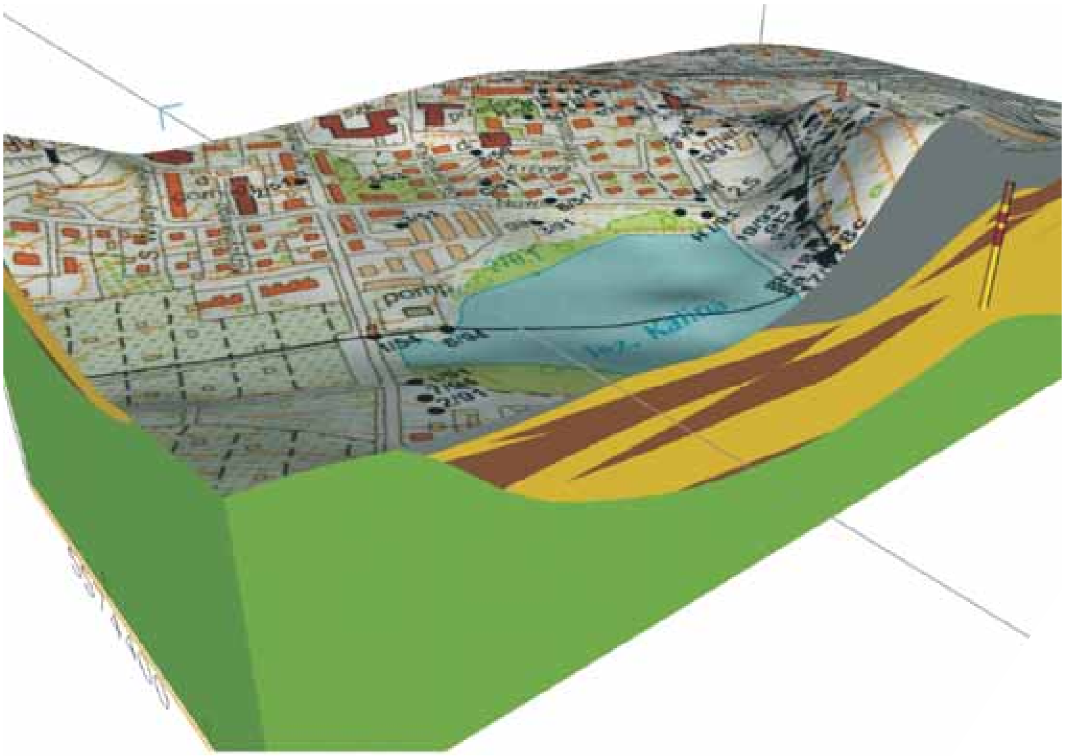

Fig. 4. Model geological cross-section (WE direction)

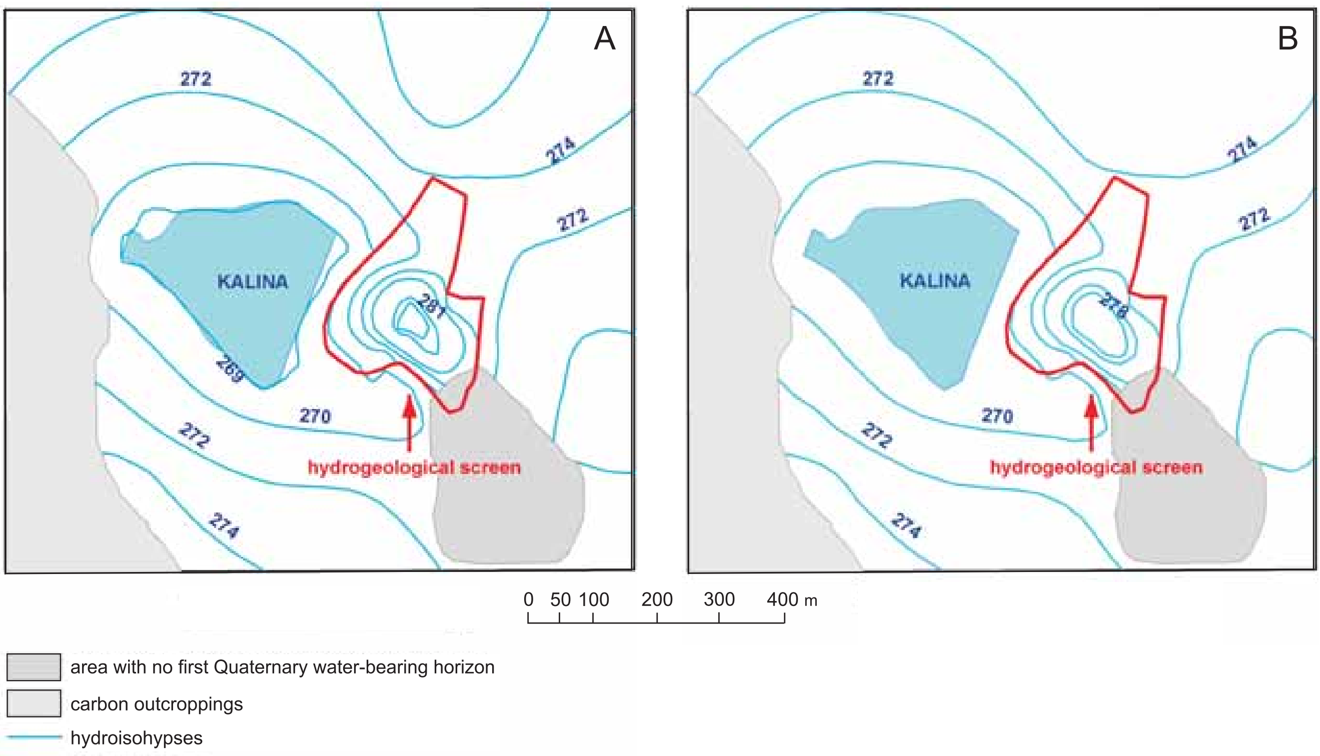


Fig. 5. A — Interpreted surface of water table of the first water-bearing layer;
B — Surface of the first water-bearing horizon water table – simulation results

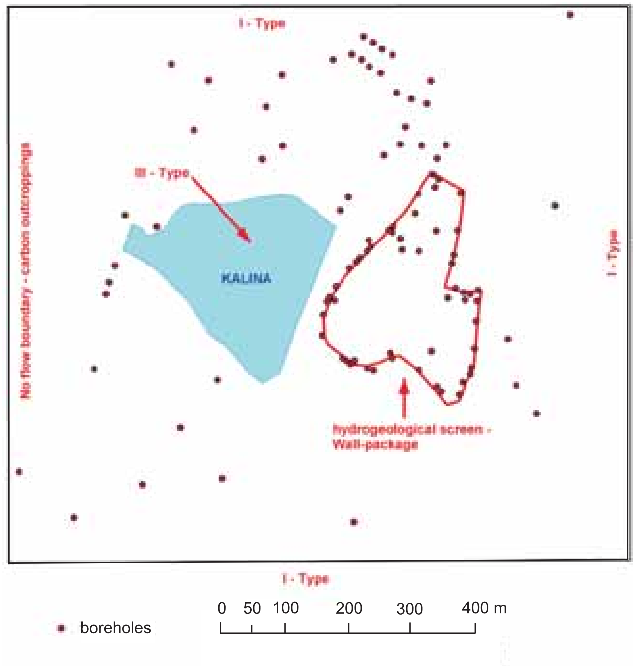


**Fig. 6. Boundary conditions for groundwater flow simulations**

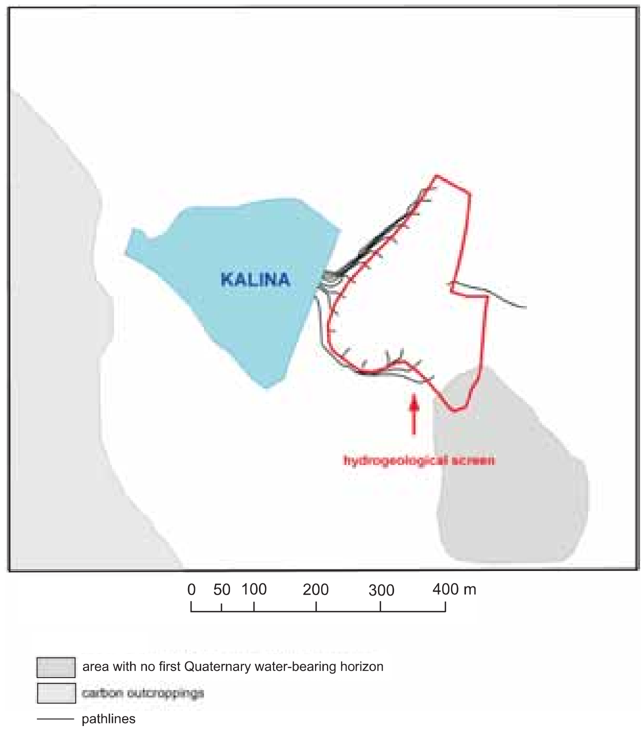


**Fig. 7. Water pathlines — the distance between the arrows represents 1 year**

Simulation performed included, beside the geological structure, also the insulation screen around the dump as boundary condition (Fig. 6).

Hydrogeological simulation done allowed for following conclusions:

— the pond is the drainage base of first Quaternary water-bearing horizon,

— second Quaternary water-bearing level stabilizes below Kalina pond bottom,

— the contaminations discharge from the dump basically takes place through the first water-bearing horizon, heading Kalina pond in general.

Based on the above conclusions and available data additional simulations focused on the first water-bearing horizon.

In order to determining the dominating groundwater flow directions in 1st water-bearing horizon numerous additional simulations were conducted using Modpath.

It allowed for depicting the distribution of pathlines corresponding to dominating migration directions of contaminations in the dump area. The simulations also allowed for estimating the time, after which the contaminants from the dump area reach the pond (Fig. 7).

The contaminations from the dump move along the screen and turn towards Kalina pond, where they get after twenty years. The possibility of partial contaminants migration eastward attract an attention too.

## SIMULATIONS OF CHOSEN RECLAMATION OPTIONS

In order to assess Kalina pond reclamation options numerous simulations of proposed actions were performed. Due to lack of data it was impossible to simulate the process of lowering the water table in the pond thus the water table level changes as result of water extraction. Such simulation requires the model of groundwater flow in separated area in non-stationary conditions. This would require data supplement with additional parameter — reserve coefficient “S”, which describes ability of the layer to water storage. Determination of spatial distribution of this parameter in all model layers would be necessary in such case.

Numerous simulation were done checking the influence of proposed pond reclamation options to modeled water-bearing layers.

One of them related to the situation of drying Kalina pond and tightening its bottom. It was calculated on the basis of calibrated model by modification the boundary condition GBH (general head boundary) so it would correspond zero inflow to the pond. Permeability of pond bottom was assumed as 0 sqm per 24 h. The results of simulation are depicted in Figure 8.

**Fig. 8. I option of the reclamation — filling up pond and sealing its bottom (simulation results)**

## CONCLUSIONS

The analysis of the results obtained leads to the conclusion that options I and II are not possible to apply. Drying Kalina pond proposed in both options results in lowering the groundwater table approximately 4 m below the present level. It is consistent to drying the significant part of the area adjacent to the pond. Some plants would probably die out then.

In I option, the construction of tomb-chamber on the separated pond sector seems to be impossible. Such option does not solve the problem but only postpones it further in time.

Filling the part of the pond proposed in II option would result in increasing the groundwater table and flooding the areas adjacent to the pond (especially in its northern vicinity). So, implementation of III option of Kalina pond reclamation with some modifications would be the most beneficial solution.

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