# Geological models of landfills in Slovakia

R. Putiška, A. Mojzeš
Department of Applied and Environmental Geophysics, Faculty of Natural Sciences, Comenius University[1]

M. Bednarik, M. Matys
Department of Engineering Geology, Faculty of Natural Sciences, Comenius University[1]

V. Vybíral
Sensor, Ltd.[2]

Abstract: Landfill is usually defined as an anthropogenic object situated in geological environment. Generally, landfills are highly polluted and from that point of view landfills represent potential sources of contamination for the surrounding environment. There is the possibility to differentiate the sources of contamination into two basic groups primary local sources (landfills, mine sites, dumps, hydraulic dumps, industrial and agricultural sites) and secondary sources (contaminated soils and groundwater). A practicle example of interaction is shown in Fig. 1, where the landfill represents the source of contamination and zone of interaction is an area, which is directly endangered by contamination.

**Key words:** landfill, contamination, geophysics, engineering geology, hydrogeology

## 1. Introduction

Investigation and evaluation of a geological environment and contaminants interference is a complicated problem which is necessary to solve as a large scale process with the demand from a dynamically changing case observation. The solution for such a complicated task requires large amounts

[1] Mlynská dolina, pav. G, 842 48 Bratislava, Slovak Republic
e-mail: putiska@fns.uniba.sk
[2] Nobelova 34, 831 02 Bratislava, Slovak Republic

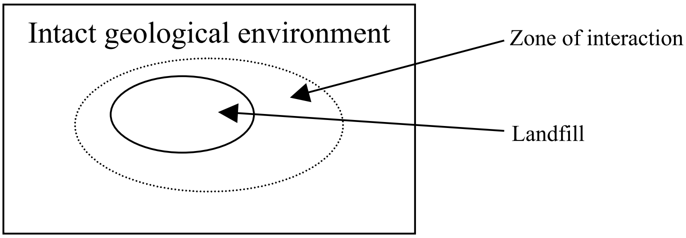


Fig. 1. Zone of interaction scheme.

of data and detailed information about the surface and groundwater regime. The water and soils physical and chemical characteristics, engineering geological conditions, environment and geological conditions. Gas production and other factors such as temperature and conductivity. All of which drastically change in time and dimensional space. Primary evaluations have shown that landfills and environment interference is not uniform. The pollution level depend on the groundwater regime, the characteristics of landfill material, the maturity of stored material and engineering geological and hydrogeological conditions.

## 2. Geological models of landfills

Based on landfill investigation during a four year period. 15 landfills were analyzed in detail. The landfills are situated in a various of geological regions. After processing the information of extensive database, the results show possibility to generalize landfill types in Slovakia into four main model types.

### a) Model with null thickness of superincumbent bed (Fig. 2)

Landfill material is deposited directly on the impermeable environment, mainly build by clays, clay loams or by intact strength rocks (granite, phaneric shale). Material is usually deposited into deep walleyes or through the slope edge. Groundwater is not impacted by landfill liquid infiltration. The risk level for the surrounding area depends on the character of outflow

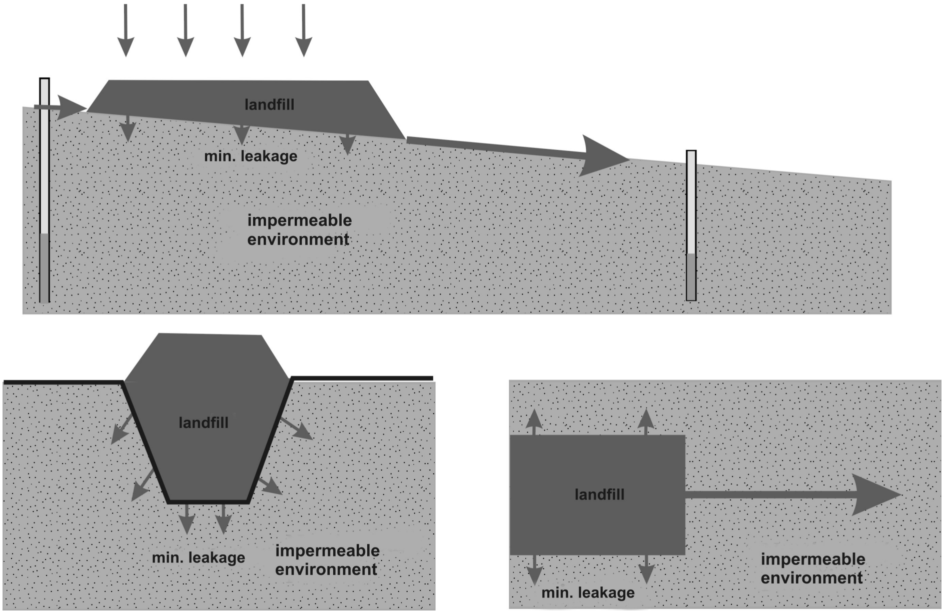


Fig. 2. Model with null thickness of superincumbent bed.

and from hydrological character of the recipient. The character of the recipient is the main factor, which affects the correct choice of reconstruction method.

From hydrogeological point of view it is typical for this model, that water (e.g. rainwater, surface water) are infiltrating through the landfill material and escaping on the form of springs at the head of the landfill. After that, they are spreading in the form of brooks. Surface and groundwater is endangered by contamination from contaminated water from the landfill site. In many cases the area of contamination is only two hundred meters from the zone of interaction (Fig. 3). Assessment of this model shows delimitation of the actual dimensions of the landfill and geological conditions. With the assistance of geophysical methods (electromagnetic profiles, multielectrode probing, magnetometry) we can locate the original boundary of the landfill and surrounding area. We are able to assess lithology and the level of permeability (Fig. 4). From an engineering geological point of view the main problem is related to the stability of the slope of the deep walleyes as well as the stability of the landfill material in the head part of the landfill.

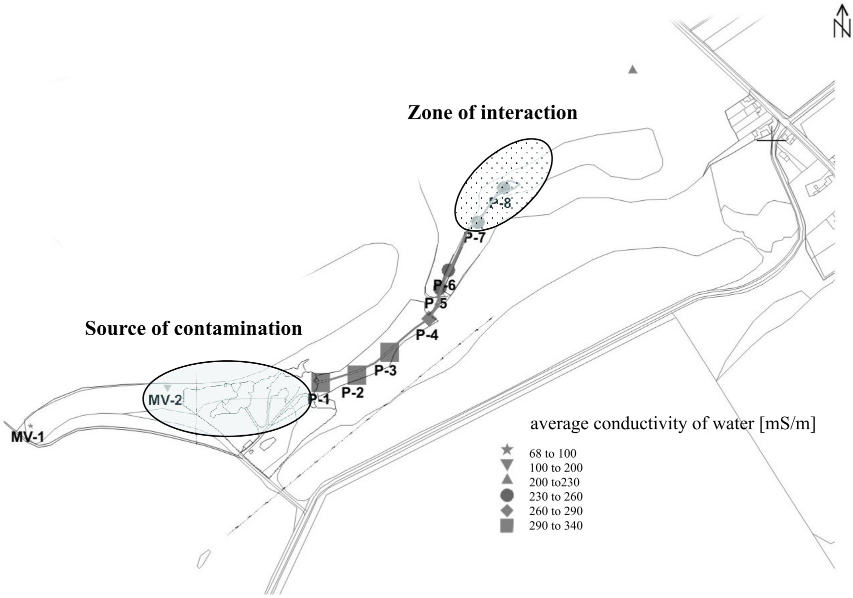


Fig. 3. Modified model of electrical conductivity in the direction of the movement of contamination – defining of the interaction zone.

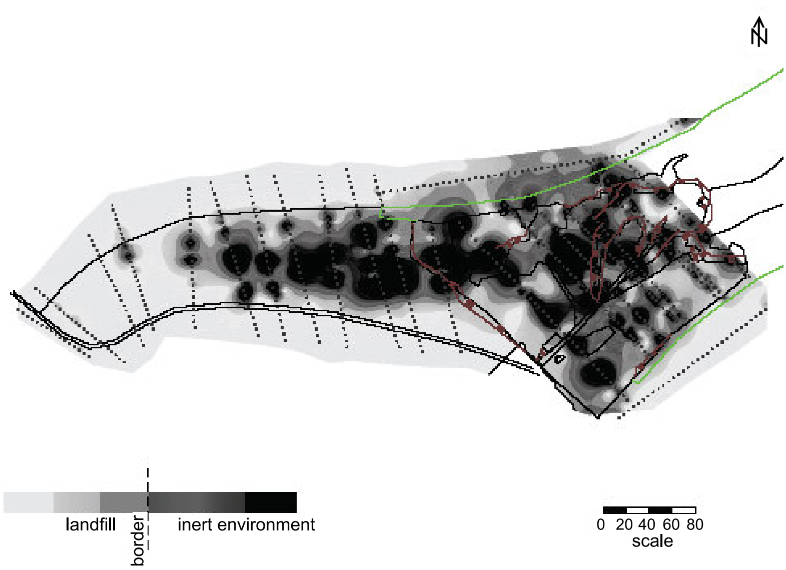


Fig. 4. Delimitation of real dimension of landfill done by magnetometry.

### b) Model with the impermeable subsoil in 10–14 m depth (Fig. 5)

The landfill material was deposited into natural or artificial depressions or onto a permeable surface material. The dielectric subsoil occurs at depth 6-10 m (it is usually quaternary gravel and tertiary clay dividing line).
The landfill material might be leached out by:

- infiltration of the atmospheric water which precipitates onto the landfill,
- water flowing into the landfill during heavy rainfall,
- groundwater flowing into the landfill,
- surface water infiltration (in the case when surface water subsidies into the zone range).

From an hydrogeological point of view with this kind of landfill it is typical that the external water with often undefining chemical composition leaks into the landfill and is polluted by soluble and insoluble elements. Contaminated water after passing through the aeration zone (if presented) reaches the groundwater table and contaminates the aquifer (Fig. 6). Precondition for the extent of contamination is presence of groundwater in the permeable subsoil and the presence of the impermeable subsoil. The extent of the

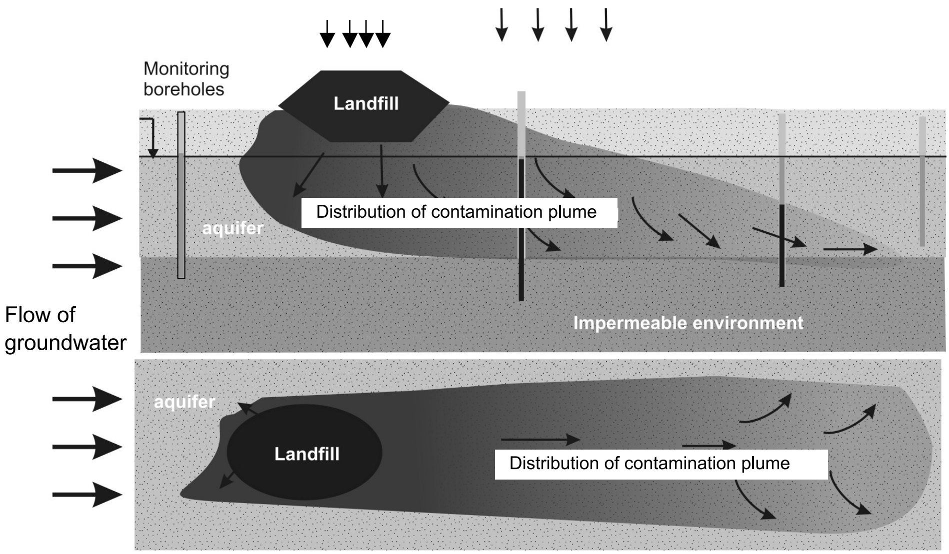


Fig. 5. Model with the impermeable subsoil in the depth 10–14 m.

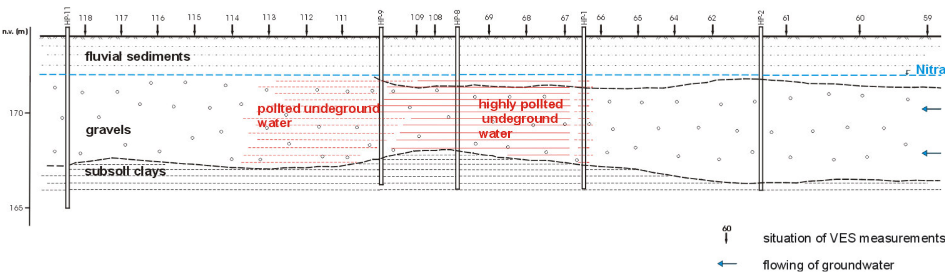


Fig. 6. Interpreted geological crossection at the head of the landfill.

contamination direction and density is effected by the groundwater regime usually directly related to the surface current. According to actual conditions the contaminant might hit the entire aquifer or its upper or bottom part. The impermeable subsoil in the relatively low depth retains a large contamination spread and helps to form a contamination plume. The plume under capable geochemical conditions is observable and its parameters can be mapped by geophysical methods (Fig. 7). Electrical resistance meth-

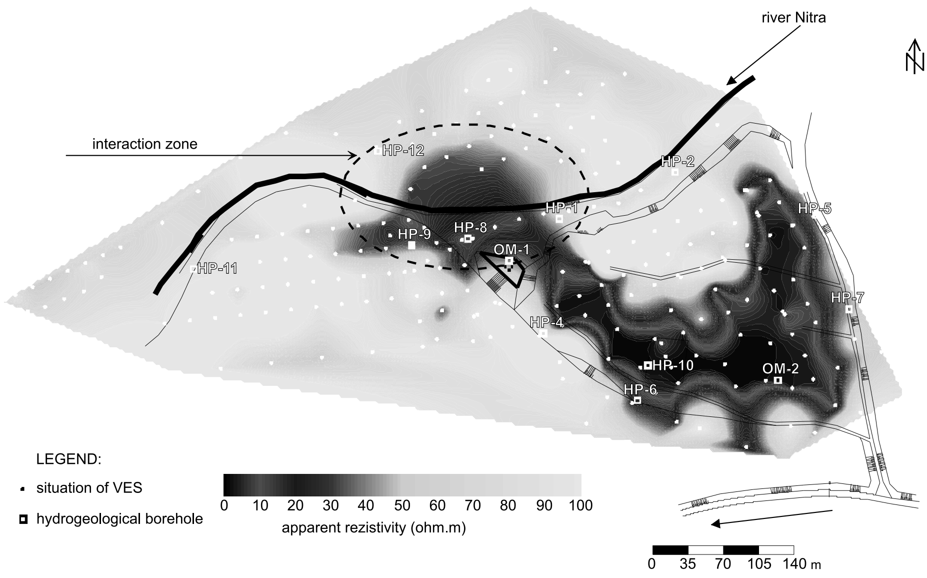


Fig. 7. Delimination of interaction zone from surface geoelectrical measurements.

ods based on correlation relations between a preservative mass (chlorides, sulphates) and groundwater physical characteristics (e.g. conductivity) are usually used for this purpose.

From an engineering geological point of view it is important to assess a landfill tops sagging dependences on time. Fig. 8 shows 0.5–2.5 m landfill top sagging which represents 10–30% deformation in comparison with the original. The sagging process is affected by many factors full details described in other literature. In this article an example of the landfill gas production and concentration is listed as the one of important factors affecting the landfill sagging (Fig. 9).

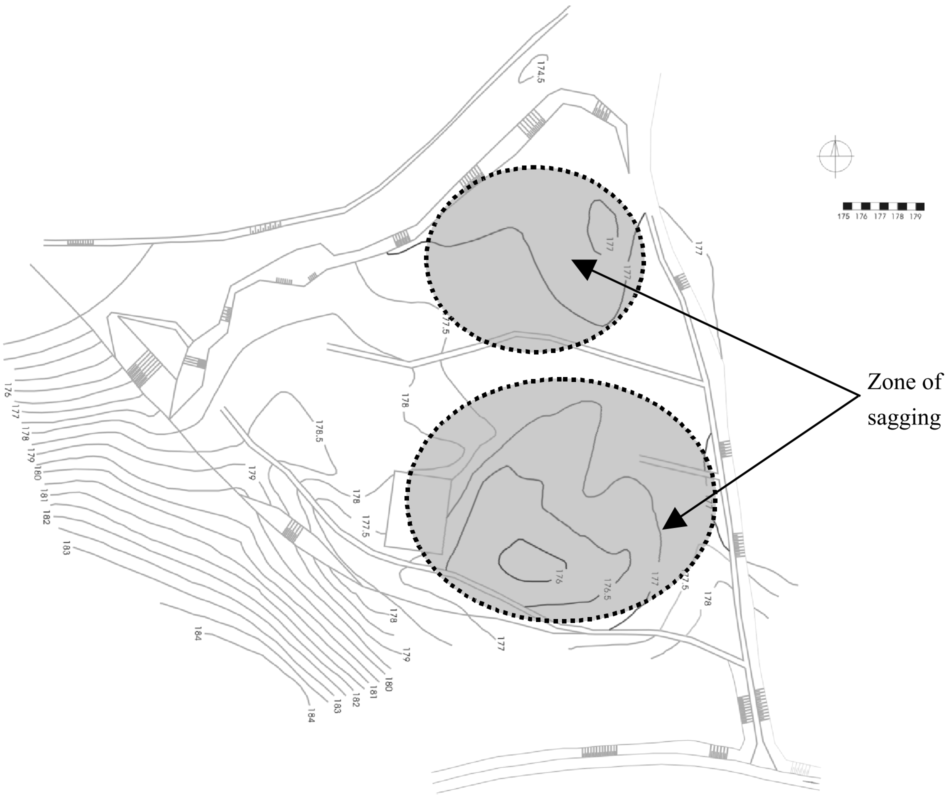


Fig. 8. Zones of sagging.

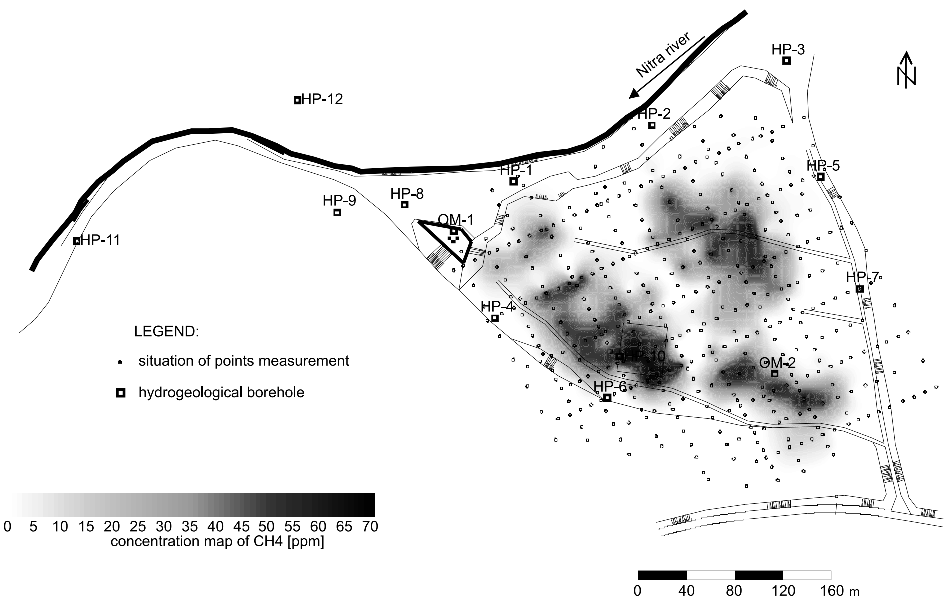


Fig. 9. Concentration of gas in landfill.

## c) Model with impermeable subsoil in "endless" depth (Fig. 10)

Landfill is deposited directly on the permeable environment, vertical movement of groundwater is unlimited. Landfill material is deposited into natural or artificial depressions, as well as, onto the natural surface. In many cases landfills are situated in old gravel pits, sand pits or in the branches of river beds.

Contamination is carried out from the landfill by infiltrating rainwater or by the water table changing. Contaminated water might be spreading from the landfill through the permeable environment over big distances and also to deep depths and in this way is contaminating the surrounding groundwater. Landfill investigation is focused on spatial circumscribing of the landfill material (thickness, distribution and character) and on the determination of the interaction landfill zone (extension of contamination cloud).

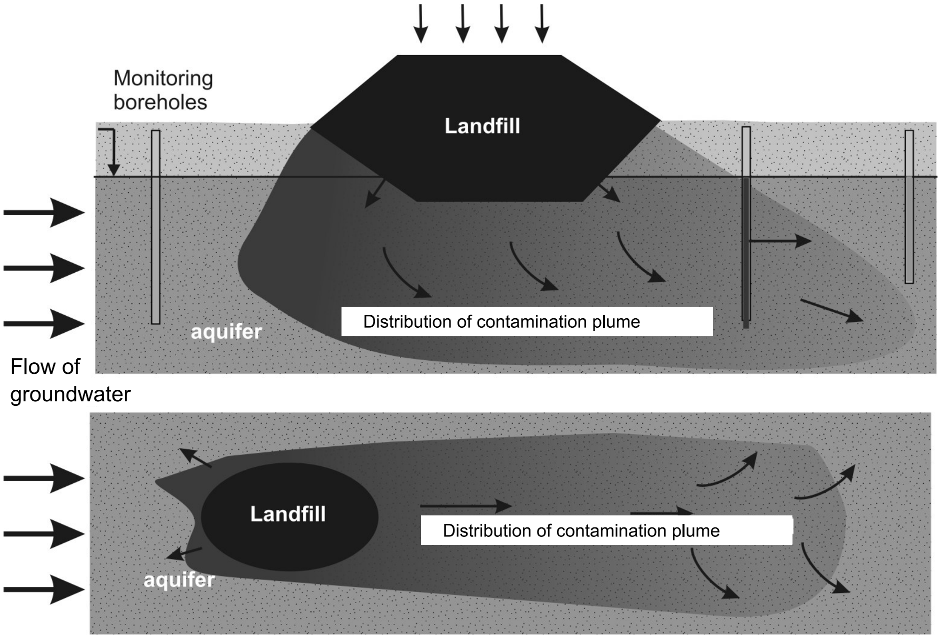


Fig. 10. Model with permeable subsoil.

### d) Model of landfill encapsulated by slurry trench walls (Fig. 11)

The geological environment contamination is the result of multiple phases of activity on its origin. Fig. 11 is showing that the contamination might come from the period before the construction of the slurry walls, the period during the construction and can be spread to the environment through defects in the slurry walls. Fig. 12 shows contours of water table and anomalies from electrical profiles measurements.

## 3. Conclusions

Evaluation of a geological environment and contaminants interference is a complicated problem. The solution for such a complicated task requires

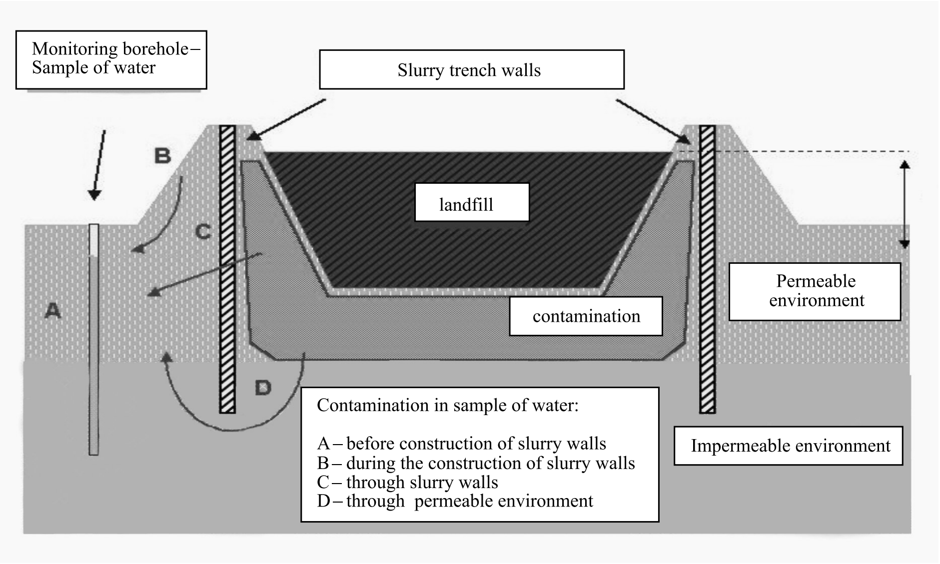


Fig. 11. Model of landfill encapsulated by slurry trench walls.

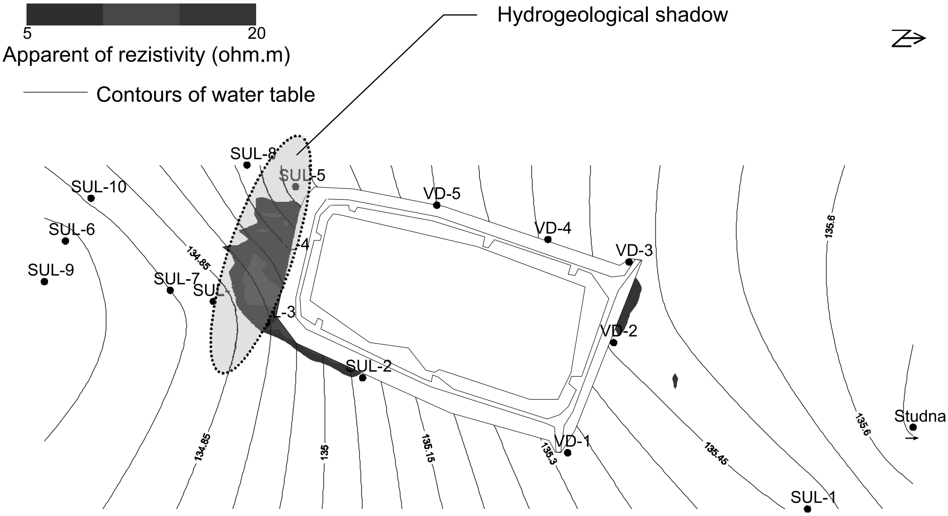


Fig. 12. Contours of water table and anomalies from electrical profiles measurements.

large amounts of data and detailed information about the surface, groundwater regime, water and soils physical and chemical characteristics, engineering geological conditions, environment and geological conditions. All of the characteristics are radically changing in time and dimensional space due to the contamination.

15 landfills were analyzed in detail during the four years investigation. The landfills are situated in a various of geological regions. After processing the information of extensive database, the results show possibility to generalize landfill types in Slovakia into four main model types:

a) model with null thickness of superincumbent bed,
b) model with the impermeable subsoil in 10–14 m depth,
c) model with impermeable subsoil in "endless" depth,
d) model of landfill encapsulated by slurry trench walls.

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