TGA	Reihe C	Nr. 36	2 Pages, 1 Figure, 0 Tables	Tübingen, Sept. 1998

Groundwater transport modelling for some petroleum hydrocarbon contaminated sites in Latvia

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Abstract Modelling of migration processes in groundwater for immiscible light hydrocarbons (called "oil" in this paper) requires a special software. The very common ARMOS program was applied for the investigation of two oil contaminated sites in Latvia. The case analysis revealed some advantages and also some limitations of ARMOS.

INTRODUCTION

The ARMOS code simulates an oil plume movement in an unconfined aquifer as a free oil apparent thickness H_o distribution (ARMOS, 1988-1996). To run ARMOS, the following digital maps of area-variable distributions must be prepared: initial H_o , elevations φ of the groundwater table, bottom elevations h_b of the aquifer for obtaining its saturated thickness $m = \varphi - h_b$. In ARMOS, the permeability k of the unsaturated zone and its vertically integrated capillary model (capillary fluid saturation relations for air, water and oil for a given soil) are area-invariable.

ARMOS has been used by the Environment Modelling Centre (EMC) team for the investigation of two oil contaminated sites in Latvia (Spalvins *et al.*, 1997). In both cases, ARMOS provided good results, if reinforced with supplemental software tools.

DISCOVERED FEATURES OF ARMOS AND ADDITIONAL SOFTWARE

The former Rumbula airbase case dealt with six slowly floating aviation fuel plumes. For the Ilukste oil storage terminal, it was necessary to simulate a diesel fuel plume with a very complex shape (see Fig. 1 from Spalvins *et al.*, 1997).

We report there on features of ARMOS discovered during the two above-mentioned projects. Specific results of modelling have been reported in Spalvins *et al.* (1997).

A good mass balance quality of the ARMOS transport module was observed and excellent properties of the analytical Van Genuchten's (VG) multiphase (water, oil, air) model accounting for the aquifer capillary properties were proved. It was very useful that ARMOS allowed to import necessary digital maps. However, the following limitations of ARMOS have been discovered:

- a limited ability to create the necessary digital maps, especially, the φ -distribution of Fig. 1;
- an incorrect calculation of the residual oil fraction volume during initial spreading time of the oil plume;
- no check-up whether the thickness of the aquifer becomes zero ($m = 0$); this may result in serious mistakes if the free oil body comes into a direct contact with the aquifer base;
- no possibility to consider the heterogeneity of the aquifer (k and VG model); for example, ARMOS, in no way, allowed to consider the probably high non-uniformity of the aquifer in Fig. 1;
- an insufficient quality of the graphical output.

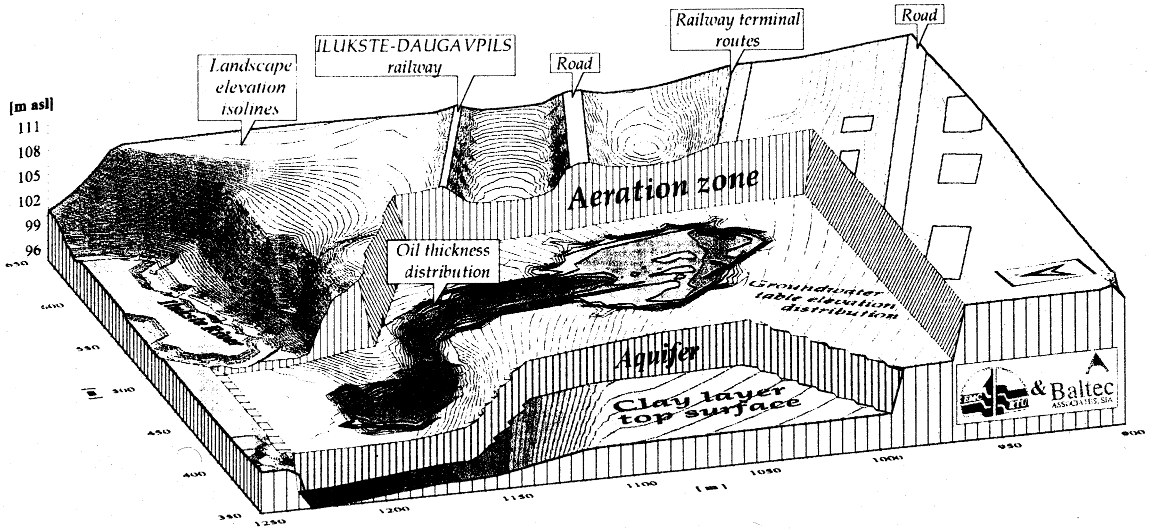

Fig. 1 The Ilukste oil storage terminal site. The complex diagram with elevation distributions of the landscape relief, the groundwater table, the clay layer top surface and the simulated oil spill thickness. The *z*-step for all kinds of isolines is 0.1 metre.

In order to overcome some of the above-mentioned limitations, ARMOS has been reinforced with additional software:

- the GDI and VOF programs developed by the EMC team (Spalvins & Slangens, 1994; Spalvins & Lace, 1997) for digital map construction and computing of oil volumes, respectively;
- Golden Software, Inc. SURFER program and Microsoft ACCESS data base manager system for providing graphical outputs and a common data environment for GDI, ARMOS and SURFER programs.

We hope that our reported experience with ARMOS will help other specialists to avoid possible mistakes caused by this code. If the aquifer is highly heterogeneous, then ARMOS cannot provide right results. One must apply other codes which can account for areal non-uniformities of an aquifer.

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