Incorporating geological sections in hydrogeological models

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ABSTRACT: The geological section presents a carrier of verified hydrogeological information. To incorporate it into a hydrogeological model (HM), the special program has been developed by the Environment Modelling Centre (EMC) of the Riga Technical University.

1 INTRODUCTION

Creating of the HM geometry is the most important part of making HM at complex practical cases. The geometry is specified, as follows:

$$h_{zp} = z_{p-1} - z_p \geq 0, \quad p = 1,2, \ldots, 2s + 1 \tag{1}$$

where, h_{zp}, z_{p-1} and z_p are, accordingly, the thickness, elevation distributions of the top and bottom of the p-th geological layer; z_0 is the landscape elevation map ψ_{rel} with the hydrographical network included (rivers, lakes, etc). Novel modelling programs apply the z-maps of (1), as initial ones and no h_z-maps of thicknesses are accepted directly (Spalvins et al., 2000a).

If piezometric heads are applied, as boundary conditions on the z_0 and z_{2s+1} surfaces then HM contains $s + 1$ aquifers and s interjacent aquitards (Spalvins et al., 2000a). These geological structures happen to be discontinous (areas with $h_z = 0$ are placed within). This discontinuity causes serious problems for usual interpolation of the z-maps, because it is difficult to keep $h_{zp} = 0$, as the difference between the top and bottom surfaces, in the non-existent part of a layer. The GDI program developed by EMC (Spalvins and Slangens et al., 1995) creates right z-maps, even for this case.

The quality of the GDI - produced maps can be considerably improved if sections are applied massively, as reliable sources for the HM geometry. In the project (Riga Technical University, 1998), the sections were amply used, although, no special software was available to prepare them for the GDI program. Therefore, a modeller beared full responsibility for this difficult performance, and the occurrence of human errors was high. The special cross section (CRS) program was developed, in order to liberate the modeller from the routine tasks (Gosk et al., 1999). In this paper, basic principles of the CRS program are discussed.

2 SECTIONS AS SOURCES OF GEOMETRICAL DATA

The section is composed of $2s + 1$ geological z-profiles, as intersections of the z-surfaces of (1) with the upright hedge of the section. In the xy-plane, the section is specified by its carrier - the broken line L passing through the master wells $j = 1, 2, \ldots, J$. The set containing $J - 1$ directed straight line segments represents the vectored form of L:

$$L = \{ c_j \}, \quad j = 1, 2, \ldots, J; \quad l_{1,J} = \sum_{j=1}^{J-1} l_{j,j+1}, \quad l_{j,j+1} = \sqrt{(x_j - x_{j+1})^2 + (y_j - y_{j+1})^2} \tag{2}$$

where $\{ c_j \} = \{ x_j, y_j \}$ is the coordinate set of the wells serving, as the turning points of L; $l_{1,J}$ and $l_{j,j+1}$ are lengths, accordingly, of L and of the elementary vector linking neighboring wells j and $j + 1$.

The z-profile L_z is rarely drawn like a simple broken graph (in the vertical plane) where the master wells of L are connected by straight lines. Usually, these connections are curvilinear, because some supplemental information is always accounted for by a hydrogeologist compiling the section. The set $\{ c_k \}$ containing K additional points must be introduced to approximate the curved profile. It is represented by vectored line drawn through the sequence of $N = J + K$ points. The locus of their xy-coordinates is the line L used as the carrier of the elevation data z:

$$L_z = \{ c_i, z_i \}, \quad \{ c_i = c_j \wedge c_k \}, \quad \{ z_i = z_j \wedge z_k \}, \quad i = 1, 2, \ldots, N. \tag{3}$$

The duo sets of xy-coordinates and z-values $\{ c_i, z_i \}$,$\{ c_j, z_j \}$, and $\{ c_k, z_k \}$ represent, accordingly, the current i-th data points (wells j and points k), the master wells j, and the additional points k dividing the straight fragments $l_{j, j+1}$, of L into collinear pieces. The form of (3) is mostly used by software applied for processing line data.

In Fig. 1, the typical example of complicated regional section taken from the report (Gosk et al., 1999) is shown. It represents a multilayered system containing nine Carboniferous layers (aquifers: *ng*, *kt*, *tr*, *ka*, *mc*, and aquitards: *dr*, *ml*, *sc*, *kr*), the Jurassic aquitard *j*, and the Quaternary aquifer *q*; the layers: *ng*, *dr*, *kt*, *ml* are discontinuous, within the section.

The example of Fig. 1 demonstrates that the set $\{ c_i, z_i \}$ of (3) must account for the following main characteristic points of the z-profiles:

- master wells j of L;
- additional points k for approximation of curvilinear profiles;
- crosspoints with elements of the hydrographical network;
- crosspoints with other sections applied;
- locus of geological boundaries for discontinuous layers.

In practice, because of different reasons not considered there, no section initially matches exactly the listed above various data lines and points involved. Errors are to be detected and corrected, possible minor discrepancies eliminated and initial data harmonized before they are consumed by the GDI program. This task is accomplished by help of the CRS program.

3 THE CRS PROGRAM

The program is a part of the system developed by EMC for creating HM (Spalvins et al., 2000b). To apply the CRS program, the following basic elements of the system must be presented (Spalvins et al., 2000a):

- hard copies of sections, geological boundaries, the situation map with point and line data included must be turned into electronic images via scanning;
- the following software tools must be ready for use:
  - the SURFER system for supporting computer graphics, electronic image digitizing and grid mathematics (Golden Software, 1997);
  - the CRP program for preparing digitised line data used by the GDI program (Slangens and Spalvins, 2000).

The CRS code is used, as the pre-processor of the CRP program. The following main services of CRS are offered:

- making alterations of the section, if necessary;
- the duo set $\{ c_i, z_i \}$ of L_z is provided by converting results of digitizing its electronic image.

To alter the section, the coordinates $\{ c_j \}$ of (2) can be corrected and the length for each $l_{i,i+1}$ of (3) can be modified by introducing its scale factor s_i, as follows:

$$L\{ c_j \} \rightarrow L\{ (c_j)_c \}, \quad s_{1, N}\; l_{1, N} = \sum_{i=1}^{N-1} s_i\, l_{i, i+1} = \sum_{i=1}^{N-1} (l_{i, i+1})_c \tag{4}$$

where $(c_j)_c$ and $(l_{i, i+1})_c$ are altered coordinates of the master wells j and the corrected lengths of elementary vectors of L_z, correspondingly; $s_{1, N}$ is the correcting scale factor for the full length of L_z. However, for the sake of simplicity, the original notations of (3) will be used in the further explanations, instead the corrected ones of (4).

A digitizer program provides the duo set $\{ l_{1, i}, z_i \}$ containing the lengths $l_{1, i}$ and the z_i-values, at the current points i of L_z. The CRS program converts values $l_{1, i}$ into the coordinates c_i, as follows:

- from the representation (2), the fragment $l_{j, j+1}$ is found where the point i is located;
- the coordinates x_i and y_i are computed:

$$x_i = x_j + \delta_{j,\,i}\,(x_{j+1} - x_j),\quad y_j = y_j + \delta_{j,\,i}\,(y_{j+1} - y_j),\quad \delta_{j,\,i} = l_{j,\,i} \,/\, l_{j,\,j+1}\,,\quad 1 \geq \delta_{j,\,i} \geq 0, \tag{5}$$

where collinearity of $l_{j,\,i}$ and $l_{j,\,j+1}$ (as vectors) are exploited.

To simplify the CRS program control, all profiles of the section (see Fig. 1) apply the common set of wells and additional points. It is easy to check-up any verticale of the section, on holding the obligatory condition $h_z \geq 0$ for each profile involved.

The CRS program can also be used to prepare the ψ-distribution for the boundary shell of HM (Spalvins et al., 2000b).

Practical experience with the CRS program (Gosk et al., 1999) has proved its effectiveness on incorporating geological sections in HM. Reliability of the HM geometry increased considerably.

4 CONCLUSIONS

Geological sections provide valuable data for creating HM. However, these data should be preliminarily checked-up, corrected and harmonized with the other data involved.

This difficult task can be accomplished by special software tools excluding a modeller from routine performances, as main sources for human errors of preprocessing data of sections.

The CRS program has been developed by the EMC team to prepare geological sections for incorporating in HM. This program enables to improve HM results considerably.

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Lāce I., Spalviņš A. Ģeoloģisko griezumu iestrādāšana hidroģeoloģiskos modeļos.
Ģeoloģiskais griezums satur pārbaudītu hidroģeoloģisko informāciju. Lai iestrādātu griezumu hidroģeoloģiskā modelī (HM), Rīgas Tehniskās Universitātes Vides Modelēšanas Centrs ir radījis speciālu programmatūru.

Лаце И., Спалвинь А. Включение геологических сечений в гидрогеологические модели.
Геологическое сечение является носителем проверенной гидрогеологической информации. Для включения этих сечений в гидрогеологические модели (ГМ), Центр Моделирования Среды Рижского Технического Университета разработал специальную программу.