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VISUALIZATION OF SPATIAL VARIABILITY OF UNDERGROUND WATER HYDROGEOLOGICAL REGIME WITH THE USE OF SURFER 8 APPLICATION

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In the article were presented the possibilities of Surfer 8 software use in geology for making the maps of deposition of roof formation subsoil (older) in hydrogeochemistry for maps making of mineralization variability, total hardness and water reaction or the individual cations and anions concentrations in waters. In the work were presented examples of software use for Quaternary and Tertiary formations hydroisolines of dry residue and magnesium, iron and manganese ions concentrations in the exploited waters or maps drawing of subsoil roof and pressures subartesian underground waters.

Introduction. During analysis of hydrogeological studies in the regions where multi-hole drilled water intakes are situated one often uses isoline geological, hydrogeological or hydrogeochemical maps [Satora and Kaczor 2004]. They are usually made for areas for which hydrogeological properties maybe assumed to be isotropic (homogenous). These are generally where Holocene Quaternary porous alluvia composed of loose clastic deposits or heavily cracked, fissure carbonate layers (lime or dolomitic) generally occur within the river terraces. Isoline maps, with the use of interpolation may be created by simple time consuming hand methods [Pazdro 1983] or mapmaking may be supported by computer applications making possible creating and interpretation of interpolation networks. The Authors of presented article made an attempt to use Golden Software Surfer 8.0 application to make hydroisoline maps of dry residue and concentrations of magnesium, iron and manganese ions and to draw maps of bedrock roof and subartesian pressures of underground waters occurring in the Quaternary and Triassic deposits. Created hydroisoline maps explicitly show not only temporary variability of the analysed feature in space but also during the selected periods of a longer multiannual time span (e.g. during longer well exploitation). Analysis of maps made for individual years in the multiannual period allows additionally to point directions and places of water contamination, to predict future changes of concentration and determine location of new wells. Presented paper shows examples of Surfer 8 application use for estimating the variability of selected chemical components of underground waters of two multi-hole water intakes in belt "D" at Ruszcza near Krakow and at "Bzin" near Skarżysko Kamienna.

Description of Golden Software 8.0 application in view of isoline map drawing. SURFER 8.0 computer programme was written for making vector maps on the basis of XYZ data input. The application enables a choice of the method of interpolation network creation. Interpolation may be conducting using the following methods: kriging, minimum curvature, nearest neighbour, natural neighbour, modified Shepard's method, radial basis function, polynominal regression, inverse distance to a power and triangulation with linear interpolation [Golden Software Inc. 2002]. If one bases on irregularly distributed data, as in case of geological information, the best results are obtained when kriging, minimum curvature or polynominal regression methods are used. Usefulness of these methods for drawing maps of geological surface was determined in the work by Goldsztejn and Skrzypek [2004]. The authors think that Shepard's method generates the fewest errors, however a map made using this method is little realistic due to accumulation of extreme values which do not refer to a general trend in data variability. On the other hand kriging and the smallest curvature method are characterized by a quality similar to interpolation. In the present paper Authors' opinion, of the two methods kriging seems optimal for hydroisoline mapmaking. Maps drawn using this method reveal high quality of equivalent projection of the analysed surface shape. Hydroisoline maps created by Surfer application were verified by traditional methods at the phase of method selection.

Characteristics of researched area. Research objects for which hydrogeological maps were drawn using Surfer 8.0 application are situated at Ruszcza near Krakow and at Bzin near Skarżysko-Kamienna.

13 wells drilled to the depth of between 27 and 32 m and well yield between 31.0 and 59.0 $m^3 \cdot ha^{-1}$ are situated in the area of Ruszcza locality in the north-eastern part of Krakow. They supply water to the Sendzimir Ironworks. On this terrain they form so called belt "D". The area of 344 ha is localized on the left bank high terrace of the Vistula River on the ordinates 207.7–218.0 m a.s.l. The captured aquifer consists of Holocene Quaternary gravel-sandy deposits with depth of 6.0–18.0 m covered by the surface by a complex of loams and loess-like silts. Tertiary Miocene sea deposits constituting the substratum of the aquifer developed as grey or greenish-grey clays, more rarely argillates (clay-stones) or often strongly limy clay-stones [Szklarczyk et al 1997]. Quaternary water table occurs on the high terrace (as of 8.11.1997) at the depth of 10.0–15.00 m. The water table is of free character and only locally may be slightly pressured.

The "Bzin" water intake bases on deep, Triassic underground waters occurring in carbonate deposits of shelly limestone. It is composed of 6 drilled wells of the depth between 37 and 60 m and yield between 74 and 341 $m^3 \cdot h^{-1}$ which supply water to Skarżysko-Kamienna – a big town in the świętokrzyskie province. The researched object is situated in the south- western part of the Skarżysko-Kamienna in the Kamienna River valley on the Mesozoic margin of the Świetokrzyskie Mts. (the area ordinates range from 231.0 to 234.0 m a.s.l.). Holocene Quaternary deposits occur near the surface of the discussed terrain and below them are Triassic and Jurassic deposits constituting the substratum. The Quaternary deposits comprise alluvial and fluvioglacial loamy and varigrained sands, alluvia and gravels with depth of between 11 and 24 m. Grey, black and yellow clays and grey sandstones interbedded by argillaceous slates constitute the Jurassic Rhaetian, whereas the Triass is represented by shelly limestone composed of organogenic limestones, flinty cherts, clays and shales.

Analysis and results. The research material used for creating isoline maps for belt "D" consists of chemical analyses determining dry residue (mineralization) and magnesium ion concentration in porous, alluvial and Quaternary underground waters originating from individual thirteen drilled wells, exploited during the researched period 1986–2001 (for 15 years).

Analysis of spatial variability of the mentioned water chemical components points to the following:

– in 1986 the amount of dry residue (Fig. 1) ranged between 500 and 1000 mg $\cdot dm^{-3}$ over a major portion of the water intake western part (71.8 % of the total area), whereas in the eastern part fluctuated from 300 to 500 mg $\cdot dm^{-3}$. In 1989–1992 mineralization of the water intake, progressing successively from south-west became marked , which caused a gradual increase in the area occupied by the dry residue of over 1000 mg $\cdot$ dm^{-3} (to c.a. 1300 in 1992 and 1700 mg $\cdot$ dm^{-3} in 2001) reaching almost 20 % share, total disappearance of the surface occupied by the 300–500 mg $\cdot$ dm^{-3} dry residue and covering of the medium and eastern part by between 500 and 1000 mg $\cdot dm^{-3}$ surface of dry residue,

– magnesium concentrations (Fig. 1) in the analysed period give a more diversified picture. In 1986 concentrations exceeding 50 mg $\cdot dm^{-3}$ occurred in the western and north-western part of the investigated area and covered 22.6 % of the total area. Concentrations below 30 mg$\cdot dm^{-3}$ occurred in the south-eastern part (the region of wells S-12 and S-13) and covered 23.3 % of the area. Magnesium concentrations of 30–50 mg dm^{-3} were the most frequent (54.1 %) among the concentrations mentioned. In 1989 the concentration of 30–50 mg $\cdot dm^{-3}$ which occupied middle and eastern part of the area still dominated (61.7 %). Since 1992 the concentration has covered a slightly smaller surface (55.4 % of the total) in the middle and western part of the area. Increase in concentrations over 50 mg $\cdot dm^{-3}$ (22.2 %) started from the east. In 1995 the concentration of 30–50 mg $\cdot dm^{-3}$ has been fixed and has occupied also the southern part of the area.

In 1998 the 30–50 mg $\cdot dm^{-3}$ increased its share to 61.6 % but its increase to 50 mg $\cdot dm^{-3}$ was observed in the middle part of the studied area and in the western and north-eastern direction. In 2001 the 30-50 mg $\cdot dm^{-3}$ occupied the area in the southern part, whereas the concentration in the north-western part grew over 50 mg $\cdot dm^{-3}$ reaching the 88.2 % coverage of the whole area.

For the Bzin water intake the research material consisted of chemical analyses determining concentrations of iron and manganese ions in the fissure Triassic underground waters originating from the exploited water intake composed of six drilled wells marked with numbers 1, 1a, 2, 3, 3b and 4. The research period during which the analyses were performed covers the ten year period 1993–2002 for wells Nos. 1, 1a, 3, 3b and 4, whereas for well No. 2- a five-year period 1993–1997. Iron and manganese ions selected for analysis from among other chemical components are characterized (in comparison to other components) by a great variability and concentrations frequently exceeding considerably the standard values permissible for potable water for humans. The analysis of area research and time variability of iron and manganese ion concentrations during the period from 1993 till 2002 in six drilled wells in the area of the Bzin water intake at Skarżysko-Kamienna revealed the following:

– occurrence of great changes in iron concentrations at the beginning of each studied multi-year period, particularly in the N-E and EE-S direction and manganese concentration during the whole period of investigations in the S-E direction;

– high concentrations of iron by the end (wells Nos.1and 1a) and in the mid-period of research (well No. 4), and of manganese in the initial period of investigations;

– manganese ion concentrations varying from 0.01 to 1.24 mg $\cdot dm^{-3}$ over the whole period of the water intake operation in the captured waters, whereas manganese ion concentrations fluctuating from 0.01 to 0.75 mg $\cdot dm^{-3}$;

– a visible prevalence of the value of manganese ion concentrations over iron ions (except the waters from well No. 4).

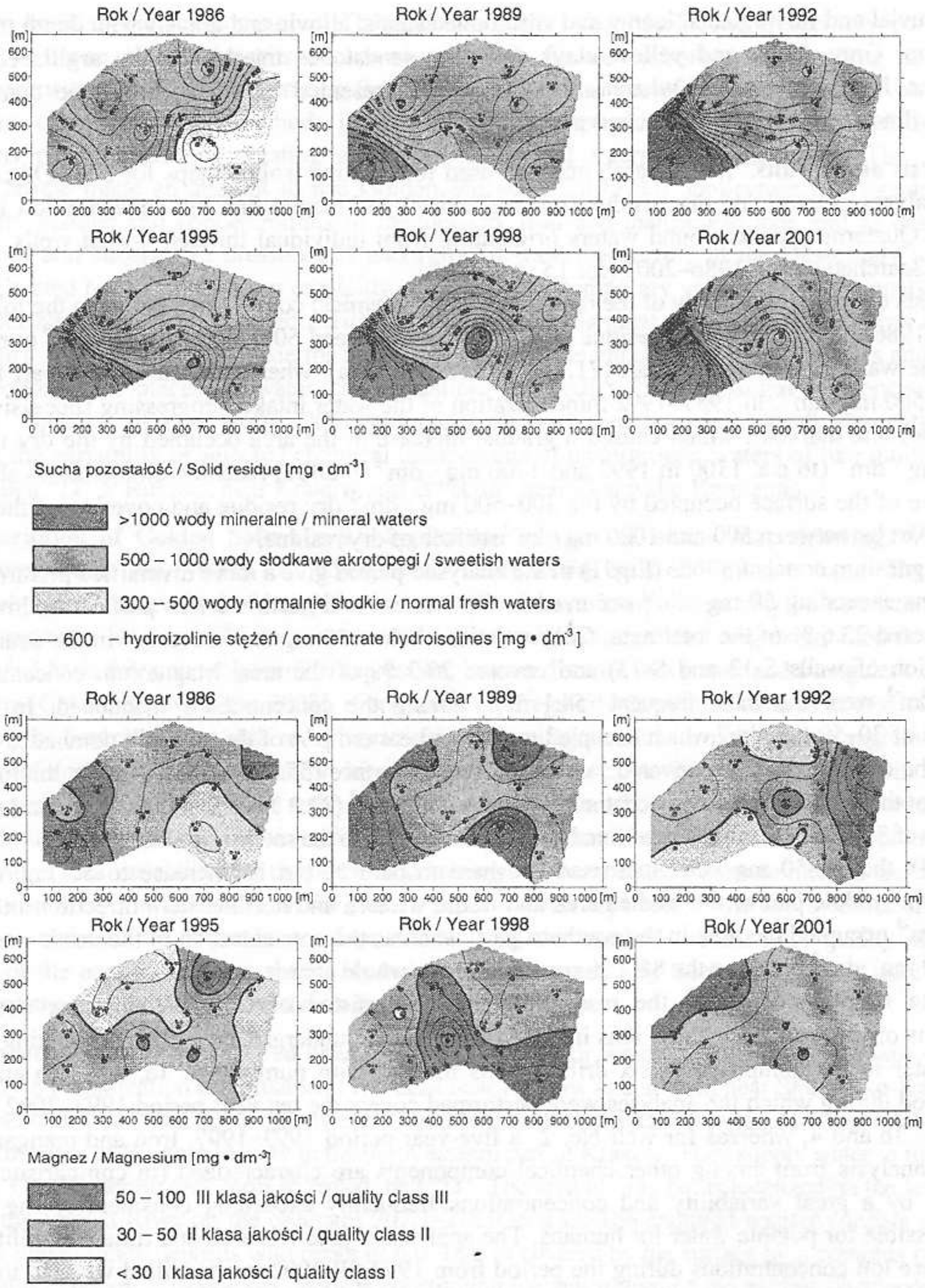

Fig. 1. The spatial variability of solid residue and magnesium ions in the Quaternary underground waters of the Vistula river terrace

Additionally an isoline map of Triassic deposit roof surface was made for "Bzin" water intake area (Fig. 3),from which underground waters are drawn in the area of "Bzin" water intake. On this map a channel depression with the S-E – N-W axis is clearly marked in the region of wells No. 2 and 3b and its lowest surface occurs in the vicinity of well 3B (ordinate 203.01 m a.s.l). The N-E flank of the depression raises to 213.68 m a.s.l. in the region of well No. 4. whereas the S-W flank in the region of well No.1 it occurs on the ordinate 232.97m a.s.l.

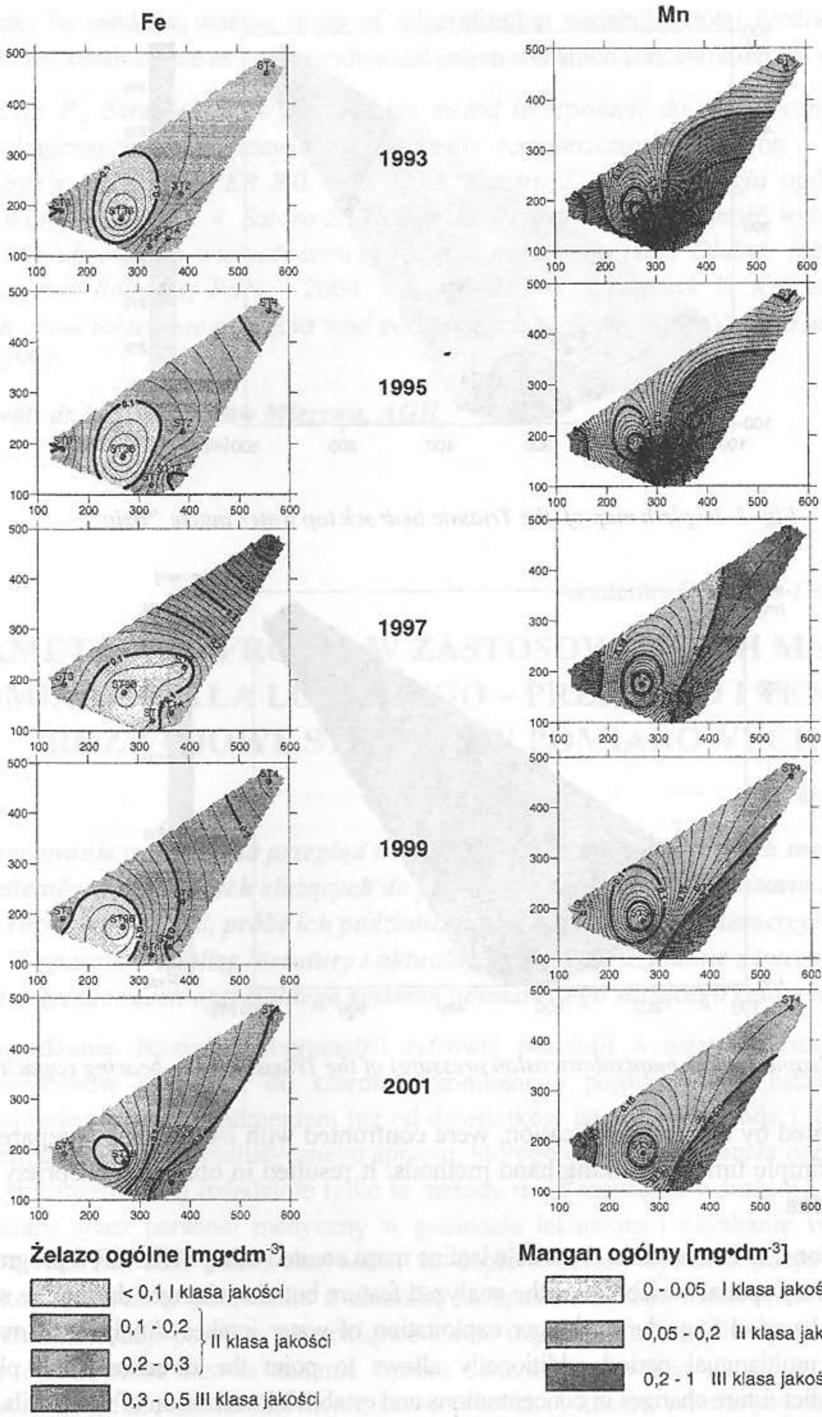

Fig. 2. The spatial variability concentrate of iron and manganese ions in Triassic underground waters multiwells intake "Bzin"

On the other hand the map showing the course of isopiestic lines of the Triassic horizon (Fig. 4) points to a visible decline in subartesian pressure of the pressure waters in the direction of well No. 3b and 1a, which stabilizes on the well No. 3b – 1a line on the ordinates between 230.22 and 230.71m a.s.l.

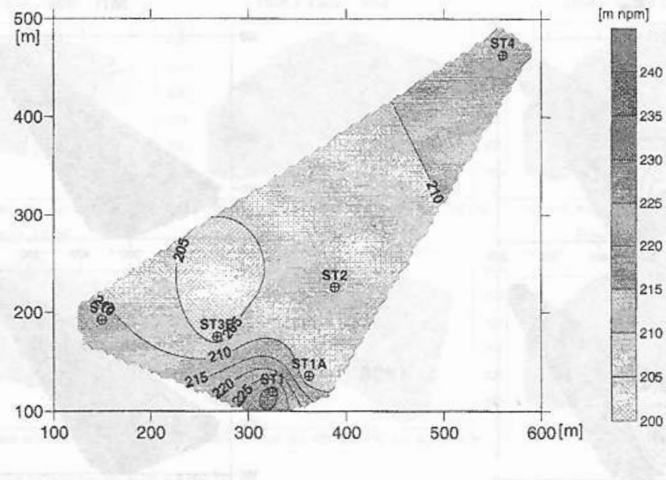

Fig. 3. Isopleth map of the Triassic bedrock top water intake "Bzin"

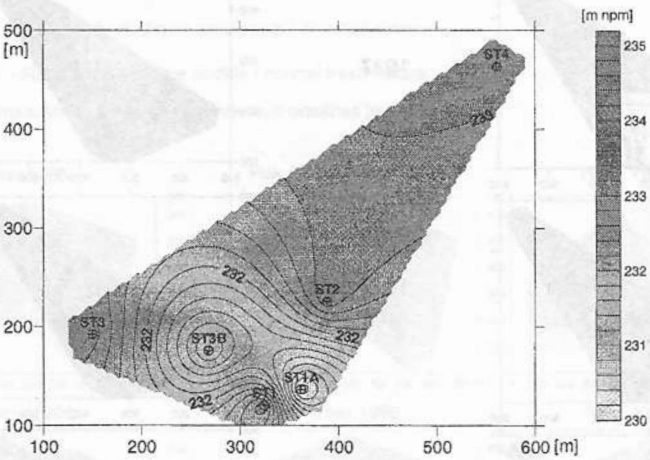

Fig. 4. Isopiestic line map(subartensian pressure) of the Triassic water-bearing capacity

The maps created by Surfer 8 application, were confronted with isoline maps prepared with the use of interpolation by simple time consuming hand methods. It resulted in obtaining propriety and adequacy of analyzed phenomena.

Final conclusions. 1. Presented in the article isoline maps created using SURFER 8 programme perfectly show not only temporary spatial variability of the analyzed feature but also changes during the selected periods of longer multiannual period (e.g. during longer explôitation of water intakes).Analysis of maps drawn for individual years of multiannual period additionally allows to point the directions and places of water contamination, to predict future changes in concentrations and establish localization of new wells.

2. Analysis of interpolation algorithms of SURFER programme data demonstrated the kriging was the optimal method for drawing isoline maps. The maps created using this method are characterized by high quality of equivalent projection of the analyzed parameter surface shape.

3. Analysis of SURFER programme operation for making isoline maps gives grounds for conclusion that the application may be used also form creating geological maps of the depth of younger overlaying rocks or occurrence of substrate roof or in hydrogeology for drawing maps of hydroisohypses, hydroisopaths, hydroisobaths, isopiestic lines or variability of single resources of underground waters. In hydrogeochemistry

the application can be used for making maps of mineralization variability, total hardness, water reaction, temperature and water conductance as well as individual cation and anion concentrations in waters.

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