Study of SPT behavior of penetration resistance under influence of the groundwater level fluctuation, using geostatistical methodology

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Abstract: The kriging ordinary geostatistical methodology was used in mapping the groundwater level to verify the influence of its fluctuation on spatial behavior of the penetration resistance index of the standard penetration test (SPT). The geostatistical mapping was made by carefully separating the 241 boreholes into two big groups, using the criterion of data base analysis monthly and annual pluviometric of the studied area; and as an end result six maps were obtained: groundwater level fluctuation map, penetration resistance index variation maps at a depth of 1,5; 6,0; 8,5; 11,0 and 13,5 m. The greatest variations of penetration resistance index in increase as well as in reduction of the resistance, occurred at a depth of 6,0 and 8,5 m; and the remaining depths: 1,5; 11,0 and 13,5 m were the smallest variations to the penetration resistance index in both situations.

Key words: Groundwater level fluctuation, Penetration resistance index, Standard Penetration Test, Geostatistical methodology, Spatial behavior.

INTRODUCTION

In the studied area, besides spring surface water extraction, the custom of groundwater extraction has become intense as a supplementary source of supply. At this rate, only in the urban area of São José do Rio Preto (Brazil) it is estimated that more than 2000 wells were drilled irregularly and without appropriate planning. Thus, it was verified that the study of the groundwater static level, as well as its form and magnitude of fluctuation, are of great importance to urban planning, within the scope of land use and occupation, as its fluctuations can change significantly the performance of the structural elements of urban infrastructure immersed in soil aggregate.

Due to intense employment of the N_{SPT} values, and of the intensive and indiscriminate exploration of the groundwater that actually occurs in the urban area of São José do Rio Preto, a geostatistical mapping of the groundwater level and of the N_{SPT} values was carried out, at various depths, to verify the influence of the groundwater level fluctuation on spatial behaviour of the N_{SPT}.

Geologically the studied area is represented by the following formations (Cretaceous): in the surface there is only the Adamantina formation (fine sandstone to very fine rosy to brown texture) meeting downwards at depth in the Santo Anastácio formation (reddish-brown sandstone of fine to average textural).

The present study was elaborated by means of 1238 boreholes executed in the studied area, from 1992 to 2000, obtained by Mendes (2001) alongside companies that carried out these tests in region.

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After the borehole compartment process, the information on the groundwater static level and of penetration resistance index was registered.

RESULTS AND DISCUSSIONS

The geostatic analysis process was carried out according to the following stages: sample explanatory analysis from basic statistic, generation and adjustment of experimental variograms, sample estimative by common kriging. Preliminarily, a study of the basic statistical parameters was carried out by GIS/Spring-3.5[t] spatial analysis module.
From the ordinary kriging, sample values of groundwater level and of N_{SPT} were estimated in 10x10 grids, considering the two borehole groups (dry and rainy season). Numeric grids of N_{SPT} variation at depths of 1.5, 6.0, 8.5, 11.0 and 13.5 m were also obtained by differences between estimated N_{SPT} values, for samples of dry and rainy seasons.
These resulting numeric grids were later sectioned in previously defined intervals, denominated “thematic types”. To reach this, thematic type values were established at intervals of 2,0 m for the fluctuation map and of the ground water at steps of 15 % for N_{SPT} variation maps.
Figure 1 map shows spatial behavior of ground water oscillation level. By analyzing this map the lowering of the groundwater can be verified, specially in the mid-west, south-east and extreme-north, including a corresponding region of 31.2 % or 18.9 km˛ of the studied area.
Groundwater elevation occurrences can also be observed in various regions of the studied area, despite such occurrences being in western regions and a central part of the east and north-east region, which correspond to a 68.8 % region or 41.6 km^2 of the studied area.

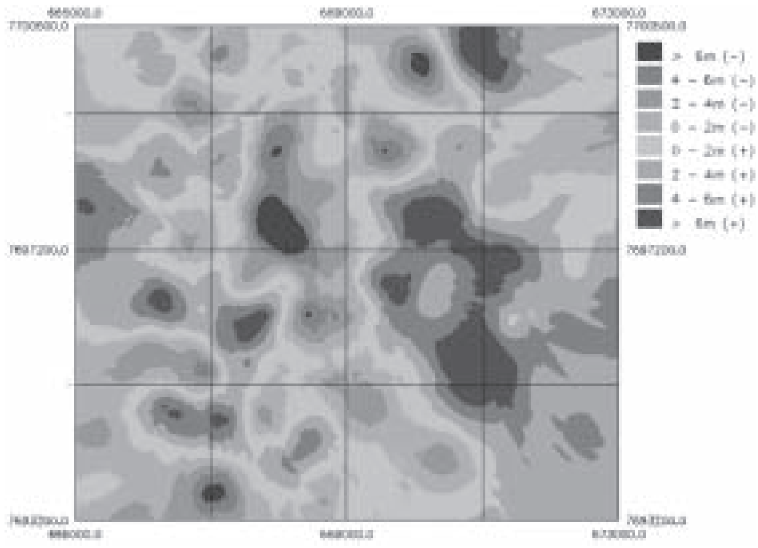

Figure 1. Groundwater level fluctuation map – the negative signal (-) indicate occurrence of groundwater lowering and the positive signal (+) indicate occurrence of groundwater elevation in studied area 20°47’13’’ and 20°51’13’’ of South latitude and 49°20’30’’ and 49°24’50’’ of West longitude).

Generally, the occurrence of the larger ground water oscillation values (above 4,0 m), with elevation possibilities as well as lowering ones of ground water, these represent approximately 21.0 % or 12.6 km^2 of the studied area. From this total value, 17.3 % (10,5 km¸)) correspond to the possibility of elevation occurrences higher than 4.0 m of ground water level.

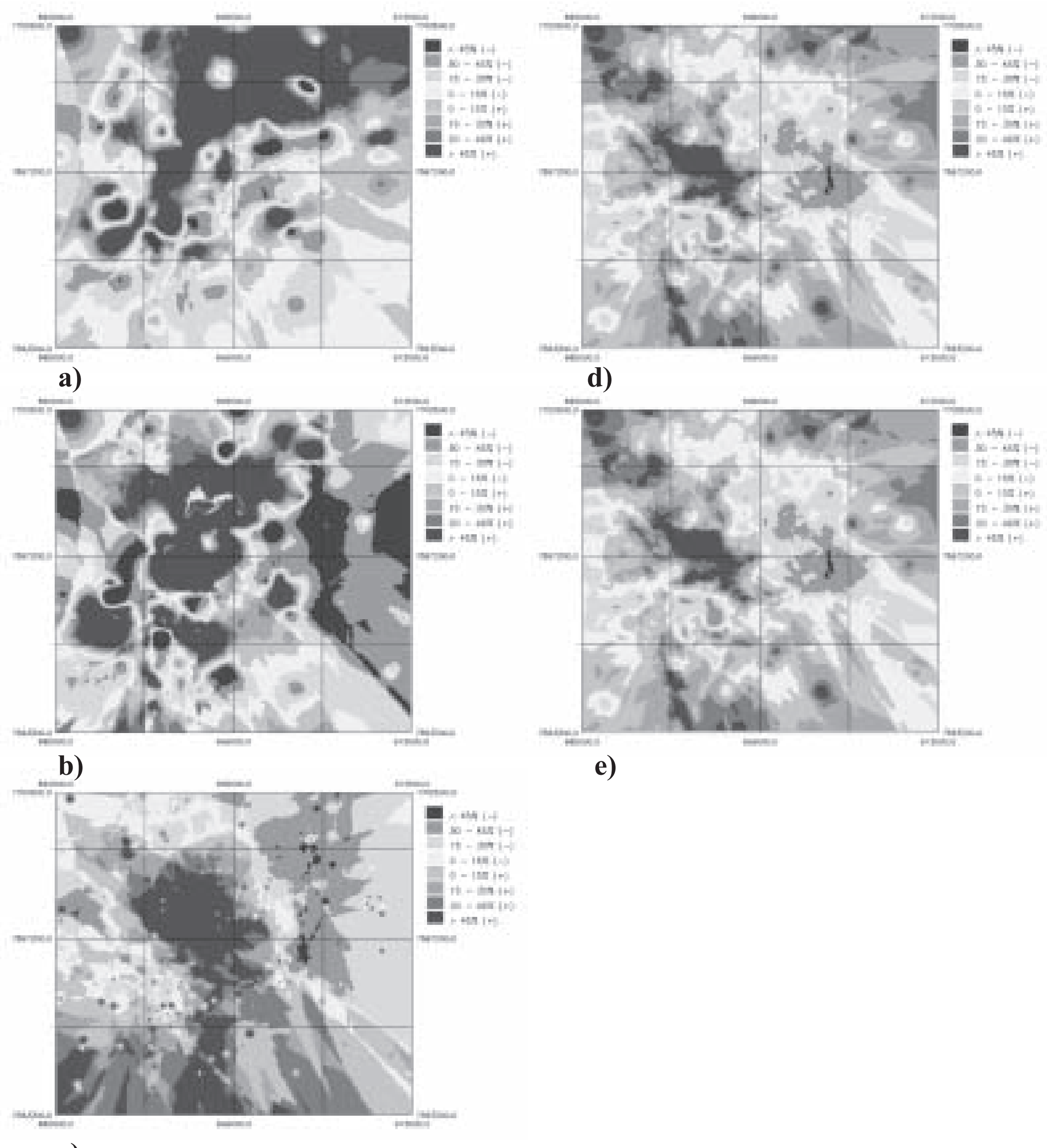

Figure 2 a – e. Penetration resistance index variation maps in depth: a – 1.5 m, b – 6.0 m, c – 8.5 m, d – 11.0 m and e – 13.5 m. In maps, the negative signal (-) indicate occurrence of resistance reduction and the positive signal (+) indicate occurrence of resistance increase in studied area.

Figure 2 maps theoretically convey the spatial behavior of penetration resistance index (N_{SPT}), due to ground water oscillation level.
In general, maps of Figures 2-a and 2-e showed the highest occurrences, area wise, for thematic types with variations below 30 % in diminishing tendency as well as N_{SPT} increase.
To resume, it can be said that the occurrence with the largest N_{SPT} variations (above 30 %) were verified mainly at depths of 6.0 and 8.5 m (Figure 2-b and 2-d) and at other depths there were lesser N_{SPT} variations (below 30 %).

CONCLUSIONS

The groundwater level fluctuation map verified that on approximately 69 % of the studied area groundwater elevations occurred, while that on the remaining 31 % of the area, groundwater lowering occurred. The main groundwater elevations (above 6.0 m) occurred mainly in north-east and centre-east regions, while the main groundwater lowering occurred in the central and north-east regions of the studied area.
The penetration resistance index maps showed that the main N_{SPT} variations occurred at depths 6.0 and 8.5 m while the remaining ones showed smaller variations. It is believed that this spatial behaviour of N_{SPT} variation is partially associated to the occurrence of significant groundwater level fluctuations at these depths.
It is even supposed, that the origin of N_{SPT} spatial variations are somehow associated to the fact that the boreholes are being carried out in different seasons of the year, whose groundwater lowering or elevation occurrence depend fundamentally on local climatic, hydrological and hydrogeological conditions. This supposition is based mainly on comparisons carried out for the parameters obtained in variogram analysis.
The result of N_{SPT} variation value maps, obtained by geostatistical methodology, proved very promising to be used in urban infrastructures planning, as they permit to warn and show to geotechnical and geological engineers the probable spatial behaviour of the N_{SPT} variation values, due to groundwater level fluctuation.

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