ANALYSIS OF THE MORPHOMETRIC PARAMETERS OF THE RIO PRETO BASIN, SERRA DO ESPINHAÇO (MINAS GERAIS, BRAZIL)

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ABSTRACT – The Rio Preto Hydrographic Basin (RPHB) is located in the North-central portion of the state of Minas Gerais, Brazil, 30 km ENE of the city of Diamantina. The sources of the stream of that name are found in the Rio Preto State Park, which has an area of 10,755 hectares. The total area, perimeter, extension, and axial length of the RPHB, as well as other morphometric characteristics, with emphasis on shape indexes, were obtained with the help of the ArcGis 9.2 program. The cartographic data were taken from digitalized topographic charts in a scale of 1:100,000 of the Brazilian Geographical Institute (IBGE). The measured drainage area is of 389.3 km^2 and the perimeter is 136.9 km. Due to structural influence, the shape of the RPHB is irrgular and elongated, with drainage developed in a dendritic and parallel pattern. Those characteristics were checked by means of the compaxity coefficient and the shape factor. The first one was estimated in 1.94, what implies that the basin is not subject to fast flooding in years with normal precipitation. The high degree of fluvial downcutting of the basin is confirmed by the fact that it is a 5th order basin, it presents a significant branching rate and a medium drainage density.

Keywords: morphometry, morphostructural analysis, RDE index, Serra do Espinhaço, Minas Gerais, Brazil.

RESUMO – *C. de S. Lima, A.C. de B. Corrêa, N.R. do Nascimento - Análise dos parâmetros morfométricos da bacia do Rio Preto, Serra do Espinhaço (Minas Gerais, Brasil)*. A Bacia Hidrográfica do Rio Preto (BHRP) está situada no centro-norte do Estado de Minas Gerais, 30 km ENE da cidade de Diamantina. A nascente do Rio Preto encontra-se no Parque Estadual do Rio Preto, que possui uma área de 10.755 hectares. A área, o perímetro, a extensão, o comprimento axial da BHRP e as outras características morfométricas, enfatizando os índices de forma, foram extraídas com o auxílio do ArcGis 9.2. Os dados cartográficos foram obtidos das cartas topográficas digitalizadas na escala de 1:100.000 do IBGE. A área de drenagem encontrada foi de 389,3 km^2 e o perímetro foi de 136,9 km. Devido às influências estruturais a forma da bacia do Rio Preto é alongada e irregular, com drenagem em padrão dendrítico e paralelo. Essas características foram comprovadas através do coeficiente de compacidade e fator de forma. O primeiro foi estimado em 1,94, o que implica que a bacia não é sujeita a enchentes em anos normais de precipitação. O alto grau de dissecação fluvial da bacia é confirmado por esta ser de 5ª ordem, apresentar uma ramificação significativa e uma densidade de drenagem média.

Palavras-chave: morfometria, análise morfoestrutural, índice RDE, serra do Espinhaço, Minas Gerais, Brazil.

INTRODUCTION

The hydrographical basin is formed by the area of the surface on which water runoff actually takes place. The slope generates the drainage of the precipitation (rain) together with transported sediments and other chemical substances dissolved or in suspension towards a common point called the mouth or discharge outlet or gate of the basin. The morphometric characteristics of the hydrographical basin control all surface runoff, and due to this condition, the hydrographic basin is considered an ideal territorial unit for integrated planning and development of the natural resources of a region. The knowledge of the physical characteristics of the basin and of their drainage network have application in several types of

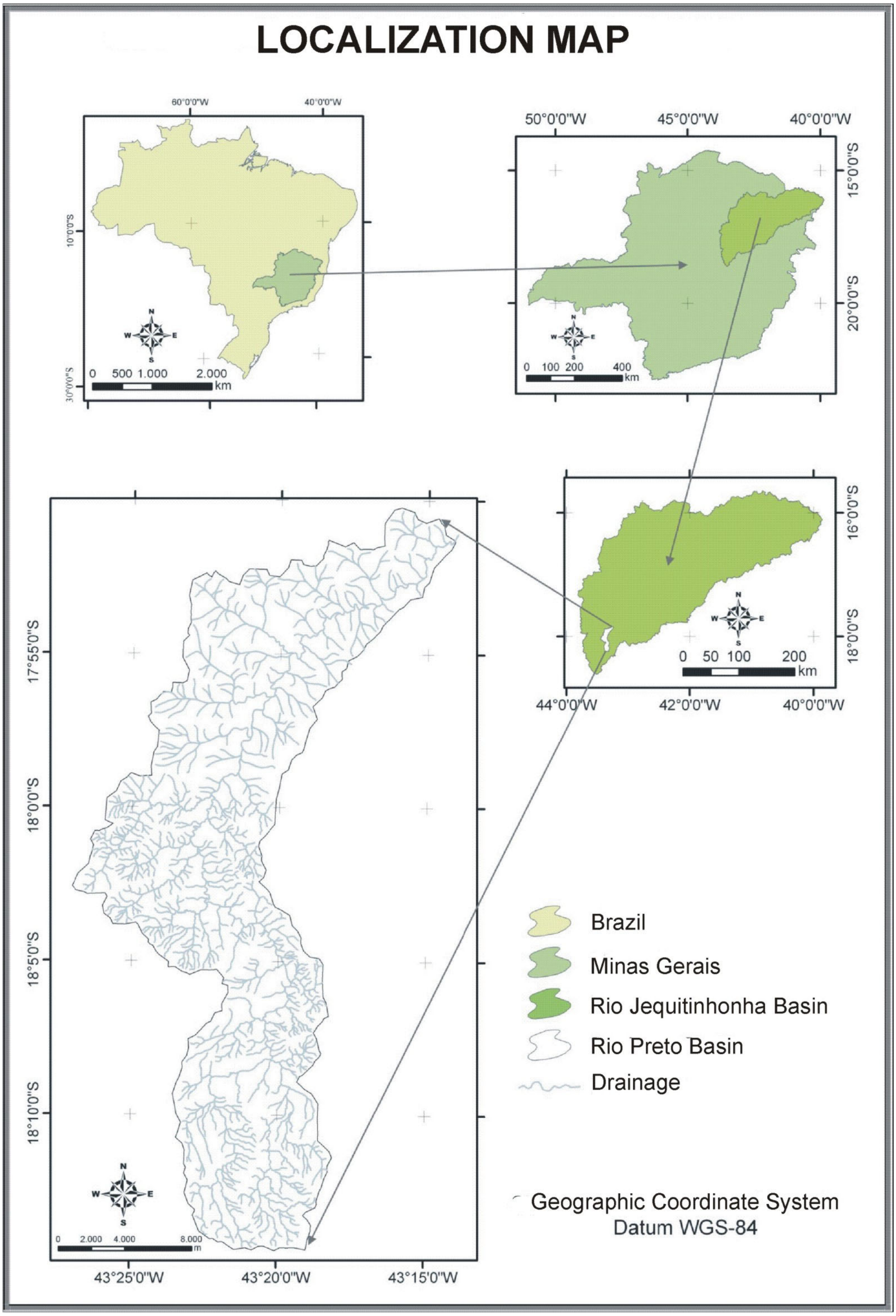

FIGURE 1. Localization map.

geomorphological and hydrological studies. The morphometric analysis is an important tool in morphological studies because it allows a quantitative approach, using values collected from a group of parameters to obtain the principal characteristics of the studied area. Such analysis is necessary so as the basin landforms could be separated, quantitatively described, compared and also interrelated and correlated with the hydrological processes within the basin area.

Based upon these considerations, this paper deals with the analysis of the morphometric indexes applied to the Rio Preto Hydrographic Basin (RPHB), used as a tool to understand how a variety of morphological controlling factors occurring within the area are explaining the indexes distribution.

CHARACTERIZATION OF THE STUDY AREA

The Rio Preto Hydrographic Basin (RPHB) (Figure 1) is located between the UTM coordinates 8026977 S and 7982433 S, and between 663989 W and 687030 W, in the North-central region of the State of Minas Gerais, approximately at 30 km ENE of the city of Diamantina, Brazil. The sources of the Rio Preto are found within the State Park of Rio Preto, county of São Gonçalo do Rio Preto, administrated by the Instituto Estadual de Florestas (IEF). The Park has an area of 10,755 hectars and it hosts several stream sources, being the most important that of the Rio Preto, which is tributary of the Rio Araçuaí, which finally joins the Rio Jequitinhonha. In 1991, the Rio Preto was declared as a stream of permanent preservation. This action determined the need of protecting the sources. Therefore, on June 1st, 1994, the state decree Nº 35,611 officially created the State Park of Rio Preto.

Among the different drainage patterns found in the basin, dendritic and parallel types should be mentioned. The latter was identified mainly in the areas where there is a major lithostructural control or in the sites with steeper slopes.

MATERIALS AND METHODS

The area, perimeter, length of the main stream and the axial length of the RPHB and other morphometric characteristics described below were obtained with the help of the *ArcGis* 9.2 program that provides, within a GIS framework, the characterization of the basin by means of spatially referred, digital information. The chartographic information was measured from the digitalized topographic maps at a scale of 1:100,000 of the IBGE (Instituto Brasileiro de Geografia e Estatísticas).

To be able to classify the RPHB according to its size, the classification by Wisler and Brater (1964, according to Duarte et al., 2007) was used, which considers “small basins” those that have an area smaller than 26 km^2 and “large basins” those with a surface extent of more than such value. The hierarchy of the basin was established following Strahler (1952, in Christofoletti, 1980), in a GIS environment using the *ArcGis* 9.2 software.

Concerning the shape of the basin, three indexes were calculated for the RPHB: the compaxity coefficient (Kc), which is the relationship between the basin perimeter and the circumference of a circle whose area would be equal to that of the basin, and which was calculated by means of the equation:

$$Kc = 0{,}28 \frac{P}{\sqrt{A}} \qquad (1)$$

in which Kc is the compaxity coefficient, P is the perimeter in km and A is the area of the basin, expressed in km^2. This coefficent is an adimensional number, which varies with the shape of the basin, independently of its actual size. Thus, as the more irregular the basin becomes, the larger the compaxity coefficient will be, that is, when closer it is to unity, more circular its shape will appear and more subject to flash flooding it will be (Villela and Mattos, 1975).

The Shape Factor (Kf) is the relationship between the mean length of the basin and its axial compaxity (from the mouth to the farthest point of the drainage basin). This parameter was calculated by means of the following equation:

$$Kf = \frac{A}{L^2} \qquad (2)$$

where K*f* is the Shape Factor, A is the surface of the basin in km^2 and L is the axial compaxity of the basin in km. A basin with a low Shape Factor indicates that it is less subject to flooding than other, for instance, of the same size but with a larger Shape Factor (Vilella and Matos, 1975).

The Circularity Index is another parameter used. It tends to be closer to unity as the basin gets closer to a circular shape and diminishes when it becomes elongated. It was calculated by means of the following equation:

$$Ic = 12{,}57 \frac{A}{P^2} \qquad (3)$$

where Ic is the circularity índex, A is the surface in km^2 and P is the perimeter in km (Tonello, 2005).

Based upon the distribution of the channel systems, it was also calculated the drainage density, which is the result of the total length of the water channels of the basin network, divided by the surface of the basin. This index may vary from 0.5 km.km-^{2} in basins with poor drainage, to 3.5 km.km-^{2} or even larger in well to very well drained basins (Vilella and Matos, 1975). Drainage Density is estimated by the equation:

$$Dd = \frac{Lt}{A} \qquad (4)$$

where Dd is the drainage density, Lt is the total length of the water channels in km and A is the surface of the basin in km^2.

The slope map of the basin was elaborated in a GIS environment starting with the digital elevation model (DEM) obtained by means of the Shuttle Radar Topography Mission of NASA. In the ArcGIS 9.2 software a "slope" tool was used which generated the slope percentage intervals of the landscape.

Hypsometry, which is the graphic representation of the mean relief of a basin, was represented with a map also elaborated based upon the NASA DEM, and the data were classified in the ArcGIS 9.2 software.

RESULTS AND DISCUSSION

A fluvial hierarchy is the process of establishing the classification of a given water channel within the total stream network of a hydrographic basin in which such channel is found. This hierarchization is done with the function of allowing to make more objective the morphometric studies about the hydrographic basins (Christofoletti, 1980).

The analyzed drainage system of the basin proved to be of 5th order (Figure 2), according to the Strahler methodology at scale 1:100,000, which showed that the basin had a drainage system with significant branching. It was also possible to verify the existence of a large amount of tributary streams of order 1 (Table 1) which, according to Wisler and Brater (1964; see Duarte et al., 2007), is a typical characteristic of rugged terrains.

The drainage system is composed of the principal or trunk stream and its tributaries, and the indexes used to characterize it are the order of the stream channels and the drainage density. In this study, the classification presented by Strahler (1952; in Christofoletti, 1980), in which the the stream channel without any tributaries are of "order 1", or first order streams. Stream channels of 2nd order are those that receive only first order tributaries, independently of the number of tributaries. Likely, those of third order are those that receive two or more second order tributaries, with also the possibility of receiving any number of first order tributaries as well, and the same for successive, higher hierarchies (Christofoletti, 1980).

Shape is one of the physical characteristics more difficult to be expressed in quantitative terms. The shape of a basin, as well as the form of a drainage system, may be influenced by some other physical characteristics of the region, mainly the geological composition, in addition to be acting upon the hydrological processes or the hydrological behavior of the basin.

The shape of the basin has direct influence upon the concentration time, that is, the necessary time for the whole basin directly contributes to the outlet runoff after a precipitation event (Romanovski, 2001; see Duarte et al., 2007). The indexes normally used are those such as the compaxity coefficient (Kc), the shape factor (F) and the circularity index (Ic). The obtained value for these indexes are presented in Table 2.

The drainage area was found to be 389.3 km^2 and its perimeter was estimated in 136.9 km. Due to structural influence, such as the presence of faults, fractures and basculated blocks, the shape of the RPHB appears as elongated and irregular and with a drainage system that presents a dendritic and palallel pattern. It is also noted the asymmetry of the valley between the right and left margins. These morphological parameters may be better estimated by means of calculation of the compaxity coefficient and the shape factor. The first one was calculated in 1.942961, which implies that the basin is not subject of flooding during years of normal precipitation, since this coefficient is quite different to unity. It is known that the closer to unity this index is, the larger the possibility for the whole area to be contributing to the trunk stream in only one episode.

The shape factor estimated for the basin has a value of 0.196202, which is showing that it is a low value and that also indicates that the basin is only marginally subject to flooding, that is, the tributaries

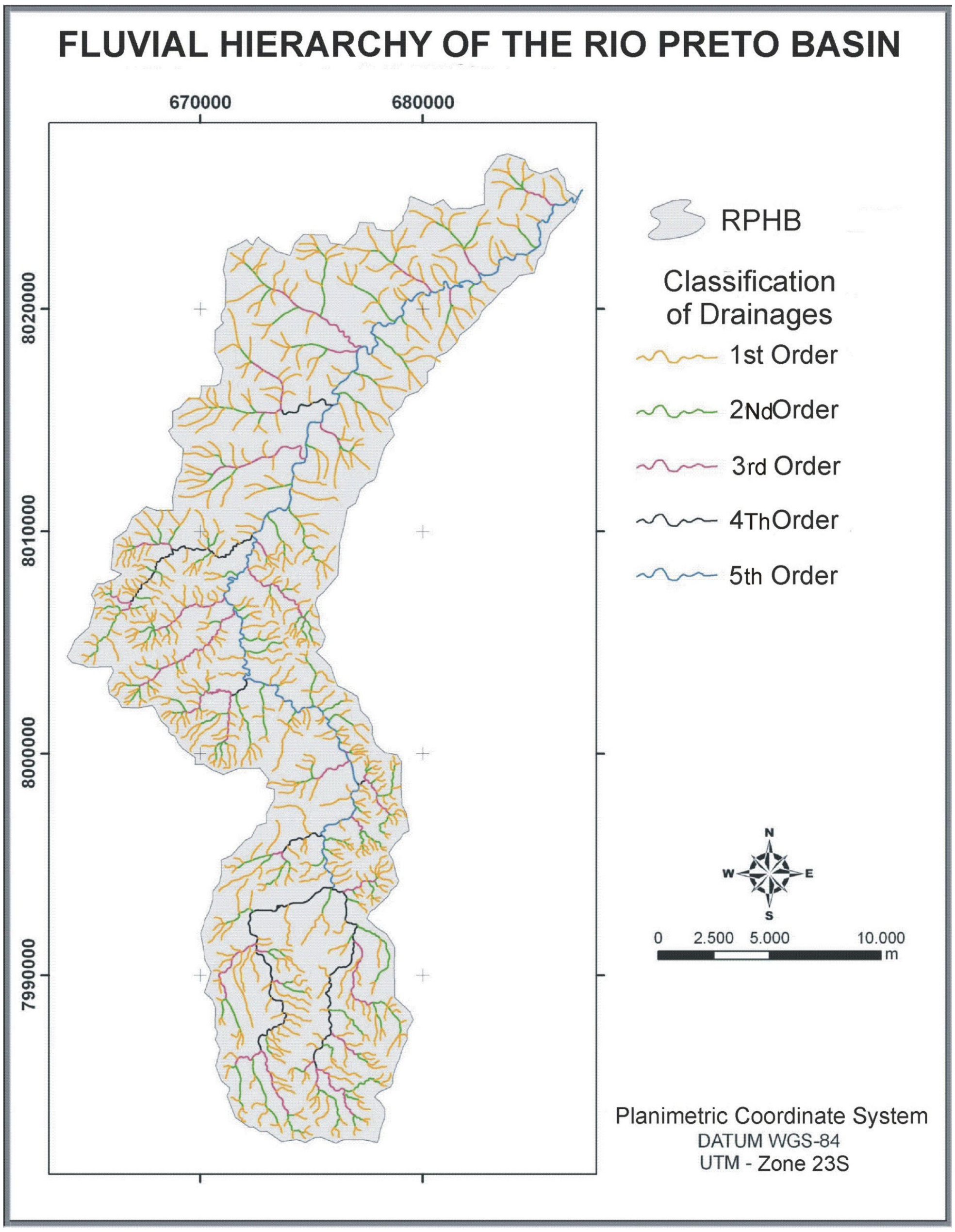

FIGURE 2. Fluvial Hierarchy of the Rio Preto Basin.

TABLE 1. Figures corresponding to the fluvial hierarchy of the Rio Preto Hydrographic Basin (RPHB), (following Strahler, 1952; in Christofoletti, 1980).

Order	Number of channels	Total Lenght of the channels	Mean Length of the channels
1st	665	564.314 km	0.848 km
2nd	158	165.161 km	1.045 km
3rd	38	88.759 km	2.335 km
4th	7	43.838 km	6.262 km
5th	1	62.160 km	62.16 km
TOTAL	**869**	**924.232 km**	**1.063 km**

TABLE 2. Physical characteristics of the Rio Preto Hydrographic Basin (RPHB).

Physical characteristics	Results
Surface of the Hydrographic Basin (km²)	389.298648
Perimeter (km)	136.913897
Axial length of the Basin (km)	44.544
Lenght of the Principal or Trunk stream (km)	62.160
Compaxity Coefficient	1.942961
Shape Factor	0.196202
Circularity Index	0.261049
Drainage Density (km.km-²)	2.374095
Order of the Basin	5th order

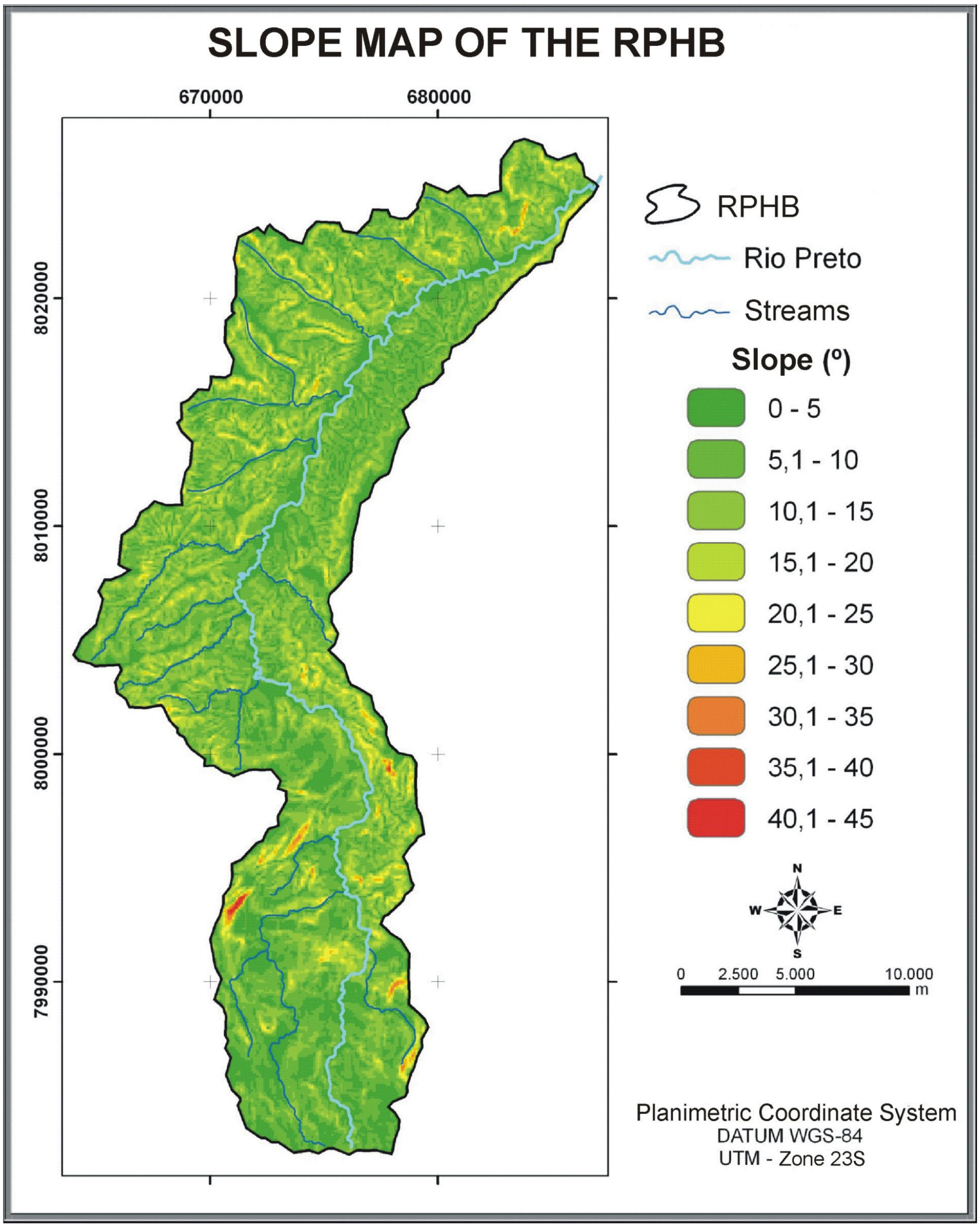

FIGURE 3. Slope map of the Rio Preto Hydrographic Basin (RPHB).

reach the main stream in many different points.

The circularity index was found to be about 0.261049, a value that also demonstrates that the basin is elongated, because this figure departs from the unity, indicating a smaller risk of large floods in normal conditions of annual precipitation, with a topography highly favorable to surficial runoff.

The drainage density index was estimated in 2.374095 km.km-[2], for the entire basin, which demonstrated that this a basin with highly branching drainage network. Visually, this figure is due to the high slopes and high branching rates present in the southern portion of the basin, which in this case shows differential responses to the precipitation, that is, the surficial runoff becomes faster in the southern portion.

In general, the RPHB presents medium to high slope indexes. In Figure 3, the slope distribution in the study basin are depicted, allowing the observation of a larger concentration of high slopes in the southwestern portion of the basin, in which the higher elevations occur abruptly, with strong influence of the geological structure in the area, with significant inicidence of major faults.

The hypsometric map (Figure 4) shows that the RPHB extends between elevations of 670 to 1820 m a.s.l. The elevations in between 670 and 1000 m a.s.l., occur in the central and northern parts of the basin, as well as in its sides, both to the east and the wesdt. The area above the main channel, in the southern end of the basin, concentrates the steeper slopes, through a short space between 1000 and 1820 m a.s.l.

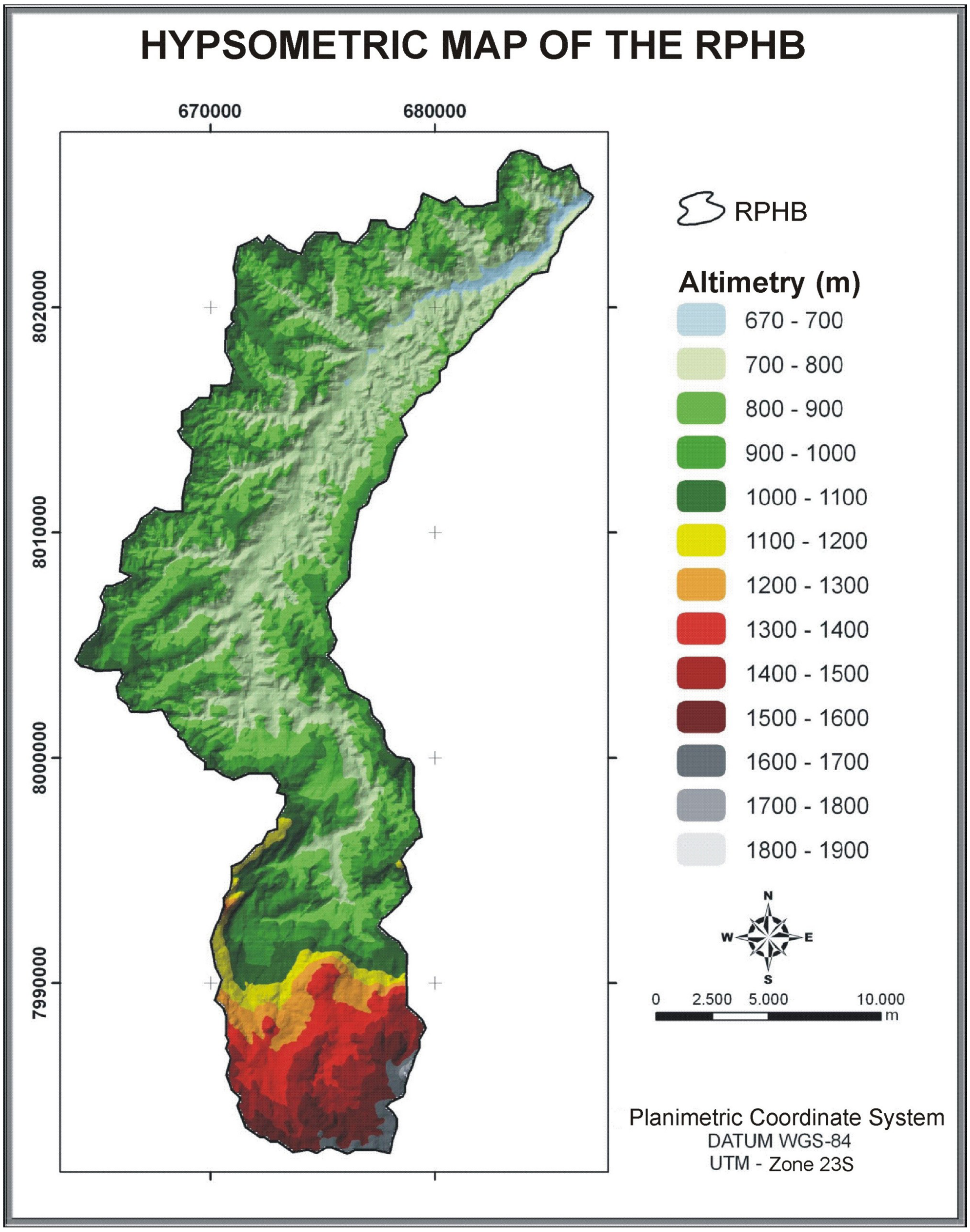

FIGURE 4. Hypsometric map of the Rio Preto Hydrographic Basin (RPHB).

CONCLUSIONS

According to the obtained data, the RPHB, in its natural state, without human interference, is only slightly subject to flooding, as a consequence of its elongated shape as revealed by the basin shape indexes. Being it a 5th order basin, it shows a significant branching ratio and a medium drainage density, suggesting a high degree of relief downcutting.

The GIS became a very appropriate tool for this kind of studies, because as the morphometric characteristics of the basin were obtained, it was possible to correlate them with several controlling factors, by means of the preparation and superposition of the thematic maps.

Such results are only a small portion of a project that is being developed. In the future, a geomorphological characterization and dating of the ancient summit surfaces and the unconsolidated Neogene deposits, in addition to other studies which are part of a larger project devoted to the differentiation of karst landscapes developed on siliciclastic rocks in the southern Serra do Espinhaco, Brazil, with financial support of FAPESP, a public organization devoted to the financial support of scientific projects in the state of São Paulo.

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