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WATER-COURSES MAPPING WITH LOW NATURAL REGULARIZATION CAPACITY

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ABSTRACT: This paper describes the studies and the methodology for mapping the water-course flows with low natural regularization capacity and located in the hydrographic regions of the Minas Gerais state and adjacent areas in Espírito Santo and Bahia states, Brazil. The relationship between the maximum water availability represented by average flow and the minimum flow during dry season is an indicator of the need for natural regularization of a water-course. This indicator so-called as minimum flow index (mfi = $Q_{7,10}/Q_{mlp}$) was estimated, by using temporary series of 307 fluviometrics stations located in the regions under study. The results were grouped into four class intervals, in which the interval of the low natural regularization capacity was established when mfi ≤ 10%). The extreme values (maximum and minimum) were identified in São Francisco basin river, that are: a) sub-basin of the Carinhanha river showing higher natural regularization capacity (mfi from 41 up to 70%), and b) sub-basin of the Verde Grande river that showed the lowest flow rates (mfi ≈ 1% Q_{mlp}). In the 58 river cross sections identified in this study as those showing low natural regularization capacity, a special attention to the management of the hydric resources is recommended to their administrators.
KEYWORDS: aquifer, minimum index flow, management of hydric resources

INTRODUCTION: In different stages of water resources planning is necessary to know the temporal and spatial flows distribution of the water courses. The flows average should not be considered as a single parameter to represent the water availability, because the flow of the rivers depend on the seasonality and climate variability. So, critical periods in terms of water availability must be evaluated to ensure a safety margin to the activities of planning and management. The flows of the dry period can be analyzed according to the frequency of occurrence in a cross section of the river basin. The relationship between maximum water availability represented by the average flow, and the minimum flow rate of the dry period is an indicator of the need for natural regularization of a water-course. The relationship between maximum water availability represented by the average flow and the minimum flow rate of the dry period is an indicator of the need for natural regularization of a water-course. This indicator, called minimum index of flow (mfi = $Q_{7,10}/Q_{mlp}$), depends on the capacity of regularization of the natural water-course, that is, as lower this index is greater will be the variation of the flow during dry periods, with a low natural flow regularization capacity (TUCCI, 2002). The values of those indexes increase as long as the course of water shows higher regularization capacity. In general, the hydrographic basins on the sedimentary formations, with a greater drainage area and/or a regular rain regime, flows during the dry period will be in the range of 20- 30% of the average flow, and can reach 70%. On the other hand, the basins on crystalline formation and an irregular rains regime, present very low flow rate during the dry period, usually, less than 10% of the average flow (ANA, 2005). Since the decade of 1960, several studies have been developed toward a better understanding of the interaction between surface and underground water systems. Several analytical solutions trying to describe the interactions between confined, semi-confined and free aquifers as well as their effects on the flow of the rivers are found in the available literature. For semi-confined aquifers a few analytical

solutions are available. This is due to the complications involving the analysis of the stratum semi-permeable overlaid the aquifer (ZHANG, 1992; BARLOW & MOENCH, 1998). Since the decade of 1960, several studies have been developed toward a better understanding of the interaction between surface and underground water systems. Several analytical solutions are found in the literature trying to describe the interaction between confined, semi-confined and free aquifers and its effects on rivers flow rate. For semi-confined aquifers a few analytical solutions are available. This is due to complications involving the analysis of the stratum semi-permeable overlaid the aquifer (ZHANG, 1992; BARLOW & MOENCH, 1998). According to LIMA et al. (2007), the analytical solutions used for confined aquifers also apply to free aquifers conditions, replacing the storage coefficient by effective porosity. Other researchers JORDAN (1977), LANE (1983) AND WALTERS (1990) analyzed river systems specific aquifer according to the rate of flow decrease along rivers course. In Brazil for the semi arid region the publications of ARAUJO & RIBEIRO (1996), REGO (2001), ARAUJO (2002) and LIMA (2004) present themselves as pioneers in this research line.
Other several aquifer modeling and system aquifers can be found in ILLANGASEKARE & MOREL-SEYTOUX (1982), GOMES (1990) and Xi CHEN & XUNHONG (2003). In the present study besides pointing out the absence of information about the behavior of the rivers flow in dry period, which occurs in a river aquifer-system, aims to provide subsidies to the organs managers responsible by the management of water resources in the state of Minas Gerais. It analyses the relationship between the flow rates that occur during dry periods and the flow averages, to identify and mapping by using the geographic information systems, the water-courses with low natural regularization capacity.

METHODOLOGY: The river basins selected for application of the methodology understand the hydrographic areas of the Minas Gerais state, besides the portions of the Doce, São Mateus, Barra Seca and Itaúnas rivers belonging to the state of Espírito Santo and the portions of the Jequitinhonha and Pardo rivers belonging to the Bahia state (total area of 661.748 Km2), and the historical series period from 1950 to 2002. The index of minimum flows (mfi) was estimated using by the ratio between the minimum flow rates (minimum flow of seven-days-duration and return period of ten years - Q7,10) and the anual daily flow average (average flow of long period - Qmlp). It was used temporary series of 307 fluvial station located in the study area (HIDROTEC, 2007). The minimum flow values (Q7, 10) were obtained on the basis of hydrological statistical through adjustments of the distributions of probabilities of Weibull and log-normal, at three parameters, to the data of minimum flows of dry period, of the each fluvial station. The data were processed using the computer program regionalization hydrology RH, version 4.0, developed under the HIDROTEC program and available in Atlas (2007). The ranges of the index of the minimum flow were established based on broad collection of hydrological information (directors plans of water resources), local information and with the application of the statistical method of Sturges' grouping. To this statistical procedure it was used a software system for Statistics Analysis-SAEG, version 9.1 (SAEG, 2007).

RESULTS AND DISCUSSION: The results were grouped into four class intervals using the criterion: low capacity of regularization (mfi $\leq$ 10%); average capacity of regularization (mfi of 11 up to 30%); high capacity of regularization (mfi of 31 up to 40%), and very high capacity for regularization (mfi of 41 up to 70%). Using the geographic information system, ArcGis 8.3 (ESRI, 2002), the fluvial sections of the studied regions, with a low natural regularization capacity (mfi $\leq$ 10%), was plotted. The Figure 1 illustrates graphically (output file RH 4.0) the adjustment of the Weibull probability distribution of the data of minimum flows of the Carinhanha River, at São Gonçalo, while Figure 2 indicate the locations where the rivers sections (stations), had a low capacity of natural regularization in the hydrographic region (Alto Médio São Francisco basin), in Minas Gerais.

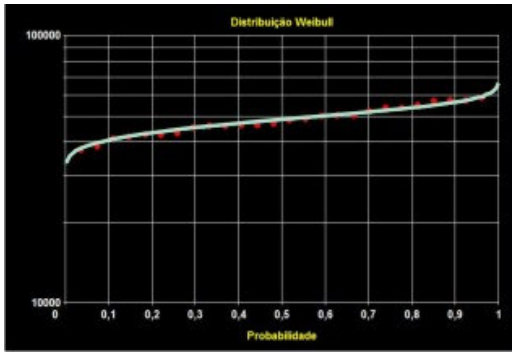

Figure 1 - Adjust of the Weibull distribution to the Carinhanha River minimum flows, in São Gonçalo.

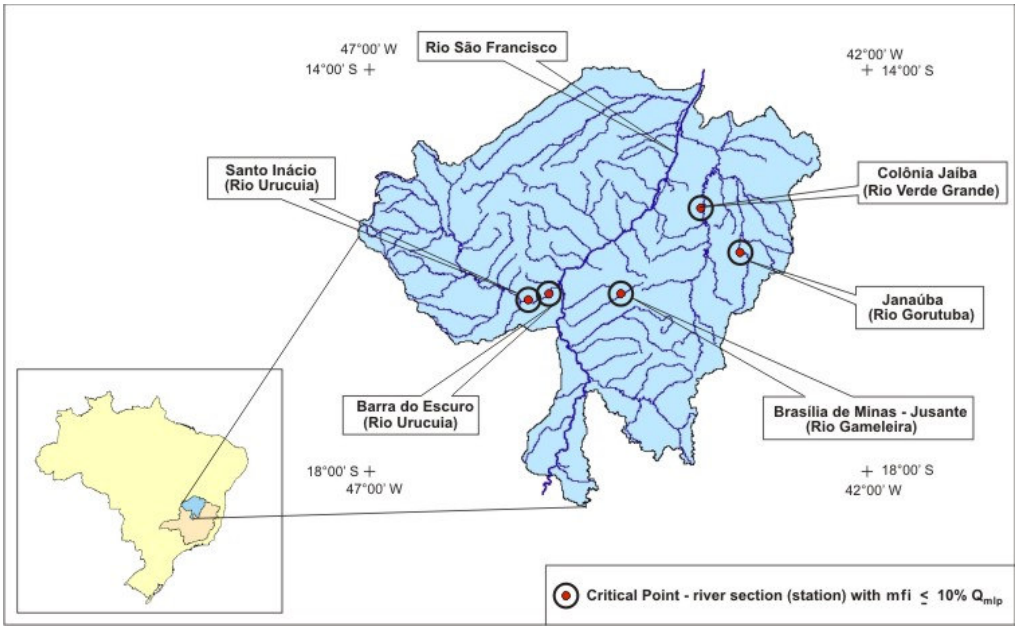

Figure 2 - Localization of the fluvial stations showing the low natural regularization capacity in hydrographic region (*Alto Médio São Francisco* basin), in Minas Gerais.

The results allowed identifying 58 sections of the rivers with low natural capacity of regularization. The river basin that showed greater capacity of natural regularization was the Sub-basin of Carinhanha River, located on the left bank of San Francisco River, border of the Minas Gerais and Bahia states. In this sub-basin index of minimum flow (mfi) fall inside of the class ware natural regularization capacity is very high (mfi of 41 to 70%) showing the influence of the Urucuia-Areado aquifer, (predominant in this sub-basin), in the maintenance of base flow to the river. Overall, the water availability of this aquifer system is high. It is important to underline that smaller minimum index of flows (mfi ≈ 1%) were identified in the sub-basin of the Verde Grande river, tributary of the right bank of the San Francisco river. This hydrographic region, under the influence of the Bambuí aquifer presents areas of intense exploitation of water. It is essential to emphasize that the calculation of flows for the dry period was based on data observed from fluvial stations and therefore in some hydrographic regions the results may be suffering influences of any regularization and/or consumptive uses.

CONCLUSION: In 58 cross section of rivers identified in this study showing a low capacities of natural regularization, a special attention to the management of the hydric resources should be recommended to their administrators. In addition, the water administrators should be careful with regard to disposal of effluents and ecosystems conservation. Aiming increase the supply of water in

these basins with low natural regularization capacity, it is recommended:: a) The allocation of water should be associated with the construction of reservoir regularization, b) The treatment of the effluents before they are disposed into water bodies should be taken into account by the granting of water, c) use of the reference flow according to the specific characteristics of each sub-basin ; d) introduction of the seasonal granting of water according to the modality which are designed water resources.

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