



Research Article

Michelle da Silva Honório*, Roberta Vieira Nunes Pinheiro, Isabella Almeida Costa, and Paulo Sérgio Scalize

Comparison of two methods for determining Q_{95} reference flow in the mouth of the surface catchment basin of the Meia Ponte river, state of Goiás, Brazil

<https://doi.org/10.1515/eng-2020-0053>

Received Mar 11, 2020; accepted Apr 27, 2020

Abstract: The preferred data for analyzing water availability are those of historical flow series of the sources of interest; however, most Brazilian watersheds do not have sufficient fluviometric monitoring. Such cases require techniques for transposing data from one region to another, otherwise known as ‘flow regionalization’. The present work aimed to compare the method proposed by Secretaria de Meio Ambiente e Desenvolvimento Sustentável (SEMAD) of the state of Goiás with the traditional method of regionalization for determining reference flow at the mouth of the surface catchment basin of the Meia Ponte river. Data from eight fluviometric stations were used for regionalization, with the regression equations being adjusted using four different models. The result revealed that the potential and linear models performed the best, both with R^2 and R^2_a values of 0.996 and 0.995, respectively. The relative error in the application of the potential model and of the method adopted by SEMAD were below 30%. The reference flows obtained by the two best performing methods differed, with flow determined by the traditional method being 5.93% lower than that of the SEMAD equation. Therefore, a more detailed study is recommended to determine which equation models better fit the region.

Keywords: Ecological flow, Regionalization, Water resources

***Corresponding Author: Michelle da Silva Honório:** Postgraduate Program in Environmental Sciences, Universidade Federal de Goiás, Goiânia, Brazil; Email: honorio.michelle@hotmail.com

Roberta Vieira Nunes Pinheiro: Civil and Environmental Engineering School, Universidade Federal de Goiás, Goiânia, Brazil; Email: robertavnp@gmail.com

Isabella Almeida Costa: Postgraduate Program in Environmental Sciences, Universidade Federal de Goiás, Goiânia, Brazil; Email: isabellaalmeidacosta@hotmail.com

1 Introduction

According to Brazilian Federal Law nº 9.433 of 08 January 1997 [1], also called Lei das Águas (Law of the Waters), to ensure the availability of water for current and future generations, management of water resources must provide for multiple uses and should be decentralized, with participation of all stakeholders, from the government to the community. Given these fundamentals of the main Brazilian legislation in force for over twenty years, the importance of studying the constituents of water resources management, such as watersheds, is clear. Various aspects of these territorial units must be characterized, such as: contribution area, main river and its tributaries, planning, slope, rainfall regime, land use and occupation, climate and flow. This last characteristic is certainly the most relevant, and poses important questions, including: What is the water availability of a given basin? How much water can be reserved? How much water should be kept in water sources to maintain ecosystems? These, among other questions, can only be answered after analysis of the flow present in a basin, which, depending on the purpose of the study, can be maximum flow, minimum flow, permanence flow and/or long-term average flow.

For the analysis of water availability, it is, according to Fioreze *et al.* (2008) [2], preferable to use data from historical series of flows of the sources of interest. For most Brazilian watersheds, however, sufficient fluviometric monitoring is lacking. Such cases, therefore, require techniques for transposing data from one region to another. This method, called ‘flow regionalization’, exploits

Paulo Sérgio Scalize: Postgraduate Program in Environmental and Sanitary Engineering (PPGEAS) and Environmental Sciences (CIAMB), Universidade Federal de Goiás (UFG), Goiânia, Brazil; Email: pscalize.ufg@gmail.com

the maximum amount of hydrological information available to estimate values in locations without data or with other faults [3].

According to Wolff *et al.* (2014) [4], two of the most used methodologies for flow regionalization stand out: application of regression equations to hydrologically homogeneous regions, and automatic extrapolation in an information systems environment. Considering the available options, it is necessary to analyze which methodology is viable for any particular study.

In addition to regionalization methods, it is important to determine which flow is to be studied. According to Silva *et al.* (2015) [5], such calculated values are also used as reference flows for granting use privileges by water resource management bodies, which directly influence total water available for withdrawal.

Brazilian states generally adopt different flows in their studies for granting use privileges, taking into account local reality and the hydrological and climatic characteristics of each location. According to Santos *et al.* (2006) [6], the states of Bahia, Ceará and Distrito Federal, adopt Q_{90} , which means that the flow is present 90% of the time, while the other 10% of the time the flow is not met. In contrast, the states of Paraná, Minas Gerais and Rio de Janeiro work with $Q_{7,10}$, the minimum flow present during seven consecutive days with the time of ten years of return.

For studies of water availability in the state of Goiás, Resolution n^o 09/2005 of Conselho Estadual dos Recursos Hídricos (CERH) [7] determines that the flow adopted as a reference for granting water use privileges is the flow that guarantees permanence 95% of the time (Q_{95}), that according to Bazzo (2017) [8] is the flow that equals or exceeds in 95% of the time, that is, 5% of the time the flow present in the river will be less than Q_{95} . However, Instrução Normativa (IN) n^o 04/2015 of Secretaria de Meio Ambiente e Desenvolvimento Sustentável (SEMAD) of Goiás [9] determines that for the calculation of water availability, the specific reference flows (Q_{95} specifically) previously defined in IN must be adopted.

In view of the above, and with the purpose of expanding scientific research on water resources and important hydrological variables for the management of water resources in the state of Goiás, the present work aimed to compare the traditional method of flow regionalization with the method used by SEMAD, to determine which method best determines reference flow (Q_{95}) at the mouth of the surface catchment basin (SCB) of the Meia Ponte river.

2 Methods

The state of Goiás, encompassing 340,111,78 km² in the Center-West Region of Brazil, contains 246 municipalities and has a population of 6,434,048 inhabitants [10]. The Meia Ponte river watershed is located in the south-central region of the state and is one of the most important basins in Goiás as it covers about 12,180 km² or 4% of its territory, while the river itself is the main water source for the population of Goiânia, the state capital.

The study area of the present work is the surface catchment basin (SCB) located in the upper part of the Meia Ponte river watershed (Figure 1). It encompasses an area of 1,633.23 km² in 10 municipalities: Itauçu, Inhumas, Ouro Verde de Goiás, Goianira, Brazabranes, Nova Veneza, Damolândia, Nerópolis, Santo Antônio de Goiás and a small part of Goiânia.

A methodology involving three stages was employed to compare reference flows, which in the state of Goiás are represented by Q_{95} . The first stage consisted of conducting a flow regionalization study, for which fluvimetric data were obtained from eight stations located throughout the Meia Ponte river watershed (Figure 1), by means of accessing the HIDROWEB platform of Agência Nacional de Águas (ANA; National Water Agency). The regionalization method applied was that proposed by ELETROBRÁS (1985a) [11], and here called the Traditional Method. The main characteristic of the Traditional Method is the application of regression equations to obtain the flow in any part of the drainage of the basin under study [12].

Pre-processing of the data was thusly carried out using SisCAH 1.0 software to select periods in common among stations with continuous data (i.e. no failures at any of the stations). Therefore, historical series between 32 and 34 years old were used and a hydrological year of September to August was adopted due to the climatic characteristics of the region. The data period used for all stations was between 1980 and 2014, with the exception of station 60680000, for which the period of between 1980 and 2012 was adopted due to the availability of data specifically from its fluvimeter. Since the Q_{95} for a given season does not depend on the Q_{95} of others, there is no problem adopting this period with a two-year difference in the data.

It is important to note that of the 13 existing stations in the Meia Ponte river watershed, it was possible to use the historical series could only be used for eight since no data records were found in the HIDROWEB database for the other stations.

With the Q_{95} values and the respective areas of each fluvimetric station within the same watershed, it was

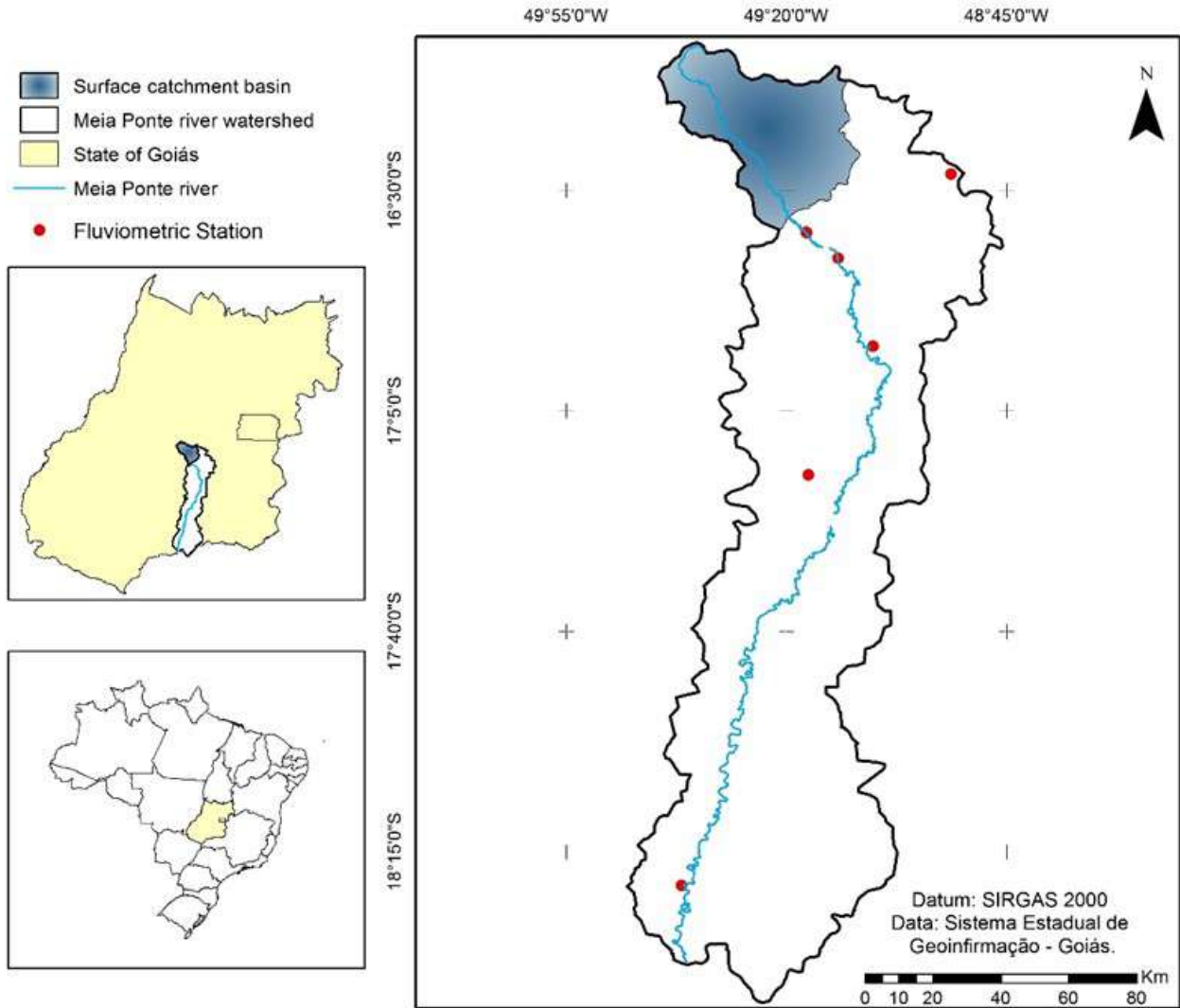


Figure 1: Study Area – Location of the surface catchment basin of Meia Ponte river where the fluviometers used in this study are located.

possible to apply regression models with the dependent variable being the reference flow present 95% of the time (Q_{95}) and the independent variable being the area of contribution of the fluviometric stations. The equations were obtained using SisCORV 1.0 software and adjusted using five different regression models: linear model, potential model, exponential model, logarithmic model and reciprocal model, according to Equations 1, 2, 3, 4 and 5 [2, 12, 13].

– Potential Model:

$$Q = \beta_0 X_1^{\beta_1} X_2^{\beta_2} + \dots X_m^{\beta_n} \quad (1)$$

– Linear Model:

$$Q = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \beta_n X_m \quad (2)$$

– Exponential Model:

$$Q = e^{\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \beta_n X_m} \quad (3)$$

– Logarithmic Model:

$$Q = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \dots \beta_n \ln X_m \quad (4)$$

– Reciprocal Model:

$$Q = (\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \beta_n X_m)^{-1} \quad (5)$$

The second stage consisted of estimating reference flows using the previously found regression equations and the methodology indicated by SEMAD of Goiás in its *Manual Técnico de Outorga* [14]. The procedure used by SEMAD consists of determining reference flow through the product of the specific Q_{95} , which for the Meia Ponte river water-

shed is 4.32 L/s.km², and the contribution area upstream of the point of interest, according to Equation 6.

$$Q_{95} = Q_{95spe} * DA \quad (6)$$

Where:

Q_{95} = flow present 95% of the time (L/s);

Q_{95spe} = specific flow (L/s.km²);

DA = drainage area (km²).

Finally, the third stage evaluated the precision of the method used by SEMAD and of the regression models proposed herein using the relative error (RE) between observed and estimated flows [15], which is given by Equation 7.

$$RE = 100 * \frac{Q_{obs} - Q_{est}}{Q_{obs}} \quad (7)$$

Where:

RE = relative error (%);

Q_{obs} = observed flow obtained from the analysis of the historical series at fluvimetric station (m³/s);

Q_{est} = estimated flow based on regionalization methodologies (m³/s).

As described by ELETROBRÁS (1985b) [16], RE values of less than 30% are considered acceptable, and can be presented in a negative way, indicating overestimation of flow, or in a positive way, indicating underestimation of flow. The method with the best performance was selected by taking into account the regression equation that presented the highest coefficient of determination R² and R²a and the lowest relative RE between observed and estimated flows[12].

3 Results and Discussion

3.1 Regression equations obtained by the Traditional Method

Table 1 shows the drainage areas and Q_{95} values for the eight fluvimetric stations used in the regionalization study.

As can be seen in Table 1, the contribution areas for the fluvimeters ranged from 51 to 11,527 km², and so it is important to note that the generated regionalization equation should not be applied to areas that require extrapolation above or below this range. According to Silveira *et al.* (1998) [17], the technique should not be applied outside the limits established by regional equations and especially for basins with areas smaller than 100 km², because the mechanism for transforming rain into flow occurs differ-

ently in small basins since they have very specific physical characteristics.

SisCAH 1.0 *software* was used to obtain flow rates present 95% of the time for all stations, which ranged 0.257 – 41.824 m³/s. Using these values, and their respective contribution areas, Equations 8, 9, 10, 11 and 12 were obtained, which are the regression models for estimating Q_{95} in the Meia Ponte river watershed.

– Potential Model:

$$Q_{95} = 0.0006 * A^{0.9478} \quad (8)$$

– Linear Model:

$$Q_{95} = 0.665 + (A * 0.0036) \quad (9)$$

– Exponential Model:

$$Q_{95} = 2.179 * 2.718A^{0.00029} \quad (10)$$

– Logarithmic Model:

$$Q_{95} = 37.243 + (6.713 * \ln A) \quad (11)$$

– Reciprocal Model:

$$Q_{95} = (0.951 + (A * -0.000115))^{-1} \quad (12)$$

Table 2 shows the results obtained for the coefficients of determination R² and R²a, as well as the standard error of the proposed models.

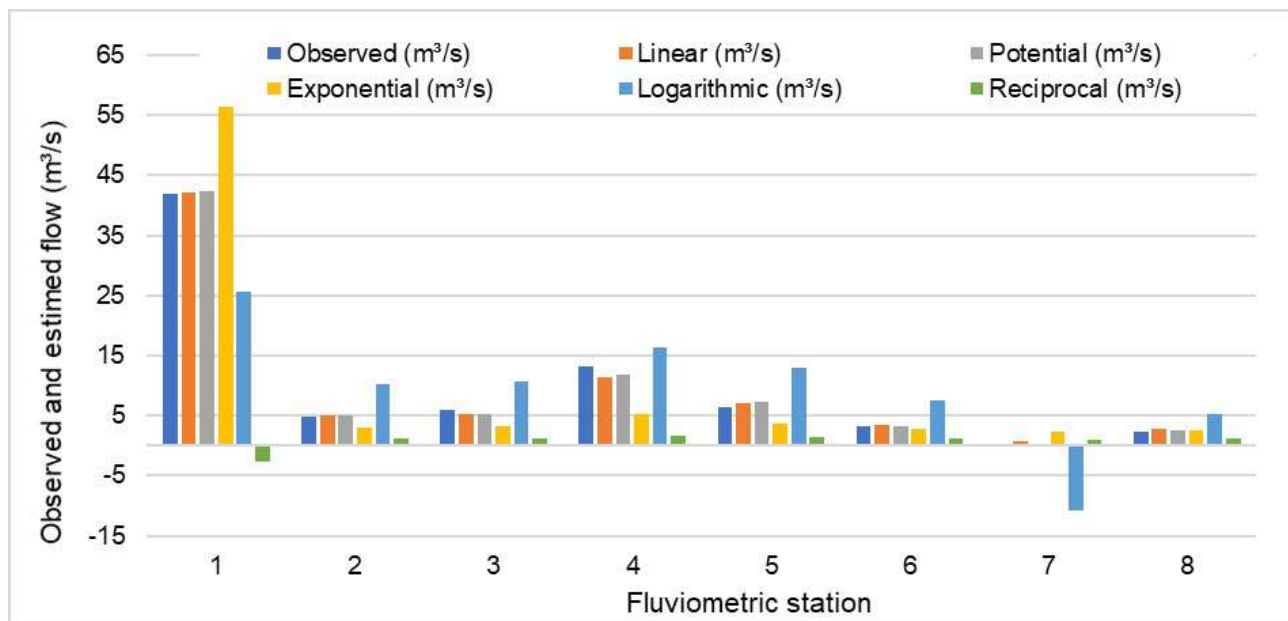
The results reveal that the potential and linear models had the best performance, with R² and R²a of 0.996 and 0.995, respectively. However, the standard error for the potential model was about ten times smaller than that of the linear model. The potential model had an adjusted coefficient of determination (R²a) of 0.99, which indicates that the proposed equation model is quite explanatory and fits the data well. Thus, the dependent variable, in this case a Q_{95} , is satisfactorily explained by this regression equation.

The exponential, logarithmic and reciprocal models had low values of R² and R²a, revealing them to be of low performance. A classification range for the coefficient of determination could not be found, but it is known that values closer to 1 indicate better models. This is because, according Naghettini & Pinto (2007) [18], in short, R² represents how much of the variability of the studied function a model can explain.

To compliment the analysis of the proposed models, Figure 2 presents the results of the estimated flows for each station in relation to observed flows. The linear and potential models obtained estimated values closer to the true values, while the others presented discrepant values and so their use is not recommended for estimating flow in this case.

Table 1: Information on the fluviometric stations used.

ID	Station	Station name	Observed period	Contribution area (km ²)	Q_{95} observed (m ³ /s)
1	60680000	Ponte Meia Ponte	1980 - 2012	11,527	41.824
2	60665000	Professor Jamil	1980 - 2014	1,198	4.767
3	60654000	Fazenda Sucuri	1980 - 2014	1,265	6.008
4	60650000	Jusante de Goiânia	1980 - 2014	2,970	13.146
5	60640000	Montante de Goiânia	1980 - 2014	1,798	6.435
6	60642000	Captação João Leite	1980 - 2014	781	3.267
7	60653000	Ribeirão das Caldas	1980 - 2014	51	0.257
8	60635000	Inhumas	1980 - 2014	568	2.243

**Figure 2:** Observed flows and flows estimated by the studied models.**Table 2:** Values of R^2 , R^2_a and standard error.

Model	R^2	R^2_a	Standard error
Potential	0.996	0.995	0.099
Linear	0.996	0.995	0.921
Exponential	0.561	0.488	1.051
Logarithmic	0.590	0.522	9.342
Reciprocal	0.109	-0.039	1.338

3.2 Relative error (RE)

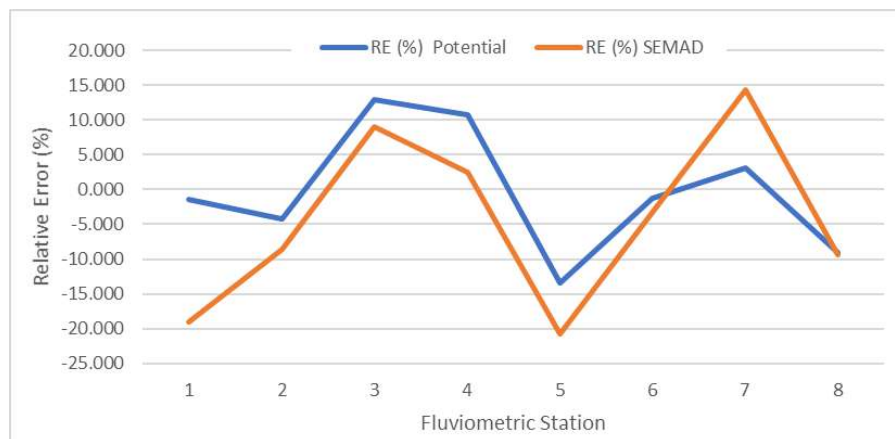
To assess the accuracy of the methods, the RE between the observed and estimated values was calculated according to Moreira & Silva (2014) [15]. Table 3 shows the RE values, which were calculated for the two models that had the best performance – linear and potential – and for the model used by SEMAD.

The REs calculated from the flow estimates obtained by the Traditional Method using the potential model were between -13.34 and 12.98% , at stations 5 and 3, respectively. The REs calculated from the flow estimates obtained by the Traditional Method using the linear model were between -230.19 and 13.61% , at stations 7 and 4, respectively. The REs calculated from the flow estimates obtained by the SEMAD method were between -20.70 and 14.27% , at stations 5 and 7, respectively.

The linear model had higher RE values than the others, however, only at station 7, Ribeirão das Caldas, was there a value above 30% , which is considered unacceptable by the method applied. This station had an overestimated flow of more than 200% , however, it has a contribution area of 51 km^2 , making it the smallest area for the set of analyzed stations. According to Junior *et al.* (2003) [19], there are several limitations that generate uncertainties in results for smaller watersheds. According to Silveira *et al.*

Table 3: Percent relative error (ER) and Q_{95} values in m^3/s , obtained from the analysis of historical series and estimated by different methods of flow regionalization.

ID	Station	Station name	Potential			Linear		SEMAD	
			Q_{95obs}	Q_{95est}	RE(%)	Q_{95est}	RE(%)	Q_{95est}	RE(%)
1	60680000	Ponte Meia Ponte	41.824	42.447	-1.489	42.162	-0.809	49.797	19.062
2	60665000	Professor Jamil	4.767	4.965	-4.152	4.978	-4.422	5.175	-8.566
3	60654000	Fazenda Sucuri	6.008	5.228	12.987	5.219	13.132	5.465	9.041
4	60650000	Jusante de Goiânia	13.146	11.739	10.703	11.357	13.609	12.830	2.401
5	60640000	Montante de Goiânia	6.435	7.295	-13.368	7.138	-10.922	7.767	-20.705
6	60642000	Captação João Leite	3.267	3.310	-1.311	3.477	-6.416	3.374	-3.273
7	60653000	Ribeirão das Caldas	0.257	0.249	3.026	0.849	-230.195	0.220	14.272
8	60635000	Inhumas	2.243	2.447	-9.117	2.710	-20.811	2.454	-9.396

**Figure 3:** Relative errors (REs) for the application of the potential model and the method used by SEMAD to estimate Q_{95} at the eight studied fluviometric stations.

(1998) [17], this happens because as basin area decreases the scale of detailing is reduced, which makes it difficult to characterize homogeneous regions.

The results for RE are provided in Figure 3 and show that the application of the potential model and the method adopted by SEMAD had values below 30%. In general, the potential model had estimated values closer to the observed, demonstrating better performance. This model has been widely used in the literature and has performed better when compared to others, as observed in the study of Ribeiro *et al.* (2005) [12], which compared flow regionalization methodologies for the Doce river basin and obtained the best performance with potential-type regression equations with an average RE of 16.56%. Fioreze *et al.* (2008) [2] evaluated the performance of flow regionalization equations for the Santa Bárbara river basin, with potential-type regression equations showing good performance for estimating Q_{95} with satisfactory REs. However, the use of the method proposed by SEMAD was not ruled out since the

results were also satisfactory, even though the RE values were higher.

3.3 Flow estimation at the mouth of the SCB of the Meia Ponte river basin

The equation indicated by SEMAD and the potential-type regionalization equation were used to estimate the reference flow values present 95% of the time at the mouth of the SCB and are shown in Table 4. The regionalization equation had a 5.93% lower flow than that of the SEMAD equation. It is noteworthy that without the possibility of applying other techniques, the use of the lowest estimate creates more security for a manager when it comes to granting water rights.

The equation indicated by SEMAD of Goiás uses specific flow as a reference, which for the Meia Ponte river and its tributaries is 4.32 L/s.km^2 . This information was obtained from the Plano de Recursos Hídricos da Bacia do

Table 4: Estimated Q_{95} .

Equation		Q_{95} (L/s)
$Q_{ref}=Q_{95esp} * DA$	Indicated by SEMAD	7055.55
$Q_{95}=0.0006 * (A^{0.9478})$	Proposed regionalization equation	6660.05

rio Paranaíba (water resources plan of the Paranaíba river basin), which does not make clear which method was used to obtain this specific flow rate, however, the Meia Ponte river watershed is over 11 thousand km^2 and its specific flow varies throughout the basin.

The regionalization equation for flow was obtained by analyzing eight fluvimetric stations present in the Meia Ponte river watershed, with historical series of 32 and 34 years old, which better describes the hydrological behavior in the region than the SEMAD equation. However, both methods use the contribution area of the fluvimeters to explain Q_{95} , and analysis of the results for flow estimates reveals that the values are on the same order of magnitude, with a difference of 5.93%.

In this case, the potential-type regression equation is recommended for use since the coefficients of determination were satisfactory and the RE was lower than that for the SEMAD equation. Nonetheless, due to the differences found in the results, adopting both flow monitoring techniques at the mouth of the SCB for a period of time is recommended, so that comparisons can be made between the observed and estimated data and a study of the performance of the two methods can be further developed.

It is important to note that such studies are of great relevance for the management of water resources, especially with regard to the granting of water rights. It is also noteworthy that this is a geographically and economically important region for the State and needs management of its water resources to avoid new conflicts over water use and maintaining the balance of the environmental system of the water sources.

4 Conclusions

It can be concluded that, based on the analyzed parameters, the potential model had the best performance of the four models analyzed using the Traditional Method. Comparing the potential model with the method used by SEMAD revealed it to have a lower RE, with estimated flows closer to the observed. The reference flows at the mouth

of the SCB of the Meia Ponte river obtained by the best performing methods differed, with the flow determined by the Traditional Method being 5.93% lower than that of the equation of SEMAD of Goiás.

The reference flows found here are on the same order of magnitude, however, their difference becomes relevant when it comes to water availability. Therefore, in order to support decision-making based on technical analysis, a more detailed study should be carried out that includes flow measurement at the mouth of the watershed and comparisons with other flow regionalization methods in order to determine which equation models best fit the region.

Acknowledgement: Thanks go to Pós-Graduação em Ciências Ambientais of Universidade Federal de Goiás and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), for funding the research.

References

- [1] Brasil. Lei nº 9.433, de 8 de janeiro de 1997. Regulamenta o inciso XIX do art. 21 da Constituição Federal, e altera o art. 1º da lei nº 8.001, de 13 de março de 1990, que modificou a lei nº 7.990, de 28 de dezembro de 1989. Diário Oficial da União, Poder Executivo, Brasília, DF, 09 jan 1997
- [2] Fioreze AP, Oliveira LFC, Franco APB. Avaliação do desempenho de equações de regionalização de vazões na bacia hidrográfica do Ribeirão Santa Bárbara, Goiás, Brasil. *Rev Ambi e Água* 2008;3(2):62-76, DOI:10.4136/ambi-agua.53.
- [3] Tucci CEM. *Hidrologia: Ciência e Aplicação*. 2. ed. Porto Alegre: ABRH/UFRGS; 2009.
- [4] Wolff W, Duarte SN, Mingoti R. Nova metodologia de regionalização de vazões, estudo de caso para o Estado de São Paulo. *Rev Bras de Rec Hídri* 2014;19(4):21-33. DOI: 10.21168/rbrh.v19n4.p21-33
- [5] Silva BMB, Silva DD, Moreira MC. Influência da sazonalidade das vazões nos critérios de outorga de uso da água: estudo de caso da bacia do rio Paraopeba. *Rev Ambi e Água* 2015;10(3):623-634. DOI:10.4136/ambi-agua.1587
- [6] Santos IH, Oliveira LG, Fioreze AP. Avaliação das Vazões Alocáveis na Bacia Hidrográfica do Rio dos Bois e sub-bacia do Rio do Peixe, Estado de Goiás. *Rev Bras Recur Hídri* 2006;11(2):47-58. DOI:10.21168/rbrh.v11n2
- [7] Secretaria de Meio Ambiente e Desenvolvimento Sustentável (Goiás). Resolução nº 09, de 04 de maio de 2005. Estabelece o regulamento do sistema de outorga das águas de domínio do Estado de Goiás e dá outras providências. Diário Oficial do Estado de Goiás 02 jun 2005; n.º 19.653.
- [8] Bazzo KR, Guedes HAS, Castro AS, Siqueira TM, Teixeira-Gandra CFA. Regionalização da vazão Q_{95} : comparação de métodos para a bacia hidrográfica do Rio Taquari-Antas, RS. *Rev Amb e Água* 2017;12(5):855-870. DOI: 10.4136/ambi-agua.2032.
- [9] Secretaria de Meio Ambiente e Desenvolvimento Sustentável (Goiás). Instrução Normativa nº 04. Define as vazões específi-

- cas para o Estado de Goiás com base em planos de recursos hídricos de bacias específicas e dados hidrológicos coletados de séries históricas para uso no cálculo de disponibilidade hídrica em cursos onde a captação é ou será realizada diretamente no curso d'água.
- [10] Instituto Mauro Borges [Internet]. Atlas do Estado de Goiás 2014 [cited 2019 nov] Available from: <http://www.sieg.go.gov.br>
- [11] Eletrobrás. Centrais Hidrelétricas Brasileiras S.A. Metodologia para regionalização de vazões. Rio de Janeiro 1985a.
- [12] Ribeiro CBDeM, Marques FA, Silva DD. Estimativa e regionalização de vazões mínimas de referência para a bacia do rio Doce. *Eng na Agríc* 2005;13:103-117.
- [13] Maciel AL, Vieira EM, Monte Mor, RC, Vasques, AC. Regionalização e espacialização de vazões de permanência: estudo aplicado na bacia rio piracicaba-MG. *Rev Bras de Climat* 2019;24:114-133.
- [14] Secretaria de Meio Ambiente e Desenvolvimento Sustentável [Internet]. Manual Técnico de Outorga, 2012 [cited 2019 nov] Available from: http://www.sgc.goias.gov.br/upload/arquivos/201507/manual_tecnico_de_outorga_versao_01.pdf
- [15] Moreira MC, Silva DD. Análise de Métodos para Estimativa das Vazões da Bacia do Rio Paraopeba. *Rev Bras Rec Hídr* 2014;19(2):313-324, DOI: 10.21168/rbrh.v19n2.p313-324
- [16] Eletrobrás. Centrais Hidrelétricas Brasileiras S.A. Manual de minicentrais hidrelétricas. Rio de Janeiro 1985b
- [17] Silveira GL, Tucci CEM, Silveira ALL. Quantificação de vazão em pequenas bacias sem dados. *Rev Bras de Rec Hídr* 1998;3(3):111-131. DOI: 10.21168/rbrh.v3n3.p111-131
- [18] Naghettini M, Pinto EJ. A Hidrologia Estatística. Belo Horizonte: CPRM; 2007.
- [19] Júnior OBDS, Bueno EDO, Tucci CEM, Castro NMR. Extrapolação Espacial na Regionalização da Vazão. *Rev Bras de Rec Hídr* 2003;8(1):21-37. DOI: 10.21168/rbrh.v8n1.p21-37