1 Article

2 Effect of a dense network of surface reservoirs on the 3 power demand for water distribution in a semiarid

4 basin

5 Tatiana Nascimento^{1,*}, Natália Cavalcanti¹, Bruno Castro¹ and Pedro Medeiros¹

6 ¹ Federal Institute of Education, Science and Technology of Ceará – IFCE

7 * Correspondence: tati16pinheiro@yahoo.com.br; Tel.: +55-85-3383-6370

8 Abstract: The power generation from hydroelectric plants has increased worldwide, contributing to 9 the participation of the renewable sources to the energy matrix. In the semiarid Brazilian Northeast 10 (NEB), thousands of small dams have been built over time as a solution for water supply. Although 11 incompatible with hydropower generation due to the conflict with human water supply in the 12 region, small reservoirs accumulate water and hydraulic energy at high altitudes. In this work, 13 simulations were performed to assess how the arrangement of various sized reservoirs impact the 14 power demand for water distribution in the Banabuiú River Basin - BRB (19,800 km²), Brazil. The 15 power required to pump water from all 1,405 reservoirs to the districts is 6.5 GWh/year, whereas in 16 the scenario with the 12 larger strategic reservoirs only, the power demand reaches 45.3 GWh/year. 17 Although representing roughly 60% of the water availability of the BRB and being able to supply 18 all the districts, the Arrojado Lisboa reservoir alone would demand 195 GWh/year to supply water 19 to the entire basin, i.e. 30 times the power required in the real reservoir arrangement. By storing 20 water at high altitudes and distributing it spatially, the small reservoirs increase the energy 21 efficiency on the water distribution system.

22 **Keywords:** energy efficiency; reservoir network; water supply.

23 1. Introduction

The population growth associated to the accelerated technological development has increased the demand for electricity. On the other hand, the use of non-renewable polluting power sources has caused environmental crisis, experienced in all the continents. In this way, the search for efficient systems and clean production has been a common task [1, 2].

According to Fitzgerald et al. [3], the power generation through renewable sources has grown, and hydroelectric plants fit within the perspective of clean power production and are globally accepted [4]. Okot [5] reported that Small Hydroelectric Power Plants (SHP's) are common in rural areas of developed and developing countries, and are included in a sustainable way of energy networks.

Mishra et al. [6] discussed on power generation in small reservoirs and stated that these
 structures present different associated uses. Among them, stand out human and animal supply,
 irrigation, flood prevention and environmental protection.

Water resources and energy are intrinsically related [7], for instance, for the production of hydroelectric energy it is necessary the storage of water. On the other hand, for water treatment and distribution on a catchment a source of energy is required. Abegaz et al. [7] pointed out that the increasing number of studies on this interdependence (water and energy) was induced by the climate crisis, which causes uncertainties both in water availability and in power production.

In Brazil, hydroelectric plants are responsible for approximately 65% of the installed capacity for
 power production [8]. Brazilian hydroelectric plants are mostly distributed in the south and southeast
 regions, where the potential for construction of new plants is low. On the other hand, the North and
 Center-West regions have great potential for hydroelectric development [9].

45 However, the Northeast of Brazil (NEB) is inserted in a semiarid region, naturally facing 46 atmospheric water deficits, with average annual precipitation and potential evaporation of 700 mm 47 and 2,000 mm, respectively, and shallow soils above crystalline basement [10]. Water scarcity in that 48 region is typical of other arid and semiarid environments, where approximately one-third of the 49 population suffers from the scarcity of running water [11]. The history of these civilizations was built 50 in the search for development of water supply techniques. Constructed as an alternative to periods 51 of rainfall deficits, surface reservoirs have become the main source of water supply, function as flow 52 regulators, accumulating water during the flood periods and releasing during the dry seasons.

Krol et al. [12] reported that the construction of a multiple dams network in the NEB has reduced their vulnerability to dry periods, constituting practically the only source of water for more than 90% of the local population. These reservoirs have several sizes, however small reservoirs, built without technical assistance, stand out. In a study by Malveira et al. [13] in the Upper Jaguaribe Basin, Brazil, the existence of thousands of small dams has been identified, with an average direct contribution area of 6.6 km² per reservoir.

The effective water supply for the districts requires the installation of adduction and distribution systems, both with consumption of electric power. In developed countries, the cost of water supply can easily represent half of the municipality's budget, as indicated by James et al. [14]. The same authors also pointed out that in percentage, the world consumption of power destined to the sector of water supply and sewage treatment for urban and industrial residences is between 2 and 3%.

Despite the high density of dams in the NEB, such network is incompatible with hydropower generation. However, small dams have an energetic benefit because they accumulate water at high altitudes and contribute to water democratization by bringing water to more remote districts, increasing the efficiency of the system [15, 16]. In this context, the present study aims to assess how the arrangement of small, medium and large reservoirs impact the power demand for water distribution in the Banabuiú River Basin (approximately 19,800km²), Brazil.

70 2. Materials and Methods

71 2.1. Study area

The Banabuiú River Basin (BRB) is located in the Northeast portion of Brazil, in a region officially recognized as the "Drought Polygon" (Figure 1), and drains an area of 19,800 km². The climate is semiarid, Bs' type according to Koppen classification [17], with average annual temperatures around

75 27°C and annual rainfall and potential evaporation of the order of 700 mm and 2,000 mm, respectively

76 [18].



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Figure 1. The Brazilian semiarid "Drought Polygon" and the Banabuiú River Basin with its surface
 reservoirs with areas larger than 5 hectares

80 2.2. Water availability and demand

81 The Banabuiú River Basin presents a dense network of surface reservoirs of various sizes. In the 82 basin, there are 18 strategic manmade surface reservoirs monitored by the Water Resources 83 Management Company of the State of Ceará (COGERH), with capacities ranging from roughly 1 x 84 10⁶ hm³ to 1.6 x 10⁹ m³, but the Foundation of Meteorology and Water Resources of the State of Ceará 85 - FUNCEME, mapped the reservoirs with areas larger than 5 ha and identified 1,405 of such structures 86 in the basin [19]. The worldwide survey of water bodies conducted by Pekel et al. [20] for 32 years 87 using 3 million LandSat satellite images, identified about 3,000 reservoirs at the BRB. The reservoir 88 network follows a cascade pattern already detected in previous studies in the Brazilian semiarid 89 region (for instance, GÜNTNER et al. [21]; MALVEIRA et al. [13]), with small reservoirs usually 90 situated upstream of larger ones. In this pattern, the inflow to each reservoir is constituted by the 91 sum of its direct contribution area with the spillages from the upstream reservoirs.

Despite the importance of the non-strategic surface reservoirs for water availability in the region, information on their storage capacities and the way they are constructed are scarce [22], and there is a lack of long and consistent series of hydrological monitoring at the small scale. Thus, the storage capacity and shape of the non-strategic reservoirs was estimated using the method proposed by Pereira et al. [22]. The authors characterized the geometry of small and medium sized reservoirs based on two shape coefficients (Equations 1 and 2), which were correlated to the maximum inundation areas of the reservoirs (Table 1).

$$V = V_0 + A_0 \cdot h' + K_{\text{mod}} \cdot h'^{\alpha_{\text{mod}}}$$
⁽¹⁾

$$A = A_0 + \alpha_{\text{mod}} \cdot K_{\text{mod}} \cdot h^{(\alpha_{\text{mod}}-1)}$$
⁽²⁾

99 where, A_0 and V_0 are parameters, meaning initial reference area (5,000 m²) and volume (2,096 m³) 100 stored at this level, respectively; K_{mod} is the aperture coefficient; α_{mod} is the shape coefficient; h' is the

101 water stage above the initial reference area (m).

102**Table 1.** Aperture and shape coefficients based on the maximum flooded of small surface reservoirs103(Source: Pereira et al. [22])

Class characteristic		Class				
		1	2	3		
Range of max.	Min.	5.1E4	3.5E5	6.4E5		
flooded area (m ²)	Max.	3.5E5	6.4E5	3.2E6		
lphamod		2.58	2.67	2.96		
K_{mod}		3,136	5,342	4,942		

104

105 Applying the abovementioned method, the storage capacities of the reservoirs in the BRB were 106 estimated from the maximum flooded areas indicated by FUNCEME [19], and the reservoirs were 107 distributed in five classes according to their storage capacities: class 1: 5×10^4 to 2×10^5 m³; class 2: 2 108 x 10⁵ to 5×10^5 m³, class 3: 5×10^5 to 2×10^6 m³, class 4: 2×10^6 to 3.5×10^7 m³, and class 5: > 3.5×10^7 109 m³.

110 The basin supply, water availability, was estimated from the equation of the water balance (Eq.111 3). The methodology was applied, for example, by Fowe et al. [23], de Araújo et al. [18] and allows

112 the understanding of the dynamics of the reservoir water supply.

$$\frac{dV}{dt} = (Q_A + Q_H) - (Q_E + Q_S + Q_G)$$
(3)

113 where: *V* is volume (m³); *t* is time (month) and the other variable are flows (m³/year): Q_A is inflow 114 from the river network; Q_H is water input by rainfall directly on the reservoir surface; Q_E is water loss 115 due to evaporation; Q_S is reservoir outflow over the spillway; Q_G is the regulated water withdrawal 116 associated with a 90% reliability level. Water fluxes between the reservoir and the bedrock was 117 considered negligible, according to the recommendation of de Araújo et al. [18].

118 The initial volume accumulated in the reservoirs was considered as one fifth of the storage 119 capacity, based on the frequency of accumulated volumes [18]. Evaporation was estimated as 30-120 years average monthly depths, made available by the Brazilian National Institute of Meteorology, 121 whereas daily precipitation data was obtained from the Brazilian official database for three 122 raingauges in the basin with time-series of 103 years. The runoff in the basin was estimated with the 123 Curve Number – CN empirical method [24], using as input data the daily rainfall from the nearest 124 gauge. It was considered that the entire volume above the storage capacity would spill within the 125 month of simulation and taking into account that the reservoirs are displaced in a cascade format, the 126 spillage from a lower class was added as inflow to the higher classes, simulating the connection 127 among the reservoirs. The withdrawal from the reservoirs was simulated until a 90% reliability was 128 achieved, and the respective flow as considered as the water availability from that specific reservoir 129 class.

130To assess the water availability in different reservoir arrangements in the BRB, six scenarios were131established: i) real arrangement of the reservoirs; (ii) reservoirs of classes 2 to 5, only; iii) reservoirs132of classes 3 to 5; iv) reservoirs of classes 4 and 5; (v) reservoirs of class 5; vi) only the Arrojado Lisboa133reservoir (storage capacity 1.6 x 10° m³).

To compute the flows to be pumped from the reservoir to supply water for the population in the BRB, the water demand of each district was calculated as the product of the per capita demand by the respective population. Data about the population of the districts was estimated for the year of 2015 based on in formation of the demographic census from the Brazilian Institute of Geography and Statistics – IBGE, by applying a fixed growth rate observed in the last decade. The per capita demand

139 was assumed as 100 L/inhabitant per day.

140 2.3. Power demand for water supply

The Euclidian distance from each reservoir (location of water source) to all the districts (location
of water demand) was calculated to generate all possible combinations of water supply in the
Banabuiú River Basin.

144 The water distribution in the BRB was simulated to each scenario of reservoirs by adopting a 145 search algorithm (Figure 2), in which the water demand is met by the closest reservoir with enough

- 146 water availability to meet the demand of the district. If the available water is not completely
- 147 consumed by the district, the remaining water can be relocated to the next closest locations.



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Figure 2. Flowchart of the algorithm to define the water supply arrangement of the demand centresby the reservoirs (D: district water demand; O: reservoir water availability; n: number of districts)

151 The hydraulic calculations for estimation of the power demand for water supply in the BRB were 152 based on the water demand for human supply of each district, to be met by the reservoirs, with the 153 simplifying hypothesis that all the water demands were concentrated in the centre of the localities. 154 For the sake of simplification, the pipelines needed transfer water to all the demand centres were

155 considered as the Euclidian distances between the reservoirs and the districts to be supplied.

156 The power of the pumping system (*P*, in W) was calculated according to Equation 4:

$$P = \frac{\gamma \cdot Q \cdot H_{man}}{\eta} \tag{4}$$

- where: γ the water specific weight (10,000 N/m³); *Q* is the water demand of the district (m³/s); *H*_{man} is the head (m), expressed as the sum of the geometric height (difference between the altitudes of the district centre and the reservoir) and the friction loss; η is the efficiency of the pumping system.
- 160 The altitudes of the districts and the reservoirs, used to compute the hydraulic head [25], were 161 estimated from a digital elevation model (DEM) with 90 m spatial resolution, generate from the
- 162 Shuttle Radar Topography Mission (SRTM) data.

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163 The friction loss (*hf*, in m) along the pipelines was calculated by the Hazen-Williams approach 164 (Equation 5).

$$h_f = 10.64 \frac{L}{D^{4.87}} \left(\frac{Q}{C}\right)^{1.85}$$
(5)

where: *L* and *D* are the pipe length (m) and diameter (m), respectively; *C* is the Hazen-Williamscoefficient (adopted as 130 for cast iron).

- 167 The diameters of the pipes were calculated based on the Bresse equation (Equation 6), which
- 168 estimates the internal diameter based on cost criteria, considering the costs of pipe acquisition as well169 as the pumping system and energy.

$$D_{eco} = K \cdot \sqrt{Q} \tag{6}$$

170 where: D_{eco} is the economic diameter (m); *K* is a coefficient that depends, among other factors, on the 171 costs of the material, system operation, and maintenance. In this study, a value of *K* = 1.3 was used

as indicated by Perroni et al. [26] for flows lower than 0.01 m³/s.

173 **3. Results**

174 3.1. Reservoir arrangement and storage capacities

The Banabuiú River Basin presents 1.405 surface reservoirs with surface areas larger than 5 ha), many of which with low storage capacities: 80% of all identified reservoirs belong to classes 1 and 2. Reservoirs of class 1 are mostly (67%) situated in altitudes above 150 m, thus in higher positions in the basin than the Arrojado Lisboa reservoir, situated at 147 m altitude. Class 2 also presents high number of reservoirs (57%) above the altitude of 150 m, but still a significant percentage of the structures are in lower altitudes, not being able to store much hydraulic potential energy.

181 Nonetheless, the sum of the storage capacities of all reservoirs belonging to classes 1 and 2 is 164 182 hm³, while the strategic reservoirs (class 5) can store 2,698 hm³, approximately 60% of this volume in 183 the Arrojado Lisboa reservoir, at 147 m altitude. That is, the water volume that can be accumulated 184 in the strategic reservoirs is 16 times that in classes 1 and 2, however, it is stored at lower altitudes 185 and is further away from most water demand centres of the more remote areas.

186 The headwaters in the Banabuiú basin do not present a large concentration of reservoirs, 187 however, the few existing ones above the altitude 600 m are mostly from class 1, in accordance with 188 the cascade method [21] adopted in the present study, which admits the simplifying hypothesis that 189 small reservoirs are situated upstream of the larger ones and in higher altitudes.

Like the strategic ones, reservoirs of class 4 can store significant water volumes, with a total accumulated capacity of 445 hm³ in the BRB. Of these reservoirs, 31% are below the altitude 150 m, contributing significantly to the water storage at more downstream positions.







195 *3.2. Water availability and demand*

196 The spatial pattern of water demand (Figure 4) follows that of the storage capacity (Figure 5) in 197 the BRB, i.e. municipalities with higher capacity to accumulate water are also those that present 198 higher human demands. This behaviour is an indication that there may be a repressed water demand 199 in some municipalities, that is, there would be demand if there were water (for example, in the

agricultural sector).



201 202

Figure 4. Spatial pattern of the water demand on the Banabuiú River Basin, per municipality





Figure 5. Spatial pattern of the storage capacity on the Banabuiú River Basin, per municipality

Another relevant feature is that strategic reservoirs can supply water to the large demand centres, as these usually have some water distribution infrastructure. On the other hand, often the service does not reach the rural population due to the deficit of pipelines to supply the remote areas. Thus, even though there may be water available in the reservoirs (for instance the Arrojado Lisboa, the third largest reservoir in the State of Ceará with capacity of 1,601 hm³), some districts may remain unassisted. Aware of this problem, Ceará [27] suggests the expansion of the capacity of water distribution systems in several municipalities of the BRB.

212 Despite the large number of reservoirs able to distribute water in the basin, the classes 1 and 2 213 present low water availability (10% of the total), relatively to the other reservoir classes. Scenario 3 214 (with reservoirs from classes 3 to 5) has 5 times more reservoirs than Scenario 4 (reservoirs from 215 classes 4 to 5), but water availability is only 12% higher than in former scenario (Table 2). The 216 discrepancy is because the larger reservoirs of class 3 (present in Scenario 3 but not in Scenario 4) are 217 able to overcome longer periods of drought than the smaller structures of the lower classes, thus 218 introducing higher hydrological efficiency to the system. On the other hand, adoption of strategic 219 reservoirs only (Scenario 5) would provide a loss of 9% of water availability in relation to Scenario 3, 220 whereas if only the Arrojado Lisboa reservoir provided water in the BRB, the loss would be 40%. 221

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 Table 2. Water availability in the different scenarios of reservoir arrangement in the Banabuiú River Basin

Water Availability (hm³/year)									
Scenario	Class 1	Class 2	Class 3	Class 4	Class 5	Sum			
1) Real	43.78	46.63	113.81	86.21	644.16	934.59			
2) Class 2 to 5		50.81	127.59	94.86	699.64	972.89			
3) Class 3 to 5			141.25	102.09	849.19	1093.52			
4) Class 4 and 5				118.99	860.51	979.50			
5) Class 5					994.32	994.32			
6) Arrojado Lisboa					658.60	658.60			

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225 3.3. Power demand for water supply

The simulations for the real scenario of reservoirs in the BRB (Scenario 1) indicate that the power required to pump water from the reservoirs to all districts is 6.5 GWh/year, equivalent to the demand of roughly 3,000 residences, considering the consumption of 180 KWh/month per residence according to the average in the region.

In Scenario 2, where reservoirs of class 1 are not considered, there is an increase of 43% in the power demand, totalling 9.3 GWh/year. The difference between the real reservoir arrangement (Scenario 1) and Scenario 2 would supply approximately 1,200 residences. Despite the low storage capacity of reservoirs from class 1, their exclusion of the simulations results in an increase of the distance from the water sources (remaining reservoirs from classes 2 to 5) to the demand centres (districts), increasing also the power required to supply water to the districts that would be served by class 1 reservoirs in the real arrangement.

In Scenario 4, the reservoirs present water availability higher than in Scenarios 1 and 2, however, they limit the water spatial distribution in the BRB, since they are in significant lower quantity than the reservoirs of the previous scenarios. This feature is even more pronounced in Scenario 5, in which only the reservoirs from class 5 are considered and the power demand is 7 times that of Scenario 1. Despite their high water availability, the eleven strategic reservoirs of class 5 are restricted to few spots in the BRB, presenting great distances to some of the water demand centres located at the headwaters.

Scenario 6, in which only the Arrojado Lisboa reservoirs supplies water, it would demand 195.6
GWh annually, about 30 times the power demand of Scenario 1. This amount is enough to supply
90,500 residences, which compared to the first scenario, results in a difference of roughly 87,500
residences.

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Figure 6. Power demand to supply water to the districts for each of the simulated scenario of reservoirs in the Banabuiú River Basin.

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In Scenarios 1, 2 and 3 there are no major changes in the power required to distribute water in the BRB, since there is a good distribution of the reservoirs of classes 1, 2 and 3 in the basin, allowing that the water demand centres can be well served within short distances.

Figure 7 ilustrates the accumulated power demand for water distribution in the BRB versus the altitudes of the districts, indicating that the enhancement of power demand in the scenarios without the smaller reservoirs is more intense in the uppermost altitudes. For Scenarios 4 and 5, for instance, the power demand at lowest altitudes is similar, and of the order of 72MWh/year. However, at higher altitudes the power demand of Scenario 5 increases more rapidly, so that at the highest district, the accumulated power demand of Scenario 5 is approximately 4 times that of Scenario 4.



Figure 7. Accumulated power demand for water distribution in the Banabuiú River Basin versus the districts' altitudes

4. Discussion

Reservoir density in the Banabuiú River Basin is 0.07 reservoirs (with surface areas larger than 5 ha) per km², amongst the highest in the globe. For example, Ghansah et al. [28] mapped the reservoirs in the White Volta Basin (49,600 km²), Ghana, using satellite images and identified 254 reservoirs with areas ranging from 1 ha to 54 ha, resulting in a density of 0.005 reservoirs per km², that is, the ratio of the reservoir density between the Banabuiú and the White Volta basins is 14. The volumetric density in the BRB, expressed as the ratio of the total storage capacity by the basin area, is 0.14 hm³/km, in the same order of magnitude of that found by Malveira et al. [13] for the Upper Jaguaribe Basin (0.22 hm³/km²), also located in the semiarid region of Brazil.

Despite the large number of dams, roughly 80% present storage capacities lower than $5 \ge 10^5$ m³. A high concentration of small reservoirs has also been observed in other basins in the semiarid region of Brazil, for instance, Peter et al. [29] observed that there is an enormous difference in the quantity of such structures among the classes in the Upper Jaguaribe Basin, where the smaller reservoirs represent 97% of the total.

Other authors (for example, KROL et al. [12]) report that the high density of small reservoirs has several positive impacts besides storing water upstream of the strategic ones, among others contributing massively to the sediment retention, avoiding the siltation of the downstream water bodies [30]. Fowe et al. [23] report that small reservoirs guarantee the supply of the most remote regions, promote diversification of agricultural activities and contribute to family and sustainable agriculture.

On the other hand, the strategic reservoirs (in the number of 12 in the BRB, representing less than 1% of all reservoirs) can accumulate as much as 16 times the total storage capacities of classes 1 and 2. Nonetheless, the water stored on those large structures is located at lower altitudes and is further away from most water demand centres of the more remote areas, promoting high power demand for water distribution in the basin.

In the BRB, the current reservoir arrangement produces a power demand of 6.5 GWh/year for human water supply of all districts in the basin, whereas in the scenario in which only the eleven strategic reservoirs are considered as water sources, the power demand is roughly 7 times that of the real reservoir arrangement. If the Arrojado Lisboa reservoir is considered alone, the system would demand 30 times the power required in the real reservoir arrangement to supply water to the entire basin.

In this study, there is no intention to estimate the hydraulic power generation from Small Hydropower Plants (SHPs), but to illustrate the importance of small reservoirs for the accumulation of hydraulic energy in the BRB. Nonetheless, in regions less impacted by water scarcity, small reservoirs may play an important role on generating power, as well. For example, in southern Brazil, Hunt et al. [31] report that SHPs have the potential to decentralize and generate power during 41 dry seasons, and therefore, these works are responsible for the increase of energy offer in the region.

The power demand in the BRB for water distribution is of the order of power generation from SHPs. Balkhair and Palman [32] observed that the potential of the main 20 sites of the Upper Swat Canal reservoir, located in the semi-arid region of Pakistan, is to generate 18 GWh annually.

Compared to other water supply systems, the power demand at the BRB is expressive. Guanais et al. [33] analysed a water supply system in Feira de Santana, Brazil, and found that the power demand of the system with capacity to distribute 21 hm³/year is 75.2 GWh/year, of which 86% corresponds to water distribution. The power required in Scenario 6 of the BRB is 2.5 times the energy required by that system.

In Scenarios 1, 2 and 3 there are no major changes in the power required to supply water in the BRB, since there is a good distribution of the reservoirs of classes 1, 2 and 3 in the basin, allowing that the water demand centres can be well served within short distances.

Liu et al. [34] argue that water spatialization is a trend that contributes to water resource management, power generation, and decision-making by government or community. In agreement, de Araújo e Medeiros [15] argument that the presence of small and medium-sized dams in the headwaters contributes to the spatial distribution of water, reducing pumping costs.

5. Conclusions

The simulations of water distribution from surface reservoirs to supply the districts of the semiarid Banabuiú River Basin – BRB (19,800 km²) indicate that, additionally to promote a spatial distribution of the water, the thousands of small non-strategic surface reservoirs substantially increase the energy efficiency of the water supply system. The small reservoirs store water at higher altitudes and closer to the most remote districts, generating low costs to pump water to such demand centres.

In the scenario with the real reservoir arrangement, the total power demand of the system is 6.5 GWh/year, which is increased by 43% (to a total of 9.3 GWh/year) if the reservoirs with storage capacity lower than 2×10^5 m³ are not considered as part of the system. Furthermore, if only the eleven strategic reservoirs monitored by the Company of Water Resources Management of Ceará – COGERH are considered as water sources, the power demand to supply water to the entire basin is 7 times that of the real reservoir arrangement.

Although representing roughly 60% of the water availability of the BRB and being able to supply all the districts, the Arrojado Lisboa reservoir alone would demand 30 times the power required in the real reservoir arrangement to supply water to the entire basin.

Author Contributions: Tatiana Nascimento led the investigation work, including data acquisition, methodology setup, analysis and manuscript writing. Natália Cavalcanti and Bruno Castro dedicated to the investigation and analysis of the water availability calculations, as well as discussion of the overall results. Pedro Medeiros proposed the research conceptualization, and worked on the supervision, definition of the methodological arrangement and manuscript review.

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