ASSESSMENT OF GROUNDWATER FAVORABILITY IN THE MUNICIPALITY OF SÃO MATEUS-ES

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ABSTRACT

Purpose: Make an assessment regarding the favorability of exploring groundwater in the municipality of São Mateus.

Theoretical framework: Guaranteeing the availability of water regularly and with good quality for everyone, without threatening public health, remains a challenge for the semi-arid regions of the country, especially for diffuse communities in large centers, which do not have adequate water infrastructure.

Method/design/approach: The methodology used in the research begins with a bibliographical review on the topic, as well as obtaining data relating to wells registered with SIAGAS E AGERH between the years 2019, 2020 and 2021; creation of cartographic products using ArcGIS™ 10.1 software; characterization of aquifer systems in the region; definition of areas with greater favorability for the exploitation of groundwater, as well as the influence of the depth of drilled wells on the flow rates obtained.

Results and conclusion: The three aquifer systems defined for the study area were characterized, namely the fractured, Barreiras and Coberturas. The Barreiras aquifer system has wells with higher flows. However, the importance of adequate planning and control by the public authorities regarding the exploitation of water in this system must be highlighted, as, as a result of intensive pumping, salt water can advance into the freshwater zone of the aquifer.

Research implications: The advancement of studies regarding the availability and potential of groundwater contributes to the implementation of more efficient management of water resources, as well as promoting the expansion of specific knowledge on how reserves inherent to underground water dynamics are exploited locally.

Originality/value: Trazer reflexões a partir da avaliação quanto a favorabilidade hídrica no município de São Mateus, de forma a garantir uma segurança hídrica tanto quantitativa, quanto qualitativa para as comunidades desta região, encontra-se em conformidade com uma das metas da Agenda 2030 para o Desenvolvimento Sustentável.

Keywords: Groundwater, Favorability, São Mateus.

RESUMO

Objetivo: fazer uma avaliação quanto a favorabilidade para a exploração de águas subterrâneas no município de São Mateus.

Referencial teórico: A garantia quanto a disponibilidade de água de forma regular e com boa qualidade para todos, sem ameaça à saúde pública, permanece sendo um desafio para as regiões semiáridas do país, especialmente para comunidades difusas dos grandes centros, não contempladas com uma infraestrutura hídrica adequada.

Método/design/abordagem: A metodologia utilizada na pesquisa inicia-se com uma revisão bibliográfica sobre a temática, bem como, da obtenção de dados referentes aos poços cadastrados no SIAGAS E AGERH entre os anos

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Assessment of Groundwater Favorability in the Municipality of São Mateus-ES

de 2019, 2020 e 2021; elaboração de produtos cartográficos utilizando-se o software ArcGisTM 10.1; caracterização dos sistemas aquiferos na região; definição de zonas com maior favorabilidade para a explotação de água subterrânea, bem como, a influência da profundidade dos poços perfurados nas vazões obtidas.

Resultados e conclusão: Foram caracterizados os três sistemas aquíferos definidos para a área de estudo, sendo eles o fraturado, o Barreiras e o de Coberturas. O Sistema aquífero Barreiras possui poços com maiores vazões. No entanto, deve-se ressaltar a importância do planejamento adequado e o controle por parte do poder público quanto a explotação das águas neste sistema pois, em decorrência de bombeamentos intensivos pode ocorrer o avanço das águas salgadas sobre a zona de água doce do aquífero.

Implicações da pesquisa: O avanço dos estudos quanto a disponibilidade e potencialidade das águas subterrâneas contribuem com a implementação de uma gestão dos recursos hídricos mais eficiente, assim como pode favorecer ampliação dos conhecimentos específicos do modo de exploração das reservas inerentes à dinâmica hídrica subterrânea localmente.

Originalidade/valor: Trazer reflexões a partir da avaliação quanto a favorabilidade hídrica no município de São Mateus, de forma a garantir uma segurança hídrica tanto quantitativa, quanto qualitativa para as comunidades desta região, encontra-se em conformidade com uma das metas da Agenda 2030 para o Desenvolvimento Sustentável.

Palavras-chave: Água Subterrânea, Favorabilidade, São Mateus.

1 INTRODUCTION

Groundwater has great storage capacity and resistance to long periods of drought, mainly due to climate change, the growth in the use of well as an important source of human supply is highlighted (Krolow, Krolow, Santos, Casali & Mulazzani, 2018; Hidrata, Suhogusoff, Marcellini, Villar & Marcellini, 2019; Machado et al, 2022). There is a growing demand for the use of groundwater as an alternative for the supply of small, medium and, under certain conditions, high population demands. In the face of the current water crisis and situation of scarcity, a large part of the population, is looking for means to supply its demands for water resources, exploiting underground water from the subsurface formations. To this end, either because of a lack of education or because of the high costs of properly constructing tubular wells, wells are constructed that do not comply with the legislation in force. It is known that underground water reserves can take up to hundreds of thousands of years to accumulate, however, their natural renewal does not happen with the ease that one imagines (FEITOSA et al., 2008). Effective management of the underground water resource can predict and prevent aquifers and reserves inherent in such systems from being put at risk (AGERH, 2018).

In Brazil and especially in the state of Espírito Santo there is a lack of detailed data, both qualitative and quantitative of underground water resources (AGERH, 2018). Unlike surface water sources, information about groundwater calls for a series of studies, which are often more expensive to carry out, to qualify and quantify it. Most water agencies do not have the necessary resources to carry out adequate monitoring of the underground water resources, therefore, there is a lack of subsidies for an assessment of the production potential of the aquifers that is close to reality.

According to HIRATA et al., (2010), surface water courses have high surface runoff and, under certain conditions, low capacity to store water, however, and it is possible to capture high instantaneous flows in these springs. On the other hand, the underground water reserves, despite
having stable flows even in periods of low rainfall, being little influenced by seasonality, are unable to offer the flows observed in surface abstractions.

In this sense, the efficient and sustainable use of the underground water resource, using an orderly exploitation, requires improvements in the management device, which can be made possible by understanding the information obtained in the database of the registration of tubular wells, as well as by the acquisition of qualitative and quantitative data, associated with the awareness of the whole population.

In the light of the above, the present study sought to evaluate and discuss the water favorability of the identified aquifer systems in the municipality of São Mateus, with a view to proposing improvements in the monitoring of groundwater exploration, aiming at the protection of local aquifer systems and their users.

2 THEORETICAL FRAME

The Espírito Santo Basin is located on the eastern continental shore of the Brazilian territory, occupying an area of approximately 115,200 km², being delimited to the south with the Campos Basin, through the top of Vitória, and to the north with the Mucuri Basin.

The first stratigraphy of the Espírito Santo Basin was proposed by ASMUS et al., (1971). The evolution of knowledge was acquired through the drilling of wells and seismic acquisitions throughout the years of exploitation of this Basin, allowing the elaboration of a new letter presented by VIEIRA et al., (1994). The recent stratigraphic chart presented by FRANCE et al., (2007), follows the lithostratigraphic principles established in the last edition of the stratigraphic chart (VIEIRA et al., 1994). The evolution of the basin can be subdivided into three main phases which are: Rift, Post-Rift and Drift.

In the Rift phase (Valangian to Lower Aptian) there was the predominance of continental deposition in a lacustrine environment, with fluvial and alluvial contribution at the edges of normal failures, developed during the opening of the Atlantic. Cokines and other carbonates were deposited in the internal structural heights. The various tectonic pulses are marked by the presence of synthetic conglomerates of fault edges, as well as by volcanics of the Cabiúnas Formation.

The post-rift phase is represented by packages of siliciclastic and evaporite sediments from the Mariricu Formation, marking the records of the first marine incursions into the basin. The sediments in this phase have a wide areal distribution, settling discordantly on the Precambrian Basis or on the Cricaré Formation. Its upper limit is in agreement with the Barra Nova Group in the eastern portion and discordant with the Urucutuca Formation in the western portion.

The drifte phase represents the thicker sedimentary package in the Espírito Santo Basin and, in the submerged portion, the most representative. This sequence can be subdivided into a transgressive marine section and a transgressive-regressive navy. The first is represented by the Barra Nova Group and the second by the Espírito Santo Group.

The Barra Nova Group consists of thick packages of arcoseous and arcosean sandstones from the São Mateus Formation and carbonaceous sediments from the Regência Formation. The Espírito Santo Group is composed of the Urucutuca Formations, Caravelas, Rio Doce and Abrolhos. The Urucutuca Formation is characterized in the terrestrial and proximal portions of the basin by presenting shales interspersed with conglomerates, in the shallower parts by limestones and sandstones and, towards deep waters, by an increase in the proportion of pelitic sediments on the thick and carbonaceous clastics, with turbidite sandstones interspersed with shales and marls of bathal and abyssal environment. The Caravelas Formation consists of bioclastic calcarenites and calcilutites. The Rio Doce Formation consists of clastic sediments
of neritic environment, whose inferior contact is gradual with the sediments of the Caravelas and Urucutuca Formation.

ASMUS et al., (1971) defined the Rio Doce Formation through subsurface studies in the Espírito Santo Basin, individualized, by means of distinctive lithological characteristics, three informal subunits: members Piraúna, Pirapitanga and Piranha. Considering the small density of drilled wells, they admitted the geographical distribution of the Rio Doce Formation in the whole area of the Basin, with very variable thicknesses, able to reach, in the domain of influence of the Rio Doce, about 3,000 meters in depth. With respect to the superior contact with the Barreiras Formation, no clear truncation surface was observed in the described outcrops. PIAZZA & ARAUJO (1972 apud BANDEIRA Jr. et al., 1975) observed in the surface exhibitions a gradual passage between the two units. VIEIRA et al., (2015), characterized some geological formations in the city of São Mateus, which are described in the following items.

Granite Medina (Terrenos Cristalinos), located in the western portion of the Municipality of São Mateus, occupies less than five percent (5%) of the area of interest, is characterized granitic land of medium to thick granulation.

Paraíba Sul Complex (Metassedimentary/Metavulcanic), mapped in the western portion of the city of São Mateus, the rocks of this geological unit are described as kinzigite gneisses, marbles, calciosilicatic rock and schists. The local relief changes as it moves away from the coastal lands towards the Paraíba Sul Complex.

The Rio Doce Formation, in the northern region of the state of Espírito Santo, the deposits of the Rio Doce Formation occur from the emersa area to the oceanic region, being a large part of the records found only in subsurface areas. These deposits were described by MORAIS (2007) as tabular packages of vertically stacked sandstones, with small pelitic intercalations. MORAIS (2007), using as a basis for interpretation the river models proposed by MIALL (1996), attributed the provenance to the model of intertwined rivers sandy, perennial and deep, varying for a model of intertwined rivers gravel.

The Barreiras Formation, the major part of the studies involving this formation were carried out in the northern and northeastern regions of Brazil, largely due to the greater exposure of these deposits in these regions, mainly in the northeastern region of Brazil. In the southeast region, few works have been carried out, the deposits taking place from the city of Búzios, in the state of Rio de Janeiro, to the north of the state of Espírito Santo, in the emerge area of the Basin of the same name. In Espírito Santo, these deposits begin to occupy a greater areal extent to the north of the city of Vitória.

The first attempts at paleoenvironmental and temporal interpretation were made by AMADOR & DIAS (1978) and AMADOR (1982). Much of the work on Barreiras points to a continental depositional environment (MORAIS et al., 2006) of currently accepted age between the Miocene and the Pliocene.

The Barreiras Formation consists predominantly of quartz sandstones, kaolinitic, sometimes massive, sometimes with stratifications, interspersed with mudstones. The deposits of this unit are quite ferruginous, presenting varied colors (red to orange). This ferratilization, when very intense, occurs as ferruginous crusts.

Coastal deposits, occurring in the easternmost portion of the Municipality of São Mateus, are described in stretches of the coast, mainly in the coastal plain of the Doce River, outcrop, under the beach ridges, beach sandstones.

Undifferentiated Cenozoic formations, so-called all sandy clay deposits found in the valleys of the municipality of São Mateus, are often found above the limit reached by the penultimate transgression, occurred in the Pleistocene.

Although the use of groundwater has been going on for thousands of years, it was only in the seventeenth century that man had a clear understanding of the hydrological interaction and the dependence that underground water has on precipitation and infiltration.
Groundwater plays a fundamental role in the hydrological cycle, although we still lack detailed qualitative and quantitative data on the underground resource in Brazil and the world. Unlike surface water sources, groundwater information can usually be obtained only by drilling wells, involving a degree of complexity intrinsic to the associated geological environments.

Most state and federal agencies lack the resources to properly monitor wells, and are therefore forced to rely on data from municipal and private wells, often with often non-existent or poorly data-driven geological and constructive information. This largely explains the lack of a consistent database on groundwater compared to surface water.

The movement of the groundwater is very slow, when compared with surface water, a laminar flow considered to be fast, has a displacement of approximately 1m/day. This fact indicates a long residence time of the groundwater with very small annual recharge rates, making it a reliable long-term reserve, effectively immune to annual fluctuations of precipitation (FEITOSA, 2008).

Various estimates of groundwater reserves unfortunately do not always agree. Despite this, perhaps the most striking fact is the percentage of groundwater in relation to all available fresh water. If we exclude polar caps and glaciers, groundwater contributes more than 95% of the fresh water available on the planet. The remaining amount is mainly composed of lakes, rivers and moisture in the soils. In Brazil, as there is no effective control system, the precise numbers of users are unknown, since the quantity of unregistered wells can reach 80% of the total (AGERH, 2018).

The studies carried out in the region have made it possible to define three systems of aquifers according to the type of permeability of the rocks. The fractured aquifers are represented by the crystalline rocks (Paraíba Sul Complex and Granite Medina) of the foundation and the granular aquifers, divided into two hydrogeological units, are composed by the Barreiras Formation (Barreiras Aquifer System), as well as by the coastal deposits and the undifferentiated cenozoic deposits (Covering Aquifer System).

Fractured Aquifer System, characterized by the crystalline terrain located in the western portion of the municipality of São Mateus, can be described as anisotropic and heterogeneous hydrogeological units, so that the underground water dynamics in this system is controlled mainly by the flow of water in zones of fractures and discontinuities present in the local geological units.

The Barreiras Aquifer System, with greater hydrogeological potential associated with the sediments of the Barreiras Formation and, in greater depth, the Rio Doce Formation, presents flows that can reach 82 m³/h, with recharge occurring mainly through rainwater. Drilling holes carried out on the coast of Espirito Santo by Petrobras, found thicknesses of up to 80 meters for the Barreiras Formation, with gradual increase in the direction of the continental shelf, and can reach 150 meters (AGERH, 2018).

Aquiferous System of Roofs, this hydrogeological unit is composed of the coastal lands and the undifferentiated Cenozoic deposits, occurs in valleys and in the coastal portion of the municipality of São Mateus. Generally speaking, this system has primary porosity and good capacity for groundwater conduction, however, no significant thicknesses are observed in this unit.

3 METHODOLOGICAL PROCESSES

The work was divided into two stages:

Initially, a bibliographic review was made based on the regional hydrogeological contextualization of the area, through the analysis of articles, book chapters, reports, geological charts, theses, dissertations and monographs related to petrography, structural geology and tectonic evolution of the area. Next, a survey was carried out of the wells already registered.
within the limits of the municipality of São Mateus-ES. The information was collected through the Groundwater Information System (SIAGAS) and the State Agency for Water Resources (AGERH).

The data obtained at the state agency of Espírito Santo refer to the tubular wells registered in the years 2019, 2020 and 2021. The information gathered, in the declarations of permission to use the underground water resource, referred to data on flow, depth and the type of use conceived for the tubular wells.

With regard to the data registered on the SIAGAS platform, it was possible to obtain information about static and dynamic levels, depths and flow rates of some wells. Available information from the well count was used to assess the volume of information available on the local aquifer system. During this stage, the available data was organized in spreadsheets, highlighting the coordinates, the constructive aspects, the productivity and the variation between static and dynamic level.

The second stage of the work involved the interpretation of the collected data and characterization of the aquifer system in the region, the deficit of existing data was highlighted, as well as the distribution of hydrogeological information for the city of São Mateus were broken down in graphic form. The spatialization of the data was mapped in thematic maps, elaborated from the software ArcGisTM 10.1, aiming at contextualizing the geographical configuration of the evaluated data. In this sense, maps have been drawn up concerning the spatial distribution of wells in relation to geological units and local aquifer systems. It should also be noted that with the use of data from the wells, geostatistical methods such as Krigagem used in the Surfer 12 software, a local potentiometric map, a map of isolines of the depths of the wells, of the flow rates and of specific local capacities were developed. Finally, this information was evaluated and it was possible, with the available data, to indicate within the municipality of São Mateus the areas most favorable for the exploration of underground water, as well as to assess the influence of the depth of the drilled wells on the flows obtained.

4 RESULTS AND DISCUSSION

In order to better understand the information gathered in the scope of this work, the data obtained in relation to the deep tubular wells existing in the city of São Mateus were grouped in different categories. Thus, by evaluating the available information about the characteristics of the wells, the spatial distribution of these abstraction points, the information acquired about the exploded flows, the local potentiometry and the specific capacities of the aquifers explored in the municipality, it was possible to evaluate which are the areas with the greatest water favorability, as well as what are the gaps in knowledge existing in relation to the hydrogeological characteristics of the local underground water sources.

In Tables 1 and 2 we observe the information obtained in the surveys carried out in the AGERH and SIAGAS databases, respectively. From the state agency's database, the main declared uses were described, with the same well having more than one assigned use, data of drilled depths and the rates captured per hour. Maximum, average and minimum values were indicated for flow and depth data. Also, for the data obtained on the SIAGAS platform, the data of static and dynamic levels, the values referring to the exploded flow and, when possible, of specific capacity, are highlighted. For these values, the information on maxima, averages and minima was also tabulated. It should be noted that, from the data obtained, it was verified the existence of 65 wells registered in AGERH and 44 wells with information on the SIAGAS website.
Table 1. Distribution of existing information from the declared wells in the AGERH database.

<table>
<thead>
<tr>
<th>Data</th>
<th>Registered Wells (AGERH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration Year</td>
<td></td>
</tr>
<tr>
<td>Year 2019</td>
<td>12</td>
</tr>
<tr>
<td>Year 2020</td>
<td>39</td>
</tr>
<tr>
<td>Year 2021</td>
<td>14</td>
</tr>
<tr>
<td>Depth</td>
<td></td>
</tr>
<tr>
<td>Max Depth (m)</td>
<td>292</td>
</tr>
<tr>
<td>Min Depth (m)</td>
<td>6</td>
</tr>
<tr>
<td>Mean Depth (m)</td>
<td>92</td>
</tr>
<tr>
<td>Flow rate</td>
<td></td>
</tr>
<tr>
<td>Q Max (m³/h)</td>
<td>45</td>
</tr>
<tr>
<td>Q Min (m³/h)</td>
<td>1.7</td>
</tr>
<tr>
<td>Q Mean (m³/h)</td>
<td>11.5</td>
</tr>
<tr>
<td>Usage Type</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>31</td>
</tr>
<tr>
<td>Human Consumption</td>
<td>18</td>
</tr>
<tr>
<td>Industrial</td>
<td>19</td>
</tr>
<tr>
<td>Leisure</td>
<td>9</td>
</tr>
</tbody>
</table>

Source: AGERH-ES

Table 2. Distribution of information from existing wells in the SIAGAS database.

<table>
<thead>
<tr>
<th>Data</th>
<th>Wells (SIAGAS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Water Level</td>
<td></td>
</tr>
<tr>
<td>Max Depth (m)</td>
<td>80</td>
</tr>
<tr>
<td>Min Depth (m)</td>
<td>0</td>
</tr>
<tr>
<td>Mean Depth (m)</td>
<td>15</td>
</tr>
<tr>
<td>Dynamic Water Level</td>
<td></td>
</tr>
<tr>
<td>Max Depth (m)</td>
<td>97</td>
</tr>
<tr>
<td>Min Depth (m)</td>
<td>3.</td>
</tr>
<tr>
<td>Mean Depth (m)</td>
<td>42</td>
</tr>
<tr>
<td>Flow rate</td>
<td></td>
</tr>
<tr>
<td>Q Max (m³/h)</td>
<td>50</td>
</tr>
<tr>
<td>Q Min (m³/h)</td>
<td>0.5</td>
</tr>
<tr>
<td>Q Mean (m³/h)</td>
<td>12.3</td>
</tr>
<tr>
<td>Specific Capacity</td>
<td></td>
</tr>
<tr>
<td>Q Max (m³/h)</td>
<td>20.00</td>
</tr>
<tr>
<td>Q Min (m³/h)</td>
<td>0.01</td>
</tr>
<tr>
<td>Q Mean (m³/h)</td>
<td>3.</td>
</tr>
</tbody>
</table>

Source: SIAGAS

JUNG et al., (2023) states that understanding the importance of water for the sustainability of life, as well as understanding its cycle on the planet, is necessary, as a subsidy for the establishment of efficient plans for the protection and preservation of this renewable but finite natural resource.

It is noted that there is a low amount of information concerning the drilled wells in the municipality of São Mateus, which demonstrates that an update of the database of registration of the platform of the (SIAGAS/CPRM) is necessary.
However, even if there is a need to update this database, it is possible to prepare an analysis of the water potential of the registered wells and an overview of the exploitation of the underground water resource in the municipality of São Mateus.

The map with the spatial distribution of the captures in the municipality of São Mateus is presented in Figure 1.

![Figure 1 - Location map of the wells assessed in the municipality of São Mateus.](image)

**Source:** Author

Among the wells assessed in the municipality of São Mateus, a certain quantity of wells in the urban spot of the municipality was observed, however, it is in the rural area where the largest number of groundwater abstractions is identified, this distribution accompanies the information related to the uses registered by AGERH, since 31 of these wells were declared as used for irrigation of coffee, pepper, cocoa, papaya and others crops.

The wells in the region have average flow rates between 12 and 15 m³/h, maximum flow rates close to 50 m³/h and minimum flow rates close to 0.5 m³/h, with average depth around 42 m, although the tubular well has a depth of up to 292 m drilling.

The average static level found in the municipality is 15 m, with the presence of emergent wells and structures with AN of up to 80 m depth. The average local dynamic level is 42 m, however, the maximum and minimum values for the variation of the level during water abstraction are 92 and 3 m respectively.

In the same context, average specific capacity values of 3m³/h/m are observed, as well as maximum and minimum measures of 20,0 and 0,01m³/h/m.

Having said that, in order to carry out the assessment of water favorability of the municipality of São Mateus it is important to understand the spatial distribution of the geological units that make up the local hydrogeological domains, as well, what are the characteristics observed in the wells installed in these lithotypes. Figure 2 shows the geological map with the distribution of the analyzed tubular wells.
It can be noted in Figure 2, for the evaluated wells, that the majority of the registered points are in the granular aquifers, a smaller portion located specifically on the crystalline and metasedimentary/metavulcanic rocks, however, it is possible to see several structures close to the contact between the Barreiras deposit and the rocks of the foundation.

In this sense, conceptually, the grouping of lithological types according to the hydrogeological characteristics of these units, in the area of the municipality of São Mateus, made possible the composition of a map of hydrogeological domains (Figure 3). For the composition of this map, they took into consideration the productive characteristics, the type of porosity and the thickness of each one of the geological units that make up the area of the municipality. Thus, the three aquifer systems defined for the area of study were characterized: Fractured Aquifer System, Barriers Aquifer System and Coverage Aquifer System.

Figure 2 - Location map of the wells assessed in the municipality of São Mateus in relation to the geological units identified in the area of the municipality (Modified CPRM, 2007).

Source: Author
When carrying out an analysis of the characteristics attributed to each one of these aquifer systems, the location of the drilled wells and the information referring to each one of the analyzed cadastres, a series of maps was drawn up to corroborate the identification of zones of greater water favorability within the municipality of São Mateus. With this, four maps were drawn up for the verification of this information, namely:

- Map of Isolinhas of Depth of Wells - for the composition of this image, a surface was generated according to the depths of the tubular wells registered;
- Potentiometric map - image referring to the depths of the static level observed in each tubular well;
- Map of Specific Capacity Isolates - illustrates a surface specializing the specific capacities calculated for wells; and
- Map of Isolinhas de Vazão - specializes the rates recorded for the various wells evaluated.

This being so, one can observe in Figure 4 the images referring to each one of the composite maps for the verification of the local water availability.

Conceptually, it is possible, from the analysis of the images illustrated in Figure 4, to make some statements, even if cautiously. It is noted that the greatest depths are observed in the recorded tubular wells that are close to the contact between the Fractured Aquifer System and the Barreiras Aquifer System, as well as in the urban area of the municipality.
Figure 4 - Compound maps for the evaluation of water availability in the municipality of São Mateus

Source: Author

The local potentiometry indicates a flow of groundwater from west to east, i.e. towards the ocean, from the fissural hydrogeological units to the porous aquifers.

In the specific capacity map, one visualizes a patch of greater value for this parameter in the northeastern portion of the area of interest, however, it is worth pointing out, that this parameter, although important for the discussions covered in this study, lacks a greater number of information for a better evaluation. However, it is plausible to assume that, in general, a specific capacity between 1 and 2 m³/h/m is expected for the study area.

The data referring to the flows observed in the inventoried tubular wells, when spatialized, make it possible to visualize portions with greater flows, in such a way that these areas where the most significant uptake was obtained converge, in the municipality, with the areas where the deepest wells are installed, and, also, are located on the deposits of the Barreiras Aquifer System.

It is noted that in the Fractured Aquifer System, the flows, in a comprehensive manner, are lower than the volumes captured in the porous domains. This situation is due to the high degree of heterogeneity and anisotropy of this hydrogeological unit, and better conditions of water circulation are expected in fracture zones and/or regions attributed to large geological structures. That said, it could be said that in order to be possible to carry out the exploration of underground water in these systems, it is important to map and identify these structures.
Therefore, it is understood that the largest flows are captured in the Aquifer Barreiras geological units. Hydrogeologically, stratifications of thick sedimentary packages are described for this domain, sometimes interspersed with clay and silt lenses, however, when analyzing the information presented in Figure 4(d), it is identified that the wells at greater depths are responsible for the greater local flows.

Also, in this sense, when one observes that deeper drilling is capable of producing a greater volume of underground water, principally in an aquifer system that is porous and not very heterogeneous, when compared to aquifers of secondary porosity, it should be noted that larger drilling lengths can generate greater explosions of subsurface water. This is also corroborated by the potentiometry of the area, since the phreatic level alters in a gradual manner and, in this unit, remains uniform.

In addition, it is important to mention that for the tubular well, even if drilled to greater depths, to be able to produce significant volumes of groundwater, this work must be carried out with care and caution. This consideration takes into account that wells where the distribution of filters and coating is poorly executed can have a high degree of reduction in the efficiency of wells.

Furthermore, it should be noted that it is not possible, in fact, to estimate the permanent local groundwater reserve with the information existing in the area of study, since in order to make such an estimate it would be necessary to better characterize hydrodynamics of the hydrogeological domains, delimit the thickness of these systems and also, if we know what the morphology of the salt wedge in the coastal zone, since this is a limiting factor in the thickness saturated by fresh water in the local porous hydrogeological units.

5 CONCLUSIONS

Advancing scientific studies and developments in the discipline of hydrogeology can contribute to the implementation of a more efficient management of underground water resources, as well as may favor the expansion of the specific knowledge of the way of exploiting the reserves inherent in local underground water dynamics.

In the last few years, this region has experienced consecutive interruptions in the water supply, mainly due to the high salinity in the waters of its main surface source, the São Mateus River. As a result, many wells have been drilled in order to mitigate the constant crises in the public supply system. However, the importance of proper planning and control by the public authorities in the face of such actions should be stressed. Otherwise, the situation may worsen as a result of intensive pumping and the consequent advance of saltwater over the freshwater zone of the aquifer.

Thus, it can be observed that in the Aquifer System Barreiras larger volumes of groundwater are captured and show good flow rates, which could be associated with a better water favorability, such a factor is attributed to a more homogeneous character of this hydrogeological unit. Well-executed tubular wells in this aquifer system can provide significant volumes of groundwater, however there is no concise determination of local underground water reserves, a fact of attention for public management bodies.

In addition, in the hydrogeological domains characterized by secondary porosity, high degree of heterogeneity and anisotropy, more detailed studies are needed during the process of leasing tubular wells in these units to ensure higher volumes.
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REFERENCES


AGERH – Agência Estadual de Recursos Hídricos do Espírito Santo - Diagnóstico e o Prognóstico das Condições de Uso da Água na Bacia Hidrográfica do Rio São Mateus como Subsídio Fundamental ao Enquadramento e Plano de Recursos Hídricos. 2018


Geologia e Recursos Minerais do Estado do Espírito Santo: texto explicativo do mapa geológico e de recursos minerais. / Valter Salino Vieira, Ricardo Gallart de


SIAGAS – SISTEMA DE INFORMAÇÕES DE ÁGUAS SUBTERRÂNEAS. CPRM-SGB.2011