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Planning as an instrument for protecting the Guarani Aquifer, municipality of Ribeirão Preto/SP, Brazil

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ABSTRACT
The Municipal Master Plan and its complementary Legislation have the function of determining rules for conducting the urban development of a city, so that the impacts of anthropic activities on the natural environment are minimized and the social function of the property is guaranteed. This research aimed to analyze the advances and setbacks of urban legislation in the municipality of Ribeirão Preto/SP, Brazil, with regard to the protection of the recharge zone of the Guarani Aquifer. To this end, the initial versions and respective revisions of the Municipal Master Plan (Municipal Complementary Laws nos. 501/1995, 1,573/2003 and 2,866/2018) and of the Land Subdivision, Use and Occupation Law (Municipal Complementary Law no. 2,157/ 2007 and Complementary Municipal Law Project nº 11/2022), with emphasis on the analysis of the update of territorial organization criteria for this area. Restrictions were added to the territorial organization in the last version of the Municipal Master Plan, however, retrogressions were observed in the urbanistic requirements in the revision of the Law of Subdivision, Use and Land Occupation in relation to the protection of the recharge zone of the Guarani Aquifer.

PALAVRAS-CHAVE: Urban planning. Municipal Master Plan. Guarani Aquifer.

1 INTRODUCTION

The main goal of the urban development policy is to promote the full development of the city's social functions and ensure the well-being of its inhabitants (BRASIL, 1988). Federal Law No. 10,257/2001 (Statute of the City) establishes norms of public order and social interest that regulate the use of urban property in favor of the public interest and environmental balance (BRASIL, 2001).

In a worrying scenario that the world is experiencing in relation to water security, it is essential that Public Policies have as one of their objectives the preservation of these resources (PASOLD and SOUZA, 2020). In particular, a holistic view of environmental management of groundwater recharge zones is required (LERNER and HARRIS, 2009), given that urbanization, industrialization, infrastructure implementation and unplanned agricultural activities can alter the quantity and quality of these waters (COSTA, LORANDI, LOLLO et al., 2019).

Among the groundwater resources, the Guarani Aquifer System (SAG) stands out, one of the largest transboundary groundwater reservoirs in the world, present in four Latin American countries: Brazil, Argentina, Paraguay and Uruguay (GONÇALVES, TERAMOTO and CHANG, 2020).

For the present research, Ribeirão Preto, a municipality located in the interior of the state of São Paulo, Brazil, was selected. Given the importance of this municipality and its possible impacts on the qualitative and quantitative aspects of the SAG; since the 1980s research has been carried out in this region, as verified in Sinelli (1984), Montenegro, Righetto and Sinelli (1988), Monteiro (2003), Villar and Ribeiro (2009), Fernandes, Maldaner, Negri et al. (2016), Bircol, Souza, Fontes et al. (2018), Alves, Machado, Zagui et al. (2019), Ferrari, Souza and Annunciation et al. (2019), Perroni, Braga and Perroni (2019), Ayer, Mincato, Lammle et al. (2020) and Hirata and Foster (2021).

The public supply of this municipality occurs exclusively by means of the SAG, through 118 deep tube wells, which, together, are exploited around 15 million liters of water per hour (RIBEIRÃO PRETO, 2022a), showing evidence of the source's overexploitation (HIRATA, KIRCHHEIM and MANGANELLI, 2020).

One of the forms of protection and preservation of water resources is the use of urban legislation as an instrument for sustainable territorial planning, especially in regions which are the most susceptible to degradation of the natural environment by human activities, as is the

case of aquifer recharge zones (COSTA, LORANDI, LOLLO et al., 2019).

However, the regulations are not limited to exclusive decisions of the Public Power. The democratic management of urban space is ensured by Federal Law No. 10,257/2001 and, in this sense, the eastern zone of Ribeirão Preto – the SAG recharge zone in the municipality – is sometimes the scene of conflicts of interest. While landowners in these areas are looking for ways to recognize their land as an urban space susceptible to real estate investment, the Public Power and part of civil society are making efforts to protect this environment to guarantee the supply of water in the future (BIRCOL, SOUZA, FONTES et al., 2018).

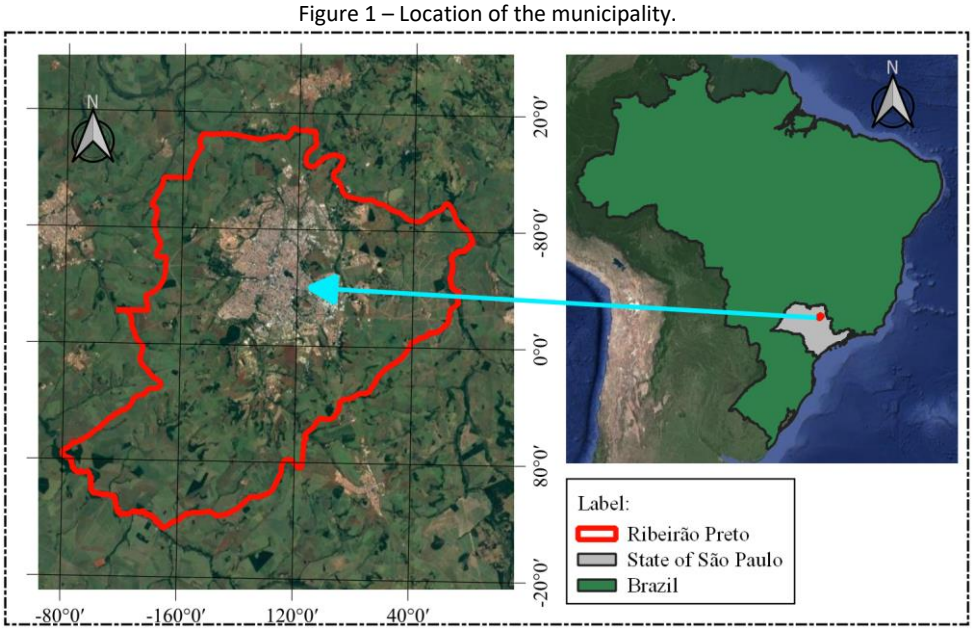
Although there are obstacles in the process of regulating land use, it is essential that they are overcame. Considering its importance, OAS (2009) highlighted it as one of the main objectives of the Strategic Actions Program (SAP) in the Organization of American States (OAS) the compatibility of the management of water resources with territorial ordering, in terms of land use and their occupation patterns.

Based on this context, the present research aimed to analyze the progress of urban legislation in the municipality of Ribeirão Preto/SP and its requirements regarding the protection of the recharge zone of the Guarani Aquifer.

1.1 Ribeirão Preto and its Urbanistic Legislation

Ribeirão Preto is a municipality located in the interior of the state of São Paulo, has an estimated population of 720,116 inhabitants (year 2021), territorial unit area of 650,916 km², Gross Domestic Product (GDP) per capita of R$ 50,270.98 (year 2019) and Municipal Human Development Index (IDHM) of 0.800 (year 2010) (IBGE, 2022). Figure 1 shows the location of the municipality.

Figure 1 – Location of the municipality.



Source: Own authorship.

Its administrative organization is divided into 16 secretariats linked to direct administration and 10 institutions of indirect administration (municipalities, mixed economy companies, etc.). Municipal planning is carried out by the Department of Planning and Urban

Development, instituted by Complementary Municipal Law (LC) 826/1999 and amended by LC 2,257/2008. Its main objectives are to plan and promote actions aimed at the physical growth and social, economic and environmental development of Ribeirão Preto, as well as to evaluate the projects to be implemented in the municipality (RIBEIRÃO PRETO, 2022a).

The first Municipal Master Plan of Ribeirão Preto was instituted in the 1990s by LC 501/1995 (deals with the institution of the Master Plan of the Municipality of Ribeirão Preto and other measures), at a time when there were no legal obligations for the municipalities to design their plans.

With the publication of Federal Law No. 10,257/2001 (Statute of the City), the elaboration of a Master Plan became mandatory for municipalities with more than twenty thousand inhabitants, members of metropolitan regions and urban agglomerations, or those in which the municipal Public Power intends to apply compulsory subdivision or building penalties, Urban Property and Territorial Property Tax (IPTU) progressive over time and expropriations with payment through public debt bonds. Those who already had it, should update them under the terms of this Legislation (BRASIL, 2001). In this sense, the municipality carried out the first revision of its Municipal Master Plan, through LC 1,573/2003 (revises LC 501/1995 and makes other provisions).

At the latest, although the ten-year period for review as stipulated in Federal Law No. 10,257/2001 was exceeded, the Master Plan was revised by LC 2,866/2018 (provides for the revision of the Master Plan implemented by LC 501/1995 and modified by LC 1,573/2003, as specified, and other measures).

The following are the complementary Legislations regarding the current Master Plan (LC 2,866/2018), as well as those which, although not having being updated yet, according to the new guidelines of LC 2,866/2018, are still in force:

- LC 1,616/2004 – Establishes the environment code, provides for the municipal system of quality management, protection, control and development of the environment, and proper use of natural resources - SIMA, the instruments of the Environmental Policy and establishes general rules for the management of environmental quality from the municipality of Ribeirão Preto;
- LC 2,157/2007 – Deals with subdivision, use and occupation of land in the municipality of Ribeirão Preto;
- LC 2,538/2012 – Establishes the Municipal Policy for solid waste and urban cleaning and makes other provisions;
- LC 2,794/2016 – Establishes the Municipal Basic Sanitation Policy of Ribeirão Preto and other measures;
- LC 2,927/2018 – Disciplines the building standards for social interest housing, social interest housing development and development in a special social interest zone in the municipality of Ribeirão Preto and makes other provisions;
- LC 14,236/2018 – Establishes the municipal tourism plan for the municipality of Ribeirão Preto and other measures;
- LC 2,932/2019 – Provides for the municipal works code, the general and specific rules to be obeyed in the preparation of the project, obtaining licensing, ordering the execution, maintenance and use of works and buildings, within the limits of the properties in the municipality, aiming to guarantee the standard of hygiene, safety and

comfort of the dwellings and makes other provisions;

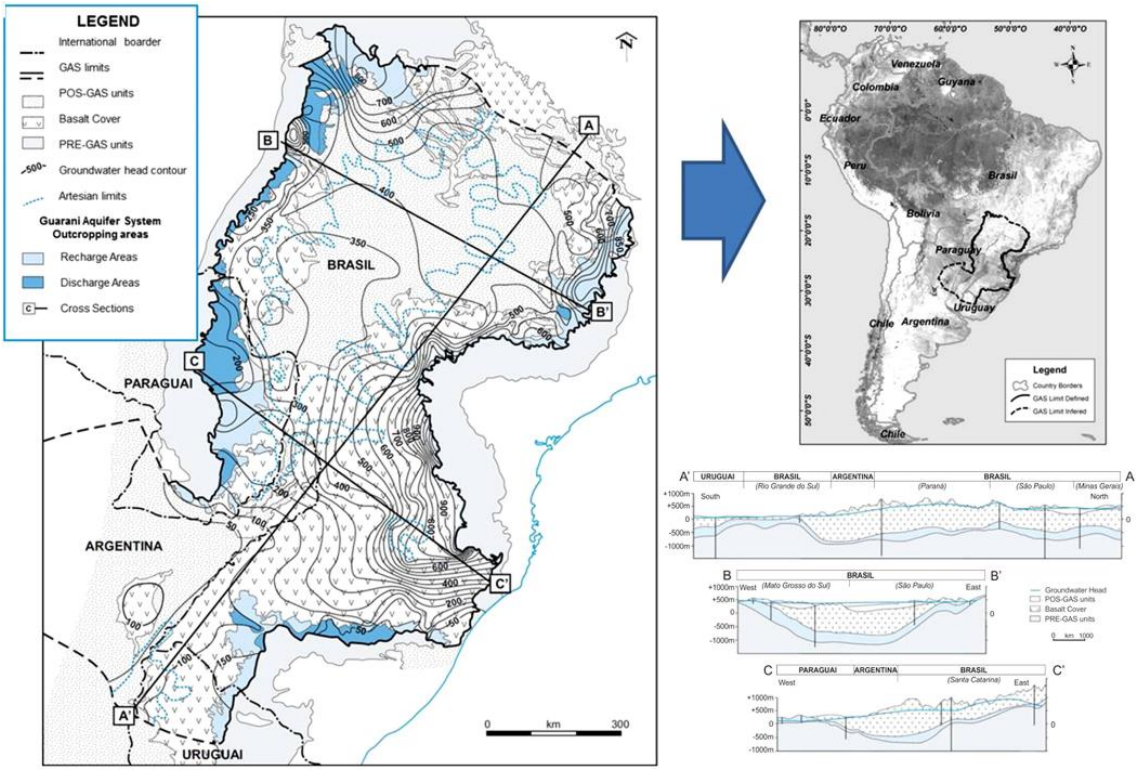
- LC 2,963/2019 – Establishes the health code of the municipality of Ribeirão Preto;
- LC 3,052/2020 – Establishes the Municipal Housing Policy in the municipality of Ribeirão Preto, approves the PLHIS - Local Social Interest Housing Plan and takes other measures; and
- PLC 11/2022 – LC project that regulates the subdivision, use and occupation of land in the municipality of Ribeirão Preto, in accordance with the guidelines established by LC 2,866/2018, which provides for the Master Plan, and other measures.

The latter (PLC 11/2022), until the date of preparation of this research was not enacted as Law, however this PLC is discussed here because it is in an advanced stage of regulation. PLC 11/2022 underwent public technical hearings and is currently under consideration by the City Council, according to Ribeirão Preto (2022a).

1.2 Guarani Aquifer System (SAG)

In the 1990s, an extensive transboundary hydrogeological aquifer was recognized, with an area greater than 1,088,000 km², shared by Brazil, Argentina, Paraguay and Uruguay, called the Guarani Aquifer System (SAG) (HIRATA, KIRCHHEIM and MANGANELLI, 2020). Of its total area, 71% is established in Brazil (839,800 km²), 19.1% in Argentina (225,500 km²), 6.1% in Paraguay (71,700 km²) and 3.8% in Uruguay (45,000 km²) (OAS, 2009). It is one of the largest groundwater reservoirs in the world (GONÇALVES, TERAMOTO and CHANG, 2020). Figure 2 presents the SAG.

Figure 2 – The Guarani Aquifer System



Source: Hirata, Kirchheim and Manganelli (2020).

In Brazil, the SAG consists of Mesozoic continental sandstones from the Botucatu and Piramboia Formations, formed between Cretaceous basaltic rocks (Serra Geral Formation and its correlates). Its recharge generally occurs in sandstone outcrop areas, as recharges are irrelevant in basalt joints and fractures (COSTA, LORANDI, LOLLO et al., 2019).

Most of the water in the Aquifer confinement region comes from infiltration that occurred hundreds or thousands of years ago in the outcrop areas (CETESB, 2022). It is estimated that its water is used for different purposes by approximately 15 million people. Although this Aquifer is in highly confined conditions, the development of deep well drilling techniques has facilitated its exploration (HIRATA, KIRCHHEIM and MANGANELLI, 2020).

2 METHODOLOGY

The adopted method comprises the development of bibliographical and documental research, with emphasis on the analysis of the updates of territorial planning criteria intended for the recharge zone of the Guarani Aquifer in the municipality of Ribeirão Preto, SP. For this purpose, the initial versions and respective revisions of the Municipal Master Plan and the Land Subdivision, Use and Occupation Law were studied.

The analysis of the regulatory instruments was organized into 4 sections, according to the chronological order of the Legislation, as shown in Table 1.

Table 1 – Organization of analysis.

Item	LC / PLC	Subject
3.1	LC 501/1995 LC 1,573/2003	Municipal Master Plan Municipal Master Plan – 1st review
3.2	LC 2,157/2007	Land Subdivision, Use and Occupation Law
3.3	LC 2,866/2018	Municipal Master Plan - 2nd revision
3.4	PLC 11/2022	Project of Law for Installment, Use and Occupation of Land - 2nd revision of LC 2,157/2007

Source: Own authorship.

In due time, it is added that the first revision of LC 2,157/2007 took place through LC 2,505/2012, but this was not addressed in this research, due to its revocation by direct action of unconstitutionality.

3 RESULTS AND DISCUSSIONS

3.1 LC 501/1995 (Municipal Master Plan) and LC 1,573/2003 (Municipal Master Plan – 1st revision)

In the 1990s, the Government had concerns regarding the recharge zone of the Guarani Aquifer, establishing, through LC 501/1995 (Municipal Master Plan), the Environmental Zoning that delimits a specific area corresponding to the Aquifer outcrop region, defined as a Special Use Zone (ZUE) (RIBEIRÃO PRETO, 1995). LC 1,573/2003 (Municipal Master Plan – 1st revision) maintained this concept (RIBEIRÃO PRETO, 2003). Figure 3 shows the location of the ZUE in relation to the municipality.

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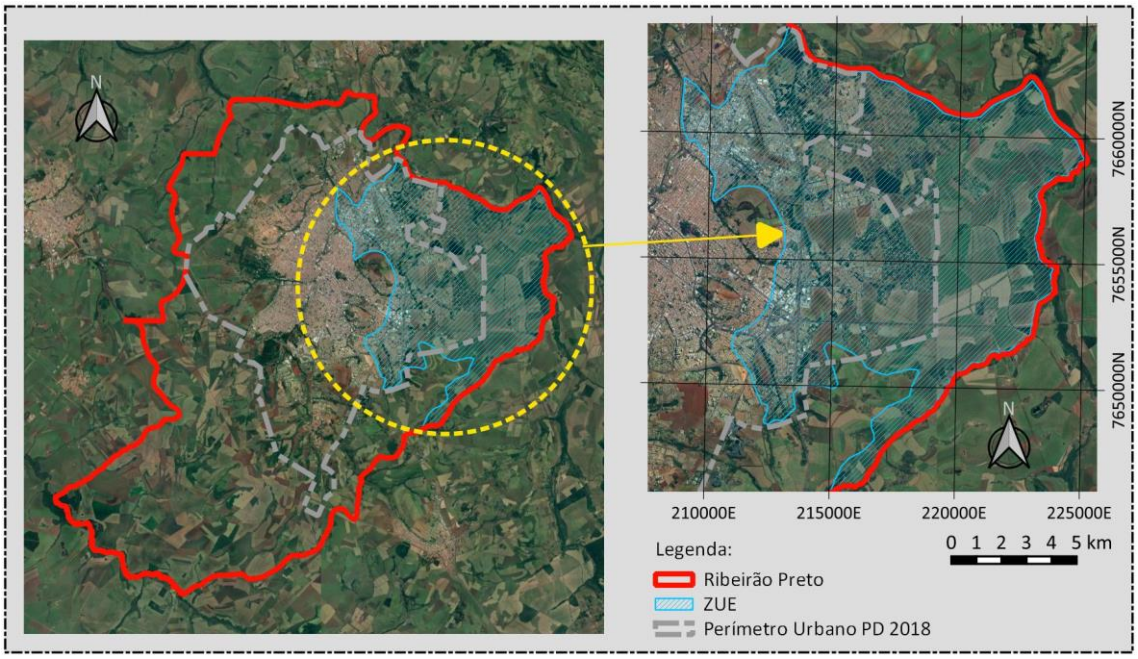
Figure 3 – Location of the ZUE in the municipality.



Source: Own authorship, based on Ribeirão Preto (1995) and Ribeirão Preto (2003).

Although both Plans did not determine specific requirements for the ZUE, they initiated a context of protection of the recharge zone of the Guarani Aquifer in the municipality, serving as a basis for subsequent legislation that established rules for the protection of this region.

3.2 LC 2,157/2007 (Land Subdivision, Use and Occupation Law)

LC 2,157/2007 organizes the municipality's macro-zoning into 6 divisions: Preferential Urbanization Zone (ZUP), Controlled Urbanization Zone (ZUC), Restricted Urbanization Zone (ZUR), Rural Zone (ZR), Maximum Protection Zone (ZPM) and Drainage Impact Zone (ZID). It is noteworthy that the ZUR corresponds to the outcrop or recharge zone of the Botucatu – Pirambóia Formations (Guarani Aquifer) (RIBEIRÃO PRETO, 2007) and is fully inserted in the Special Use Zone (ZUE) of the Environmental Charter of LCs 501/1995 and 1,573 /2003, as shown in Figure 4.

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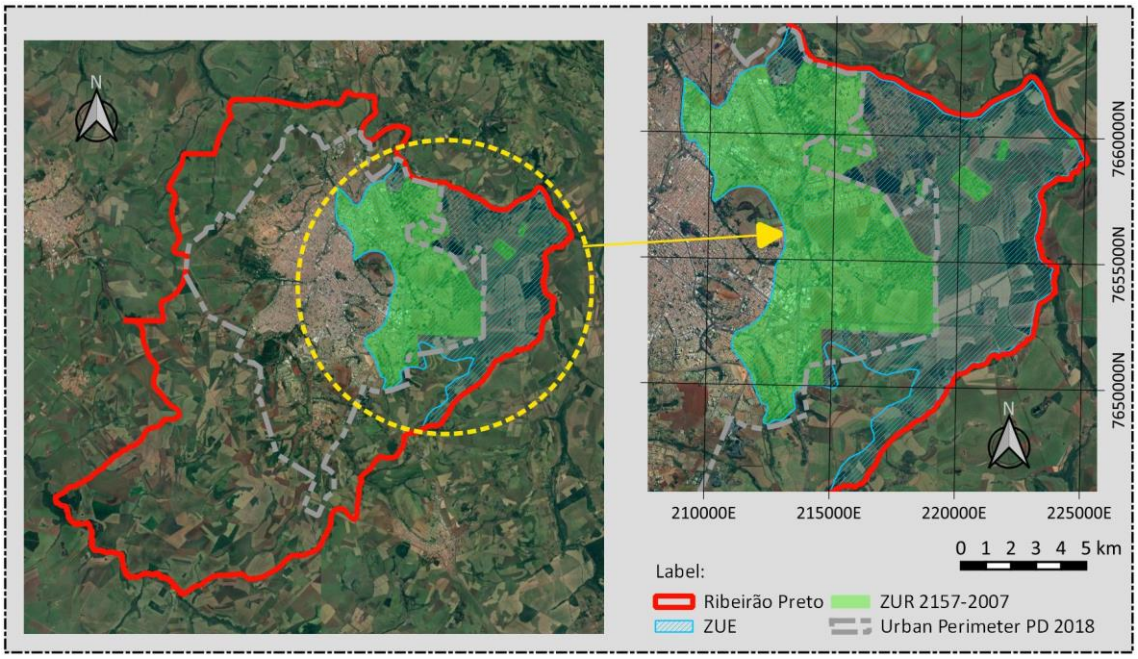
Figure 4 – Integration of the ZUR (LC 2157/2007) with the ZUE (LCs 501/1995 and 1573/2003).



Source: Own authorship, based on Ribeirão Preto (2007).

To favor greater protection of the Aquifer, LC 2,157/2007 establishes more restrictive environmental, population and construction parameters for the projects to be inserted in the ZUR, when compared to other urbanization zones (ZUP and ZUC).

Reserves of percentages of green and institutional areas intended for public use in subdivisions, condominiums and subdivisions are foreseen according to the zone in which the development is located. Table 2 summarizes the established percentages.

Table 2 – Percentage of areas destined for public use.

Area	ZUP	ZUC	ZUR
Area intended for public use in relation to the development, excluding the road system	25%	25%	40%
Institutional area	5%	2,5%	5%
Heritage area	-	2,5%	-
System of green and leisure areas	20%	20%	35%

Source: Own authorship, based on constant data in Ribeirão Preto (2007).

It is observed that for the ZUR “Green and leisure area systems” a percentage 75% is required above the percentage of this same reserve in the ZUP (20%) and ZUC (20%). Therefore, in the ZUR there is a higher percentage of permeable area in the developments when compared to the others (ZUP and ZUC). On the other hand, the Government grants a 50% discount on Land and Urban Property Tax (IPTU) to undertakings included in the ZUR intended for leisure activities that demand large extensions of permeable areas, effectively implemented (RIBEIRÃO PRETO, 2007).

Regarding population occupation, the population density restrictions stipulated in LC 2157/2007 are summarized in Table 3.

Table 3 – Percentage of areas destined for public use.

Criterion	ZUP	ZUC	ZUR
Maximum net population density (DPL)	2.000 inhabitants/hectare	2.000 inhabitants/hectare	850 inhabitants/hectare

(*) DPL = P / A; where P = number of units planned for the lot, multiplied by the average number of people (3.4 inhabitants/residential unit for residential use and 0.2 people/m² of area effectively used by the activity, in the case of non-residential property) , A = land plot area (RIBEIRÃO PRETO, 2007).
Source: Adapted from Ribeirão Preto (2007).

It turns out that the maximum DPL allowed for ZUR is 57.5% lower than for ZUP and ZUC. Under these conditions, the ZUR tends to be more horizontal, spaced and with a smaller population when compared to the others (ZUP and ZUC).

In construction terms, LC 2,157/2007 applies restrictions to the municipality's macro-zoning, as shown in Table 4.

Table 4 – Building limits according to the development zone.

Criterion	ZUP	ZUC	ZUR
CA*	5 times the land area	5 times the land area	3 times the land area
Gabarito**	10 m, which can be exceeded under the terms of LC 2,157/2007	10 m, which can be exceeded under the terms of LC 2,157/2007	10 m

(*) CA = Usage coefficient; is the ratio between the buildable area and the land area (BRASIL, 2001).
(**) Gabarito = height of the building counted from the ground floor to the top floor elevator threshold (RIBEIRÃO PRETO, 2007).
Source: Own authorship, based on constant data in Ribeirão Preto (2007).

The Public Power, in this context, directs the occupation of the ZUR to smaller buildings, both in terms of area and height.

3.3 LC 2.866/2018 (Municipal Master Plan - 2nd revision)

At first, it is noteworthy that after 23 years of publication of the first Environmental Charter of the municipality (LC 501/1995), the region indicated as ZUE (Figure 3 above) remained the same in LC 2,866/2018.

LC 2,866/2018, when compared to the previous ones (LC 501/1995 and LC 1,573/2003), presented, however, advances regarding to the protection of the Aquifer. While the latter mentioned in a generic way the need to protect the Aquifer recharge zone, LC 2,866/2018 included new protection conditions, guidelines for the elaboration of a new Law on Land Subdivision, Use and Occupation (revision of LC 2,157 /2007) and criteria for basic sanitation.

With regard to the protection of the Aquifer, LC 2,866/2018 envisages the planned occupation and appropriate uses of the recharge zone, requiring that the enterprises inserted in this area adopt efficient technological means and effective projects for capturing, filtering and absorbing water that enhance the infiltration of water underground. For the security of the application of these measures, this same Law conditions the approval of the subdivision of the soil in the Aquifer recharge zone to the proof, through studies and projects, of a recharge of the source superior to the natural state of the land, as well as the guarantee of the quality of infiltrated water (RIBEIRÃO PRETO, 2018).

Concerning the guidelines for the revision of LC 2,157/2007, LC 2,866/2018

determines, in its Article 57, that the new Law on Installment, Use and Occupation of Land must carry out the use and occupation of land in the ZUE in a sustainable manner , through a strategic plan that guarantees:

> *"I - the creation of a system of green areas formed by parks, linear parks and forest remnants interconnected through ecological and fauna corridors;*
> *II - the study and management of existing environmental liabilities;*
> *III - the solution for urban liabilities related to the road system;*
> *IV - the solution for liabilities related to basic sanitation, especially sewage collection and urban drainage;*
> *V - the disciplining of anthropic activities;*
> *VI - the preservation and conservation of the mouth of the sewage stream with a view to implement a system for capturing and treating water from the Pardo River for public supply;*
> *VII – the implementation of rainwater harvesting, filtering and infiltration systems, enhancing the recharge of the Guarani aquifer;*
> *VIII - control of the quantity and quality of infiltrated water;*
> *IX - environmental sanitation in urban and rural areas; It is*
> *X - the control and monitoring of the occupation of agricultural areas." (RIBEIRÃO PRETO, 2018).*

In addition to these guidelines, another point to be highlighted that LC 2.866/2018 imposes on the new Law on Land Subdivision, Use and Occupation corresponds to the minimum reserve of the total to be divided into free areas for public use intended for forest recomposition and leisure systems. Although the indicated percentage remained at 35%, this Law determines that if the technical studies do not prove the effectiveness of the rainwater infiltration system, a percentage above 35% may be required for these areas.

Finally, on the subject of basic sanitation, LC 2,866/2018 provides for the mandatory use of rainwater drainage systems associated with techniques for artificial aquifer recharge for land subdivisions, which are to be carried out in the Guarani Aquifer recharge zone. The method adopted in each case must be submitted for approval by the Municipal Environment Secretariat (SMMA), as stipulated in this Law.

3.4 PLC 11/2022 (Project of Law for Subdivision, Use and Occupation of Land - 2nd revision of LC 2.157/2007)

PLC 11/2022 defines the ZUE as an area whose actions and anthropic activities must be disciplined with a view aimed towards the protection and conservation of the source, based on special parameters of use and occupation of the soil in a sustainable manner. The sustainable use of the ZUE in this PLC is related to the control of non-residential activities, under the conditions established in the incident Use Zones and complementary legal provisions; as well as enabling the Municipal Secretary of the Environment to demand additional mitigation and control measures for the undertakings to be established in the ZUE.

However, this same PLC organizes the macro-zoning of the municipality into 5 divisions: Preferential Urbanization Zone (ZUP), Controlled Urbanization Zone (ZUC), Restricted Urbanization Zone (ZUR), Rural Zone (ZR) and Mata de Santa Tereza (ZMT); in which the ZUR started not to completely cover the ZUE area, transforming the area inside the ring road as a ZUP, although inside the ZUE, as shown in Figure 5

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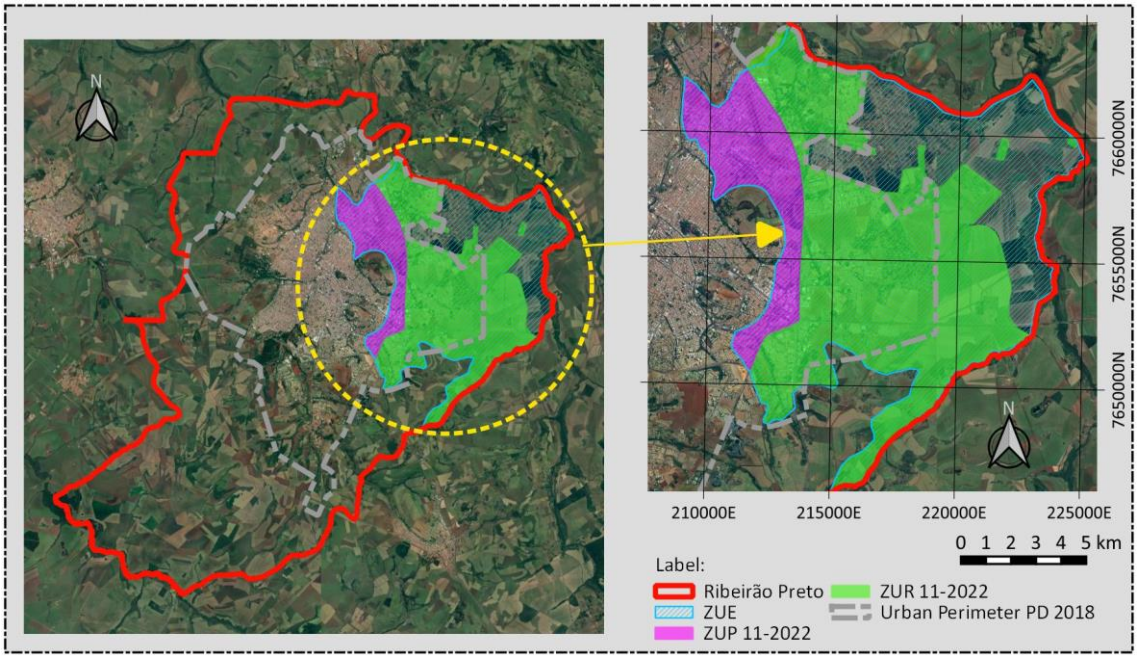
Figure 5 - Integration of ZUR (PLC 11/2022) and ZUP (PLC 11/2022) with ZUE (LCs 501/1995, 1,573/2003 and 2,866/2018).



Source: Own authorship, based on Ribeirão Preto (2022b).

Regarding population density, permissions in the ZUR were changed from LC 2,157/2007 to PLC 11/2022, as shown in Table 4.

Table 4 – Percentage of areas destined for public use.

Criterion	ZUR LC 2,157/2007*	ZUR PLC 11/2022**
Maximum net population density (DPL)	850 inhabitants/hectare	650 inhabitants/hectare, reaching 850 inhabitants/hectare for developments covered by the Social Interest Housing Law

(*) DPL = P / A; where P = number of units planned for the lot, multiplied by the average number of people (3.4 inhabitants/residential unit for residential use and 0.2 people/m² of area actually used by the activity, in the case of non-residential property); A = land plot area (RIBEIRÃO PRETO, 2007).
(**) DPL = P / AT; where P = estimated population for the housing development, determined by the number of planned units, multiplied by the average number of people (3 inhabitants/residential unit and 2 people per unit for buildings with up to one bedroom per residential unit); A = area of the plot of land (RIBEIRÃO PRETO, 2022b).
Source: Own authorship, based on data from Ribeirão Preto (2007) and Ribeirão Preto (2022b).

Although the reduction of the maximum DPL allowed in the ZUR from LC 2,157/2007 to PLC 11/2022, from 850 inhabitants/hectare to 650 inhabitants/hectare (undertakings that do not fall under the Social Interest Housing Law) is notorious, it is clear that the DPL calculation method has also changed. In LC 2,157/2007, 3.4 inhabitants per residential unit and 0.2 people per square meter of area actually used by the activity were considered in the case of non-residential property; in PLC 11/2022, 3.0 inhabitants per residential unit and 2 people per unit are considered for buildings of up to one bedroom, excluding the population of non-residential properties from the calculation.

Thus, comparative studies are needed to assess whether the reduction in density allowed in the ZUR will occur in practice or not, since the criterion for calculating the number of inhabitants per unit generates a smaller population estimate when comparing PLC 11/2022 with LC 2,157/ 2007.

As for permeability in the ZUE, PLC 11/2022 maintains the requirement of LC 2,157/2007 of 35% of the reservation of free space systems for public use as permeable areas in land subdivisions. In the building context, PLC 11/2022 imposes a minimum Permeability Rate (permeable area, within the lot or plot, where water infiltration and flow into the soil is allowed, free from any building or paving, through the lot or plot area) 15% of the total land area for plots of up to 250 m² and 20% for other situations; which was not required in LC 2,157/2007.

As an alternative to permeable areas, PLC 11/2022 allows the use of a containment or infiltration system according to Table 5.

Table 5 - Outflow Retention Box and/or Infiltration System.

Zoning	Retention Box	Infiltration System
Preferential Urbanization Zone (ZUP)	Lot ≤ 1.000 m²	Lot > 1.000 m²
Controlled Urbanization Zone (ZUC)	Lot ≤ 500 m²	Lot > 500 m²
Restricted Urbanization Zone (ZUR)	**-**	**All**

Source: Adapted from Ribeirão Preto, 2022b.

It appears that in the ZUR the option for “retention box” is not allowed, but only “infiltration system”; however, with the exception that this method is applied only in lots with an area of up to 1,000 m² and the volume of harvested rainwater is conducted to an infiltration system aiming for the forced recharge of the Aquifer.

In the construction aspects, there were changes, which are shown in Table 6.

Table 6 – Construction limits according to the development zone.

Criterion	ZUR LC 2,157/2007	ZUR PLC 11/2022	Urban perimeter expansion zone within the ZUR PLC 11/2022
CA*	3 times the land area	5 times the land area	3 times the land area
Gabarito**	10 m	Due to the setback of the building, which may exceed 10 m under the terms of Law	Due to the setback of the building, which may exceed 10 m under the terms of Law

(*) CA = Usage coefficient; is the ratio between the buildable area and the land area (BRASIL, 2001).
(**) Gabarito (LC 2,157/2007) = height of the building counted from the ground floor to the top floor elevator threshold (RIBEIRÃO PRETO, 2007); Gabarito (PLC 11/2022) = height of the building from the finished floor of the ground floor to the finished floor of the last floor, regardless of the existence of an elevator (...) (RIBEIRÃO PRETO, 2022b).
Source: Own authorship, based on data from Ribeirão Preto (2007) and Ribeirão Preto (2022b).

According to Table 6, PLC 11/2022 reduces the construction restrictions in the ZUR, allowing larger buildings when compared to the construction parameters established in LC 2,157/2007. In the expansion zone within the ZUR, PLC 11/2022 maintains the CA limit, but allows buildings to exceed the 10m height limit.

4 CONCLUSIONS

Progress was observed in the urban legislation of Ribeirão Preto in terms of protection of the Guarani Aquifer. LC 501/1995 (Municipal Master Plan) and LC 1,573/2003 (Municipal Master Plan – 1st revision), although superficially, led off to the theme of specific treatment for the undertakings to be implemented in the Aquifer recharge zone – Zona of Special Purpose

(ZUE).

LC 2,157/2007 (Law on Subdivision, Land Use and Occupation) determined stricter rules regarding environmental, construction and population aspects for subdivision, use and occupation of land in the Restricted Urbanization Zone (ZUR), favoring horizontal occupation, less densely populated and with a larger permeable area, when compared to the Preferential Urbanization Zone (ZUP) and Controlled Urbanization Zone (ZUC).

LC 2,866/2018 (Municipal Master Plan – 2nd revision) presented advances in the Legislative approach for the protection of the Aquifer, including new criteria of environmental and construction aspects for the ZUE, as well as guidelines for the elaboration of a new Law of Installment, Use and Land Use (revision of LC 2,157/2007).

PLC 11/2022 (revision of LC 2,157/2007), although it sometimes contextualizes the sustainable use of the ZUE, it leaves doubts regarding the construction parameters (size of buildings) and population (density) allowed in the ZUR, since they have fewer restrictions when compared to those stipulated in LC 2,157/2007. In addition, the ZUR area presented by PLC 11/2022 does not completely cover the ZUE, as stated in LC 2,157/2007.

In short, progress was made in the latest version of the Municipal Master Plan in protecting the Guarani Aquifer recharge zone. As for the Laws of Subdivision, Land Use and Occupation, there was a retrogression of the urban requirements in the ZUR, as well as the alteration of its area, which now does not fully cover the ZUE (area of aquifer recharge in the municipality).

This research sought to contribute to the scientific community in the study of urban legislation as a way of protecting water resources. For future research, it is suggested that analyzes be carried out on the urban parameters of other municipalities which have SAG recharge zones in their geographical limit; as well as comparing these parameters with those stipulated in the Laws of Ribeirão Preto.

REFERENCES

ALVES, R. I. S.; MACHADO, G. P.; ZAGUI, G. S.; BANDEIRA, O. A.; SANTOS, D. V.; NADAL, M.; SIERRA, J.; DOMINGO, J. L.; SEGURA-MUÑOZ, S. I. Metals risk assessment for children's health in water and particulate matter in a southeastern Brazilian city. **Environmental Research**. 2019, v. 177, article number 108623. https://doi.org/10.1016/j.envres.2019.108623

ARAÚJO, L. M. de; FRANÇA, A. B.; POTTER, P. E. Arcabouço hidrogeológico do aquífero gigante do Mercosul (Brasil, Argentina, Uruguai e Paraguai): Formações Botucatu, Pirambóia, Rosário do Sul, Buena Vista, Misiones e Tacuarembó. *In*: MERCOSUL DE ÁGUAS SUBTERRÂNEAS, 1995, Curitiba. **Congress Proceedings** [...]. Curitiba: Federal University of Paraná, 1995. p. 110-120.

AYER, J. E. B.; MINCATO, R. L.; LAMMLE, L.; SILVA, L. F. P. M.; GAROFALO, D. F. T.; SERVIDONI, L. E.; SPALEVIC, V.; PEREIRA, S. Y. Hydrosedimentological dynamics in the Guarani Aquifer System, Ribeirão Preto, State of São Paulo, Brazil. **Agriculture and Forestry**. 2020, v. 66, n. 1, p. 215-232. https://doi.org/10.17707/AgricultForest.66.1.20

BIRCOL, G. A. C.; SOUZA, M. P. de; FONTES, A. T.; CHIARELLO, A. G.; RANIERI, V. E. L. Plannyng by the rules: A fair chance for the environment in a land-use conflict area. **Land Use Policy**.2018, v. 76, p. 103-112. https://doi.org/10.1016/j.landusepol.2018.04.038

BRASIL. **Constitution of the Federative Republic of Brazil of 1988**. 1988.

BRASIL. **Federal Law No. 10,257, of July 10, 2001**. Regulates arts. 182 and 183 of the Federal Constitution, establishes general guidelines for urban policy and other measures.2001.

CETESB. Companhia Ambiental do Estado de São Paulo. Águas Subterrâneas. 2022. Available in: https://cetesb.sp.gov.br/aguas-subterraneas/programa-de-monitoramento/consulta-por-aquiferos-monitorados/aquifero-guarani/ . Access at: 19/mai./2022.

PARDO RIVER BASIN COMMITTEE (CBH-Pardo). **Plano de Bacia Hidrográfica**. 2017.

COSTA, C. W.; LORANDI, R.; LOLLO, J. A.; SANTOS, V. S. Potential for aquifer contamination of anthropogenic activity in the recharge area of the Guarani Aquifer System, southeast of Brazil. **Groundwater for Sustainable Development**. 2019, v. 8, p. 10-23. https://doi.org/10.1016/j.gsd.2018.08.007

FERNANDES, A. J.; MALDANER, C. H.; NEGRI, F.; ROULEAU, A.; WAHNFRIED, I. D. Aspects of a conceptual groundwater flow model of the Serra Geral basalt aquifer (São Paulo, Brazil) from physical and structural geology data. **Hydrogeology Journal**. 2016, v. 24, n. 5, p. 1199-1212. https://doi.org/10.1007/s10040-016-1370-6

FERRARI, R. S.; SOUZA, A. O.; ANNUNCIAÇÃO, D. L. R.; SODRÉ, F. F.; DORTA, D. J. Assessing Surface Sediment contamination by PBDE in a Recharge Point of Guarani Aquifer in Ribeirão Preto, Brazil. 2019, v. 11, n. 8, article number 1601. https://doi.org/10.3390/w11081601

GONÇALVES, R. D.; TERAMOTO, E. H.; CHANG, H. K. Regional groundwater modeling of the Guarani Aquifer System. **Water**. 2020, v. 12, n. 9, article number 2323. https://doi.org/10.3390/w12092323.

HIRATA, R.; FOSTER, S. The Guarani Aquifer System – from regional reserves to local use. **Quarterly Journal of Engineering Geology and Hydrogeology**. 2021, v. 54, n. 1, https://doi.org/10.1144/qjegh2020-091

HIRATA, R.; KIRCHHEIM, R. E.; MANGANELLI, A. Diplomatic advances and setbacks of the Guarani Aquifer System in South America. **Environmental Science and Policy**. 2020, v. 114, p. 384-393. https://doi.org/10.1016/j.envsci.2020.07.020

IBGE. Brazilian Institute of Geography and Statistics. **Electronic Portal**. 2022. Available in: https://cidades.ibge.gov.br/

LENER, D. N.; HARRIS, B. The relationship between land use and groundwater resources and quality. **Land Use Policy**. 2009, v. 26, p. S265-S273. https://doi.org/10.1016/j.landusepol.2009.09.005

MONTEIRO, R. C. **Estimativa espaço-temporal da superfície potenciométrica do Sistema Aquífero Guarani na cidade de Ribeirão Preto (SP)**. Thesis (Doctorate in Geosciences) – Paulista State University, UNESP, 2003.

MONTENEGRO, A. A. A.; RIGHETTO, A. M.; SINELLI, O. Modelação do manancial subterrâneo de Ribeirão Preto – 1 Descrição do domínio. *In*: CONGRESSO BRASILEIRO DE ÁGUAS SUBTERRÂNEAS, 1988, São Paulo. **Congress Proceedings** [...]. São Paulo: ABAS, 1988. p. 32-41.

OAS. Organization of American States. **Guarani Aquifer:** Strategic action program = Acuífero Guaraní: programa estratégico de acción. Bilingual edition – Brazil; Argentina; Paraguay; Uruguay. 224 p. 2009.

OSÓRIO, V. da C.; MOURA, C. S. Water level alterations on the southern rim of the Guarani Aquifer due to the rain regime. **Brazilian Journal of Geology**. 2021, v. 51, n. 2, article number e20200079. https://doi.org/10.1590/2317-4889202120200079

PASOLD, C. L.; SOUZA, M. C. da S. A. de. Sistema Aquífero Guarani (SAG) e a implementação integral do acordo sobre as águas. **Revista Jurídica**. 2020, v. 2, n. 59, p. 359-376.

PERRONI, J.; BRAGA, L. V.; PERRONI, H. P. Critérios para gerenciamento da explotação do aquífero Guarani em Ribeirão Preto – SP. *In*: CONGRESSO BRASILEIRO DE ÁGUAS SUBTERRÂNEAS, XX, 2018, Campinas. **Congress Proceedings** [...]. Campinas: ABAS, 2019. Available in: https://aguassubterraneas.abas.org/a subterraneas/article/view/29298

QUEIROZ, S. C. N.; FERRACINI, V. L.; GOMES, M. A. F.; ROSA, M. A. Comportamento do herbicida hexazinone em área de recarga do Aquífero Guarani cultivada com cana-de-açucar. **Química Nova**. 2009, v. 32, n. 2, p. 378-381.

RIBEIRÃO PRETO. **Complementary Municipal Law No. 1,573, of November 21, 2003**. Master Plan Revision (Municipal Complementary Law nº 501/95) and other measures. 2003.

RIBEIRÃO PRETO. **Complementary Municipal Law No. 2,157, of January 31, 2007**. Provides for subdivision, use and occupation of land in the municipality of Ribeirão Preto. Ribeirão Preto. 2007.

RIBEIRÃO PRETO. **Complementary Municipal Law No. 2,866, of April 27, 2018**. Provides for the review of the Master Plan implemented by Complementary Law No. 501, of October 31, 1995 and modified by Complementary Law No. 1,573, of November 13, 2003, as specified, and other provisions. 2018.

RIBEIRÃO PRETO. **Complementary Municipal Law No. 501, of December 1, 1995**. Provides for the institution of the Master Plan of the municipality of Ribeirão Preto and other measures. 1995.

RIBEIRÃO PRETO. **Electronic Portal**. 2022a. Available in: https://www.ribeiraopreto.sp.gov.br/portal/

RIBEIRÃO PRETO. **Complementary Municipal Law Project No. 11/2022**. Deals with the revision of the Law of subdivision, use and occupation of land in the municipality of Ribeirão Preto. Ribeirão Preto. 2022b.

SINELLI, O. Análise do nível piezométrico nos últimos 50 anos – município de Ribeirão Preto (SP). *In*: CONGRESSO BRASILEIRO DE ÁGUAS SUBTERRÂNEAS, III, 1984, Fortaleza. **Congress Proceedings** [...]. Fortaleza: ABAS, 1984. p. 450-464.

VILLAR, P. C.; RIBEIRO, W. C. Sociedade e gestão do risco: o aquífero Guarani em Ribeirão Preto-SP, Brasil. **Revista de Geografia Norte Grande**. 2009, v. 43, p. 51-64.