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Proposed Action Plan for Water Security at the Paineiras Surface Water Intake as a Contributing Factor to Urban Resilience in the Municipality of Jaú (SP)

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Proposição de Plano de Ação à Segurança Hídrica na Captação Superficial Paineiras como Fator de Contribuição à Resiliência Urbana no Município de Jaú (SP)

RESUMO

Objetivo – O objetivo geral é propor plano de ações à segurança hídrica na captação superficial Paineiras como fator de contribuição à resiliência urbana no município de Jaú (SP).

Metodologia - O método consistiu em revisão bibliográfica, visita a campo no Rio Jaú, aplicação da matriz de priorização de riscos, uso da matriz 5W2H.

Originalidade/relevância - O estudo insere-se na lacuna da falta de planejamento municipal integrado para gestão hídrica em rios urbanos, agravado por urbanização descontrolada, impermeabilização do solo e mudanças climáticas, como exemplificado pelo Rio Jaú em Jaú-SP. A relevância acadêmica reside na interseção entre urbanização, segurança hídrica e resiliência urbana, alinhada ao ODS 6 e estudos sobre vulnerabilidades em bacias como Tietê-Jacaré.

Resultados - Os resultados ilustraram que 39% dos riscos ambientais atingiram níveis grave ou muito grave, sendo destacado o risco construído com mais agressivo devido às alterações no curso d'água, excesso de impermeabilização e construção de obras de drenagem urbana não integrada à paisagem natural. Entre as ações estruturantes, a execução de obras adaptativas para o uso do solo (erosão, descarte irregular de resíduos sólidos e controle de enchentes). Entre as ações não estruturantes, tem-se os programas de mobilização ambiental de forma contínua para ampliar a conscientização e motivação da população em caráter colaborativo e voluntário no combate à contaminação da água. Como conclusão, tem-se que a resiliência urbana, baseada na segurança hídrica, depende do engajamento do gestor público com planejamento e monitoramento a longo prazo dos efeitos adversos ao meio e à sociedade.

Contribuições teóricas/metodológicas - As principais contribuições incluem a aplicação da matriz semiquantitativa de priorização de riscos (NBR 17080) e da matriz 5W2H para estruturar planos de ação contra 39 riscos graves. Esses achados metodológicos oferecem ferramentas objetivas para análise de riscos em captações superficiais, complementando revisão bibliográfica e dados de campo para priorizar riscos construídos, naturais, sociais e produtivos.

Contribuições sociais e ambientais - A principal contribuição foi a estruturação de ações para o monitoramento de eventos perigosos que podem impactar negativamente à qualidade hídrica no Rio Jaú e, assim, comprometer o abastecimento de água e os diversos usos no município, especialmente frente às mudanças climáticas.

PALAVRAS-CHAVE: Riscos Ambientais. Gestão Hídrica. Resiliência Urbana.

Proposed Action Plan for Water Security at the Paineiras Surface Water Intake as a Contributing Factor to Urban Resilience in the Municipality of Jaú (SP)

ABSTRACT

Objective – The general objective is to propose an action plan for water security at the Paineiras surface water intake as a contributing factor to urban resilience in the municipality of Jaú (SP).

Methodology – The method consisted of a literature review, a field visit to the Jaú River, application of a risk prioritization matrix, and use of the 5W2H matrix.

Originality/relevance – The study addresses the gap of lack of integrated municipal planning for water management in urban rivers, exacerbated by uncontrolled urbanization, soil sealing, and climate change, as exemplified by the Jaú River in Jaú-SP. The academic relevance lies in the intersection between urbanization, water security, and urban resilience, aligned with SDG 6 and studies on vulnerabilities in basins such as Tietê-Jacaré.

Results – The results showed that 39% of environmental risks reached severe or very severe levels, with constructed risk highlighted as the most aggressive due to changes in the watercourse, excessive soil sealing, and construction of urban drainage works not integrated with the natural landscape. Among structural actions, the implementation of adaptive works for land use (erosion, irregular solid waste disposal, and flood control). Among non-structural actions, there are continuous environmental mobilization programs to increase awareness and motivation of the population

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on a collaborative and voluntary basis to combat water contamination. In conclusion, urban resilience, based on water security, depends on the engagement of public managers with long-term planning and monitoring of adverse effects on the environment and society.

Theoretical/methodological contributions – The main contributions include the application of the semi-quantitative risk prioritization matrix (NBR 17080) and the 5W2H matrix to structure action plans against 39 severe risks. These methodological findings offer objective tools for risk analysis in surface water intakes, complementing literature review and field data to prioritize constructed, natural, social, and productive risks.

Social and environmental contributions – The main contribution was the structuring of actions for monitoring hazardous events that can negatively impact the water quality of the Jaú River and, thus, compromise the water supply and its various uses in the municipality, especially in the face of climate change.

KEYWORDS: Environmental Risks. Water Management. Urban Resilience.

Propuesta de Plan de Acción para la Seguridad Hídrica en la Captación Superficial Paineiras como Factor de Contribución a la Resiliencia Urbana en el Municipio de Jaú (SP)

RESUMEN

Objetivo – El objetivo general es proponer un plan de acciones para la seguridad hídrica en la captación superficial Paineiras como factor de contribución a la resiliencia urbana en el municipio de Jaú (SP).

Metodología – El método consistió en revisión bibliográfica, visita de campo al Río Jaú, aplicación de la matriz de priorización de riesgos y uso de la matriz 5W2H.

Originalidad/Relevancia – El estudio se inserta en la brecha de la falta de planificación municipal integrada para la gestión hídrica en ríos urbanos, agravada por la urbanización no controlada, la impermeabilización del suelo y los cambios climáticos, como lo ejemplifica el Río Jaú en Jaú-SP. La relevancia académica reside en la intersección entre urbanización, seguridad hídrica y resiliencia urbana, alineada con el ODS 6 y estudios sobre vulnerabilidades en cuencas como Tietê-Jacaré.

Resultados - Los resultados ilustraron que el 39% de los riesgos ambientales alcanzaron niveles grave o muy grave, destacándose el riesgo construido como el más agresivo debido a las alteraciones en el curso de agua, el exceso de impermeabilización y la construcción de obras de drenaje urbano no integradas al paisaje natural. Entre las acciones estructurales, la ejecución de obras adaptativas para el uso del suelo (erosión, descarte irregular de residuos sólidos y control de inundaciones). Entre las acciones no estructurales, se encuentran los programas de movilización ambiental de forma continua para ampliar la concienciación y motivación de la población de carácter colaborativo y voluntario en el combate a la contaminación del agua. Como conclusión, se tiene que la resiliencia urbana, basada en la seguridad hídrica, depende del compromiso del gestor público con la planificación y el monitoreo a largo plazo de los efectos adversos para el medio ambiente y la sociedad.

Contribuciones Teóricas/Metodológicas – Los principales aportes incluyen la aplicación de la matriz semicuántitativa de priorización de riesgos (NBR 17080) y de la matriz 5W2H para estructurar planes de acción contra 39 riesgos graves. Estos hallazgos metodológicos ofrecen herramientas objetivas para el análisis de riesgos en captaciones superficiales, complementando la revisión bibliográfica y los datos de campo para priorizar riesgos construidos, naturales, sociales y productivos.

Contribuciones Sociales y Ambientales – El principal aporte fue la estructuración de acciones para el monitoreo de eventos peligrosos que pueden impactar negativamente la calidad hídrica del Río Jaú y, así, comprometer el abastecimiento de agua y los diversos usos en el municipio, especialmente frente a los cambios climáticos.

PALABRAS CLAVE: Riesgos Ambientales. Gestión Hídrica. Resiliencia Urbana.

GRAPHIC SUMMARY

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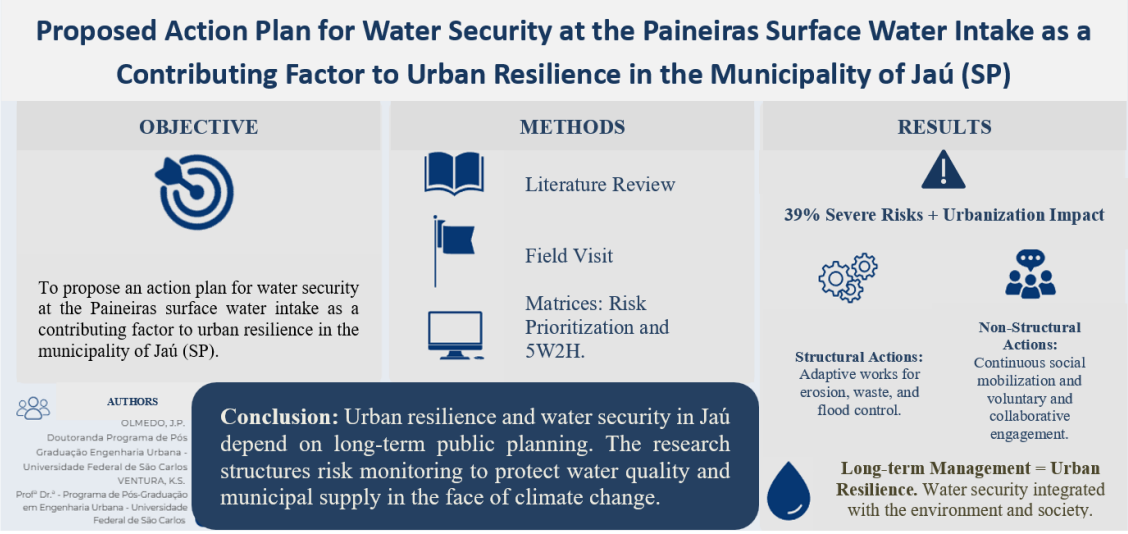

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1 INTRODUCTION

The phenomenon of urbanization, characterized by the rapid expansion of urban areas, has significantly impacted the management of water resources, raising critical issues for the sustainability of cities. Accelerated urbanization and demographic growth result in intensified exploration of natural resources, exacerbating pressure on aquatic ecosystems (Coulibaly and Managi, 2025). In Brazil, land occupation often occurs in a disorderly manner, without due consideration for environmental characteristics, compromising the quality of urban rivers and generating situations of water scarcity and pollution, which, allied with the intensification of extreme events and the lack of territorial planning and water resource management, compromises the resilience of cities and increases natural disasters (Piroli; Elias; Elias, 2025).

Urban rivers, which historically were central elements in the formation of cities, face a series of contemporary challenges. Soil sealing, resulting from urban expansion and civil construction, increases surface runoff and the pollutant load that affects water bodies (Gesualdo et al., 2021; Rivers et al, 2021). In this context, the Jaú River, located in the interior of the state of São Paulo, exemplifies the environmental risks associated with uncontrolled urbanization. Analyses conducted by Rezende and Helene (2023) indicate that canalization and irregular occupation on the riverbanks have increased the region's vulnerability to flooding events, compromising both urban infrastructure and the safety of the populations living nearby.

This reality highlights the need for integrated and sustainable management of water resources, which aims not only at conservation but also promotes the responsible use of water, ensuring a developed municipality (Ahmed et al., 2024), in line with the Sustainable Development Goals (SDGs), especially SDG 6, which proposes ensuring the availability and sustainable management of water and sanitation for all.

Thus, the intersection between urbanization and water resource management emerges as a fundamental field of study for the sustainable development of cities. The adoption of a strategic and environmentally responsible approach to land occupation is essential to ensure that urban rivers, such as the Jaú River, continue to play a vital role in urban dynamics, promoting environmental health and the quality of life of the populations living in them. Therefore, it is important to reinforce that the responsibility for managing water resources should not be delegated only to the State and Union, with municipal action being of great importance, especially in areas with water abundance but with conservation problems (Santos and Piroli, 2025).

The main contribution was the structuring of actions for the monitoring of hazardous events that can negatively impact water quality in the Jaú River and, thus, compromise the water supply and the various uses in the municipality, especially in the face of climate change.

2 URBANIZATION AND WATER RESOURCE MANAGEMENT IN THE CONTEXT OF URBAN RESILIENCE

Urbanization, an accelerated global phenomenon, has generated a series of challenges related to the management of water resources. The disorderly growth of cities, soil sealing, and

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the resulting pollution directly affect the quality and availability of water. As pointed out by (Hanley et al, 2024), the alteration of the natural characteristics of hydrographic basins, combined with the increase in urban population, has contributed to an increase in surface runoff and a reduction in water infiltration into the soil. This situation is worsened by the lack of adequate drainage infrastructure, resulting in flood events that affect urban life (Travassos et al., 2022).

An emblematic case of this problem is the Jaú River, located in the interior of the state of São Paulo. This river, which once played a vital role in the ecological dynamics of the region, has been subject to various interventions, such as canalization in strategic stretches. Although these measures were implemented with the intention of controlling the flow of water and preventing floods, reality has shown that such actions often result in adverse effects. Santos and Almeida (2019) highlight that canalization, in addition to modifying the local water regime, has contributed to an increase in runoff speed and bank erosion, which, in periods of heavy rain, increases the risk of flooding.

Furthermore, land occupation in the areas adjacent to the Jaú River has been marked by irregular constructions and a lack of urban planning, further aggravating the situation. Many of these areas are occupied by vulnerable communities that, due to the lack of housing alternatives, end up settling in risk regions. This combination of factors not only compromises the safety of local populations but also requires profound reflection on water management and use practices in the region, highlighting land use transformations as a leading theme in environmental issues in the current scenario (Kalfas et al., 2023).

The intersection between urban resilience, water security, and climate change represents an emerging and crucial field of study for the management of contemporary cities. The municipality of Jaú exemplifies the challenges faced by many Brazilian localities, especially concerning water vulnerability. Historically, the city has been severely impacted by flooding, particularly in the areas adjacent to the Jaú River. Studies such as those by Lima et al. (2025) reinforce the importance of multidimensional strategies to ensure sustainability and urban resilience, highlighting the fundamental role of green areas in thermal and water regulation. Heavy rainfall events highlight this fragility through material and social damage caused by the overflowing of the river. Such occurrences underscore the urgency of developing robust strategies that not only mitigate the immediate effects of water disasters but also promote long-term sustainability and resilience.

Urban resilience is understood as a city's capacity to adapt and recover from disturbances, whether natural or anthropogenic. In this sense, water security emerges as a central element in building this resilience. Ventura et al. (2019) highlight that the implementation of Water Safety Plans is fundamental to ensuring the supply and quality of water in situations of water stress, proposing the adoption of strategies that consider both infrastructure and participatory management. The Practical Guide for the Development of Municipal Water Safety Plans (MIERZWA et al, 2020) also emphasizes the need for an integrated approach, encompassing not only the technical aspect but also collaboration between different sectors of society, including the local population.

In the specific case of Jaú, a strategic focus must include the prioritization of risks associated with the Jaú River, with an emphasis on the surface intake in Paineiras. The

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development of action plans that promote water security must address both the mitigation of flooding effects and adaptation to future climate scenarios. Ventura et al. (2020) suggest that indicators and assessment protocols be integrated into planning to monitor the effectiveness of implemented actions and ensure the continuity of essential public services. This approach will not only contribute to the protection of water infrastructure but will also strengthen the city's capacity to recover and adapt, promoting an urban resilience that meets the demands of an uncertain and increasingly challenging future in the face of climate change.

The problem of urbanization and water resource management, exemplified by the case of the Jaú River, highlights the urgent need for integrated and sustainable approaches that consider both environmental protection and urban development. Thus, the construction of smart cities happens through the capacity of urban societies to integrate technical innovation with social inclusion, institutional capacity, and democratic values (Silva and Godoy, 2025), integrating technological solutions with efficient management of natural resources, strengthening the resilience and quality of life of the urban population (Lima et al, 2025).

Therefore, the implementation of public policies that promote the recovery of degraded areas and the adoption of nature-based solutions can be promising ways to mitigate the negative impacts of urbanization (Farjalla et al., 2021).

3 OBJECTIVES

The general objective is to propose an action plan for water security at the Paineiras surface water intake as a contributing factor to urban resilience in the municipality of Jaú (SP). As specific objectives, the following were defined:

- Prioritize risks of hazardous events in the Jaú River, starting from the Paineiras intake;
- Propose action plans for water security and urban resilience in the municipality.

4 CHARACTERIZATION OF THE STUDY AREA

The municipality of Jaú is located in the state of São Paulo, at coordinates 22º17'20'' south latitude and 48º33'18'' west longitude, at an altitude of 541 meters. The city belongs to the Bauru Mesoregion and the Jaú Microregion, and is situated about 296 km from the capital, São Paulo (IBGE, 2024).

With an HDI of 0.785, Jaú is classified as a municipality of high human development, according to the PNUD (2010). This index reflects good performance in the areas of education, longevity, and income (PNUD, 2024). Jaú is known as the "footwear capital for women," being one of the largest footwear hubs in Brazil. In addition to industry, the local economy is also strengthened by trade, services, and agriculture, with highlights being sugarcane and orange cultivation (IBGE, 2024).

The Jaú River originates in the Serra de Jaú and is part of the Tietê-Jacaré Hydrographic Basin, flowing into the Tietê River. The river is crucial for water supply and for agricultural and industrial activities in the region. However, it suffers from pollution and siltation problems due

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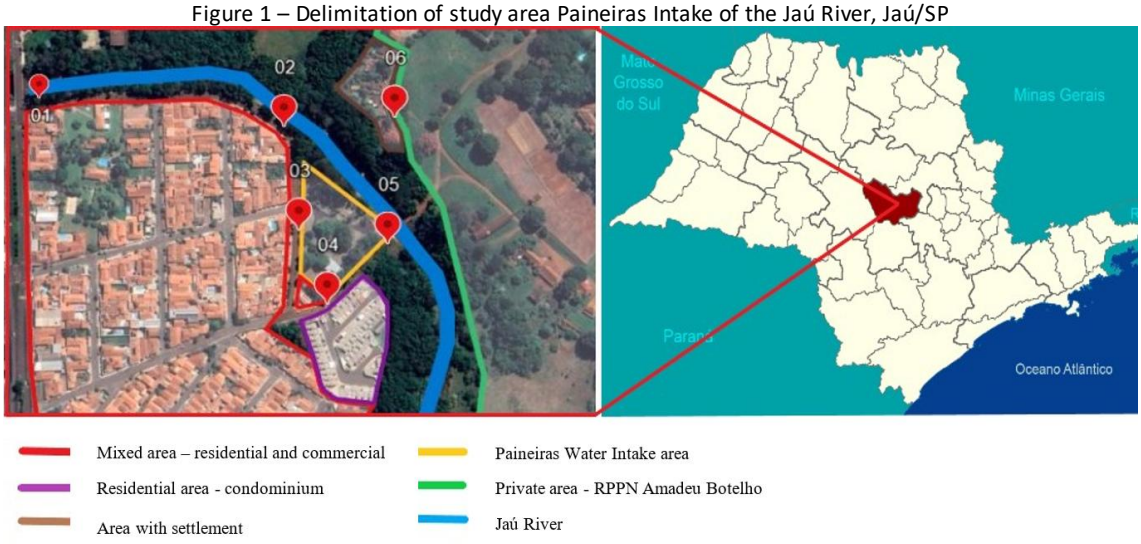
to human action (Tietê-Jacaré Hydrographic Basin Committee, 2024).

The study area is located around the municipality's surface intake (Figure 1).

Figure 1 – Delimitation of study area Paineiras Intake of the Jaú River, Jaú/SP



Source: Own authorship with adaptation from Google Maps (2024) and IBGE (2024)

Water intake in the municipality of Jaú occurs mainly in the Jardim Paineiras neighborhood, where the city's surface water intake station is located, being fundamental for local water supply (Prefeitura de Jaú, 2024).

The municipality of Jaú has a recurring history of flooding, mainly in times of heavy rainfall. The areas near the Jaú River are the most affected, with notable episodes in 2016 and 2022, when the river overflowed, causing material damage and disruption to the population (Comitê da Bacia Hidrográfica Tietê-Jacaré, 2024).

Even with a certain abundance of water resources available, environmental changes, as well as water storage and consumption, must be considered in the management of the Tietê-Jacaré basin, with the adoption of adaptive management strategies (Santarosa et al., 2022), since due to climate change surface water may have reduced availability, increasing dependency on groundwater resources (Hirata et al., 2025).

5 METHODOLOGY

The methodology for analyzing the environmental risks of the Jaú River, with a focus on the Paineiras water intake, followed a structured and systematic approach to ensure a comprehensive assessment of environmental risks. The methodological stages adopted for the development of this study are described below.

Step 1 – Literature Review. This stage made it possible to gather theoretical information and previous studies related to environmental risk analysis, particularly in water intake areas. Academic sources, books, and scientific articles addressing the context of the Jaú River watershed were consulted, as well as risk assessment methods and impact mitigation techniques. In addition, this stage provided the theoretical foundation necessary for structuring the study, collecting secondary data, and selecting appropriate analytical tools.

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Step 2 – Semi-Quantitative Risk Prioritization Matrix. This matrix (Table 1) is widely used in environmental risk studies due to its ability to classify and prioritize different types of risks by considering both the probability and the severity of impacts. The selection of this tool was based on its practical application in similar contexts, allowing for an objective and structured approach to identifying risks associated with water intake in the Jaú River.

The environmental risks analyzed in this study were based on the research conducted by Apaza, Ventura, and Menezes (2024).

Table 1 – Semi-quantitative Risk Prioritization Matrix

Ocurrence	Severity				
	Insignificant	Low	Moderate	Severe	Very severe
Almost certain	5	10	15	20	25
Very frequent	4	8	12	16	20
Frequent	3	6	9	12	15
Infrequent	2	4	6	8	10
Rare	1	2	3	4	5
Risk Score		<6	6-9	10-15	>15
Risk Classification		Low	Medium	High	Very High
	Very high: Extreme and intolerable risk; need for immediate action.				
	High: High and intolerable risk; requires special attention.				
	Medium: Moderate risk; requires attention.				
	Low: Low risk and tolerable, controllable through routine procedures.				

Source: Adapted from NBR 17080 (2023).

Step 3 - Field Survey. At this stage, during the field visit to the Paineiras water intake area, primary data were collected regarding environmental, hydrological, and land-use conditions. In addition, hazardous events that could affect the quality and quantity of the abstracted water were identified, such as deforestation, erosion, irregular occupation, and potential water pollution. The field survey was essential to ensure that the collected data were representative of the local reality and to complement the information obtained from the literature review.

Step 4 - Data Analysis and Discussion of Results. Using the Semi-Quantitative Risk Prioritization Matrix established by NBR 17080 (ABNT, 2023), risks were classified into different categories: natural risks (such as floods and erosion), constructed risks (such as inadequate or poorly maintained infrastructure), social risks (such as irregular occupation and lack of community awareness), and productive risks (such as agricultural or industrial activities that may affect water quality). This classification was essential to prioritize which risks required more urgent intervention and which mitigation actions would be most effective. To complement the analysis, the 5W2H Matrix (Table 2) was applied in the development of action plans aimed at mitigating or reducing environmental impacts.

The 5W2H matrix (What, Why, Who, Where, When, How, and How Much) is an effective tool for defining action plans and minimizing key challenges, enabling a clear structuring of the proposed actions by defining responsibilities, timelines, and the resources required for implementing each measure (Ventura & Suquisaqui, 2020).

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Table 2 - Example of the 5W2H Matrix structure

Weakness: Problem Identification	
What (What will be done?)	Describes the activity to be carried out.
Where (Where will it be done?)	Specifies the location where the activity will be implemented.
Why (Why will it be done?)	Presents the justification for carrying out the activity.
Who (Who will carry it out?)	Identifies the individuals, sectors, or institutions involved in the activity.
When (When will it be done?)	Indicates the period, timeframe, or schedule for implementing the activity.
How (How will it be done?)	Describes the method and procedures involved in carrying out the activity.
How Much (How much will it cost?)	Estimates the cost of implementing the activity.

Source: Adapted from Silveira, Martelli, and Oliveira (2016).

It should be clarified that the costs of the proposed actions were not estimated; however, measures were suggested to obtain funding for the actions indicated in this article.

6 RESULTS

6.1 Environmental Contamination Risks to the Water of the Jaú River

Over the years, the Jaú River has undergone significant interventions, such as the channelization of certain sections and alterations to its natural course, aiming to meet urban demands and support city development. These modifications have resulted in a series of negative impacts on urban drainage and local ecology.

Prior to channelization in some parts of its perimeter, the Jaú River followed a more sinuous course, forming meanders and floodplain areas that functioned as natural flood zones. These areas were essential for maintaining the balance of the hydrological cycle, as they allowed rainwater infiltration into the soil, helping to recharge the groundwater table and reduce flood risk.

The interventions, as well as land use and land occupation patterns, can be observed in the field visit images (Figure 2), which show the presence of bridges and a high degree of soil sealing within its natural floodplain area.

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Figure 2 – External points around the Paineiras water intake for analysis

	
Point 01 – Jardim das Paineiras Bridge	Point 02 – Riparian Forest of the Jaú River | side of the water intake
	
Point 03 – View of residential area | in front of the water intake entrance	Point 04 – View of residential condominium | behind the water intake
	
Point 05 – View of wooden truss bridge over the Jaú River | behind the water intake	Point 06 – View of settlements | wooden shelters on the left and private area (Amadeu Botelho Private Natural Heritage Reserve – RPPN) on the right

Source: Author's own elaboration, 2024.

Table 4 illustrates the prioritized risks, identifying that constructed risks present the highest degree of contamination to the watercourse due to alterations in the urban and environmental landscape.

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Table 4 – Risk prioritization matrix for the study object

RISK	HAZARDOUS EVENT	PROBABILITY	SEVERITY	SCORE
CONSTRUCTED	Alterations and/or rectifications in the shape of the watercourse (narrowing, channelization, galleries, bridges).	Almost certain	Severe	20
	Increase in soil sealing within the watershed contribution area.	Almost certain	Severe	20
	Drainage works (storm drains, collector networks, channels, reservoirs, others) often not aligned with the natural flow behavior of the watercourse.	Almost certain	Severe	20
	Presence of irregular occupation/constructions in the surroundings.	Very frequent	Severe	16
	Disposal and accumulation of solid waste in general (sediments, construction debris, animalexcreta, others).	Frequent	Severe	12
	Soil exposure (bare soil) or lack of vegetation.	Frequent	Severe	8
	Transport of contaminants by surface runoff.	Infrequent	Severe	8
	Poorly dimensioned corrective maintenance works or works carried out without compliance/standardization.	Infrequent	Moderate	6
	Destruction of pavement along the stream banks.	Infrequent	Moderate	6
	Presence of excessive noise from motor vehicles.	Almost certain	Insignificant	5
	Presence of gas stations in the vicinity.	Rare	Severe	4
	Portions of the river stretch lacking riparian vegetation.	Rare	Moderate	3
NATURAL	Presence of irregular occupation and constructions in the surroundings.	Very frequent	Severe	16
	Presence of specific points with erosive processes along the watercourse.	Very frequent	Severe	16
	Occurrence of flooding events, overflows, and urban inundation.	Almost certain	Moderate	15
	Soil exposure (bare soil) or lack of vegetation.	Frequente	Severe	8
	Changes in perceptible water characteristics (color, odor, turbidity) and presence of unpleasant odor.	Rare	Severe	4
	Absence of aquatic life (fish, others).	Rare	Severe	4
	Portions of the river stretch lacking riparian vegetation.	Rare	Moderate	3
SOCIAL	Existence of protected areas and Permanent Preservation Areas (PPAs) not being respected.	Very frequent	Very severe	20
	Growth of inappropriate vegetation along the river course.	Very frequent	Moderate	12
	Few initiatives for the implementation of environmental education.	Very frequent	Moderate	12
	Lack of maintenance of green areas along the riverbanks.	Infrequent	Severe	8
	Presence of excessive noise from motor vehicles.	Frequent	Low	6
	Vandalism and sabotage, and perception of insecurity along the riverbanks.	Infrequent	Low	4
	Area close to or belonging to recreational environments.	Frequent	Insignificant	3
PRODUCTIVE	Alterations and/or rectifications in the shape of the watercourse (narrowing, channelization, bridges).	Almost certain	Severe	20
	Artificial material composing the riverbed (concrete, construction debris, others).	Rare	Severe	4
	Presence of gas stations in the vicinity.	Rare	Severe	4
	Presence of excessive noise from motor vehicles.	Frequent	Insignificant	3
	Presence of poultry/animal breeding in the surroundings.	Rare	Low	2

Source: Author's own elaboration, 2024.

6.2 Actions for urban and sustainable development in the municipality

The prioritized risks (Table 4) show a great anthropic influence on their events, as well as an absence of adequate planning, inspection, and monitoring. Of all the risks presented, 39% are classified as severe and very severe risks. Therefore, these risks, which demand an extreme

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need for an action plan or are close to it, were prioritized for the study with the presentation of action plans based on the 5W2H matrix concept.

The action plans stem from the six points around the Paineiras intake in Jaú, but they open up the possibility of application throughout the river's perimeter outside the study area, as well as for other water sources that face risks similar to those prioritized. Therefore, Tables 5, 6, 7, and 8 were prepared by type of risk—constructed, natural, social, and productive—and they present comprehensive ideas; financial costs were not considered, as they may vary in each case and according to each specific schedule for adopting the action plan.

The proposed action plans present the following topics:

- Management of Permanent Preservation Areas (APPs) and erosion control;
- Implementation of sustainable drainage systems;
- Environmental education and community participation;
- Solid waste management;
- Strict inspection of works and irregular occupations.

Irregular occupation in risk areas, especially in APPs, is a serious environmental problem that increases vulnerability to natural disasters, such as floods and landslides (Table 5). Therefore, the action plans are focused on monitoring, planning, adaptation, and management, with the intention of increasing stormwater runoff, rescuing aquatic biodiversity, and clearing drainage channels (OECD, 2022).

The conservation of APPs is an essential measure for the protection of water resources (Table 6). These areas function as natural barriers that reduce the siltation of water bodies and mitigate the impacts of erosion. In this way, the action plans are aimed at identifying erosion points and controlling improper vegetation, with the aim of recovering riparian vegetation, restoring soil fertility, and clearing the water flow.

Changing the population's behavior regarding the preservation of water resources depends on effective environmental education (Table 7). Educational programs in schools and communities near preservation areas have the power to transform people's relationship with the environment. Thus, the action plans are focused on the inspection and regularization of irregular occupations, environmental regularization, and the implementation of environmental programs, with the aim of controlling erosion and preserving biodiversity, raising awareness, recovering degraded areas, and protecting lives that are occupying risk areas.

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Table 5 – Action Plans for Constructed Risks in the Municipality of Jaú

Risk	Alterations and/or rectifications in the shape of the watercourse (narrowing, channelization, galleries, bridges).	Increase in soil sealing within the watershed contribution area.	Drainage works (storm drains, collector networks, channels, reservoirs, others) often not aligned with the natural flow behavior of the watercourse.	Disposal and accumulation of solid waste in general (sediments, construction debris, animal excreta, others).	Presence of irregular occupation/constructions in the surroundings.
What?	Monitor and adapt the shape of the watercourse to prevent alterations that cause narrowing or inadequate channelization, maintaining natural flow and preventing flooding.	Plan and implement drainage works in accordance with the natural behavior of water flow to minimize the impact of soil sealing.	Design drainage infrastructure in alignment with the natural flow of the watercourse, avoiding systems that may increase the risk of flooding or siltation.	Eliminate improper disposal of solid waste by promoting adequate management and regular cleaning of areas prone to waste accumulation.	Inspect and regularize irregular occupations in preservation areas and riverbanks, preventing constructions that negatively impact the environment.
Where?	In areas where interventions occur in the watercourse, such as bridges, galleries, and channelization works.	In urban and suburban areas where soil has been sealed by construction or paving, and in watershed recharge areas.	In urban areas, especially near rivers and streams affected by drainage infrastructure works.	In urban areas, construction zones, riverbanks, and locations with irregular waste disposal.	In Permanent Preservation Areas (PPAs), riverbanks, and areas at risk of landslides or flooding.
Why?	They impact the natural flow of the watercourse, resulting in flooding, environmental degradation, and loss of aquatic biodiversity.	Soil sealing prevents water infiltration into the ground, increasing surface runoff and flood risk.	Poorly planned works can divert water flow and cause flooding in other areas, in addition to generating negative environmental impacts.	The accumulation of solid waste can obstruct drainage channels and pollute water bodies, affecting local fauna and flora and increasing flood risk.	Irregular occupations can lead to deforestation, erosion, flooding, and risk to the lives of occupants.
Who?	Municipal managers.	Public works managers and drainage specialists.	Public managers and environmental inspection agencies.	Municipal government, construction companies, urban cleaning service providers, and the local community.	Municipal governments, environmental and urban inspection agencies, and property owners.
When?	Before any infrastructure works are carried out, with continuous monitoring after completion.	During urban planning processes and whenever works involving soil sealing are conducted.	During the planning and execution of drainage works.	Continuously, with periodic awareness campaigns and inspection actions.	Immediately, with preventive actions to prevent new irregular occupations and interventions in already occupied areas.
How?	Conduct environmental impact and hydrological studies, in addition to applying sustainable engineering techniques and watercourse naturalization strategies.	Implement solutions such as permeable pavements, green areas, and drainage systems that respect the natural flow of the watercourse.	Carry out detailed hydrological studies; use sustainable drainage solutions such as retention basins and permeable pavements; and perform periodic maintenance of drainage systems.	Through selective waste collection, inspection, and enforcement of penalties for improper disposal, in addition to environmental education initiatives for the population.	Through continuous inspection, implementation of land tenure regularization policies, promotion of adequate housing in appropriate areas, and relocation programs for residents living in risk areas.

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Table 6 – Action Plans for Natural Risks in the Municipality of Jaú

Risk	Presence of specific points with erosive processes along the watercourse.	Occurrence of flooding events, river overflows, and urban inundation.	Growth of inappropriate vegetation along the river course.
What?	Identify and contain erosion points along the watercourse through erosion control and environmental restoration techniques.	Develop efficient drainage systems and flood containment measures, in addition to monitoring urban occupation in risk areas.	Carry out management and control of inappropriate vegetation that may obstruct the watercourse or negatively affect the quality of the aquatic ecosystem.
Where?	Along the margins of the watercourse, especially in areas with unstable soil or steep slopes.	In flood-prone areas, particularly in low-lying regions near rivers and in urban areas with low drainage capacity.	On riverbanks and riverbeds where vegetation is growing in an inadequate or uncontrolled manner.
Why?	Erosion may cause river siltation, loss of fertile soil, and degradation of riparian vegetation, increasing flood risk and compromising water quality.	Flood events may cause infrastructure damage, loss of property and lives, in addition to significant environmental impacts.	Invasive vegetation may obstruct water flow, lead to sediment accumulation, and compete with native species, thereby harming local biodiversity.
Who?	Environmental engineers, specialists in degraded area restoration, environmental managers, and riparian landowners.	Local government, civil defense authorities, hydraulic engineers, and urban planners.	Environmental managers, local flora specialists, and green area maintenance teams.
When?	Immediately after identifying critical erosion points, with continuous monitoring and preventive measures.	Before the period of intense rainfall, combined with continuous urban planning and preventive monitoring.	Periodically, during seasons of rapid vegetation growth (generally in spring and summer), and whenever obstruction is identified.
How?	Implement practices such as riparian reforestation, construction of physical barriers (terraces, gabions), and application of bioengineering techniques.	Implement retention basins, appropriate drainage systems, river desiltation, and meteorological forecasting monitoring for preventive alerts.	Through sustainable management practices, such as manual or mechanical removal of inappropriate vegetation and restoration of native species that promote soil stability and river flow.

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Table 7 – Action Plans for Social Risks in the Municipality of Jaú

Risk	Existence of protected areas and Permanent Preservation Areas (PPAs) not being respected.	Few initiatives for the implementation of environmental education.	Presence of irregular occupations and constructions in the surroundings.
What?	Inspect and ensure the preservation of Permanent Preservation Areas (PPAs), promoting environmental regularization in invaded or degraded areas.	Develop and implement environmental education programs in local communities and schools, focusing on water resource preservation and sustainable management.	Inspect and regularize irregular occupations and constructions in protected areas and risk zones, promoting adequate housing alternatives.
Where?	In PPA areas along rivers, slopes, and groundwater recharge zones.	In communities, schools, and urban centers near water bodies.	Along riverbanks, slopes, and other environmentally protected areas or areas susceptible to natural disasters.
Why?	The protection of PPAs is fundamental for maintaining water resources, erosion control, and biodiversity preservation.	The lack of environmental education may result in inappropriate practices that harm the environment, such as improper waste disposal and irregular occupation.	Irregular occupation may cause environmental degradation, flooding, and put the population at risk.
Who?	Environmental inspection agencies, landowners, and local governments.	Educational institutions, NGOs, local governments, and environmental agencies.	Inspection authorities, municipal governments, and local communities.
When?	Continuously, with periodic inspections and corrective actions when necessary.	Continuously, with special emphasis on campaigns during environmental events and critical periods, such as World Water Day.	Immediately, with preventive measures to avoid new occupations and regularize already occupied areas.
How?	Through environmental recovery programs, reforestation initiatives, and legal actions against irregular occupation, in addition to promoting awareness and compliance with environmental laws.	Promote lectures, workshops, practical field activities, and include environmental education in school curricula, along with public awareness campaigns.	Through inspection, relocation of residents to safe areas, and land tenure regularization in accordance with the Municipal Master Plan.

The adoption of Sustainable Urban Drainage Systems (SUDS) can minimize the impacts of traditional drainage practices (Table 8). Solutions such as permeable pavements, retention basins, and green roofs allow rainwater to be better absorbed by the soil, thereby reducing surface runoff. Therefore, the action plan is directed toward the application of ecological and restorative engineering solutions in order to mitigate and/or minimize impacts on fauna and flora.

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Table 8 – Action Plan for Productive Risk in the Municipality of Jaú

Risk	**Alterations and/or rectifications in the shape of the watercourse (narrowing, channelization, bridges).**
What?	Avoid interventions that drastically modify the natural course of the river by applying engineering solutions that respect hydrological dynamics.
Where?	At points where the river course is altered by narrowing, channelization, or bridge construction.
Why?	Unplanned alterations may cause siltation, flooding, and impacts on aquatic fauna and flora.
Who?	Civil engineers, hydrologists, and environmental inspection agencies.
When?	Before the execution of works and during urban planning processes.
How?	Conduct environmental impact studies and apply nature-based solutions, such as ecological and restorative engineering techniques.

6.3 Measures for Financing the Proposed Actions

From 2007 to 2023, the municipality and civil society of Jaú jointly secured approximately BRL 692,000 for projects involving water reuse, rural sanitation systems, environmental education for the general population, reduction of water supply system losses, urban drainage planning, educational nurseries, and ecological restoration of Permanent Preservation Areas (CBH-TJ, 2023). Thus, the watershed committee represents an annual source of funding viability in the sector, provided that public managers have a qualified technical team capable of submitting projects in accordance with the guidelines of the State Water Resources Fund (FEHIDRO).

The projected funding allocation for the Jaú Watershed Committee in 2024 is BRL 1,000,000, with emphasis on a hydrogeological study in municipalities such as Jaú and São Carlos, which face intense groundwater exploitation. This study is crucial for the sustainable management of water resources, enabling a deeper understanding of aquifer reserves and the implementation of effective strategies for preservation and rational water use.

In addition to these resources, Jaú may access funding from the Inter-American Development Bank (IDB), the Brazilian Development Bank (BNDES), and Caixa Econômica Federal (CEF), provided that it identifies projects aligned with the guidelines of these institutions. The IDB offers financing for infrastructure and water management initiatives, while BNDES provides credit lines for sustainable actions and innovation. CEF supports projects integrating

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resilient infrastructure. Partnerships with private foundations and NGOs may provide not only financial resources but also technical expertise; therefore, the municipality must remain attentive to public calls and funding opportunities.

In this context, to enhance urban resilience, it is essential to implement sustainable drainage systems, create green areas, and restore degraded spaces. Educational campaigns promoting conscious water use and encouraging rainwater reuse will help reduce reliance on groundwater resources. By integrating these measures, Jaú may become a model of sustainable and resilient water management, benefiting its population while preserving natural resources.

7 CONCLUSION

This article sought to provide support and discuss hazardous events that may occur not only in the Jaú River but also in most urban rivers in Brazil. To mitigate these issues, the municipality must adopt measures such as restoring floodplain areas and Permanent Preservation Areas (PPAs), implementing Sustainable Urban Drainage Systems (SUDS), and strengthening inspection of irregular occupations. Solutions such as permeable pavements and rain gardens may help improve water infiltration and reduce flood risk.

The most critical environmental risks (score 20) were identified as constructed, productive, and social risks, characterized by a high degree of water quality contamination and/or landscape alteration through interventions in the watercourse.

The challenges faced by the Jaú River, as well as by other water bodies, reveal the urgency of implementing action plans that prioritize urban resilience, integrating the guidelines of the Sustainable Development Goals (SDGs) and effective public policies. Water resource management must consider the interconnection between environmental, social, cultural, and political dimensions, recognizing that urbanization and water health are cross-cutting and multidisciplinary issues.

Given the complexity and magnitude of these challenges, the adoption of appropriate public policies is crucial—not only to address immediate needs but also to promote long-term sustainable development. The discussion surrounding this topic must be continuously expanded, involving multiple sectors of society, academics, and public managers in order to build a more resilient and sustainable future for cities and their rivers.

Urban resilience integrated with water security analysis is dynamic, as it is associated with water availability; effective and adequate treatment; system reliability in delivering potable-quality water; investments in training, infrastructure, and monitoring of hazardous events; the city's capacity to respond and prepare for emergency or pandemic-related situations; the strategic vision of public managers; and, above all, societal engagement, open dialogue with the population, and continuous long-term planning for water use and future demands.

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DECLARAÇÃO DE CONFLITOS DE INTERESSE

Nós, **Jacqueline Priscila Olmedo** e **Katia Sakihama Ventura**, declaramos que o manuscrito intitulado "**Proposição de Plano de Ação à Segurança Hídrica na Captação Superficial Paineiras como Fator de Contribuição à Resiliência Urbana no Município de Jaú (SP)**":

1. **Vínculos Financeiros**: O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES).
2. **Relações Profissionais**: Não possuímos relações profissionais que possam impactar na análise, interpretação ou apresentação dos resultados.
3. **Conflitos Pessoais**: Não possuímos conflitos de interesse pessoais relacionados ao conteúdo do manuscrito.