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Cities and water: A fluvial and environmental analysis of Espinharas River in Patos city, Paraíba State

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ABSTRACT

The urbanization process over the last 70 years has provided cities with a distance from their relationship with the natural elements that comprise their surroundings and urban formation. Highlights include urban rivers that have mainly been deteriorated and forgotten by the population. Rivers have always been linked to the history and development of cities, but this relationship has led to conflicts over the years, starting a process of degradation that has culminated in deteriorating the relationship between rivers and cities. Based on this, the present work aims to analyze the fluvial and environmental conditions of a stretch of the Espinharas River in Patos city, Paraíba State, pointing out its weaknesses and potential. Based on the results obtained, a framework is proposed with guidelines capable of establishing this connection between the urban and natural environment, based on a tripod formed by the integration of the river with the city, recovery of its waters, and raising the population´s awareness of the importance from the river to the local quality of life. The research uses the hypothetical-deductive method, and its methodological steps are performed in three phases: the first is the literature review; the second, diagnosing the stretch of the river under analysis; and the last step addresses the construction of the framework of the guidelines. Finally, an understanding of the current situation of the stretch of the Espinharas River under analysis and the hypothetical effects of applying all selected guidelines is obtained, thus contributing to the qualification of relationship between the river and cities.

KEYWORDS: Urban River. Diagnosis. Guidelines.

1 INTRODUCTION

Rivers and cities have always maintained a close relationship throughout history, at times acclaimed and recognized as a necessary agent for urban life, at other times despised, degraded or seen as an undesirable presence in everyday life. In the current scenario, rivers have been the topic of numerous debates that aim to reconcile water with cities, aiming at restoring and integrating them into the existing urban landscape (GORSKI, 2008).

There is currently a worldwide trend to recuperate the relationship between cities and their water resources. This process began in the 1970s with the emergence of the first environmental movements. After recognizing water as something vital for humanity, between the 1990s and the 2000s, there was an increase in the number of conferences, plenary sessions, audits, and congresses addressing the topic that unites environmental resources and cities. In this same period, many projects and plans also highlighted the relationship between river banks and their cities. These urban interventions bring ordering, requalification, and valorization of the margin spaces, building a relationship between the urban and natural environments (MELLO, 2005).

Gorski (2008) advocates plans for integrating rivers into cities, seeking urban solutions that unify infrastructure with the existing landscape conditions. In addition, Maricato (2001) considers that urban planning entails social and territorial changes, including implementing the social function of property, the right to the city, and urban justice. Urban plans and guidelines, in short, are created to improve the quality of life of the urban population, contributing to a more dignified standard of living from more qualified spaces and respecting environmental resources.

Costa (2006) presents the ideas exposed by Landscape Architect, Lawrence Halprin, through which complicity factors interconnect cities and their landscapes. Halprin (Halprin apud COSTA, 2006, p.45) states that the most interesting and intelligent cities develop a harmonious relationship with their natural landscape, where "our experience of the urban landscape is enriched when the complexity of the landscape is in the shape and design of the city."

Following this line of thought, Coy (2013) states that, from an urban perspective, the relationship and interaction between rivers and cities are primarily performed by the functions that riverbank areas play or can play in the reality of the urban set, as well as how they are inserted into the daily life of a city. Accordingly, Mello (2012) states that “the banks of urban rivers, when valued, become spaces for social interaction, and this is due to the appeal that water has on people.”

According to Spirn (1995), understanding how water settles and moves through cities will lead to introducing efficient, effective, and economic measures, regardless of the scale of the project, whether it is a drainage ditch, a source, or a plan for the metropolitan region (SPIRN, 1995, p.161).

In Brazil, in the 1990s, an integrated and participatory policy for water resources was instituted, incorporating the hydrographic basin as a planning and management unit (GORSKI, 2008, p.25). It can be observed that throughout history, the formation of Brazilian cities has seen the usual presence of water bodies as influencers for its emergence; rivers, streams, and creeks have been used as sources of resources to develop communities and future cities and as a means of mobility for people and goods (PENNA, 2017).

According to Delijacov (1998), rivers are key factors in developing and emerging many cities in the Brazilian context. As an example, the author cites the Tietê River, which brought about progress in the countryside in Brazil and commercialization of products in the 17th century through its waterways and branches that formed other rivers in several Brazilian states.

The problem defined here addresses the Brazilian context, where interventions, plans, and projects for restoration, naturalization, and reconciliation of waters with cities are still incipient, with only a few specific interventions for the environmental preservation of natural beds. On the one hand, when considering issues of the relationship between rivers and cities in urban aspects, it can be observed that rivers offer many benefits for cities, as they provide – for example, ¬– riverbank areas that can contribute to making public spaces, such as linear parks, squares, bike paths, recreation and leisure areas, places to lives, paths to walk, among others in the urban context. On the other hand, due to degradation, neglect, or other issues, these rivers have become inappropriate places, which points to possible negligence from urban planning managers and city users.

Therefore, the research aims to make an analysis referring to a certain stretch of the Espinharas River in Patos city, Paraíba State, to understand the degradation processes of the river and to know which urban and sustainable measures can directly collaborate for the requalification and naturalization of the existing landscape.

2 OBJECTIVES

2.1 General objective

The main aim of the research is to make a diagnosis of a stretch of the Espinharas River, evaluating its fluvial and environmental dimensions.

2.2 Specific objectives

The specific objectives of the research are as follows:

- Identify the levels of degradation of the stretch of the river under analysis.

- Understand river and environmental factors.
- Develop a framework of guidelines.

3 METHODOLOGY / ANALYSIS METHOD

3.1 Scientific Method

Understanding that the method is a way to fulfil a certain purpose and given the research problem and its questions, the methodology adopted predominantly uses the hypothetico-deductive method. The hypothetico-deductive method was developed in the 20th century by the philosopher Karl Popper (1935), and it is linked to the philosophical principle of neo-positivism (PRODONOV E FREITAS, 2013).

According to Prodanov and Freitas (2013, p.32), "the hypothetico-deductive method begins with a problem or a gap in scientific knowledge, postulating a hypothesis and a deductive inference process, which tests the prediction of the occurrence of phenomena covered by the hypothesis mentioned above."

According to Karl Popper, each piece of research or investigation originates from a problem whose question involves conjectured solutions, hypotheses, theories, and error elimination (PRODONOV AND FREITAS, 2013, p.33). In agreement, Lakatos and Marconi (2007) state that the method proposed by Popper is that of eliminating errors.

Finally, according to Gil (2008), the hypothetico-deductive method has significant acceptance in academia, especially in the field of natural sciences. Therefore, it is justified as a plausible method to be applied in research.

3.2 Methodological steps

3.2.1 Step 1: Bibliographic research

As conceptual bases for the construction of the problem, texts by authors such as Gorski (2008), Tucci (2008), Costa (2006), Saraiva (1999), Gehl (2013), Delijaicov (1998), and Mello (2005, 2008, 2012), among others, aiming to establish the main statements on the topic involving the relationship between rivers and cities. It is intended to elucidate possible divergences in the relationship between rivers and cities, its importance for urban development, and urban applications in the areas of riverbanks in the current scenario. This search was carried out in books, websites, journals, dissertations, theses, and articles related to the topic.

3.2.2 Step 2: Diagnosis of the river and environmental conditions

In the diagnostic stage, the watercourse factor and its ramifications were evaluated: its fluvial and environmental conditions. The diagnosis of fluvial and environmental conditions is foreseen for a stretch of the study area, and the following structure is made for the study.

3.2.2.1 Division of the watercourse into homogeneous sections

To guide the analysis of the degradation of the watercourses, it is proposed to divide the object of study into sections, where this division will also help the analysis and diagnosis stage. From this division, a single section is chosen to carry out the studies, and the way to proceed is the researcher's decision.

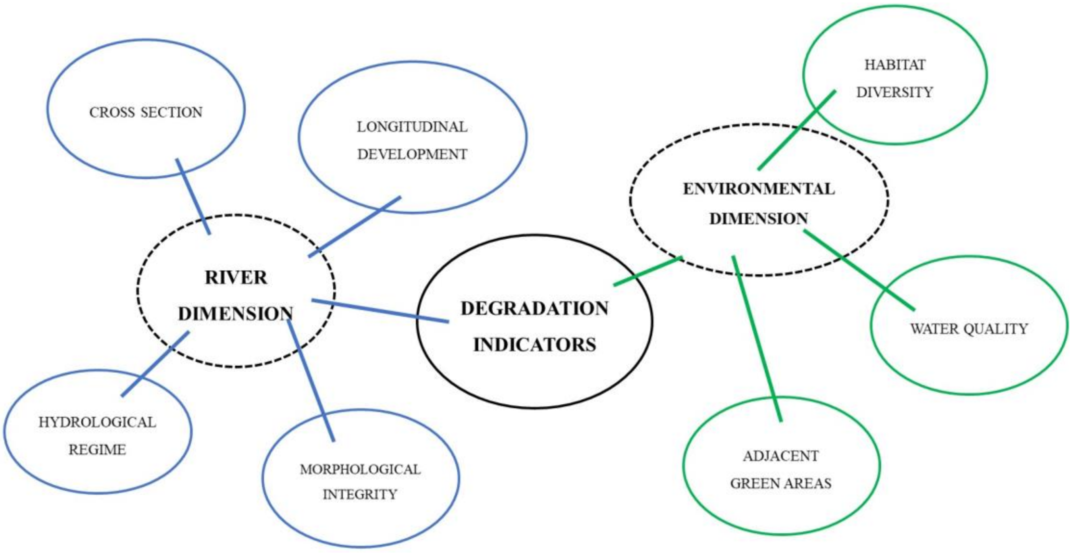
3.2.2.2 Diagnosis of stretches: fluvial and environmental aspects

This is the diagnostic phase itself, divided into two moments:

Data collection: For the survey, it is proposed to use a form (the form is presented in the diagnosis) based on protocols and manuals related to the restoration of watercourses and consolidated with field visits (CARDOSO (2008), URBEM (2003, p.10).

Assessment of the level of fluvial and environmental degradation: Based on its current state (from the previous survey), the section is evaluated using indicators, as discussed below:

Figure 1. Proposed indicators for assessing the level of degradation of watercourses according to fluvial and environmental dimensions



Source: Adapted from Cardoso (2012)

The entire framing of the dimensions can be justified by the ease of structuring the reasoning that sought to guide the research and its analyses. Finally, each indicator of a degradation scale is divided into five levels: absent, low, medium, high, and very high, applied to each indicator evaluated (CARDOSO, 2012).

In the fluvial dimension, the physical and functional aspects are evaluated in the following points: (1) longitudinal development, (2) morphological integrity, (3) hydrological regime, and (4) cross-section. In the environmental dimension, aspects are evaluated in the following points: (1) habitat diversity, (2) adjacent green areas, and (3) water quality.

3.2.3 Step 3: Discussion of Results

In the last stage, the results obtained in analyzing the fluvial and environmental dimensions of the evaluated section will be carried out. Finally, the framework of guidelines and measures for necessary interventions to promote the relationship between rivers and cities is also made at this same stage.

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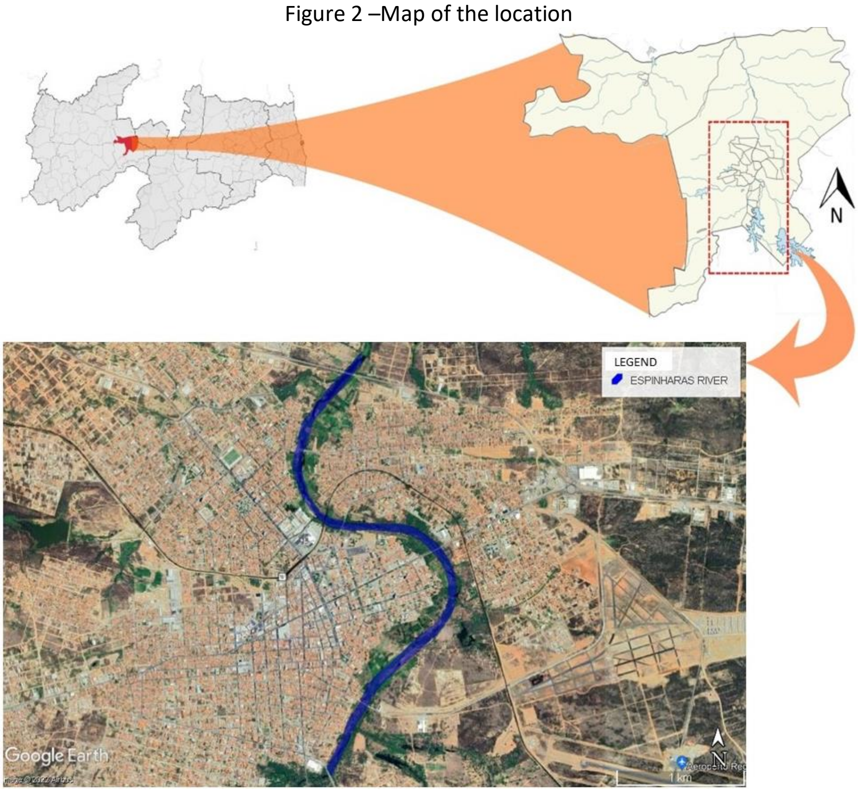
4 DIAGNOSIS / RESULTS

4.1 Object of study

Patos was emancipated around 1903 and was the third largest city in Paraíba State, with an estimated population of 117 thousand inhabitants, according to the Brazilian Institute of Geography and Statistics (IBGE, 2022). The urban formation was on the banks of the Espinharas River and around the lakes, which over time, were deprived of the natural landscape.

According to Silva, Lima & Mendonça (2013), Espinharas River is formed by the confluence of the Rio da Cruz, which rises in the municipality of Imaculada, near Patos, together with Rio da Farinha, in the municipality of Salgadinho, where they meet in the urban area of Patos city. Espinharas River is the main river in the Piranhas River basin, with an intermittent regime and an approximate length of 81.41 km, starting in Serra da Teixeira in the municipality of Patos and ending in Jardins de Piranhas city in Rio Grande do Norte State (IBGE, 2022).

Figure 2 –Map of the location



Source: Adapted by the author (2022)

4.1 Division of the stretches

Aiming to support the research, the sectorization of the river course is proposed into five sections subdivided by the bridges that are part of the river and, with it, the designation of the section selected for possible urban interventions, which can transform the urban reality of Patos city and its entire cultural, economic and social context (Figure 3).

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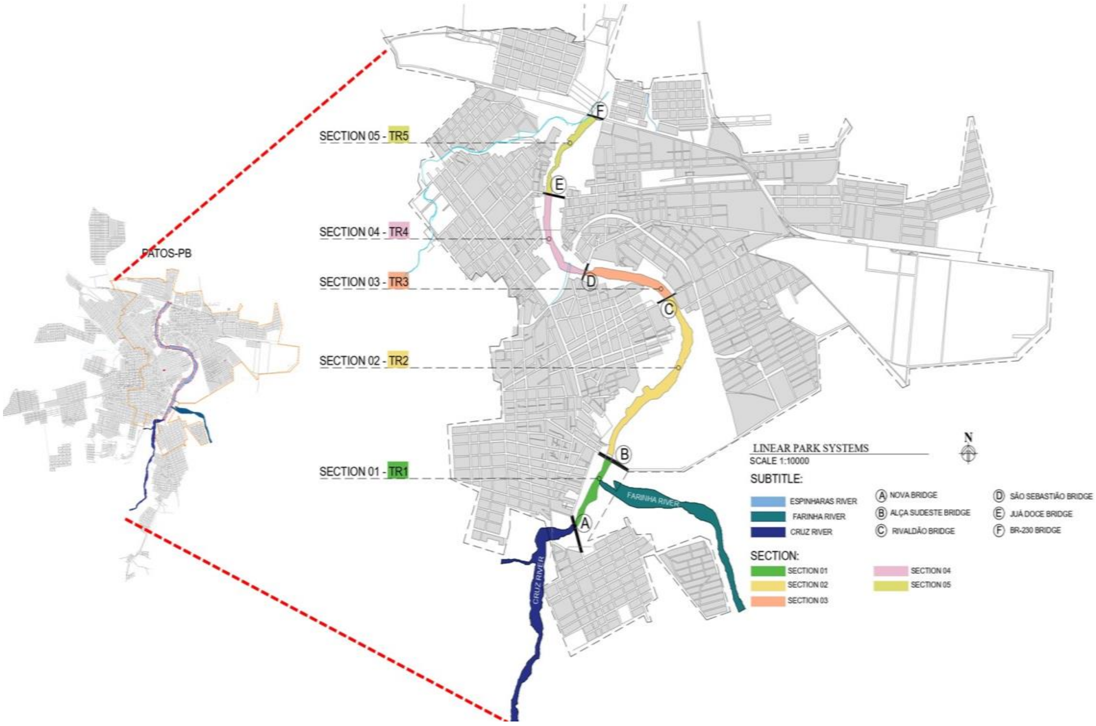
Figure 3 – Map showing Espinharas River and the selected sections.

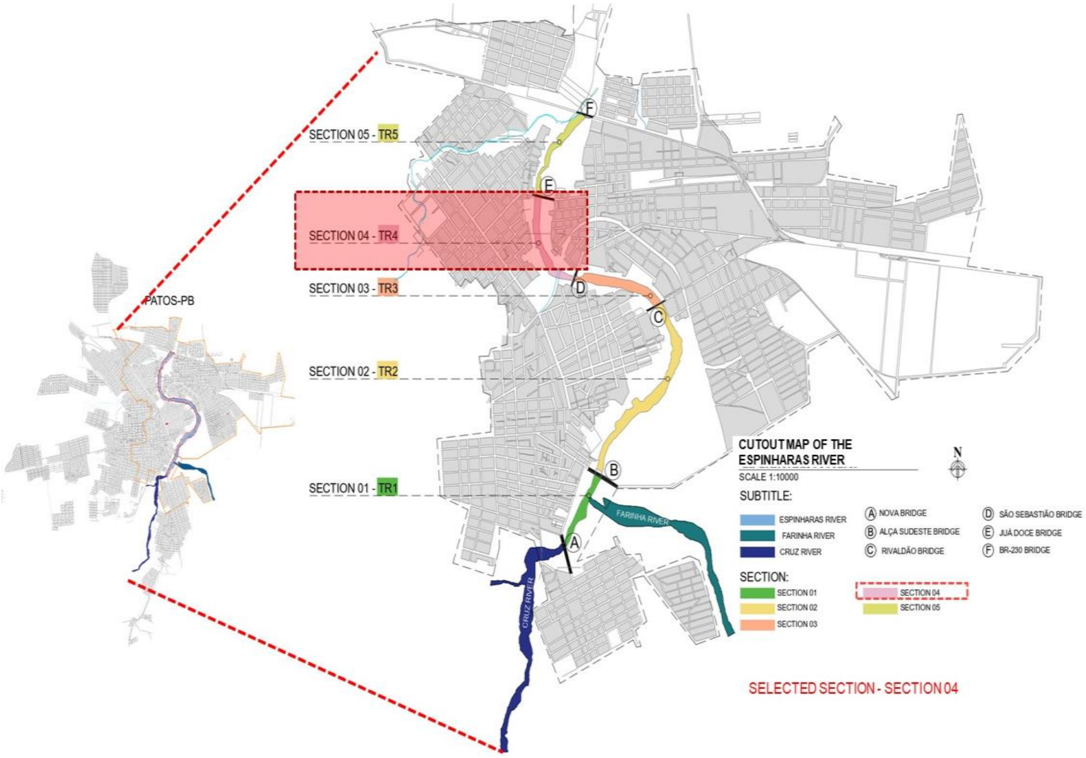


Source: Prepared by the author (2022)

4.2 Selection of the stretch

After segmenting the stretches, we were able to choose the stretch to analyze the river and environmental dimensions. The selection criteria took into account the following aspects (1) irregular occupation level, (2) deterioration of the natural landscape, (3) more central section in relation to the river course, and (4) dimensioning.

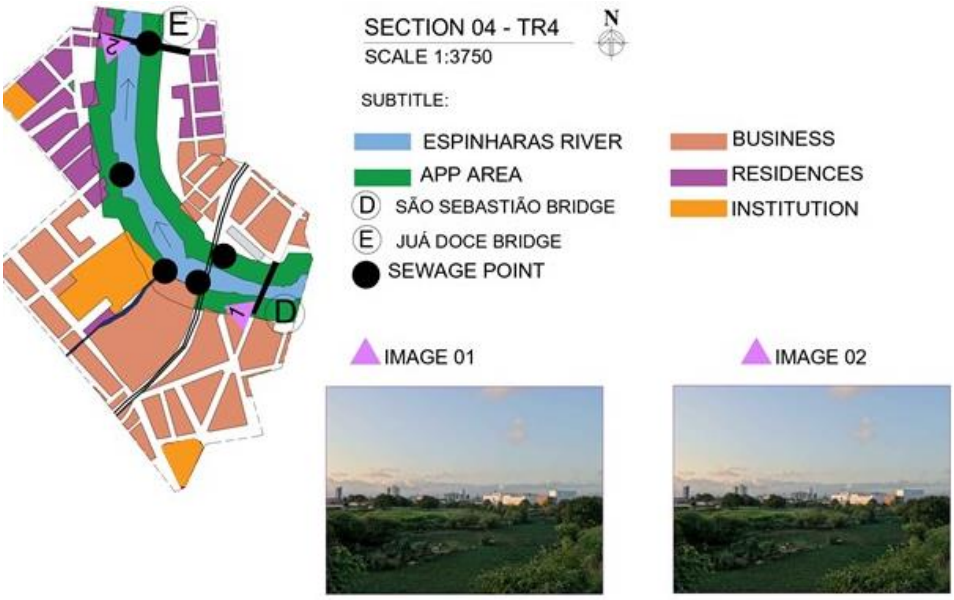
Figure 4. Selected stretch



Source: The author (2022)

Figure 5 shows the clipping referring to Section 4 that was chosen for analysis.

Figure 5 - Section 04 - TR4



Source: The author (2022)

In terms of degradation and deforestation, stretch 4 is presented as one of the stretches with the greatest problems caused by the development and urban growth of the city. Established in one of the most densely populated areas of the city, its area reaches 39,098 m², and its location is between the São Sebastião and Juá Doce bridges. In these stretches, problems can be found, such as the riparian forest's absence and/or loss of character, irregular constructions, and water pollution, among others.

4.3 River and environmental diagnosis of stretch 4

4.3.1 Application of the analysis sheet

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Table 1 - Analysis sheet of the fluvial and environmental dimension - Section 4

INFORMATION ABOUT THE WATER COURSE				
General aspects				
Name: university section	**Excerpt**: 04	**Date**: 04/22/2022	**Responsible: Emmanoel Marques**	
Identification of the stretch in the basin:				

Physical, functional and environmental aspects				
hydrological conditions				
Period in which the survey was carried out(X) dry ( ) rainy				
Rain in the last 24 hours (X) none ( ) weak ( ) strong ( ) constant ( ) intermittent				
Flow regime during field survey ( ) torrential (X)river				
Frequency of floods with damage				
nonexistent ( )	rare or little frequent ( )	occasional - between 2 and 10 years (X)	frequent - 1 once a year ( )	Very common – more once a year ( )
dimensions				
Extension:~718m	**average width**:~58m	**average depth**:~4.50m		
Slope:(X) low ( ) medium ( ) high	**Longitudinal profile:**	**unevenness:**		
type of voucher				
docked ( )	semi-docked ( )		open valley (X)	
	symmetrical plain ( )	asymmetric plain ( )	symmetrical plain ( )	asymmetric plain ( )
Sinuosity				
( ) Natural (X)slightly changed ( ) moderately changed ( ) greatly changed/rectified				
( )	(X)	( )	( )	( )
Section				
Coating				
uncoated section		coated section		
Natural (X)	changed ( )	( ) a margin	( ) both margins	( ) bed and banks; ( ) closed section

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Bed substrate and margin coverage

(X) silt-clay ( ) silt-sandy ( ) sand (X)pebble/gravel (X)rock ( ) grass (X)vegetation()
geotextile ( ) thrown/prepared rock riprap ( ) mortared rock riprap ( )*cribwall*
( ) bag/blanket gabion ( ) box gabion ( ) concrete ( ) other ....

morphological integrity ( ) stable (X) unstable

enlargement/ deepening ( )	undermining ( )	Slipping ( )	silting (X)	erosion ( )

Gutter changes

none ( )	berms ( )	reinforcement/containment ( )	dam ( )	Other (X)

Marginal vegetation (me: left margin md: right margin)

dense	to be continued	sparse	trip	nonexistent
( ) me ( )	( ) me ( )	( ) me ( )	(X)me (X)omg	( ) me ( )

diversity of *habitats* in the channel

( ) none (X)low ( ) medium ( ) high

Water quality aspects

( ) no visible changes (X)presence of sewage – visible releases ( ) presence of sewage – not visible releases ( ) presence of solid waste ( ) presence of suspended material

Additional Information

Comments: Stretch 4 shows visible problems throughout its route. These problems appear on both banks that are part of the stretch. There is the presence of sewage looping, sliting of the river, deforestation, irregular housing, presence of exortic vegetation among other points that make the stretch fragile in its fluvial and environmental aspects.

Photos:

Source: Adapted by the author, Cardoso (2012)

The catalog sheet developed by Cardoso (2012) allowed a clearer and more objective understanding of the current fluvial and environmental situation of stretch 4, thus enabling the design of more specific guidelines for future intervention scenarios on this route and on other river routes that have similar degrees of degradation.

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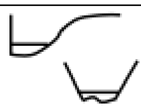
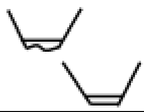
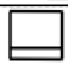
4.3.1 Application of river dimension indicators

Table 2 - River Dimension Indicators - Section 4

Degradation compared to natural condition	Longitudinal development
Absent	Tracing in plan, slope and continuity close to the natural condition, of according to the type of valley and watercourse
Low	Little significant changes, associated with human interventions in the gutter and/or the natural search of the watercourse itself for a condition of balance
Average ***(X)***	Moderate changes, especially associated with human interventions in the gutter and/or the occupation of marginal areas, resulting in width restriction and associated impacts
High	Considerable changes in width and sinuosity, with reflections on other analysis items
Very tall	Significant changes in longitudinal development, such as narrowing of section width, rectification and interruption of continuity

Degradation compared to natural condition	morphological integrity
Absent	Stable margins
Low	Stable margins with minimal evidence of erosion points and undermining points and/or landslides
Average	Partially unstable margins, with isolated erosion foci and restricted areas of undermining and/or landslides
High ***(X)***	Unstable margins, with extensive erosion foci and/or areas of undermining and landslides
Very tall	Unstable margins along the entire length of the study section

Degradation compared to natural condition	Hydrological regime/hydraulic capacity
Absent	Level of risk of flood damage absent
Low	Reduced risk level of flooding with damage
Average ***(X)***	Level of risk of flooding with moderate damage
High	Level of risk of flooding with considerable damage
Very tall	Level of risk of flooding with significant damage

Degradation compared to natural condition	Transversal section	
Absent	Section close to natural condition	
Low ***(X)***	Minor changes in the watercourse section, associated with human interventions in the channel and/or its natural search for a balanced condition, compatible with the changes that occurred in the basin	
Average	Moderately altered shape and connectivity; naturally coated or partially coated gutter	
High	Significantly altered shape and connectivity; partially or fully coated gutter	
Very tall	closed section	

Source: Cardoso (2012)

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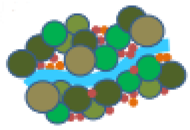
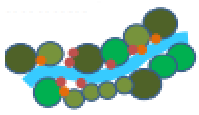
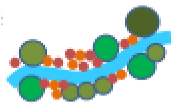
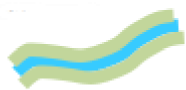
In applying the indicators of the fluvial dimension, the stretch showed the levels of water degradation and the factors, directly and indirectly, involved with the water. This made it possible to draw up guidelines for the requalification of water and riparian zones.

4.3.2 Application of environmental dimension indicators 04

In the environmental dimension, aspects are evaluated in the following points: (1) habitat diversity, (2) adjacent green areas, and (3) water quality.

Table 3 - Indicators Environmental dimension - Section 04

Degradation compared to natural condition	Habitat diversity
Absent	Compatible with the watercourse typology
Low	*Small* changes in the natural conditions of the watercourse conducive to the creation/reproduction of species (longitudinal development, section shape and coating, water flow conditions, among others)
Average ***(x)***	*Moderate* changes to the aforementioned conditions
High	*Considerable* changes to the aforementioned conditions
Very tall	*Significant* changes in the aforementioned conditions, with possible absence of habitats

Natural reference condition of the marginal vegetation in terms of diversity				
Dense	To be continued	Sparse	Trickle	Nonexistent
				

Degradation compared to natural condition	Adjacent green areas
Very low	Presence of vegetation and species close to the natural condition
Low	Little significant changes regarding the presence of vegetation and/or species
Average ***(X)***	Moderate changes in the presence of vegetation and/or species
High	Considerable changes in the presence of vegetation and/or species
Very tall	Significant changes regarding the presence of vegetation and/or species

Degradation compared to natural condition	Water quality
Very low	*Absence of* sewage and/or solid waste
Low	*Little* presence of sewage and/or solid waste
Average	*Moderate* presence of sewage and/or solid waste
High	*Considerable* presence of sewage and/or solid waste
Very tall ***(x)***	*Significant* presence of sewage and/or solid waste

Source: Cardoso (2012)

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In applying indicators of the environmental dimension, it is possible to understand how the margin areas are in relation to their vegetation, the levels of habitat presented in their perimeter, and the water quality. The three points have weaknesses, and water quality is the most affected factor due to sewage and solid waste.

4.3.3 Table of results showing the analysis of indicators

After analyzing the indicators applied to the selected stretch of river, a general table is proposed to evaluate all indicators of the fluvial and environmental dimensions.

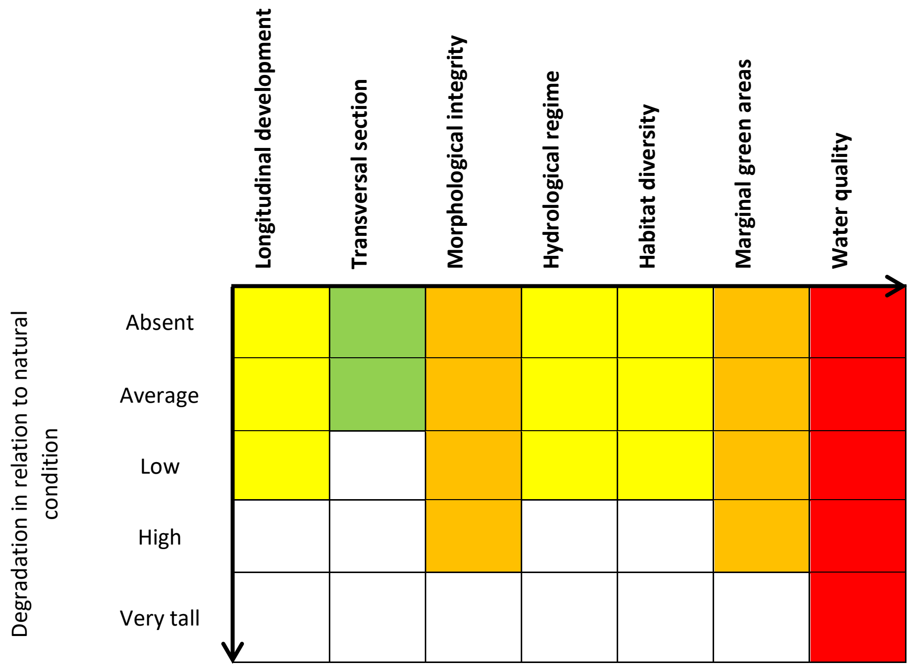
Table 04- Assessment of indicators of fluvial and environmental degradation of watercourses.

Dimension	**Indicator**	**Degradation in relation to natural condition**				
		Absent	**Low**	**Average**	**High**	**Very tall**
River	Longitudinal development			X		
	Transversal section		X			
	Morphological integrity				X	
	Hydrological regime			X		
Environmental	Habitat diversity			X		
	Marginal green areas				X	
	Water quality					X

Source: Adapted from Cardoso (2012)

In addition to the table showing the evaluation of the indicators, a graph with the results of the analysis of the fluvial and environmental conditions is presented.

Table 5- Proposal for a graphic representation of the results of the evaluation of indicators of fluvial and environmental degradation of watercourses



Source: Cardoso, (2012)

4.4 Framework of guidelines

Based on the above, after carrying out the analysis and diagnosis, guidelines are described that can mitigate the degree of degradation of river and environmental conditions, and that can generate some impact on the restoration and revitalization of the river banks and their relationship with the city.

To draw up the guidelines, three axes were considered: integration, recovery, and awareness, as shown below:

Table 07- Table of guidelines.

	INTEGRATION	RECOVERY	AWARENESS
GUIDELINES	Linear parks	Filter gardens	Educational projects on the relationship between rivers and cities (Environmental education)
	Bike lanes	Rain gardens	Educational and informative totems about the local fauna and flora
	Pedestrian paths (sidewalks and trails)	Urban agriculture	Cultural activities
	Green squares and corridors	Sewage treatment plants	Debates and public forums with the participation of the population and managers

Source: Prepared by the author (2022)

Therefore, each guideline presented aims to inhibit the progress of the degradation process of the fluvial and environmental dimensions on the banks of Espinharas River and, in particular, in stretch 4 that was analyzed throughout the research.

5 CONCLUSION

The urban and environmental complications faced by contemporary cities, especially concerning the issues of river banks and their relationship with the city, point to the importance of changing the way we perceive water resources in our cities. For years, with the justification of development, which is necessary and unstoppable, the areas along the banks of urban rivers and their waters have been degraded and irregularly occupied, aiming at economic objectives to the detriment of preservation and the balanced relationship between urban and natural environments.

Given the above, the present work sought to present guidelines for the recovery and reinsertion of Espinharas River to Patos city, bringing as a basis for such guidelines the analysis of the fluvial and environmental dimensions applied in a certain stretch of the river (section 4), using degradation indicators. The results are satisfactory and specific for understanding the actual urban and environmental situation of the stretch under study.

The guidelines were developed to propose the provision of more green areas for the city, sports and leisure areas, spaces for walking, and the use of bicycles, in addition to a greater extension of permeable areas and a harmonious relationship between urban elements and natural environments. It is hoped that a methodology can be followed that provides the inclusion of the river in the urban design of cities again, where it begins to be part of the plans and projects that involve the urban aspects of a city, thus collaborating to livelier, safer and more sustainable cities.

Therefore, it is concluded that the water infrastructure, adding the green infrastructure and the organization of urban planning, and the guarantees of the application of the legislation involving water resources must be the most coherent and advantageous way for the integration of urban planning and environmental planning, aiming at urban and environmental rehabilitation between water resources and cities.

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