

# QUARENTA STREAM RENATURALIZATION: HARMONY BETWEEN DEVELOPMENT AND HISTORICAL PRESERVATION IN BRAZIL

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## ABSTRACT

Climatic issues have drawn the attention of researchers to the Amazon, referring above all to environmental sustainability and the preservation of the largest tropical forest in the world. However, urban environmental degradation is related to the stagnation of watersheds by canalization; rectification of watercourses and urban spaces occupation disorderly, impacted by social inequalities, compromise socio-environmental and cultural sustainability. Avoiding or mitigating such degradation is generally attributed to the sphere of public policies, whose insufficiency and/or absence aggravate urban problems, whether water and sewage, atmospheric pollution, solid and/or industrial waste. Manaus, the largest financial, corporate, and commercial point in the north of Brazil is embedded in the heart of the Amazon Forest, endowed with a set of hydrographic basins, whose numerous streams permeate all areas of the city, coexists each year with the recurring Negro River floods. In 2021, the Rio Negro flood reached 30.02 m, a historic record in 119 years. The official data indicate that in that year 15 districts suffered flooding, impacting the lives of approximately 24,000 people. The Educandos district, one of the oldest and with the greatest urban concentration, whose history is intertwined with the history of Manaus, located in the middle-south of the city, was very affected by the flood. The mainsprings of the watershed that permeates Educandos are the Educandos, Mestre Chico, and Quarenta streams, which flow into the Negro River. This work, based on the successful experience of a Mindu section basin renaturalization and the creation of the Mindu National Park, studies the important and urgent need for the Quarenta stream renaturalization, to prevent and minimize floods in Manaus, while proposing the creation of a historical site of stilts and the floating city, preserving the culture and respect for the native people.

*Keywords:* urban floods, renaturalization, Quarenta stream.

## 1 INTRODUCTION

Climate issues have drawn the attention of researchers to the Amazon, referring above all to environmental sustainability and the preservation of the world's largest tropical forest, where record droughts and floods are an unmistakable indication of ongoing climate change. The Amazon River, located in South America, is the largest river in terms of water volume in the world and the second largest in terms of land area [1]. With about 6,992 km, it travels the north of South America, the Amazon Forest, and flows into the Atlantic Ocean [2]. Among its more than a thousand tributaries are the rivers: Madeira, Negro, and Japurá. Which are also among the ten largest rivers on the planet [3]. The Amazon, with the largest hydrographic basin in the world, with more than 7,000,000 km<sup>2</sup>, is responsible for about one-fifth of the total river flow in the world [4], with the water that flows through Amazon rivers equivalent to 20% of the water liquid sweet from Earth [3].

The Amazon River has several names, since its origin at the source of the Apurímac River (upper western part of the Andes Mountain range), in southern Peru, enters Brazilian territory under the name of the Solimões River and finally, in Manaus, after Negro River junction, it receives the name of Amazonas and as such follows until its mouth in the Atlantic Ocean. Since 1902, researchers have been monitoring the water level of the Rio Negro, measured as



it passes through the port of Manaus. The study results, published in *Science Advances*, show that extreme events are increasingly frequent. Droughts and floods, until the middle of the last century, occurred almost in parallel and had a frequency of twenty years. Now, floods occur every four years.

The three largest floods recorded at the Port of Manaus: 30.02 m; 29.97 m and 29.77 m, occurred in the last 12 years (2021, 2012, and 2009, respectively) [5]. In Manaus, the announced tragedy causes flooding, where houses on the banks of the streams are invaded by water, causing loss of goods, a proliferation of diseases caused by contaminated water, interruption of essential services, and widespread unhealthiness for the affected population. The contaminated water stench is involved with garbage, human waste, and rats that float around the houses. In addition to snakes, mosquitoes, and other poisonous and/or disease-transmitting animals, they leave the local population in a situation of extreme vulnerability.

In Manaus, public policies have focused on emergency actions, seeking to help the population through the construction of temporary bridges, made of wooden slats to give mobility to the affected population, obstruction of manholes, removal of garbage from streams, distribution of baskets basic and rent aid. However, bold public infrastructure policies that make it possible for the population to coexist with the hydrological cycle of the Rio Negro are still far from what is necessary. Despite the successful Social and Environmental Program of Igarapés de Manaus (PROSAMIM) and the successful restoration action of the Mindu basin piece that culminated in the creation of the Mindu Park.

In 2021, the Negro River flood reached 30.02m, a historic record in 119 years of a historical series. Manaus is a city embedded by the Rio Negro, with around 150 polluted streams and families living on its banks. Official data indicate that, in that year, 15 districts suffered flooding, impacting the lives of approximately 24,000 people. Educandos, located in the south center of the Manaus, was one of the hardest hit by the floods.

In this work, based on the successful experience of restoration in the Mindu basin, we propose the renaturalization of the Quarenta stream, at its mouth in the Educandos district, restoring banks and integrating elements of historical and cultural preservation.

## 2 RESTORATION OF WATERCOURSES IN URBANIZED AREAS

Restoration is the process of a place intentional alteration to its natural form through processes and processes that lead to the reestablishment of the sustainability relationship and health between the natural and the cultural, as defined by the Ecological Restoration Society [5], [6]. The goal, according to scholars, is to simulate the structure, function, diversity, and dynamics of a specific ecosystem, according to its historical characteristics [6]–[9]. However, given the difficulty or even impossibility of returning to the original ecosystem, the authors have considered expanding this concept, incorporating other dimensions such as landscape, ecological, and water quality within the perspective of river restoration [7]. Research in Saxony-Anhalt (Germany) highlight the special importance of integrated ecological methods in measuring the success of streams and rivers renaturation [10].

Scientists recognize this research agenda is diverse and ambitious. But recommend we should also not ignore the existing knowledge that can already be leveraged, building on the practice changes that have been achieved through efforts to implement water-sensitive cities [11]. However, the solutions implemented are complex, including technological and social innovations, urban reorganization, public policies, cooperation between different sectors of society, socio-environmental education, behavior change.

In Brazil, restoration/renaturalization terms are used, without distinction [12], [13]. Thus, in this work, they mean human interventions in all or parts of watercourses, with a view to the environmental recovery of the function, balance, and dynamic but the sustainable

ecosystem behavior. This also includes removing any disturbance so that the natural process can recover. This is not necessarily about recovering a pre-existing system, but about restoring landscapes that are stable from a hydrological and geomorphological point of view, capable of supporting healthy and biodiverse ecosystems, while preventing urban floods.

### 3 THE SUCCESSFUL RESTORATION EXPERIENCE OF MINDU, MANAUS, AM

The RIMA Environmental Impact Report [14] prepared to support the Mindu restoration project, considers the Igarapé do Mindu to be the most expressive watercourse in the urban area of Manaus, capital of the State of Amazonas, whose basin According to the aforementioned report, it occupies approximately 1/4 of the urban territory and concentrates approximately 30% of the population. It also reports that the disorderly occupation of part of the basin over the decades resulted in a series of environmental and social problems, enabling unhealthy conditions for its residents. It points out among the main consequences, polluted streams and watercourses, silted up and obstructed both by the clearing of vegetation and by the presence of large amounts of garbage, resulting from the construction of houses on its banks, and in some cases, in the stream bed itself.

Therefore, Mindu restoration required a set of socio-environmental and engineering interventions, such as sanitation works and services; urbanization; Housing; improvement of the road system, and environmental protection in the area of influence of the streams located in the Mindu Hydrographic Basin. The project is part of a Federal Government Program entitled "Sanitation for All", it has as a proponent the Municipality of Manaus in partnership with Federal Bank (Caixa Econômica), within the Stormwater Management modality, under contract No. 216,881, with a budgeted amount in 120 million of Reais, of which 108 million correspond to financing and 12 million as counterpart. The Resettlement Plan, as a result of the implementation of engineering works expropriations, it will contemplate the acquisition of properties for 2,285 families, residing in Permanent Preservation Areas (APP) of Igarapé do Mindu, distributed in the communities that make up the district. Each family consists of an average of 5 people, making a total of approximately 11,425 people, to be benefited. The Mindu creek (Fig. 1), the scope of the Manaus City Hall revitalization project, is located in the large hydrographic basin of the São Raimundo creek. At its mouth is the Franceses stream, forming the Cachoeira Grande stream, which flows into the São Raimundo watercourse (Fig. 2).

The hydrographic basin, the physical base of hydrological studies, is an area of natural precipitation capture that makes the flow converge to a single exit point, the outlet. The water displacement on the basin surface, in rivers, canals and reservoirs are one of the most important parts of the hydrological cycle. In the aforementioned report, the hydrographic basin of the Mindu creek has the Cachoeira Grande creek as its outlet. The set of interventions was varied, according to the section covered: the Ecological Corridor – did not suffer major interventions, as it is a protected area (green area) of the city.

The Mindu river has 21 km in its entirety, where the corridor corresponds to 7.0 linear km, therefore the intervention area covered an area of 14 km (before and after the corridor), this section starts at the source of the same. igarapé, in the Cidade de Deus district, close to the Adolpho Ducke Forest Reserve, following the Colina do Aleixo bridge. At this point, the Ecological Corridor begins (an area that has not suffered significant interference), ending at Av. Humberto Calderaro Filho. Where the second stretch of interference began, ending at its mouth, located near the Ponte dos Bilhares, in the Nossa Senhora das Graças district.



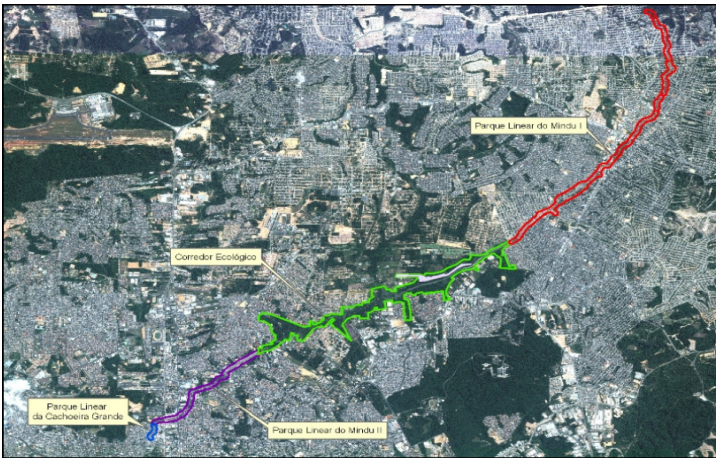


Figure 1: Mindu stream, from its source to its mouth [14].



Figure 2: The mouth of the Mindu stream, confluence with the French stream and the Cachoeira Grande stream [14].

Therefore, the intervention section of the Mindu stream revitalization project; starts at its source, in the Cidade de Deus district, close to the Adolpho Ducke Forest Reserve, it is interrupted by urban occupation, in the districts: São José; Armando Mendes; Mutirão and other districts in the east side of Manaus, returning close to the SESI Worker's Club, passing through private green areas (Private Natural Heritage Reserve – Honda) and green areas of housing developments (Villar Câmara, Tiradentes, Petros – on the left bank – Barra Bela,

Jardim Primavera, Imperial Park – on the right bank). The corridor brings together four Municipal Conservation Units: the Adolpho Ducke Botanical Garden, the Nascentes do Mindu Municipal Park, the Mindu Municipal Park, a Private Natural Heritage Reserve owned by Honda. The entire course of the Mindu stream was revitalized.

To support the recovery planning of the river banks, a situation and zoning survey of their occupation was carried out. This zoning defines different strategies for margin recovery, cf. the occupation zone: relocation of existing houses, in areas of high population density, implementation of Linear Parks in a marginal strip of the watercourse and a preservation strip revegetation, in addition to integration between vegetation and public spaces such as the implementation of lanes walk, bike path, gym equipment, and children's playgrounds, giving the population opportunity to enjoy these environments and supervise the conservation of watercourses. The areas that still have a riparian forest for a large part of their extension were defined as Urban Ecological Corridor in which the vegetation located in the Permanent Preservation Area allows connectivity between different already existing protected areas. In areas of relevant environmental or urban interest, conservation units or public parks were implemented.

Among the main works carried out for the renaturalization of Mindu stand out:

- Engineering and Architecture: Execution of macro and micro-drainage, with reservoirs implementation (or swimming pools) and restoration of natural gutters; Collection and Transport of Civil Construction Waste; The Road System Expansion; Urban Requalification and Landscaping, with the main results – the environmental recovery of its margins; containment implementation works and creation of natural water retention spaces. In addition, the reincorporation of the watercourse into the urban landscape with social and urban requalification along its path.
- Social: Relocation of floodplain residents; insertion of public leisure spaces such as small sports courts, children's playgrounds, and bicycle paths; The linear park was bordered by a right of way for infrastructure for basic services, with public roads to facilitate the movement of the local population.
- Sanitary: Concentration of actions such as garbage and sediments removal.
- Ecological: The creation of the Municipal Park of the source Mindu River, and Municipal Conservation Unit. Existing private spaces in the Park area were expropriated by the City Hall; implementation of the Mindu Stream Ecological Corridor, which allows, through the preserved Permanent Preservation Area, connectivity between the Mindu Municipal Park, the Honda Natural Heritage Private Reserve, and the various green areas of the surrounding housing complexes; the expansion of the Bilhares' Bridge Park (located along the Mindu) to the São Jorge bridge, after the relocation of the existing houses in the permanent preservation strip of the Cachoeira Grand stream.
- Technicians Studies: Preparation of Complementary Master Plans for Drainage, Sanitation, Protection of the Watercourse Margins, to provide basic information to municipal managers in the environmental, urban, and infrastructure areas of Manaus, on the best alternatives from the economic and socio-environmental point of view for the management of urban waters in the studied area.

The restoration of the Mindu resulted in recovered riverbanks and springs; reduced flooding effects, with macro-drainage and clearance of streams; urbanized margins with structures for recreation and leisure and a low level of waterproofing, due to the implantation of green areas; new roads implemented and interconnection of existing ones, as part of the proposed implementation of the new road system and facilitated circulation in the adjacent

road network; the public reduction spending in the fight against endemic water transmission; the generation of work and income during construction; the optimization of the result of infrastructure maintenance actions, particularly macro-drainage; the improvement of urban mobility, with the creation of a cycle path for alternative transport linking the East Zone to the South Center Zone of the city, reducing the pressure on the collective public transport system and illegal means of transport, in addition to the elaboration of Complementary Plans to the Manaus Urban and Environmental Master Plan, specifically: Master Plan for Drainage, Sanitation, and Protection of the banks of the Watercourses.

4 RENATURALIZATION OF IGARAPÉ DO QUARENTA:  
HARMONY BETWEEN HISTORICAL PRESERVATION  
AND DEVELOPMENT

In 2021, the Rio Negro flood reached 30.02 m, a historic record in 119 years. Official data indicate that, in that year, 15 districts suffered flooding, impacting the lives of approximately 24,000 people. Educandos district, located in the south center of the city, was one of the oldest and with the greatest urban concentration, whose history is intertwined with the own history of Manaus, was one of the most affected districts.

The mainsprings of the watershed that permeates Educandos are the following streams: Educandos, Mestre Chico, and Quarenta, which flow into the Negro River. Educandos, in the South Center Zone of Manaus, is one of the oldest and with the greatest urban concentration, with commercial and industrial areas. Its perimeter starts on the Negro River between the Educandos stream and the 40 streams; goes to Leopoldo Peres Avenue and goes to Pres. Kennedy Avenue to the source of the Colonia Oliveira Machado stream; returning to the Negro River to the Educandos stream.

The history of the Quarenta/Educandos basin, represented in Fig. 3, is intertwined with the own history of Manaus. It goes back to the rubber boom, whose economic effervescence boosted trade, with an intense flow of migrants (1), which gave rise to the floating city (2).



Figure 3: History of the Educando district, where the exit of the Quarenta stream is located. (Source: Adapted by the author. Images [www.acritica.com.br](http://www.acritica.com.br).)



The wealth generated by the rubber cycle brought to Manaus an urban model mirrored in the French model, known as the Belle Époque (3), where cities were seen as chessboards with their aligned and parallel streets, which resulted in the removal of original housing and regulations that prevented certain types of construction in downtown. Thus, the original populations were removed (4). Another important consequence was the canalization of rivers and streams of the downtown, with the mere function of sewage collectors being delegated to the other remaining streams. The population that was being displaced, tried to remain as close as possible to their original habitat, causing the intense occupation of the remaining streams' banks (5). This occupation and the disorderly growth of Manaus, in more recent history, was also intensified with the creation of the Manaus Free Trade Zone (6). The absence of public policies and/or the State's indifference to those populations further aggravated the health, education, housing, and security issues that generated numerous problems, including the large fires (7), which marked the basin's history of the Quarenta/Educandos. Recently, an important intervention, the PROSAMIM (8) project, which, despite having brought great and significant improvements to the region and to a part of the population that managed to remain in place, adopted, centuries later, the same solution for watercourses, the channelling, and mischaracterization of the landscape.

Another emblematic issue in the struggle for survival at the mercy of the waters can be traced back to the end of the rubber monopoly; the twenties of the last century economic crisis and; the demographic growth due to the migratory flow of riverside dwellers and workers from other regions to Manaus, aggravated by the scarcity of resources, contributed to the crisis of homelessness in Manaus. In this adverse scenario, in 1920, the floating city of Manaus emerged, as a result of the public policies absence aimed at poor populations and investments destined for the construction of low-income housing.

Initially, the floating city in its primitive version was a conglomeration of wooden houses covered with Buçu straw, light, and resistant fiber. The entire structure of the house, comprising a roof, walls, floor, and balcony, was placed on wooden logs seated on Açacu "floater", which ensured the security, functionality, and floating condition of the house. The streets of the floating city were made with huge and thick kapok planks, the widths varied between about 50 cm [15] There was everything a city needs for its existence: pharmacy, nightclub, clothes, shoes, stores everything the river gave this. The city served as an entrepot for large companies that exported alligator hides, rubber, pirarucu, jaguar skins, snakes, gold, and contraband. The Floating City gained features in national magazines and international notoriety. However, the floating dwellings did not present the minimum conditions of comfort and hygiene for their users and constituted a serious social problem.

The floating city extended towards the waters of the Manaus, Quarenta, and Cachoeirinha streams, reaching gigantic proportions [13]. In 1960, mon. official census data, Manaus had a population of 175,343 inhabitants. That year the floating city had 2,145 houseboats. "The incredible territorial and demographic dimensions of the floating Manaus ships that transform them into an urban phenomenon and a social issue for the authorities, in which the title: 'floating city', built during this time, is the most emblematic historical index. Faced with this new reality, some official surveys began to be carried out on the 'floating city', to better understand the 'problem' and then give an account of its 'resolution' materialized in its complete destruction in 1967" [16].

In 1967, Governor Reis (1964–1967), under strong pressure from the Amazon Military Command and the Port Authority, backed by the military government, dismantled the floating city, transferring its residents to several districts, among which we highlight Alvorada, Coroado, Costa e Silva and Santo Antônio Complex.



The dramatic outcome, however, did not destroy the Amazonian way of life, where it is common to find, until today, part of the riverside populations throughout the state living on their floating ships. The government itself, when the floods of the Negro River invade Manaus, making traffic unfeasible, resort to “floating fairs” so those producers can sell their products. In other words, the force of the way of life remains active in the region, being one of the most significant cultural expressions of the Amazonian man, inhabiting the waters and seeking their livelihood and leisure in them.

In this way, “the floating culture is one of the most significant and impactful ways of claiming the city to Manaus residents” [16].

The Quarenta stream is widely studied for its length (38 km), average width (6 m), and average depth (50 cm), as it has several springs. But mainly due to its socio-environmental degradation, chemical contamination, and accumulation of solid waste. The disorderly occupation, in the Educandos district, proved to be a favorable scenario for the occurrence of large floods, with a history of repetitions, accumulating significant environmental and social damage: houses collapse; proliferation of endemics, and epidemics and widespread health unhealthy conditions. In addition, the precariousness of the facilities and the dense occupation favored the occurrence of large-scale fires, increasing their impacts.

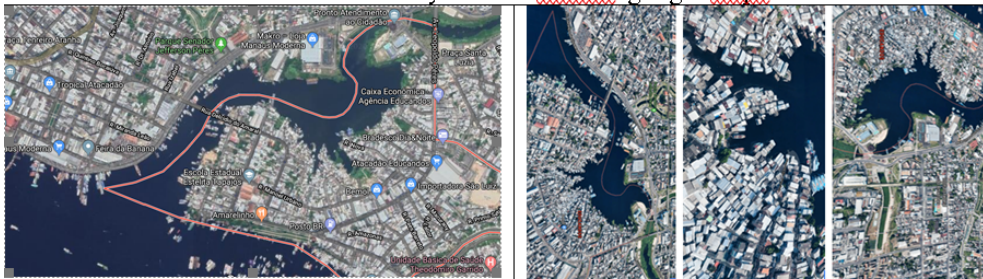


Figure 4: Views of the Educandos district and the mouth of the Quarenta stream. (Source: Google Maps.)

We propose the renaturalization of the mouth Quarenta stream that involves in addition to the dimensions of infrastructure; architecture, and urbanism; public and socio-environmental governance also involves the historical and cultural dimension (Fig. 4). Which, from preliminary actions such as surveying the area and identifying problems and potential; families' registration that still live on stilts; the mapping the access to basic sanitation situation; identification of areas subject to relocation, and the land regularization that guarantees citizenship and social justice. In this sense, guidelines must be defined to overcome the following challenges:

- i. Civil Engineering Challenges: Execution of macro and micro-drainage, with the implementation of reservoirs and restoration of natural gutters; The Collection and Transport of Civil Construction Waste; Implementation of basic sanitation with innovative technological solutions for areas subject to flooding; The Depollution of the Quarenta/Educandos stream basin;
- ii. Architecture and Urbanism Challenges: urbanization and requalification of houses with innovative, sustainable housing (a reinterpretation of the stilts), respecting the logic of the community's social organization, while restoring the meandering route of the stream;



- iii. Public Governance Challenges: Land tenure regularization without major displacements; The relocation in an area of the industrial district of enterprises/ industries, which promote the development of micro and small businesses, common in the district (recyclable material collectors, locksmiths, furniture makers, etc.), organized in cooperatives and associations with training and incentives for adding values to its products, fostering the circular economy, which generates wealth for those workers. It also encourages the production of alternative materials for civil construction, such as ecological tile (produced from long-life packaging), panels and building blocks, produced from the reuse of materials; The regulation of the profession of recyclable material collectors, providing the means to carry out this work with dignity; The inclusion in urban planning of a rigorous environmental education policy; The promotion of tourism to the created historic site and the renaturalized hydrological basin;
- iv. Social and environmental challenges: The development of ongoing environmental education programs; Involvement of residents and beneficiaries in processes to qualify local labor for ongoing actions, maintenance, and inspection focused on socio-environmental issues;
- v. Historical and Cultural Dimension Challenges: The requalification of the stilts and creation of the historical site of the stilts, the floating city, and the landscape, with the watercourses being the structures of urban development – a historic repair

## 5 CONCLUSIONS

The successful experience of Mindu restoration encourages the struggle for the restoration of the Quarenta/Educandos stream, due to socio-environmental issues. It is also necessary the historical site creation of the stilts and the floating city, for the sake of social justice and cultural preservation.

The reinterpretation of the stilts and the creation of the floating city's is, above all, a matter of social justice for the native peoples, who since the rubber cycle have resisted the invisibility imposed by the public authorities. And it represents the reparation to the Amazonian historical and cultural heritage, for the important role of keeping the memory of its people and strengthening its roots.

The peculiarities of Manaus, such as the hydrographic basins magnitude that still have their springs preserved, the low population density despite being the seventh most populous city; one of the biggest tourist destinations in Brazil and, especially, being located in the center of the largest tropical forest in the world, it should lead its managers to consider the renaturalization of its watercourses, making them structural elements of urban infrastructure.

In addition, the watercourses renaturalization of Manaus, benefits the sustainability of the hydrographic basin, through the restoration of the drainage network and the streams renaturalization. It also has the potential to expand the perception of the Manaus population to issues related to sustainability and socio-environmental awareness. Moreover, the possibilities of boosting the economy and attracting investment in tourism. And in this way, contributing to a paradigm shift in public management.

The renaturalization of watercourses is essential for the rivers' preservation and the other water reserves. It necessarily depends on greater social and environmental responsibility, both on the part of politicians and the entire society involved.

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