COLÓQUIO
REVISTA DO DESENVOLVIMENTO REGIONAL
FACCAT
ISSN 2318-180X

HYDRAULIC LANDFILLS OVER WATER BODIES IN BRAZIL: LEGAL ASPECTS AND SOCIO-ENVIRONMENTAL IMPACTS

Luana do Nascimento Dias [1]
Alef Fontinele Teixeira [2]
Marina Rocha de Carvalho [3]
Paula Verônica Campos Jorge Santos [4]
Leonardo Silva Soares [5]
Antonio Carlos Leal de Castro [6]

Abstract: *The rapid and disorderly growth of Brazilian cities has driven the use of hydraulic landfills as an urban expansion strategy, causing profound environmental, social, and economic transformations. This study analyzed current legislation on hydraulic landfills in water bodies, as well as their consequences, through a review of scientific literature, technical documents, and environmental standards. The results indicate that, despite the existence of instruments such as the National Environmental Policy, the Water Law, the City Statute, and CONAMA resolutions, there is no specific and comprehensive regulation for hydraulic landfills, generating legal uncertainty and the application of regulations indirectly or by analogy. In the environmental field, it was found that such works intensify soil impermeability, reduce water infiltration, contribute to siltation, biodiversity loss, and aquatic pollution. Socially, they foster irregular occupations and urban inequalities, while economically, they result in losses related to flooding and sanitation costs. It is concluded that the absence of a specific and cohesive legal framework compromises the adequate management of this practice, and it is recommended that specific regulations be created that consider the technical risks and multidimensional impacts of hydraulic landfills, in order to guide public policies aimed at sustainable urban development.*

Keywords*: Urban expansion; environmental legislation; river basin; urban sustainability.*

ATERROS HIDRÁULICOS SOBRE CORPOS HÍDRICOS NO BRASIL: ASPECTOS LEGAIS E IMPACTOS SOCIOAMBIENTAIS

Resumo: O crescimento acelerado e desordenado das cidades brasileiras tem impulsionado o uso de aterros hidráulicos como estratégia de expansão urbana, provocando profundas transformações ambientais, sociais e econômicas. Este estudo analisou a legislação vigente sobre aterros hidráulicos em corpos hídricos, bem como suas consequências, por meio de revisão de literatura científica, documentos técnicos e normas ambientais. Os resultados indicam que, apesar da existência de instrumentos como a Política Nacional do Meio Ambiente, a Lei das Águas, o Estatuto da Cidade e resoluções do CONAMA, não há uma regulamentação específica e abrangente para os aterros hidráulicos, gerando insegurança jurídica e a aplicação de normas de forma indireta ou por analogia. No campo

[1] Ph.D. Candidate in Development and Environment, Federal University of Maranhão (PRODEMA/UFMA). Federal University of Maranhão (UFMA). ORCID: https://orcid.org/0009-0001-3812-6843. Lattes: http://lattes.cnpq.br/4751400835677074. E-mail: dias.luana@discente.ufma.br
[2] Ph.D. Candidate in Development and Environment, Federal University of Maranhão (PRODEMA/UFMA). Federal University of Maranhão (UFMA). ORCID: https://orcid.org/0000-0002-2630-7006. Lattes: http://lattes.cnpq.br/2870437090385406. E-mail: alef.fontinele@discente.ufma.br
[3] M.Sc. in Development and Environment, Federal University of Maranhão (PRODEMA/UFMA). Federal University of Maranhão (UFMA). ORCID: https://orcid.org/0009-0006-5110-7061. Lattes: http://lattes.cnpq.br/0456061615739254. E-mail: marina.carvalho@discente.ufma.br
[4] Ph.D. in Biodiversity and Biotechnology, Federal University of Maranhão (BIONORTE/UFMA). Professor at the Federal University of Maranhão (UFMA). ORCID: https://orcid.org/0000-0002-3184-9627. Lattes: http://lattes.cnpq.br/6303029152591989. E-mail: paula.veronica@ufma.br
[5] Postdoctoral Researcher in Environmental Planning and Landscape Geoecology, Federal University of Ceará (UFC). Professor at the Federal University of Maranhão (UFMA). ORCID: https://orcid.org/0000-0003-0373-2971. Lattes: http://lattes.cnpq.br/5352983119262178. E-mail: leonardo.soares@ufma.br
[6] Ph.D. in Environmental Engineering Sciences, University of São Paulo (USP). Full Professor Emeritus at the Federal University of Maranhão (UFMA). ORCID: https://orcid.org/0000-0002-8681-4587. Lattes: http://lattes.cnpq.br/9450410023114396. E-mail: alec@ufma.br

ambiental, verificou-se que tais obras intensificam a impermeabilização do solo, reduzem a infiltração hídrica, contribuem para assoreamento, perda de biodiversidade e poluição aquática. Socialmente, fomentam ocupações irregulares e desigualdades urbanas, enquanto economicamente resultam em prejuízos relacionados a inundações e custos de saneamento. Conclui-se que a ausência de um marco legal específico e coeso compromete a gestão adequada dessa prática, sendo recomendada a criação de regulamentação própria que considere os riscos técnicos e impactos multidimensionais dos aterros hidráulicos, de modo a orientar políticas públicas voltadas ao desenvolvimento urbano sustentável.

Palavras-chave: Expansão urbana; legislação ambiental; bacia hidrográfica; sustentabilidade urbana.

1 Introduction

The city's disorderly growth, mainly due to the irregular soil division, lead to urban and environmental that are reflected in the antropic activities, with heavy pressure on natural resources (Freitas, 2020). The brazilian metropolitan areas, in particular the coastal cities, have been suffering changes in the lasts decades, affecting the cities urban dinamics, in witch is molded by the productive sectors that support the economic growth (Clementino, 2017).

With the unchecked and unplanned growth of coastal cities, the strategy of expanding these cities toward the sea through land reclamation has become a common practice in many countries, it is a technique that has been used since the time of Imperial Rome and Ancient Greece (Landon *et al*., 2016).

The landfills are formed by the accumulation of soil removed to level or alter land, resulting in the movement of sediments to specific areas and changing the original configuration of the environment (Ferraro, 2020). The process consists in transporting the material in the form of a thick slurry through pipes. It's an economic option, however, caution is required due to the high water content, which can pose risks related to permeability, drainage, liquefaction, and pipeline blockages (Panchal; Deb; Sreenivas, 2018).

The construction of landfills in urban areas not only alters specific functions related to mobility, traffic, and recreation, but also substantially changes the landscape of the affected region, directly impacting the local flora and fauna (Vilani, Cruz, Pedlowski, 2021). These projects are carried out in various contexts, such as the continuation of existing urban fabric, but primarily in the creation of urban space, promoting the expansion of the urban network and the consolidation of new urban centers (Momm, Kinjo, Frey, 2020).

The present study aims to fill in an important gap by providing an integrated analysis of the legal framework related to hydraulic landfills, such as one of the environmental impacts, social and economic arising from this activity. By bringing together consists research grants, it is expected that the results shown here may guide the formulation of public policies that are more effective and responsive to the complexity of the issue, promoting more sustainable and socially

responsible decisions.

2 Materials and methods

The research underlying this analysis is qualitative in nature and is exploratory and descriptive in scope, structured around a systematic review of the literature and documents. The primary objective was to understand the historical, technical, political, and legal-institutional evolution of hydraulic landfills in Brazil, as well as their territorial, environmental, and socioeconomic implications.

The initial stage consisted of identifyng and selecting scientifc works, including artivles published in national and international journals, masters degree dissertations, theses, books and book chapters, besides that, technical and institutional materials produced by government agencies, environmental agencies, urban and port planning institutions, and multilateral organizations. The literature search was conducted in recognized databases, such as SciELO, Google Scholar, and CAPES Periódicos, as well as institutional repositories and digital libraries of Brazilian universities.

The treatment of the collected material was carried out through thematic content analysis, based on the procedures proposed by Bardin (2011). After a systematic reading of the bibliographic materials, the material was codified and inductive construction of thematic categories were carried out, organized around the following dimensions: (i) the historical evolution of hydraulic landfills in Brazilian territory; (ii) technical and operational aspects of this practice; (iii) its insertion in the process of urban and port expansion; (iv) the associated environmental and social impacts; and (v) the legal, normative and political framework that regulates its implementation. Preferably, it was considered works published from the second half of the 20th century, a period marked by the intensification of these interventions, without prejudice to the inclusion of classical references of historical relevance.

At the same time the literature reviwew, it was developed a documental analysis, covering federal, state, and municipal laws, technical standards, resolutions of environmental councils, urban master plans, port plans, and environmental impact reports, in order to understand the legal and institutional frameworks that guide the construction of hydraulic embankments in Brazil. This step alowed to identificate regulatory changes over the time, as well as tensions and points of convergence among urban development policies, port infrastructure, and environmental protection.

As a complementary empirical procedure, an in-depth analysis was conducted of representative case studies of interventions related to urbanization and hydraulic landfill practices

in Brazil, focusing primarily on the Anil and Bacanga river basins, located in the municipality of São Luís do Maranhão. The choice of these watersheds is justified by their relevance in the context of the urban expansion of the capital of Maranhão, characterized by the occupation of estuarine areas and the construction of landfills that have brought about significant changes in the territorial and environmental dynamics of the region. Additionally, the case of Balneário Camboriú, in Santa Catarina, was used as a comparative reference, given its national prominence and two instances of hydraulic land reclamation and artificial beach nourishment. The comparative analysis of these cases enables to understand the different contexts of technical application, as well as their socio-environmental impacts, contributing to the discussion on urban planning, environmental management, and sustainability in coastal and estuarine environments.

Finally, the synthesis of the data collected and analyzed provided the basis for a comprehensive and well-founded interpretation, contributing to a deeper academic debate on the impacts of hydraulic landfills in Brazil, as well as to critical reflection on the limitations and challenges of this practice in light of current demands for sustainability and land-use planning.

3 Development of hidraulic landfills

Although the term “hydraulic landfill” is a modern one, the ancient Egyptians already used similar techniques. Tuan (1976) points out that dikes, canals, and reservoirs made it possible to settle areas prone to flooding, expand arable land, and consolidate urban centers and centralized power. Haug (2016) adds that state control of irrigation was essential for planning, distributing water, and maintaining infrastructure, thereby promoting the organized expansion of habitable space in ancient Egypt.

Land reclamation through the creation of landfills over the sea began to intensify in the 17th century, starting in Boston, United States, in 1640. Records indicate that this expansion became common in port docks to extend the city’s territory, which was growing rapidly due to intense trade and industrialization (Landon et al., 2016).

In Brazil, this strategy gained momentum in the final decades of the 20th century, with the first instances occurring in Salvador, followed by Rio de Janeiro; both cities shared the same objective as their American counterparts: to create new spaces for mooring vessels. Landfills were thus directly linked to urban expansion due to population growth, leading to the transformation of cities such as Rio de Janeiro, Salvador, Porto Alegre, São Luís, and Vitória (Ferraro, 2020).

Although hydraulic landfills techniques have advanced considerably and are widely applicable, some construction aspects still lack sufficient information, such as the mechanism of embankment formation and the factors that influence its properties. Consequently, projects of this

nature are often based on previous experiences, which do not always represent the safest and most economical construction alternatives (Norberto et al., 2024).

4 Advantages and disadvantages of the hydraulic landfills de aterros hidráulicos

The hydraulic landfills has pratical and economic advantages, while in the technical aspects, stands out the high construction rate and the separation of particles through hydraulic segregation (Moretti; Cruz, 1996).

Grishin (1982) In his research, he lists various advantages and disadvantages of the hydraulic landfill technique (Table 1).

Table 1 – Advantages and Disadvantages of the Hydraulic Fill Technique.

Advantages	Disadvantages
High construction capacity, capable of placing more than 200,000 m³ of fill per day;	The need for stricter requirements regarding the composition of landfill soil, which is not always available on site;
The method allows for the construction of submerged landfills;	Take extra care when the pulp is transported through pressurized pipes;
Simple construction methods compared to conventional methods;	Extensive use of metals, which are subject to wear from friction and must be in good condition;
Low demand for human labor;	Loss of aquatic and coastal ecosystems;
Lower unit cost of the project;	Changes in the hydrological regime of watersheds, affecting natural drainage;
Applicable to a wide range of materials;	Increased risk of flooding due to obstruction of surface runoff; soil instability, with a risk of landslides,
Possibility of separating particles from the construction material.	Increased costs for retaining and drainage work.

Source: Adapted from Grishin (1982); Dias *et al.* (2025).

Thus, although hydraulic landfills may provide benefits related to territorial expansion, real estate appreciation, and the implementation of urban infrastructure, their impacts cannot be analyzed exclusively from a technical and economic perspective. The loss of aquatic ecosystems, the suppression of mangrove areas, alterations in the hydrological regime, and the impacts on the natural dynamics of river basins demonstrate that such interventions produce long-term environmental consequences (Dias *et al*., 2025).

In this context, the effectiveness of these works should be assessed in an integrated manner, considering not only their technical feasibility but also their socio-environmental implications, the

capacity of territorial management instruments to mitigate impacts, and the adoption of governance mechanisms that ensure ecosystem conservation and the sustainability of the affected areas.

5 Hydraulic landfills in urban environments

The absence of adequate urban planning, combined with accelerated growth, causes changes in land use, intensifies soil sealing, aggravates the pollution of water bodies, and promotes the irregular occupation of vulnerable areas, exposing the population to the risks of landslides and erosive processes (Evaristo; Oliveira, 2024; Nicolete; Piroli, 2024).

The advancement of urbanization and industrialization drives transformations in the environment, causing environmental and social problems. (Dias; Pereira; Guerra, 2024; Dias *et al.,* 2024). During Brazil's urbanization process, wetlands and floodplains were modified through drainage and landfilling techniques, enabling their use for urban occupation (Christofidis *et al.*, 2019).

Menezes (2017), in his research on the Aterro do Flamengo, located in the city of Rio de Janeiro, it is noted that initially the landfill sought to meet road infrastructure demand by connecting the city center to the neighborhood in the South Zone, in order to improve urban mobility. However, over the years, the area underwent various other projects and private developments aimed at the expansion of the region, which resulted in social and environmental conflicts.

According to Sayd e Britto (2016), The coastal city of Macaê, Rio de Janeiro, also suffered as a result os the various changes driven by the uncontrolled urban expansion. The estuary of the Macaé River underwent channelization and landfilling processes that generated environmental disturbances, such as hydrological loss and deforestation, as well as social conflicts due to the occupation of environmentally vulnerable areas, which resulted in flooding and limited access to public services.

Ferraro (2020) highlights that in Florianópolis, Santa Catarina, the area known as the Baía do Sul landfill is the result of a massive expansion project in the 70s. In the area adjacent to the city center, growth occurred around the body of water, directly affecting the water flow, sanitation, landscape, and cultural aspects of the landfill area.

Balneário Camboriú, still in Santa Catarina, showcases one of Brazil's most emblematic coastal hydraulic landfills. Biancini *et al*. (2024) They classify this modality as beach nourishment (BN), a practice globally adopted to mitigate coastal erosion in urban coastal areas. The project, initiated in 2021, underwent an environmental licensing process with the preparation of an

Environmental Impact Assessment and Environmental Impact Report (EIA/RIMA), a legal requirement for interventions with significant environmental impact. However, subsequent studies shown that the started goals of coastal protection and environmental restoration were not fully achieved: a UFSC (2025) documented significant morphological changes on the filled-in beaches, including steeper profiles, increased sand compaction, and changes in coastal bathymetry that intensified the formation of rip currents, resulting in an approximately 120% increase in the number of rescue operations carried out by the Fire Department following the construction project. Biancini *et al*. (2024) also found that the environmental monitoring programs—which were a condition for the validity of the permits—were not carried out after the completion of the construction work, revealing a significant gap between the provisions set forth in the legal and regulatory framework and their effective application in the environmental management of the projects.

The Bacanga and Anil river basins are hydrographic units of great ecological, hydrological, and urban significance, which have historically been subject to intense urban expansion in estuarine areas of high environmental sensitivity (Teixeira *et al.,* 2024; Dias *et al*., 2025). In estuarine mangrove regions, particularly in stretches under tidal influence, the replacement of natural ecosystems with impervious surfaces and fills alters sedimentary flows, reduces local biodiversity, and compromises essential services. (Wu *et al.,* 2024).

As stated by Dias *et al*. (2025), The link between urban expansion and the practice of hydraulic landfills has led to soil sealing, changes in surface runoff patterns, the degradation of springs, and an increase in hydrological risks such as flooding and water quality degradation. The authors further argue that, although the national regulatory framework provides for environmental management tools, their application proves insufficient given the complexity of the degradation processes observed, with institutional fragility and the lack of coordination among sectoral policies hindering the implementation of measures for the control, conservation, and restoration of the studied watersheds.

Dias *et al*. (2025) conclude that the sustainability of the Bacanga and Anil basins depend on the adoption of integrated models of environmental governance that articulate territorial planning, protection of sensitive areas and institutional strengthening. But Biancini *et al*. (2024) einforce that continuous monitoring is the indispensable condition for the sustainability of these interventions, without which the declared objectives of environmental protection and restoration remain as unfulfilled promises.

Hydraulic works in urban spaces generate changes in water bodies and drainage and sewage systems, reducing their environmental importance, affecting biodiversity and water quality. The set of transformations analyzed reveals that the impacts of hydraulic landfills, whether

in the hydrographic basins of the municipality of São Luís do Maranhão or on the tourist waterfront of Balneário Camboriú, transcend the local scale and reveal a structural pattern in Brazilian territorial management.

In this sense, the comparison between the two contexts not only broadens the empirical basis of the debate, but also points to the urgency of public policies that integrate environmental management, water resources and territorial planning as inseparable dimensions of sustainable urban development in Brazil.

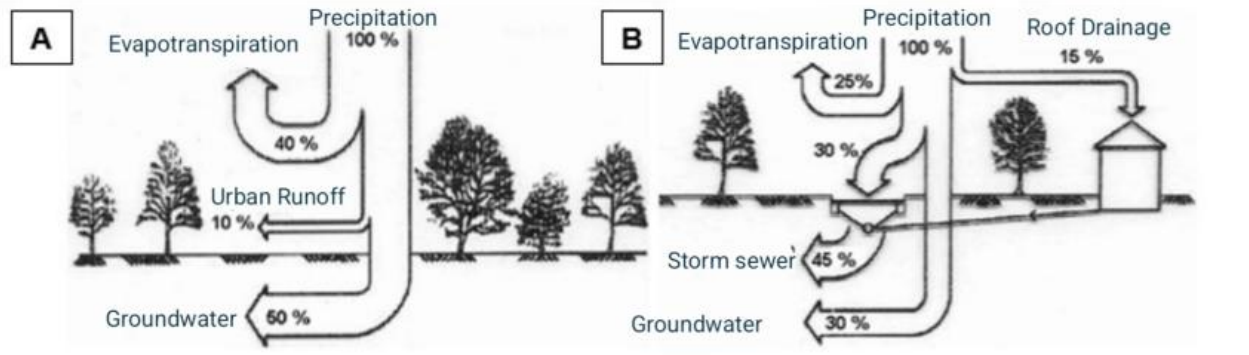
6 Environmental implications of hydraulic landfills

Tucci (2005) states that the advancement of urbanization alters vegetation cover, causing various effects that modify the components of the natural hydrological cycle, with the main effect being the reduction of soil infiltration, driven by surface waterproofing. The volume that fails to infiltrate remains on the surface, increasing surface runoff and significantly altering the hydrological dynamics of urban river basins.

In the view of Souza, Rodrigues e Danelon (2024), the waterproofing resulting from urban expansion modifies the natural circulation patterns of rainwater, compromising the efficiency of drainage systems and increasing the occurrence of flooding and inundations. In this sense, the increase in surface runoff does not represent merely a hydraulic problem, but triggers a chain of environmental impacts.

With stormwater conduits, the speed of surface runoff increases, reducing travel time (Figure 1). Pereira and Nunes (2025) state that this surface increase can reach critical levels and result in environmental, economic and social damages, especially during severe hydrological events.

Figure 1 – Water balance in na Urban River Basim. A) Scenario without urbanization. B) Urbanized scenario.



Source: Tucci (2005)

Durães, Gomes e Gomes (2022) point out that with the reduction of infiltration, the aquifer tends to lower the water table level due to lack of recharge, especially when the urban area is extensive, as it contributes to the reduction of underground runoff. Gomes, Trolles and Nascimento (2020) explain that due to the replacement of natural cover by impermeable areas, a reduction in evapotranspiration occurs, since the urban surface does not retain water like vegetation cover. Tôrres et al. (2025) add that the water table becomes vulnerable to impacts resulting from soil modification in the river basin in which it is inserted.

According to Tucci (2005), with the advance of urban development, there is a significant growth in sediment production by river basins caused by construction works, landings and expansion of avenues and highways. Zanella et al. (2023) explains that sediment production generates significant impacts, with surface erosion being one of the main effects. Erosion not only directly affects the soil, but is also linked to sediment transport, which can lead to siltation and contamination of water bodies, harming the quality of the soil and water.

Nunes *et al.* (2025) explain that another consequence of sediment production by the river basins is the silting of drainage sections, with reduced capacity for drainage of pipelines, rivers and urban banks. Siltation reduces the water-holding capacity of rivers and dams, which in turn diminishes the accessibility of water for both public use and agricultural irrigation, for instance.

Another relevant problem is the accumulation of waste. Marques et al. (2012) state that solid waste, in addition to reducing runoff capacity, can obstruct urban detention basins, impacting local water flow control. The lack of proper maintenance and the absence of planning that accounts for siltation in very wide sections can result in drainage failures. Pordeus et al. (2024) explain that the accelerated generation of solid waste, associated with the lack of effective public policies, preservation, and rational use of natural resources, creates challenges in the environmental sphere, encompassing the management and final disposal of solid waste.

The relationship between human activities and aquatic ecosystems is complex and multifaceted. Cruz et al. (2025) argue that water quality and the health of aquatic ecosystems are directly linked by human actions, in view of the release of domestic and industrial effluents, disorderly urban expansion and intensive agriculture are factors that compromise the integrity of water bodies.

The pollution of these water bodies in urban basins presents a wide diversity, varying from organic compounds to highly toxic metals. The main contaminants identified in urban runoff include sediments, nutrients, heavy metals, as well as pathogenic bacteria and viruses (Righetto; Gomes; Freitas, 2017).

7 Social implications of hydraulic landfills

Paulo (2018) points out that The intense influx of migrants toward the cities resulted in disordered and unplanned growth. The high demand for jobs could not meet the needs of the population, leading individuals to settle in urban peripheries. Sousa-Felix, Figueiredo, and Sousa (2025) explain that the lack of planning directly affects the quality of life of residents living around the basin, especially in peripheral neighborhoods where essential services are often neglected.

The marginalization of this population is reflected in the construction of irregular housing in risk areas, resulting in significant environmental impacts. The emergence of slums and urban communities on the banks of water bodies are home to populations marked by extreme poverty, widespread lack of services and very unsanitary housing conditions (IBGE, 2022). The presence of irregular housing in risk areas should be understood as a result of structural processes of unequal production of urban space.

In this context, socio-spatial segregation and the insufficiency of effective housing policies contribute to socially vulnerable groups occupying environmentally sensitive regions or areas unsuitable for urbanization (Maroz; Thielen, 2024). Such a dynamic not only aggravates and expands the exposure of these populations to adverse events, such as floods and landslides, but also reinforces cycles of social vulnerability and environmental degradation, highlighting the interdependence between urban, social, and ecological issues. (Passos; De Paula Costa, 2024; Segnor; Reis, 2025).

Alvim, Kato e Rosin (2015) state that irregular settlements in environmental protection areas, especially in watershed regions, worsen environmental impacts and the living conditions of the population. This is because the precariousness of infrastructure in these areas increases social risks and hinders the preservation of water resources. Schorn and Vieira (2023) add that the vulnerability of communities to disasters caused by natural events is directly linked to the level of social and economic development.

Batista (2025) argues that inadequate sanitation services result in social exclusion, which creates an environment of fragility and distrust between residents and authorities. The accumulation of solid waste and lack of adequate infrastructure, cause unsanitary conditions that favor the spread of diseases, increasing the socioeconomic cost for families and the state. The author notes that this cycle of poverty and poor health can fuel violence, given that social exclusion and limited prospects for low-income individuals boost the likelihood of associating with illegal activities.

Oliveira e Machado (2022) explain that the peripheralization in Latin America and Brazil is due to public policies that favor real estate appreciation in urban centers and seek the interests

of elites, deepening social segregation and exposing this fragile population to environmental risks. Ferreira, Nascimento and Yoshikawa (2022) argue that sociospatial inequality in Brazil prevents a large part of the population from having adequate access to housing and basic services, while rampant urban growth accentuates various environmental impacts.

8 Economic implications of hydraulic landfills

Ribeiro, Zilli e Hochheim, (2024) Researchers report that urban growth in Brazil, which intensified starting in the 1960s, has driven the occurrence of floods, causing significant impacts on public health, the population's quality of life, human losses, and substantial economic damage, especially in the real estate sector, as properties suffer structural damage that generates high costs and makes the economic recovery of affected regions more difficult.

Silva, Leal e Loureiro (2023) detailed that deficiencies in stormwater management exacerbate environmental impacts, lead to high public expenditures on emergency costs, and compromise the urban economy. Furthermore, poor urban drainage contributes to the deterioration of public infrastructure, affecting roads and the real estate sector, resulting in financial and social losses.

Amarante (2017) points out that degradation in river basins generates economic losses related to agricultural productivity and public health costs, and lacks greater investment in infrastructure. Furthermore, despite the positive relationship between infrastructure and economic growth, investments can generate resource shifts that favor certain sectors over others.

Carvalho *et al.* (2021) discuss the importance of economic valuation of ecosystem services provided by river basins, as a basis for efficient agroenvironmental management. The incorporation of these values into economic accounting can guide public policies for sustainable development in those territories.

Santos (2021) evaluated the economic and social consequences of the São Francisco River Integration Project (PISF) in the hydrographic basins of the Northeastern Northeast. The authors identified that the project obtained positive results when there was adequate investment and planning in projects that benefit activities in river basins.

9 Arcabouço legal de aterros hidráulicos

The regulation of urban hydraulic landfills over water bodies in Brazil is not concentrated in a single piece of legislation, but is spread across various federal laws (Table 2), resolutions of the National Environment Council (CONAMA) and technical standards of the Brazilian

Association of Technical Standards (ABNT).

Table 2 – Main Federal Laws and Their Implications for Hydraulic Fills

Law (Name, Nº e Year)	**Primary Regulatory Agency**	**Key Provisions**	**Implications of Urban Hydraulic Landfills on Water Bodies**
National Environmental Policy (PNMA) – Law nº 6.938/1981	CONAMA, IBAMA, state and municipal agencies (SISNAMA)	It establishes principles, objectives, and measures for the protection and restoration of the environment. It requires environmental permits for polluting activities.	Legal basis for environmental permitting of landfills; requires environmental impact assessments (EIA/RIMA) for projects that cause significant degradation; provides the basis for environmental enforcement.
National Water Resources Policy (PNRH) – Law nº 9.433/1997	ANA, state and municipal water resources agencies	It considers water to be a limited public good with economic value. It establishes the granting of water use rights for projects that alter the flow regime, quantity, or quality of water.	It requires a permit for landfills located on water bodies; it imposes quantitative and qualitative controls on water use; the watershed is the planning unit.
City Charter – Law nº 10.257/2001	Municipalities (via the Master Plan)	It regulates urban policy, governing the development of the social functions of the city and of property. It makes the Master Plan mandatory for most municipalities.	The Master Plan should guide urban expansion, preventing and correcting distortions and environmental impacts; landfills must comply with zoning regulations and urban planning guidelines.
National Solid Waste Policy (PNRS) – Lei nº 12.305/2010	MMA, state and municipal environmental agencies	It provides for the integrated management and handling of solid waste, prioritizing waste prevention, reduction, reuse, recycling, and environmentally sound disposal.	This is relevant if the landfill material consists of waste (e.g., contaminated dredged material or construction waste); it requires proper disposal of waste and control of "dumps."

Forest Code – Law nº 12.651/2012	MMA, state and municipal environmental agencies	It establishes general rules regarding the protection of native vegetation, defining Permanent Preservation Areas (APPs) and their use restrictions.	Landfills built over bodies of water often encroach on APPs; such projects are prohibited, except in cases of public utility or social interest, which are subject to strict licensing and compensation requirements.
Supplementary Law nº 140/2011	União Federal Government (IBAMA), States, Municipalities	It establishes rules for cooperation among federal entities in the exercise of shared jurisdiction over environmental matters, including licensing.	It specifies which level of government has jurisdiction to issue a permit for the landfill, depending on the scale, scope of the impact, and location (local, regional, federal).

Law nº 6,938/1981, which established the National Environmental Policy (PNMA), is the cornerstone of Brazilian environmental legislation. Although the PNMA does not explicitly mention them, the nature of hydraulic fills—which involve the alteration of water bodies and the movement of sediments—places them directly within the general scope of the PNMA. The application of this law, however, is indirect, relying on more detailed regulations, such as CONAMA resolutions and ABNT standards, to operationalize its broad principles.

Law nº 9.433/1997, Known as the 'Water Law,' it acts as a fundamental pillar for hydrological sustainability in hydraulic fill projects. The direct intervention in a water body, which is inherent to a hydraulic fill, triggers the application of the PNRH instruments. This compels a detailed assessment of the project's impact on water resources, ensuring that alterations to the hydrological regime, reduction in water volume, or potential pollution are considered and mitigated.

CONAMA resolutions and ABNT standards (Table 3) play a crucial role by detailing and complementing federal laws, providing specific technical guidelines and requirements for the design, execution, and control of engineering works and environmental activities. Despite the vast range of standards and resolutions, a technical gap is observed: the lack of a single, comprehensive ABNT standard specifically dedicated to the design and construction of hydraulic fills over water bodies for urban expansion.

Table 3 – CONAMA Resolutions and ABNT Standards for Hydraulic Fills

Regulation/ Resolution (Name, Nº and Year)	Main Focus	Specific Relevance to Urban Hydraulic Landfills Above Water Bodies
CONAMA resolution nº 357/2005	Classification of water bodies and effluent discharge standards.	It defines the water quality of receiving bodies and the requirements for the disposal of effluents generated during construction.
CONAMA resolution nº 369/2006	Exceptional cases of intervention or removal of vegetation in APPs.	It establishes strict conditions for authorizing landfills in APPs, requiring proof that no alternatives exist and that compensatory measures will be taken.
CONAMA resolution nº 404/2008	Criteria for environmental permitting of small-scale landfills.	If the hydraulic landfill involves waste disposal, the relevant licensing and environmental control requirements (lining, effluents) apply.
CONAMA resolution nº 454/2012	Management of dredged material in waters under national jurisdiction.	Directly applicable to landfills that use dredged material, establishing criteria for its use based on contamination levels and encouraging its beneficial use.
ABNT NBR 10004:2004	Classification of solid waste.	This is essential for characterizing the landfill material—especially if it is of waste origin—and determining its appropriate disposal method.
ABNT NBR 13896:1997	Criteria for the design, construction, and operation of non-hazardous waste landfills.	It provides principles of geotechnical and environmental engineering applicable to the construction and operation of landfills, including site selection and drainage.
ABNT NBR 15113:2004	Landfills for construction waste and inert waste.	This applies if the landfill uses construction debris or fill soil, with requirements for identification, segregation, and monitoring.
ABNT NBR 6122:2019	Design and construction of foundations.	Essential for ensuring the structural stability of structures built on fill, especially on soft soils or in flooded areas.
ABNT NBR 11682:2009	Stability of slopes and embankments.	It provides principles for the study and control of slope stability in landfills, which is crucial for safety and durability.

ABNT NBR 9820:1997	Collection of undisturbed soil samples.	Essential for geotechnical investigations of foundation soil and fill material.
ABNT NBR 7181:2016	Solo - Análise granulométrica.	Soil - Particle size analysis.
ABNT NBR 6484:2001	Conducting simple soil investigation borings.	Required for the geotechnical investigation of the landfill site, to determine soil type, water table, and strength.
ABNT NBR 12266:1992	Design and construction of trenches for the installation of water, sewer, or stormwater drainage pipes.	Relevant to the design of drainage systems associated with the landfill.
ABNT NBR 13969:1997	Septic tanks - Units for the secondary treatment and final disposal of liquid effluents.	It may be relevant to the treatment and disposal of sanitary effluent in areas affected by the landfill.

Source: Elaborado pelos autores

Legal fragmentation on urban hydraulic landfills causes complexity and practical challenges in the interpretation and application of regulations. The need to articulate different legal devices and technical regulations, often not designed for hydraulic landfills, can lead to legal uncertainties, overlapping requirements and regulatory gaps.

Reliance on analogous legislation for such complex projects is inadequate (Krell, 2021). Existing standards, such as NBRs for landfill or for slope stability are often applied to hydraulic landfills. Nonetheless, these projects exhibit distinctive technical features including the elevated moisture content in the filling material and the risk of liquefaction.

The application of generic standards or other landfill typologies may underestimate or neglect the specific risks and complexities inherent in hydraulic landfills. This approach may not adequately cover all phases of the project, from material origin to long-term stability. As a consequence, there may be weaknesses in the processes of licensing, impact assessment and definition of mitigation measures, undermining the ability of environmental management instruments to anticipate and control the resulting effects (Carvalho, 2026).

Furthermore, the adoption of regulatory standards that are poorly aligned with the specific characteristics of hydraulic landfills may create a false sense of technical security, masking cumulative impacts on aquatic ecosystems and the associated ecosystem services. In this context, it becomes essential to develop specific guidelines that recognize the complexity of these works

and incorporate an integrated preventive and adaptive approach to territorial planning and management.

10 Final considerations

The results of this study revealed that hydraulic embankments are projects of great technical, environmental, and territorial complexity. The analysis showed that, although such projects can contribute to improved urban and economic development, their implementation is associated with significant changes in hydrological dynamics, the configuration of aquatic ecosystems, the provision of ecosystem services, and social impacts.

It was also found that the effectiveness of environmental control mechanisms depends not only on the existence of legal and regulatory instruments but also on the integration of institutional capacity for planning, monitoring, and enforcement throughout the project's entire life cycle.

However, some limitations were identified. The limited availability of systematic information on the environmental performance of hydraulic landfills after their implementation, as well as the lack of long-term monitoring studies, hinders a more comprehensive understanding of their cumulative impacts and environmental effectiveness.

Looking ahead, it is recommended that research be conducted to assess long-term environmental impacts, analyze the effects of climate change on reclaimed areas, and improve environmental monitoring methodologies specific to this practice. It is also of great importance to conduct more in-depth studies on environmental governance, social participation, and adaptive management mechanisms capable of supporting more transparent decision-making processes.

Concerning public policy, the results highlight the need to strengthen territorial planning and environmental management tools applicable to hydraulic landfills. Of particular importance is the development of specific guidelines for this type of intervention, the expansion of post-implementation monitoring mechanisms, and the integration of urban, environmental, social, and water resource policies. Additionally, it is recommended that environmental permitting processes incorporate more comprehensive assessments of cumulative impacts, in order to promote decisions that are more aligned with the principles of territorial sustainability.

It is understood that the growing demand for interventions in coastal, estuarine, and riverine environments requires that hydraulic embankment practices be understood not only as engineering solutions, but as processes involving various environmental, social, economic, and institutional dimensions. Thus, the development of more sustainable territorial development models depends on the adoption of integrated, preventive, and participatory approaches capable of reconciling

urban needs with the conservation of ecosystems and the maintenance of essential environmental functions for present and future generations.

References

ALVIM, A. T. B.; KATO, V. R. C.; ROSIN, J. R. G. A urgência das águas: intervenções urbanas em áreas de mananciais. **Cadernos Metrópole**, São Paulo, v. 17, n. 33, p. 83–107, 2015. https://doi.org/10.1590/2236-9996.2015-3304 Acesso em: 19 mai. 2026.

AMARANTE, A. Infraestrutura e crescimento econômico regional: o efeito da pavimentação de rodovias interestaduais sobre a atividade econômica municipal na Região Sul do Brasil. **Revista Catarinense de Economia**, Santa Catarina, v. 1, n. 1, p. 28-51, 2017. https://doi.org/10.54805/RCE.2527-1180.v1.n1.4 Acesso em: 19 mai. 2026.

BATISTA, P. A. S. Saneamento básico e violência: uma análise da relação entre infraestrutura urbana e segurança pública. **Revista ft: Ciências Sociais Aplicadas**, Rio de Janeiro, v. 29, n. 145, 2025. https://doi.org/10.69849/revistaft/ni10202504301436 Acesso em: 19 mai. 2026.

BARDIN, Laurence. **Análise de Conteúdo.** Tradução de Luís de Anteiro Reto e Augusto Pinheiro. São Paulo: Edições 70, 2011.

BIANCINI, A.; BARBOZA, E. G.; BITENCOURT, V. J. B.; KLEIN, A. P. O Licenciamento Ambiental e a Atividade de Alimentação Artificial de Praias: Canasvieiras e Ingleses – Ilha de Santa Catarina. **Pesquisas em Geociências**, *[S. l.]*, v. 51, n. 1, p. e136654, 2024. https://doi.org/10.22456/1807-9806.136654 Acesso em: 3 jun. 2026.

CARVALHO, W. D. S.; CUNHA, M. L. C.; AMARAL, I. D. C.; e MAGALHÃES FILHO, F. J. C. Valoração de serviços ecossistêmicos em uma bacia de abastecimento na Rota de Integração Latino-Americana. **Interações** (Campo Grande), v. 22, p. 869-881, 2021. https://doi.org/10.20435/inter.v22i3.3041 Acesso em: 19 mai. 2026.

CARVALHO, A. B. J. Licenciamento ambiental e a realização do direito fundamental ao meio ambiente: limites, fragilidades institucionais e desafios normativos no Brasil. **Revista Ambientale**, [S. l.], v. 18, n. 1, p. 158–170, 2026. https://doi.org/10.48180/ambientale.v18i1.690 Acesso em: 3 jun. 2026.

CHRISTOFIDIS, D.; ASSUMPÇÃO, R. S. F. V.; KLIGERMAN, D. C. A evolução histórica da drenagem urbana: da drenagem tradicional à sintonia com a natureza. **Saúde Debate**, Rio de Janeiro, v. 43, n. especial 3, p. 94–108, 2019. https://doi.org/10.1590/0103-11042019s307 Acesso em: 19 mai. 2026.

CLEMENTINO, J. São Luís: cidade portuária em transformação. **Revista de Ciência & Tecnologia**, São Paulo, v. 21, p. 3-14, 2017. https://doi.org/10.15600/2238-1252/rct.v21n41p19-30 Acesso em: 19 mai. 2026.

CRUZ, W. L.; SILVA, Q. D.; RIBEIRO, D. Q.; SANTANA, R. G. Análise do relevo do alto curso da bacia hidrográfica do rio anil (São Luís - MA) como subsídio para o planejamento ambiental. Anais do XIV ENANPEGE... Campina Grande: Realize Editora, 2021. Disponível em: https://www.editorarealize.com.br/artigo/visualizar/78553 Acesso em: 19 mai. 2026.

DIAS, F. T.; PEREIRA, D. M.; GUERRA, J. B. S. O. A. Entre crescimento urbano e desenvolvimento sustentável: a urbanização, o problema ambiental e a nova agenda urbana. **Revista de Ciências da Administração**, v. 1, n. especial, p. 1–12, 2024. https://doi.org/10.5007/2175-8077.2023.e96285 Acesso em: 19 mai. 2026.

DIAS, L. N.; TEIXEIRA, A. F.; SILVA, M. H. L.; CASTRO, A. C. L. Avaliação da qualidade ambiental da sub-bacia do rio das Bicas, ilha de São Luís – MA. REDE - Revista Eletrônica do PRODEMA, [S. l.], v. 16, n. 2, 2024. DOI: 10.22411/1602.02. Disponível em: https://www.revistarede.ufc.br/rede/article/view/784 Acesso em: 19 mai. 2026.

DIAS, L. N.; TEIXEIRA, A. F.; CARVALHO, M. R.; CASTRO, A. C. L. Expansão urbana e impactos nas bacias do Bacanga e do Anil: um olhar sobre o desenvolvimento sustentável em São Luís, Maranhão. **Revista Geográfica Acadêmica**, v. 19, n. 2, p. 102, 2025. https://revista.ufrr.br/rga/article/view/8785 Acesso em: 3 jun. 2026.

DURÃES, R. C. F.; GOMES, A. J. L.; GOMES, J. L. S. Rebaixamento do lençol freático nos espaços urbanos da cidade de Montes Claros-MG. **Research, Society and Development**, v. 11, n. 7, p. e20211730018-e20211730018, 2022. http://dx.doi.org/10.33448/rsd-v11i7.30018 Acesso em: 19 mai. 2026.

EVARISTO, A. C. P.; OLIVEIRA, A. R. O Crescimento Urbano Desordenado no Entorno das Nascentes Urbanas de Garanhuns/PE. **OLAM: Ciência & Tecnologia**, v. 19, n. 1, p. 164–173, 2024. http://doi.org/10.5281/zenodo.14562920 Acesso em: 19 mai. 2026.

FERRARO, L. H. Sobre territórios, limites e relações físicas e visuais no Aterro da Baía Sul em Florianópolis, SC. **arq. urb**, n. 27, jan- abr, 2020. https://doi.org/10.37916/arq.urb.v27i.395 Acesso em: 19 mai. 2026.

FERREIRA, R. F. S.; NASCIMENTO, A. P. B.; YOSHIKAWA, N. K. O avanço imobiliário em áreas contaminadas: uma alternativa de urbanização sustentável sobre a perspectiva dos objetivos de desenvolvimento sustentável da agenda 2030. **Journal of Urban Technology and Sustainability**, v. 5, n. 1, p. 1-17, 2022. https://doi.org/10.47842/juts.v5i1.39 Acesso em: 19 mai. 2026.

FREITAS, A. R. Degradação ambiental na bacia hidrográfica do Rio das Antas, Sudeste do Paraná: análise quantitativa e qualitativa mediante a utilização da metodologia do IDA. **Revista GEOgrafias**, v. 16, n. 1, p. 22-42, 2020. https://doi.org/10.35699/2237-549X.2020.21485 Acesso em: 19 mai. 2026.

GOMES, A. H. P.; TROLLES, J. O.; NASCIMENTO, E. A. Recarga Artificial Do Lençol Freático Como Controle Dos Impactos Da Urbanização Na Bacia Hidrográfica. **Águas Subterrâneas**, [S. l.], n. 1, 2004. Disponível em: https://aguassubterraneas.abas.org/asubterraneas/article/view/23612. Acesso em: 19 mai. 2026.

GRISHIN, M. M. **Hydraulic structures**. Moscow: Mir Publishers, 1982. 2 v.

HAUG, Brendan. Water and power: Reintegrating the state into the study of Egyptian irrigation. **History Compass**, v. 15, n. 10, p. e12394, 2017. http://dx.doi.org/10.1111/hic3.12394 Acesso em: 19 mai. 2026.

IBGE – Instituto Brasileiro de Geografia e Estatística. **Censo Demográfico 2022:** favelas e comunidades urbanas: resultados do universo. Rio de Janeiro: IBGE, 2024. Disponível em: https://biblioteca.ibge.gov.br/visualizacao/livros/liv102134.pdf. Acesso em: 19 mai. 2026.

KRELL, A. J. A reduzida programação normativa das leis de proteção ambiental no Brasil e a sua interpretação metodicamente pouco organizada. **Jus Scriptum's International Journal of Law**, v. 6, n. 2, 2021. https://doi.org/10.29327/238407.6.2-7 Acesso em: 3 jun. 2026.

LANDON, D.; TRIGG, H.; BAIN, A.; e MORIN, E. Urbanization and landscape change in early-eighteenth-century boston: the environmental archaeology of town dock. **Historical Archaeology**, v. 50, n. 1, p. 80-93, 2016. https://doi.org/10.1007/BF03377178 Acesso em: 19 mai. 2026.

MARQUES, R. F. P. V.; SILVA, A. M.; RODRIGUES, L. S.; COELHO, G. Impacts of urban solid waste disposal on the quality of surface water in three cities of Minas Gerais - Brazil. **Ciência e Agrotecnologia**, Lavras, v. 36, n. 6, p. 689-696, dez. 2012. https://doi.org/10.1590/S1413-70542012000600010 Acesso em: 19 mai. 2026.

MENEZES, M. L. P. O Aterro e o Parque do Flamengo. 50 anos de espaço público. Sucessos e conflitos. **Revista Bibliográfica de Geografía y Ciencias Sociales**, v. 22, n. 1.195, 2017. https://doi.org/10.1344/b3w.0.2017.26422 Acesso em: 19 mai. 2026.

MOMM, S.; KINJO, V.; FREY, K. Weavings of planning and governance in the transformation of rivers in global metropolises: a reflection on international cases and ongoing cases in the São Paulo Macrometropolis (Brazil). **Cadernos Metrópole**, v. 22, p. 499-525, 2020. https://doi.org/10.1590/2236-9996.2020-4808 Acesso em: 19 mai. 2026.

MORETTI, M. R.; CRUZ, P. T. **Aterros hidráulicos e sua aplicação na construção de barragens.** *In* Cruz; P. T. (Org.). 100 barragens brasileiras: caso históricos, materiais de construção, projeto (2ª ed., cap.17, pp. 555-590). São Paulo: Oficina de textos, 1996.

MOROZ, C. B.; THIEKEN, A. H. Urban growth and spatial segregation increase disaster risk: lesson learned from the 2023 disaster on the North Coast of São Paulo, Brazil. Natural Hazards and Earth System Sciences, v. 24, n. 9, p 3299-3314, 2024. https://doi.org/10.5194/nhess-24-3299-2024 Acesso em: 03 de jun. 2026.

NICOLETE, D. A. P.; PIROLI, E. L. Assessment of The Impact of Changes In Land Use and Land Cover on Surface Runoff. **Mercator (Fortaleza),** v. 23, p. e23012, 2024. https://doi.org/10.4215/rm2024.e23012 Acesso em: 19 mai. 2026.

NORBERTO, A. S.; OLIVEIRA JÚNIOR, A. I.; BESERRA, L. B. S.; GUIMARÃES, L. J. N. Fissuras em aterros sobre solos moles: abordagens, mecanismo e influências. **Revista Semiárido De Visu**, v. 12, n. 2, p. 910-928, 2024. https://doi.org/10.31416/rsdv.v12i2.1033 Acesso em: 19 mai. 2026.

NUNES, N. C.; ANGELINI, L. P.; ALVES, W. S.; CASTRO, R. M.; MORAIS, W. A.; MORAIS, N. G. Análise espaço-temporal da erosão hídrica por meio de modelagem e geotecnologias em bacias hidrográficas no

Centro-Oeste do Brasil. **Revista Brasileira de Geografia Física**, v. 18, n. 2, p. 1465–1492, 2025. https://doi.org/10.26848/rbgf.v18.2.p1465-1492 Acesso em: 19 mai. 2026.

OLIVEIRA, Y. A.; MACHADO, D. B. P. Invisibilidade social e espacial em aterro metropolitano: o caso de Jardim Gramacho (RJ), Brasil. **Bitácora Urbano Territorial**, v. 32, n. 1, p. 163–176, 2022. https://doi.org/10.15446/bitacora.v32n1.87530 Acesso em: 19 mai. 2026.

PASSOS, R. C. S.; DE PAULA COSTA, Eder Dion. Urbanização brasileira e vulnerabilidade socioambiental: saúde e desenvolvimento como liberdade. **Revista Brasileira de Direito Social**, [S. l.], v. 7, n. 2, p. 62–72, 2024. Disponível em: https://rbds.ieprev.com.br/rbds/article/view/323. Acesso em: 3 jun. 2026.

PANCHAL, S.; DEB, D.; SREENIVAS, T. Mill tailings based composites as paste backfill in mines of U-bearing dolomitic limestone ore. **Journal of Rock Mechanics and Geotechnical Engineering**, v. 10, n. 2, p. 310-322, 2018. http://dx.doi.org/10.1016/j.jrmge.2017.08.004 Acesso em: 19 mai. 2026.

PAULO, R. F. **Crescimento urbano desordenado:** o papel do Estado e da sociedade diante dos impactos socioambientais [recurso eletrônico]. Porto Alegre, RS: Editora Fi, 2018. 173 p. Disponível em: https://www.univem.edu.br/arquivos/Livro%20Rodolfo%20Fares.pdf Acesso em: 19 mai. 2026.

PEREIRA, M. F. S.; NUNES, A. A. Impactos da urbanização no sistema de macrodrenagem: estudo hidráulico-hidrológico da bacia do Barro Preto – Mariana/MG. **Além dos Muros da Universidade**, v. 10, n. 1, p. 33–47, 2025. https://doi.org/10.70615/alemur.v10i1.7754 Acesso em: 19 mai. 2026.

PORDEUS, A. B. P.; BARROS, A. S.; SANTOS, F. K. N.; SANTOS, F. M. N. Influência da disposição final de resíduos sólidos nos recursos hídricos da Bacia Hidrográfica do Rio Apodi-Mossoró/RN. **Contribuciones a las Ciencias Sociales**, v. 17, n. 7, p. e8285, 2024. https://doi.org/10.55905/revconv.17n.7-133 Acesso em: 19 mai. 2026.

RIBEIRO, M. D.; ZILLI, C. A.; HOCHHEIM, N. Impacto econômico de inundações no valor dos imóveis na bacia do Rio Tubarão, Brasil. **Revista Valorem**, v. 3, n. 1, p. 1–15, 2024. https://doi.org/10.29327/2290393.3.1-1 Acesso em: 19 mai. 2026.

RIGHETTO, A. M.; GOMES, K. M.; FREITAS, F. R. S. Poluição difusa nas águas pluviais de uma bacia de drenagem urbana**. Engenharia Sanitária e Ambiental**, v. 22, p. 1109-1120, 2017. https://doi.org/10.1590/S1413-41522017162357 Acesso em: 19 mai. 2026.

SANTOS, A. H. S. Avaliação ex-post das consequências socioeconômicas do Projeto de Integração do Rio São Francisco com Bacias Hidrográficas do Nordeste Setentrional. **Cadernos de Finanças Públicas**, v. 21, n. 1, abr. 2021. https://doi.org/10.55532/1806-8944.2021.128 Acesso em: 19 mai. 2026.

SAYD, J. L. C.; BRITTO, A. L. Obras hidráulicas e espaço urbano no estuário do rio Macaé. **InSitu– Revista Científica do Programa de Mestrado Profissional em Projeto, Produção e Gestão do Espaço Urbano**, v. 2, n. 2, p. 27-48, 2016. Disponível em: https://revistaseletronicas.fiamfaam.br/index.php/situs/article/view/468 Acesso em: 19 mai. 2026.

SEGNOR, C. R.; REIS, A. F. Ocupação urbana e vulnerabilidade socioambiental na sub-bacia do rio Itacorubi, Florianópolis/SC. **Cadernos Metrópole**, *[S. l.]*, v. 27, n. 64, 2026. Disponível em: https://revistas.pucsp.br/index.php/metropole/article/view/74328 . Acesso em: 3 jun. 2026.

SCHORN, F. A.; VIEIRA, R. Análises sobre a ocupação do solo em áreas urbanas de preservação permanentes e suscetíveis à inundação: estudo de caso no Vale do Itajaí, SC. **Urbe, Revista Brasileira de Gestão Urbana**, v. 15, e20220110, ago. 2023. https://doi.org/10.1590/2175-3369.015.e20220110. Acesso em: 19 mai. 2026.

SILVA, J. B. V. **Tudo isso era maré:** origens, consolidação e erradicação de uma favela de palafitas em São Luís do Maranhão. 2016. 146 p. Dissertação (Mestrado em Arquitetura e Urbanismo) – Universidade Federal de Minas Gerais, Núcleo de Pós-graduação em Arquitetura e Urbanismo, Belo Horizonte, 2016. http://hdl.handle.net/1843/MMMD-AJJKW4 Acesso em: 19 mai. 2026.

SILVA, K. T. G.; LEAL, T. A.; LOUREIRO, A. F. C. Problemas causados por planos de drenagem inadequados das águas pluviais em área urbana. **Engenharias**, v. 27, e. 128, 2023. http://doi.org/10.5281/zenodo.10213081 Acesso em: 19 mai. 2026.

SOUSA-FELIX, R. C.; FIGUEIREDO, C. M. S.; SOUSA, R. P. C. Urban Watershed Management In The Brazilian Amazon. **Mercator (Fortaleza),** v. 24, p. e24002, 2025. https://doi.org/10.4215/rm2025.e24002 Acesso em: 19 mai. 2026.

SOUZA, L. H. F.; RODRIGUES, S. C.; DANELON, J. R. B. Contribuições da Geomorfologia no contexto da modelagem hidrológico-hidráulica do escoamento superficial urbano. **Revista do Departamento de Geografia**, São Paulo, Brasil, v. 44, p. e225331 , 2024. https://doi.org/10.11606/eISSN.2236-2878.rdg.2024.225331 Acesso em: 19 mai. 2026.

TEIXEIRA, A. F; ROSA, D. T. V.; DIAS , L. N.; CASTRO, A. C. L. Impactos da ocupação humana na sub-bacia do Rio Maracanã, pertencente a bacia hidrográfica do Bacanga, ilha de São Luís - MA. Revista Territorium Terram, [S. l.], v. 7, n. 13, p. 574–586, 2024. Disponível em: http://www.seer.ufsj.edu.br/territorium_terram/article/view/5447. Acesso em: 19 mai. 2026.

TÔRRES, L. M. G.; PEIXOTO, F. S.; CASTRO, S. S. L.; SILVA, R. M.; SANTOS, C. A. G. Impact Of Land Use And Cover On Groundwater Quality, Challenges Of Scarcity And Contamination For Water Management In Brazilian Semi-Arid Cities. **Mercator (Fortaleza),** v. 24, p. e24008, 2025. https://doi.org/10.4215/rm2025.e24008 Acesso em: 19 mai. 2026.

TUAN, Yi-Fu. **Early Hydraulic Civilization in Egypt**: A Study in Cultural Ecology. Chicago: University of Chicago Press, 1976. Disponível em: https://isac.uchicago.edu/sites/default/files/uploads/shared/docs/early_hydraulic.pdf Acesso em: 19 mai. 2026.

TUCCI, C. E. M. **Gestão de águas pluviais urbanas**. Programa de Modernização do Setor Saneamento, Secretaria Nacional de Saneamento Ambiental, Ministério das Cidades, 2005. Disponível em: https://www.mpf.mp.br/atuacao-tematica/ccr4/coordenacao/grupos-de-trabalho/encerrados/residuos/documentos-diversos/outros_documentos_tecnicos/curso-gestao-do-terrimorio-e-manejo-integrado-das-aguas-urbanas/GestaoAguasPluviaisUrbanas.pdf/view Acesso em: 19 mai. 2026.

UFSC – UNIVERSIDADE FEDERAL DE SANTA CATARINA. Programa Ecoando Sustentabilidade – PES. Nota Técnica PES nº05/2025: os aterros de praia e a saúde da população e do ambiente. Florianópolis: UFSC, 2025. Disponível em: https://repositorio.ufsc.br/bitstream/handle/123456789/265096/AlargamentoPraia2025_assinado.pdf. Acesso em: 03 de jun. 2026.

VILANI, R. M.; CRUZ, J. L. V.; PEDLOWSKI, M. A. O sal do porto: conflitos ambientais no Porto do Açu, Rio de Janeiro, Brasil. **Ambiente & Sociedade**, v. 24, p. e01901, 2021. http://dx.doi.org/10.1590/1809-4422asoc20200190r1vu2021L5AO Acesso em: 19 mai. 2026.

WU, S.; YUAN, B.; LIU, S.; WANG, Q.; LIU, J.; YAN, C.; HONG, H.; PAVAO-ZUCKERMAN, M. A.; LU, H. Urbanization-driven anthropogenic and environmental factors shape soil dissolved organic matter in mangrove ecosystems. **Ecosystem Health and Sustainability**, v. 10, p. 0154, 2024. Disponível em: https://doi.org/10.34133/ehs.0154 Acesso em: 19 mai. 2026.

ZANELLA, J. R. D.; TOMAZONI, J. C.; DE AGUIAR, W. Determinação da Erosão e Transporte de Sedimentos em Bacia Hidrográfica do Sudoeste do Paraná. **Revista Brasileira de Geografia Física**, v. 16, n. 4, p. 2103–2118, 2023. https://doi.org/10.26848/rbgf.v16.4.p2103-2118 Acesso em: 19 mai. 2026.