SPATIAL ANALYSIS AND STRUCTURAL DIAGNOSIS OF SILTING IN URBAN MICRODRAINAGE SYSTEMS: A CASE STUDY IN CANOINHAS, SANTA CATARINA, BRAZIL

ANÁLISE ESPACIAL E DIAGNÓSTICO ESTRUTURAL DO ASSOREAMENTO EM SISTEMAS DE MICRODRENAGEM URBANOS: UM ESTUDO DE CASO EM CANOINHAS, SANTA CATARINA, BRASIL

ANÁLISIS ESPACIAL Y DIAGNÓSTICO ESTRUCTURAL DEL AZOLVE EN SISTEMAS DE MICRODRENAJE URBANO: UN ESTUDIO DE CASO EN CANOINHAS, SANTA CATARINA, BRASIL

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RESUMO
A urbanização acelerada e a impermeabilização do solo alteram significativamente o ciclo hidrológico, elevando o escoamento superficial e o transporte de sedimentos para os sistemas de microdrenagem. Esta pesquisa avaliou as condições físicas e funcionais das caixas de captação (bocas de lobo) no perímetro urbano de Canoinhas, Santa Catarina, Brasil. Um levantamento quantitativo e exploratório

de campo foi realizado entre janeiro e agosto de 2025 em 13 bairros, abrangendo 4.637 estruturas. As unidades foram classificadas quanto aos materiais constituintes, integridade estrutural e nível de obstrução superficial (assoreamento). A correlação espacial com as sub-bacias hidrográficas municipais foi executada via Sistemas de Informação Geográfica (SIG). Os resultados indicaram que 52% das tampas são de concreto, 43% de ferro e 4% combinadas, enquanto 1% não possui tampa. Embora 86% das estruturas apresentem boa condição estrutural, 14% encontram-se danificadas. Adicionalmente, 20% apresentaram obstrução parcial e 3% obstrução total. A análise espacial revelou que 54% das caixas totalmente obstruídas concentram-se na Bacia do Arroio Monjolo, área vulnerável a alagamentos. A manutenção preventiva insuficiente e o aporte de sedimentos reduzem drasticamente a capacidade hidráulica, comprometendo a resiliência urbana. O cumprimento das diretrizes de saneamento e planos de desobstrução contínua são indispensáveis para a gestão sustentável das águas pluviais.

Palavras-chave: Drenagem Urbana. Caixas de Captação. Assoreamento. Microdrenagem. Bacias Hidrográficas.

ABSTRACT

Accelerated urbanization and land impermeabilization significantly alter the hydrological cycle, increasing surface runoff and sediment transport to microdrainage systems. This research evaluated the physical and functional conditions of catch basins (stormwater inlets) in the urban area of Canoinhas, Santa Catarina, Brazil. A quantitative and exploratory field survey was conducted between January and August 2025 across 13 distinct neighborhoods, sampling 4,637 catch basins. Structures were classified regarding material composition, structural integrity, and level of surface obstruction (silting/clogging). Spatial correlation with municipal hydrographic sub-basins was performed using Geographic Information Systems (GIS). Results indicated that 52% of covers are made of concrete, 43% of iron, and 4% combined, while 1% lack covers. Although 86% of the structures presented good structural condition, 14% were damaged. Furthermore, 20% exhibited partial surface obstruction and 3% total obstruction. Spatial analysis revealed that 54% of totally obstructed catch basins are concentrated in the Arroio Monjolo Basin, a critical area prone to urban flooding. Insufficient preventive maintenance and sediment deposition drastically reduce hydraulic capacity, threatening infrastructure resilience. Compliance with national sanitation guidelines and proactive maintenance protocols are essential for sustainable urban water management.

Keywords: Urban Drainage. Catch Basins. Silting. Microdrainage. Hydrographic Basins.

RESUMEN

La urbanización acelerada e impermeabilización del suelo alteran significativamente el ciclo hidrológico, aumentando la escorrentía superficial y el transporte de sedimentos hacia sistemas de microdrenaje. Esta investigación evaluó las condiciones físicas y funcionales de las cámaras de captación (entradas de aguas pluviales) en el área urbana de Canoinhas, Santa Catarina, Brasil. Se realizó un levantamiento de campo cuantitativo y exploratorio entre enero y agosto de 2025 en 13 barrios distintos, muestreando 4.637 cámaras de captación. Las estructuras se clasificaron respecto a la composición del material, integridad estructural y nivel de obstrucción superficial (sedimentación/colmatación). Se realizó correlación espacial con subcuencas hidrográficas municipales utilizando Sistemas de Información Geográfica (SIG). Los resultados indicaron que el 52% de las tapas están hechas de concreto, el 43% de hierro y el 4% combinado, mientras que el 1%

carece de tapas. Aunque el 86% de las estructuras presentaron buen estado estructural, el 14% estaban dañadas. Además, el 20% exhibió obstrucción superficial parcial y el 3% obstrucción total. El análisis espacial reveló que el 54% de las cámaras de captación totalmente obstruidas se concentran en la Cuenca del Arroio Monjolo, un área crítica propensa a inundaciones urbanas. El mantenimiento preventivo insuficiente y la deposición de sedimentos reducen drásticamente la capacidad hidráulica, amenazando la resiliencia de la infraestructura. El cumplimiento de las directrices nacionales de saneamiento y los protocolos de mantenimiento proactivo son esenciales para la gestión sostenible del agua urbana.

Palabras clave: Drenaje Urbano. Cámaras de Captación. Sedimentación. Microdrenaje. Cuencas Hidrográficas.

1 INTRODUCTION

Accelerated and unplanned urbanization, coupled with the replacement of natural soil cover by impervious surfaces, represents one of the primary drivers of hydrological imbalance in contemporary cities (Tucci, 2004). The loss of soil infiltration capacity alters fundamental hydrological cycle parameters, leading to increased surface runoff volumes, substantial elevation of peak discharges, and a drastic reduction in basin concentration time (Baptista *et al.*, 2011; Canholi, 2014).

Historically, urban stormwater management relied on hygienist concepts aimed at rapidly evacuating stormwater through networks of rigid conduits and open channels. However, the continuous expansion of urban areas has demonstrated the unsustainability of this paradigm, as it merely transfers flooding problems downstream (Baptista *et al.*, 2011; Cardoso *et al.*, 2024). Parreirão *et al.* (2021) and Silva (2021) emphasize that surface runoff in urbanized areas carries substantial loads of suspended solids, municipal solid waste, and eroded sediments from unpaved roads or construction sites. This transported material accumulates within microdrainage inlet structures—particularly catch basins and stormwater inlets—triggering clogging and silting processes (Poleto, 2012; Ahmed *et al.*, 2022).

The silting of inlet structures severely reduces the effective cross-sectional flow area, creating hydraulic bottlenecks that prevent water intake and cause localized street flooding, damage to road infrastructure, and public health risks (Avila *et al.*, 2011; Canholi, 2014; Silva, 2021). Internationally, sediment retention efficiency in catch basins has been identified as a critical factor in maintaining urban drainage performance, as excessive sediment deposition leads to scour and pollutant resuspension during intense rainstorm events (Karlsson & Viklander, 2008; Wei *et al.*, 2021). Consequently, assessing the physical and functional conditions of these devices constitutes a strategic requirement for maintaining urban hydraulic resilience and designing effective drainage routes.

Within the Brazilian regulatory framework, urban stormwater management is linked to environmental and basic sanitation legislation. Federal Law No. 9,433/1997 established the National Water Resources Policy, designating the river basin as the fundamental territorial unit for management (Brasil, 1997). Federal Law No. 11,445/2007, updated by the New Sanitation Legal Framework (Federal Law No. 14,026/2020), explicitly includes urban stormwater drainage and management as an essential component of basic sanitation, demanding operational efficiency and quality standards (Brasil, 2007; Brasil, 2020). Furthermore, Reference Standard No. 1/2021 of the National Water and Sanitation Agency (ANA, 2021) and Federal Decree No. 7,217/2010 require continuous diagnostic monitoring of stormwater networks and structured preventive maintenance plans.

At state and local levels, Santa Catarina State Law No. 9,748/1994 and Municipal Complementary Law No. 052/2011 (Canoinhas Master Plan) mandate the integration between land-use planning and infrastructure conservation. In addition, CONAMA Resolution No. 357/2005 sets strict limitations on pollutant and sediment loads discharged into urban receiving water bodies, such as the Monjolo Stream, which flows through urban Canoinhas, SC (CONAMA, 2005).

Given these regulatory and technical imperatives, this study aimed to analyze the physical and functional status of catch basins in the urban microdrainage system of Canoinhas, Santa Catarina, Brazil. Specifically, the study sought to categorize material composition and structural integrity, measure surface obstruction and silting levels, and spatially correlate structure failures with municipal hydrographic basins.

2 MATERIALS AND METHODS

2.1 STUDY AREA DESCRIPTION

This case study was conducted in the urban perimeter of Canoinhas, located in the Northern Plateau of Santa Catarina State, Southern Brazil. The municipal urban area encompasses several sub-basins, notably the Arroio Monjolo Basin, Canoinhas River Basin, Água Verde River Basin, and Piedade River Basin. The regional climate is humid subtropical (Cfb according to Köppen-Geiger classification), characterized by well-distributed rainfall throughout the year and intense rainfall events that frequently overload the microdrainage network.

The field sampling covered 13 representative urban neighborhoods with varying population densities, socioeconomic profiles, and land uses (residential, commercial, and industrial): Água Verde, Alto da Tijuca, Alto das Palmeiras, Boa Vista, Campo da Água Verde, Centro, Industrial 1, Industrial 2, Jardim Esperança, Marcílio Dias, Piedade, Sossego, and Tricolin.

2.2 SAMPLING PROCEDURE AND FIELD SURVEY

Field data collection occurred between January and August 2025, involving an in situ census inspection of 4,637 catch basins. The survey adhered to a standardized technical inspection protocol and georeferenced registration adapted from municipal technical cadastre guidelines (CEPAG, 2026).

For each sampled unit, the following technical parameters were evaluated and cataloged (Table 1):

- Georeferenced Identification: Assignment of a unique sequential numeric code and UTM coordinates (SIRGAS 2000 Datum, Zone 22S).
- Cover/Grate Material: Classification into Concrete, Iron, Concrete and Iron (combined), and Missing cover/grate.
- Structural Integrity: Rated as "Good" (intact structure, free of structural cracks or collapse in walls and covers) or "Damaged" (compromised structure, broken covers, collapsed brickwork/concrete).
- Surface Obstruction / Silting Level: Qualitative-quantitative classification into "Unobstructed" (<10% area reduction), "Partially Obstructed" (10% to 80% clogging by sediment/waste), and "Totally Obstructed" (>80% clogging, complete intake blockage).

Tabela 1. Technical parameters and sampling criteria for urban microdrainage units.

Attribute	Technical Description	Classification Categories
Point Code	Unique georeferenced structure code	NNN (Sequential integer)
Cover Material	Material composition of cover or grate	C (Concrete); F (Iron); CF (Combined); M (Missing)
Structural Condition	Physical evaluation of box and cover integrity	1 = Good (Intact); 2 = Damaged (Compromised)
Surface Obstruction	Degree of clogging by sediment and solid waste	U = Unobstructed; P = Partial; T = Total

Fonte: Adapted from authors (2026)

2.3 GIS SPATIAL PROCESSING AND STATISTICAL ANALYSIS

Field data were integrated into a Geographic Information System (GIS) using the digital cartographic base of Canoinhas Municipality provided by the Center for Environmental Studies and Geoprocessing (CEPAG, 2026). Descriptive statistical analyses (absolute and relative frequencies) were performed alongside spatial overlay operations (spatial joins) linking obstructed catch basins to the polygonal boundaries of municipal hydrographic sub-basins.

3 RESULTS AND DISCUSSION

3.1 SPATIAL DISTRIBUTION AND MATERIAL TYPOLOGY

The census survey cataloged 4,637 catch basins across the 13 analyzed neighborhoods. Table 2 presents the numeric and percentage distribution of units per neighborhood.

Tabela 2. Absolute and relative distribution of catch basins per neighborhood in Canoinhas, SC.

Urban Neighborhood	Number of Catch Basins (units)	Relative Proportion (%)
Centro	987	21.3%
Campo da Água Verde	913	19.6%
Jardim Esperança	430	9.2%
Alto das Palmeiras	358	7.7%
Boa Vista	342	7.3%
Industrial 1	326	7.0%
Água Verde	281	6.0%
Sossego	227	4.8%
Alto da Tijuca	204	4.3%
Piedade	188	4.0%
Tricolin	171	3.6%
Industrial 2	140	3.0%
Marcílio Dias	70	1.5%
TOTAL	**4,637**	**100.0%**

Fonte: CEPAG (2026)

Microdrainage structures are heavily concentrated in the Centro (21.3%) and Campo da Água Verde (19.6%) neighborhoods, which together account for over 40% of the city's total inlets. This distribution reflects high building density and extensive soil impermeabilization in these areas, requiring higher inlet densities per street kilometer.

Regarding cover materials (Table 3), reinforced concrete covers predominate (52.0%), followed by cast iron/steel grates (42.4%). Combined concrete-iron covers represent 4.4%, while 1.2% of the units (53 structures) completely lacked covers or grates.

Tabela 3. Frequency of material types used in catch basin covers. Source: CEPAG (2026).

Cover/Grate Material	Quantity (units)	Proportion (%)
Concrete	2,413	52.0%
Iron	1,967	42.4%
Concrete and Iron (Combined)	204	4.4%
Missing cover/grate	53	1.2%
TOTAL	**4,637**	**100.0%**

Fonte: CEPAG (2026)

The existence of 53 uncovered catch basins presents severe hazard risks to pedestrians and traffic, while simultaneously facilitating the direct entry of bulky urban debris and street sweepings, thereby accelerating downstream pipe silting (Poleto, 2012).

3.2 STRUCTURAL INTEGRITY AND PHYSICAL CONSERVATION

Physical condition evaluations (Table 4) indicated that 4,004 catch basins (86.3%) are in good conservation state, displaying no major structural cracks or collapses. Conversely, 633 units (13.7%) were classified as damaged or structurally compromised.

Tabela 4. Structural conservation status of urban catch basins. Source: CEPAG (2026).

Structural Condition	Quantity (units)	Proportion (%)
Good (Intact)	4,004	86.3%
Damaged (Compromised)	633	13.7%
TOTAL	**4,637**	**100.0%**

Fonte: CEPAG (2026)

Structural damage in 13.7% of the infrastructure stems from heavy traffic loads, concrete aging, and lack of corrective maintenance. Broken covers and collapsed box walls retain coarse sediments and hinder manual or mechanical cleaning operations.

3.3 SURFACE CLOGGING AND SILTING DIAGNOSIS

Regarding flow entry capacity and surface obstruction, field measurements revealed significant functional impairment (Table 5). While 77.1% of catch basins (3,573 units) were unobstructed, 19.5% (904 units) were partially clogged, and 3.4% (160 units) suffered total obstruction by sediment, sand, gravel, vegetation, and municipal solid waste.

Tabela 5. Surface obstruction and silting status of catch basins. Source: CEPAG (2026).

Surface Obstruction Level	Quantity (units)	Proportion (%)
Unobstructed	3,573	77.1%
Partially Obstructed	904	19.5%
Totally Obstructed	160	3.4%
TOTAL	**4,637**	**100.0%**

Fonte: CEPAG (2026)

Combined, functionally impaired structures (partially or totally clogged) account for 22.9% of the municipal microdrainage network (1,064 inlets). Partial clogging drastically reduces design inlet capacity, promoting gutter overflow and street flooding during moderate-to-intense rainfall events (Canholi, 2014; Tucci, 2004).

3.4 SPATIAL ANALYSIS AND HYDROGRAPHIC BASIN CORRELATION

Spatial overlay analysis of the 160 totally obstructed catch basins against municipal sub-basin boundaries identified a severe spatial concentration (Table 6).

Tabela 6. Spatial distribution of totally obstructed catch basins per hydrographic sub-basin.

Hydrographic Sub-Basin	Totally Obstructed Catch Basins (units)	Relative Proportion (%)
Arroio Monjolo Basin	87	54.4%
Other Basins (Canoinhas, Água Verde, Piedade)	73	45.6%
TOTAL	**160**	**100.0%**

Fonte: Os Autores, 2026

The Arroio Monjolo Basin concentrates over half (54.4%) of all completely clogged inlets in the city (87 units). Topographically, the Arroio Monjolo Basin is the most flood-vulnerable urban area in Canoinhas, with a documented history of recurring flash floods and waterlogging.

Severe inlet clogging in this basin reduces concentration time and prevents runoff entry into underground conduits, forcing water onto road surfaces and overloading the main stream channel. This finding aligns with observations by Poleto (2012) and Baptista *et al.* (2011), who emphasize that microdrainage maintenance failures exacerbate socio-environmental hazards in low-lying basin sectors.

3.5 INTEGRATED DISCUSSION AND MANAGEMENT IMPLICATIONS

Integrated data analysis demonstrates that although 86.3% of the physical structures remain structurally sound, Canoinhas' microdrainage system suffers from a lack of systematic preventive maintenance. The 22.9% overall obstruction rate (partial and total) directly compromises local hydraulic performance. Internationally, studies on catch basin dynamics (e.g., Karlsson & Viklander, 2008; Ahmed *et al.*, 2022) demonstrate that sediment accumulation exponentially reduces trapping efficiency and inlet intake capacity. When the sediment fill-up depth exceeds critical thresholds, surface runoff bypasses stormwater inlets, amplifying urban flooding risks and triggering pollutant resuspension during peak flow events (Wei *et al.*, 2021).

This operational failure observed in Canoinhas mirrors challenges reported in global urban environments, where traditional gray infrastructure operates under sub-optimal conditions due to reactive rather than condition-based maintenance protocols (Avila *et al.*, 2011). Furthermore, the heavy concentration of completely obstructed inlets in the Arroio Monjolo Basin (54.4%) reinforces the

necessity of integrating spatial hazard diagnostics into municipal sanitation policies, aligning local management with both national regulations (ANA Reference Standard No. 1/2021; Federal Law No. 14,026/2020) and international sustainable urban drainage framework practices (SUDS/NbS).

Sediment runoff in central and rapidly expanding residential sectors originates from unpaved roads, construction sites lacking sediment barriers, and illegal waste dumping. As stressed by Silva (2021) and Cardoso *et al.* (2024), gray infrastructure solutions are ineffective without street sweeping, routine clearing, and community environmental education programs.

4 CONCLUSIONS

This study established a comprehensive diagnosis of the physical and functional conditions of urban microdrainage in Canoinhas, SC, Brazil. The main conclusions are:

- The inlet system relies predominantly on concrete (52.0%) and iron covers (42.4%), with a critical safety and operational defect identified in 53 missing cover structures.
- While most units exhibit good structural condition (86.3%), 13.7% are damaged and require urgent repairs.
- Silting and clogging affect 22.9% of all catch basins (19.5% partially and 3.4% totally obstructed), severely impairing stormwater intake.
- The Arroio Monjolo Basin represents the most critical urban sector, concentrating 54.4% of total obstructions, thereby heightening urban flood risks during heavy rainfall.
- It is recommended that municipal authorities implement a targeted Preventive Maintenance Plan prioritized in the Arroio Monjolo Basin, standardize inlet structures, enforce ANA Reference Standard No. 1/2021, and integrate sustainable drainage techniques (SUDS).

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