



## USE AND OCCUPATION OF THE HYDROGRAPHIC MICRO-BASIN OF IGARAPÉ DO MARIANO IN THE MUNICIPALITY OF MANAUS-AMAZONAS

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### ABSTRACT

**Objective:** To analyze the dynamics of the use and occupation of land based on the planning and sustainability of natural resources at the micro-basin of Igarapé do Mariano.

**Method:** This study is characterized by a quali-quantitative approach based on field-collected primary data, followed by data treatment in a laboratory and data analysis in an office. It presents an exploratory nature, with research and information regarding a micro-basin.

**Results and conclusion:** The urban expansion of Manaus advances towards the Mariano micro-basin, likely leading to an intensified use and occupation of land. The recent interventions on the routes and areas of leisure at the riverbed have been provoking negative environmental impacts that are typical of the urban micro-basins of Manaus, which have been and continue being destroyed as the city expands.

**Implications of the research:** Based on the realizations from the analyses of the use and occupation of land, the research is expected to contribute to a planning policy for the territory, be it the Mariano micro-basin or other geographical areas.

**Originality/value:** The study's value lies on the peculiar location of the studied area, which is situated in the transition vector of urban expansion; on the lack of studies and of deeper information on the subject; on the use of a Remotely Piloted Aircraft in the field work for the photographic and aerophotogrammetric survey, which has proven to be an effective support for the study of the geographical area. All these aspects are of high relevance to the acquired knowledge and could potentially contribute to socioenvironmental actions.

**Keywords:** Silting, Micro-Basin, Subdimension, Erosion, Urban Expansion.

### USO E OCUPAÇÃO DA MICROBACIA HIDROGRÁFICA DO IGARAPÉ DO MARIANO NO MUNICÍPIO DE MANAUS-AMAZONAS

### RESUMO

**Objetivo:** Analisar a dinâmica de uso e ocupação da terra com base no planejamento e na sustentabilidade dos recursos naturais na microbacia do Igarapé do Mariano.

**Método:** O presente estudo é caracterizado pela abordagem qualiquantitativa a partir de dados primários coletados em campo, com tratamento de dados em laboratório e análise em escritório. Apresenta característica exploratória com pesquisa e informações de uma microbacia.

**Resultados e conclusão:** A expansão urbana de Manaus avança em direção da microbacia do Mariano, é provável que o uso e ocupação da terra se intensifiquem. As intervenções ocorridas nas vias e áreas de lazer no leito do

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igarapé vêm ocasionando impactos ambientais negativos típicos das microbacias urbanas da cidade de Manaus que foram e continuam sendo destruídas na medida em que a cidade se expande.

**Implicações da pesquisa:** Embasado no entendimento a partir das análises sobre o uso e ocupação da terra, espera-se contribuir com a pesquisa para uma política de planejamento sobre o território, seja da microbacia do Mariano ou de outros espaços geográficos.

**Originalidade/valor:** Pela peculiaridade da localização da área estudada, que se encontra no vetor de transição da expansão urbana, falta estudo e informações mais aprofundadas e a utilização de Aeronave Remotamente Pilotada no trabalho de campo para o levantamento fotográfico e aerofotogramétrico, que mostrou ser eficaz no apoio ao estudo do espaço geográfico, são de grande relevância no conhecimento adquirido e que pode contribuir nas ações socioambientais.

**Palavras-chave:** Assoreamento, Microbacia, Subdimensão, Erosão, Expansão Urbana.

## USO Y OCUPACIÓN DE LA MICROCUENCA HIDROGRÁFICA DE LA BAHÍA DE MARIANO EN EL MUNICIPIO DE MANAOS-AMAZONAS

### RESUMEN

**Objetivo:** Analizar la dinámica del uso y ocupación de la tierra en base a la planificación y sostenibilidad de los recursos naturales en la microcuenca del Igarapé do Mariano.

**Método:** Este estudio se caracteriza por un enfoque cuali-cuantitativo basado en datos primarios recolectados sobre el terreno, seguido del tratamiento de datos en un laboratorio y el análisis de datos en una oficina. Presenta un carácter exploratorio, con investigación e información sobre una microcuenca.

**Resultados y conclusión:** La expansión urbana de Manaus avanza hacia la microcuenca del Mariano, lo que probablemente conduzca a una intensificación del uso y ocupación de la tierra. Las recientes intervenciones en las rutas y áreas de ocio en el cauce del río han estado provocando impactos ambientales negativos que son típicos de las microcuencas urbanas de Manaus, que han sido y siguen siendo destruidas a medida que la ciudad se expande. Implicaciones de la investigación: A partir de las realizaciones de los análisis del uso y ocupación de la tierra, se espera que la investigación contribuya a una política de planificación del territorio, ya sea la microcuenca del Mariano u otras áreas geográficas.

**Originalidad/valor:** El valor del estudio radica en la ubicación peculiar del área estudiada, que se sitúa en el vector de transición de la expansión urbana; en la falta de estudios y de información más profunda sobre el tema; en el uso de una aeronave pilotada a distancia en el trabajo de campo para el levantamiento fotográfico y aerofotogramétrico, que ha demostrado ser un apoyo efectivo para el estudio del área geográfica. Todos estos aspectos son de gran relevancia para el conocimiento adquirido y podrían contribuir potencialmente a acciones socioambientales.

**Palabras clave:** Endeudamiento, Micro-cuenca, Subdimensión, Erosión, Expansión Urbana.

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## 1 INTRODUCTION

In the current phase of growth the city of Manaus, capital of the state of Amazonas, projects its expansion vector following two major road axes: one interstate/international integration (BR-174) and another municipal connection (AM-010). It expands its urban site to



a large polygonal area, beyond the quadrant of the current Northern Zone, in the northern segment to the interior of the Amazon forest and moving away from the great river complex Negro river/Solimões/Amazonas, the starting point of its historical occupation mark.

In the segment of this expansion is the Hydrographic Microbasin of the Mariano Igarapé (MHIM), which extends from LNE/OSO and has much of its left margin area consolidated inside the urban site belonging to the neighborhoods Lago Azul and Tarumã-Açu. They are spatial areas belonging to the medium and low course of the microbasin. It presents strong expansion pressure on the high course that has as main access projected over this area the highway AM-010 (Manaus - Itacoatiara).

Based on the systemic, ecodynamic and morphodynamic approach (TRICART, 1977) that comprises the natural and anthropic analysis on land use and occupation, the study allows to understand the socio-environmental relationship of this hydrographic area, since different interests are expressed in the multiple uses in the microbasin. According to Manaus (DOM Nº 3332, 2014) for the Urban and Environmental Master Plan of the Municipality of Manaus 2014 (PDUAMM), restrictions are imposed on this area of the microbasin with use without degradation.

The natural aspect is related to the ecodynamics between the variables: vegetation, soil, relief and drainage network. In the social aspect, the focus is the spatial production from the anthropic and morphodynamic association that express different interests and contradictions among the social actors. According to the understanding of Alves, Freitas and Santos (2020), one must understand that man acts as a transforming agent of space, modifying the elements of nature for development, comfort and survival. However, these transformations that lead to multiple uses need to be supported in good management without leading to degradation.

In this context of the approach, it is important to understand the dynamics of occupation at the present time and to try to envision a projection based on research, planning, preservation and conservation of existing resources in the MHIM, because, on the one hand, the environmental issue is first and foremost a social issue and, on the other, from the environmental legislation, the river basin, due to its great importance, is a territorial unit of planning and management.



## 2 THEORETICAL FRAME

It is imperative to analyze how land use is processed to understand quantitatively and qualitatively how a given territorial area with several compartments of the landscape is consolidated over time transformed by antagonistic forces.

According to the Brazil Land Use Coverage Monitoring Project 2016 - 2018, from the Brazilian Institute of Geography and Statistics (IBGE, 2020) data on land use dynamics is an instrument of environmental planning in support of effective environmental policies. It enables reliable data to be provided for guidance in decision-making for different actions that signals a study aimed at sustainable development.

Due to the pressure for the forms of use and occupation in the hydrographic ecosystem, between the vegetation and water components, this last natural resource is usually the most affected by anthropic action, reaching levels capable of disrupting its state of resilience. According to Teubner Junior and Barroso (2018) water resources are always in constant vulnerability due to pollution caused by land use due to anthropogenic changes without planning.

Land use by unplanned human activities has considerably altered the biogeochemical flows of hydrographic ecosystems. It is therefore essential to understand the dynamics of occupation based on the social characteristics that appropriate natural resources through multiple uses and to understand how these relations are intrinsically established. Any significant change can alter the hydrological cycle in a river basin and, if unplanned, can cause irreversible negative impacts. Da Silva et al. (2022) state that among the most relevant factors in the process of river basin changes are attributed the forms of land use and occupation.

The New Forestry Code of 2012, Law No. 12,651, of May 25, 2012, Article 3, paragraph VI, understands that land use is an appropriation that takes place in a secondary way and an alternative for man to provide his needs. This law describes that the alternative use of land is a substitution of primary vegetation and successor formations for other soil cover, such as farming, industrial, energy generation and transmission, mining and transportation, urban settlements or other forms of human occupation (BRAZIL, 2012).

For the IBGE (2020), changes caused by land use generally cause impacts on resources that are environmental services made available by nature to human beings directly or indirectly from ecosystems. The PDUAM, expressed in Article 23 that the urban land use and occupation strategy has the general objective of ordering and regulating land use and occupation to



guarantee the quality of life of the population, including the reconfiguration of the urban landscape and the valorization of non-urban landscapes (MANAUS, DOM, N° 3332, 2014).

An evaluation is important to understand the changes in land use and to evaluate the interrelation, as it provides subsidies for land use planning with a view to the sustainability of human actions (TEUBNER JUNIOR and BARROSO, 2018). In this sense, due to the way of use and occupation of the land in the urban scenario of Manaus, the micro basins - abundant parts, without the proper quality that they ought to have - were occupied and continue in this process of appropriation without planning and without support for environmental legislation, so that they became and continue to be harmful environments.

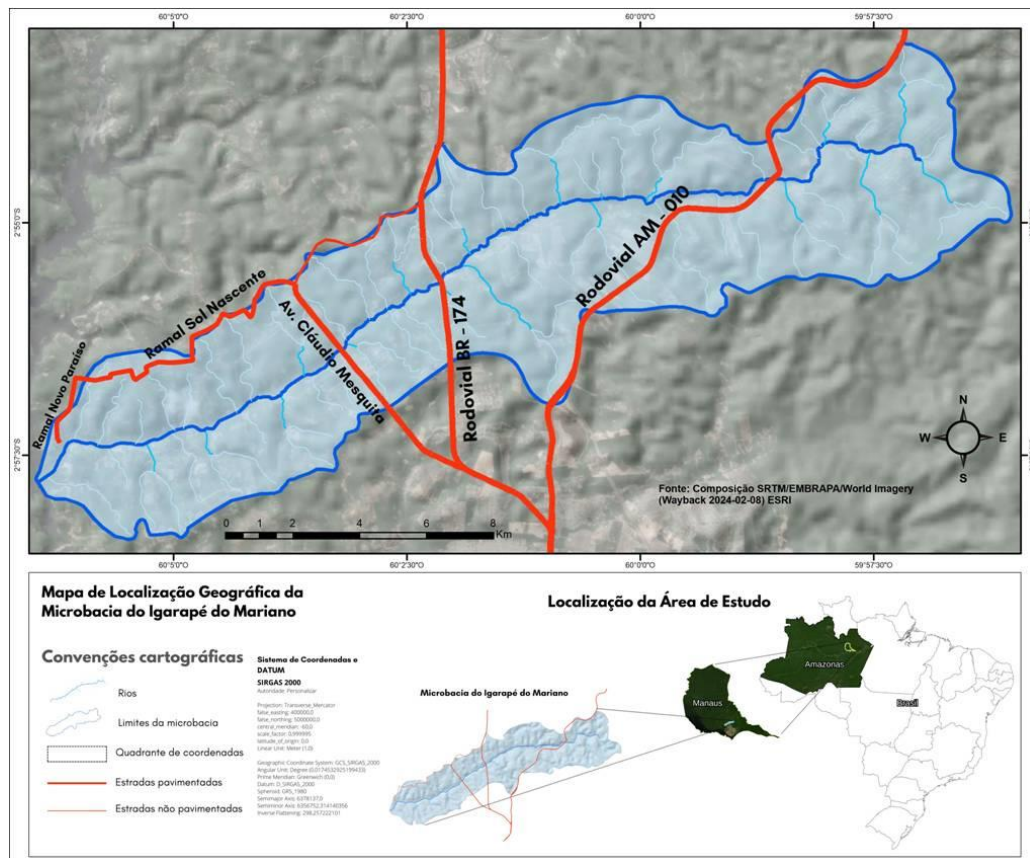
### **3 METHODOLOGY**

The Mariano creek is one of the tributaries by the left bank of the most expressive hydrographic catchment area in the Municipality of Manaus, the River Tarumã-Açu, which flows into the left bank of the River Negro and this is swollen in a large flow. It also flows down the left bank of the Solimões/Amazonas River to form the richest and most complex hydrographic system on earth. The Hydrographic Microbasin of the Mariano Igarapé (MHIM) is located in the northern portion of the city of Manaus, in the quadrant of Geographic Coordinates 2°56'7.75"S and 2°59'6.51"S, 59°55'51.48"O and 60°5'56.36"O and occupies an approximate area of 70,12 km<sup>2</sup> (Figure 1).



**Figure 1**

*Geographical location of the Mariano Igarapé Hydrographic Microbasin in the municipality of Manaus*



Fonte: Elaborado pelos autores (2024)

Its spatial area presents a peculiarity when compared to other basins in the urban area. It is a transition zone from urban to rural areas with a predominance of the Equatorial Large-leaf Forest, with the use and occupation of land focused on primary activities. However, due to the urban expansion front of the city of Manaus continuing without planning towards its geographic location, it is currently a micro-basin that is highly threatened and vulnerable to degradation.

The left bank of the watershed is already part of the city's urban administrative divisions. A portion of the upper course is in the North Zone (Lago Azul neighborhood), the medium and low course is included in the West Zone (Tarumã-Açu neighborhood). These are consolidated areas without adequate urban planning and although there are some residential complexes, the majority of housing is made up of slums without public service infrastructure. Three roads provide easier access to the interior of the micro-basin: The AM-010 highway (Manaus-Itacoatiara) runs from the middle and upper reaches, the BR-174 (Manaus-Roraima) in the





middle course, and Avenida Cláudio Mesquita in the lower reaches. course, paved with other extensions in 2023.

The scenario in the study area has been reflecting the same occupation model in which each social actor is the administrator of the geographic space according to their interests and financial resources. The figure of the state that should precede the normative application of the master plan aiming at socio-environmental action, carries out superficial public policies to only serve the interests of a certain group or social class.

### 3.1 CHARACTERIZATION OF THE RESEARCH

The present study is characterized by a qualitative and quantitative approach based on primary data collected in the field, with data processing in the laboratory and analysis in the office. For Freixo (2012) it is a description and study of phenomena based on explanations of the relationships between phenomena.

In its scope, as Severino (2007) describes, field research, which consists of observation, collection and survey of data in the natural environment where phenomena occur, corresponds to the most descriptive forms of the most analytical studies. It presents an exploratory characteristic, as narrated by the aforementioned author, in which information about an area is researched, mapping the attributes and their changes.

It is explanatory because it records and analyzes phenomena and, according to Severino (2007), seeks to identify their causes and effects through interpretation facilitated by the qualitative method. By adding a set of technical approaches and complementary to the method, procedural methods in research are more concrete stages of investigating phenomena, according to Lakatos and Marconi (2011), a set of techniques for a concrete approach when studying phenomena.

### 3.2 DATA COLLECT

The vector bases referring to the limits of the river basin and the river network of Igarapé do Mariano were obtained through the website of the National Water and Basic Sanitation Agency (ANA, 2022). Additionally, the territorial limits were acquired from the IBGE reference vector base (2022) and the urban subsectors, neighborhoods and environmental qualification of the PDUAMM (2014). Environmental Systems Research Institute (ESRI)



ImageryBasemap satellite imagery was used to provide a detailed visual representation of the study area.

### 3.3 DATA PROCESSING

In this segment, data processing was carried out in the Geoprocessing Sector of the Municipal Department of Education (SEMED) using the ArcGIS 10.1 and ArcMap 10.8 software. First, the images and vector data were imported, followed by a preliminary analysis to assess the quality and adequacy of the data. Subsequently, the drainage network of the study area was extracted to identify watercourses and other relevant hydrographic characteristics.

### 3.4 DATA INTEGRATION

The vector bases were superimposed on the satellite image, integrating data from the hydrographic network and the limits of the basin with the visual representation provided by the satellite image. Scale, resolution and symbology adjustments were made to ensure an accurate and detailed representation of the area on the image chart. The delimitation of the area of the Mariano igarapé watershed was done using the clip tool in ArcGIS, aiming to precisely define the limits of the area of interest.

### 3.5 FIELDWORK

Field trips took place at five points in the Mariano watershed corresponding to the upper, middle and lower reaches during the months of May and October 2022, January, May, June and October 2023. To proceed with collecting information in the field, the work was based on the technique of direct observation with notes in a field notebook with the aid of a 4 GB Panasonic pocket IC RR-XS450 pen drive digital recorder, field map, photographic record, GPS (Global Positioning) sensor device System) GPSMAP 78s series from the GARMIN brand to identify the geographic coordinates of the worked points.

For the aerial photographic and aerial photogrammetric survey, flights in 2022 were carried out with an ARP type multirotor rotary wing quadcopter DJI Mavic Air 2 Pro 4K. In 2023, flights were carried out with an ARP DJI Mini 3 Combo Fly More Rc with 4K resolution E3 screen. The flight plan was drawn up on the Google Earth Pro platform, including the





expected mission time, battery level, number of photos taken, height, flight speed, distance between the ARP and the home point.

The overlapping of the photos at the time of capture was established with 80% longitudinal (overlap) and 60% lateral (sidelap) coverage. According to Droneng (2020), it is the ideal flight scenario for rural areas where the image overlapping procedure aims to find homologous points that appear in more than one photograph captured from different perspectives. The flights were carried out automatically, intermittently and remotely piloted, at an altitude of 120 meters, as determined by ANAC (2018), with a level of terrain detail corresponding to the ground sample distance GSD (GroundSampleDistance) of 10 cm/pixel (SILVA NETO, 2020).

## 4 RESULTS AND DISCUSSIONS

The municipal government compartmentalized the urban area of the capital Manaus into several macro areas. Among these, the transition area, which, in physical terms, presents a homogeneous characteristic in its use and occupation with low demographic density, reduced environmental impact and a focus on tourist activities.

### 4.1 TRANSITION AREA AND URBAN EXPANSION ZONE

In the context of the administrative division, MHIM is located in two transition zones, located above the large area of the North Zone and the Adolpho Ducke Reserve. The 2014 PDUAMM defines in article 57 the Transition Area as being the strip of municipal territory that surrounds the limits of the Urban Area, including the Adolpho Ducke Forest Reserve, which can house agricultural activities, uses and low-density urban activities, where they are encouraged ecotourism activities (MANAUS, DOM N° 3332, 2014). The master plan adopted the spatial model of division of the transition area, which was divided and identified as the Transition Zone (ZT), where the Mariano microbasin is inserted only in the Tarumã-Açu ZT.

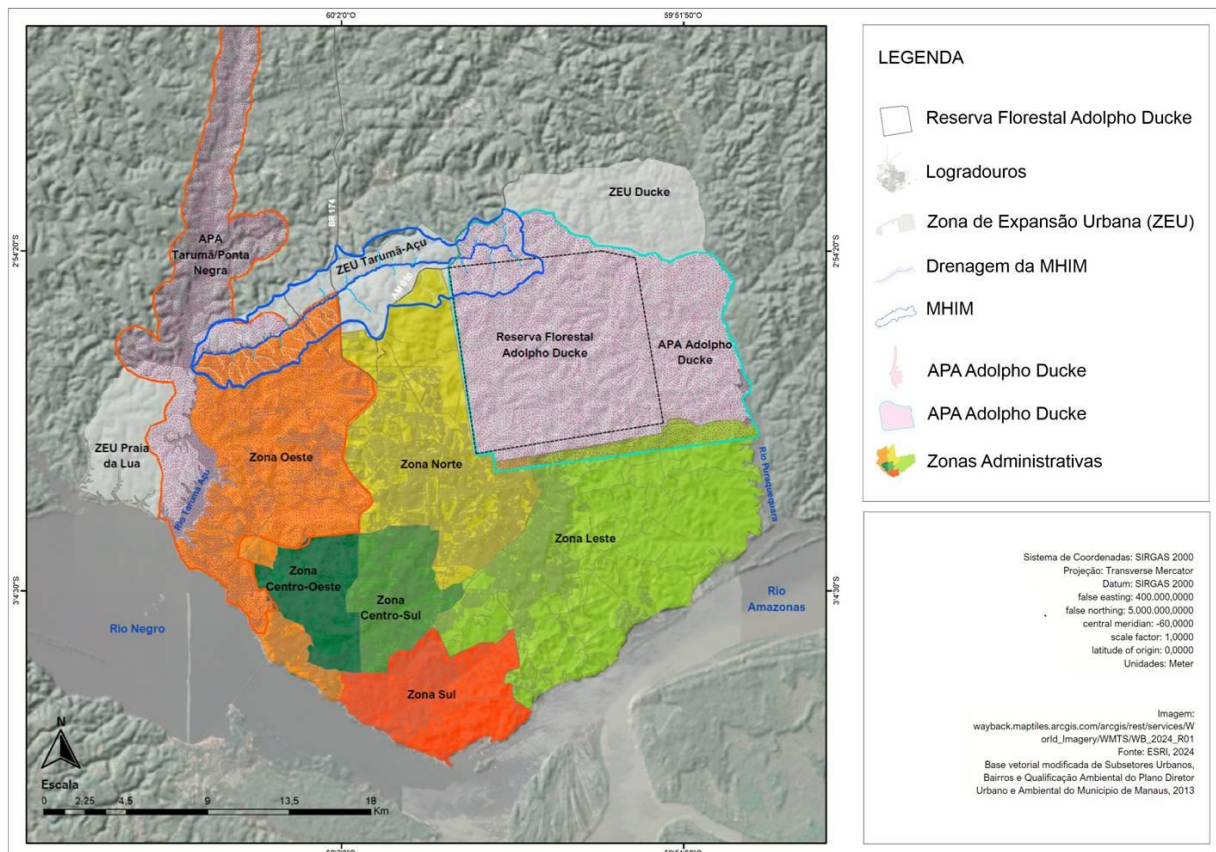
The PDUAMM map of the urban expansion zone and urban zone of Manaus shows six geographic zones and the ZTs are identified as three Urban Expansion Zones (ZEU): ZEU Praia da Lua in the western part, ZEU Tarumã-Açu in the northern part and ZEU Ducke in the northern and eastern part. In this division, the limit of the Mariano microbasin area meets the upper course at ZEU Ducke and ZEU Tarumã-Açu, the middle course and the entire extension of the lower course are at ZEU Tarumã-Açu. The largest area of the headwaters with the main



springs forming the hydrographic network is in ZEU Ducke and the smallest area is within the Adolpho Ducke Reserve (Figure 2).

**Figure 2**

*Map of Manaus with the Geographic Zones, the ZEUs, the APAs and the location of the MHIM*



Source: Organized by the authors (2024)

Although the municipal administrative division has the objective of planning the territory based on environmental management, it appears that the form of use and occupation that has been consolidating in the Mariano microbasin has caused environmental impacts resulting from the exploitation of sand in several mines that are abandoned without the recovery plan for the degraded area being carried out and interventions in the watercourse to build a leisure area (bathhouses) where riparian vegetation has been suppressed and the course has been dammed.



## 4.2 APA ADOLPHO DUCKE AND APA TARUMÃ/PONTA NEGRA

The MHIM is inserted in two environmental vectors of special attention which, according to Brasil (2000), are conservation units corresponding to the definitions of the National System of Conservation Units (SNUC). The Environmental Protection Area (APA) is an integral part of sustainable use units that are intended to protect biological diversity by disciplining the occupation process based on the sustainability of natural resources. Conservation units are essential in the provision of environmental services because they aim at quality of life and human development (MOREIRA, 2019).

For the Municipal Secretariat for the Environment and Sustainability (SEMMAS), the APA is spatially extensive and presents a certain degree of human occupation, rich in biotic and abiotic attributes and scenic beauty aimed at the quality of human life, with the aim of protecting biological diversity and focusing on disciplining use and occupation to ensure the sustainability of the site (SEMMAS, 2022).

According to Manaus (DOM No. 2897, 2012), through Municipal Decree No. 1,502, of March 27, 2012, the Adolpho Ducke Environmental Protection Area was created, aiming to ensure environmental preservation based on common use assets, in quality of life, the well-being of the population and the improvement of local ecological conditions. This APA covers the entire Adolpho Ducke reserve, followed by a strip in the eastern portion up to the limits of the Puraquequara river course, covering the northeast and northern part above the reserve until reaching the limits of AM-010. It forms a large protection vector on the edge of the capital's urban zone with a total area of 18.2 thousand ha.

A large part of the upper course of the Mariano is in the Adolpho Ducke APA, where the entire headwaters with its five main springs are included in this environmental protection space. For Manaus (DOM N° 2897, 2012) the APA Adolpho Ducke aims to discipline the occupation process, avoid irregularities, protect abiotic, biotic, aesthetic and cultural attributes and ensure the sustainability of the use of natural resources, presenting itself as a merely formal discourse, as they do not apply in the form of concrete actions in the context of the watershed.

It is an environmental area formed by a territorial parcel made up of private and public lands in which the owners must be committed to ensuring environmental quality above any interest that could degrade the components that make up the entire ecosystem. It becomes a challenge to be overcome, considering that the occupation and use of land is a process that already occurs in the microbasin. Sand was one of the resources explored in the 1990s and 2000s, mostly without environmental criteria during its extraction, causing several negative



environmental impacts, contradictory to the purposes of the APA. Riker et al. (2016) comments that the sand explored in the Manaus region is used in the construction industry and that its exploitation occurs largely clandestinely.

Silva (2016) observed that at the beginning of the 2000s there were some sand exploration mines in the Mariano microbasin with access via the BR-174 at km 6 and in the lower course close to the Vivenda do Pontal Condominium, and they were exploited in clandestine way. Following the main channel of the Tarumã-Açu river from the upper to the lower course, the APA Tarumã/Ponta Negra, created through Decree 9,556, of April 22, 2008, projects latitudinally from North to South, with a total area of 22.7 thousand ha (MANAUS, DOM N° 1947, 2008), enters the urban part of Manaus covering a vast area of the West Zone, extending towards the lower course with total protection coverage up to the outlet of the Tarumã-Açu river. Inside the Mariano microbasin, the APA covers part of the left bank from BR-174 and the entire lower course.

According to Costa (2020), the disorderly urban expansion in the lower course of the left bank of the Mariano is consolidated in an urban area, control and planning are necessary especially in the Tarumã/Ponta Negra APA. Despite the creation of a conservation unit such as APA Tarumã/Ponta Negra, it is unable to inhibit conflicts that are constant, especially invasions. For the author, this happens because there is no management plan for the area. In 2019, the city of Manaus discovered an invasion in the APA Tarumã/Ponta Negra area and, with support from environmental policing and Companhia Interativa Comunitária, the group of invaders was removed from the site, leaving the Permanent Environmental Protection Area (APP) impacted. , on the banks of the watercourse (AMAZONAS ACTUAL, 2022).

According to IBGE (2013), conservation units aimed at sustainable use, such as APAs, allow exploration for economic use. However, they must be carried out based on properly regulated planning. APAs represent an effort by public authorities in an attempt to guarantee socio-environmental benefits with the conservation of natural assets and improvements in the quality of life, however, it is necessary to converge efforts between prevention measures, inspection, planning, environmental education and mainly compliance with what is determined environmental legislation.

In this sense, special attention is needed for the Mariano watershed so that a management plan can be established for the best use and occupation of the land. Furthermore, it can become a study area, a natural laboratory for research institutions due to the ease of land access to its interior, proximity to the urban area and because it is part of the river system of the Tarumã-Açu basin, rich in natural resources. and scenic beauty suitable for leisure and tourism.



#### 4.3 PHYSIOGRAPHIC CHARACTERIZATION AND ANTHROPIC CHANGES OF MHIM

The Mariano watershed is located on the Alter do Chão geological formation. It is the same structure as the urban site of Manaus with sediments of varying red color corresponding to clayey sandstones, mudstone, quartz-grauvacas and quartz-sandstones (SANTOS, 2001). According to Silva (2016), this Alter do Chão formation developed in a continental area in a fluvial and lacustrine environment, forming an intercalation between siltstones, sandstones and conglomerates. Modeling the relief forms of the Alter do Chão formation, unconsolidated sand packages appear with a thickness of around 4 meters, massive, white in color, with granulometry ranging from fine, medium to coarse with the sporadic presence of pebbles (BARROS et al., 2003; SILVA, 2016).

According to SGB/CPRM (2019), the sands are presented with unconsolidated materials formed by spodosols or quatzarene neosols and in urban areas such as the Lago Azul neighborhood that extends into the Mariano microbasin. Former sandy lands are occupied by people with low purchasing power, transforming these places into vulnerable areas with the appearance of erosion processes (ravines and gullies).

Some of these mines were explored close to the banks of the Mariano stream without technical standards, lack of supervision or clandestine exploration and compromised the geomorphological characteristics of the floodplain. The floodplain is made up of hydromorphic soils and hydrophilic vegetation and includes riparian vegetation protecting the banks of water bodies. If human action occurs, such as the removal of vegetation, erosion, deposition and silting of the river may occur (FELIPPE, GOMES and MAGALHÃES JÚNIOR, 2022). According to the authors, this natural environment acts effectively in flood control, especially in the middle and lower river courses.

The relief patterns present in the area are characterized as hills with varying amplitudes between 20 m and 60 m and low slopes, interfluves with rounded tops and convex slopes and concave base. The topographic shape of the relief follows the sinuosities of the gentle hills separating the streams that have gullies (APP area) more than seven meters high, made up of small valleys forming the floodplain. They are structures also from the urban area of the capital incorporated into a low plateau, where according to Ab'Sáber (2004), this plateau is located between 20 and 30 m from the average level of the Rio Negro. However, it has a steep slope towards the sandy beaches, annually leaving the streams at the mercy of the fluctuation of the waters of the large flow of dark waters.





Ross (2009) states that it is an environment in which the action of rainwater is intense and the relief of rounded or convex tops presents a rich hydrographic network of many channels. When these structures are deforested and exposed over time, they become susceptible to erosion processes. Erosive processes are associated with adverse weather conditions. In a hot humid equatorial climate with intense rainfall and despite a short rainy season like the one that predominates in the Amazon and consequently in the Mariano watershed, according to Florenzano (2008) pluvial erosion resulting from rainwater is common. Rain in the Amazon is generally rapid, falls in the form of torrential downpours and can cause severe soil erosion (SIOLI, 1985).

Of the large amount of rain that falls, Costa (2020) states that rates are greater than 2,300 mm per year and much of it is intercepted by the forest. The Heterogeneous Equatorial Latifoliada terra firma forest, green throughout the year with broad, large leaves and different extracts, covers the microbasin area from the top to the bottom, integrated with the campinarana formations that appear on the sandy deposits, next to the capoeira formations and the buritizais of the waterlogged areas of the floodplains.

Despite the natural wealth that makes up the entire mosaic that goes from forest to water, human actions are interfering in the hydrographic dynamics of the microbasin. Without the presence of public authorities with management or inspection action to prevent those who violate environmental legislation, the occupation and use of land grows according to the particular interests of each social actor according to their purchasing power.

#### 4.4 HIGH COURSE AND HEADBOARD AREA

Aiming for a better description and understanding of the transformation processes and the collection of both quantitative and qualitative data from the studied spatial area, taking into account the hydrography, terrain topography and longitudinal profile, the MHIM was cartographically compartmentalized into high, medium and low course. Its hydrographic area has three main access roads that project over each compartment: the AM-010 in the upper course, the BR-174 in the middle course and Avenida Cláudio Mesquita in the lower course (Figure 3).

In the space of the first-order drainage headwaters, with slopes modeled by convex tops, it is composed of primary rainforest and secondary fragments. It is possible to see five springs forming the Mariano stream, three of which are in the ZEU Ducke and two in the Adolpho Ducke Forest Reserve area, among these, the one located in the southeast portion extending

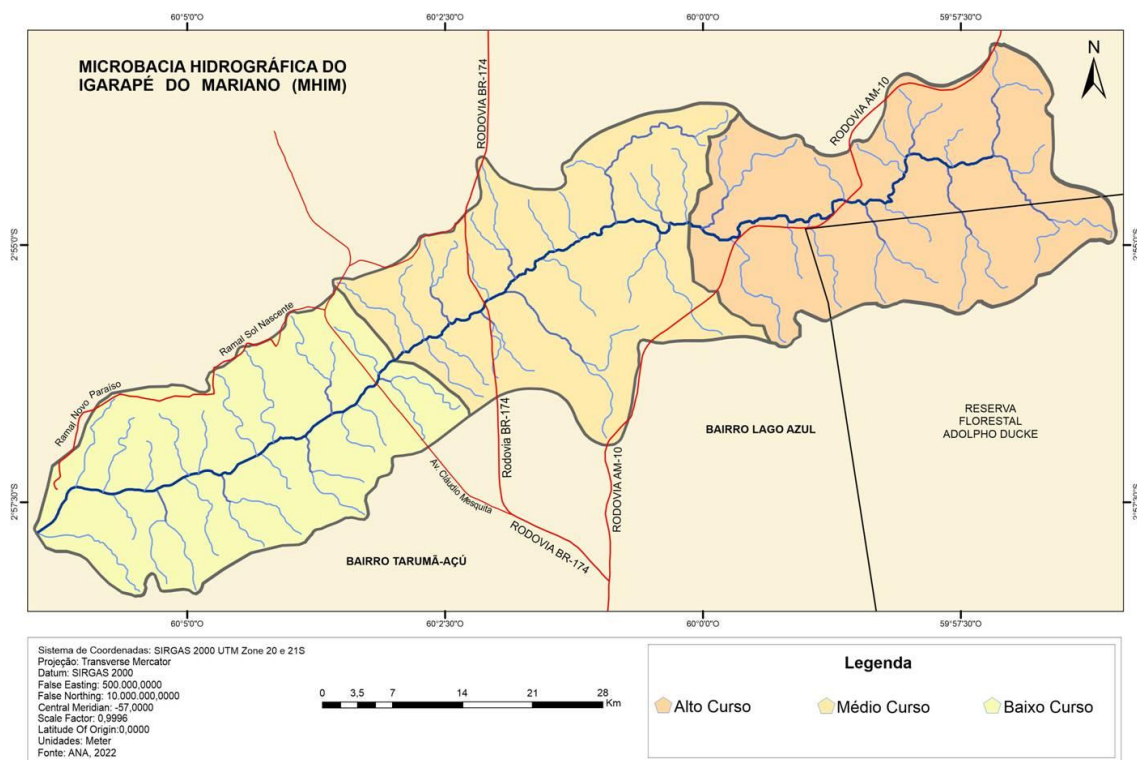




from L/W is the main spring of the hydrographic network . This area with several tributaries and numerous unpaved branches and others with total or partial asphalt coverage interconnect, forming a space with diverse use and occupation with influence and direct access via the AM-010 highway (Manaus-Itacoatiara).

**Figure 3**

*Map of the hydrographic network of the Mariano Stream microbasin with the divisions of the course and the main access routes*



Source: Prepared by the authors (2023)

The MHIM drainage head area with a predominance of forest is one of the fragile parts of the river system and susceptible to erosion processes. It is important to conserve the forest, especially the slopes, to protect the soil from erosion and constantly maintain the water supply to the spring. Without vegetation, the system could collapse, as it houses the springs, the primary source (first order course) that initially supplies the hydrographic network. The system forms a set of parts that are related to each other, elements, states and relationships between states and elements (STEVANUX and LATRUBESSE, 2017).

The current use and occupation are diversified, ranging from houses scattered between the rainforest and areas of secondary vegetation, farms, farms, spas, sand mining areas without recovery with soil exposed to erosive processes (ravines and gullies), others older ones that are



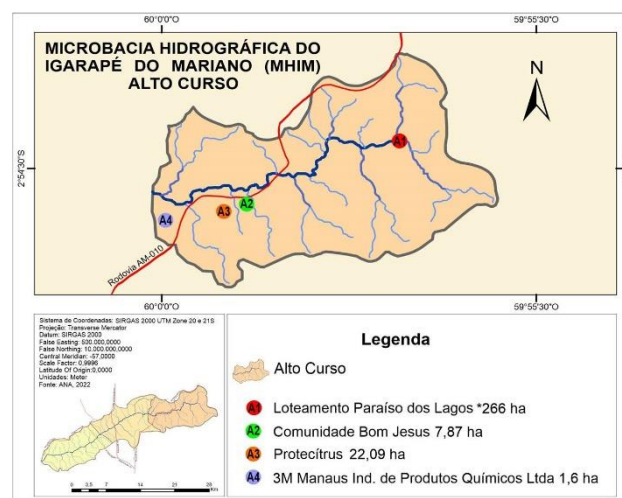
in the process of natural regeneration, subdivisions, electricity substation, photovoltaic plant, national companies that are subsidiaries of multinationals and a small community formed by a single street.

The level of some information exposed to contextualize the diverse process of use and occupation that has been occurring in the Mariano microbasin is in accordance with the greater or lesser degree of ease obtained in the field, through internet access and with an area above 1 ha. In the area corresponding to the upper course, four shapes are identified between km 22 and 30 of Rodovia AM-010 (Figure 4).

1) Paraíso dos Lagos Subdivision (point A1) is located at km 30, with access also via Ramal Bons Amigos at km 26, in the LNE portion of the upper course of the microbasin, extending over the plateaus forming the headwater area where the main sources of the hydrographic network of the Mariano stream.

#### Figure 4

*Identification map of some land use and occupation in the upper reaches with an area above 1 ha. \*Area requested for the project was 21.01 há*



Source: Prepared by the authors (2023)

With data acquired from the Federal Public Ministry (MPF, 2022), in January and February 2019, the Amazonas Environmental Protection Institute (IPAAM) was inspected to investigate the environmental offenses reported and plant suppression was found on both banks of the stream. , intervention in an APP of 1.96 ha, cutting of buritizeiros (*Mauritia flexuosa* L.f.), additional forest of 0.4506 ha, diversion of the natural course, silting, fixing of manilas in the bed, embankment and dams with the aim of building a spa. Due to the environmental impacts, Infraction Notices were drawn up. In August 2019, in another inspection, IPAAM,



found that the Paraíso dos Lagos subdivision was being implemented and the lots were being sold on the internet and, as it did not have an environmental license, another Notice of Infraction was drawn up.

In 2020, it received Installation License No. 020/2020 from IPAAM, authorizing the implementation of a subdivision with an area of 21.0123 ha, of a total area of 45.5236 ha Lot 13, Gleba 10 Ephigênio Ferreira Salles property. IPAAM certified that 21.01 ha was licensed for the project, but the area covered 266 ha, (MPF, 2022). The main paving of the street was intended for the dam, channeling for the formation of a lake in the main course and significant erosion processes were observed. Infraction notices were drawn up on that occasion.

According to information from the MPF (2022), there is a history of environmental crimes involving the subdivision since 2019, considering that works began without authorization from the competent public body and broadcast advertising with false information about legality. This situation led the MPF in August 2022 to file a Public Civil Action with a request for Emergency Protection, as, as stated in the action, around 2.41 hectares of native forest on public domain lands were deforested without authorization from the competent body.

The environmental damage in the area is notorious, with negative environmental impacts on the watercourse, flora and fauna, because as indicated by the MPF (2022), it is an area where the collared tamarin (*Saguinus bicolor* Spix) is an area of incidence, a threatened species. of extinction. If the damage is not repaired and there is no present and active inspection, this area, being close to the headwaters, leaves the main springs where the entire hydrographic network system begins vulnerable to changes and interventions.

2) Bom Jesus Community (point A2) located at km 25 in the OSO portion of the upper course, emerged in 1995 from a subdivision (field data from 01/26/2023). It has 7.87 ha, has a single street that extends for 1 km in length, starts from AM-010, extending in the NNO/SSE direction, with residences on both sides. On the left side, as you enter the community, the backyards at the back of the residences border the Adolpho Ducke Reserve and through satellite images it is possible to see that there is an area of exposed soil within the reserve's forest of 0.244 ha.

The community has precarious infrastructure with poorly maintained paving and deteriorated asphalt. Inland, most of the road is unpaved and in a precarious state of traffic, without sidewalks and without a drainage system to drain rainwater. With 28 years of existence and approximately 131 houses, the majority of unfinished masonry (exposed brick without plaster). These are houses built using the self-construction model, built over time and according to financial possibilities, some built from wood and erected on the slope area below street level.



Many goods are selective, one of which is decent housing and the vast majority of the population does not have the income to purchase it. The possibility is the house produced by the self-construction system in peripheral public or private subdivisions, becoming, at the cost of a lot of extra work, the owner of land and a property producing its own space (CORRÊA, 2002).

3) Protecítrus (point A3) is located at km 25 in the OSO portion of the upper course, occupying an area of approximately 16.71 ha of orange (*Citrus sinensis* L. Osbeck) and lemon (*Citrus limon* L. Burmann f) seedlings. .) and tangerine (*Citrus reticulata* Blanco).

4) 3M Manaus Indústria de Produtos Químicos Ltda (point A4) multinational located at km 24 in the West portion. It is the largest industrial park that opened on December 2, 2015, occupying 16 thousand m<sup>2</sup> of built area (JCAM, 2015). The company benefits from tax incentives administered by the Manaus Free Trade Zone Superintendency (Suframa).

The location of the project of this size outside the central area can be explained due to the recurrent turmoil in the urban centers of the metropolises, which tends to get worse, as it is a way of getting away from the problems of the physical spatial structure that overwhelm themselves, such as the issue of traffic that it becomes more chaotic with vehicle traffic jams, causing greater loss of time for movement, lack of parking space, air pollution and noise pollution where it causes more stress.

Santos (2008) analyzes this process, relating the presence of large companies in spaces further away from the urban center by stating that large companies move to strategic locations where there is greater logistics efficiency. Many large companies that require space and logistics to transport products and employees (efficiency, fluidity and strategy) generally migrate from central areas to more distant peripheral areas. In this sense, AM-010 is an example of a location because it allows easy access, land with large areas and lower values.

#### 4.5 MIDDLE COURSE

The space that extends between the AM-010 and BR-174 highways is a vast area of primary forest, interrupted by the segment of undergrowth through which the power transmission line of the Eng. Isidoro Lechuga Substation passes, which is on the right bank of the stream. This large area corresponds to the middle course of the watershed, where there are seven types of land use and occupation influenced by AM-010 and BR-174 (Figure 5).

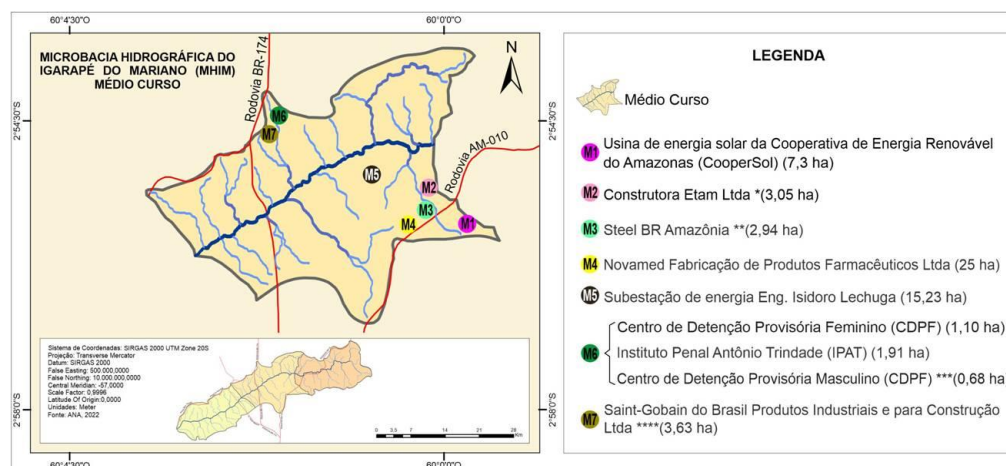
1) Solar energy plant of the Amazonas Renewable Energy Cooperative (CooperSol) (point M1), was established in 2020 and formally launched in 2021, located in the eastern portion of the middle course. According to Portal A Crítica (2021), the plant is located at kilometer 23 with 2,880 photovoltaic energy panels and generates energy for 86 members and



companies. The panels are installed in two areas, one with 3.7 ha and the other with 3.6, totaling 7.3 ha.

### Figure 5

*Map of the middle course of the MHIM with the identification points of some land use and occupation under the influence of access from the AM-010 and BR-174 Highways. Area identified in satellite image: \* 4.7 ha. \*\* 6.97 ha. Use and occupation with total area outside the watershed \*\*\*1.73 ha and \*\*\*\*5.84. there is*



Source: Prepared by the authors (2023)

This type of renewable energy, which is beginning to consolidate itself in the municipality of Manaus, despite being completely sustainable from an environmental point of view, is still not accessible to many, especially to the classes that reside on the distant outskirts of the city, which generally do not have access to greater financial resources. Depending on the place where he lives, man does not have the same purchasing power and enjoyment within the total space, this can be seen as he descends to the periphery (SANTOS, 2007). The minimum investment required for this plant installed at MHIM is 12 plates at an average cost of R\$1,700.00 per unit resulting in a basic total of R\$20,400.00 (ACRÍTICA.COM, 2021).

2) Construtora Etam Ltda (point M2), received in 2021 from IPAAM (2023) the Installation License (LI) no. 141/13-02 for the implementation of the asphalt plant and construction site in an area of 3,055 ha, in height of km 22 and is located in the eastern portion of the middle course. It is classified as a major polluter/degrader potential.

However, the asphalt concrete production plant has an area of bare soil of around 4.7 ha. It is important for the public authorities to maintain more effective supervision in view of the verification of this mismatch in data between the requested area and the effective area,





observed in a satellite image that proves to be efficient in monitoring land occupation. Another point of discrepancy in data information refers to the location of the project, since the installation location described in the LI document describes the location as being at km 21, but this is located between km 22 and km 23.

3) Steel BR Amazônia manufacturing of drawn metal products Ltda (point M3), located at km 22 in the eastern portion of the middle course, has a deforestation area of approximately 6.95 ha. The company obtained the Installation License (LI) and the Single Environmental License for Plant Suppression (LAU-SV) in 2021 (IPAAM, 2021), which authorized the implementation of infrastructure for the metallurgical industry in an area of 2.9453 ha with the appropriate domestic/sanitary sewage treatment plant with a flow rate of 7m<sup>3</sup>/day. Classified as potentially polluting/major degrading.

Despite having followed the procedures to withdraw the licenses from the competent body, there are contradictions in information in the document and in the deforested area, as according to measurements carried out and analyzed in satellite images, it was found that the area is larger than that described in the LI.

4) Novamed Fabricação de Produtos Farmacêuticos Ltda (point M4) was opened in August 2014, located at km 22 in the LSE portion of the middle course, has 3.5 ha of built area on a plot of land with a total area of 25 ha, It is the first industry to produce medicines in the Manaus Free Trade Zone with 500 direct jobs and around two thousand indirect jobs (GRUPO NC, 2014). According to information on the website, the company follows all environmental policies and determinations of the competent bodies in Manaus: SEMMAS, IPAAM and the Municipal Infrastructure Secretariat (SEMINF).

5) Energy substation (500 kV) Eng. Isidoro Lechuga (point M5), is located inside the micro-basin in the LNE portion close to the watercourse, the access entrance is at km 22. The substation is under the responsibility of Evoltz (2023), which has control over the operation of Manaus Transmissora de Energia and occupies an area of around 15.23 ha. Using satellite images, it was verified that the construction took place just over 300 m from the edge of the watercourse and removed the forest next to a large uncovered area (an old abandoned sand mining mine).

As you move towards BR-174, small clusters of houses can be seen nearby. The highway almost transversely crosses the course of the Mariano stream at km 6 and extends within the micro-basin from one divide to the other for a segment of 3.33 km. The presence of four forms of land use is recorded, all on the right margin of the hydrographic ecosystem with areas inside and outside the microbasin.





6) At Km 8, with access via a branch that extends into the interior of the micro-basin, there are three detention complexes in the NNO portion of the middle course (point M6): the Women's Provisional Detention Center (CDPF) with 1.10 ha, the Antônio Trindade Penal Institute (IPAT) with 1.91 ha and the Men's Provisional Detention Center (CDPF) with a total area of 1.73 ha. However, only 0.68 ha is in the watershed.

7) In the Manaus-Roraima direction, on the dividing edge of the watershed, in the NW portion, there is the company Saint-Gobain do Brasil Produtos Industriais e para Construção Limitada (point M7), with a total area of approximately 5.84 ha and 3 .63 ha is within the watershed. The company has benefits and incentives through Suframa, with the support of the Secretariat for Planning and Economic Development (SEPLAN) with tax incentives from the Tax on the Circulation of Goods and Services (ICMS).

BR-174 limits the urban area of Manaus on the bridge that crosses the Mariano stream at km 6, at geographic coordinates 02°55'37.0" S and 60° 02'05.4" W. Despite being a highway federal interstate connecting Manaus to the state of Roraima, and Brazil itself through the northern part of the country with Venezuela, does not present the same dynamism in land use and occupation along its route as seen in AM-010.

In terms of proximity and distance, the stretch of AM-010 that is located within the Mariano microbasin, despite being further from the urban center of Manaus, has a greater number of companies. One of the factors attributed is due to the greater length of the highway within the micro-basin, however, what can influence the location of projects along AM-010 is the geographic location and logistics of transporting products to the lower Amazon and agricultural products to supply the Manaus market, facilitated by the road-fluvial system.

#### 4.6 LOW COURSE

This sector of the lower part of the microbasin presents several deforested areas with more intensive use and occupation of land, with numerous branches that interconnect. Avenida Cláudio Mesquita (formerly Ramal Cláudio Mesquita), which is the main access road to the right bank and interconnects with Ramal Sol Nascente and Ramal Novo Paraíso, ran parallel to the edge of the watershed until the mouth. In this division of the lower course, five forms of occupation are highlighted, representing the diversification of land use and occupation (Figure 6).



**Figure 6**

*Map of the lower course of the MHIM with the identification points of five forms of land use and occupation, all on the left bank. \* Total area 4.7 ha with most of it outside the watershed. \*\* Corresponds to two areas of 1.22 ha and 1.82 há*



Source: Prepared by the authors (2023)

In this vector, the primary activity is more present, where fish farming in excavated ponds, poultry farming for poultry farming and egg production can be seen. Many quadrants of sectors of agricultural areas of small farmers (right bank) forming a mosaic of secondary vegetation between spaces of primary forest and areas of exposed soil from old sand exploration mines that stand out over the interfluves.

1) Located on the limit of the edge of the hydrographic network in its eastern portion, close to Avenida Cláudio Mesquita km 2, there is a poultry farm with an approximate area of 4.56 ha with 26 sheds for confinement of birds, of which this area In total, 4.19 ha are located within the watershed (point B1). There are several enterprises in this sector dispersed within the micro-basin for the production of birds for slaughter and production of eggs destined for the capital's consumer market.

2) Forming one of the quadrants of land use and occupation in the lower part of the lower course in the SSE portion, there is the Civil Police Parking Lot of the Department of Public Security in Manaus with 1 ha of area, where hundreds of vehicles learned from different situations of irregularities.

3) Vivenda do Pontal Condominium made up of houses with a standard for the middle/upper class with 11.24 ha, located in the Center-SO part of the lower course of the watershed. The project originated from a subdivision of the company Eletroferro, and was approved by the Municipality of Manaus in October 1982. It is built on an extensive plateau



that projects over the course of the Mariano stream as a water divider between a tributary of first order on the left (downstream) and a second order tributary on the right (upstream).

The transformation that occurred over the interfluvium with the construction of the condominium, which is separated from the bank of the watercourse by a narrow strip of fragmented and suppressed riparian vegetation due to the advance of construction over the slope area.

Close to the condominium on an extensive plateau between two tributaries, bordered by vegetation, there are two exhausted sand mines with accumulation of negative environmental impacts for more than 20 years. The exploration left the rock exposed with fragments of thin vegetation in the old mining square; In the interior there are erosion processes (grooves and ravines) and a gully with mass movement into the course. For Stevaux and Latrubesse (2017), the environmental impacts caused by mineral exploration occur when environmental legislation is weak, has no supervision or is precarious or ineffective. Costa (2020), states that the mining explored in the microbasin was for civil construction, which increases urban growth and is responsible for negative impacts.

4) Hope Bay Park (2023) is located on the edge of the watershed in the SSO portion of the lower course (point B4) built on a total area of 8 ha with 2.78 ha within the watershed. It is an entertainment enterprise aimed at leisure with different modalities and infrastructure (water park, artificial beach, resort, cabins, chalets, restaurant, steakhouse and parking). The project is located in the Tarumã-Açu neighborhood with paved access roads. The interior of the edge of the microbasin is largely limited to a forested area that protects a spring of one of the Mariano's tributaries near the headwaters.

5) Hydroponic lettuce cultivation (point B5) occupies two areas, one of 1.22 ha and the other of 1.62 ha located in the SW portion of the lower course of the watershed, both structured in the plasticulture system, totaling 2.84 ha of building area. Production aims to supply the capital's local market, with production flowing via paved branches.

In this sector of the lower course, Avenida Cláudio Mesquita is the main access road to the right bank of the Mariano with paving completed in 2023, together with the Sol Nascente, Novo Paraíso and Frederico Veiga branches. According to Seinfra, the project to recover and pave the branches of the lower course of the Mariano had an investment worth R\$ 22.9 million (AMAZONAS, 2023). According to the sign displayed in the field, the work began in October 2020 and would cost the public coffers R\$ 16,583,255.70.

Due to the infrastructure works that were carried out in the area, there was a dynamism in occupation that is facilitated by the paving of the roads, with a greater flow of vehicles and



people. This transformation on the right bank of the lower course with the infrastructure works on the roads and the connection of numerous branches that radiate into the interior of the micro-basin allowed small farmers in the area to transport their production more efficiently and move the local economy more quickly.

However, being a Transition Zone in which the entire length of the lower course is in the Tarumã-Açu Urban Expansion Zone, the asphalt infrastructure works consolidate this expansion on the right bank. It is very likely that this sector on the right bank, which before the infrastructure works was more isolated due to the difficulty of access with branches that somewhat impeded the population's more effective transit, will lose its character as a rural area (subsistence farmers, farms, farms, afforestation, natural water courses) due to an increasingly urban occupation (population density, condominiums of houses and apartments, degradation of streams) with concrete structures and increased soil waterproofing.

Despite the occurrence of exposed soil from old sand mines on some plateaus that form the interflaves, the presence of primary and secondary vegetation stands out, mainly on the banks of the tributaries and the main course with the preservation of riparian vegetation.

#### 4.7 ENVIRONMENTAL ASPECT OF CALHA DO MARIANO

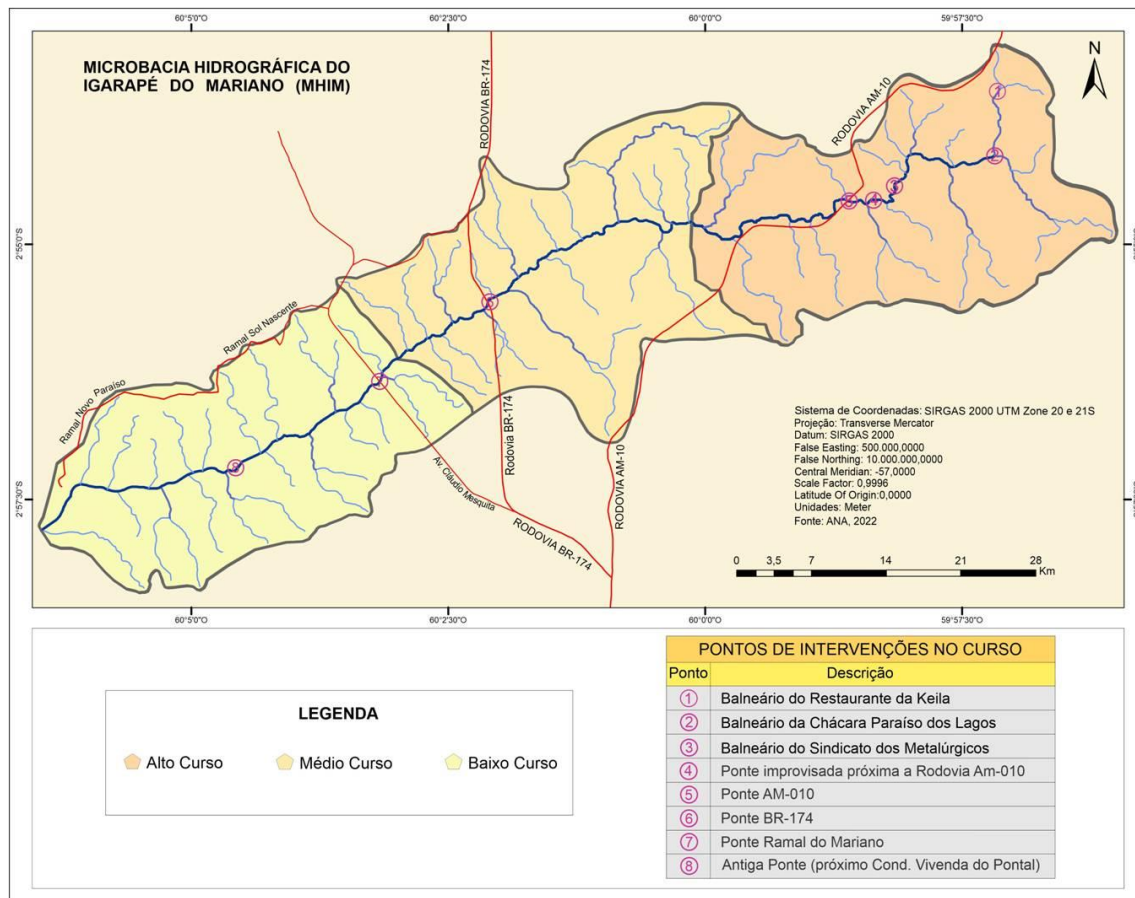
In much of the upper and middle course, the stream channel is narrow from one bank to the other and almost imperceptible due to the forest that covers the route. Ab'Sáber (2021), when referring to the streams of the Brazilian Amazon macrodomain, explains that the majority of these watercourses, due to their narrow channel, are covered by the forest canopy that flanks them.

The most aggravating environmental impacts on the Mariano riverbed are due to engineering works in the construction of bridges in the cross-section of the course that interfere with the natural passage of water flow, leisure area (bathhouse) and direct or indirect involvement by mining exploration of sand abandoned without recovery on the bank of the stream with the suppression of vegetation, erosion and movement of soil into the channel. These impacts are present from the headwaters close to AM-010, on BR-174 on Avenida Cláudio Mesquita and upstream from Condomínio Vivenda do Pontal, where there are sections in which the gutter and some tributaries of the stream are uncharacterized by damming, silting and strangulation of the watercourse (Figure 7).



**Figure 7**

*Map of the location of intervention points in the headwater area and along the course of the Mariano stream*



Source: Prepared by the authors (2023)

1) The Restaurante da Keila development (point 1) with great infrastructure in the leisure segment (changing room, tents, playground, stand up paddle boarding and kayaking), food (restaurant with coffee and lunch) and fish farming in the dam system. It is located at km 30 on the right side of the AM-010 Highway towards Manaus/Itacoatiara, at the head of the hydrographic network in the NE portion of the upper course, forming an area of liquid surface mass around 2.97 ha.

The biggest changes occurred on the right bank of the tributary to facilitate access to the highway near the headwater area. The modifications for the construction of the parking lot, restaurant and formation of an artificial beach took place on the slope and floodplain area. With the suppression of natural vegetation and topographic modification, the shape pattern of the slope area became uncharacterized. The modification process with the construction of the dam in two transversal sections to control the flow of the current destroyed the natural course and



formed a 2.97 ha lake with an average width of 75 m and a depth of 1.5 m. The artificial lake formed by the interventions is divided into two forms of use.

In the upper part, the first intervention in the cross section was intended for leisure, where a 1.34 ha lake was formed for the spa. The downstream for the formation of tanks in a dam system was confined in three areas, the largest being 1.11 ha. The other two fish farming areas, one with 0.32 ha for the intermediate tank and the other with 0.2 ha for the smaller tank, were built by advancing along the left bank over the slope area.

To control the flow, there is a bleed system built in the shape of a concrete box, which rises from the bottom of the gutter to the height of the water depth corresponding to the main spillway. To help control the flow, several secondary spillways (bleeders) made of tubes with diameters of around 30 cm were built. The bottleneck systems (undersizing the water passage) have as their final output from the interventions that were built transversally across the watercourse section, a concrete manacle with a diameter of around 1 m that crosses the embankment and releases the flow to the natural course that integrates directly with the main channel of the microbasin's hydrographic network.

2) At this initial point of the main third-order course, another intervention occurred that changed the character of the stream channel. Over the area of the bifurcation (union) of the second-order tributaries is the Balneário da Chácara Paraíso dos Lagos (point 2). Dams were built on the site over the floodplain to build a bridge and create a lake for the spa. The undersizing strangled the water flow and caused an extensive flooded area upstream, creating an artificial lake through human action and downstream, the destruction and reduction of the water flow in the channel.

Perennial flooding causes the gradual death of palm trees in humid (waterlogged) areas, forming the “toothpick tree” scenario where only the stem (stem) can be seen in decomposition, for example, the buritizeiro, a very common species belonging to the hydrographic ecosystem, present in banks and surroundings of springs in micro-basins in the municipality of Manaus.

The alteration of the channel by undersizing, which passes through the concrete spillway and a smaller bleeder, has been destroying the vegetation and in periods of intense rain it can cause flooding. According to Botelho (2011), the occurrence of a choke point becomes critical due to the reduction in flow sections, making the closed area extremely vulnerable to floods. The scenario worsens especially when paving occurs in adjacent areas. Negative environmental impacts occur synergistically and what occurs upstream degrades and compromises environmental quality downstream.





3) Next to the AM-010 Highway, at km 27, there is the Balneário do Sindicato dos Metalúrgicos do Amazonas (Sindmetal-AM, 2023) (point 3) with a large part of the leisure structure on the right bank of the Amazonas stream. Mariano, occupying an area of around 5.88 ha. With the intervention on the watercourse destined for the leisure area (bathhouse), a 1.0 ha lake was formed.

The modifications to the slope area formed a flank with a gentler topographic slope in the form of a ramp due to the earthworks. The suppression of vegetation in the hillside area and riparian vegetation was replaced by buildings, a swimming pool and an artificial beach on the right bank.

The interventions took place directly on the slope area, floodplain and in the watercourse channel. These are interventions that require authorization, control and supervision from public bodies, as they conflict with what is determined by environmental legislation. Law No. 1838, of January 16, 2014, which establishes rules for land use and occupation in the municipality of Manaus, includes wording with references to watercourses and springs. Article 106 shows that for all water courses, whether in urban or transitional areas, a minimum marginal protection strip of 30 meters is adopted from each bank of the greatest flood and 50 meters from the sources (MANAUS, 2014).

4) Downstream of the Metalúrgicos resort, close to the AM-010 highway, the earth dam for the construction of an improvised bridge (point 4) undersized the flow of the course with the placement of a concrete manifold. The dam with the bridge over the floodplain gives direct access to several fish farming tanks that are on the left bank of the stream and are deactivated.

At the intervention site, the gutter has a narrow geomorphology between the banks, the water confined over the floodplain did not kill the buri vegetation, it is still preserved. Close to the bridge structure, the soil is exposed to exogenous agents, vulnerable to mass movement into the watercourse, especially during the rainy season due to the effect of flash floods. A soil devoid of vegetation has a greater probability of rainwater runoff due to reduced infiltration and accelerated erosion (STEVAUX and LATRUBESSE, 2017). During rain, the tiny trickles of water thicken, become concentrated and form floods and have greater erosive power (CHRISTOFOLETTI, 1980).

5) On Highway AM-010, at km 26, the intervention on the course of the Mariano was carried out by public engineering work, where the channel was undersized for the construction of the bridge (point 5). Despite the undersized water passage, the scenario is one of regeneration and balance, without erosive processes due to the protection of riparian vegetation. This regeneration can be attributed to time as the work was carried out more than 50 years ago.



However, some residences close to the highway advanced into the APP space, confining a narrow strip of vegetation on the slope and floodplain. To prevent further disturbances to the course of the stream, it is necessary to maintain the vegetation that covers the channel. They are mostly buri trees, which are very important for the maintenance and balance of the watercourse.

On the left bank of the stream there is an area without large vegetation on a sandy remnant that did not have a recovery procedure for the degraded area at the time after exploration. The mining square presents fragments of vegetation due to the lack of organic matter, soil exposed to erosion processes, where the development of furrows and ravines can be identified.

On the surface of the soil there is a brown spot that identifies the formation of crusts creating a more rigid carapace on the soil. This situation occurs due to human action that left the soil bare without vegetation and organic matter. Guerra (2003) points out that the upper part of the soil becomes sealed and this makes water infiltration difficult, as this occurs due to the lack of protection of the organic matter that aggregates the soil, making infiltration difficult and increasing runoff.

6) At km 6 of BR-174, engineering work on the cross section of the Mariano (point 6) caused an environmental impact with the construction of the bridge, which undersized the canal and strangled the natural passage of the water flow. Upstream of the bridge, the water was confined and increased the width from one bank to the other by around 140 meters, contrasting downstream where the narrow channel follows the course practically covered by vegetation. Several anthropogenic changes that were not mitigated and, consequently, modified the landscape. Because they are subject to exogenous agents, a scenario of negative environmental impacts on the hydrographic ecosystem is seen, with actions starting from the removal of vegetation, exposed soil, erosion and changes in the water course.

As in the situation observed on the Chácara Paraíso dos Lagos bridge, the same situation occurs in the bridge system built on BR-174, with the difference in the geometry of the structure, which instead of being tubular, is square. However, it causes the same impact with flow strangulation, formation of a perennial lake upstream, death of vegetation in the floodplain. This scenario is repeated in the following intervention.

7) The bridge over the Mariano stream is located at km 3.4 of Avenida Cláudio Mesquita (point 7) on a segment perpendicular to the riverbed. In measurements along this section of the branch, the width of the microbasin from one edge to the other is 3.3 km. During fieldwork in June 2023, the section was still being carried out with earthworks to receive the asphalt layer.



The engineering work repeats the same construction pattern as the BR-174 bridge that was built in the 1970s.

The construction of the dam over the floodplain triggered negative environmental impacts such as erosion (gullies) on the slope flank and silting on the bank, creating a vulnerable scenario and will certainly fail during the period of intense rain. With the intervention on the stream channel, the negative environmental impact on the natural vegetation is notable. Upstream on the floodplain, low vegetation replaced large vegetation, contrasting with large vegetation downstream.

What is still largely preserved on the two banks upstream and downstream of the bridge are the APP areas. The vegetation is seen on the top of the slope area following the convex symmetry of the relief, extending with the vegetation cover to the valley where the floodplain is located, protecting the soil against exogenous agents, mainly the impacts of raindrops. and floods.

The wider gutter increases the pressure on the intervention area, especially during rainy periods when the volume of water and speed tends to increase and with the undersized spillway the pressure on the dam will be greater. The flow of the watercourse increases downstream due to the greater number of tributaries flowing water into the channel, which causes the width, speed and depth to significantly increase (PRESS et al., 2006). This perhaps explains the rupture that occurred in the early 2000s, where the force of the water destroyed the dam and left only the iron pipe in the middle of the canal.

8) To facilitate the flow of clandestine sand extraction from the right bank in the lower reaches of the watershed, a bridge was built without technical standards by miners with an earth embankment over the floodplain, close to Condomínio Vivenda do Pontal. The force of the water destroyed the bridge, leaving environmental impacts such as the deviation of the concrete structure in the canal and the death of vegetation in the floodplain (SILVA, 2016).

The earthen dam that was part of the destroyed bridge has been under the action of exogenous agents (weather and erosion agents) for a long time. On both sides of what remains of the dam on both banks, a large volume of soil is being deposited in the floodplain, contributing to siltation in the river channel. The speed of the current decreased during the dry period, there was greater sedimentation on the floodplain and consequently the death of the vegetation, which turned into a toothpick scenario. Inside the canal there was a concrete block that supported the bridge and has continued to resist the weather for more than 25 years, preventing the flow of the current in the thalweg.



Any intervention in the cross section of the stream requires a multidisciplinary study by specialized people and engineering work for bridge construction, taking into account mainly the flow, speed, width of the channel and elevation of the relief. Despite involving other variables, these four factors may have been the points of vulnerability that led to the destruction of the bridge in the lower reaches of the Mariano.

What is understood about the impacts caused by the bridge is the ease of circumventing the law, the fragility of environmental agencies due to ineffective operation/inspection and the absence of public authorities due to the fact that they do not act to mitigate what is impacting the hydrographic ecosystem. According to ANA (2022), the growing number of dams globally greatly impacts freshwater ecosystems, requiring urgent emergency plans to mitigate the harmful effects, with deactivation measures (unblocking) to release the flow water supply, recovery and protection in order to guarantee the environmental quality of critical habitats.

## 5 FINAL CONSIDERATIONS

The appropriation of natural space and the contradictions that are expressed through the transformation of the place and the value of this place that differs in relation to another place is established according to purchasing power. Due to the pressure of urban expansion in Manaus, which is advancing towards the Mariano watershed, it is likely that land use and occupation will intensify in the near future. This occupation process already occurs under the control of highways BR-174 and mainly AM-010. With the asphalt infrastructure that took place on the lower course of Avenida Cláudio Mesquita, on the Sol Nascente and Novo Paraíso branches, it facilitated and is intensifying the occupation of the right bank, as well as the left bank, which already belongs to the Tarumã-Açu neighborhood.

The forms of use and occupation and the interventions that occurred with the construction of roads and leisure areas (bathhouses) on the stream bed have been causing negative environmental impacts typical of the urban micro-basins of the city of Manaus, which have been and continue to be destroyed as the city expands. Intervention works involving damming and throttling, which cause undersizing, are recurrent in micro-basins. It is an action that requires multidisciplinary participation with different perspectives from experienced professionals, because it involves several ecosystems (vegetation, soil and water) with natural and interdependent dynamics.

It is necessary for the public authorities to cover and support a management plan to organize the forms of occupation and put environmental laws into operation to demand



appropriate measures in areas that have not respected the standards. That mitigating measures are carried out with due compensation, this would alleviate the negative impacts and the past degradations that occurred in other streams in the urban area of Manaus would not be repeated.

As a limiting factor in the work, the difficulty in obtaining some information about certain companies and other forms of occupation that did not allow access to the location stands out. Based on this understanding based on analyzes of the vulnerabilities and potentialities caused by the use and occupation of land, it is expected to contribute to a planning policy on the territory, whether in the Mariano microbasin or other geographic spaces.

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