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VÁRZEA DO TIETÊ: RESTAURO AMBIENTAL, URBANIZAÇÃO E INOVAÇÃO TECNOLÓGICA THE TIETÊ FLOODPLAIN: ENVIRONMENTAL RESTORATION, URBANIZATION AND TECHNOLOGICAL INNOVATION

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Abstract

The critical social and environmental conditions on the outskirts of São Paulo are the reference of ZL Vórtice, a collaborative project focused on the urbanization, environmental recovery, and technological innovation of the Jardim Helena district, known as Pantanal. The project proposes to develop, with the participation of the local community, new drainage and paving solutions, sustainable water treatment devices and restoration of degraded areas, new technologies for the containment of ponds and streams banks, and social monitoring devices for the river system and urban settlement. ZL Vórtice intends to introduce an important differential in public policies for metropolitan peripheries, particularly the floodplain areas: the agency of research laboratories to develop technologies and specific materials for critical situations. The question of method is fundamental when different research laboratories come together to face critical situations such as the Tietê River floodplain, in cooperation with local communities. Transdisciplinary projects, in which each agent has its requirements and procedures, establish major methodological challenges. The aim is to give the proposals an experimental character, focused on technological innovation, including knowledge transfer and technical training of residents to face increasingly recurrent extreme events in the floodplain areas.

Palavras-chave: Floodplains, Environment, Urbanization, Technology, Method, Participation

1 Introduction

On the outskirts of the city of São Paulo, conflicts involve the necessary protection of the environment, occupations of precarious housing settlements, and major works of metropolitan infrastructure, especially to contain floods and control water quality. These processes are often contradictory. The result is the increasing degradation of urban and environmental quality, affecting vulnerable populations and hydromorphological and ecological systems. This situation requires a rapid paradigmatic shift in urban development processes and points to the need to develop new approaches and techniques (Brissac Peixoto, 2017).

A collaborative project of an integrated system for the management and treatment of water and urban and environmental requalification is being developed and its implementation is going to happen at the meandering plain of the Tietê River, in the eastern section of the Municipality of São Paulo, Brazil. The ZL Vórtice Project proposes sustainable means of urbanization, with technological innovation and economic and social inclusion, and also actions focused on the restoration of the geomorphological remnants and the hydrological functionality of the river plain, strongly impacted by major infrastructure works and the precarious urban occupation.

The project's area of influence covers the last stretch where the Tietê River, in the Municipality of São Paulo, partially sustain its meander dynamics, affected by numerous anthropic interventions, from old extractive activities to informal occupations and flood containment works. Figure 1 shows the project’s area and the floodplain urbanization process. This is an extreme condition that requires the development, with local communities, of water management and treatment and re-urbanization infrastructures, engaged with the recovery of the floodplain's environmental functions in critical situations.

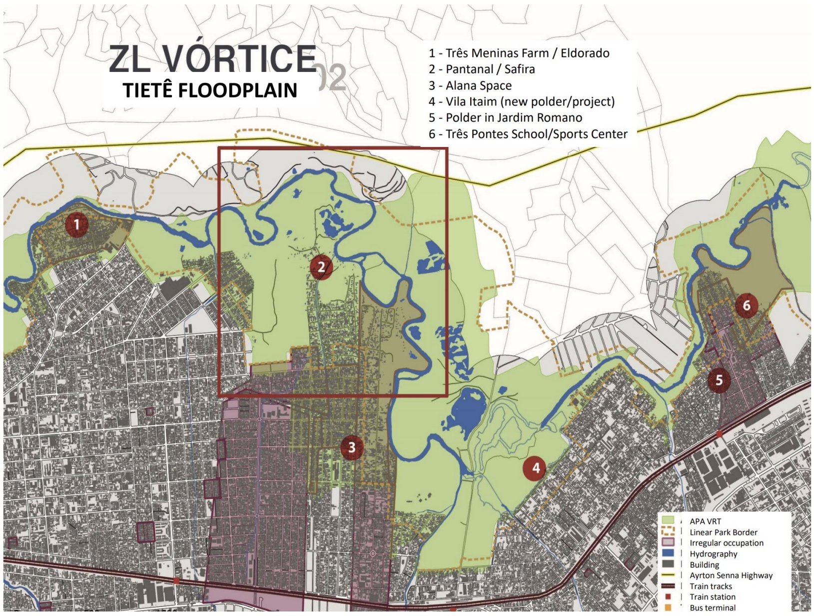

Fig. 1: Map of the project’s area, with the main urban references. Source: Lígia Pinheiro / Projeto ZL Vórtice, 2017.

The intervention area extends from the mouth of the Itaim stream to the Água Vermelha stream basin, configuring a large section of the Tietê River's meander belt. In the urban occupation area of the floodplain, it corresponds to the Jardim Helena district, known as Pantanal, with about 135,000 inhabitants. That area is the subject of different public programs and policies, such as the Macrodrainage Plan for the Upper Tietê Basin (PDMAT-3) and the APA-VRT Management Plan, in addition to the Tietê Floodplains Park project.

In the city of São Paulo, the Tietê River is the target of the major flood prevention works. The policies currently adopted by the local administration consist basically of promoting radical segregation of the river from the urban occupation area, implementing systems of polders and large tanks to isolate the river from the floodplain. On the other hand, there is an accelerated process of landfilling the entire area, emphasizing the conflicts between housing demands and environmental preservation.

The purpose of the ZL Vórtice Project is to structure Jardim Pantanal environmentally and urbanistically by developing an integrated urban infrastructure project for drainage and water treatment with the residents and conserving the floodplain remnants. The project proposes to recover the drainage function and the environmental services that the river plain is no longer capable of fully carrying out, with actions to promote the coexistence of urban occupations and the river and its floods, adapting the city to the meandering river. A question arises from this idea: is it possible to establish a new model for urbanization and environmental recovery, based on technological innovations and a broader social engagement?

2 About the methodology

ZL Vórtice Project was created in 2013 and has promoted seminars and technical visits with Emplasa (São Paulo Metropolitan Planning Company), CDHU (São Paulo State Housing and Urban Development Company), São Paulo State Forest Foundation, SP Urbanismo (Municipal Secretariat for Urban Development - SMDU), and

Secretariat for Infrastructure and Environment (SIMA), aiming to interact with government institutions and contribute to public policies (Information available at https://zlvortice.wordpress.com/).

The project seeks to introduce an important differential in public policies for the metropolitan peripheries, in particular the floodplain areas: the engagement of research laboratories to develop technologies and specific materials for critical situations. The aim is to give the proposals an experimental character, focusing on technological innovation, which includes knowledge transfer and technical training of the residents to face extreme events that are increasingly recurrent in those areas.

The research laboratories associated with the development of the proposal are FabLab SP - FAU-USP Digital Fabrication Laboratory; LME - Laboratory of Microstructure and Eco-efficiency of Materials at Poli-USP; LabGeo - FFLCH-USP Geomorphology Laboratory; Luiz Fernando Orsini Yazaki, former coordinator of Hydraulic Technology Center Foundation (FCTH); URCA-PROURB - Postgraduate Program in Urban Design at FAU-UFRJ; LabTIDD - Technologies of Intelligence and Digital Design at PUC-SP; Department of Civil and Environmental Engineering at the Politecnico di Milano, Italy; and Laborg Studio.

The Jardim Pantanal Residents Association (AMOJAP), directed by Reginaldo Pereira, has contributed decisively to the project's development, guiding field expeditions, indicating the critical points of greatest importance to the community, providing a place for workshops and tests, organizing the different workshops that the laboratories carry out with residents and participating in the elaboration of the proposed technological solutions.

The question of method, the theme of this V!RUS journal's issue, is fundamental when different research laboratories, in cooperation with local communities, come together to face critical situations such as the Tietê floodplain. Important method challenges arise in transdisciplinary projects, in which each agent has its terms and procedures. The project requires exploring innovative means of research, creating methodologies for social participation, and public bottom-up actions for decision-making processes.

There are several technical challenges for these laboratories: to research geomorphology, hydrology and the urbanization process in critical, highly degraded areas; to identify, in the stretch of the meander belt, the configurations that still present their essential functionalities, such as the delay of the water flow which, consequently, reestablishes the conditions for the water quality improvement through its self-purification; to create drainage and stream banks containment devices and make permeable sidewalks in the floodplain public spaces; to develop equipment for collecting environmental data and monitoring the river network adapted to floodplain conditions; to ensure that all procedures are developed with the residents' participation.

Hydrogeomorphological surveys of the stretch of the meander belt were programmed in detail by LabGeo-USP and by Luiz Orsini. The URCA-PROURB of the Postgraduate Program in Urban Design at FAU-UFRJ will investigate design practices that enable technological innovations and the provision of basic infrastructures, seeking to connect ecology and urban design (Mostafavi *et al.,* 2019). The FabLab-FAU the LME PoliUSP and LabTIDD-PUC/SP promoted several workshops with residents for the development and diffusion of technologies for critical situations. Laborg Studio carried out a systematic survey of the floodplain area, focused on its hydrology and transformations due to the processes of landfilling and urban occupation. That field research enabled the development of interactive devices for the visualization of the existing dynamics of the area.

The rigor of research laboratories in the definition of environmental restoration strategies and water treatment devices, and qualification and standardization of materials and procedures for drainage infrastructure projects in the Tietê River floodplain, will be confronted with the area's extreme conditions. The challenge is, while sustaining technical precision and economy principles, to develop technologies adapted to situations of great environmental and urban instability and promote the dissemination of knowledge and social participation during all of the process stages.

A technical-scientific lab operates by carrying out experiments in which the performance of devices and materials is assessed through accurate measurements. Laboratories demand strictly controlled working conditions (asepsis, constant temperature, calibrated equipment). How to build a laboratory on the Tietê River floodplain with the residents' participation?

The construction of a field lab implies the transformation of the floodplain into a laboratory, with the possibility of replicating operations in the area, ensuring the basic parameters of accuracy and measurement established by researchers during their investigations. The procedures proposed by laboratories can only work if the prescribed principles and techniques are incorporated by local administrations and communities and converted into a shared culture (Latour, 2017). It requires a set of techniques (manuals, instruments, labor training, systematization of parameters, and procedures) to support the proposed technological solutions and the laboratories' operations in the floodplain.

So far, laboratories have carried out visits and workshops with residents in the university campus and communities. The technological research is in an initial formulation stage. There are also discussions with residents and small-scale prototype production. Only resources from the laboratories were used. Financing proposals were submitted to FEHIDRO (State Water Resources Fund), where they have encountered resistance, especially from DAEE (Department of Water and Electric Power), which is responsible for the major engineering works designed for the area.

3 Technologies

The ZL Vórtice Project proposes to design an integrated water management and treatment system for the urban and environmental requalification of the Tietê River’s meandering plain, in São Paulo's eastern zone. A systemic articulation of the different technologies is proposed so that drainage devices flow into streams and ponds provided with erosion containment and equipment for water purification, as seen in Figure 2:

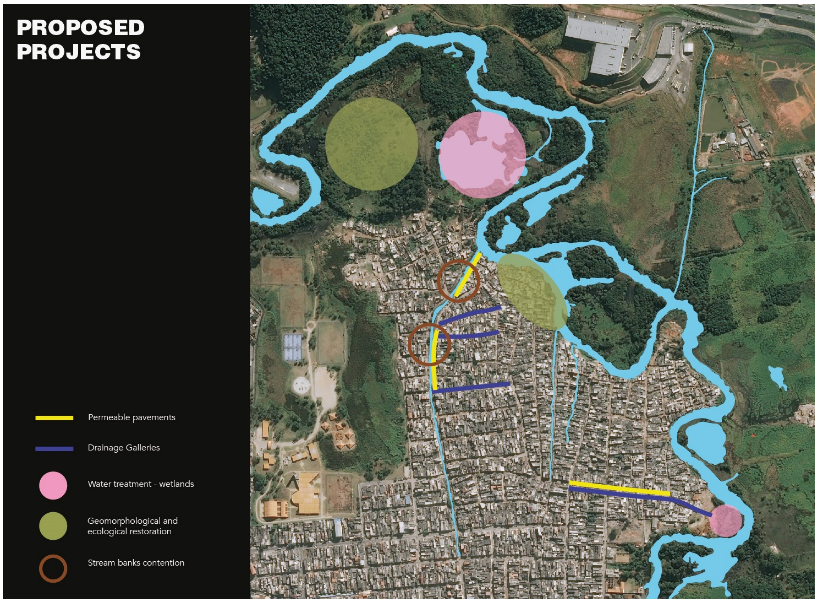

Fig. 2: ZL Vórtice: Integrated water management and treatment system for urban and environmental requalification. Source: Estúdio Laborg and URCA-PROURB - FAU-UFRJ, 2020.

A crucial issue regarding the implementation of drainage galleries in areas of urban floodplain occupation is the final discharge site. In order to constitute an integrated system, the micro drainage device must end up in areas where the project foresees the implantation of wetlands for rainwater treatment, along with non-collected sewage. The effluents treatment is essential for the recovery of hydrological and environmental conditions of the area.

Likewise, the reduction of surface drainage by permeable pavements contributes to mitigate the effects of floods and to preserve the river ecosystem, as well as the proper structuring of stream banks, which receive those flows, preventing their silting. These interventions, when interlinked, acquire relevance and systemic effectiveness.

3.1 Drainage galleries

It is a system of prefabricated modules for surface drainage and rainwater management. The project, developed by FabLab of FAU-USP, directed by Professor Paulo Fonseca, consists of developing, together with residents, drainage galleries for the retention and evacuation of surface flows, in an area with a dense urban anthropic occupation, characterized by the lack of urban and sanitation structures.

Fig. 3: Module and mold digitally fabricated. Source: Projeto ZL Vórtice, 2017. Available at: https://zlvortice.wordpress.com/. Accessed on 05/06/2020

The system consists of lightweight prefabricated modules that combine, in a single cross-section, the sidewalk floor and the underground gallery for storing and draining rainwater, as shown in Figure 3. The parts are prefabricated in high-performance micro concrete, a specially developed material that presents higher resistance, lightness, and durability, dismissing heavy equipment for production and installation.

Micro concrete (reinforced mortar) is a particular type of reinforced concrete, with physical and mechanical behavior similar to the conventional compound, but with particular performance properties. It allows the production of thinner prefabricated elements without coarse aggregates. It results in lighter construction elements, allowing a reduction in material consumption and loads on structures. The technology implies searching for cementitious matrices capable of making thin reinforced concrete structures viable and their possible application in light prefabrication due to its high-performance properties (Fonseca de Campos, 2014).

Fig. 4: 1:1 scale prototype of the drainage gallery module. Source: Projeto ZL Vórtice, 2018. Available at: https://zlvortice.wordpress.com/. Accessed on 05/06/2020

The project includes another important technological innovation: the molds are modeled and executed based on a digital manufacturing process, as shown in Figure 4. This allows us to obtain prefabricated elements that vary according to specific situations of topography or hydrological system demand: a combination of prefabricated micro concrete production and new 3D prototyping technologies. The process demands training the residents in the existing public digital manufacturing laboratories of the area.

The proposed construction system aims to mitigate flood impacts, since drainage galleries for capturing rainwater may accelerate the settlement's drainage. Due to the various landfills carried out to the floodplain’s occupation, the soil was waterproofed and the region's topography modified, drastically modifying water behavior. The micro drainage system must, therefore, address the problem of being in a lower area, susceptible to water return.

The reinforced micro concrete prefabrication technology is a consolidated process but it presents only a few recent applications and innovations. Then, the proposed solutions are: to research new technologies for concrete, high-strength mortars, with fibers and additives; to research the integration of the micro concrete elements' production with digital modeling and CNC milling of casts; to develop a computational model to simulate rainwater flow from drainage gallery systems in low slope areas.

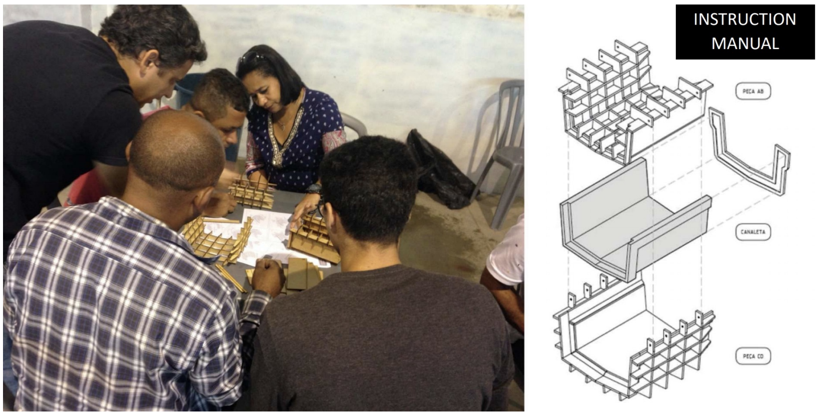

Fig. 5: Workshop for assembling molds at Jardim Pantanal, with a handbook. Source: Projeto ZL Vórtice, 2018. Available at: https://zlvortice.wordpress.com/. Accessed on 05/06/2020

The project also intends to define procedures to promote the local communities' participation in the modeling and manufacture of molds and the production of construction modules, such as the preparation of assembly handbooks and training workshops, as shown in Figure 5. The first workshop for the assembly of digital-produced molds focused on testing the proposed procedure and handbook. It revealed that the scheme is still very complex, even for experienced masons. There were suggestions to make the model more operational.

3.2 Wetlands

A constructed wetland is a manageable artificial system that reproduces the functionalities of natural wetlands in wastewater purification, with a controlled hydrological regime. The device, proposed by Luiz Fernando Orsini Yazaki, former coordinator of FCTH, must integrate with the local hydrogeomorphological system, reinforcing the environmental role naturally performed by the floodplain (Orsini Yazaki; Kahtouni, 2010).

The surface flow wetlands, which have a lower construction cost and are easier to maintain and operate, are the most appropriate for the situation. The wetlands of treatment by surface flow reproduce naturalwetlands, in which water drains shallow among dense vegetation, typical from swampy regions. They consist of an excavated area protected by levees, in which the topsoil works as a means of rooting and an appropriate structure for the inflow and outflow for the hydraulic control, as shown in Figure 6.

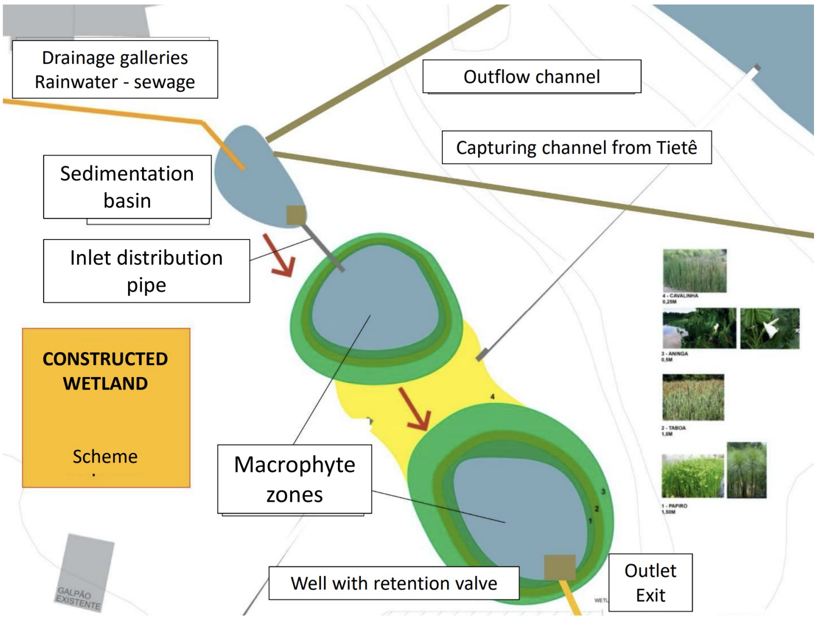

Fig. 6: Scheme of a constructed wetland. Source: Projeto ZL Vórtice, 2018.

The proposed wetland consists of a set of sequential cells. Before entering the wetland's body, the effluents previously go through a treatment consisted of sieving coarse solids and a sandbox. The first cell is covered by vegetation of native species, interspersed with deep areas for the retention of solids, hydraulic equalization, and formation of an open-water habitat. In the second cell, there is a dense swamp with emerging vegetation, important for controlling the planted species' growth. At the end of the last cell, the treated water is conducted to the Tietê River.

Wetlands located in floodplains are subjected to periodic flooding. Important restrictions are taken into account for the project’s detailing. The wetland's cells, structures, and levees must be designed to withstand periodic inundation and complete floods. The facilitation of the wetland's total flooding occurs through flow equalization tubes at half the height of the levee, which allows the river water, when arising, to enter the wetland and equalize with the remaining flow. When the floodwater completely covers the wetland, itwill already be flooded and less susceptible to disturbances.

The project foresees the conduction of a hydrological survey with field inspections for dimensioning the volume of the existing wetlands and determining the water retention capacity and the ponds' hydrological period. Geotechnical tests, which include the analysis of granulometry, humidity, infiltration capacity, and permeability, and topographic surveys will measure the ponds' submerged configuration. Measurements of hydrological data, including inflows from the channels into the ponds and the outflow to the Tietê River, will allow assessing the natural flow control held by the marsh.

A water quality monitoring program is proposed along with the definition of quality parameters and training of the residents responsible for sample collection and logistics. The water quality monitoring aims to specifically subsidize constructed wetlandprojects and geomorphological-environmental restoration. The monitoring, which is carried out with the participation of trained residents, also aims to engage the community on the conservation of the treatment system and environment in general.

3.3 Areas of geomorphological and ecological restoration

The ZL Vórtice Project poses the problem of environmental restoration in extreme conditions. The question is: how to deal with socio-environmental systems highly collapsed, and perhaps irreversibly? The geomorphological structure and hydrological system that characterized the Tietê River's functioning in São Paulo are strongly impacted and almost brought to the collapse. What is the threshold from which the river system's hydrological and ecological behavior decisively change? Could Tietê River have reached that limit?

The ponds located in the project area are hydrogeomorphological components of the remaining meander plain, undermined in different degrees by anthropic interventions. The project, coordinated by Professor Cleide Rodrigues, from LabGeo-FFLCH-USP, seeks to restore part of its remaining elements, forms, sedimentary materials, and soils, as an essential physical support to the ecological recovery of the area. The goal is to promote the conservation of the fluvial plain elements and its functionalities, identifying the remaining hydrogeomorphological configurations of the meander belt that are more likely to subsist, and conducting interventions that contribute to their protection. These actions also aim to recover some of its hydrological potential (rainwater retention, river flooding regulation) and environmental functions (water purification) (Rodrigues, 2015). Figure 7 shows the proposed restoration areas with their zoning parameters.

The implementation of a restoration area aims to test the possibility of preserving the remaining original geomorphology and hydrological dynamics, contributing to the natural wetland recovery concomitantly to the water treatment performed by constructed wetlands. The experience has the potential to contribute to the general increase of the water quality in the floodplains and to the urban environmental recovery of the whole area.

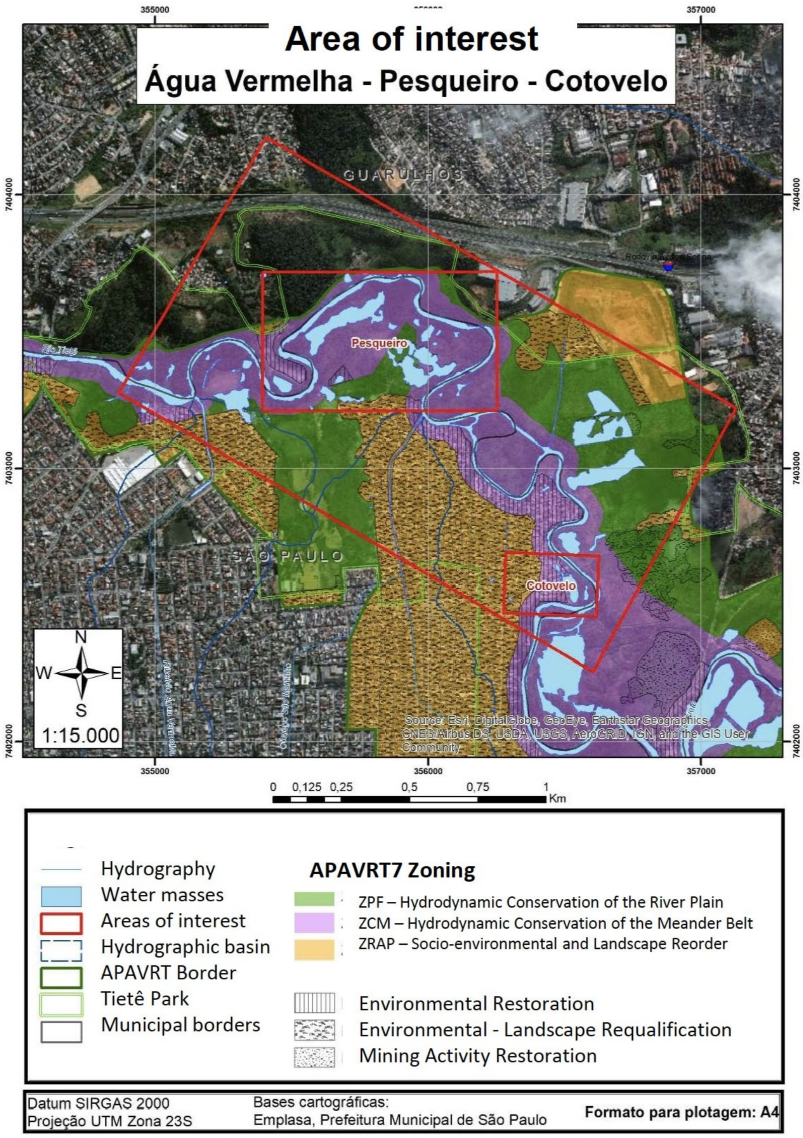

Fig. 7: Area of interest and proposed restoration areas. Source: LabGeo-FFLCH-USP, 2018.

A survey to verify the presence of geomorphological remnants is necessary for interventions that ensure the hydrological and ecological features of the river plain. The purpose is to determine the chances of reestablishing the plain's geomorphological conditions and its hydrological services, in the outlined section, essential in actions for the ecosystem's restoration.

In meandering river plains, when certain geomorphological attributes are preserved, it is possible to consider as potential environmental services: the extreme flow damping and flood mitigation; temporary water storage; improvement of downstream water quality; mitigation of downstream erosive and silting processes; and maintenance of the geodiversity heritage.

Which restoration actions are possible in critical situations? This requires verifying if the floodplain’s delimited area still has environmental attributes that allow recovery projects. Especially due to the evidence of high disturbance levels of morphological attributes in those areas. It is also necessary to define the projects that are environmentally sustainable under those conditions.

Community participation in environmental preservation projects is essential. Some local practices, such as the recovery of the Cotovelo area by its residents, who conducted the removal of car wrecks thrown into the river, must be incorporated into restoration actions of areas next to environmental collapse.

3.4 Stream and flood containment systems

In Jardim Pantanal, structural interventions for erosion containment are designed to contribute to consolidating forms of the river plain and remaining hydrological dynamics (ponds, meanders curves), preserving the streams' banks. Marina Correia, from URCA-PROURB - Postgraduate Program in Urban Design at FAU-UFRJ, with the consultancy of Mariana Marchioni, from the Politecnico di Milano, conceived specific interventions with articulated concrete blocks and gabions made from construction and demolition waste.

The articulated block system attaches the construction elements to form an erosion-resistant layer. Blocks are molded in interlocking shapes, generating an articulated typical section. The system ensures the blocks' capacity to adapt to alterations at the subgrade level, as seen in Figure 8. After installing the articulate system, the voids between blocks are filled with soil and plants.

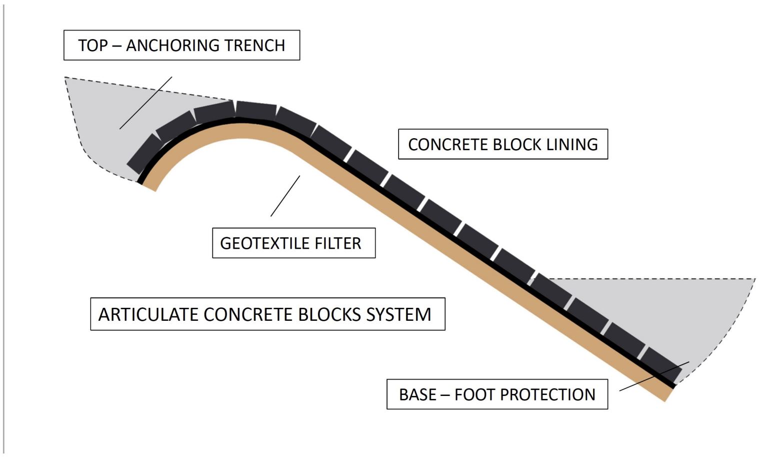

Fig. 8: Example of an articulated concrete block system. Source: URCA-PROURB - FAU-UFRJ, 2020.

The project proposes the reuse of construction waste to manufacture containment elements – blocks and gabions – for ponds' and streams' banks. It also aims to prevent, with the engagement of communities, the intensification of the flooded areas' landfilling. This process requires collecting and crushing the construction waste deposited in the area. It also demands a technical study on recycling (granulation, resistance) and fabrication of blocks and gabions with the material, a constructive device that does not obstruct the flow and adapts to the channels' geometry. The margins' stabilization is also indispensable for fixing the exits of the rainwater drainage galleries that discharge into streams.

However, it is necessary to consider the possible impacts resulting from the implementation of erosion control structures on rivers' and streams' banks. Rigid structures can have undesired effects, such as the elimination of the margins' irregularities and variations in the channels' width, and also the limitation of geomorphic changes and diversity of habitats. The use of these structural devices must, therefore, adopt bioengineering resources (bio-blankets, vegetal walls) and be punctual, applied in stretches of the margins to promote the area's geomorphological consolidation.

The conventional solutions for stabilizing stream banks, based on rigid structures, are artificial and static. Proposals are: to evaluate the adopted engineering solutions, defining those that should be implemented in floodplain areas; to evaluate the construction waste recycling technology according to its applicability in banks containing; to develop sustainable technological drainage alternatives, based on bioengineering principles, with technical measurements of their performance concerning conventional engineering rigid structures; to test the construction system and installation with the residents.

3.5 Permeable sidewalks

The project proposes the installation of permeable sidewalks, made with interlocking blocks, designed and locally manufactured by residents. The proposal aims to incorporate the use of permeable materials as an auxiliary measure in rainwater management. These sidewalks can be connected to the rainwater outflow galleries, contributing to preserving the drainage system.

There is a correlation between the urban drainage system and the degradation of rivers and streams. The redesign of drainage systems to reduce runoffs, generally channeled directly to watercourses, could contribute to the conservation and restoration of river ecosystems degraded by urbanization. The redesign consists of diverting the rainwater runoff through pipes directly into the rivers, promoting measures to increase the permeability of urban surfaces.

Along the streams, and in addition to mitigate floods effects, permeable sidewalks will have the important function of helping to prevent silting caused by waste disposal. The production of sidewalks by the residents intends to configure public spaces, areas of belonging and coexistence along the streambanks.

Fig. 9: Design workshop for permeable sidewalks in Jardim Pantanal, with Regina Silveira. Source: Projeto ZL Vórtice, 2017. Available at: https://zlvortice.wordpress.com/. Accessed on 05/06/2020

The sidewalks are produced with interlocked concrete paving blocks, which are permeable and colored. The design is being developed together with residents according to artist Regina Silveira's proposal, as shown in Figure 9, with themes and chromatic patterns chosen by the community.

The technical development of compositions and production processes, including molds, is conducted by Professor Rafael Pileggi, from LME-PoliUSP. The molds are shaped and manufactured with plastic polymers to allow manual demoulding. Each piece is filled with layers of concrete and pigment, according to the sidewalk design. Concrete dosing is an important aspect of the technology. It assures the material's expected performance and avoids the excessive use of cement. The monitoring of inputs (the calibration of the mixture recipe) aims to maintain the performance of the cement mix, ensuring adequate levels. The concrete pigmentation technique, on the other hand, must guarantee the pavement's chromatic consistency.

LME has promoted workshops for molding concrete elements with the Jardim Pantanal residents, as shown in Figure 10. LME initially intended to prepare the mixture in advance and take it to the site to avoid improper preparation of the material, which would reduce the role of the community in the technology development. Workshops showed that it is necessary to technically train residents and, at the same time, to encourage the laboratory to count on the improvement of local practices.

Fig. 10: Molding workshops for concrete elements with LME, at PoliUSP and Jardim Pantanal. Source: Projeto ZL Vórtice, 2018. Available at: https://zlvortice.wordpress.com/. Accessed on 05/06/2020

The sidewalk is designed to help mitigate the effects of flooding. Each pavement piece is divided by narrow trenches that serve to drain rainwater, which infiltrates in spaces between them until the base where they are seated. This base is designed to drain, so it should reduce puddling, allowing the radial diffusion of water into the subsoil. Figure 11 shows a reduced scale model of the pavements, with trenches and pigmentation.

Fig. 11: Manufacture of a test model on a reduced scale of the interlocking pavement. Source: Projeto ZL Vórtice, 2018. Available at: https://zlvortice.wordpress.com/. Accessed on 05/06/2020

The permeable pavements have interlocking concrete pieces, with multiple layers that store rainwater until it infiltrates underground or drains through drain pipes. Allowing water infiltration, the permeable pavement reduces the volume and peak flow of the runoff produced by precipitation events and works as a filter, retaining the sediments found on surfaces and consequently reducing the load of pollutants.

The installation of permeable pavements in a floodplain area must consider the level of the water table in the rainy season. Among the design requirements, the sidewalk designed for the floodplain must take into account the soil's infiltration capacity, which influences the infiltration devices' performance. It must also consider two other aspects. First, the soil fragility due to water action, since some soil types may lose their characteristics and undergo disruptions. Second, the destination place for the discharge of the regularized water volume, since that permeable pavements must have overflow pipes connected to the network of micro-drainage and affluence with a high rate of sediments and waste, requiring maintenance and control of the pollution source (Marchioni, Silva, 2011).

In Brazil, there are no specified and tested procedures for pavement installation in flood areas with risks of clogging and permeability loss. Proposals are: to develop and test the most suitable cement mixes for the manufacture of pavements for sidewalks on the site and by the residents; to define the technical requirements (suitable pigments, application method) for homogeneous and resistant coloring of pavements; to promote the technical training of residents to make the on-site composition of cement mixtures, the blocks manufacture, and sidewalks implementation; to develop engineering solutions for the implementation of interlocking block systems in floodplain areas.

3.6 Monitoring the river, water quality, and waste deposits

The environmental education and social mobilization program, conducted by professors Marcus Bastos and Renato Hildebrand, from Lab TIDD-PUC/SP, offers training workshops aimed at monitoring and preserving environmental conditions (Bastos, 2013). The workshops dedicated to measuring the river behavior and water quality, streams' and drainage channels' maintenance, and recycling waste.

The proposal consists of developing, with the community, devices that allow residents to visualize and predict changes in the river behavior, which are fundamental for a better adaptation of these urban settlements to the floodplain. Figure 12 shows a workshop focused on assembling and testing a river monitoring sensor in the community. The objective is to engage residents in flood monitoring and alert practices and to monitor the water quality required for the projects of wetland*s* and environmental restoration. The purpose, above all, is to create a culture of environmental preservation in communities that have conflicting relations with the river.

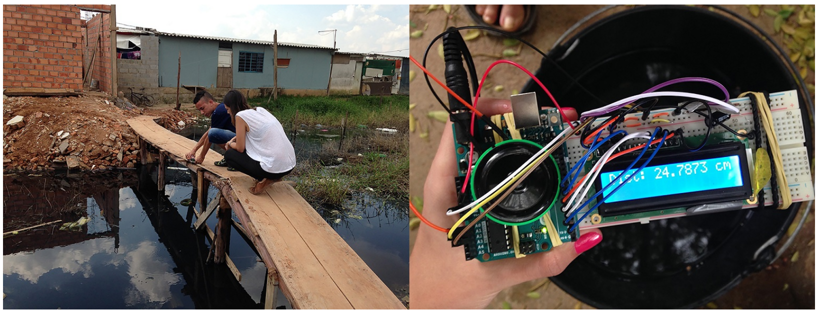

Fig. 12: Workshop with sensors to monitor the river level, in Jardim Lapenna. Source: Projeto ZL Vórtice, 2017. Available at: https://zlvortice.wordpress.com/. Accessed on 05/06/2020

The workshops should use Arduino kits to develop sensors to measure the water level in the river and the influx of pipes to alert to the possibility of flooding. An ultrasonic sensor emits pulses that measure the distance from the water to the device, monitoring water level changes. Another sensor, which measures the amount of water (liters per second) in a discharge, works to indicate the flow of springs and pipes. Sensors must be assembled and tested on the site. Afterwards, tests can be done at different points on the river or stream banks to assist the construction of the measuring device. Finally, devices are designed to fix sensors in places and monitoring is prepared to be carried out by the community.

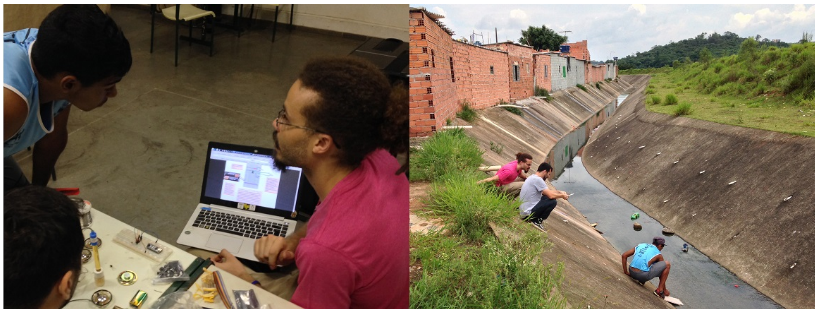

Fig. 13: Sensor workshop for measuring water quality in Jardim Romano. Source: Projeto ZL Vórtice, 2017. Available at: https://zlvortice.wordpress.com/. Accessed on 05/06/2020

There is also the development of participatory tools for measuring water quality and indicating pollution by sewage, garbage, or industrial contamination to encourage the participation of residents in the proposed water quality monitoring and environmental restoration programs. This monitoring workshop assembles open-source sensors for environmental measurement with the residents, as shown in Figure 13. The procedure consists of amplifying signals about water quality (pressure, temperature, hydrogen potential, oxidation potential, and electrical conductivity) to create a georeferenced digital cartography for the visualization of the measurements taken along the river. The sensor measures the water conductivity, indicating the presence of pollutants (metals, sewage, fertilizers). The device is calibrated and tested in a drainage channel and a flooded area.

Finally, the program promotes the location of dumps and garbage disposal points by using a digital platform. It aims to mobilize communities to monitor disorderly disposals and intensify the removal of solid waste, often thrown into streams and rivers. The *Monitoring the City* application, developed in a partnership with MIT (Center for Civic Media), is used, as shown in Figure 14. The application allows residents, with a cellphone, to collect data about the location, such as garbage dumps or flooding points. The information is gathered on an online platform, which allows the community to be involved in monitoring the situation.

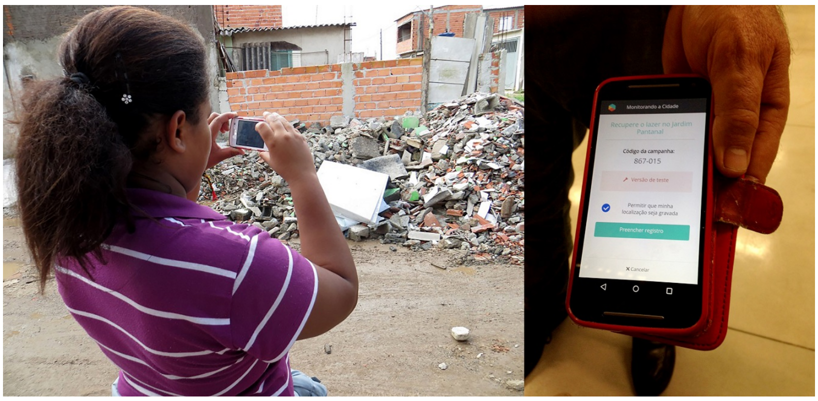

Fig. 14: Workshop to monitor waste dumps in Jardim Helena. Source: Projeto ZL Vórtice, 2017. Available at: https://zlvortice.wordpress.com/. Accessed on 05/06/2020

Public systems of urban and environmental management that are centralized and with low accessibility hinder social participation. Proposal: to research the conversion of electronic prototyping platforms for applications into simple, operational and low-cost tools for peripheral communities; to verify the efficiency in using sensors assembled and installed by residents to monitor the river system; to evaluate the sensors' efficiency in measuring water conductivity, identifying the presence of pollutants; to develop an application for monitoring garbage and locating construction waste deposits, with a digital platform. The sensor assemblage and installation workshops attracted younger residents, indicating that the rest of the community, whose participation is essential for the devices' efficiency, may have difficulties to understand and handle the technology.

A key differential of the ZL Vórtice Project is to produce all the construction components locally, in a production unit installed in the area. The articulated blocks and gabions of recycled material, the wooden molds, and the concrete modules for draining galleries, the permeable and colored interlocking blocks, and the sensors for the river and water quality monitoring will be formatted and manufactured by the residents, with guidance from the laboratories involved. The low-cost equipment, eliminating the use of heavy machinery, aims to allow the conduction of the work sustainably by the communities.

4 Final considerations

The goal of the research laboratories mobilized by ZL Vórtice is to set up an integrated system for the management and treatment of water for the urban and environmental renewal of Tiete River meander plain in the east zone of São Paulo. This implies proposing re-urbanization and environmental restoration projects specifically designed for critical situations. The project seeks a new model of urban intervention, distinct from conventional procedures based on large works that isolate the river from the city. They are new techniques to face the challenge of urbanizing areas of disordered occupation and recovering the environment.

This strategy requires methodological procedures, ways of designing and doing, adequate to conditions of great social and environmental imbalance. It is a question of method: finding technological solutions that are effective to mitigate the impacts of extreme events and developed in conjunction with local communities to ensure their implementation and maintenance. The feasibility of environmental restoration and urbanization projects with technological innovation, in critical conditions such as floodplains in metropolitan perimeters, is tested here.

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