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THE ROLE OF GREENWAY IN IMPROVING THE KLANG RIVER CORRIDOR AT BANDAR KLANG, SELANGOR

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ABSTRACT

Greenway is a green, sustainable approach applied in a linear form park and can be in various types of public spaces including waterfront, urban parks, street parks, and many more. This greenway approach offers many benefits, especially connected jogging pathways, bicycle lanes, and habitat corridors for wildlife. However, the problems with applying this method toward our river corridor are still lacking due to anthropogenic factors like plastics, paper, and debris discarded improperly. This includes the issues of dumping areas in the river corridor along the Klang River, Selangor. This study used a direct observation method such as photographic documentation, and a mapping technique to spot the dumping within the area while the measurements were taken, covering aspects such as riparian woodland, roads, sidewalks, active channels, and river channels. The results visualized through the heatmap of the dumping spot in ArcGIS Pro, highlight the optimal strategies implementation. Additionally, the river measurement was analysed using comparative analysis against the ecological standard, revealing that while the dimensions meet the guidelines, they still fall within the minimum requirements. To address this, the study suggests the formation of buffer zones to reduce the narrowing of river sections caused by ongoing urban development. In summary, this research underscores the need for strategic greenway planning and the establishment of a buffer zone to balance ecological integrity and urban growth in the Klang River corridor.

Keyword: *Greenway, River corridor, Linear Park, Klang River, River Reserve,*

INTRODUCTION

River Corridor

According to the Vermont Department of Environmental Conservation (2024), one important part of the river is the river corridor. The river corridor includes lands adjacent to and including the course of a river. River corridors are crucial because they are vital in balancing riparian needs for flora and fauna, not only humans. These include native vegetation, public accessibility, flood control, and community engagement to sustain a healthy river corridor. Therefore, ensuring the appropriate dimensions, like the width and length of the river corridor, can give more significant offers for wildlife.

The corridor's width is defined by the lateral extent of the river meanders, called the meander belt width (Figure 1). This area also supports habitat by allowing natural vegetation to grow and protecting the riverbank from erosion. This width area includes where the river naturally shifts its course over time due to erosion and deposition if nonnatural protection exists. Therefore, this part of the river is vital in maintaining a good ecosystem, such as habitat connection.

The length of the corridor is known as the continuous stretch of the river, starting from the source of spring water and extending to its confluence, such as another river, lake, or ocean. The corridor length of the river can be segmented into three parts, the upper, middle, and lower reaches, each with unique ecological and hydrological characteristics. The length of the corridor can affect ecological connectivity, enabling the movement of species, sediments, and nutrients across landscapes. A continuous and well-managed river corridor can ensure a great ecosystem by linking habitats along its path. Therefore, providing a long corridor can also offer a variety of landscapes and ecosystems, starting from forested uplands to agricultural plains and urban areas.

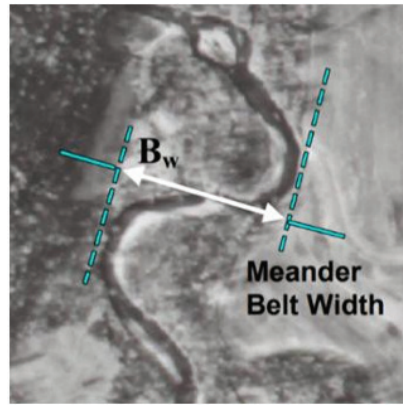

Figure 1. Example of Meander Belt Width
Source: Vermont Department of Environmental Conservation (2024)

This river corridor can create a way or trails for wildlife to ecological networks, connecting fragmented habitats and allowing wildlife movement and migration. It also supports ecological networks, especially for riparian plants such as emergent plants. In Malaysia, based on the Development Guidelines for River Reserves of Klang (2023), the river corridor is a 50-meter strip of land on both banks that is gazetted and measured from the highest river level. River corridors act as buffer zones that protect river ecosystems and adjacent lands from unforeseen incidents. The development control by the government along these 50m river corridor areas includes:

1.Continuity of Waterfront Development
2.Business (Non-Permanent Structures), Landscaping and Recreation
3.Infrastructure and Utilities
4.Urban Agriculture

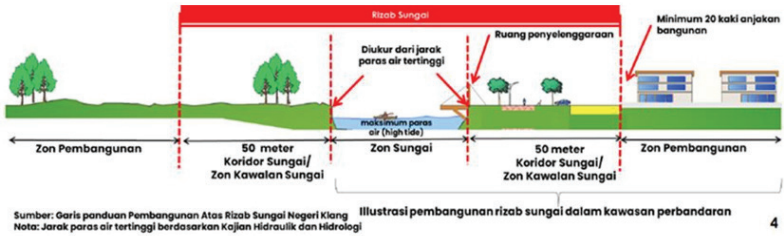

Figure 2. River Corridor Measurement Guideline

Klang River

Klang River is a river that flows through Kuala Lumpur and Selangor in Malaysia to the Malacca Strait. It is about 120 km long and drains a basin of about 1,288 square km. The Klang River has 11 main river branches that connect with Sungai Gombak, which is the starting point of Kuala Lumpur. Since this river flows through the densely populated Klang Valley and has over four million people along it, it has been polluted through time. Rapid development has narrowed part of the river to resemble a large ditch, which often results in flash floods in Kuala Lumpur, especially when it rains heavily.

The history of Klang dates to earlier times than Melaka, and this country was part of the colonies of the Kingdom of Sri Vijaya and Majapahit. This came up with the name Klang, which originated from the Mon-Khymer language, which is "Klong." Klang can be interpreted as a warehouse, as stated by C.O. Blagden, which made Klang an important port with many warehouses. Other than that, Charles A. Fisher which is a politician and jurist from New Brunswick, Canada, gives an opinion that "Klang" means "canal" or waterway. This opinion is agreed upon as Klang has many waterways, namely the tributaries Sg. Klang, Sg. Bertek, Sg. Pinang, Sg. Meanwhile, Sg. Agas, Sg. Kandis, Sg. Binjai, Sg. Kapar, Sg. Teak, Sg. Aur, Sg. Rasau and Sg. Break up. Therefore, the name of this river continues until this day.

Transportation and connection are some of the reasons why the Klang River still functions to this day. Before the existence of modern roads, this river served as the main transport route. Then, it became a trade route for goods such as tin, agricultural products, and daily necessities. Other than that, residents and traders also use the river to travel from one area to another, as well as commute or use the shuttle during their business days. Next, this river also functioned as a source of water for the human settlement along it; river water is used for cooking, washing, and crop irrigation by the local community, and even to this day, the water is filtered through the treatment process including filtration, coagulation, flocculation, sedimentation, filtration, and the addition of chlorine to make the water fit for drinking.

Problem Statement

For a long time, the Klang River has been used as one of our primary means of transportation and business, especially in local community settlements. However, the rapid development driven by the high demand for economic, cultural, and social activities along the river has significantly reduced the value of the Klang River corridor. This has led to the nominated Klang River as one of the 50 most polluted rivers in the world (Vocket,2019) in 2019, giving the bad image of this city to the country. Over time, if these issues have not been solved correctly, we will face a lousy sequence of pollution, such as high sedimentation waste on water that kills native fish, rubbish floating and flowing entirely into the river, loss of riparian native plants, and more. Even right now, the latest situation of the river corridor in Klang River is already becoming a dumping area full of rubbish from the river litter trap called a log boom, and even trash that local people throw also contributes to the dumping area (Figure 3.0). The rivers that should be our daily water source for routines like washing, drinking, cleaning, and even for environmental use, such as fish, amphibians, and birds, are no longer valued as they once were because of human activity.

Figure 3. Dump Area Along the River Corridor At Klang River.

River corridors are also important parts of rivers because they act as natural elements that prevent many issues, including flood control, wildlife habitats, and species movement. Therefore, the greenway approach has played a vital role and is an innovative solution for maintaining ecosystem balance and providing recreational opportunities for a healthy environment.

The greenway approach is an eco-friendly approach that can achieve many sustainable design goals (SDG). Greenways are known as a linear form park that creates fragmentation issues by providing a connected space for a balanced ecosystem. Through this approach, this study aims to achieve three key objectives:

1.To understand the role of greenways in highly developed areas along river corridors.
2.To implement greenway planning strategies to protect river corridors from becoming dumping site areas.

LITERATURE REVIEW

Greenway

A greenway is a linear corridor that requires a point and origin and has significant ecological and socio-cultural value toward the environment along it. They can be adapted to any open space, like parkways and river corridors. Greenway also had many categories and types that we can adapt to various conditions depending on their landscape setting. It refers to the type of landscape in which the greenway is situated and includes the following classification codes. For example, adaptive reuse involves rebuilding spaces initially designed for other purposes, such as highways or railways, and turning them into greenways. Similarly, greenways can be categorized based on their settings: waterfront greenways run alongside water bodies, complete streets integrate greenways into multimodal transportation networks, new-build greenways are incorporated into newly developed or conserved areas, and multiple-setting greenways span two or more of these categories (Horte & Eisenman, 2020).

Greenways also provide strategic advantages for sustainable landscape planning by offering three interconnected benefits: ecological restoration, public space vitality, and cultural sustainability (Li & Mei, 2024). The benefits also include environmental benefits that provide habitat along the purpose area, help improve air and water quality, especially on river corridors or urban areas, create a relaxing space for humans to escape from busy city areas and provide a resting area for wildlife. In addition, this approach can be applied in various ways, including in waterfront, university, and urban areas.

Waterfront Greenway

The waterfront greenway is defined as a linear and public space

planned to be built as part of the waterfront Seattle program area and located facing the sea or river. This area is focused more on ecological restoration but also comprehensively offers the versatility of cultural sustainability and public spaces. The greenway waterfront also highlights the key points of the primary trail and is linked with many activities, such as walking, hiking, nature observation and picnicking (Sun et al., 2024). Other than that, waterfront elements can also be emphasised as the flood mitigation solution or stormwater management function while also locating the sustainable function as a recreational space that connects humans with nature, such as linking several communities.

Urban Greenway

Urban greenways are focused more on long-term planning. It generally emphasizes the general thinking about the current state and future public connections between development and nature. The urban greenway has also pointed the planning on a micro-scale, including connecting the fragmented landmarks, neighbourhoods, and transportation like roads and pedestrian lanes while also serving the ecological ways (Quayle, 1995). On the other hand, urban greenways also focus on walkability factors and the physical built environment of streets. The elements that are selected include scales of urban blocks, plots, and green spaces. These combined items can impact the importance of designing spaces at a human scale, focusing on how urban environments connect to people's physical experiences (Gabr et al., 2019).

CONCLUSION

In conclusion, it proves that these greenway approaches are highly adaptable and can be applied or used in any environmental situation. They are versatile in terms of solution and design because they help to achieve sustainable development goals and create flexibility in design if the form is linear. It can be integrated into any place, starting from urban areas, rural areas, waterfront areas, river corridors, educational areas, and many more. It is also beneficial for both humans and nature, highlighting health and well-being, preserving a balanced ecosystem, and restoring the essential habitat for wildlife.

RESEARCH METHODOLOGY

Site Study

In the local setting, the Klang River is one of the local water bodies. It starts from the capital city of Malaysia, Kuala Lumpur, and passes through several towns before discharging into the sea at Port Klang. Indeed, the river is wholly located in Klang District, Selangor, including the core areas like Alam Impian, Bandar Klang, Kampung Delek and Pelabuhan Klang (Figure 4.0). In Selangor, the river has only covered an area of approximately 573.80 sq. km. Nevertheless, the study area covers the Klang River corridor near Kampung Sungai Kandis, 606m long and 147m wide. The length and width of the river are determined based on how big the dumping spot area is and the accessibility of the data collection.

Due to the vast area of the river corridor, its study is limited to a part of the stretch south of the study region. This limitation was mainly selected because of its low availability during data collection and some safety issues. The lack of proper road infrastructure to access and safety concerns from tall and wild bushes to certain parts of the river corridor posed challenges to obtaining a comprehensive understanding of the site's conditions. Consequently, the selected study area was chosen because it can help provide a focused but representative framework for analysing the corridor's environmental and spatial characteristics.

Figure 4. Klang River Passes from KL Through Several Towns Before Discharging into The Sea at Port Klang

Figure 5. Site Study

Data Collection

The direct observation method was utilized to collect data directly from the field. As referred to in Noraini Baharin's 2019 research, this method outlines an effective approach for conducting direct observations. This observation also uses a photograph to snap the site's current condition using an iPhone Pro with a 12 MP triple-camera system,12MP front camera, night mode,4k HDR video and a LiDAR.The technique involves mapping all the fragmentary elements suitable for the site requirements. In this research, specific tasks included identifying and documenting all dumping spots and measuring the width of the river corridor.

For dumping spot mapping, these tasks were carried out following the methodology outlined in the study by Li & and Mei (2024). This dumping mapping required base maps that played a crucial role in the process, and this approach provided a comprehensive spatial understanding of the site's issues. Additionally, mapping tools such as Google Maps and Google Earth (2024 version) were utilized to identify observation points, integrate data, and perform measurements effectively. Beyond these tools, ArcGIS Pro (2024 version) was employed, as highlighted in Amir et al.'s 2023 study. ArcGIS Pro proved to be an innovative tool for supporting fieldwork, offering a robust solution for integrating data collection with analysis.

Additionally, measurements of the river corridor were taken to assess

the extent of dumping's influence and to evaluate the greenway approach or to determine the available area for designing the greenway, including pathways, vegetation buffers, recreational areas, and other amenities.

Dumping Spot

The dumping spots are categorized as fragmentary items in this river corridor (Figure 6.0). The rubbish dumping includes plastic bottles, plastic bags, cans, Styrofoam boxes, leaf stalks, wood plates, food waste, and more. They are located on the map to determine their impact on the river corridor and help assess the pollution level in the river corridor and adjacent greenway areas. This location data can also determine the visual analysis of the river corridor and suggest the best remediation, such as waste removal, soil cleaning, and vegetation replanting.

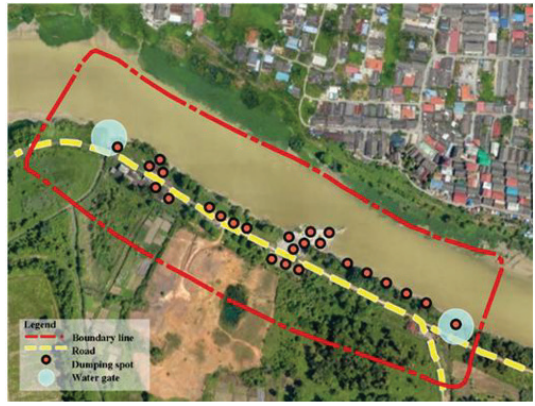

Figure 7. Location of Dumping Spots in Site Study

River Width Corridor Measurement

The full width of the river corridor, including the river area, is 90.5m. The zoning of the river corridor is divided into several parts for measurement, starting from riparian woodland, road, sidewalk, active channel, and river or wetland channel (Figure 7.0). This measurement and section river is important to create a detailed and precise location mapping. It helps to visualize and understand the arrangement of the surroundings around the river corridor. Furthermore, it will also help to increase the availability of space for new vegetation, wildlife restoration, and flood capacity management.

Riparian Woodland

Based on the data collection, this area is about 3 meters wide, and it is primarily overgrown with wild bushes, which block the view of the site context. Numerous creeping plants can also be seen hanging and sprawling over the electric poles and wire, potentially disrupting the streetlamp at night.

Road

The road at this site is measured as 3m wide and functions as a one-way route only. The condition is poor and only consists of the use of gravel, so it is not suitable for ordinary vehicles to use or enter this place. Various sizes of poles and muddy areas create significant challenges for accessibility. This condition compromises the safety of users attempting to access the river area.

Sidewalk

Same patterns as the previous data, the sidewalk is also not suitable for people to use; even with a suitable width of 2.5m, this area is still lacking in many ways.

Active Channel

The 4-meter-wide active channel area is predominantly filled with dead trees, sharp branches, and trash the river carries. Throughout the river, only a few trees and patches of wild ground cover are visible within the site.

River/ Wetland Channel

Many species of floating rubbish are carried on the river channel. Numerous invasive birds can be seen perching on the trash traps because they use the rubbish as a food source. These birds are commonly known as African Egrets, typical migratory birds that have settled in urban areas due to the abundance of food waste found here.

Figure 8. View of the Egrets that Perching on the Trash Trap

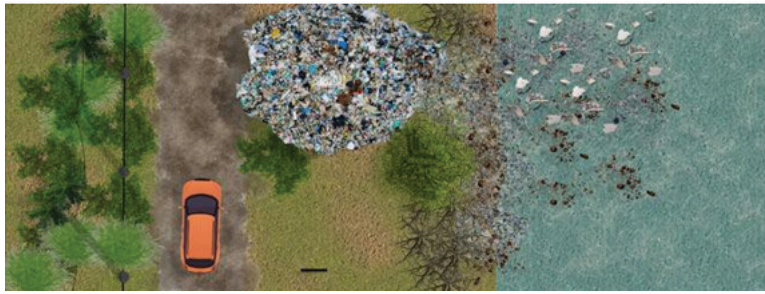

Figure 9. Plan View of the River width Measurement

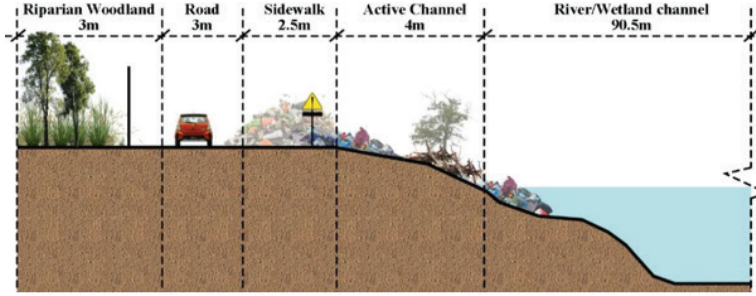

Figure 10. Section Width Measurements of River Corridor of Klang River

ANALYSIS AND DISCUSSION

This data analysis uses ArcGIS Pro, a software developed by California's Environmental Systems Research Institute (ESRI). GIS stands for

geographical information systems and functions as a user decision tool. This software can digitize all the data input into a mapping concept (Michael Kennedy, 2006). It can be used in multiple industries, such as urban planning, environmental science, transportation, resource management, and landscape architecture. Even in daily life, ArcGIS Pro has been used behind our daily apps like Google Maps, Waze, and Google Earth. In this research, the analysis is based on two phases to run the analysis data: first point to input the dumping spot, then the heatmap analysis.

Heatmap Analysis for Dumping Spot Mapping

Heatmap analysis (Figure 8.0) is one of the commands that can be done through ArcGIS Pro. This analysis requires point data input in the first step, filling in the maps before running the data, and then finally, you will get the result. Once the analysis is performed, the ArcGIS will generate a raster layer where different color gradients represent the density of each point. Raster is a type of spatial data representation that consists of a matrix of cells arranged in rows and columns. So, the warmer colors (e.g., red, orange) represent areas with a higher concentration of points, while cooler colors (e.g., blue, green) indicate lower concentrations.

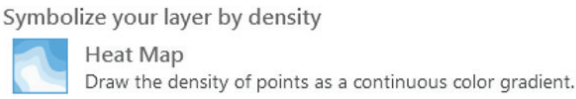

Figure 11. The Symbol View of the Heat Map on ArcGIS Pro

In this research, color coding represents the various degrees of dumping activity along the river, helping to highlight areas that require immediate attention for greenway planning. The color scheme ranges from yellow and red to purple to blue, each indicating the density of dumping activity in specific areas. From yellowish orange, it highlights the highest density of dumping activity and the most significant and stormy conditions. Next, red to purple indicates a high, medium, or middle density of dumping, still high but with a lower level of urgency than those marked in yellow. Finally, blue represents the lowest part of this gradient color; it shows the most minimal impact from water activity. This type of visual representative provides a clear identifying area, making it easy to analyze the dumping spot rather than only using a point. Each of the radius points is 25m.

Figure 9. Heat Map Representing the Dumping Spot

Dumping Spot Result

The dumping issue along the Klang River corridor has arisen from the pile of trash traps in the river, and waste disposal by local people near the neighbourhood has created persistent problems in that area. The analysis shows that many crucial spots need immediate action. The best application that this study can apply to cater to this problem after site investigation and remediation is by using a buffer zone application through the greenway. This buffer will prevent many people from easily accessing the river corridor to throw garbage and trash traps pile up.

Greenway Optimize Strategies

Based on this, greenway optimization strategy applications are the best solutions to prevent this dumping issue, and the application of greenways is also the best to sustain the positive impact for the long-term future. The first strategy that can be done is by connecting people by using space. This will be aimed by applying continuous pedestrian trails and bicycle lanes along the river corridor with good access to the river corridor, accessibility like road and entrance also will attract many public people to come (Li & Mei, 2024). Second, Create a public space for recreation. Many multipurpose activities including physical interaction can increase the function of space such as picnic areas, riverside walks, basketball courts, and plazas. Third, construct an innovative green planting. These approaches include swale for stormwater management, riparian planting for habitat corridors, and smart irrigation. These are not only capable of function but also consider the aesthetic value of the river.

Although greenway systems have traditionally been valued for their ecological and scenic roles in previous research and practice, they hold greater potential. The case study of Qinhuangdao, China on developing the urban waterfront greenway led to the solution of a dumping area and providing natural habitats along the river while creating new opportunities for recreation and environmental education. (Andy Safa, 2016). Such results suggest that a similar greenway approach could effectively address the issues along the Klang River Corridor. Considering all the items above including ecological function, life balance, and aesthetic measures, it shows that the application of greenways based on the study has proven that greenways can be the best solution for Klang River corridor dumping areas.

River Width Corridor Comparative Analysis

Based on the data collection of the river width measurement, it shows that every section of the river starting from riparian, road, sidewalk, and active channel to river or wetland channels does not follow the standard guidelines or regulations. Through this comparative analysis of the guideline or ecological benchmark, this research will be able to assess the adequacy of these zones in providing critical ecological and functional services, such as preventing erosion, filtering pollutants, and supporting biodiversity. This comparative analysis is based on the study of Lestari & Nurpratiwi, 2022. This method of analysis illustrates the visual by preparing the maps and demonstrating the practical implementation by comparing or differentiating the existing river width to the recommended guidelines to inform the management decision.

Table 1. Comparison of Existing width with the Regulatory or Ecological Standard

No	Section	Measured Width (m)	Recommended Width (m)	Compliance (Yes/No)
1	Riparian woodland	30	At least 15m based on Michigan Department of Environmental Quality Guideline	Yes
2	Road	3	Single Carriageway Roads: Typically have lane widths ranging from 3.0 to 3.5 meters per lane (based on JKR guidelines)	Yes
3	Sidewalk	2.5	Minimum of 2.0, Standard 3.0–5.0 based on Urban Stormwater Management Manual for Malaysia (MSMA 2nd Edition) and international greenway guidelines.	Yes

4	Active Channel	4.5	5 meters to 15 meters: For small rivers or streams in urban areas	No
5	River Channel	90.5	Depending on the river's width itself	Yes

Riparian Width Analysis

Together, the present Table 1 findings confirm that four out of the five section river width measurements are follow the standard guideline that suitable based on the urban areas. Even though most of it followed the guidelines, still it can be categorized as narrow due to the existing measurement that mostly falls within the minimum category, for example, it is located at the lower end of the recommended range, this could indicate that while the river channel is technically compliant and may not be providing optimal functionality. This indicates that the uncontrol development of the river corridor area had tightened the measurement standard that created an unbalanced ecological function. As a result, this has led to the degradation of the river corridor, creating an unhealthy or depressing environment life for both humans and wildlife River Width Corridor Measurement Result

Based on the analysis data of the river measurement, the best recommendation is to prevent the extension of further development and maintain the river's dimensions towards the river corridor in Klang by applying the formation of a buffer throughout the greenway approach. This type of formation buffer will create a limitation in the development along the river corridor including agriculture, residential and commercial areas.

Formation of Buffer

A formation buffer can help to protect the river corridor by establishing a physical boundary that limits urban development close to the river's edge. This prevents the construction of buildings, roads, and other infrastructure that might encroach on the river corridor. Furthermore, a strict policy by the local authority also helped to prevent further narrowing of the river through reclamation or construction of structures that could reduce the active channel width. Without such restrictions, the natural river system could be compromised by development projects. The buffer area that includes a variety shape of plants and types also helps create a mini habitat for aquatic living like frogs, then balances the ecological needs for the river's riparian

area. This area can also provide a natural setting view of the river. Studies indicate that areas with strong buffer zones have a significantly lower rate of urban encroachment compared to those without such protections. After applying the buffer within the greenway, the issues of tight dimensions and encroaching development around the river corridor are gradually resolved. The buffer not only improves the river's ecological health but also raises public awareness and appreciation for these spaces. As people value and engage with the greenway, they help preserve it over time. Tight dimensions and urban development often reduce the space for the river to function naturally. By applying the greenway buffer, more space is preserved for the river, ensuring it isn't compromised by further development. This approach creates a sustainable balance, protecting the river corridor while allowing urban growth to coexist with environmental conservation.

Figure 10. The Formation and Arrangement of the Area that can be Applied Buffer Zone

CONCLUSION

In summary, the river corridor is a critical environment that requires our care and protection. Without proper management, it can lead to a series of negative consequences. The application of a greenway approach can effectively connect key elements such as space, people, and habitat characteristics, while also addressing fragmented issues like dumping areas and resolving several small problems, including foul odors and the spread of invasive species. Furthermore, providing recreational spaces that link people with green areas for wildlife, can enhance both the environmental and social value of the area, contributing to a more sustainable future. The greenway model proves its adaptability to various conditions if it meets

the essential requirement of ensuring all elements are interconnected. One of them is the linkage as the key characteristic of a successful greenway. Through these outcomes, this paper has demonstrated that river corridor areas can become a successful path towards connecting landscapes with public people.

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