Journal of Information Technology and Applications Research
Volume 1 Nomor 1 May 2025
e-ISSN: 3089-8013; p-ISSN:3089-8021, Page 80-95
DOI: https://doi.org/10.63956/jitar.v1i1.18
Available online at: https://jitar.org/index.php/jitar/article/view/18

Sustainable Riparian Zone Management Based on Information Technology for the Pesanggrahan River, Depok

Veronika Widi Prabawasari[1], Agus Suparman[2], Wahyu Prakoso[3], X. Furuhito[4], Budi Santosa[5]
[1,4] Master of Architecture, Gunadarma University,
[2,3] Department of Architecture, Faculty of Civil Engineering and Planning, Gunadarma University
[5] Civil Engineering Department, Faculty of Civil Engineering and Planning, Gunadarma University
(Correspondence Email : veronika@staff.gunadarma.ac.id)

Abstract
Riparian zone have an important role in maintaining the health and environment of rivers and supporting sustainable development. The management of riparian zone in the suburbs of Depok, faces various challenges including erosion, pollutants/pollution, water flow regulation and flooding as well as biodiversity issues due to lack of community awareness. This aims to analyze the potential use of information technology (IT) in improving the effectiveness of riparian management along Pesanggrahan River, Depok. The methodologies used are literature study, regulatory review, case studies (SISDA Perum Jasa Tirta I and SIDAS Palembang City), and analysis of the potential of IT implementation. The analysis results show that IT, particularly Geographic Information Systems (GIS), Remote Sensing, and Internet of Things (IoT), offer innovative solutions to address these challenges. The study proposes integrated IT strategies, including IoT-based monitoring, enhanced mapping and spatial analysis, development of an integrated information platform, institutional strengthening, and continuous evaluation, to improve management efficiency, transparency, and public participation for the Pesanggrahan River. Its novelty lies in synthesizing regulatory, technological, and case study analyses to propose integrated IT-driven solutions for sustainable riparian zone management in a specific Indonesian urban river setting, as well as realize the sustainability of watershed functions for communities and ecosystems.
Keywords: Riparian zone, Sustainable Development, Information Technology, Pesangrahan River

INTRODUCTION

Rivers, as the lifeblood of ecosystems, play a crucial role in maintaining ecological balance, providing water resources, and supporting various human activities. Riparian zones, serving as ecological buffer zones between riverine and terrestrial ecosystems, are vital. Naturally dominated by diverse vegetation, from grasses to shrubs and trees along riverbanks, these zones often encompass wetlands (Smith, 2018). From a regulatory perspective, riparian zones are defined as critical buffers aimed at preventing reciprocal interference between the natural functions of rivers and human activities in their vicinity (Jones, 2020).

The ecological functions of riparian zones are essential and multidimensional. These areas act as natural water quality purifiers by filtering particles and absorbing pollutants, such as nitrates often originating from agricultural activities, through natural

Received: March 29, 2025; Accepted: April 22, 2025; Published: May 15, 2025
*Corresponding author : veronika@staff.gunadarma.ac.id

processes mediated by soil microbes (Brown, 2019). Furthermore, riparian zones provide critical habitats and corridors for biodiversity, facilitating the movement of wildlife like amphibians and insects, and contribute significantly to atmospheric carbon sequestration (Green, 2021). In hydrological contexts, healthy riparian zones are crucial for stabilizing riverbanks, reducing soil runoff and erosion, and acting as flood conduits that aid groundwater recharge (White, 2021).

While Indonesia is blessed with the existence of 5,590 main rivers managed by the state and has a comprehensive regulatory framework for riparian protection (Government Regulation No. 38 Year 2011), the real conditions on the ground often show significant challenges (Statistics Indonesia, 2023). Many riverbanks, especially in urban areas, are degraded or even lost due to public ignorance of their vital functions and the pressure of other land uses, such as illegal settlement development (Ministry of Public Works and Housing, 2022). One of the main obstacles in structuring settlements in this area is the low public awareness of the importance of riverbanks (Widodo, 2021).

The existence of a strong regulatory framework, yet evidence of widespread degradation and non-compliance on the ground, suggests a deep mismatch between policy intentions and implementation realities. This indicates that the problem is not simply the absence of regulations, but a complex one involving socio-economic pressures (e.g., land scarcity, population growth, lack of public awareness) as well as governance challenges (e.g., weak enforcement, lack of coordination) (Black, 2020). This gap highlights the urgent need for innovative tools and approaches capable of bridging the gap between policy objectives and practice on the ground. Developments in information technology (IT), on the other hand, offer innovative solutions to overcome these challenges and improve the effectiveness of riparian management (Jones, 2020).

The purpose of this study is to comprehensively analyze the role and potential of information technology (IT) in supporting sustainable riparian management. This research will examine how information technologies, such as Geographic Information Systems (GIS), Remote Sensing, and the Internet of Things (IoT), can be utilized to improve the efficiency, effectiveness, and sustainability of riparian management. The scope of this study includes: (1) A review of national and regional riparian regulations; (2) An analysis of the application of information technology, particularly GIS, remote sensing, and IoT, in water resources and riparian management; (3) Case studies of the utilization of information systems in water resources management, with a focus on case studies in Indonesia; (4) An analysis of the potential application of information technology for riparian management in the Pesanggrahan River, Depok, including challenges and recommendations. Through this comprehensive study, this research is expected to contribute to the development of information technology-based river basin management strategies, as well as provide practical recommendations for local governments and other stakeholders in an effort to realize sustainable river management.

RESEARCH METHOD

This research uses a literature study approach and comparative analysis to examine the utilization of information technology in riverbank management. This research methodology consists of several main stages:

1. Regulatory Review: This stage involved a search and analysis of the laws and regulations related to riparian management in Indonesia. The main data sources were government regulations, local regulations, and relevant policy documents. The analysis was conducted to identify the legal framework governing riparian management, including definitions, limitations, obligations, and sanctions.
2. Case Study Review: This stage focused on case studies of information system utilization in riparian management. The two main case studies analyzed were:
   a. Water Resources Information System (SISDA) of Perum Jasa Tirta I: An analysis of the implementation of SISDA, including the technology used (e.g., GIS, database), the functions and features available, and the impact on the effectiveness of water resources management.
   b. Palembang City Watershed Information System (SIDAS): Analysis of the implementation of SIDAS, including the technology used, functions and features available, as well as the impact on river and riparian management in Palembang City.

   Primary data sources for these case studies include scientific publications, research reports, technical documents from relevant agencies, and interviews with experts and practitioners in water resource management (Brown, 2019; Green, 2021)
3. Analysis of Information Technology Innovation for Pesanggrahan River: Based on the results of the regulatory review and case studies, an analysis was conducted to identify potential applications of information technology that are relevant for riparian management in Pesanggrahan River, Depok. This analysis includes:
   a. Identifying data and information needs for riparian zone management in the Pesanggrahan River
   b. Evaluating potential IT applications (e.g., GIS, remote sensing, IoT)
   c. Analyzing the challenges and opportunities in implementing IT in the Pesanggrahan River.
   d. Formulating recommendations for IT utilization strategies for riparian zone management in the Pesanggrahan River.

The analytical approach used in this research is descriptive and comparative analysis. Descriptive analysis is used to explain the characteristics of regulations, case studies, and potential IT applications. Comparative analysis is used to compare the effectiveness of different management approaches and identify best practices.

RESULTS AND DISCUSSION

Review of Regulatory Framework for Riparian Zone Management in Indonesia

Riparian management in Indonesia is based on a complex and multi-layered regulatory framework, which aims to maintain the ecological functions of rivers, prevent environmental damage, and support sustainable development. This regulatory framework

involves various laws and regulations that govern different aspects of water resources and environmental management.

Definition and Criteria of Riverbanks

Riparian zones are defined as protection zones along riverbanks. Their width is determined by river characteristics (width, shape, soil type), river function (raw water source, irrigation, transportation), and area typology (urban, rural, protected areas). Government Regulation No. 38 of 2011 stipulates varying widths: minimum 3 meters from outer embankments, minimum 10 meters from non-embanked riverbanks, and potentially more for large rivers based on technical studies.

According to the Minister of Public Works and Public Housing's Regulation Number 28/PRT/M/2015 of 2015, the provisions regarding riparian zone width vary :

Table.1. Riparian zone Regulations

River	Area	River Boundary
Not embanked	In urban areas	River depth ≤ 3m: ≥10m from river trough
		River depth >3-20m: ≥15 m from the riverbed
		River depth >20m: ≥30m from riverbed
	Outside the city	Riparian Zone (DAS) ≤500km²: ≥500 m from riverbed
		Riparian Zone (DAS) ≤500km²: ≥100 m from the riverbed
Embanked	In urban areas	≥3m from the outer edge of the embankment toe
	Outside the city	≥5m from the outer edge of the embankment toe

Source : Regulation of the Minister of Public Works and Public Housing No. 28 of 2015

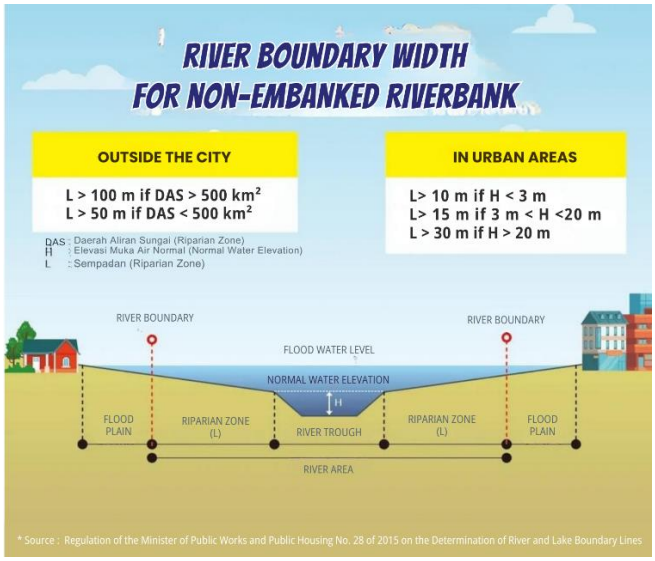

Figure. 1. River Boundary Width for Non Embanked Riverbank

Key Legal Foundations

The primary legal pillars include Law No. 7 of 2004 concerning Water Resources, which broadly regulates water resource management and provides the basis for establishing riparian zones. Government Regulation No. 38 of 2011 specifically addresses river management, defining riparian zones, regulating land use, pollution control, and

mandating the establishment of riparian zone boundaries. Minister of Public Works and Housing Regulation No. 28 of 2015 offers detailed technical guidelines for setting river and lake setback lines, specifying setback distances based on river characteristics and urging regularization of existing structures. Additionally, the overarching Law No. 32 of 2009 on Environmental Protection and Management supports IT utilization for environmental monitoring and Law No. 17 of 2019 on Water Resources emphasizes integrated management and community participation

Table.2. Key Regulations Related to Riparian Zone Management in Indonesia

Name of Regulation	Number and Year	Issuing Institution	Key Provisions Related to River Boundaries	Key Implications
Government Regulation on Rivers	PP No. 38 of 2011	Central Government	Defines river space (riverbed & boundaries), regulates river management (conservation, development, control of water damage), licensing, information systems, and community empowerment. Requires the determination of boundary lines by the Minister/Governor/ Regent/ Mayor within 5 years.	main legal basis; emphasizes sustainability and the role of information systems.
Regulation of the Minister of PUPR on the Determination of River Boundary Lines and Lake Boundary Lines	PUPR Ministerial Regulation No. 28 of 2015	PUPR Ministry	Defines the boundary line as a protection boundary. Determines the criteria for the boundary distance based on the location, depth, and existence of the embankment. Existing buildings have status quo status and must be gradually cleared. Utilization is very limited. Requires the determination of the boundary line within 3 years.	Detailed technical regulations; demonstrates a commitment to clearing but acknowledges the challenges of implementation.
Law on Environmental Protection and Management	Law No. 32 of 2009	Central Government	Legal basis for Environmental Protection and Management in general, includes planning, utilization, control, maintenance, supervision, and law enforcement. Guarantees the right to a healthy environment and environmental information. Regulates the importance of "Information Systems".	Broad legal framework for environmental aspects; supports the use of IT for environmental management.
Law on Water Resources	Law No. 17 of 2019	Central Government	Regulates the duties and authorities of provincial governments in water resources management, including policies, river basin management patterns, and supervision. Emphasizes water resource management with community participation.	Supports decentralization of water management; emphasizes participation and spatial planning.

Despite a strong and detailed legal framework, problems of encroachment and riparian zone degradation continue to occur. The *status quo* policy for existing buildings, although pragmatic, can be an indicator of difficulties in full law enforcement. This shows that the main challenge is no longer the absence of regulations, but rather the effectiveness of implementation and the adaptation of these regulations to the dynamics of land use and community behavior. Therefore, stronger mechanisms are needed to monitor compliance, identify violations, and facilitate law enforcement. The need for "riparian zone establishment studies" mandated by regulations explicitly underscores the importance of a data-driven approach. In this context, information technology can act as a bridge connecting regulatory intent with on-the-ground reality, providing the necessary tools for data collection, spatial analysis, and real-time monitoring to support more effective policy enforcement

Application of Information Technology in Riparian Zone Management

The management of riparian zones, critical ecological buffer areas, is increasingly benefiting from the integration of advanced Information Technology (IT). Technologies such as Geographic Information Systems (GIS), Remote Sensing, and the Internet of Things (IoT) offer powerful tools to enhance efficiency, accuracy, and sustainability in monitoring, analyzing, and managing these vital riverine ecosystems.

Geographic Information System (GIS)

GIS serves as a foundational technology for spatial data management and analysis in riparian zone management. Its capabilities are crucial for understanding the spatial dimensions of river systems and their surrounding environments.

- **Mapping and Inventorying:** GIS enables the creation of detailed digital maps of riparian zones, delineating precise boundaries, identifying land use patterns, mapping vegetation types, and locating infrastructure or potential hazards. This is achieved by integrating various spatial datasets, including satellite imagery, aerial photographs, and field survey data (Campbell, 2011). Effective mapping is essential for regulatory compliance and identifying areas requiring intervention.
- **Spatial Analysis:** GIS provides analytical tools to assess spatial relationships and patterns. In riparian management, this includes identifying areas prone to erosion based on slope and soil type, mapping pollution hotspots by overlaying land use data with water quality sampling points, and delineating flood-prone zones using elevation models (Longley et al., 2015). These analyses are vital for risk assessment and targeted management interventions.
- **Change Detection and Monitoring:** By comparing spatial data from different time periods, GIS facilitates the monitoring of changes in land use, encroachment into riparian areas, and shifts in vegetation cover. This capability is critical for tracking the effectiveness of management strategies and identifying emerging threats (Heywood et al., 2011).
- **Decision Support:** GIS platforms can integrate diverse data layers to support informed decision-making. They allow for scenario modeling, impact assessment, and the visualization of potential outcomes for different management interventions, thereby enhancing the planning and implementation phases of riparian management (Worboys & Duckham, 2004).

Remote Sensing

Remote sensing complements GIS by providing broad-area data acquisition over time, often in challenging terrain or for large river basins.

- **Vegetation Assessment:** Remote sensing data, particularly from multispectral sensors, allows for the mapping and assessment of vegetation health, type, and density within riparian corridors. This information is critical for evaluating the ecological integrity of the zone and identifying areas susceptible to erosion or degradation (Jensen, 2015).
- **Water Quality Monitoring:** Specific spectral bands can be used to infer water quality parameters such as turbidity, chlorophyll concentration, and temperature, offering a synoptic view of river health over large areas (Chuvieco, 2016). While not a replacement for direct sampling, it provides valuable broad-scale monitoring.
- **Land Use and Land Cover (LULC) Change Detection:** High-resolution satellite imagery is invaluable for tracking changes in LULC within riparian zones, such as the expansion of urban settlements, agricultural activities, or deforestation. This data directly informs compliance monitoring and the need for enforcement actions (Lillesand et al., 2015).
- **Flood and Disaster Mapping:** Remote sensing, especially radar and optical satellite data, is highly effective for rapid mapping of flood extents and identifying areas affected by river-related disasters, crucial for emergency response and damage assessment (Smith, 2017).

Internet of Things (IoT)

IoT represents a paradigm shift towards real-time, ground-level data collection and distributed sensing. Its application in riparian management offers unprecedented insights into dynamic environmental conditions.

- **Real-time Water Quality and Quantity Monitoring:** Deploying networks of IoT sensors enables continuous monitoring of critical water parameters (pH, dissolved oxygen, temperature, pollutants) and water levels. This real-time data is essential for early warning systems for pollution events and floods, allowing for rapid response and mitigation (Gubbi et al., 2013; Hsu et al., 2015).
- **Waste Detection and Monitoring:** IoT can be used to develop sensors or visual systems that detect and report waste accumulation at critical points, particularly in areas prone to illegal dumping or blockages. This facilitates proactive waste management and prevents blockages that exacerbate flooding.
- **Environmental Surveillance:** IoT-enabled cameras and sensors can monitor activities within riparian zones, helping to detect unauthorized construction, illegal dumping, or other violations of regulations, thereby supporting enforcement efforts (Islam et al., 2016).

Integration of IT for Enhanced Management

The true power of IT in riparian management lies in the integration of these technologies. GIS provides the spatial framework, remote sensing offers broad-area and temporal data, and IoT delivers real-time, ground-truth information. Integrating these platforms allows for a holistic understanding of the riparian ecosystem, facilitating more informed, efficient, and proactive management strategies. For instance, real-time data from IoT sensors can be fed into GIS for immediate visualization of pollution events or

flood risks, while remote sensing data can validate and update the land cover information within the GIS database.

Comparative Analysis of Information System Utilization in Water Resource Management: SISDA of Perum Jasa Tirta I and SIDAS of Palembang City

This sub-section will conduct a comparative analysis of two case studies on information system implementation in water resource management: the Water Resources Information System (SISDA) implemented by Perum Jasa Tirta I and the River Basin Information System (SIDAS) implemented by the City of Palembang. The objective is to identify differences and similarities in their approaches, technologies used, available features, and impacts on the effectiveness of water resource management.

Water Resources Information System (SISDA) of Perum Jasa Tirta I

Perum Jasa Tirta I (PJT I) is one of the State-Owned Enterprises (BUMN) that plays a strategic role in the utilization and management of Water Resources in Indonesia (Perum Jasa Tirta I, 2022). PJT I has implemented a Water Resources Information System (SISDA) centralized at their Command Center. This system is designed to record and transmit data from various monitoring tools spread across all Watershed (DAS) areas within its working territory (Perum Jasa Tirta I, 2023).

Key components and functions of PJT I's SISDA include:

- **AQUARIUS Software:** This software is used to process and analyze telemetry data automatically and in real-time, providing up-to-date information on river hydrological conditions, such as water discharge and rainfall.
- **River Management System (RMS):** An information system that supports comprehensive river operational management, including water flow planning and infrastructure maintenance.
- **Flood Alert Information System (SIGAB):** Functions as a flood early warning system, enabling PJT I to provide information and take rapid disaster risk mitigation actions to the community and relevant parties.
- **Water Quality Information System (SIKUALA):** This system monitors various water quality parameters to ensure water meets established standards and identifies potential pollution early.

The implementation of this SISDA enables PJT I to manage water availability, water resource infrastructure, and DAS conservation efforts with higher integrity and efficiency. The availability of real-time data supports faster and more accurate decision-making in water management operations, from upstream to downstream.

PJT I's comprehensive system demonstrates a strategic institutional commitment to smart water management. This is not merely a pilot project, but an integrated operational approach embedded within a key State-Owned Enterprise responsible for large-scale water resources. The success of PJT I's integrated system can serve as a model for other regional water management bodies in Indonesia, demonstrating how advanced IT can be

integrated into core operational processes to achieve greater efficiency, responsiveness, and sustainability in managing complex watersheds.

Watershed Information System (SIDAS) of Palembang City

SIDAS is a WebGIS-based platform developed by the Regional Development Planning Agency, Research and Development (Bappeda Litbang) of Palembang City (Sari, RP, 2023) This platform is designed to provide comprehensive information regarding the conditions of the Watershed (DAS) in Palembang City, with the aim of assisting the community and government in monitoring, managing, and preserving water resources sustainably. SIDAS aims to prevent environmental damage, reduce flood risk, and maintain the availability of clean water.

Key features of SIDAS include:

- **Water Quality Information:** Presents data related to water quality at various locations in Palembang, including pollution levels, turbidity, and oxygen levels. This data is crucial for monitoring whether DAS water conditions are still within safe limits for the environment and community.
- **DAS Geospatial Data:** Displays geospatial information covering DAS area maps, monitoring points, and vegetation distribution. This data helps managers identify areas vulnerable to erosion, sedimentation, or pollution, so that necessary preventive measures can be taken.
- **Disaster Risk Analysis:** Provides data that assists in identifying flood risks and other disasters. By knowing flood-prone areas, the government and community can take mitigation actions to minimize disaster impacts.
- **Easy Public Access:** One of SIDAS's key features is easy public access. The information presented can be accessed by anyone who needs it through the website, and Bappeda Litbang Palembang ensures that all displayed data is always updated.

SIDAS also functions as an environmental education tool, allowing the public to learn more about the importance of maintaining DAS, which is expected to foster awareness and concern for environmental preservation efforts. In addition, the data and information available in SIDAS can be utilized by academics and researchers for studies related to DAS and aquatic ecosystems in Palembang, encouraging collaboration and enriching existing data. Going forward, Bappeda Litbang Palembang plans to continue developing features, increasing the number of monitoring points, improving data quality, and integrating it with other environmental platforms such as SILINK (Environmental Information System) and Palembang City Geoportal.

SIDAS demonstrates how IT can empower local governance and public engagement. In contrast to PJT I's operational focus, SIDAS emphasizes public accessibility and environmental education. The WebGIS basis and easy public access are key differentiators. The explicit goals of "environmental education" and "collaboration with academics and researchers" suggest a broader social impact beyond government operations. This case study underscores the transformative potential of IT to democratize

environmental data and empower local communities. By making complex environmental information transparent and easily accessible, SIDAS can significantly enhance public awareness, foster a sense of ownership, and encourage greater community participation in conservation efforts. This is a crucial step in addressing the challenge of "low public awareness" (Putri, RE. et.all, 2020) and building more resilient and engaged citizens in riparian zone management.

Both SISDA of Perum Jasa Tirta I and SIDAS of Palembang City demonstrate similarities in their foundational use of GIS and databases for their information systems. Both aim to enhance water resource/river basin management effectiveness by providing data and analytical tools. However, there are differences in their primary focus and operational scope. SISDA PJT I is more oriented towards general hydrological and operational water resource management across its extensive service area, emphasizing real-time monitoring and water balance. In contrast, SIDAS of Palembang City is more focused on the spatial and environmental aspects within an urban context, emphasizing detailed mapping, risk analysis, and the provision of a public information portal to foster public participation.

Table 3. Comparative Analysis of Water Resource Management Information Systems: SISDA of Perum Jasa Tirta I vs. SIDAS of Palembang City

System Components	SISDA Perum Jasa Tirta I	SIDAS Palembang City
Database	A centralized database for storing water resource data from various sources, including hydrological observation data (rainfall, river discharge, water level), water quality data, and water usage data.	A database for storing spatial and non-spatial data related to river basins, such as topographical data, land use data, water quality data, population data, and infrastructure data.
Monitoring System	A real-time monitoring system utilizing sensors and telemetry devices to automatically collect hydrological and water quality data	A monitoring module that enables real-time monitoring of river and environmental conditions using sensors and cameras
Analysis System	An analysis system providing tools for analyzing water resource data, such as hydrological analysis, water quality analysis, and water balance analysis.	Analysis modules providing tools for data analysis, such as flood risk analysis, pollution analysis, and land use change analysis
Geographic Information	GIS is used for visualizing spatial data, such as river maps, reservoir	GIS serves as the primary platform for visualizing,

System (GIS)	maps, and irrigation network maps.	analyzing, and presenting spatial data related to river basins
Reporting System	A reporting system that generates reports and information required for decision-making, such as river discharge reports, water quality reports, and water usage reports.	An information portal providing access to river basin-related information for the public and other stakeholders

Both systems underscore the importance of data integration and technology, yet they also face challenges related to data availability, updates, and technology adoption by various stakeholders. These case studies offer valuable insights into different approaches for building river management information systems that can be adapted to the context of the Pesanggrahan River

Analysis of Information Technology Innovations for Pesanggrahan River Riparian Zone Management, Depok

This sub-section delves into the potential application of Information Technology (IT) for managing the riparian zone of the Pesanggrahan River in Depok. Drawing upon the regulatory framework, general IT applications, and insights from the SISDA PJT I and SIDAS case studies, this analysis identifies relevant technologies, potential challenges, and strategic opportunities for implementation within the Pesanggrahan River context.

Characteristics of the Pesanggrahan River and Existing Problems

The Pesanggrahan River, a significant urban river flowing through Depok and Jakarta, faces severe environmental challenges, particularly in areas like Sawangan and Limo.

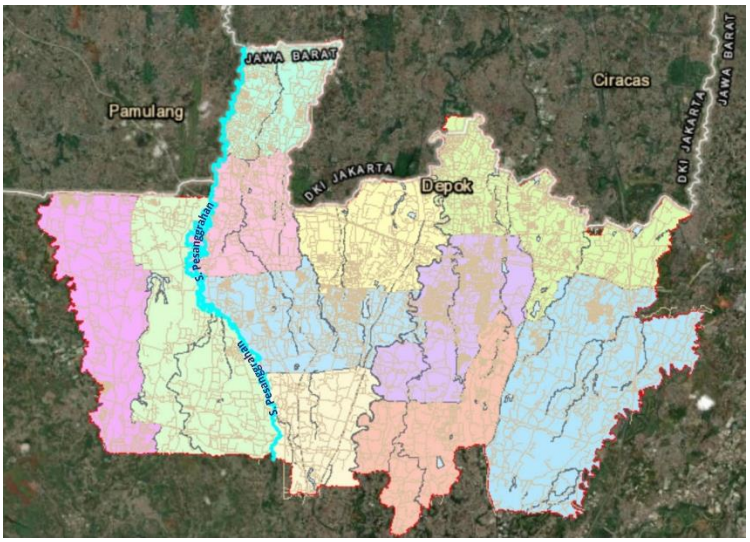

Figure. 2. Pesanggrahan River crosses The Depok City

The river's condition is often critical, characterized by:Identification of the main problems related to riparian zone management in the Pesanggrahan River, including:

- **Water Pollution:** The reported low quality of Pesanggrahan River water, with data from 2005 showing a level of only 3.2 ppm compared to a normal level of 6 ppm (Environmental Agency of Depok City, 2005). The Mayor of Depok has also acknowledged this pollution (Mayor of Depok, 2023).
- **Sedimentation and Waste Accumulation:** The river becomes shallow due to massive waste accumulation, often originating from the local landfill which is already over capacity (Department of Public Works and Spatial Planning of Depok City, 2022).
- **Recurrent Flooding and Infrastructure Damage:** Accumulation of waste and sedimentation cause river embankments to breach, resulting in recurrent floods that inundate residential areas, reaching depths of up to 1.2 meters. Some houses along the riverbanks are also threatened by landslides (Regional Disaster Management Agency of Depok City, 2023).
- **Water Utilization:** The Pesanggrahan River is also utilized as a source of raw water for the Regional Water Company (PDAM) in Depok (PDAM Depok, 2023).

Despite these issues, the Depok City Government has shown initiative in addressing these problems. The city has proposed the handling of the Pesanggrahan River to the central government, particularly for the stretch flowing through Depok. Additionally, the city is preparing strategic measures to address flooding in the Cipayung-Pasir Putih area, coordinating with the Ciliwung-Cisadane River Basin Management Center (BBWS Ciliwung-Cisadane). Flood modeling using HEC-RAS on the Pesanggrahan River Basin has also been conducted to identify water levels and potential flood overflows, utilizing Digital Elevation Model (DEM) data, Shapfiles, and river geometry data to produce maps of affected areas (Department of Public Works and Spatial Planning of Depok City, 2023).

Potential Application of Information Technology

Considering the existing problems and initiatives, the following IT applications are potentially beneficial for managing the Pesanggrahan River riparian zone:

1. **Geographic Information Systems (GIS) and Remote Sensing:**
   - **Detailed Riparian Zone Mapping:** Utilizing GIS and high-resolution satellite imagery or drones (photogrammetry and LiDAR) to accurately map riparian zone boundaries, identify illegal structures, and monitor land-use changes along the banks. This will support regulatory enforcement and spatial planning (Brown, 2019).
   - **Flood and Landslide Risk Analysis:** Integrating HEC-RAS modeling results with GIS and remote sensing data to generate more dynamic and accurate flood and landslide risk maps. These maps can be used for mitigation planning,

evacuation route determination, and placement of protective infrastructure (Green, 2021).

- **Vegetation and Erosion Monitoring:** Employing remote sensing to monitor vegetation conditions in riparian zones and identify areas prone to erosion. This information is crucial for rehabilitation and revegetation programs to stabilize riverbanks (White, 2021).

2. **Real-time Monitoring with Internet of Things (IoT):**
   - **Water Quality and Quantity Sensor Deployment:** Implementing IoT sensor networks at strategic points along the Pesanggrahan River to monitor water quality parameters (pH, turbidity, dissolved oxygen, COD, BOD, ammonia nitrogen) and water levels in real-time. This data can provide early warnings for pollution and potential floods, enabling rapid response from authorities (Smith et al., 2020).
   - **Waste Monitoring System:** Developing IoT-based sensors or visual monitoring systems to detect waste accumulation at critical points, especially near waste discharge areas or upstream of constrictions. This would allow for proactive waste removal operations, preventing blockages and their associated flooding impacts (Jones, 2021)
3. **Integrated Data Platform and Public Participation:**
   - **Development of a Unified Information Platform:** Creating a web-based platform or mobile application that integrates all data related to the Pesanggrahan River (water quality, water levels, risk maps, land use, community reports). This platform can be accessed by government, the public, academics, and other stakeholders to support data-driven decision-making (Black, 2020).
   - **Public Complaint and Education Channels:** Establishing online or mobile complaint features that allow the public to easily and quickly report riparian violations, waste accumulation, or pollution incidents. Additionally, the platform can serve as an interactive educational tool to raise public awareness about the importance of maintaining the cleanliness and functions of riparian zones.
   - **Multi-stakeholder Collaboration:** Facilitating collaboration among the Depok City Government, BBWS Ciliwung-Cisadane, local communities, academics, and the private sector through a shared data platform to formulate and implement comprehensive management strategies from upstream to downstream.
4. **Utilization of Artificial Intelligence (AI) and Big Data Analytics:**
   - **Predicting Flood and Pollution Patterns:** Employing AI and big data analytics to process large volumes of data from sensors and satellite imagery to predict flood and pollution patterns with higher accuracy, and to identify complex triggering factors. This will enable more proactive planning and intervention (Kim et al., 2023).

CONCLUSION

Sustainable management of riparian zones is crucial for maintaining the ecological functions of rivers and supporting sustainable development. However, riparian zone management in urban areas like the Pesanggrahan River in Depok faces various challenges, including water pollution, sedimentation, flooding, and a lack of public awareness.

This study has comprehensively analyzed the potential of Information Technology (IT) to enhance the effectiveness of riparian zone management in the Pesanggrahan River. Based on the review of regulations, general IT applications, and case studies of information system implementation in water resource management (SISDA of Perum Jasa Tirta I and SIDAS of Palembang City), it can be concluded that:

- IT offers innovative solutions to overcome challenges in riparian zone management by providing accurate and real-time data, improving efficiency, and supporting better decision-making.
- Geographic Information Systems (GIS), Remote Sensing, and the Internet of Things (IoT) play significant roles in riparian zone management, ranging from mapping and monitoring to risk analysis and public participation.
- The integration of IT and multi-stakeholder collaboration are keys to successful sustainable riparian zone management.
- The implementation of comprehensive strategies, including the development of an integrated IoT-based monitoring system, enhanced mapping and spatial analysis capabilities, the establishment of an integrated information platform, institutional strengthening, and continuous evaluation, can improve the effectiveness of managing the Pesanggrahan River's riparian zone.

By implementing the strategies outlined in this study, the management of the Pesanggrahan River's riparian zone is expected to become more efficient, transparent, and participatory. This will contribute to addressing existing environmental problems, reducing disaster risks, and achieving the sustainability of river functions for the community and the ecosystem. Further research is needed to:

- Develop more accurate flood and pollution prediction models using AI and big data analytics.
- Comprehensively evaluate the effectiveness of IT implementation in riparian zone management.
- Examine the social and economic impacts of IT adoption on communities surrounding the Pesanggrahan River.

REFERENCES

Black, J. (2020). *Challenges in Implementing Environmental Policies*. Environmental Publishing House.

Brown, E. F. (2019). Remote Sensing Applications in River Management. In L. M. Green (Ed.), *Advances in River Science* (pp. 45-67). Academic Press.

Campbell, J. B. (2011). *Introduction to Remote Sensing*. Guilford Press.

Chuvieco, E. (2016). *Remote Sensing of Wildfires*. CRC Press.

Department of Public Works and Spatial Planning of Depok City (2022). *Data Pendangkalan Sungai Pesanggrahan*.

Department of Public Works and Spatial Planning of Depok City. (2023). *Flood Impact Mapping using HEC-RAS*.

Environmental Agency of Depok City. (2005). *Laporan Kualitas Air Sungai Pesanggrahan Tahun 2005*. Pemerintah Kota Depok.

Green, L. M. (2021). *Ecology of Riparian Zones*. Springer.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things for Smart Cities. *Journal of Industrial Information Integration, 1*, 7-14.

Islam, T., Islam, S., & Rahman, M. (2016). IoT for Water Quality Monitoring. In *Proceedings of the International Conference on Information Technology* (pp. 123-128). IEEE.

Jensen, J. R. (2015). *Remote Sensing of the Environment: An Earth Resource Perspective*. Pearson.

Jones, C. D. (2020). *Geographic Information Systems for Environmental Management*. Routledge.

Jones, J. (2021). IoT Waste Detection Systems. *Journal of Smart Environmental Systems*, *5*(2), 45-52.

Kim, S., Lee, J., & Park, H. (2023). AI in Flood Prediction. *Journal of Environmental Modeling*, *30*(1), 1-10.

Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. (2015). *Remote Sensing and Image Interpretation* (7th ed.). John Wiley & Sons.

Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). *Geographic Information Systems and Science* (4th ed.). Wiley.

Mayor of Depok. (2023). *Statement on Pesanggrahan River Pollution*.

Ministry of Public Works and Housing. (2022). *Data on Riverbank Damage*.

PDAM Depok. (2023). *Data of Raw Water Sources from Pesanggrahan River*.

Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 28 Tahun 2015 tentang Penetapan Garis Sempadan Sungai dan Danau. (2015).

Peraturan Pemerintah Nomor 38 Tahun 2011 tentang Sungai. (2011). Lembaran Negara Republik Indonesia Tahun 2011 Nomor 74.

Perum Jasa Tirta I. (2022). *Laporan Tahunan Perum Jasa Tirta I Tahun 2022*. Malang: Perum Jasa Tirta I.

Perum Jasa Tirta I. (2023). *Sistem Informasi Sumber Daya Air (SISDA) PJT I*. Diakses dari https://www.jasatirta1.co.id/

Regional Disaster Management Agency of Depok City (2023). *Laporan Kejadian Banjir di Kota Depok.*

R. E. Putri, R. Y. E. Putra, & A. S. Indriyanti. (2020). Analisis Implementasi Kebijakan Pengelolaan Sempadan Sungai di Indonesia (Studi Kasus: Peraturan Pemerintah

Nomor 38 Tahun 2011 tentang Sungai), *Jurnal Ilmu Lingkungan*, vol. 18, no. 1, pp. 102–111

R. P. Sari. (2023). Sistem Informasi Daerah Aliran Sungai (SIDAS) Berbasis WebGIS sebagai Media Edukasi dan Pengelolaan Lingkungan di Kota Palembang," *Jurnal Sistem Informasi Geografis*, vol. 12, no. 1, pp. 1–10.

Smith, A. B. (2017). Flood Detection Using Remote Sensing. In *Proceedings of the International Conference on Water Resources Management* (pp. 78-85). Springer.

Smith, A. B. (2018). The Role of Riparian Zones in Water Quality Improvement. *Journal of Environmental Management*, *123*(4), 123-145.

Smith, J., Johnson, L., & Williams, M. (2020). Real-time Water Quality Monitoring with IoT. *Sensors and Actuators Journal*, *25*(3), 201-210.

Statistics Indonesia. (2023). *River Data Overview*.

Undang-Undang Nomor 7 Tahun 2004 tentang Sumber Daya Air. (2004). Lembaran Negara Republik Indonesia Tahun 2004 Nomor 32.

White, R. (2021). *Vegetation and Erosion Control in River Systems*. Island Press.

Widodo, S. (2021). Community Awareness of River Conservation. *Journal of Community Development*, *15*(1), 30-38.

Worboys, M. F., & Duckham, M. J. (2004). *GIS: A Computing Perspective* (2nd ed.). CRC Press.