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Water Resources Management in Progo River Basin using SWOT Analysis

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ABSTRACT About 3.1 million people use the water from Progo River for domestic use, agriculture, livestock and even for religious rituals which solidifies the importance of Progo River to the residence. However, the characteristics of the Progo River has not been studied well. This paper aims to understand the characteristics of the Progo River and the main threat to the river. To achieve those objectives, a SWOT analysis was used particularly in three segments of Progo River Basin, which is upstream, midstream, and downstream reach. The upstream segment has a basin slope more than 25%, the middle segment has a basin slope of 8-25%, and the downsteam segment has a basin slope less than 8%. The SWOT analysis would be based on desk study, hydrological analysis, water quality analysis and field observation. The upstream segment is characterized by high land erosion rate, steep slope, and the presence of Umbul Jumprit, a holy site for Buddhism. The midstream segment is very close to the residence area which reduces the water quality of the river. Furthermore, some scouring issues and flooding risk have become the main concern in this area. The downstream segment is crossed by several bridges of national roads while also having a gravel mining activity. This activity causes a massive scouring problem to the structures. It is clear that the main threat to the Progo River Basin is volcanic and human activities. For a starter, the government should prioritize the revitalization act in the upstream area which has a great impact on the midstream and downstream areas. Because SWOT analysis from water resources management perspective have never been done in the Progo River Basin, these findings can be served as a foundation for the integrated water resources management in the basin.

KEYWORDS Sabo Dam; Sedimentation; SOFT Analysis; Water Quality; WRPM

1 INTRODUCTION

Water resources planning and management is the comprehensive process of strategically planning, developing, and regulating water resources. This goal is to effectively meet water demand, minimize water-related disasters, and preserve the natural state of water and land resources (Eslamian, 2014). Water resources planning and management is important for all water resource sectors, including drinking water supply, domestic usage, industrial needs, irrigation requirements, electricity generation, navigation, tourism, environmental conservation, and urban water systems. The management of water resources in a river basin should consider the triple bottom line (TBL) analysis, including social, economic, and environmental factors (Chin, 2014; Cole et al., 2018).

In recent years, the concept of water resources planning, and management has evolved into integrated water resources management (IWRM) to address the increasing complexity of water-related issues. The challenges associated with water resources extend beyond quantity and quality concerns. These challenges also encompass erosion, sedimentation, sanitation, hygiene, involvement of public and private sectors, public participation, transboundary issues, data availability, and even instrumentation and monitoring (Karamouz et al., 2010). The IWRM framework necessitates a comprehensive analysis and research of water resources, usually in the scale of a watershed or river basin. Solutions to water problems are proposed by integrating key findings from each subject area while considering the triple bottom-line factors. Grigg (2008) stated that there are eight elements for integration in IWRM, namely policy sectors, water sectors, government units, organizational levels, management functions, geographic units, management phases, and disciplines and professions. Academic professionals must be more active in generating new knowledge on IWRM for policy leaders and public authorities. This would enable the implementation of more effective solutions for water-related challenges (Grigg, 2021).

SWOT (Strength, Weakness, Opportunity, and Threat) analysis, known as SOFT analysis (Satisfactory, Opportunities, Faults, and Threats), is a valuable strategic planning and management tool. Its purpose is to evaluate the strengths, weaknesses, opportunities, and threats associated with a specific planning issue (Helms and Nixon, 2010; Namugenyi et al., 2019; Puyt et al., 2023). The findings obtained through a SWOT analysis are then utilized to determine recommended strategic actions for resolving the identified issue. This analytical framework can also be applied effectively in the field of water resources planning and management. Several case research have showcased the application of SWOT analysis in resource planning and management. Examples include the works of Diamantopoulou and Voudouris (2007); Stathopoulos et al. (2013); Ali et al. (2019); Triatmadja et al. (2020); Goli et al. (2021).

Indonesia has set an ambitious economic goal to become one of the top five economies in the world by 2045. To achieve this, it is assumed that the country will experience an average real GDP growth rate of 5.7 percent annually between 2015 and 2045, with a 5 percent average growth rate in GDP per capita. The development of water resources and services has been pivotal in driving sustained economic growth and increasing per capita incomes in Indonesia (*Indonesia Vision 2045: Toward Water Security*, 2021). In order to support the attainment of Indonesia's economic goals, implementing Integrated IWRM across all river basins in the country is imperative. IWRM entails managing river basins comprehensively, from the upstream to the downstream areas, in an integrated manner. The planning of IWRM in Indonesian river basins is primarily carried out by the public authority, specifically the River Basin Organization (Balai Besar Wilayah Sungai/BBWS in Indonesian) responsible for the respective river basin under the Ministry of Public Works and Housing. The principles of IWRM in Indonesia are in accordance with the five pillars of water resources management, as stipulated in Regulation No. 17/2019. These pillars include the conservation of water resources, utilization of water resources, control of the destructive power of water, establishing water resources information systems, and fostering community and private sector participation in water resource management.

The Progo River Basin plays a vital role in meeting the diverse water resource needs of Semarang, Temanggung, Magelang, Boyolali, Purworejo, Wonosobo, Sleman, Kulon Progo, Bantul, and Yogyakarta City, both in terms of physical and non-physical requirements. However, the Progo River Basin faces significant challenges that impede its optimal functioning, including water pollution, water-related disaster, spatial problem, erosion & sedimentation, poor performing water infrastructure, etc. These problems hinder the quality and availability of water resources, impacting the surrounding communities and ecosystems. The Progo River Basin spans multiple administrative boundaries, potentially leading to management authority issues and complicating decision-making processes. Furthermore, substandard management and maintenance practices contribute to the poor performance of certain water infrastructures within the basin.

Approaches to water resource management in the Progo River Basin are based on various references, including the Water Resources Management Plan (RPSDA) for the Progo Opak Serang River Basin and the Strategic Plan 2020-2024 (RENSTRA) of both the Directorate General of Water Resources and the Serayu Opak River Basin Organization (RBO). These strategic plans are in accordance with the 2020-2024 National Medium-Term Development Plan (RPJMN), which serves as a comprehensive reference for management activities throughout Indonesia. By thoroughly reviewing different aspects, mature management planning guides integrated water resources management in the Progo River Basin. It is important to note that these documents primarily focus on strategic-level water resources management planning, while the RBO requires a master plan for implementation. Therefore, in the preparation of the IWRM master plan for the Progo River Basin, it is crucial to conduct a detailed analysis and gain a clear understanding of each segment of the river. This initial

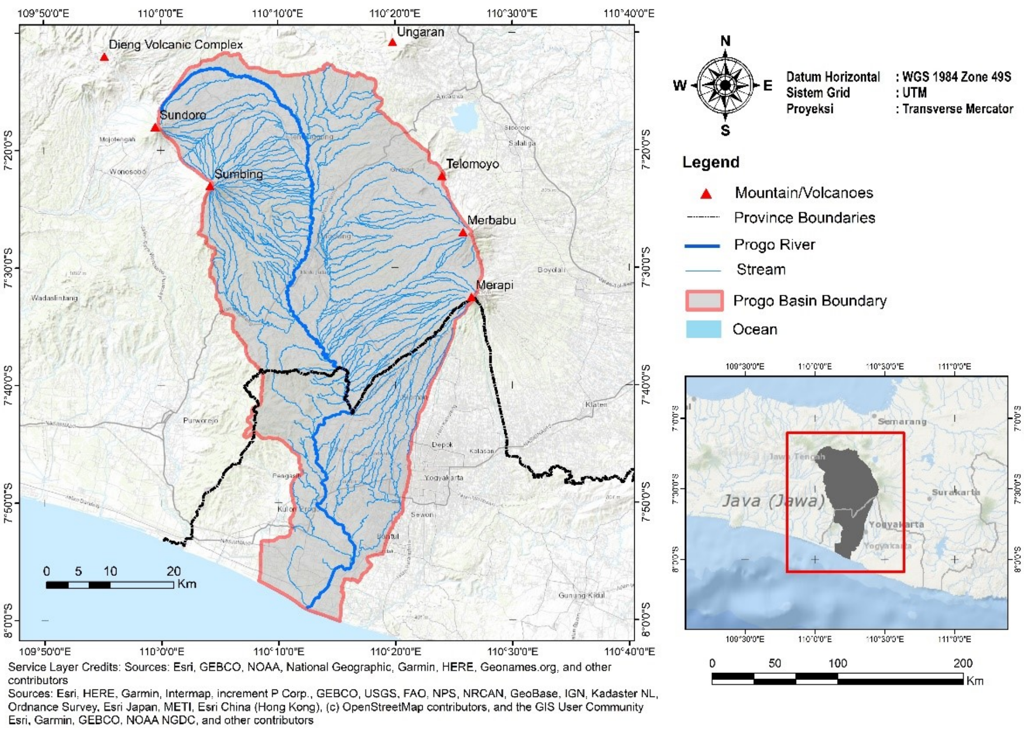

Figure 1 The location of Progo River Basin

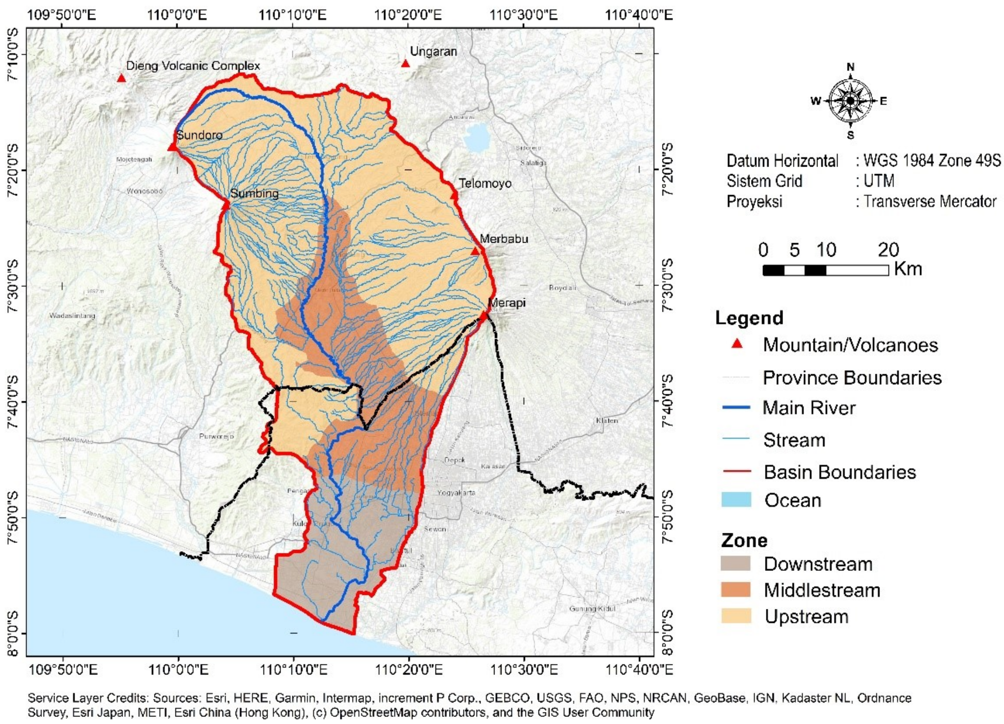

Figure 2 The upstream, midstream, and downstream reach division of Progo River Basin

step lays the foundation for effective and targeted management strategies in the basin.

This research aims to address two key research questions, namely 1) What are the characteristics of the Progo River Basin? and 2) What are the main driving factors for changes in the Progo River Basin? To achieve this objective, the research aims to provide holistic knowledge and a clear understanding of the characteristics of the Progo River Basin. The Progo River Basin analysis will be completed using SWOT analysis, particularly the upstream, midstream, and downstream segments. The knowledge gained from this research is crucial for the community and water managers, particularly public authorities, in formulating appropriate and integrated approaches for water management in the Progo River Basin.

2 METHODS

2.1 Research Area

The Progo River Basin is geographically located 7°10’48”S – 8°00’36”S latitude and 109°58’48”E – 110°27’36”E longitude, as shown in Figure 1. It spans several major cities in Central Java and the Special Region of Yogyakarta, including Semarang, Temanggung, Magelang, Boyolali, Purworejo, Wonosobo, Sleman, Kulon Progo, Bantul Regency, and the City of Yogyakarta. The total area of the Progo River Basin is approximately 2,421 square kilometers, with a main river length of 138 kilometers. The basin originates from four prominent mountains in Central Java and the Special Region of Yogyakarta, namely Mount Sindoro, Mount Sumbing, Mount Merbabu, and Mount Merapi. It then flows towards the South Coast of Java, shaping the river basin’s landscape and hydrological dynamics.

The morphological characteristics of the Progo River basin facilitate its division into three distinct reaches, including upstream, midstream, and downstream. The primary morphological characteristic for this division is the bed slope of the river basin, as shown in Figure 2. The upstream, midstream, and downstream have basin slopes above 25%, 8 – 25%, and less than 8%.

The upstream segment of the Progo River Basin comprises approximately 63% of the total area. It covers Temanggung and Magelang Regencies in Central Java Province, as well as small portions of Sleman and Kulon Progo in the Special Region of Yogyakarta. This segment is characterized by relatively steep slopes, primarily due to the presence of five mountains, namely Mount Sindoro, Sumbing, Telomoyo, Merbabu, and Merapi. The midstream segment represents around 23% of the total river basin area, which passes through Magelang City, Central Java, as well as Sleman Regency and a small part of Yogyakarta City. This area is predominantly residential and includes various economic zones. The downstream segment is the smallest portion, accounting for approximately 14% of the total area, and includes the Regencies of Kulon Progo and Bantul. The topography in this segment is relatively flat, and the river widens as it flows directly towards the southern coast.

As of December 2017, the population of the Progo River Basin was approximately 3.1 million, according to data from the Department of Population and Civil Registration. This translates to a population density of around 1,245 people per square kilometer in the basin. The majority of the population in the Progo River Basin are employed as farmers, primarily working in irrigated paddy fields or plantations, as shown in Figure 3. This agricultural focus leads to significant water usage for irrigation purposes in the basin. In terms of land use, the Progo River Basin is predominantly characterized by plantations, which cover approximately 28.13% of the total area. This is followed by irrigated rice fields, settlements, rainfed rice fields, and moorland, with percentages of 20.82%, 16.68%, 16.07%, and 11.87%, respectively. The remaining portion of the basin consists of water bodies, forests, grasslands, and other vegetated lands.

Due to the presence of numerous mountains and active volcanoes in the Progo River Basin, the government has constructed several sediment control structures throughout the area, as shown in Figure 4 (Serayu Opak RBO, 2022). These structures include various types, such as check dams, sabo dams, groundsills, consolidation dams, and cribs. All the buildings were made to overcome the high frequency of sediment and debris due to upstream activities. These sediment control structures play a crucial role in maintaining the slope condition of the riverbed and reducing the potential for down-

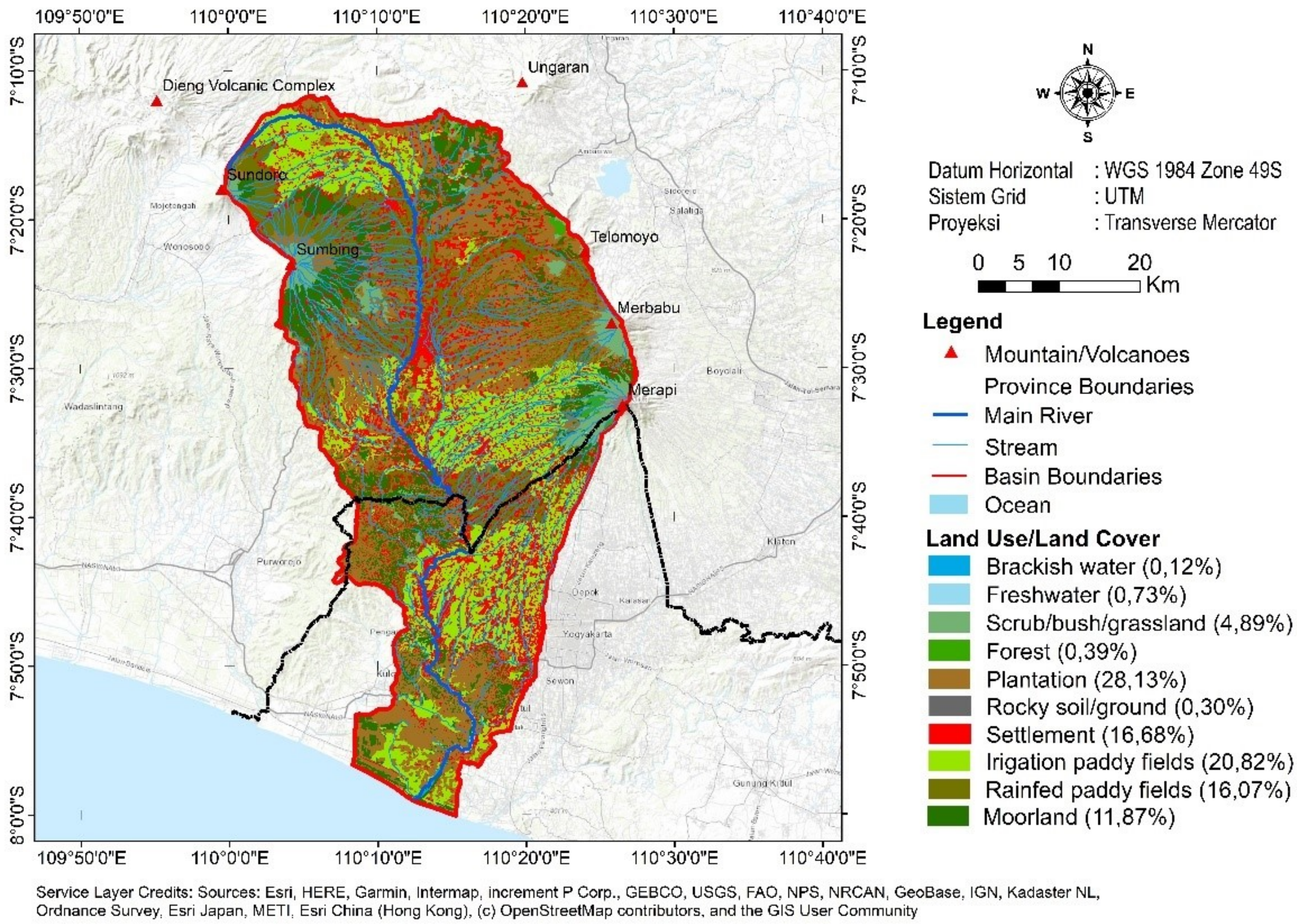

Figure 3 Land use of the Progo River Basin (Modified from Serayu Opak RBO, 2022)

stream disasters.

2.2 Hydrological Condition

Monitoring and measuring rainfall is important to understanding the global climate system and the water cycle, as it provides valuable insights into the management of water resources (Kidd and Huffman, 2011). The average annual and seasonal rainfall is particularly significant as it directly influences water availability. Rainfall measurements determine precipitation values over a specific spatial area, such as a river basin, which is important for water use and development (Wolff et al., 2020). In the Progo River Basin, rainfall and water level measurements are essential for describing the discharge characteristics of the watershed. The Ministry of Public Works and Housing has installed 9 rain stations and 14 automatic water level recorders (AWLR), as shown in Figure 5. Among these stations, Caturanom and Badran represent the rainfall conditions in the upstream reach, while the remaining 7 stations are located in the midstream and downstream reach of the river basin. The selected stations have a complete data set spanning ten years (2007-2017), which is the minimum requirement for hydrological analysis. The data set is consistent based on the RAPS (Rescaled Adjusted Partial Sums) consistency method. Precipitation and river water level are strongly dependent (Wang et al., 2022). Figure 6 shows the annual maximum daily rainfall, reflecting the precipitation rate from the 9 stations in the Progo River Basin. The annual maximum daily rainfall is commonly used for water resources infrastructure planning, particularly in hydrological analysis. The precipitation rate shows relatively similar conditions across the upstream, midstream, and downstream reaches, although there was an overall increase from 2007 to 2017, with the highest rate recorded in 2017.

Rainfall comparison for 2007 and 2017 produces extremely different rainfall conditions, as shown

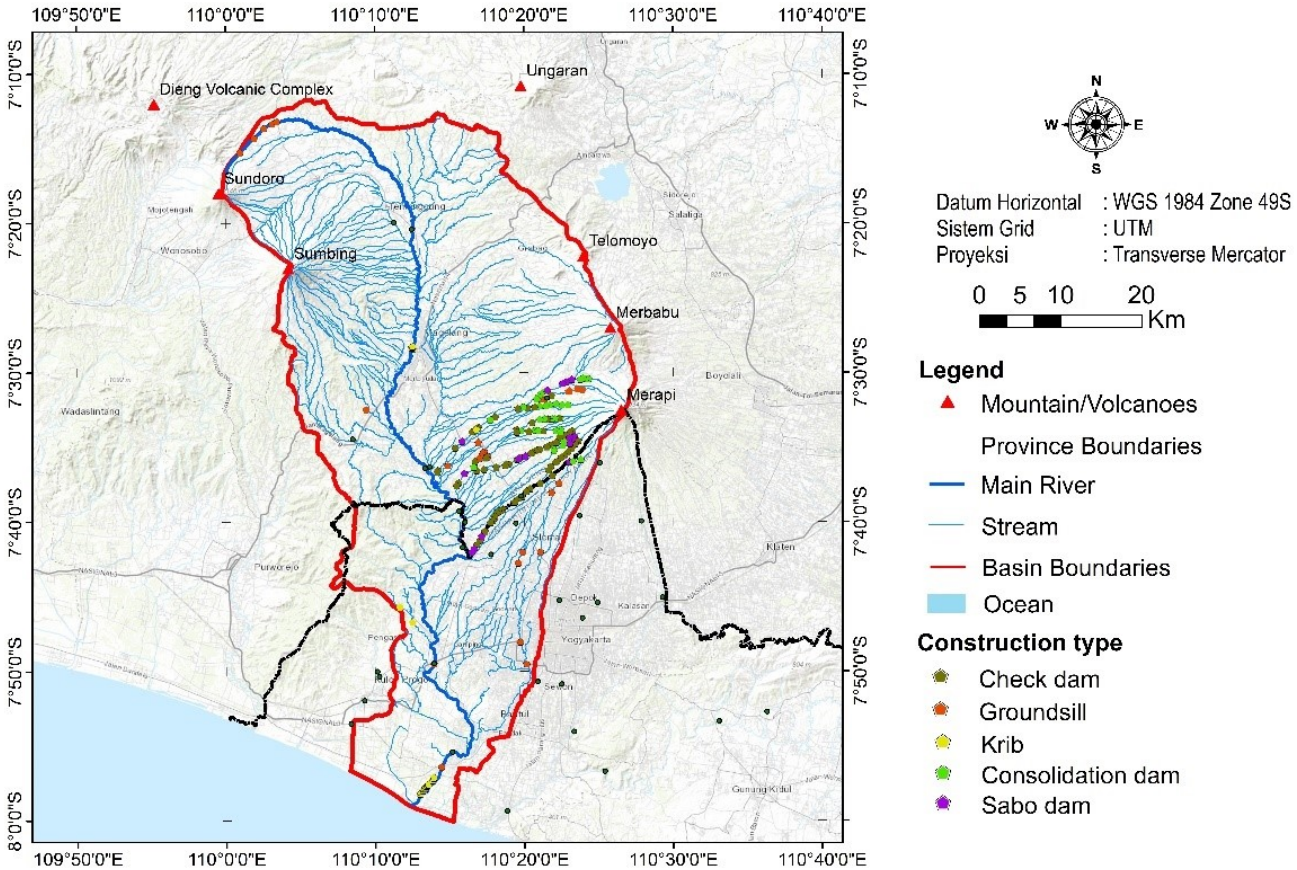

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Figure 4 The location of the sediment control structure in the Progo River basin

in Figure 7. In 2007, the upstream area experienced the highest annual maximum daily rainfall, while the midstream and downstream areas received comparatively lower amounts. However, in 2017, the situation was reversed, with the maximum daily rainfall at Caturanom Station being the lowest among all stations, while the highest was recorded at Kalijodo Station with 343 mm. These variations in precipitation rates can be attributed to the impact of climate change.

2.3 Water Quality

Water quality is crucial in integrated water resources management (IWRM). Figure 8 shows the water quality measurements at various locations within the Progo River Basin. The corresponding results are summarized in Table 1, which shows that the water quality in several locations exceeds the standard guidelines. Out of the 11 measurement locations, 9 samples were slightly polluted. The potential sources of pollution near these sampling points include residential areas, industrial activities, and other domestic practices. The dominant parameters contributing to pollution rise from domestic activities, particularly high chemical indicators such as BOD, COD, and DO.

2.4 Field Observation

On 13-14 June 2022, field observations were conducted to examine the characteristics of the upstream, midstream, and downstream areas within the Progo River Basin. These observations aimed to gain insights into the specific features of each segment and were carried out at various location points. The upstream observations were conducted at Umbul Jumprit and the River in the Mount Merapi area, as shown in Figure 9. In the midstream, observations were carried out in the urban and suburban areas of Magelang and Yogyakarta, as shown in Figure 10, and the downstream was represented by the Srandakan Check dam in Figure 11.

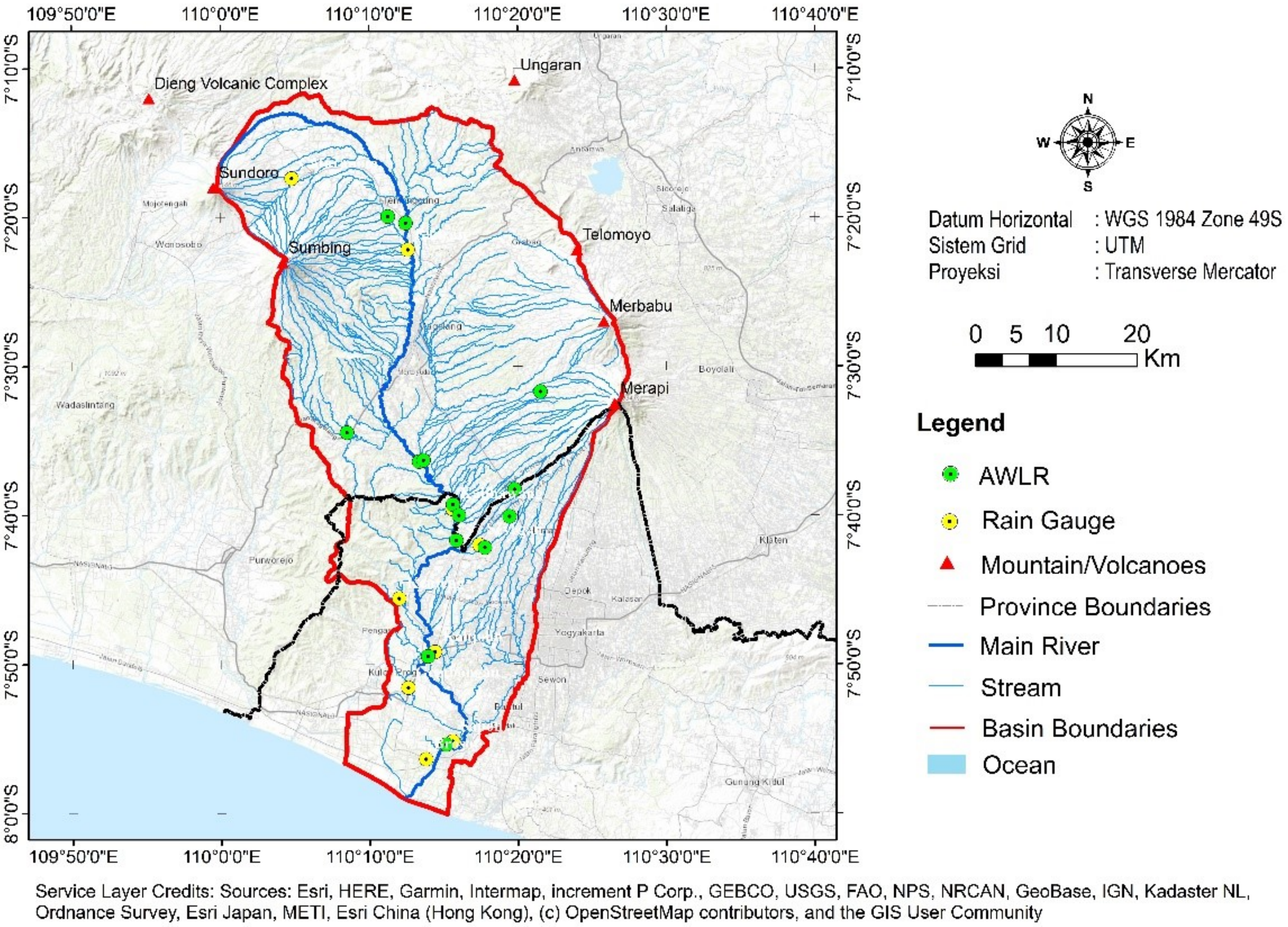


Figure 5 The location of the rain gauge in the Progo River basin

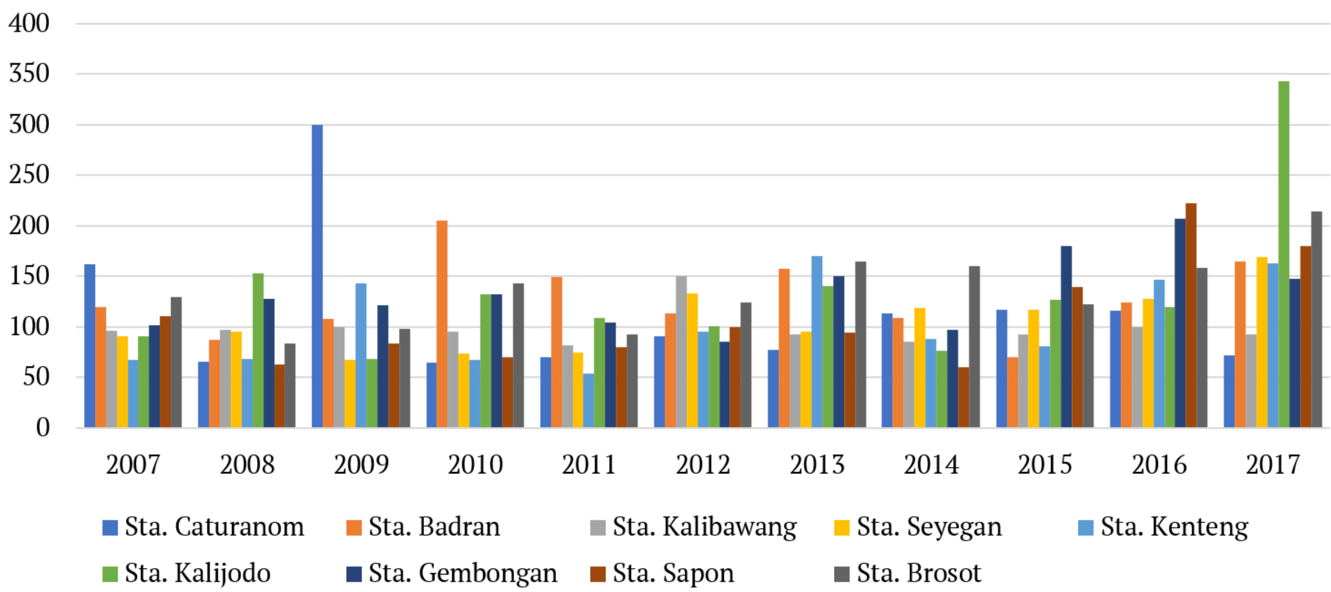


Figure 6 The annual maximum daily rainfall for 9 stations in 2007 - 2017

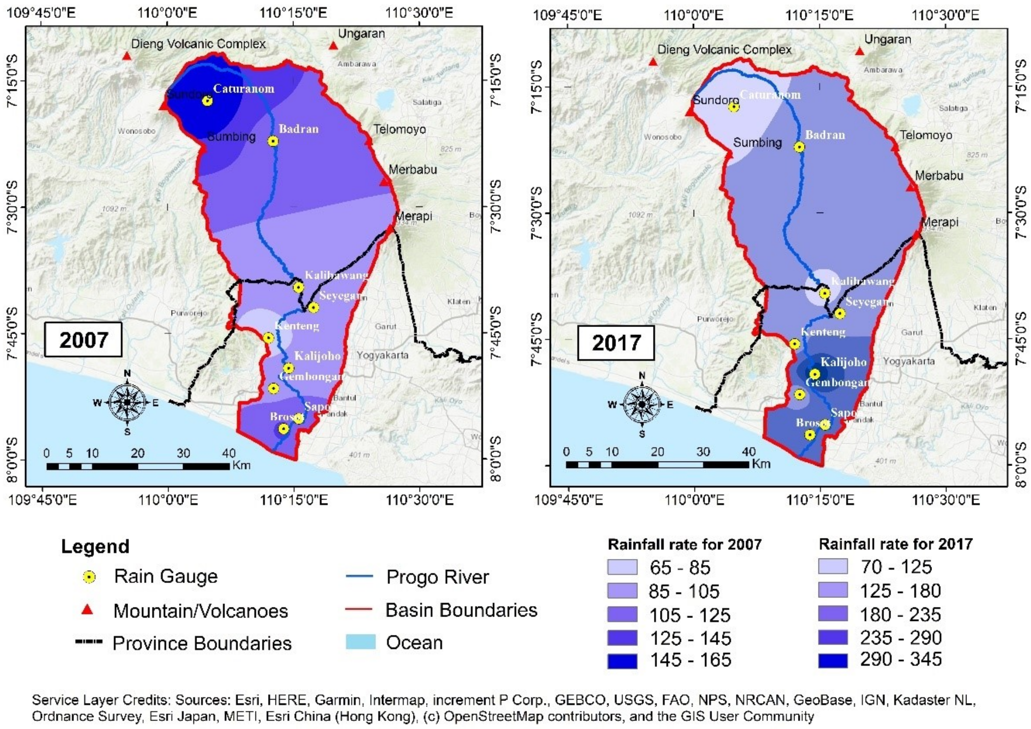


Figure 7 Precipitation rate conditions around 2007 and 2017 in the Progo River basin

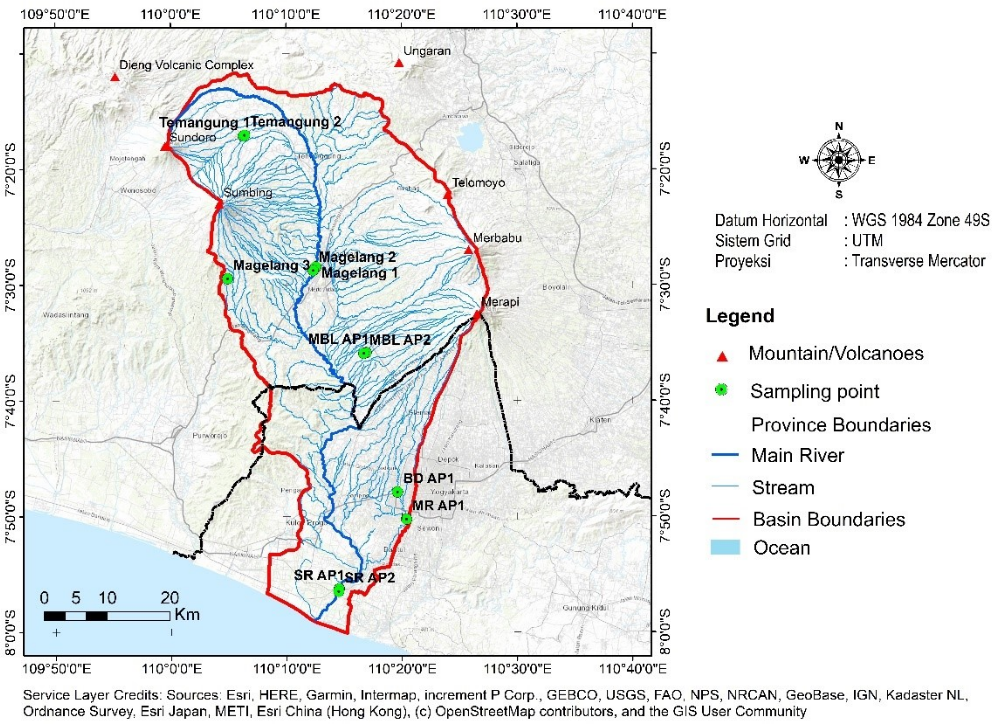


Figure 8 Sampling point (Modified from Serayu Opak RBO, 2022)

Table 1. The testing results of water quality and the pollution index (Serayu Opak RBO, 2022)

No	Parameter	Unit	Class II Quality Standards	Results										
				TM 1	TM 2	MG 1	MG 2	MG 3	MBL AP 1	MBL AP 2	BD AP1	MR AP1	SR AP1	SR AP2
PHYSICS														
1	Temperature	°C	22-28	29.7*	29.7*	27.7	27.7	27.7	29.7*	26.7	26.7	27.7	27.7	27.7
2	TSS	mg L^{-1}	50	4	4	12	4	4	4	4	4	4	56*	16
CHEMISTRY														
3	pH		6-9	8.42	8.22	8.52	8.32	8.06	8.32	8.38	8.38	8.13	8.13	8.31
4	BOD	mg L^{-1}	3	5.71*	5.97*	6.51*	5.08*	3.69*	3.9*	4.19*	3.88*	3.37*	3.37*	5.67*
5	COD	mg L^{-1}	25	17.1	11.9	19.1	16	14	14	12.9	11.9	12.9	12.9	15
6	DO	mg L^{-1}	4	5.97*	3.85	6.74*	5.49	6.74*	7.71*	7.61*	7.61*	7.51*	7.22*	7.8*
7	NO_3-N	mg L^{-1}	10	13.9*	16.1*	1.88	2.17	2.05	0.85	0.63	2.15	2.67	2.44	2.36
8	Phosphate	mg L^{-1}	0.2	0.14	0.14	0.12	0.09	0.1	0.07	0.06	0.17	0.23*	0.12	0.18
MICROBIOLOGY														
9	Total Coliform	MPN/100 mL	5000	24	107	36	20	31	19	11	31	61	131	700
ANALYSIS RESULTS														
10	Pollution Index	Against Class II Quality Standards		Lightly polluted	Lightly polluted	Lightly polluted	Lightly polluted	Lightly polluted	Lightly polluted	Lightly polluted	Lightly polluted	Meet the quality standard	Meet the quality standard	Lightly polluted

*indicates a value higher than the maximum quality standard limit

The upstream segment marks the beginning of the river flow, characterized by relatively fast water velocity and the potential for erosion to the riverbed, resulting in a ”V” shaped cross-section of the channel. U Umbul Jumprit, located on the slopes of Mount Sindoro at an altitude of 2,100 meters above sea level Figure 9a, serves as one of the springs contributing to the Progo River Basin. To address the frequent debris flow from Merapi Volcano, the government has constructed the Sabo Dam Nglumut Figure 9b. However, due to the high occupancy rate of the dam, regular maintenance is required. There are several potential springs in the vicinity of the sabo dam, further contributing to the water resources of the Progo River Basin.

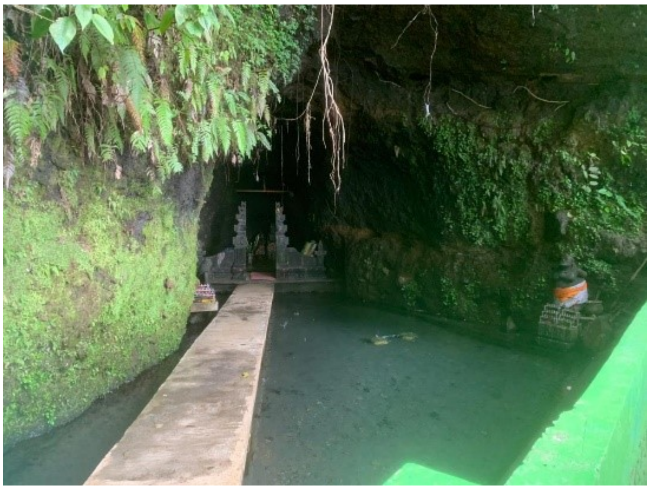
Midstream is usually located in a relatively flatter area than the upstream segment. As the flow velocity decreases, the erosive force diminishes, allowing sedimentation to take place. The midstream area often exhibits a wide, gently curving ”U” shape. Unfortunately, improper development practices in floodplains have resulted in the encroachment of settlements, roads, and irrigation canals. This has disrupted the natural dynamics of the river.

Figures 11a and 11b show the downstream condition of the river, which represents the final stretch before it reaches the estuary and flows into the sea. The velocity is slow, resulting in high sedimentation. The river material primarily consists of silt and fine sand. However, there is an issue with sand mining occurring downstream of the check dam, which is causing structural damage to the river.

3 RESULT AND DISCUSSION

The Progo River Basin was analyzed using SWOT for each upstream, midstream, and downstream segment. The analysis was based on the secondary data and field observation of topography, geography, social aspect, land use management, hydrological condition, and water quality in each Progo River Basin segment. The result of the SWOT analysis is shown in Table 2.

In general, the upstream segment of the Progo River Basin has a very steep slope with a V-shaped channel. The segment is heavily affected by volcanic activities, particularly from Mount Merapi. These volcanic activities contribute to the presence of highly fertile soil in the upstream area, which is well-suited for agriculture. As a result, agriculture plays a prominent role in the local



(a) Umbul Jumprit Holyspring

(b) Nglumut Check Dam, M. Merapi

Figure 9 Observation of current condition in the upstream segment

(a) Stream conditions at Galeh Bridge

(b) Stream conditions at Gemping Bridge

Figure 10 Observation of current condition in the midstream segment

(a) Srandakan check dam

(b) Downstream main river condition

Figure 11 Observation of current condition in the downstream segment

Table 2. The SWOT analysis of the Progo River Basin for upstream, midstream, and downstream segments

Upstream	Midstream	Downstream
A. Strength		
High flow discharge and fast flow velocity	High flow discharge with medium flow velocity	High flow discharge with slow flow velocity
The ecological condition in this segment is relatively good	Relatively consistent high rainfall and discharge over a year	Very wide floodplain used for agriculture
Abundant raw water due to high precipitation over a year	The presence of medium to big sediment based on field observation	High fine sediment transport based on field observation
Many groundwater sources became spring water along the river channel based on observation	A sufficient number of rainfall gauge and river monitoring instrument	The number of rainfall gauges and river monitoring instruments is sufficient
B. Weakness		
High land erosion rate due to unsustainable agricultural activity based on field observation	Relatively steep slopes and high sediment transport cause dynamic riverbed elevation and planform	The brackish water that unsuitable for domestic use
Frequent debris flows due to the presence of many volcanoes in the river basin	Frequent debris flows due to the presence of many volcanoes in the river basin	Sedimentation problem in the estuary due to longshore current, which causes flooding
Lack of rainfall gauge and river monitoring instrument	Scouring problems near river infrastructure and curvature	Massive scouring problem at the bridge piers and abutment
The trend of precipitation in the upstream area is decreasing in recent years based on the rainfall data	The increase in maximum daily rainfall could raise the risk of flooding	Vast operation and maintenance cost for infrastructure due to a very wide and tall channel
C. Opportunity		
Natural conservation areas such as the arboretum or Sabo Dam Laboratory, for example, in Nglumut Sabo Dam	Suitable for sport tourism such as rafting and canoeing	Suitable for sport competition (canoe & kayak)
Development early warning system for debris flow	Development early warning system for debris flow	Development early warning system for debris flow
Holy sites for Buddhists, along with Borobudur and Dieng Plateau	Holy sites for Buddhists at Borobudur, along with Umbul Jumprit	Fisheries and Aquaculture
Materials from volcanic eruptions can support the surrounding community through the controlled gravel mine activity	Consistent flow rate can be used to meet the domestic water and irrigation demand	Materials from volcanic eruptions can support the surrounding community through the controlled gravel mine activity
Sustainable agricultural activity with terracing to utilize the fertile soil	River beautification for a riverfront and family park	Development of remote river monitoring to collect real-time data
D. Threat		
Lack of operation & maintenance of water infrastructure along the river	Lack of operation & maintenance of water infrastructure along the river	Inadequate operation & maintenance of water infrastructure along the river
Inadequate public awareness of protecting the environment and natural resources, as seen in the observation	Inadequate public awareness of protecting the environment and natural resources, as seen in the observation	Lack of public awareness to protect the environment and natural resources, as seen in the observation
Global warming and climate change are proven by the recorded rainfall	Global warming and climate change are proven by the recorded rainfall	Global warming and climate change are proven by the recorded rainfall
Coordination gap between central and local governments for upstream development	Coordination gap between central and local governments for midstream development	Coordination gap between central and local governments for downstream development
Illegal and excessive gravel mining	Poor spatial planning indicated by human settlement in floodplain	Illegal and excessive sand mining
Rapid land use change, particularly from tropical forest into residential and agriculture	Water pollution, due to poor sanitation and industry, based on water quality measurements	Water pollution, due to poor sanitation and industry, based on water quality measurements

community's livelihoods. The rapid conversion of forested land to agricultural use has led to an increased erosion rate, which can diminish the capacity of the Progo River in the midstream and downstream segments. Moreover, the river's morphology is affected by the occurrence of large debris flows and the presence of boulders. To reduce the damage from debris flow, the public authority has built several series of check dams, also known as Sabo Dam. These structures aim to reduce the impact of debris flows on the river. Furthermore, the upstream segment is abundant in gravel and fine sediment, leading to gravel mining activities. It is important to regulate and control these activities to preserve the environmental condition of the upstream segment. For instance, sand mining should be limited to areas situated downstream of the check dams. From a social perspective, the upstream segment holds significant spiritual importance for Buddhism with the connection between Umbul Jumprit, Borobudur, and Dieng Plateau.

The activities in the upstream reach affect the midstream segment of the Progo River Basin. It has a relatively milder slope than the upstream reach and is predominantly characterized by human settlements as well as tourism activities. The moderate slope and the presence of medium-sized sediment make it an attractive location for water sports such as rafting. However, field observations indicate that the human settlements in the midstream area have had a detrimental effect on water quality in the river. The improper disposal of domestic waste and untreated wastewater is a prevalent issue. Moreover, the abundance of road crossings and bridges exacerbates problems such as flooding and local scouring. These issues particularly arise around the bridge piers, contractions, and the outer side of river curvature. The situation is further aggravated by the sedimentation of the washload resulting from land erosion in the upstream area, which reduces the overall capacity of the river.

The downstream segment of the Progo River Basin is located adjacent to the Indian Ocean. In this segment, the water level is influenced by the inflow from the upstream and midstream reaches, as well as the tides and tidal waves from the ocean. The river channel in the downstream segment is notably wide, and the flow velocity is relatively slow. This slow velocity allows debris and sediment from upstream to settle in the downstream reach. There are several bridges for national roadways and river infrastructures, including the Srandakan Groundsill, making this segment crucial for economic activities. However, the presence of gravel mining activities in this segment poses challenges. It causes riverbed degradation and reduces the stability of the aforementioned structures.

In this SWOT analysis, the problems and factors that influence water resource activities of the Progo River Basin are clearly identified. This provides valuable insights for determining appropriate management directives. It is crucial to adopt an integrated management approach encompassing the upstream, midstream, and downstream segments, despite trans-regional boundaries. However, based on the results of SWOT analysis and field observation, water resources activities in upstream greatly affect the midstream and downstream reach conditions. This finding is consistent with the research conducted by Montazeri et al. (2023). It is recommended that water resources management efforts commence in the upstream reach. Measures should be implemented to reduce land erosion rates, such as adopting terraced fields for sustainable agricultural practices or regularly maintaining check dams.

4 CONCLUSION

In conclusion, the Progo River Basin is a critical region for approximately 3.1 million inhabitants who rely on it for their livelihoods and residential needs. However, there are indications of watershed degradation, such as floods, landslides, and land erosion. This research provided insights into the characteristics of the Progo River Basin from a water resources management perspective and identified the primary threats to the basin. The SWOT analysis method was employed with secondary data and field observations used to assess the three main segments, namely upstream, midstream, and downstream, of the Progo River Basin. In the upstream segment, the damage caused by debris flow from volcanic activities was mitigated through the use of check dams. The sediment deposited due to these processes became a source of livelihood for the local communities, particularly through gravel mining activities in both the upstream and downstream reaches. The upstream is presently a sacred site in Umbul Jumprit for Buddhism in conjunction with Borobudur and Dieng Plateau. The midstream segment faces challenges due to human activities contributing to the deterioration of water quality in the Progo River. Meanwhile, extensive gravel mining activities make the downstream segment susceptible to scouring problems. Volcanic activities and human interventions heavily influence the Progo River Basin. Effective water resources management, with a specific focus on sediment management, should be prioritized for the upstream reach of the Progo River Basin. The relevant authorities can develop and implement appropriate water resources management plans and actions by understanding these characteristics. This will ensure equitable access to water for all while mitigating the risks associated with water-related disasters.

DISCLAIMER

The authors declare no conflict of interest.

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