



# Hydrological Analysis for Spatial Plan of Hamparan Rawang District to support Resilient Urban Development

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**Abstract:** Hamparan Rawang District plays a crucial role in the overall spatial planning and development strategy of Sungai Penuh City. However, Hamparan Rawang District encounters significant environmental challenges that threaten its natural resources and ecosystems, biodiversity, and overall sustainable development and resilience. Hydrological analysis and spatial planning of Hamparan Rawang District is conducted for disaster mitigation and resilient urban development strategies. The descriptive analysis method is carried out by direct observation of the characteristics and potential problems in Hamparan Rawang District. During the rainy season, several places in the watershed in the Hamparan Rawang District are prone to flooding. In 2016, the area of flood inundation in Hamparan Rawang District reached 11 percent of the area of Hamparan Rawang District. The area of flood inundation increased in 2020 to 18.58 percent of the area. In general, drainage channels in Hamparan Rawang District have reached almost the entire city area. However, its maintenance management has not been optimal, this is evidenced by the overflow of water onto the road surface when it rains. In the future, an inventory of these channels needs to be carried out because the drainage network with irrigation is still mixed with each other.

**Keywords:** district, flood disasters, hydrology, spatial planning, water resources



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## 1. Introduction

Hamparan Rawang District is an integral part of Sungai Penuh City, located in the highlands of Kerinci Valley, Jambi Province, Indonesia with an area of 11.15 km<sup>2</sup> consisting of 13 villages [1]. This district plays a crucial role in the overall spatial planning and development strategy of Sungai Penuh City. Hamparan Rawang District possesses significant potential for sustainable development and economic growth such as assessment of natural resources, geographical advantages, agricultures, fisheries, and economic opportunities from difference sectors of development. However, Hamparan Rawang District encounters significant environmental

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challenges that threaten its natural resources and ecosystems, biodiversity, and overall sustainable development and resilience. The average daily rainfall in Hamparan Rawang District in one year is around 49.4–169.2 mm/year, while the average daily temperature in one year is between 17.2 °C – 29.3 °C with air humidity being at 39% on average per year and the average wind speed in one year is around 13 m/sec [2]. In addition to that, Hamparan Rawang has three river namely Batang Merao River with waterflow debit of 270 m<sup>3</sup>/s, Air Sempit River with waterflow debit of 95 m<sup>3</sup>/s, and Air Hitam River waterflow debit of 90 m<sup>3</sup>/s [3]. Therefore, Hamparan Rawang also vulnerable to hydrological disasters such as floods due to its geographical and environmental characteristics.

In addition to that, population growth trends and demographic shifts is poised for significant development over the next two decades has an impact on land use change due to urbanization, agriculture expansion, and infrastructure demand [4, 5]. The change in agricultural land use to increasingly residential land is not accompanied by changes in channel design [6]. Changes in land use that are not in accordance with planning, especially in riverbank areas and canal bodies for residential areas, have an impact on reducing water catchment areas. Some of the existing channels are still natural channels even though the previously empty land has become densely populated. Therefore, hydrological analysis and spatial planning of Hamparan Rawang District is rigorously required for disaster mitigation and resilient urban development.

A systematic spatial planning is conducted to establish the physical and socio-economic development of regions, cities, and districts [7]. This approach including management of land use and development in a sustainable manner within a defined area. It involves analyzing current conditions, identifying opportunities and challenges, setting goals, and designing policies and strategies to guide future growth and development. Research on spatial planning have been conducted encompasses a broad spectrum of region and approaches, diverse case studies, and theoretical frameworks to explore innovative solutions for creating sustainable, inclusive, and resilient communities [8]. Previous research on hydrological analysis and spatial planning for Hamparan Rawang District is still rarely carried out. However, some study related have been conducted such as evaluation of land use and spatial patterns in flood plains in Sungai Penuh city [9, 10, 11], and Potential Land Development for Arabica Coffee in Sungai Penuh [12], and Collaborative Governance in Overcoming Floods in the City of Sungai Penuh [13, 14, 15] where Hamparan Rawang District is a part of it. As has been mentioned, several studies focus on the entire Sungai Penuh area and there is no specific and detailed research on the Hamparan Rawang area, especially hydrological analysis and spatial plans that focus on studying sustainable urban development models by understanding its unique context thoroughly. In this paper, we explores the current condition of Hamparan Rawang district, analyse the potential and challenges, predicting future challenges, and provide a comprehensive plan as strategic framework for sustainable development in Hamparan Rawang District. Research is focus on spatial planning of Hamparan rawang District in the hydrological field. Detail of the research results is explained in this paper.

## 2. Method

This research apply descriptive analysis which involves a comprehensive process of existing conditions analysis, identifying development goals, and designing a detailed land-use plan for a specific area, typically including steps like data collection, environmental assessment, and zoning regulations. All steps aimed at creating a sustainable and well-structured spatial development strategy. Descriptive analysis is intended to obtain information about various existing conditions

in the study area. The descriptive analysis method is carried out by direct observation of the characteristics and potential problems in Hamparan Rawang District. Primary data are collecting directly in site by using sampling maps, camera, and gps. The secondary data are obtained from literature, internet browser, or related agencies such as the Central Statistics Agency (BPS), Regional Development Planning Agency (BAPPEDA), Public Works and Spatial Planning Agency (PUPR) of Sungai Penuh City. Data then is analysed using ArcGIS software and other related tools to find a correlation between physical conditions reviewed from topography, climatology, and others that cause geological hazards, facilities and infrastructure so that the potential and existing problems can be estimated, which can then be used as a reference to provide solutions for spatial planning of Hamparan Rawang District.

### 3. Results and Discussion

#### 3.1 Current Physical Condition of Hamparan Rawang District

Hamparan Rawang District is located in Sungai Penuh City. The area of Hamparan Rawang sub-district is 1.115 Ha divided into 163 Ha buildings; 8,5 Ha yard; 50 Ha field; 643,3 Ha ricefields; 0,107 Ha fishpond; and 79 Ha others that are spread across 13 villages. Hamparan Rawang District is bordered to the north by Depati VII District, Kerinci Regency, to the east by Air Hangat Timur District, Kerinci Regency, to the south by Sungai Penuh District and Tanah Kampung District and to the west by Koto Baru District as shown in the administrative map of the Hamparan Rawang District Figure. 1.

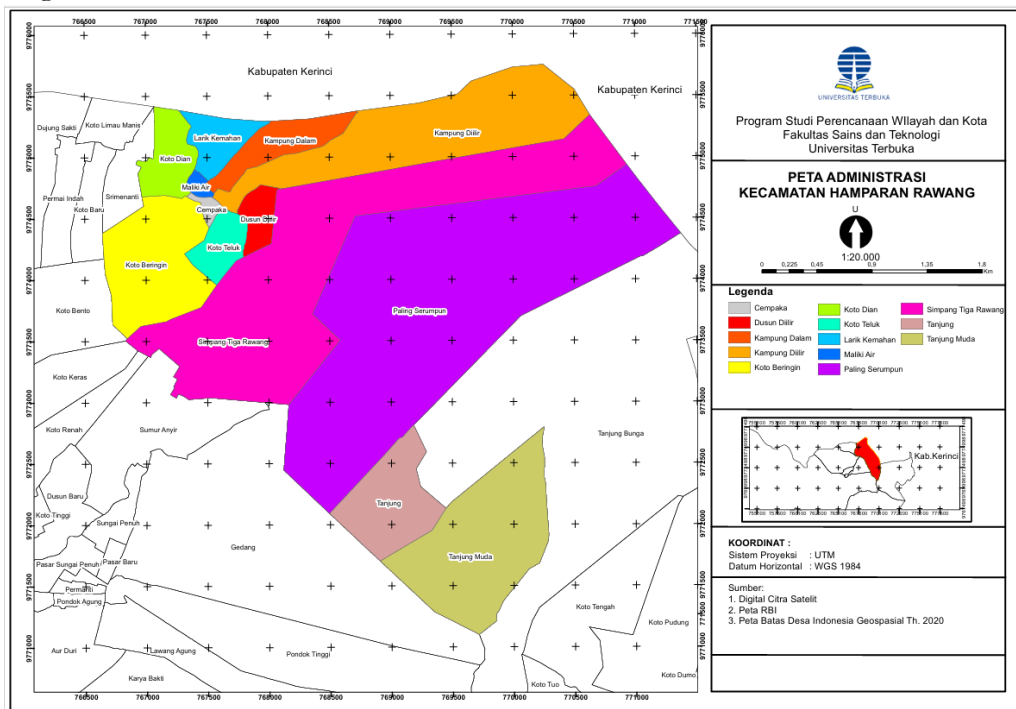


Figure 1. Administrative Map of Hamparan Rawang District

Hamparan Rawang District height is around 500-1000 m above sea level about 15.73 percent of the area, more than 1000 meters above sea level 83.75 percent of the area, while the remaining <1 percent is at an altitude of less than 500 meters above sea level. Hamparan Rawang District is the crossing point of the regional river system, which flows from upstream in the north to downstream

in the south. The drainage system in Hamparan Rawang District is supported by a regional river system, by channeling rainwater runoff that falls in Hamparan Rawang District to the related river system, which topographically flows downstream to the south of Kerinci Regency. Even though the location is on a plateau, the slope most of the Hamparan Rawang District area (which is 1044.9 Ha, 86%) is relatively flat as shown in Figure 2.

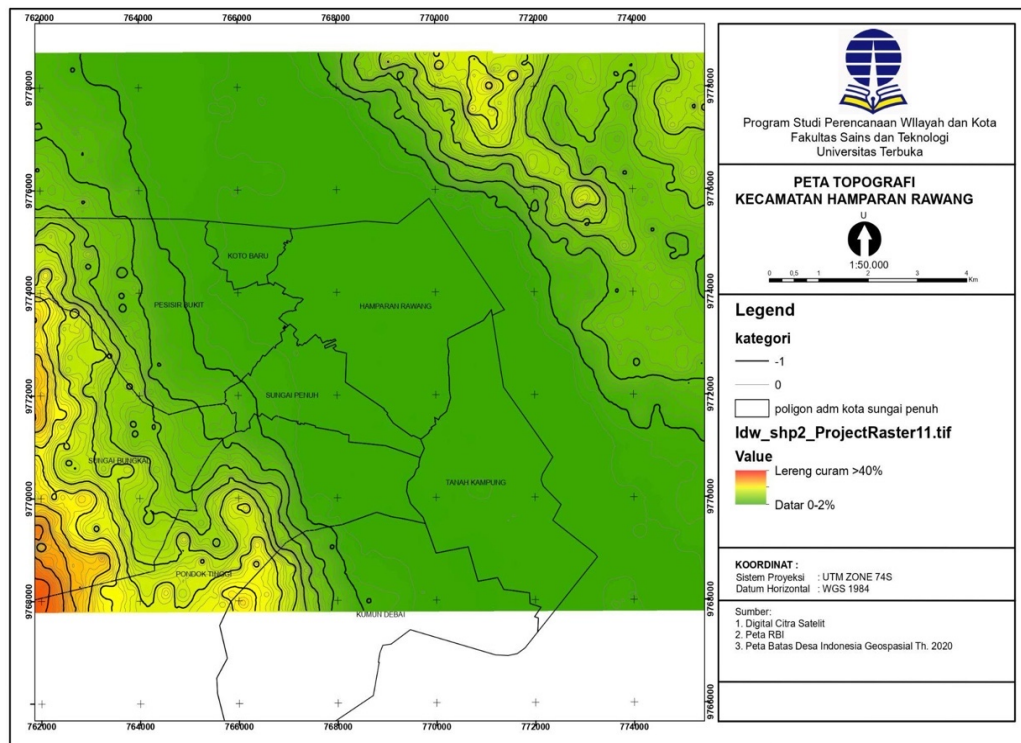


Figure 2. Topography map of Hamparan Rawang District

Hamparan Rawang District is regionally located in the Bukit Barisan environment which is formed by a hilly and mountainous landscape with generally high surface relief. The formation of the landscape that looks like today is greatly influenced by the composition of the rocks (lithology), the developing geological structure, and ongoing geological processes. Geological structures in the form of folds, faults and lineaments are often found in the Hamparan Rawang District area, where they generally trend southeast to northwest. The types of soil found in Hamparan Rawang District include 4 (four) types, namely: andosol (12,564 Ha; 32.09%), latosol (15,577 Ha; 39.79%), pedzolic (5,594 Ha; 14.29%), and alluvial (5,415 Ha; 13.83%). Utilization of alluvial type soil in agricultural businesses can be carried out in river deposit areas or tidal swamp areas, while alluvial soil derived from alluvium is generally fertile soil. The type of alluvial soil in Hamparan Rawang District is generally fertile land which is used for rice fields.

### 3.2 Hydrological Condition

Basically, the hydrological conditions of Hamparan Rawang District can be seen from the existence of water sources, whether in the form of surface water, springs or ground water. The hydrological map of Hamparan Rawang District can be seen in Figure 3. The Hamparan Rawang District area is included in the Batanghari River Watershed (DAS), which is a series of river watersheds in Kerinci Regency. The Kerinci Regency area is dominated by the Bukit Barisan



mountains, as part of the Bukit Barisan mountain range which extends along the West coast of Sumatra, the highest point is the peak of Mount Kerinci. There are many plains along the Bukit Barisan valley. The Bukit Barisan Mountains, which are located to the west and east of Kerinci, are the highest points in the Hamparan Rawang District and Kerinci Regency, so that all the rivers that flow in Hamparan Rawang District flow towards the center and south towards and empty into Lake Kerinci and then flow into the Batanghari River.

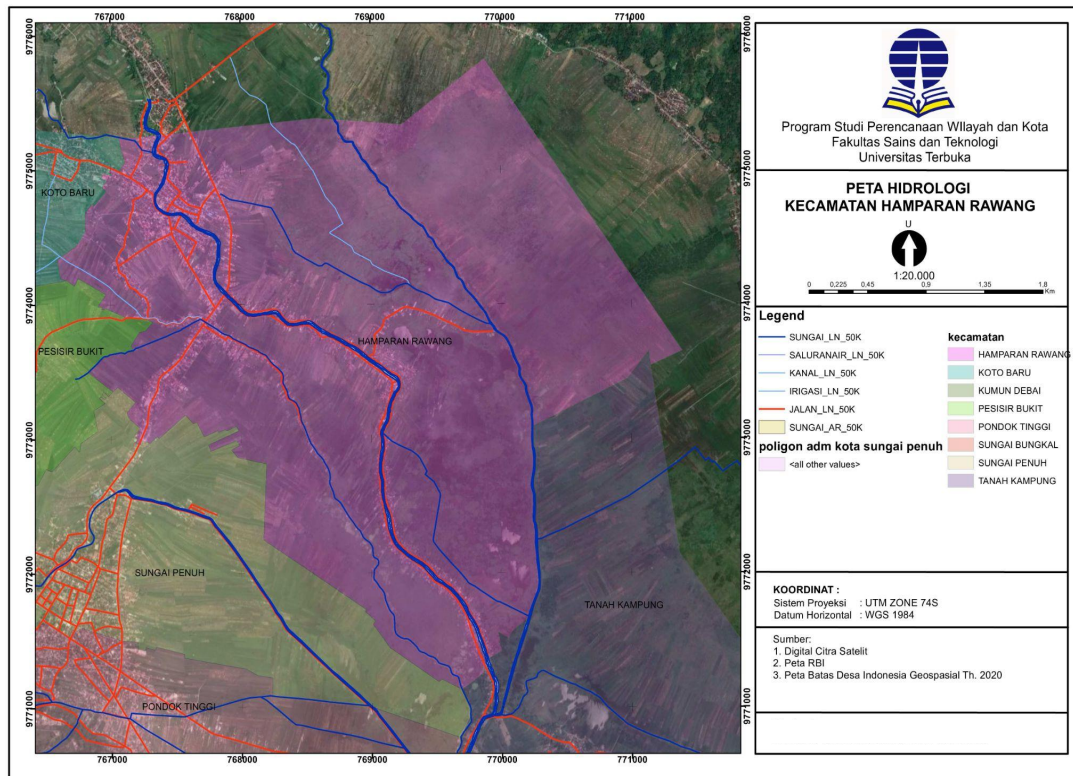


Figure 3. Hydrological Map of Hamparan Rawang District

Based on the results of regional hydrogeological investigations, the Hamparan Rawang District sheet can be divided into three aquifer productivity areas (water-bearing layers), namely: (1). Medium Productive Aquifers with wide distribution, low to medium continuity, varying groundwater levels and well discharge of less than 5l/sec; (2). Aquifers with low local productivity where generally low continuity, medium local, groundwater in sufficient quantities can be obtained especially in valleys or fault zones and weathering; and (3) Aquifers with high productivity.

Hamparan Rawang District also has a spring, which is formed from the bottom of the valley or the foot of the hills due to the presence of a layer of impermeable rock beneath it, so that the stretch does not continue inward but towards the cathedral and appears at the foot of the cliff/valley or foot of the hills. The presence of groundwater is influenced by rainfall, the area of the absorption area, the nature of the surface material and the rocks beneath it and morphology. Groundwater potential is generally relatively deep, around >60 meters. Almost the entire Hamparan Rawang District has an effective soil depth of >90 meters. The main rivers in Hamparan Rawang District are the Batang Merao River, the Air Sempit River, and the Air Hitam River. The physical profile of the river in Hamparan Rawang District is shown in Table 1.

Table 1. Physical Profile of Rivers in Hamparan Rawang District

No	River	Length (m)	Width (m)		Depth (m)	Debit (m <sup>3</sup> /s)	
			Surface	Base		Max	Min
1	Batang Merao	10247	20,00	16,00	5,00	270,00	6,00
2	Air Sempit	1140	6,00	4,00	2,00	95,00	0,95
3	Air Hitam	2793	10,00	8,00	3,00	90,00	0,80

Source: Public Works and Spatial Planning Agency, 2020

Hydrological conditions in Hamparan Rawang District based on field surveys there are three rivers, namely Batang Merao River, Air Sempit River, and Air Hitam River. Batang Merao River has a relatively wide width but lacks maintenance. The condition of Air Hitam River is located between rice fields which are one of the sources of irrigation for the rice fields. While Air Sempit River is located near a shopping center so that the condition of the river is full of garbage, does not get attention and maintenance from the community.

### 3.3 Climatology Condition

Hamparan Rawang District had an average temperature of 23.1<sup>0</sup>C during 2020. The maximum temperature of 29.4<sup>0</sup>C occurred almost every month, and the minimum temperature of 18.8<sup>0</sup>C occurred almost every month. In 2019, the average rainfall per month was 156.9 mm with the lowest rainfall of 37.8 mm occurring in August and the highest rainfall of 342.5 mm occurring in December. The average rainfall per month throughout 2020 was 181.8 mm with the lowest rainfall of 25.5 mm occurring in July and the highest rainfall of 268 mm occurring in January. The average relative humidity per month in 2019 was 82 percent with the lowest humidity of 76 percent (September and October) and the highest humidity of 87 percent occurring in December. In 2020, the average relative humidity per month was 81 percent, with the lowest humidity of 74 percent in December and the highest humidity of 83 percent occurring in January, March, April and November. The area in Hamparan Rawang District that is traversed by active faults covers the entire area.

Tabel 2. Rainfall Intensity Score

Class of Slope	Rainfall Intensity	Description	Score
1	0-13,6	Very Low	10
2	13,6-20,7	Low	20
3	20,7-27,7	Medium	30
4	27,7-34,8	High	40
5	>34,8	Very High	50

As with the previous score determination analysis, in determining the score value for rainfall intensity, the score that has been determined will also affect the land suitability class that will be obtained in Hamparan Rawang District where the score value for rainfall intensity >34.8 (very high) is determined as Tabel 2.

### 3.4 Disaster Prone Area

Disaster-prone areas in Hamparan Rawang District consist of areas prone to ground movement, areas prone to inundation (floods) and fault line areas (earthquakes). The Hamparan Rawang District area in particular is generally included in the MMI scale V, VI and VII earthquake

zones. Floods have the potential to occur in the Hamparan Rawang District, which is caused by high and long-lasting rainfall in the upstream part of the Batang Bungkal River and Ampuh River Watersheds which merge into the Batang Bungkal River water body towards the rivers in the Hamparan Rawang District area, namely the Batang Merao River, Air Sesat River, and Air Hitam River. Floods according to Law Number 24 of 2007 concerning Disaster Management are events or conditions in which an area or land is submerged due to increased water volume. Rainwater absorption in the upstream part is not good so that water flows directly into the surrounding river basin area which flows directly into the Batang Bungkal River which crosses the Sungai Penuh City area then heads to the Batang Merao River, Air Sesat River, and Air Hitam River. This has the potential to cause negative impacts on physical buildings, bridges, and houses around the riverbanks. Other impacts greatly affect the Kerinci Regency area which is located in the downstream part of the river. Flood-prone areas in Hamparan Rawang District include land around the watershed and its tributaries. Based on the results of the flood risk analysis, it is estimated that flood-prone areas are located in part of Sungai Penuh District, part of Hamparan Rawang District and part of Tanah Kampung District and Kumun Debai District covering an area of 1,049 ha. Therefore, there needs to be preparedness from the city to face this risk.

### 3.5 20 years Projection of Hydrological Facilities Requirements

To determine the public facility needs of Hamparan Rawang sub-district for the next 15-20 years, we must refer to population data for the last 5 years. The following is population data for the last few years:

Table 3. Population of Hamparan Rawang District 2017-2022

No.	Year	Male	Female	Total
1.	2017	6772	6988	13760
2.	2018	6874	7076	13950
3.	2019	6966	7193	14159
4.	2020	7077	7304	14381
5.	2021	7519	7613	15132
6.	2022	7746	7683	15429

Based on the table above, it can be seen that the average annual population growth is 334 people. This is caused by birth factors and the number of immigrants who live in the Hamparan Rawang sub-district area. The population growth rate can be calculated using the following equation [16]:

$$r = ((Pt/Po)^{1/t}) \times 100\%$$

Where:

Pt = Population in year t (15429 people)

Po = Population in the initial year (13760 people)

r = population growth rate

t = time period between the initial year of and year t (2022-2017 = 5 years)

Based on these data, the population growth rate of Hamparan Rawang District is 2.2%. Using this data, a population growth projection for the next 10 years can be made. Population projections are made to estimate population growth in the future. Population growth projections are needed to map the needs of residential facilities and infrastructure. To project the population of Hamparan Rawang District in the next 10 years (2022-2032), the geometric projection method will be used.

Therefore, it can be seen that the future population growth rate is taken based on the average percentage of population growth over the last 5 years in Hamparan Rawang District. The calculation of population projections according to the geometric method uses the following formula [17]:

$$P_t = P_o(1+r)^t$$

Where:

$P_t$  = Population in year  $t$

$P_o$  = Population in the initial year

$r$  = population growth rate

$t$  = time period between the initial year and year  $t$

The Geometric Method is a population projection method where population growth is proportional to the population figures at that time and is graphically logarithmic. Or in other words, this method is based on the average annual population growth ratio. Projections with this method assume that population growth automatically doubles. With the initial population growth. This method observes that at one time there was a decline in development and then settled because the population density was approaching the maximum. From Table 4, the population projection calculation above can be seen that the population in the next ten years will be 19,180 people, or an increase of 3,751 people. In addition to that, the population in the next twenty years will be 23,842 people, or an increase of 8,413 people.

Table 4. Population Projection of Hamparan Rawang District in the Next 20 (Twenty) Years

No	Year	Population Projection
1	2023	15.768
2	2024	16.115
3	2025	16.470
4	2026	16.832
5	2027	17.203
6	2028	17.581
7	2029	17.968
8	2030	18.363
9	2031	18.767
10	2032	19.180
11	2033	19.601
12	2034	20.033
13	2035	20.473
14	2036	20.924
15	2037	21.384
16	2038	21.855
17	2039	22.335
18	2040	22.827
19	2041	23.329
20	2042	23.842

The guidelines for determining minimum service standards issued through the decree of the Minister of Settlement and Regional Infrastructure [18]. The standard for arranging settlement facilities is a reference framework that functions as planning, designing and the need for facilities in space. Based on the minimum standard guidelines, minimum standards required for clean water



facilities 55 to 75% of the population is served, with requirements water debit is 6-220 liters/person/day. The drainage or flood control should be make height of inundation less than <30 cm, duration of inundation/2 hours, frequency of inundation maximum 2 times a year. In addition to that, a septic tanks and toilets are adjusted by the community and provided a septic tank car should be available to serve a maximum of 120,000 people. Those facilities availability should be adjusted based on population growth. Therefore, development planning can used the projection of population growth in 20 years.

### 3.6 Water Resources Facilities

Hamparan Rawang District is crossed by three rivers, namely the Batang Merao River, the Air Sesat River and the Air Hitam River and has many springs with varying discharges. Considering that rivers and springs are vital facilities in agricultural activities, this needs attention and priority. The irrigation network in Hamparan Rawang District is spread across every Sub-district / Village, the area of irrigation services in Hamparan Rawang District reaches 4,348 ha. The condition of the irrigation network in Hamparan Rawang District in 2016-2020 continued to improve, in 2016 the irrigation network was in good condition by 52.21 percent increasing to 64.13 percent in 2020. The condition of the irrigation network in Hamparan Rawang District in 2016-2021 can be seen in the following table:

Table 5. The Condition of Irrigation Network in Hamparan Rawang District

Year	Condition of Irrigation Network (%)			
	Fair	Minor Damage	Medium Damage	Severely Damage
2016	52,21	3,33	6,96	37,49
2017	55,86	3,13	5,96	35,05
2018	58,32	3,73	4,48	33,46
2019	62,98	3,73	4,48	28,79
2020	64,13	3,98	4,68	27,21

Source: Public Works and Spatial Planning Agency, 2021

The good condition of the irrigation area in 2016 was 2,521 ha or 57.98 percent, in 2020 the irrigation area in good condition was 2,229.17 ha or 51.27 percent. During the rainy season, several places in the watershed in the Hamparan Rawang District are prone to flooding. In 2016, the area of flood inundation in Hamparan Rawang District reached 11 percent of the area of Hamparan Rawang District. The area of flood inundation increased in 2020 to 18.58 percent of the area. This happens because the flood inundation areas are areas that are lower than the surrounding areas and the drainage capacity is inadequate, the act of throwing garbage into the river is also a result of these places being flooded. In addition, changes in land use around the river have an impact on the increasing area with impermeable surfaces, thus disrupting the process of water infiltration into the soil, causing rainwater to overflow on the ground surface.

Drainage management in Hamparan Rawang District is handled by the Public Works Department. In general, drainage channels in Hamparan Rawang District have reached almost the entire city area. Drainage channels aim to drain rainwater runoff in the form of artificial drainage or natural drainage. However, its maintenance management has not been optimal, this is evidenced by the overflow of water onto the road surface when it rains. In the future, an inventory of these channels needs to be carried out because the drainage network with irrigation is still mixed with

each other. Drainage channels have a pattern that is parallel to the road. With relatively sloping topography, and with the city's height above sea level which is quite high, this can provide benefits for water flow in the drainage system so that surface flow flows directly to the lower plains, namely the Batang Merao River. The drainage system in Hamparan Rawang District is generally divided into three systems:

- Open drainage system: The current open drainage system is sufficient to accommodate and drain water.
- Closed drainage system: The current closed drainage system is also quite adequate, but is constrained in cleaning/dredging sediment, due to the presence of some shops above the channel.
- Ground channel drainage system: This system has been around for a long time and is very useful for city drainage when it rains so that the existing ground drainage can accommodate quite high rainfall loads.

The general condition of the channels can be described as follows:

- The condition of the channels in the residential environment in Hamparan Rawang District generally flows on the side of the highway or main road, where the main road currently has a fairly good drainage channel so that both in the rainy season and the dry season, the drainage channels in the residential environment and on the main road can still handle water entering the channel.
- The location of Hamparan Rawang District has a hilly contour, so that water flows using gravity to a lower place.
- City drainage uses closed channels, the top of the channel cover is used as a site walk/sidewalk, manhole to determine the smoothness of water flow.
- There are still puddles during the rainy season in several places due to the lack of drainage and sedimentation.
- The dimensions of the channels are not uniform, resulting in rainwater overflowing onto the road.

### 3.7 SWOT analysis

Hamparan Rawang District has abundant natural resources, such as agricultural land and is located around Batang Merao. The designated fisheries area is spread throughout the districts in Sungai Penuh City, the direction for developing this area is carried out in each district to utilize the Batang Merao River as an area for developing inland fisheries cultivation and developing the Fish Seed Center to support the development of fisheries cultivation. However, there is no waste management system yet, because people process waste by collecting waste and burning it in their yards. In addition, many people still throw waste into rivers such as the many piles of garbage in the Air Sempit River. Another problem is uneven drainage and sanitation systems.

The areas around the Batang Merao River, Air Sempit River and Air Hitam River have the potential to cause flooding in the Hamparan Rawang District and its surroundings. Moreover, the condition of the Air Sempit River which is located in the middle of the community's economic center, is full of piles of garbage. As an area located around a river, it has the potential for flooding. The impact of the flood disaster also resulted in losses starting from the destruction of residents

houses and reducing the potential in the agricultural and fisheries sectors. The land cover condition of Hamparan Rawang District, Sungai Penuh City is dominated by agricultural and residential land, which of course requires good quality drainage systems. However, the condition of the Air Sempit River is very concerning because there is a lot of garbage in the river basin which has an impact on Hamparan Rawang District becoming one of the areas prone to flooding every year in the Sungai Penuh City area.

To reduce floods in Hamparan Rawang, a combination of engineering, environmental, and planning strategies must be implemented. One of the most effective approaches is improving stormwater management systems by upgrading and expanding drainage infrastructure to handle heavy rainfall. The use of detention and retention basins can also help by temporarily storing excess water and releasing it slowly. Incorporating permeable surfaces, such as permeable pavements and green areas, allows water to infiltrate the ground instead of running off into the streets. Green infrastructure, including green roofs, rain gardens, and urban forests, not only helps absorb rainwater but also improves air quality and urban aesthetics. Additionally, regular maintenance of drains, public education on waste disposal, and community-based rainwater harvesting systems support flood prevention at the local level. Together, these integrated strategies can significantly reduce the risk and impact of flooding.

#### 4. Conclusion

The hydrological conditions of Hamparan Rawang District can be seen from the existence of water sources, whether in the form of surface water, springs or ground water. The Hamparan Rawang District area is included in the Batanghari River Watershed (DAS), which is a series of river watersheds in Kerinci Regency. The good condition of the irrigation area in 2016 was 2,521 ha or 57.98 percent, in 2020 the irrigation area in good condition was 2,229.17 ha or 51.27 percent. During the rainy season, several places in the watershed in the Hamparan Rawang District are prone to flooding. In 2016, the area of flood inundation in Hamparan Rawang District reached 11 percent of the area of Hamparan Rawang District. The area of flood inundation increased in 2020 to 18.58 percent of the area. In general, drainage channels in Hamparan Rawang District have reached almost the entire city area. Drainage channels aim to drain rainwater runoff in the form of artificial drainage or natural drainage. However, its maintenance management has not been optimal, this is evidenced by the overflow of water onto the road surface when it rains. In the future, an inventory of these channels needs to be carried out because the drainage network with irrigation is still mixed with each other.

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