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INNOVATIVE STRATEGIES FOR MANAGING HYDROMETEOROLOGICAL DISASTER RISKS: OPTIMIZING ENVIRONMENTALLY FRIENDLY DRAINAGE SYSTEMS (ECO-DRAINAGE) TO PREVENT FLOODING AND OVERFLOW IN CLIMATE CHANGE ADAPTATION IN KARAWANG REGENCY

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Abstract

Urban drainage is a network system for waste disposal in urban areas that functions to manage or control surface water, so that it does not disrupt or harm the community and provides benefits for human activities. This research aims to create synergy and steps for the implementation of eco-drainage in the urban characteristic conditions of Karawang Regency. The method used involves data collection through observation, interviews, historical data analysis, and mapping based on SNI Number 02-2406-1991 regarding the General Planning Procedures for Urban Drainage. The research results indicate that the Eco drain infrastructure consists of 7 elements, namely rainwater harvesting, infiltration wells, retention ponds, trash filters, bioremediation, biofilters, and water quality treatment using constructed wetlands. Meanwhile, the local government of Karawang Regency does not yet have the infrastructure to implement eco-drainage. After conducting an analysis, it was determined that among the 7 elements of eco-drainage, rainwater harvesting is the most needed to address the issues of flooding and drought in the Karawang area. The research results also include calculations and explanations regarding the Eco drain facilities for rainwater collection on a land scale and environmental/community storage tanks, as well as the quality of rainwater in Indonesia.

Keywords: Hydrometeorological Disasters, Ecological Drainage, Climate Change

Introduction

Law Number 24 of 2007 (Undang-Undang Republik Indonesia Nomor 24 Tahun 2007 Tentang Penanggulangan Bencana, 2007) on Disaster Management is a law that regulates the fundamentals of disaster management, which is the responsibility and authority of the Government and local governments, carried out in a planned, integrated, coordinated, and comprehensive manner; disaster management is conducted at the pre-disaster stage, during the emergency response, and post-disaster, as each stage has different handling characteristics; during the emergency response, disaster management activities, in addition to being supported by the state budget (APBN) and regional budget (APBD), also have ready-to-use funds provided with accountability through a special mechanism; and oversight can be conducted by the government and the community (Ghani et al., 2004).

With the enactment of Law Number 24 of 2007 concerning Disaster Management and to realize this, in 2008 the government issued Government Regulation Number 21 (Peraturan Pemerintah (PP) Nomor 21 Tahun 2008 Tentang Penyelenggaraan Penanggulangan Bencana, 2008) on the Implementation of Disaster Management, which allows innovative strategies such as Eco-drainage to be implemented in a structured manner and in accordance with the applicable legal framework. This provides a foundation for disaster investigation and evaluation, supports the understanding of hydrometeorological disaster risk factors, and ensures that risk mitigation actions are carried out in accordance with applicable legal principles (Yendri & Andry, 2021). Thus, this law becomes an important instrument in the effort to achieve disaster resilience and climate change adaptation in Karawang Regency.

Eco-drainage is carried out in stages, from prevention before a disaster occurs, response during a disaster, and recovery after a disaster (Siswarsito & Hakim, 2021). These stages are part of a cycle of activities for managing flood and inundation disasters, water pollution, and the accumulation of aquatic waste that is continuous (Wibisono et al., 2022). Ecological drainage activities follow a life cycle that begins long before a disaster occurs, through planning and development activities, action plans, and preventive measures (Anggraeni et al., 2013). The next step is pre-disaster activities and the period leading up to a disaster, which includes mitigation and disaster preparedness. When a disaster occurs, stakeholders are recommended to manage the impacts through response actions, and in the post-disaster phase, recovery actions and studies can be conducted for planning and developing disaster management strategies (Firmansyah et al., 2019).

"Climate Change Adaptation Through the Implementation of Environmentally Conscious Drainage (Eco Drain)" researched by Joleha et al. (2023), using a literature review method and scientific information from books, journals, and research report drafts, with data analysis utilizing Microsoft Excel software and applications. The research findings indicate that an area of 2.38 hectares experiences a flow rate of 1.19 m3/second. Meanwhile, the design of individual infiltration wells for 143 houses results in a storage capacity of 0.88 m3/second and is capable of reducing runoff by 73.95%.

"Planning an Environmentally Friendly Drainage System (Eco-drainage) in Sekaran Village, Gunungpati District, Semarang City," researched by Ulya et al. (2015). This research method involves interviews and observations conducted on three aspects, namely (1) Evaluation of the existing conditions of the drainage system in the planned area, Wibisono et al. (2022) development of an environmentally conscious drainage system, and Arahuetes & Olcina Cantos (2019) comparison of the existing drainage system with ecodrainage. The research findings indicate that the presence of an environmentally conscious drainage system can reduce the amount of rainwater runoff entering the drainage channels by 7.61 m3/second, resulting in a total runoff entering the drainage channels of only 9.02 m3/second. "The Environmentally Conscious Drainage System (Ecodrain) at the Backup Depot Area of KBN SBU Marunda Area" researched by Wibisono et al. (2022). This research method uses a quantitative research type, interviews, and documentation with descriptive analysis. From this research, a closed channel made of concrete was obtained for the central part of the depot, supplemented with 45 infiltration wells measuring 10 cm in diameter and 20 cm in depth. The planned channel system aims to reduce the runoff discharge from 0.1211 m^3/s to zero runoff (Wismarini & Ningsih, 2010).

"Study on the Application of Ecodrain in Urban Drainage Systems (Case Study: Sawojajar Housing Complex, Malang City)" researched by Ardiyana et al. (2016). This research was conducted by processing data obtained through modeling rainfall runoff with a return period of 5 years using the Storm Water Management Model instrument. (SWMM). The percentage reduction in runoff flow from land and channels with the implementation of infiltration wells, bioretention, and permeable pavements ranges from 14.49% to 92.26%, while the reduction in flood discharge at the final outlet reaches 37.55%. Based on the considerations of the references used, this test is planned to employ direct survey methods and interviews. In the data collection process, it is carried out in a way (Felix & Sentosa, 2020).

Research Methodology

In general, the stages of this research implementation consist of: Preparation Stage, Data Collection Stage, Analysis and Review Stage, and Finalization Stage. The arrangement of the stages of this research is tailored to the reporting needs, where the objectives of each stage are as follows: The Preparation Stage includes preparatory activities that will significantly influence the processes carried out in the subsequent stages. The initiation of the study involves team consolidation, literature review, and solidifying the methodology. The survey preparation includes selecting the survey method based on the results of discussions. A structured interview method was chosen for stakeholders such as the Public Works and Spatial Planning Office of Karawang Regency, the Regional Disaster Management Agency of Karawang Regency, and the Regional Development Planning Agency of Karawang Regency. Following that, an observational survey method will be used at several location points. Afterward, the preparation of forms and survey equipment will take place, along with determining the points and number of survey samples in accordance with the recommendations from the structured interviews with stakeholders, as well as the Human Resources (HR) for the introduction to the study area, which includes the survey locations and the preparation of the survey team. The output at this stage is the selection of methods and ways to conduct field surveys, accompanied by a timeline to ensure that the research implementation is more focused. The Data Collection phase includes the implementation of primary surveys consisting of: problem data and quantitative data at each inundation and/or flood location, which includes area, duration, average depth, and frequency of inundation; data on the condition of functions, systems, geometry, and dimensions of channels; data on river basins or channels that includes topography, hydrology, river morphology, soil characteristics, land use, and so on; data on existing and planned urban infrastructure and facilities.

The Analysis Stage includes initial analysis activities in the form of identifying reviews present in the checklist for each field. Further analysis involves finalizing the report of the team's findings. The output at this stage consists of the results of data analysis from field surveys and interviews, which are analysed using descriptive analysis and refer to SNI Number 02-2406-1991. Finalization Stage, which includes activities for substantial and editorial refinement based on input from the Team.

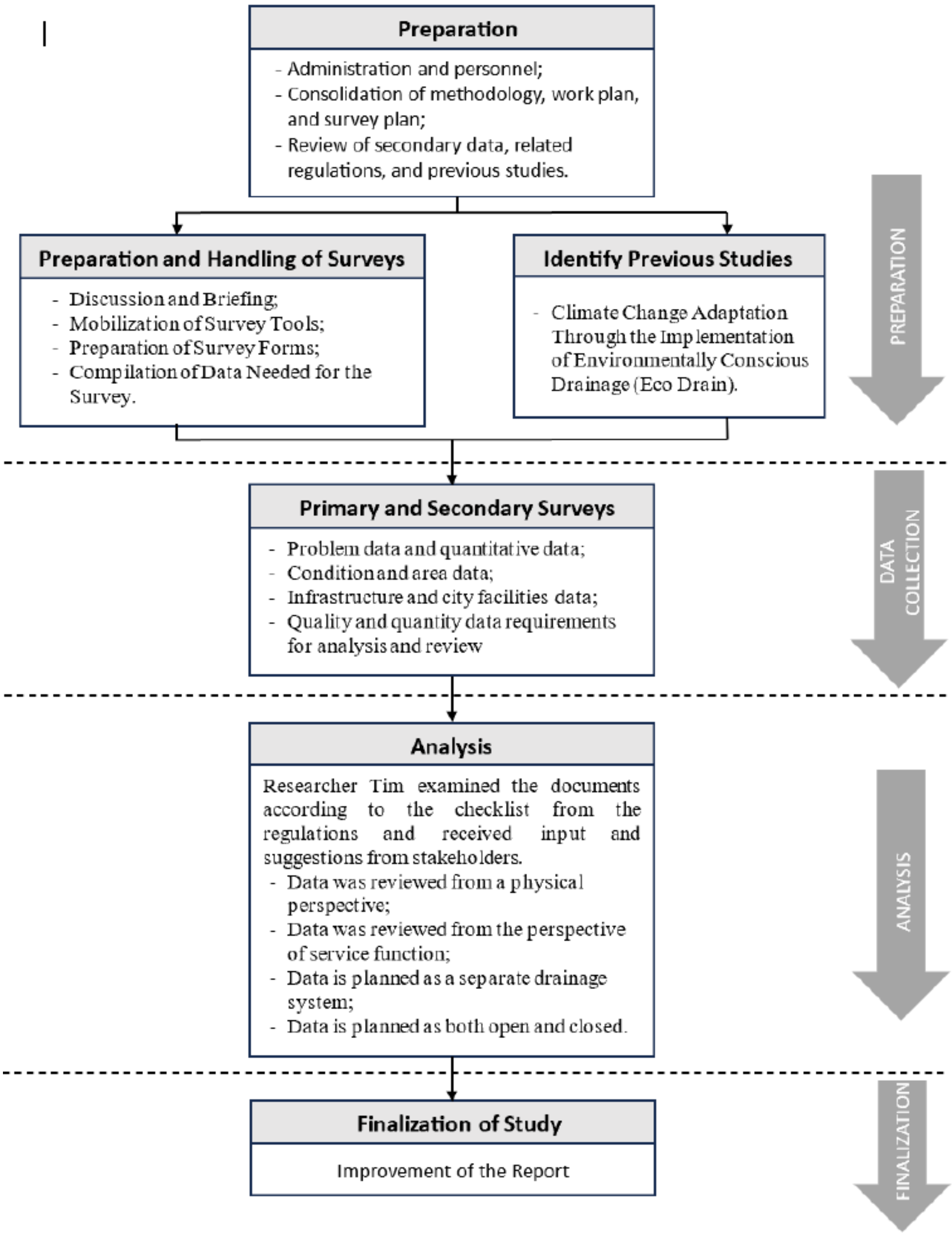

Figure 1. Research Flowchart

types of research, time and place of research, targets/objectives, research subjects, procedures, instruments and data analysis techniques, as well as other matters related to the research methods. targets/objectives, research subjects, procedures, data and instruments, data collection techniques, and data analysis techniques, as well as other matters related to the research methods.

Research Results and Discussion

Karawang Regency is one of the regencies in West Java Province, which has a topology where most of its area consists of lowlands, and a small part consists of highlands. Based on these conditions, Karawang Regency is classified as a disaster-prone area, susceptible to natural disasters such as floods, landslides, and tornadoes.

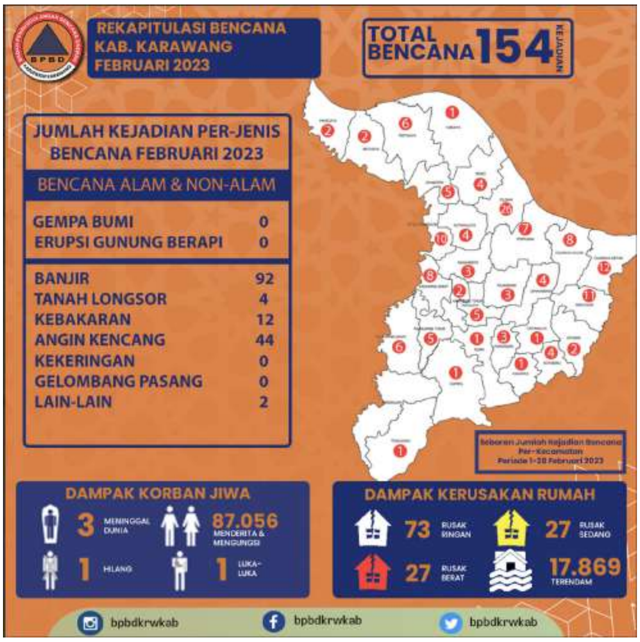

Figure 2. The Worst Disaster Conditions of 2023

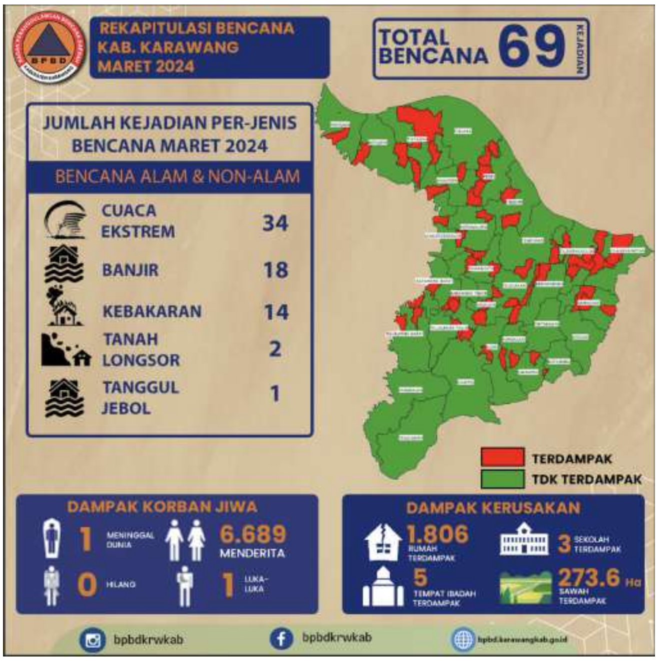

Figure 3. The Worst Condition of the Disaster in 2024

According to the data in Figure 2, the worst disaster conditions in 2023 occurred in February, with a total of 154 disaster events, consisting of 92 flood incidents. Similarly, the data in Figure 3 represents the Worst Disaster Conditions in 2024, specifically in March, with a total of 69 incidents, including 18 flood events (Yunianta et al., 2018). The necessity for development in Karawang Regency needs to consider the carrying capacity of natural resources and the environment, waste management, vulnerability to disasters, as well as climate change issues such as drought and others. Based on SNI Number 02-2406-1991, discussions with local government officials, and collaborative analysis with the research team, it is concluded that to address the issues of flooding and drought, Rainwater Harvesting (RWH) is needed in Karawang Regency.

Rainwater Harvesting (RWH)

Rainwater harvesting is one of the structural solutions for collecting rainwater on a scale from individual plots, community environments, to larger areas, so that it does not directly enter drainage systems and ultimately get discharged into the sea (Putra, 2021). This technology is very simple; it involves collecting rainwater that falls on the roof of a house/building using a specific container. Water in storage can be used for watering plants, filling fish ponds, washing vehicles, and more. In this way, the peak surface flow discharge around the location will decrease. The types of Rainwater Harvesting Systems are divided into individual scale storage tanks and community/environmental scale storage tanks (Ellis et al., 2003).

An explanation regarding the utilization of rainwater (URW) is conducted both at the plot scale and the regional scale, which is expected to provide an overview of the utilization system and its application in supporting the implementation of ecodrain (Desain et al., 2013). This aligns with the explanation in the book "Guidelines for Integrated Environmentally Sound Drainage Management (Ecodrain)" issued by the Ministry of Public Works, Directorate General of Human Settlements in 2013, the scope of ecodrain services is classified into plot scale, environmental/community scale, and regional scale (Subekti et al., 2023). Review of Rainwater Harvesting (RWH) Ecodrain Facilities, it will be carried out using a capacity calculation approach and the utilization of Rainwater Harvesting (RWH), which is expected to provide an overview of the potential for rainwater utilization in supporting water supply needs (Andana et al., 2016). Designing a Rainwater Harvesting (RWH) system requires several calculations and important data to determine the system's capacity and its effectiveness in collecting and utilizing rainwater. The data needed includes rainfall data, the area of the collection surface, runoff coefficient data, water demand data, and storage capacity data (Pratama et al., 2018).

Persil Scale

An explanation regarding the ecodrain Rainwater Harvesting Facility (RHF) for parcel scale will be conducted through an example calculation of the availability of Rainwater Storage Tanks, illustrated as follows:

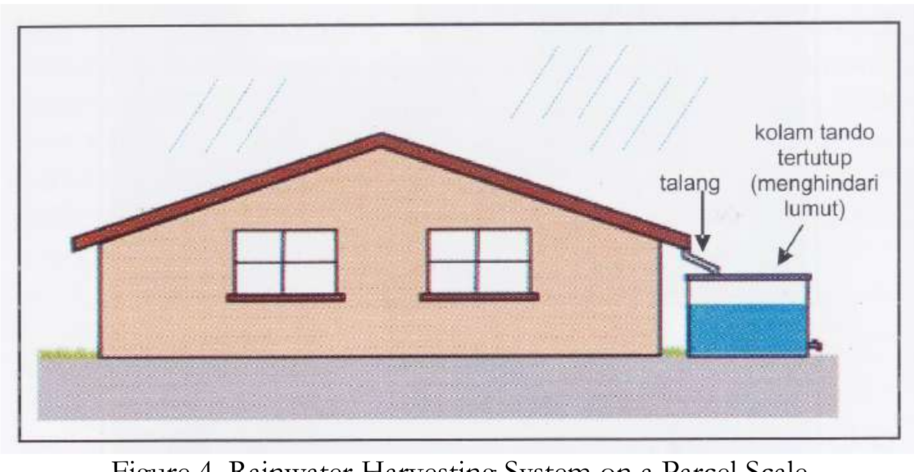

Figure 4. Rainwater Harvesting System on a Parcel Scale

It is known :

- Roof area of the plot: $A = 100\ m^2$;
- Rainfall intensity: $I = 25$ mm/hour;
- Duration of rainfall (length of rain): $T = 1.5$ hours/1 rainfall event.

Solution:
The volume of rainwater that falls on the roof of the plot will be channeled to the Rainwater Storage Tank as follows:
$V = \alpha \,.\, \beta \,.\, I \,.\, A \,.\, T$
$V = 0.9 \times 1 \times 0.025 \times 100 \times 1.5$
$V = 3.375\ m^3$ (1 rainfall event)

Assuming it rains 3 times a week, the volume of rainwater during 3 days of rain in a week can be calculated (Zakaria et al., 2018). The approach of using three times the rainfall per week provides a more detailed and specific calculation for certain rainfall patterns, while using the average rainfall is more suitable for long-term planning and gives an overview of the potential rainwater that can be collected over a year or month (Sumarno, 2017). The details of the calculation are as follows:

$V = 3.375$ X 3 days $= 10.25\ m^3$.

Where:
V = Volume of rainwater storage (m^3)
α = Runoff coefficient
β = Rain distribution coefficient
I = Rain intensity (mm/hour)
A = Roof area of the building (m^2)
T = Duration of rain (hour)

The utilization of rainwater is assumed for a family with 4 members, and with a daily water requirement set between 60 – 120 liters per person, the calculations can be made as follows:

- Daily requirement: 4 people x 120 liters/person = 480 liters (for each household)
- Weekly requirement: 480 liters x 7 days = 3,360 liters = 3.36 m3

With the availability of water in 1 week amounting to $V = 10.25\ m^3$, what is the remaining water in the reservoir after 1 week :

$$10{,}25\ m^3 – 3{,}36\ m^3 = 6{,}89\ m^3 = 6.890 \text{ liter}$$

The remaining water in the reservoir can be used for other purposes to support household and environmental needs (Sidek et al., 2002). The approach to calculating the capacity of rainwater storage volume on the plot scale mentioned above can be used as a basis for similar calculations on a community or environmental scale, using the same calculation patterns and approaches for several plots combined into one storage tank (Suartana, 2023).

Area Scale
At the area scale, an example of calculating the availability of Rainwater Harvesting Tanks will be taken from an industrial area (Desain et al., 2013), with the following description:
Given:

- Two industrial buildings with roofs measuring 100 meters in length and 50 meters in width;
- Rainfall intensity: I = 25 mm/hour;
- Duration of rainfall: T = 1.5 hours/1 rainfall event.

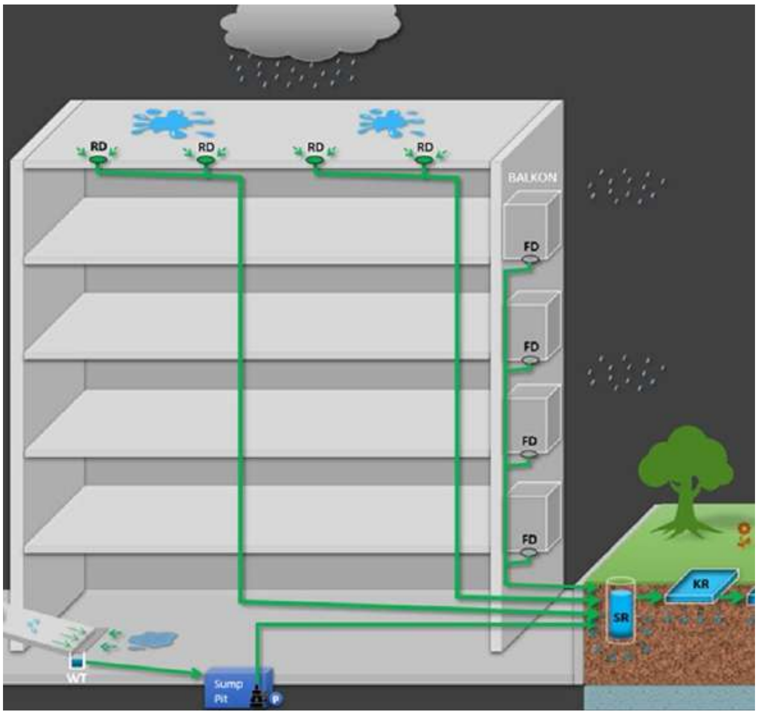

Figure 5. Rainwater Harvesting System on a Regional Scale (Industri)

Solution:
The area size of the roofs of 2 (two) industrial buildings is :
A = 2 x 100 m x 50 m
= 10.000 m^2

The volume of rainwater that falls on the roof of the property will be channeled to the Rainwater Collection Tank of :
V = α . β . I . A . T
V = 0,9 x 1 x 0,025 x 10.000 x 1,5
V = 337,5 m^3 (1 rainfall event)
Assuming that it rains 3 times a week, we can calculate the volume of rainwater that will be produced over 3 days of rain in a week :
V = 337,5 X 3 hari
= 1.012,50 m^3 (3 rainfall event)

With illustrations of the calculations for the volume of rainwater that can be collected on a plot and area scale, it is evident that the potential for utilizing rainwater is quite significant in supporting water needs and other activities (Hendriyani et al., 2022).

The Quality of Rainwater in Indonesia

The Meteorology, Climatology, and Geophysics Agency Indonesia (BMKG) operates 27 rainwater quality monitoring stations spread across Indonesia. The monitored parameters include acidity level (pH), electrical conductivity, concentrations of cations such as Magnesium (Mg), Calcium (Ca), Ammonium (NH4), Sodium (Na), and Potassium (K), as well as concentrations of anions such as Sulfate (SO4), Nitrate (NO3), and Chloride. (Cl) (Idfi et al., 2018). Among these various components, the acidity level (pH) of rainwater receives special attention, especially in its use as drinking water or for other purposes related to easily corrodible materials. The internationally accepted pH limit for rainwater is 5.6, which is considered the normal or natural pH value. If the pH of rainwater is lower than 5.6, it is acidic, while if it is higher than 5.6, it is basic. Acid rain with a low pH can cause corrosion on buildings and construction materials, as well as damage the ecology of plants, forests, lakes, and rivers. charge. Grassed swale system in Engineering (Lai et al., 2009). Monitoring results indicate that the quality of rainwater has declined. pH data of rainwater in June 2024 shows that almost all regions in Indonesia have rainwater with a pH of less than 5.6 (Figure 6).

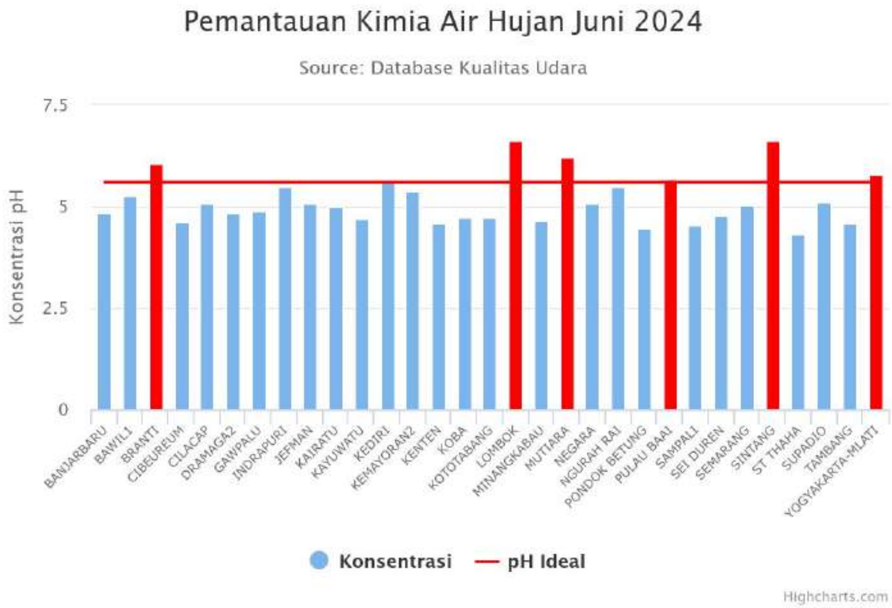

Figure 6. Chemical Monitoring of Rainwater in June 2024 in Indonesia.

Rainwater pH Description:

- > 7: Basic pH;
- 6.1 - 7: Very good rainwater, tends to be neutral like surface water;
- 5.6 - 6: Ideal rainwater pH;
- 4.1 - 5.5: Acid rain;
- 3 - 4: High acid rain;
- < 3: Acid rain.

Referring to the results of the monitoring, it can be concluded that the quality of rainwater in Indonesia no longer meets international standards for rainwater that can be consumed directly or used for cleaning corrosive equipment (Abdurrasheed et al., 2019). Furthermore, for the direct use of rainwater for drinking purposes, especially in areas where the pH of rainwater is significantly below the threshold, methods for improving its water quality need to be implemented (Ramadhani et al., 2024). A simple method that can be taken is to use rapid sand filters, as the interaction between rainwater and the sand filter can raise the pH value or lower the acidity level to neutral. (mendekati nilai pH 5,6). The authorities and parties involved with water quality and public health are expected to conduct more detailed and equitable inspections of rainwater quality, as well as develop appropriate methods to improve rainwater quality in their respective areas (Handayani & Suryanto HS, 2016).

Mapping Solutions

Figure 7. PAH Recommendation Map for Flood Solutions

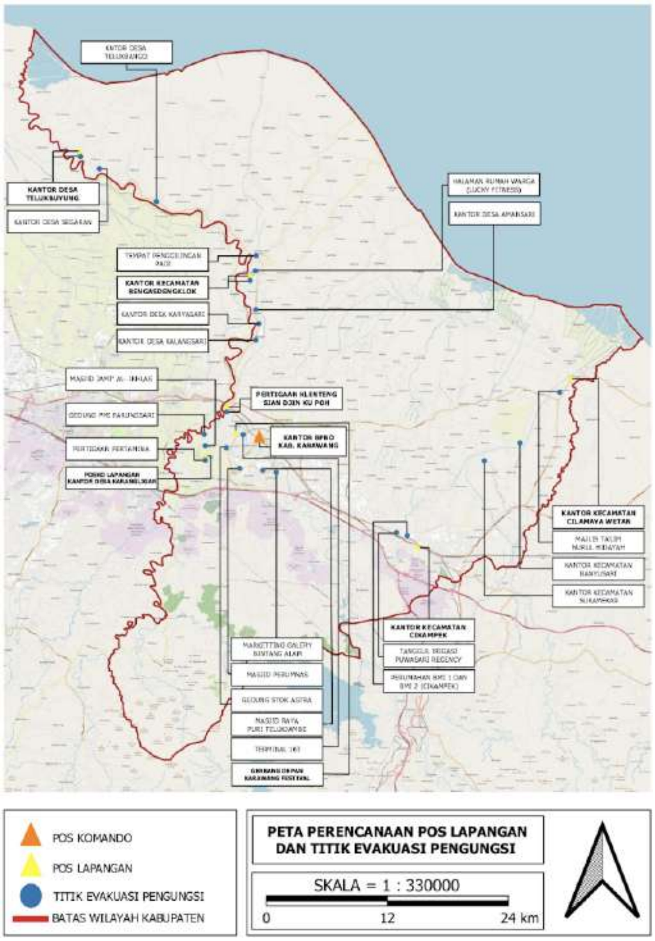

Figure 8. Flood Disaster Evacuation Point Map

Table 1. Utilization of Rainwater for Clean Water, Flood Prevention, and Drought Mitigation

Recommended Method Institutions	Government / Private Institutions		Industry		Urban Society		Suburban and Rural Communities		
	Office Complex, Educational Facilities	Urban Forest, Park, Experimental Garden	Factory Complex, Office Buildings Housing	Agricultural, Plantation Agro-Industry Area	Residential Area	Public Space	Residential Area	Public Space	Agricultural and Plantation Areas
Rainwater Harvesting Basin	√		√		√	√	√	√	
Infiltration Well	√		√		√	√		√	
Infiltration Ditch		√		√			√		√
Rainwater Infiltration Area	√	√	√	√	√	√	√	√	
Garden Fence	√			√			√	√	√
Pay for the Yard	√		√	√			√	√	√
Hole in the Ground	√	√	√	√	√	√	√	√	√
Landscape Modification	√	√	√	√	√	√	√	√	√
Groundwater Conservation Area		√		√					√
Rainwater Conservation Pond	√	√	√	√	√	√	√	√	√
Revitalization of Ponds, Lakes, and Water Bodies		√		√					√

The presented Table 1 offers a robust framework for selecting appropriate rainwater harvesting techniques across various settings. The findings underscore the versatility of rainwater harvesting basins, while highlighting the suitability of infiltration ditches for larger-scale applications (Hamdani, 2019). Notably, the integration of these methods with green infrastructure strategies can significantly contribute to achieving Sustainable Development Goal 6 (Semarang et al., 2005). Future research should delve deeper into the economic and environmental implications of different harvesting techniques, considering factors such as initial investment, maintenance costs, and water quality with detailed explanation:

1. Robust Framework: The table offers a strong foundation for selecting rainwater harvesting methods. It provides clear guidelines and recommendations based on different locations and needs (Mustari et al., 2022)
2. Versatility of Basins: Rainwater harvesting basins are adaptable to various settings, making them a popular choice. They can be used in urban areas, rural communities, and even industrial settings (Nuclear et al., 1997)
3. Suitability of Ditches: Infiltration ditches are particularly effective for larger areas, such as farms or industrial parks. They help to reduce runoff and improve groundwater recharge (Kumwimba et al., 2017)
4. Green Infrastructure Integration: Combining rainwater harvesting with green infrastructure strategies, like green roofs or rain gardens, can enhance the overall benefits of both systems. This can include improved water quality, reduced stormwater runoff, and increased biodiversity (Junaidi et al., 2020)
5. Future Research: The paragraph suggests that more research is needed to fully understand the economic and environmental implications of different rainwater harvesting techniques. Factors such as the initial cost of installation, ongoing maintenance expenses, and the quality of the harvested water should be carefully considered (Ismahyanti et al., 2021).

Conclusion

The conclusion of the research indicates that the ecodrain infrastructure consists of 7 elements, namely rainwater harvesting, infiltration wells, detention ponds, trash filters, bioremediation, biofilters, and water quality treatment using constructed wetlands. Meanwhile, the local government of Karawang Regency does not yet have the infrastructure to implement ecodrainage. After conducting an analysis, it was determined that among the 7 elements of ecodrainage, rainwater harvesting is the most needed to address the flooding and drought issues in the Karawang area. The research results also include calculations and explanations of ecodrain facilities for rainwater harvesting on a plot scale and communal/environmental storage tanks, as well as the quality of rainwater in Indonesia.

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