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WATER SENSITIVE URBAN DESIGN APPROACH BASED ON THE SPONGE CITY CONCEPT FOR RAINWATER CATCHMENT DESIGN CRITERIA. CASE STUDY : ANALYSIS OF INFILTRATION AREAS FEASIBILITY IN WAI MHOROCK, PAPUA.

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ABSTRACT

Wai Mhorock sub-district has problem with changes in land use, which have an impact on changes in infiltration of each land use and can cause inundation and flood problem. Based on Sponge City concept, the Water-Sensitive Urban Design (WSUD) approach is essential to placing open spaces that can function as rainwater catchment and absorption areas. This research used three variables, land structure, land use and land slope. For infiltration testing using a double-ring infiltration at each sample point that had been determined using the purposive sampling method. Horton and Mononobe infiltration analysis methods were used to test the water infiltration rate at sample points. The result of the Horton infiltration test showed variations in the infiltration rate between 12 mm/hour, 84 mm/hour, 360 mm/hour and 384 mm/hour. The Mononobe method finds the maximum rainfall intensity graphic value for ten years. The Mononobe intensity value is 196.51 mm/hour. The infiltration rate test graph and the Mononobe top rainfall intensity graph determine the test result of sample points with a degree of water infiltration. Based on these hydrological constraints and spatial analysis, the study formulates specific design criteria for feasible locations: an open retention basin integrated with green open space (GOS) for expansive areas (Sample B) and an underground water storage tank for limited spaces (Sample C). These localized Water-Sensitive Urban Design approaches serve as a sustainable mitigation strategy against flooding in the Wai Mhorock area.
Keywords: *Infiltration Rate, Horton Method, Mononobe Method, WSUD, Sponge City*.

INTRODUCTION

Flooding is a water level that exceeds the standard limit in a river so that it overflows the river bank and the overflowing water inundates an area (Balsells et al. 2013; K. H. Liao, Le, and Nguyen 2016; Yao et al. 2015). Two factors cause floods, namely natural floods and floods due to human intervention (Balsells et al. 2013). Floods can occur due to changes in land use in water catchment areas, namely upstream or upland. Flooding in an urban area will worsen with heavy rain and extreme climate (Balsells et al. 2013; Derkzen, van Teeffelen, and Verburg 2017; Fitzgerald and Laufer 2017; De Valck et al. 2019). Fine-textured soil types have a higher chance of flooding than coarse-textured soil types because fine-textured soil types have low permeability (Yang et al. 2015; Rau et al. 2022). If an area has a gentle slope, the greater the percentage of flooding, conversely if it has a steep slope, the percentage of flooding in that area will be smaller (Darmawan et al., 2017). Changing the slope of the land from vertical to gentle slope result in forming an apex area and impacts changes in surface flow velocity so that the possibility of flash floods becomes greater (Mulyanto et al., 2012). The presence of sedimentation that enters the river layer impacts reducing the river's capacity (Kodoatie and Sjarief, 2010).

Building located on river borders result in drainage degradation through flow blockages and make monitoring and maintaining river difficult (Kodoatie and Sjarief, 2010). The reduced drainage function in flowing water is also caused by human waste

(Douglas et al., 2008). Infiltration is a process of water entering the soil layer, which comes from rainfall. The infiltration rate is the amount of rainwater that enters the soil layer in units of time (Triatmodjo, 2008). Water on the soil's surface does not always enter the soil layer; water at the top soil will be evaporated into the atmosphere through the soil surface or soil evaporation (Zeiser et al. 2023; Yao et al. 2015). Infiltration capacity is the ability of soil elements to absorb water into the soil layer (Hedblom et al. 2017; Z. L. Liao et al. 2013). The amount of infiltration capacity can reduce the percentage of surface flow in the soil. The loosened soil pores are due to compaction in the soil, resulting in decreased infiltration; this situation is also caused by soil pollution due to the use of chemicals (Shankar 2017). Land use factors, land structure, and land slope influence the infiltration rate (Z. L. Liao et al. 2013). The infiltration rate has different values in different land uses (Agustina et al., 2012). Water flow entering the soil can move sideways or downwards (Asdak, 2007). The flow at the surface can be regulated by increasing the soil's ability to store water through stages of improving infiltration capacity (Kurnia et al., 2006). Land cover in vegetation can increase infiltration (Kabisch and van den Bosch 2017; Yu et al. 2018). Vegetation factors have a significant role in determining infiltration capacity (Utaya, 2008). The infiltration rate has different classifications in determining the infiltration rate (Z. L. Liao et al. 2013). In the context of Jayapura City, the combination of high rainfall intensity, hilly topography, and rapid land-use conversion significantly amplifies the risk of localized flooding and inundation in sub-districts like Wai Mhorock.

Testing the infiltration rate is most suitable using the Horton method (Putra, 2013). Horton stated the infiltration capacity decreases as time passes until it reaches a constant point (Harisuseno et al., 2019) Planned rainfall is calculated to predict the intensity of rainfall with a specific return period that will be used (Soewarno, 1995). Calculations of flood discharge using rational methods require rainfall intensity data. Rainfall intensity is the intensity of rain that occurs when the water is concentrated (Loebis, 1992). In reality, the variance of hydrological data is not the same as the average value (Ariyani, 2021). Variation is the amount of variance around the mean. If rainfall data is available over a short period, then the equation used is the Mononobe equation (Suripin, 2003). Due to the specific constraints of hourly rainfall data availability at the local meteorological stations in Jayapura, the Mononobe method is highly appropriate for predicting the maximum rainfall intensity in this study.

Therefore, the research was conducted in Abepura District, based on flood hazard data from Jayapura City RTRW for 2013-2033, requiring a Water-Sensitive Urban Design planning approach based on the Sponge City concept as an effort to handle, control and reuse rainwater as a result of extensive rain and the possibility of flooding will occur. This research proposes the Sponge City concept with a Water-Sensitive Urban Design approach to control flooding and reuse rainwater specifically in Wai Mhorock Village, Abepura District, through localized spatial design criteria.

Theoretical Framework

1. Sponge City as a Concept to Minimize the Impact of Floods

Sponge City is an opportunity to use surface run-off to deal with water scarcity (Wei et al. 2021; Jiao and Han 2022; Deng, Deng, and Zhang 2022). Sponge City is a city that is planned to absorb, utilize and clean rainwater using methods that are friendly to the surrounding environment, thereby reducing the negative impact of the dangers of polluted water run-off (Ji and Rao 2023; Jiao and Han 2022; Deng, Deng, and Zhang 2022; Hamidi, Ramavandi, and Sorial 2021). To create Sponge City, roads in an area are not watertight; the concept of vertical gardens, green open space (GOS), and the other are used (Köster et al. 2023; Jiao and Han 2022). Sponge City not only reduces the impact of rainwater run-off but also handles floods better and can accommodate rainwater discharge as one of the water source options in urban areas (Zhang, He and Zhang, 2019). In general, the application of Sponge City is the same as how a sponge works, which can absorb water naturally and be filtered by the soil network until it reaches the urban aquifer (Xie et al. 2017; Xu and Kong 2021). This process makes it possible to extract water from the soil layer through water sources and can be easily reprocessed to become a water resource in an area.

Inspired by concept that have been used by several countries around the world, such as “Low Impact Development” (United States, 1990) (Bécsi et al. 2017), “Water Sensitive Urban Design” (Australia, 1994), “Sustainable Urban Drainage System” (England, 1997), “Low Impact Urban Design and Development” (New Zaeland, 1997) (MOHURD, 2017). Sponge City is the application of a concept that has a close relationship between the community as users, the city and water. The National Guideline for Sponge City is a guideline for introducing planning and designing Sponge City created by The State Council of China (2020). Sponge City refers to areas with urban infrastructure in the form of open regions and roads that function like a sponge (absorbing water). The Sponge City concept focuses on urban spatial management that can drink water, improve water quality, and store rainwater to deal with waterlogging problems and flood disasters that occur in cities and minimize the urban heat island effect through natural based problem solving (Jiao and Han 2022; Ji and Rao 2023; Deng, Deng, and Zhang 2022; Liang et al. 2020; Zaręba et al. 2022).

There are six elements in implementing the Sponge City concept, namely (a) infiltration, (b) retention, (c) water storage, (d) improving water quality, (e) water reuse, (f) drainage (The State Council of China, 2015). These elements are carried out to minimize the negative impacts of urban development on the environment. Sponge City planning is an effort to conserve, restore, and rehabilitate natural ecosystems in urban areas to establish a city’s resilience. Preserving river basins, lakes, water catchment areas, ponds, and other ecosystem optimally connected to the water element to maintain natural hydrological characteristics is fundamental in planning Sponge City. There are three principles issued by The State Council of China (2015) namely (a) implementing ecological functions that area integrated with natural cycles, (b) following pre-planned rules, and (c) following participation social issues that have a positive impact on the environment. There are six qualifications for planning the Sponge City concept, including the following planning map:

a. These base map consists of land slope, soil type and land use, geology, green open space, drainage flow system, and other elements that influence the application of the Sponge City concept
b. Sponge City’s natural ecological spatial pattern map
c. Sponge City zoning planning
d. The Sponge City planning control map consists of data on the maximum intensity of annual rainfall in various sub-regions
e. Determining the layout of infrastructure that is related to water, such as a map of Sponge City’s natural ecological spatial pattern, drainage channels, handling puddles, water storage areas and water reuse areas
f. Sponge City planning data in stages

There is a technical guide to planning the Sponge City concept. The technical guide helps realize the Sponge City concept as stages of planning, design, construction and periodic maintenance at each level (MOHURD, 2017). This technical guide instructs coordination between city planning agencies, environmental service agencies, road infrastructure and related agencies in supervising the planning of the Sponge City concept.

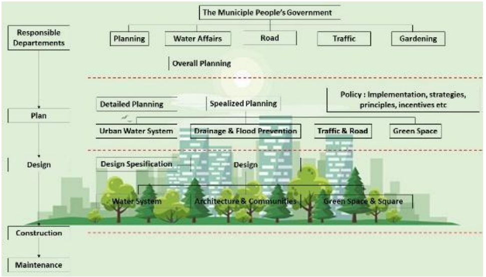

Figure 1. Inter-agency coordination in the Sponge City program (MOHURD, 2014)

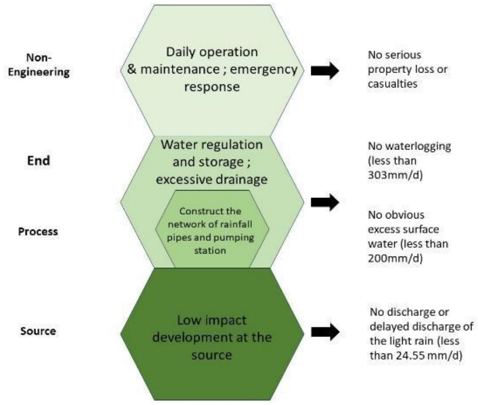

Figure 2. Sponge city planning management ideas (MOHURD, 2014)

Planning and designing the Sponge City concept must be determined in accordance with the different Sponge City indices to maximize how sponges work. Table 1 illustrates the six factors that are interrelated with Sponge City infrastructure design, as follows:

Table 1. The framework of National Building Standard Design System for Sponge City Construction

Solution	Sponge Infrastructure	Infiltration	Retention	Storage	Purification	Utilization	Drainage
Nature Based	Green roof						
	Sunken green areas						
	Infiltration ponds						
	Bio-retention facilities						
	Green swales						
	Rain gardens						
	Stromwater wetlands						
	Wet ponds						
	Retention ponds						
	Detention basin						
	Vegetation buffer zone						
Grey Based	Permeable pavements						
	Underground rainwater tank						
	Water storage modules						
	Seepage wells, pipes, canals						
	Rainwater drainage						
	Rainwater purification						
	Green area irigation						
	Artificial soil infiltration						

Based on the framework in Table 1, several Nature-Based Sponge Infrastructure solutions can be applied depending on the spatial characteristics of the area. For instance, the use of grass swales aims to prevent erosion and filtering run-off by moving water from one point to another. Grass swales can be used in areas with a vast landscape expanse in the form of straight lines; the direction and shape resemble drainage. A swale is a shady place with a slope of at least 1 %, which means that grass swales can be applied in the Sponge City concept, provided that there is a large area in the planning (Fox et al., 2018).

Strom-water wetlands are rainwater control structures in the form of wet ponds, consisting of a combination of shallow and vegetation zones. Strom-water wetlands are one of the most effective ways of controlling post-construction rainwater to handle pollutants (NPDES: Strom-water Wetlands, 2021). This means this concept can be used in the Sponge City concept.

Wet ponds or storm-water ponds, damp retention basin are ponds shaped like basins with standing water permanently (throughout the rainy season). Wet ponds are suitable as water reservoirs in a city so that they can be reused as city water reserves someday when needed (NPDES: Wet Ponds, 2021). This means the wet ponds concept can be applied to the Sponge City concept.

A detention basin is a pool in the shape of a basin with vegetation around it. Detention basins aim to hold surface run-off form surfaces impervious to water, unlike usual holding ponds that do not allow water infiltration. Detention basin have benefits such as improving water quality by filtering to remove sediment, adsorption, and biochemical degradation. The application of a detention basin is ideal for playing fields, recreation areas or public areas to improve the visual quality of an area and serve as a shelter for surrounding animals (NWRM, 2023). The detention basin concept can be applied to the Sponge City concept.

Vegetation buffer are areas that have naturally formed aims to protect water quality. Areas where rainwater can seep into the soil, slowing down the flow of rainwater, can help reduce soil erosion and help filter sediments. Vegetation buffers can be applied in areas that frequently experience flooding and river watersheds and used in the regions that support vegetation (NPDES: Vegetated Buffer, 2021). The vegetation buffer concept is suitable for implementing the Sponge City concept.

2. Sponge City concept approach

There are eight approaches to the Sponge City concept (Hawxwell and Knieling 2020), as follows:

a. Best Management Practices system (BMPs). This method approach uses a traditional drainage system to channel rainwater, a brand BMPs, by implementing an engineering system for controlling rainwater. Rainwater will be directed through the nodes. If this node method fails, this method will burden other nodes and ultimately result in a flood disaster (EPA, 2012)
b. Green Infrastructure (GI). In effort to handle rainwater management, many countries are adopting the Green Infrastructure (GI) concept approach. This method will manage rainwater by combining commonly used natural methods. This method uses biological systems to utilize water resources such as water filters, minimize the risk of flood disasters, and improve water management (Everett, 2015)
c. Integrated Urban Drainage System (IUDS). This method has a purpose in planning and developing systems in an urban area. IUDS combines various components of water systems such as distribution, sewerage, water management, drainage for rainwater, and wastewater management. IUDS mainly aims to combine drainage channels to manage rainwater to become a sustainable resource and considers economic factors (CIWEM, 2021)
d. Low Impact Development (LID). This method is almost the same as green infrastructure, which focuses on water run-off and waste using drainage channels. LID prepares sediment separators and collects rainwater through drainage channels,

which are small but widely spread in several places. LID also includes management of water consumption (EPA, 2023)

e. Water Sensitive Urban Design (WSUD). WSUD is one way to change the impact of urban development on natural water hydrological systems, where urban water management will comprehensively cover the use of water resources by rainwater to make it more efficient and positively impact urban communities. WSUD is a combination of water-sensitive and urban design (Hawxwell and Knieling 2020). Water-sensitive refers to a society or government that views water as an unlimited source and hurts the sustainability of life. Urban design refers to process of creating areas, environments and cities that have the goal of an optimally sustainable city area (Hoban, 2019)
f. Sustainable Urban Drainage System (SUDS). This SUDS method utilizes excessive surface run-off due to urbanization through the stages of collecting, absorbing, and retaining water due to the intensity of rainfall. SUDS is strongly influenced by natural processes such as water absorption, evaporation and biological treatment. The SUDS method can improve urban flooding and water pollution (Susdrain, 2023)
g. Low Impact Urban Design and Development (LIUDD). The LIUDD method focuses on rational development for both urban and surrounding areas, considering the quality and quantity of water, biodiversity and surrounding land use (van Roon, 2009)
h. Active Beautifull and Clean Water Programme (ABC). The ABC method is an effort to change the shape of a canal and water reservoir, which has its traditional function remaining in drainage, collecting rainwater into a channel, and controlling flood disasters, lakes and rivers so that they merge with the surrounding landscape. This ABC method of planning focuses on environmental cleanup (Centre for Liveable Cities, 2017)

Even though it has many variations, it generally has the same goal in efforts to manage various types of water hydrology in cities (Zevenbergen, Fu and Pathirana, 2018). This research uses a water-sensitive urban design approach considering rainwater management by infiltrating it into the ground or storing it in retention basins, weirs, buildings and other physical formations as a reserve resource for a city. It can be reused so that it can become a sustainable city. The Sponge City concept approach (a) Best Management Practices system, (b) Integrated Urban Drainage System, (c) Low Impact Development, (d) Sustainable Urban Drainage System, (e) Active Beautiful and Clean Water Program, focuses on handling rainwater through a drainage system, while the (a) Green Infrastructure, (b) Low Impact Urban Design and Development approach focuses on natural, rational handling and development in cities with consideration of the quality and quantity of water, land and biodiversity, which means the opposite with a problem formulation that focuses on discussing the ability of land to absorb rainwater through soil elements and catchment areas that can be used a rainwater reservoirs.

3. Water-Sensitive Urban Design

Water-Sensitive Urban Design is an approach in the urban planning and design process. It is related to water cycle management, positively impacting urban development (Verlag, 2011). Water-Sensitive Urban Design is integrated with the urban water cycle as follows:

a. Integrated management of groundwater, drinking water, wastewater and water run-off to protect the surrounding environment, recreation areas, and places that have cultural value
b. Store and select run-off water for reuse

c. Carry out treatment and reuse of wastewater
d. Vegetation is a landscape element that aims to maintain it so that water entering the ground occurs efficiently and can increase the city's biodiversity

Water-Sensitive Urban Design is an approach to implementing the concept of sustainable and green cities, with the goal of sustainable city development, managing city water and more specifically. Sustainable water management includes drinking water and rainwater which impact waterways, water quality, wastewater management and water conservation. Water-Sensitive Urban Design aims to design and manage the environment that influences the city scale planning process to minimize losses to a city in the long term (Lloyd, Wong and Chesterfield, 2002). Water-Sensitive Urban Design in Rainwater Management for City Scale Planning according to Verlag (2011):

a. Protects natural cycles resulting form changes in city development
b. Reduce the impact of water run-off due to rain and peak water flows by applying the local retention concept to minimize the affected areas
c. Planning land for optimal ecological functions to reduce excessive infrastructure costs, especially drainage infrastructure
d. Rainwater management that is integrated with the city landscape as an added value to the visuals of the city itself

The principles of planning and designing Water-Sensitive Urban Design can be carried out through land capability analysis, land use analysis and site analysis (Hawxwell and Knieling 2020).

Site analysis functions to identify and explain existing conditions on the land. The data required are drainage network data, soil type data, land cover area data, area sensitive data, water corridor data and topographic data. Once the analysis has been explained, the location for planning and developing the Water-Sensitive Urban Design concept can be determined to minimize the negative impacts that will occur. The Water-Sensitive Urban Design concept has two essential elements, namely (a) water management (water treatment) and (b) water reuse. Water resulting from rain and wastewater are factors that significantly influence the implementation of Water-Sensitive Urban Design. These two elements are considered; (a) land areas that can absorb rainwater as an ecological function (broad absorption basins), (b) ditches or swales, (c) road design, (d) roof slopes, (e) reservoirs to collect water, (f) pavement forming materials that have pores (porous pavements), (g) sand filters, (h) drainage cover materials, (i) walls retaining water flow, (j) urban forests and (k) type of vegetation including water edge vegetation (South Eastern Councils, 2011).

There are two typologies for applying Water-Sensitive Urban Design techniques; design techniques for industrial areas and design techniques for organizations. This research uses design techniques for organizational areas located in *Wai Mhorock* Village, Abepura District, Jayapura City. This location is in a densely populated corporate area and is accompanied by supporting facilities such as educational facilities, economic services and other government facilities. The application of design techniques to ecosystem is divided into four areas, namely (a) open space for the public, (b) street design, (c) housing design and (d) streetscape design. These four areas are related to the water management system due to rain and aim to impact the surrounding community economically and socially positively. Areas that absorb water need as much water as possible.

Rain can seep into the soil layers optimally and material that are not impervious to the water absorption process can be used so that the water quality in a city can be maintained well. Nine things need to be done when implementing Water-Sensitive Urban Design in the organizational sector as follows:

a. Utilization of rainwater to irrigate vegetation in an area
b. The placement of electricity and telecommunications network channels is changed to an underground system
c. Planning parallel roads according to the topography of the area
d. Use of structural planes that function to facilitate water going straight to the ground and being optimally absorbed by the ground
e. Minimize the use of water tight materials
f. Orientation of the organization's area toward public open space
g. Use of drainage corridors to channel water run-off into rainwater storage areas
h. Integration of land that functions as an ecological element to absorb rainwater into active and passive open space
i. The use of buffer strips elements and grass swales in specific areas, such as pedestrian paths and designed as much as possible so that they are parallel to the road

The 'Sensitive' aspect in Water-Sensitive Urban Design practically integrates the six fundamental elements of the Sponge City concept—infiltration, retention, storage, purification, reuse, and drainage—into a cohesive urban landscape strategy. In its application, WSUD serves as an instrument for managing stormwater runoff. It has a relationship with the city landscape, so rainwater can be used as an idea in city planning and design. Water-Sensitive Urban Design has essential functions for cities: reducing erosion, increasing the groundwater recharge process and reducing the risk of flooding (European Environment Agency, 2016)

RESEARCH METHOD

1. Research location and sample

The location chosen in this research was Wai Mhorock Village based on flood-prone data in RTRW Jayapura City 2013-2033. The purposive sampling technique is used to determine sample point for infiltration testing, which are influenced by land use factors, land slope and land structure in infiltration testing in the field.

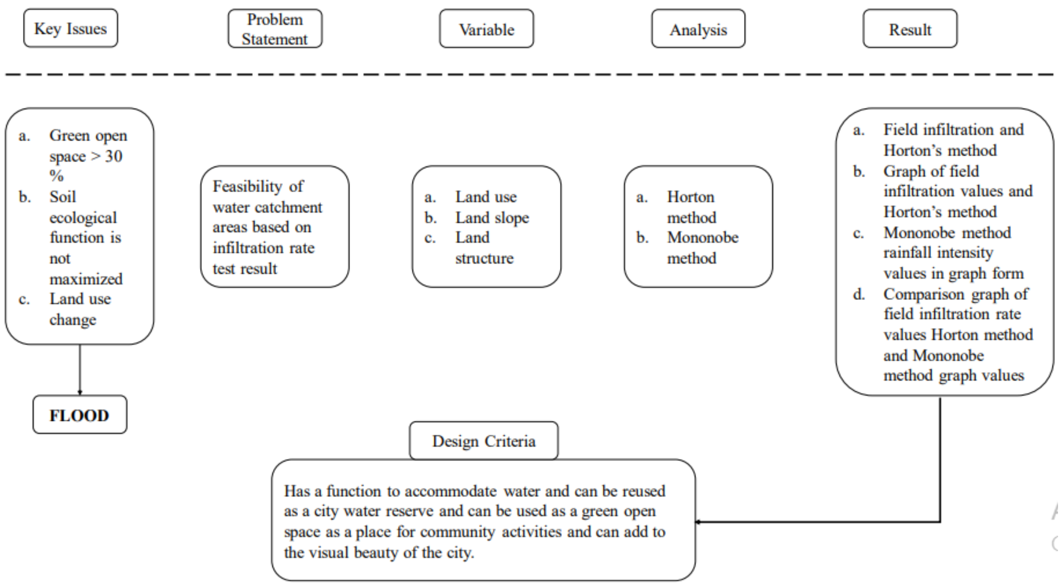

Figure 3. Research Framework

2. Data collection and analysis

Data collection in this research is divided into two types, namely (a) primary data collection in the form of field infiltration testing based on SNI 7752: 2012 (National Standardization Board, 2012) using a double ring infiltrometer and (b) secondary data collection in the form of administrative maps, land use maps, land slope maps and land structure map. Based on variables that affect infiltration testing in the field in accordance with SNI 7752 guidelines: 2012 (National Standardization Board, 2012) there are 4 sample points that are used as testing points for infiltration rates (figure 4).

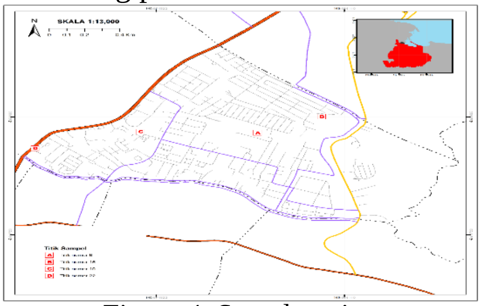

Figure 4. Sample point

Data analysis in this research is divided into two sections: (a) infiltration analysis using the Horton method and (b) rainfall intensity analysis using Mononobe method

a. Infiltration analysis using the Horton method

$$F\ (t) = fc + (f0 - fc)e{-}kt$$

$f\ (t)$	Infiltration rate
fc	Initial infiltration rate
$f0$	Final infiltration rate
$e0$	Exponential number 2,718
t0	Constant (-1/0.434)
m	Time (minute)
e-kt	Linear regression value

b. Mononobe method rainfall intensity analysis

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}}$$

I Rainfall intensity (mm/hour)

t Rainfall duration (hours)

R24 Maximum 24-hour rainfall (mm)

Classification of infiltration rates using FAO, 1951 parameters.

Table 2. Infiltration Classification

Classification	Infiltration Rate (mm/hour)
Versy slow	< 1
Slow	1 – 5
A bit slow	5 – 20
Currently	20 – 63
Rather fast	63 – 127
Fast	127 – 254
Very fast	> 254

RESULT AND DISCUSSION

A. Horton method of infiltration

1. Field infiltration

Infiltration testing is carried out until the soil reaches a constant state if absorbing water. Figure 5, sample point C (gray) experienced a significant decrease in infiltration rate compared to sample point A (blue) and D (purple), which experienced a non-significant reduction in infiltration. Meanwhile, sample point B (red) experienced up and down in the infiltration rate. The infiltration rate at sample point A experiences a constant in interval 7 to interval 9. Sample point B encounters a constant in interval 25 to interval 27. Sample point C encounters a constant in interval 24 to interval 26. Sample point D meets a constant in interval 6 to interval 8 (see figure 5). Each sample point experiences up and down changes at different times, according to the theory of Agustina (2012), which states that infiltration values vary if they are located in other land uses or places in an area.

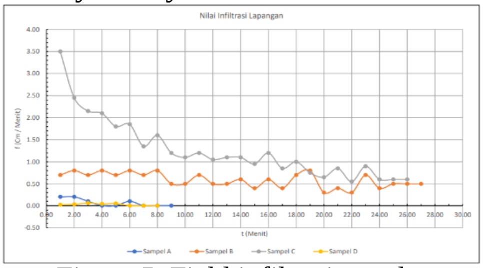

Figure 5. Field infiltration value

The field infiltration value is then processed to obtain the f Horton value using equation 1. See figure 6 for the f Horton value

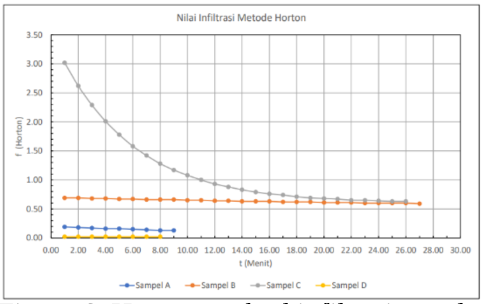

Figure 6. Horton method infiltration value

In figure 6, sample point C (gray graph) experienced a significant decrease in the value of f Horton from interval 1 to interval 26 while sample points A (blue), B (orange) and D (yellow) experienced an insignificant decrease in the value of f Horton at each interval. In the previous discussion, it has been described that the value of f Horton will be converted into a graph and converted from cm/min to mm/h to get the classification of the infiltration rate with the highest value when it reaches a constant point at each sample point.

2. Horton method infiltration value conversion

The Horton method infiltration value in figure 6 has units of cm/minute. It is converted into units of mm/hour to obtain the infiltration rate classification according to the parameters of FAO, 1951 (table 1).

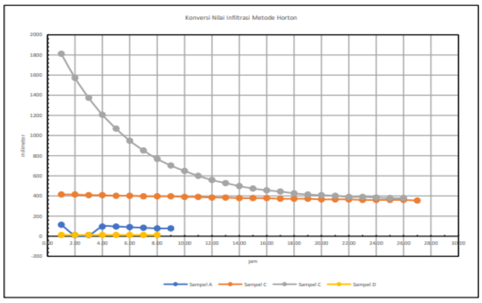

Figure 7. Horton method infiltration value conversion

For the values to be converted, see figure 7. Sample point A (blue) has the highest constant value of 84 mm/hour. Sample point B (red) has the highest constant value of 360 mm/hour. Sample point C (gray) has the highest constant value of 384 mm/hour. Sample point D (purple) has the highest constant value of 12 mm/hour. Sample points B and C have almost the same highest constant conversion value.

3. Classification of infiltration rates

The value used determining the infiltration rate classification is the highest value when constant at each sample point A,B,C and D. Based on the Horton method infiltration value, the classification for each sample point is obtained as follows :

Table 2. Infiltration Classification

Sample Point	Infiltration Rate (mm/hour)	Classification Infiltration
A	84	Rather fast
B	360	Very fast
C	384	Very fast
D	12	A bit slow

B. Mononobe's intensity

The value sought in the intensity of the Mononobe method is the return period (T) value in 10 years in the form of a graph as a comparison of the Horton method infiltration graph and the Mononobe rainfall intensity graph.

1. Analysis of rainfall data

The rainfall data covers a 10 years period from 2014-2023 at Dok II Station of the Jayapura City Meteorology Climatology and Geophysics Agency (BMKG) see figure 8. The rainfall value used is the highest annual value as a reference value in calculating statistical parameter analysis and subsequent calculations.

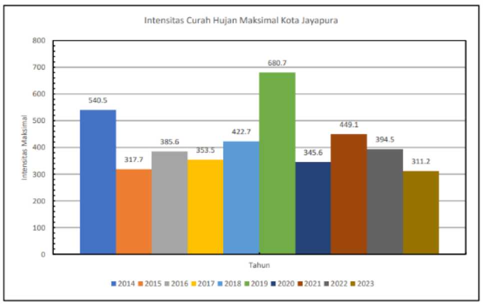

Figure 8. Rainfall intensity in Jayapura City

2. Statistical parameter analysis

Average rainfall value $(\underline{x})$: 4201.10 mm, standard deviation value : 114.228, skewness coefficient value : 1.522, variation coefficient value : 0.272, kurtosis coefficient value : 5.973, Log $(\underline{x})$ value : 2.611, S Log value : 0.106, Cs Log value : 1.072, Cv Log value : 0.041 and Ck Log value : 4.072.

3. Recapitulation of probability distributions

The stage for determining the type of distribution used a parameter for calculating rainfall intensity using the Mononobe method is based on average distributions values, log normal, gumbel and log pearson III.

Table 3. Recapitulation of probability distribution

Periode Ulang (Tahun)	Jenis Distribusi			
	Normal	Log Normal	Gumbel	Log Pearson Tipe III
2	420.110	408.162	408.899	390.993
5	516.062	501.400	546.512	490.311
10	566.322	558.454	635.527	566.821
20	607.444	609.932	722.136	668.851
50	654.278	674.362	834.007	766.487
100	686.262	722.233	918.210	865.444

The next step is to determine the distribution limits that will be used as reference values for the return period T of Mononobe method. The type of distribution that qualifies is the value that has no limit, namely the log Pearson III distribution (see table 3).

Mononobe method of calculating rainfall intensity (figure 9) has units of mm/hour with a return period of 10 years, which will then be compared with the Horton method infiltration graph value to see the feasibility of water catchment areas in *Wai Mhorock* Village, Abepura District, Jayapura City (see figure 10 – 13). The maximum rainfall intensity is 196.51 mm/hour (figure 9).

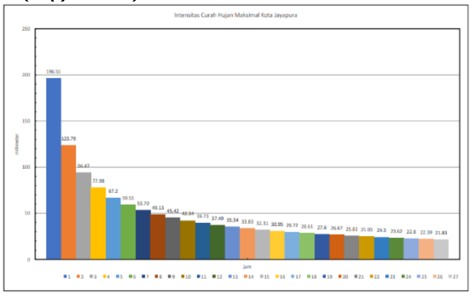

Figure 9. Mononobe method rainfall intensity

Sample point A (figure 10) shows that form interval 1 to interval 3, the soil cannot absorb rain water optimally. It can absorb water optimally from interval 4 to interval 9 but with the total interval reaching a constant at maximum interval 9. Sample point B (figure 11) shows that from interval 1 to interval 27, the soil can optimally absorb rain water based on the infiltration value of the Horton method (red) and the maximum rainfall intensity value of the Mononobe method (gray)

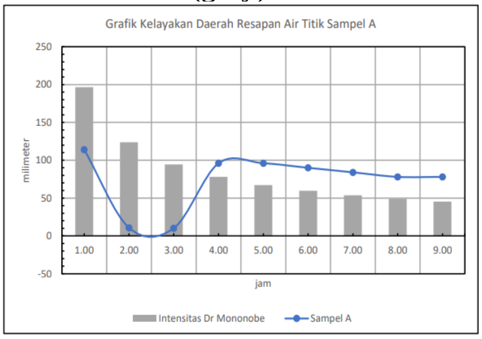

Figure 10. Comparison of sample points A

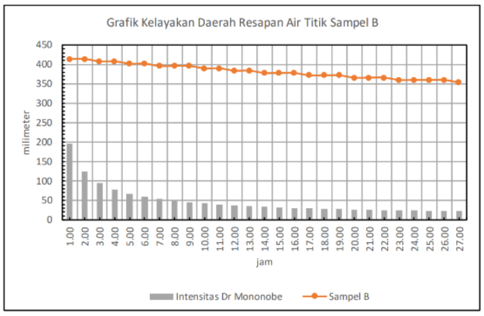

Figure 11. Comparison of sample points B

Sample point B has the most extended interval up to interval 27. Likewise with the sample point C (figure 12) from interval 1 to interval 26, the soil can absorb rainwater optimally and optimally with a long distance between rainfall intensity and infiltration, as shown in figure (12). Sample point D (figure 13) shows that the soil cannot absorb water optimally from interval 1 to interval 8 and has the fastest to constant interval.

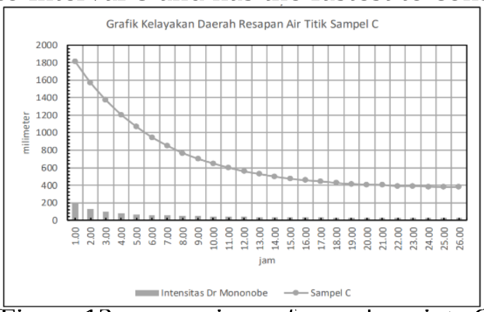

Figure 12. comparison of sample points C

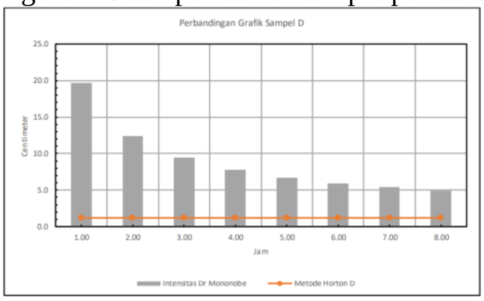

Figure 13. comparison of sample points D

Inverse Distance Weighted (IDW) interpolation map. In the Inverse Distance Weighted interpolation stage, the infiltration rate classification values of 4 sample point (table 2) are processed using Geographic Information System (GIS) software. Then, an interpolation stage is carried out (figure 14) to predict the values in the surroundings with the values obtained form the closest points. Color gradations for each infiltration rate represent predicted values around sample points.

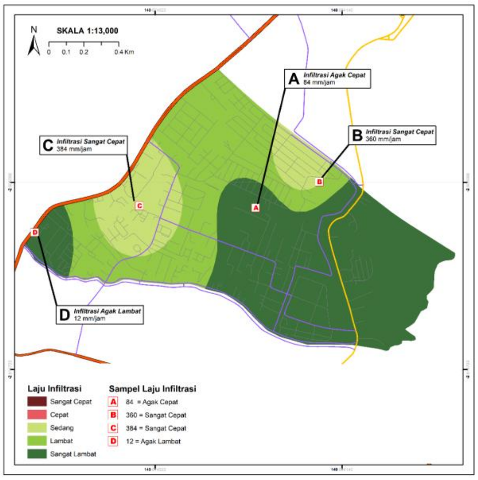

Figure 14. IDW interpolation map

The feasibility of water catchment areas based on infiltration testing of the Horton method (figure 5 to figure 7, table 2) and calculation of the Mononobe method (figure 10 to figure 13) results in 4 sample points with different results, as follows :

Table 3. Infiltration Classification

Sample Point	Feasibility of water catchment areas
A	Not recommended
B	Feasible
C	Feasible
D	Not recommended

The next step is mapping the service area of the feasible water catchment points based on the Riverside County (2011) guidelines, which establish a minimum drainage area threshold of 10,000 ft2 (equivalent to 929.03 m2) to effectively implement such water management facilities. The distance of each sample point and the feasibility map of the water catchment area will be described through table 3 and figures 15.

Table 4. Sample point distance

Sample Point	Distance to sample point	Meter
A	B	391.7611
A	C	665.4063
A	D	1.272,407
B	C	1.037,492
B	D	1.653,025
C	D	618.1533

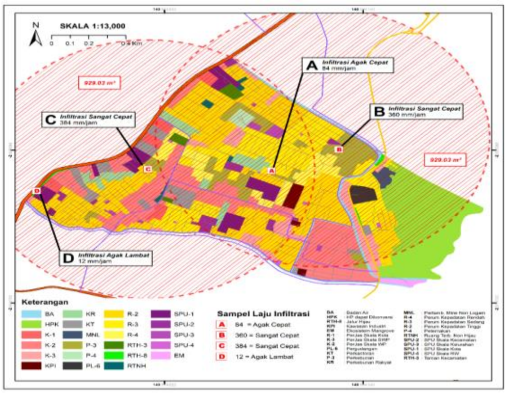

Figure 15. Service radius of water catchment area

In Figure 15, sample points B and C are sample points that have feasible results in absorbing water and can serve a radius according to the specified distance "Riverside Country, 2011" with water catchment area services covering *Wai Mhorock*, Abepura District.

Water catchment area design criteria

In determining the design criteria to be applied to the selected sample points, it is necessary to know the area of each sample point as a reference in applying the design concept. The area of each sample point is shown in the table 5.

Table 5. Sample point area

Sample Point	Area (ha)
B	4.8692
C	0.77034

Sample point B has a large enough area and will be applied to the concept of a retention pond with green open space so that it can become a place for local community activities, become a place for tourism and can be an added value in the beauty of the Wai Mhorock area, Abepura District, Jayapura City (see figure 16). Sample point C has a smaller area than sample point B. It is necessary to apply a good concept for water storage and water reuse as a city water reserve towards a sustainable city. The concept to be used at sample point C is an underground water storage tank with supporting facilities above it in the form of a green open space area as a place for community activities (see figure 16)

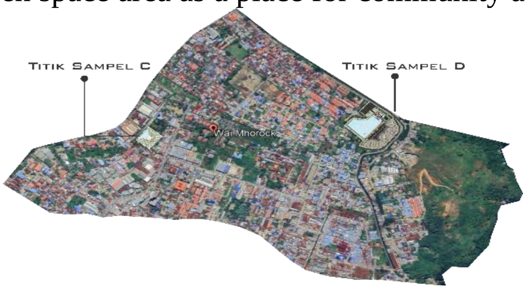

Figure 16. Key plan sample point

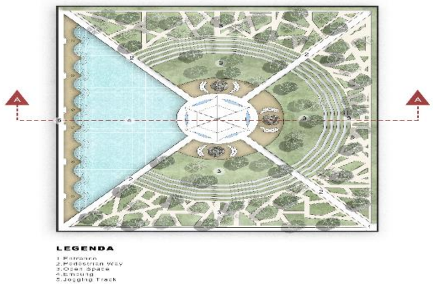

Figure 17. Masterplan sample point B

Sample point B in figure 17 focuses on rainwater storage through a small pond that has a size of 30 x 50 meters in accordance with the guidelines of PUPR (2018) and other activity support areas around the pond.

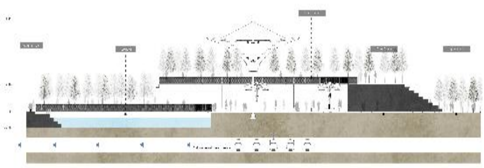

Figure 18. Section sample point B

In figure 18, rainwater will be collected in the reservoir and other rainwater will seep through the soil layer in the open space area. Rainwater that enters through the soil layer will then be collected in the underground water storage basin. How the underground water storage basin works when the water in the storage basin is full, the water in the basin will be channeled to the nearest city water channel and if the water in the basin will be used as a city water reserve, it will be sucked using a suction pipe.

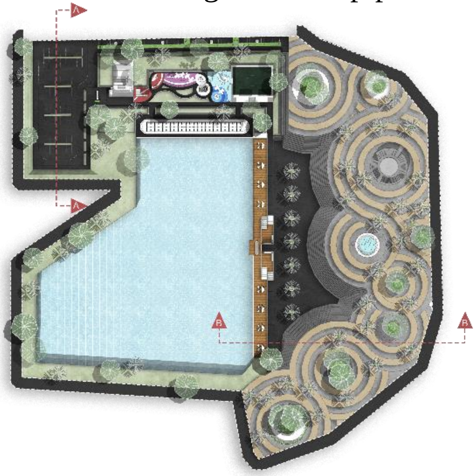

Figure 19. Section sample point C

Sample point c in figure 19 consists of a large reservoir and other supporting facilities around it. Figure 20 shows that there are several elevation differences according to the function of each area. There is a ramp for wheelchair users to make it easier to get to the pedestrian way area. Figure 21 shows the embung area as a large-scale water reservoir at this sample point. There is a relaxation area with a lower elevation than the other areas. The green open space area is a large enough area for community activities with an amphitheater, a relaxing area with shade vegetation and a fountain as a vocal point.

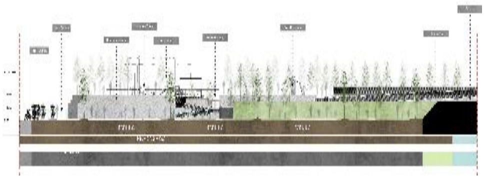

Figure 20. Section A sample point B

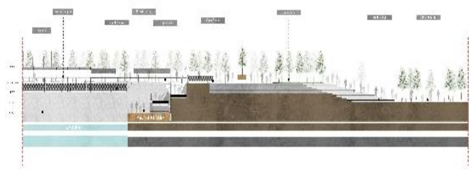

Figure 21. Section B sample point B

CONCLUSION

The planning of water catchment areas in Wai Mhorock Village, Abepura District, Jayapura City has been through field infiltration calculations, the Horton method and Dr. Mononobe rainfall intensity resulting in sample points B and C which are suitable as water catchment areas. Sample points B (360 mm/hour) and C (384 mm/hour) become sample points with a very fast infiltration rate classification and sample point A has a rather slow infiltration classification (84 mm/hour) and sample point D becomes a sample point with a very slow infiltration rate classification (12 mm/hour). Sample points B and

C become feasible sample points in the absorption of rainwater while sample points A and D become unfeasible sample points in the absorption of rainwater based on the comparison of the infiltration graph of the Horton method and the rainfall intensity graph of the Mononobe method.

The spatial design criteria for the feasible water catchment areas are tailored to their respective land capacities. For Sample Point B, which possesses a sufficiently large area, the proposed concept is an open retention basin (retarding basin) integrated with a green open space to serve as a communal hub and enhance urban aesthetics. Conversely, due to the limited spatial footprint at Sample Point C, the design is adapted into an underground water storage tank, with the surface area utilized for public recreational facilities. Both designs emphasize rainwater harvesting and reuse, embodying a sustainable Water-Sensitive Urban Design approach for Jayapura City.

Recommendations

This research focuses on soil infiltration and maximum rainfall intensity, so further research is needed on drainage analysis and catchment area analysis, retention basin - retarding basin dimensions in Wai Mhorock Village so that it has a connection between studies.

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