ISSN 2354-9114 (online), ISSN 0024-9521 (print)
Indonesian Journal of Geography Vol 56, No 3 (2024): 395-407
DOI: 10.22146/ijg.89112 website: htps://jurnal.ugm.ac.id/ijg
©2024 Faculty of Geography UGM and The Indonesian Geographers Associaton

INDONESIAN JOURNAL OF GEOGRAPHY

RESEARCH ARTICLE

Potential study of retention Ponds in the Samudra University environment to meet raw water needs and control floods

Irwansyah Irwansyah[1], Faiz Isma[2*], Haikal Fajri[3], Defry Basrin[4]
Faculty of Engineering, Universitas Samudra, Langsa, Aceh, Indonesia

Received: 2023-09-18
Revised: 2024-09-03
Accepted: 2024-09-27
Published: 2024-10-18

Key words: Retention Pond; Sustainable Water Management; Flood Mitigation; Raw Water; Water Quality Universitas Samudra

Correspondent email: faizisma.ts@unsam.ac.id

Abstract. This study aims to evaluate the potential locations and volume capacities of retention ponds at Universitas Samudra (Unsam) to reduce flood discharge, provide raw water supply, and ensure water quality. The research supports the concept of a *smart and green campus* at Unsam. Water availability was calculated using the FJ Mock model, while water demand was projected based on the number of users. The retention pond capacity for flood control and raw water availability was assessed using the HEC HMS model. Water quality testing, including physical, chemical, and biological parameters, was conducted at the BTKLPP Class I Medan laboratory. The results indicate that the water demand at Unsam is 3 m^3/day, which can be met by the reliable discharge of 16,344.93 m^3/day. The existing reservoir retention pond, with a volume of 509,788.80 m^3, contributes to flood discharge reduction; however, its water quality does not meet raw water standards, particularly due to high concentrations of Total Coliform and Escherichia Coli. Meanwhile, the Cotkala-Unsam retention pond can provide 103,596.96 m^3 of water with quality that meets acceptable limits.

©2024 by the authors. Licensee Indonesian Journal of Geography, Indonesia.
This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution(CC BY NC) licensehttps://creativecommons.org/licenses/by-nc/4.0/.

1. Introduction

Universitas Samudra is a growing state university located in Langsa City, Aceh Province. The Universitas Samudra (Unsam) campus spans approximately 50 hectares and frequently experiences annual flooding, which significantly impacts campus operations and infrastructure. The floods have damaged newly constructed roads leading to the Faculty of Law, the PGSD Laboratory, and the Basic Laboratory. In addition, flooding has obstructed access to the Student Secretariat Building and the Dance Studio. Although, so far, the flooding has not disrupted classes or caused class cancellations, if the issue is not addressed, there is potential for future floods to interfere with academic activities, particularly due to access problems between older buildings and the newly developed campus facilities. Besides access disruptions, the flooding also poses safety risks for students and staff.

The Unsam campus is located within the Langsa River Basin (LRB), which is traversed by a main river that experiences annual flooding during the rainy season (Ismida et al., 2021). The urban drainage system, which discharges into the river and estuary in Langsa City, often causes localized flooding during heavy rainfall, affecting rural areas around the campus. This issue also impacts the Unsam drainage system, as its flows merge with the main drainage channel leading to the Langsa River. The primary and secondary drainage systems in the area are unable to manage water flow efficiently, primarily due to channel narrowing caused by sediment buildup from severe soil erosion in the critical Langsa River Basin (F. Isma & Purwandito, 2019). Sediment transport involves both suspended and bed load sediments (Irwansyah et al., 2023; F. Isma & Purwandito, 2020), highlighting the need for adequate retention ponds to effectively control flooding on the campus.

Retention ponds play a crucial role in controlling runoff volume during the rainy season and maintaining water balance (Zevri & Isma, 2021). To mitigate flood risks, several retention ponds have been constructed on the Unsam campus. However, the current retention ponds are inadequate for managing flood discharge, particularly during extreme rainfall events. Additionally, these ponds were not designed to handle the increasing frequency of floods caused by changing rainfall patterns. As a result, water still overflows despite the presence of retention ponds.

This deficiency is largely due to the high water flow from the PTPN I plantations and downstream settlements near the IAIN Cot Kala reservoir. Additionally, soil erosion in the Langsa River Basin has led to sediment accumulation, obstructing water flow in the campus's main drainage channels, thereby reducing the efficiency of the retention ponds (Isma et al., 2019; Irwansyah, Isma, & Ismida, 2023). Rainfall data from the PTPN I station indicate an increasing trend of extreme rainfall events in the Langsa region over recent years. In October 2022, rainfall reached 404 mm at the Kebun Lama station, resulting in severe flooding around the Unsam campus. Previously, floods were often associated with daily rainfall ranging from 100 to 200 mm. This data highlights a long-term trend of increasing rainfall intensity, which raises the risk of future flooding. This study also explores how these changing rainfall patterns affect flood management planning at the Unsam campus. The rise in extreme rainfall events underscores the urgent need for improvements in the campus flood management system (Förster et al., 2005; Trilita et al., 2020).

This study aims to address knowledge gaps, particularly in evaluating the capacity of existing retention ponds to reduce flood risk and in identifying potential locations for new retention pond construction. Additionally, the research explores how retention ponds can function as sustainable sources of raw water while maintaining water quality. This is critical for supporting the future of Universitas Samudra as a Smart and Green Campus, enhancing understanding of flood management within and around the campus, and promoting more sustainable water management practices (Day et al., 2009; Florince et al., 2015; Lauda et al., 2017; Singh, 2018). As part of the Green Campus initiative, Unsam is committed to implementing efficient environmental management practices, including optimizing the use of water resources. Sustainable water management through conservation and recycling aligns with the core goals of the Green Campus concept, which aims to reduce excessive water consumption and maximize resource use efficiency. This is crucial for ensuring adequate raw water availability and maintaining environmental sustainability (Förster et al., 2005; Trilita et al., 2020; Ujianto et al., 2022). Efficient water use also plays a key role in minimizing the environmental impact of uncontrolled water consumption, aligning with Unsam›s Green Campus vision.

The research area is situated within the Unsam campus environment, which falls under the Langsa River Watershed Area. This designation makes the area a catchment for water from the PTPN I Langsa plantation, as depicted in Figure 1. Consequently, the research area holds the potential to serve as a runoff collection area through the implementation of retention ponds.

Figure 1 illustrates the campus of Unsam, which is equipped with two retention ponds located around Samudra University: the Old Unsam Pond (coordinates: lat: 4°27›4.78»N; long: 97°58›21.10»E) and the New Unsam Pond (coordinates: lat: 4°27›23.25»N; long: 97°58›21.27»E). Additionally, there is one retention pond near IAIN Cot Kala Langsa (coordinates: lat: 4°27›23.23»N; long: 97°58›13.11»E). All these locations form part of a single Catchment with a total area of 8.334 km².

The rainfall data used in this study was obtained from the Kebun Lama Station (KLM) of PTPN I Langsa, covering the period from 2010 to 2022. This station was selected due to its proximity to the study area, ensuring that the rainfall data is highly representative of conditions at Universitas Samudra (Unsam). This data is critical for conducting design rainfall analysis, which aims to estimate extreme rainfall intensities that could trigger flooding and for simulating surface runoff within the Unsam campus catchment area. To map the topography and delineate the Catchment of Unsam, the study utilized Digital Elevation Model Nasional (DEMNAS) data, downloaded from the official website of Badan Informasi Geospasial (https://tanahair.indonesia.go.id/demnas/#/demnas). DEMNAS data plays a crucial role in this research by providing information for Catchment delineation, determining flow direction, and estimating land elevation and slope conditions. This information is essential for modeling surface runoff and identifying areas vulnerable to flooding during heavy rainfall events.

Field measurements were conducted to collect detailed elevation data for existing retention ponds and drainage networks within the Unsam campus. These measurements included data on pond height, capacity, and the physical condition of the drainage systems. Such direct measurements offer additional accuracy needed to calibrate the hydrological model and ensure that runoff simulations align with real-world conditions in the field. The study also utilized land cover data obtained from the Ministry of Environment and Forestry, accessible via the Lapak GIS website (https://www.lapakgis.com/2019/05/shapefile-peta-tutupan-lahan-klhk-2017.html). This data provided key insights into the distribution of land use types within the study area, including oil palm plantations owned by PTPN I and residential areas. Such information is essential for understanding how different land cover types influence infiltration rates and surface runoff in the Unsam Catchment.

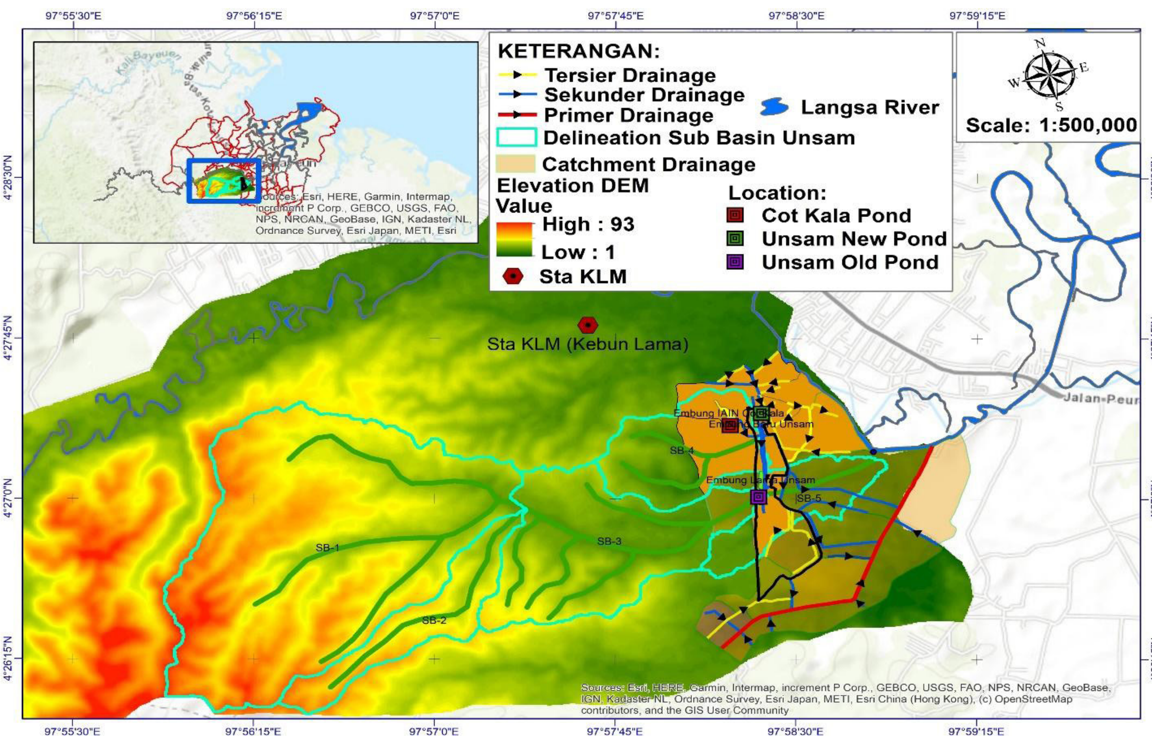

Figure 1. Research Study Area

The dimensions of the existing retention pond at Unsam were measured using a Bench Mark (BM) located at the Faculty of Engineering, with reference to the Mean Sea Level (MSL). This measurement was used to determine the elevation of the pond›s bottom, which also serves as a reference for assessing the potential dimensions of new ponds and evaluating the existing ponds at Unsam. The goal is to ensure sustainable water availability and effective flood control at Unsam. The determination of elevation is crucial for understanding the dead storage condition in the context of a retention pond. Dead storage refers to the volume of water stored at the bottom of the pond that cannot be drained or used. This portion of the pond always contains water and does not directly contribute to the active storage capacity during flood events. Dead storage is typically designed to accommodate sediment and prevent contamination in the pond. The effective storage volume is then calculated as the volume of water that can be stored and utilized during flood events, which is the water held above the dead storage level. This differs from the total storage volume, which includes the entire pond capacity, including dead storage. Effective storage volume only accounts for the portion that can be used for flood control.

To support the geological and soil analysis of the area, the study incorporated global geological data from the Global Hydrological Soil Group, which can be accessed at (https://daac.ornl.gov/SOILS/guides/Global_Hydrological_Soil_Group.html). This data is crucial for determining soil characteristics within the Unsam Catchment, which significantly impact the soil›s water absorption capacity and influence the magnitude of surface runoff. Overall, the combination of various data sources—including rainfall, topography, elevation, land cover, and soil type—was used to conduct a comprehensive analysis of flood discharge potential and retention pond efficiency within the Unsam campus area. This analysis aims to provide targeted recommendations for improving water management infrastructure within the study region.

2. Methods

This study employs various comprehensive and complementary analytical methods. The multidisciplinary approach incorporates the use of statistical distribution methods to analyze design rainfall, the FJ Mock method to calculate water availability, and hydrological modeling using HEC-HMS combined with the Curve Number (CN) method for flood discharge simulation. Additionally, sampling methods are applied in the water quality analysis of the retention ponds, while water demand calculations are performed according to national standards, following the guidelines of SNI-03-7065-2005 and criteria from the Ministry of Public Works. This combination of methods is designed to provide more accurate solutions for addressing flood challenges and sustainable water management within the campus environment. The research workflow is illustrated in Figure 2.

Figure 2 illustrates the workflow of the methodology for evaluating retention ponds at the Unsam campus, starting with the analysis of annual maximum rainfall from 2010 to 2022. Daily rainfall data was used to calculate design rainfall, focusing on extreme events that could cause flooding. The analysis was conducted using statistical distribution methods such as Normal, Log Normal, Log Pearson III, and Gumbel. This analysis produced design rainfall for 2 and 5 year return periods, which was then used to estimate flood discharge. These distribution methods have proven effective in various studies, including research by (Ismida et al., 2021), and frequently used in long-term rainfall distribution analysis, particularly for flood risk evaluation.

The Digital Elevation Model Nasional (DEMNAS) data was processed with HEC-HMS version 4.11 using GIS tools. These tools included Preprocess Sinks, Preprocess Drainage, Identify Streams, Break Point Manager, and Delineate Elements to delineate the Unsam sub-basin. DEM data was also used to identify flow direction and analyze the topography of the study area using QGIS 3.34, helping to determine areas prone to runoff during heavy rainfall. Potential sites for new retention ponds were identified based on flow accumulation toward lower elevations in the downstream part of the catchment.

Water demand at the Unsam campus was calculated based on the number of students and staff actively using the campus facilities. This calculation was conducted on an annual basis, considering seasonal variations that affect water usage. The guidelines used followed SNI-03-7065-2005 (SNI-03-7065-2005 Tentang Tata Cara Perencanaan Sistem Plambing, 2005),

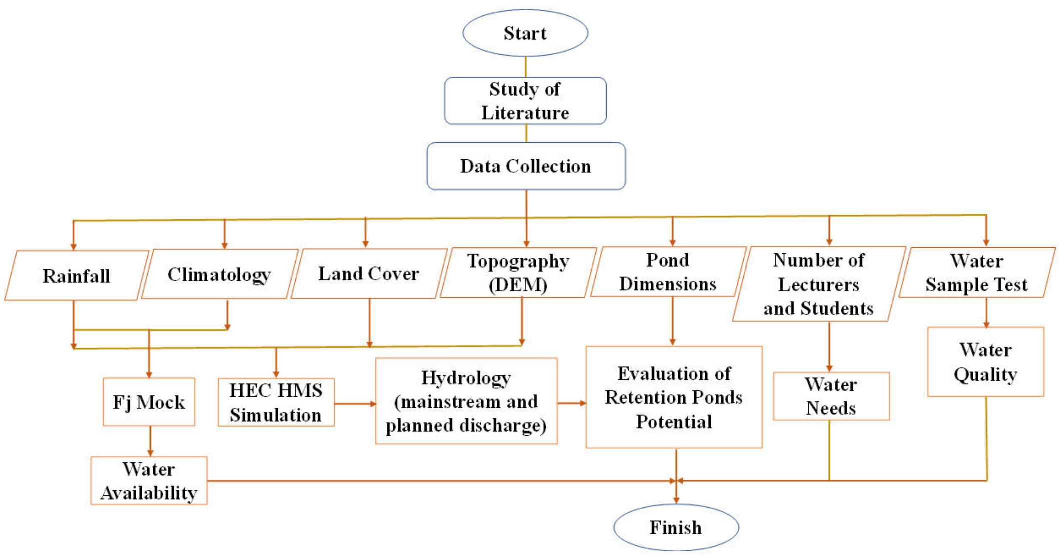

Figure 2. Methodological Flow Chart

which governs the planning of plumbing systems in Indonesia. For non-domestic water needs, such as for campus operations, the calculations followed the criteria set by the Department of Public Works in Water Supply Criteria (Standar Nasional Indonesia, 2012), ensuring that the water demand was computed in accordance with national standards.

The FJ Mock method was used to estimate reliable discharge or water availability during the dry season. This method took into account evapotranspiration, which was calculated using the modified Penman method. This approach was selected for its ability to provide accurate estimates by considering climatological factors such as sunshine duration, wind speed, humidity, and temperature. Climatological data was obtained from BMKG Malikussaleh in North Aceh, which accurately reflects the local climate conditions. The Penman method was considered superior to simpler methods as it incorporates dynamic local climate factors, leading to more precise estimations of water loss through evaporation and transpiration. This supports the FJ Mock method in providing more realistic estimates of water availability at the Unsam campus.

Flood discharge and flow volume simulations were performed using HEC-HMS version 4.11, a widely accepted tool for modern hydrological modeling. The data used for the simulation included design rainfall from the five-year return period, land cover, and geological conditions. These inputs were used to calculate the Curve Number (CN), which helps estimate surface runoff and flow volume based on land cover and the infiltration capacity of the soil, which is influenced by the geological composition. The simulated flow volume was used to evaluate the capacity of the existing retention ponds at the Unsam campus and identify potential sites for new natural retention ponds to mitigate flood risks and ensure water availability during the rainy season.

Water quality in the retention ponds at Unsam was tested through sampling at three key locations: the outflow from Cot Kala pond, New Unsam pond, and Old Unsam pond. Sampling was conducted on August 15, 2023, following rainfall events to observe the potential influence of fertilizers from the nearby palm oil plantation entering the ponds due to runoff from the Unsam catchment. These sampling locations were strategically selected based on their role as low-lying areas that may serve as natural retention ponds. Water quality analysis included physical parameters such as turbidity (NTU), total dissolved solids (TDS), temperature, taste, and odor. Chemical parameters such as pH, fluoride, hardness ($CaCO_3$), nitrite (NO_2), nitrate (NO_3), and iron (Fe) were also tested. Biological analysis was performed to detect Total Coliform and Escherichia coli, essential for determining whether the water meets raw water standards. These standards were referenced from studies by Nandal et al., (2020); Sukristiyono et al., (2021); Widyastuti & Haryono, (2016). Water quality testing in the Laboratory of the Environmental Health and Disease Control Technical Center (BTKLPP) Class I in Medan.

The selection of new retention pond locations at the Unsam campus was based on several critical criteria. These included the analysis of water flow direction, distance from the main campus roads, and proximity to the palm oil plantation owned by PTPN I. Additional factors considered were the distance from areas planned for future campus development. The goal of this analysis was to ensure that the new retention ponds could function optimally in reducing flood risks while supporting sustainable campus development.

However, there are several limitations to the data used in this study. Although the rainfall data is representative, local micro-climatic variations might not be fully captured due to the limited availability of nearby weather stations. The KLM station of PTPN I, the closest rainfall station, has limited data, with daily records available for only 13 years. This poses challenges in understanding the long-term impacts of climate change. Future research should incorporate climate change considerations to better predict rainfall variability. Furthermore, the resolution of the DEMNAS data, while useful for general mapping, may not be detailed enough for smaller areas or regions with highly varied topography. These limitations could affect the accuracy of the hydrological simulations, so the results should be interpreted with caution.

3. Result and Discussion

The delineation of Catchment from the DEM data resulted in five Catchment draining into the Langsa River outlet with a total area of 8.334 km², as depicted in Figure 3. The majority of these Catchment are covered by oil palm plantations owned by PTPN I.

Figure 3. illustrates the delineation of inflow and outflow from the Catchment. The Cot Kala pond flows towards Unsam and is located within Catchment 4 (SB-4), while the old Unsam pond, denoted as Junction 2 (JC-2), exits towards the Sink (Langsa River). The planned discharge for the Return period in surface runoff estimation, utilizing the maximum rainfall data from the Kebun Lama station (KLM) over a span of 13 years, yields planned discharge for Return periods as depicted in Figure 4.

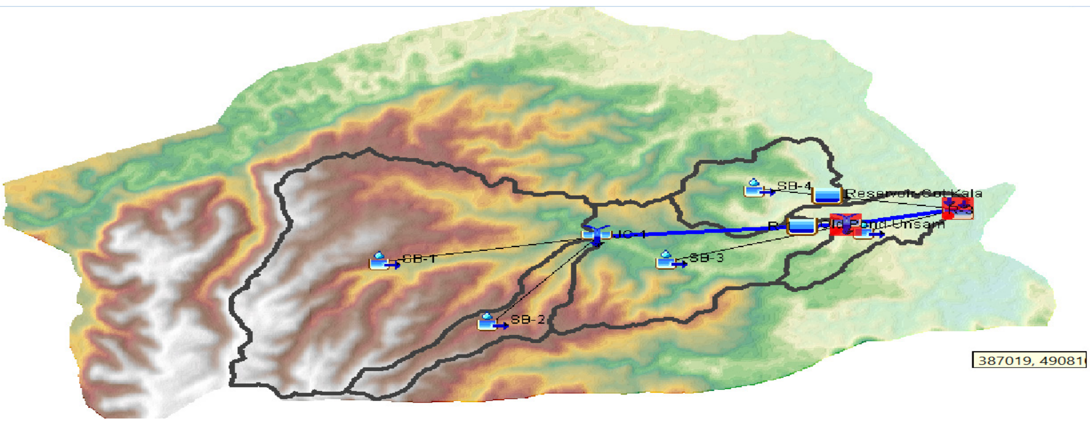

Figure 3. Delineation of the Unsam Catchment

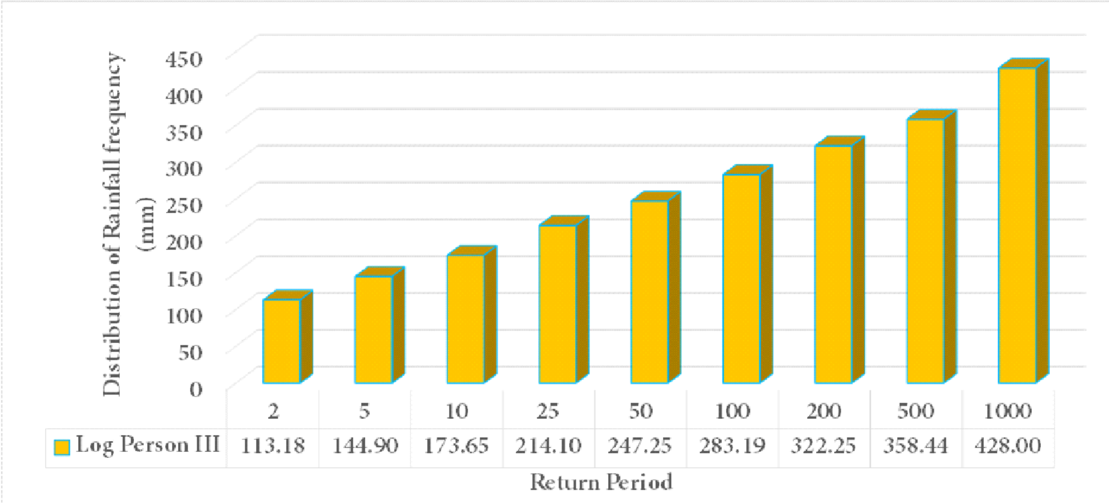

Figure 4. Return Period Rainfall Plan from KLM Station

Table 1. Hydrological Parameters for Planned Discharge Return Period

Catchment	Luas (km²)	Persen Luas	Curve Number (CN)	Max Storage (S)	Initial Abstraction (Ia)	l (Flow Length (km))	l (ft)	y (Slope)	y (%)
SB - 1	4.410	52.91	81.51	57.631	11.526	4.108	13182.55	0.1070	10.70
SB - 2	0.710	8.52	82.14	55.227	11.045	2.886	9259.78	0.1126	11.26
SB - 3	1.713	20.56	80.37	62.022	12.404	3.348	10743.934	0.06606	6.606
SB - 4	0.874	10.49	82.82	52.701	10.540	1.731	5554.245	0.06392	6.392
SB - 5	0.627	7.53	84.08	48.091	9.618	1.859	5968.346	0.0364	3.64
Total	8.334	100	81.66	57.049	11.410	13.933	44708.864		

Table 2. Planned Discharge Potential Inflow Volume into Retention Pond

Time	Juction - 2 (JC-2) Unsam				Catchment 4 (SB - 4) (Cot kala - Unsam)			
	Discharge Q_2 (m³/s)	Volume	Discharge Q_5 (m³/s)	Volume	Discharge Q_2 (m³/s)	Volume	Discharge Q_5 (m³/s)	Volume
00:00	0	0	0	0	0	0	0	0
01:00	0	0	0	0	0	0	0	0
02:00	25.36	365,184	1.462	31,579.2	5.258	132,501.6	0.375	9450
02:00	25.36	365,184	1.462	31579.2	5.258	132501.6	0.375	9450
03:00	35.402	509,789	46.046	994,593.6	3.58	90216	9.047	227984.4
04:00	16.501	237,614	58.341	1,260,165.6	2.11	53172	5.479	138070.8
05:00	11.056	159,206	23.238	501,940.8	1.446	36439.2	3.017	76028.4
06:00	6.369	917,13.6	15.519	335,210.4	0.351	8845.2	2.002	50450.4
07:00	4.241	610,70.4	9.273	200,296.8	0.065	1638	0.48	12096
08:00	2.777	399,88.8	6.168	133,228.8	0.01	252	0.088	2217.6
09:00	1.533	220,75.2	3.232	69,811.2	0.01	252	0.014	352.8
10:00	0.744	10,713.6	2.563	55,360.8	0.01	252	0.014	352.8
11:00	0.127	1,828.8	1.397	30,175.2	0.01	252	0.014	352.8
12:00	0.275	3,960	1.025	22,140	0.01	252	0.014	352.8
13:00	0.198	2,851.2	0.537	11,599.2	0.01	252	0.014	352.8
14:00	0.172	2,476.8	0.449	9,698.4	0.01	252	0.014	352.8
15:00	0.161	2,318.4	0.354	7,646.4	0.01	252	0.014	352.8
16:00	0.132	1,900.8	0.229	4,946.4	0.01	252	0.014	352.8
17:00	0.14	2,016	0.285	6,156	0.01	252	0.014	352.8
18:00	0.1	1,440	0.198	4,276.8	0.01	252	0.014	352.8
19:00	0.099	1,425.6	0.188	4,060.8	0.01	252	0.014	352.8
20:00	0.079	1,137.6	0.165	3,564	0.01	252	0.014	352.8
21:00	0.067	964.8	0.135	2,916	0.01	252	0.014	352.8
22:00	0.051	734.4	0.126	2,721.6	0.01	252	0.014	352.8
23:00	0.043	619.2	0.036	777.6	0.01	252	0.014	352.8

The planned rainfall for return periods of 2 and 5 years is used to determine the distribution of rainfall over time, which serves as the runoff volume against the potential volume of the retention pond as both inflow and outflow. Surface runoff is influenced by the curve number of land cover, predominantly composed of plantations and settlements, and results in a delay in peak flood discharge in the catchment area, as shown in Table 1.

Table 1 describes the condition of Catchment parameters that flow into the Unsam Campus Area, with a Curve Number (CN) value of 81.66 and Initial Abstraction (Ia) of 11.41 as the initial loss value, which is closely related to the S value (maximum storage capacity) in this process. The parameter influencing the runoff volume of a watershed is the impervious area (water-resistant) obtained from the planned discharge for return periods in Table 2, representing the potential availability of flow volume for 2 and 5-year Return periods.

The reliable discharge is calculated using the F.J. Mock method. This method simulates the monthly water balance based on the relationship between rainfall, evapotranspiration, and watershed characteristics, as described in Figure 5. The estimated minimum reliable discharge available is 0.18 m^3/second or 15,552 m^3/day at 80% condition, and 0.17 m3/second or 14,688 m^3/day at 90% condition. Both of these conditions are still considered reliable in meeting the water needs of the old Unsam retention pond.

When compared to the water demand conditions based on the number of occupants in the Unsam Campus Building, considering both students and faculty members, which is 3 m3/day as shown in Table 3.

The 90% reliable water supply can still meet the water demand on the Unsam campus, especially during a 50% increase in occupants. The planned discharge for a 2-year Return period has the potential to fulfill the water demand, but accommodating the excess discharge requires an expansion of the existing pond area. Additionally, to meet this water demand, water quality needs to be ensured for potable use within the study area. The maximum potential of the retention pond in handling the excess discharge for the 2-year planned Return period is illustrated in Figure 6.

Figure 6 illustrates the potential and evaluation of the retention pond storage area at Unsam campus based on the inflow volume from a 2-year design storm. The inflow discharge in SB-4 (Cot Kala – Unsam), with a volume of 132,501.6 m^3, was derived from hydrological modeling using specialized software. This model incorporated historical rainfall data to determine the 2-year design storm, as well as local geographic conditions, as shown in Table 2. Currently, the IAIN Cot Kala retention pond has a capacity of 28,904.64 m^3 (measured directly in the field based on area and depth). This requires the construction of a new retention pond around Unsam with a volume of 103,596.96 m^3 (132,501.6 m^3 minus 28,904.64 m^3), requiring a land area of 39,998 m^2 with a depth of 2.59 m. The potential for a new retention pond at Unsam, which can be implemented through adjustments in the pond's area and depth, aims to reduce excess runoff from the Unsam catchment area. An evaluation is also necessary for the existing pond, covering an area of 9.012 hectares, and for the potential Cot Kala – Unsam pond, which spans 3.988 hectares. However, the implementation of this plan requires cooperation between

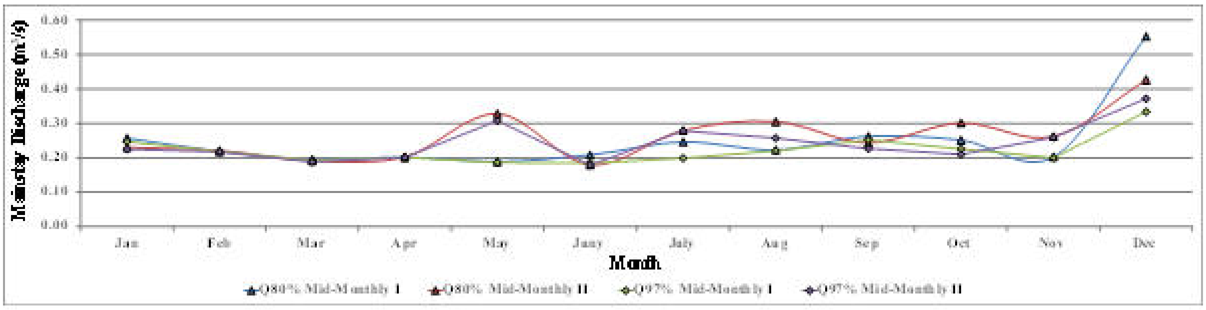

Figure 5. Availability of Reliable Water Supply at 80% and 97% in the Unsam Catchment.

Table 3. Unsam Campus Water Needs

Building	Lecturer	Employee	Student	Person capacity	Water Requirements liters/person/day	Water Requirements (Liter/day)	Water Requirements (m3/day)
Hukum	27	12	545	584	10	5,840	0.24
Ekonomi	40	15	1187	1242	10	12,420	0.52
Teknik	75	20	1550	1645	10	16,450	0.69
FKIP	85	19	1604	1708	10	17,080	0.71
Pertanian	34	15	841	890	10	8,900	0.37
Rektorat	20	129	-	149	10	1,490	0.06
UPT Perpustakaan	1	9	-	10	10	100	0.004
UPT Lab Dasar	1	5	-	6	10	60	0.003
Lab PGSD (Prodi PGSD dan Pend Jasmani)	21	1	947	969	10	9,690	0.40
Total						72,030	3.00

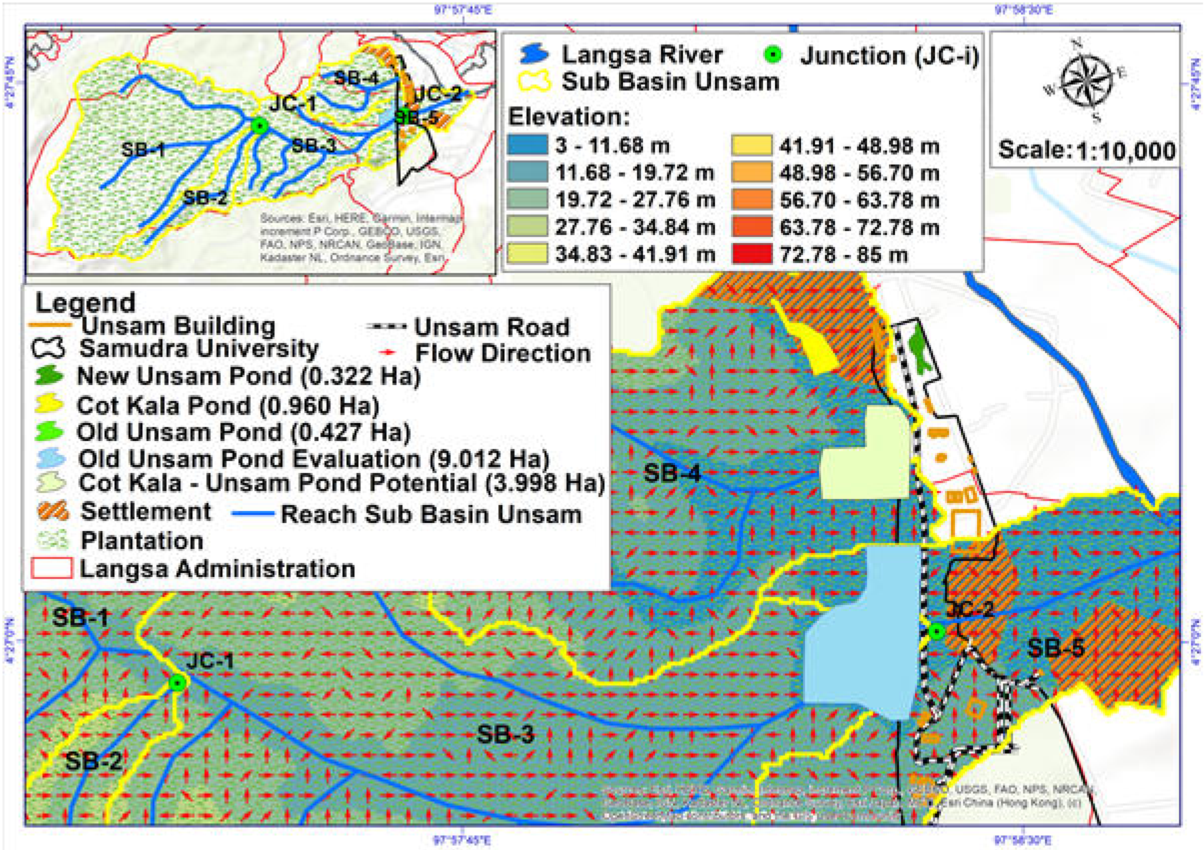

Figure 6. Potential for retention ponds in the Unsam environment

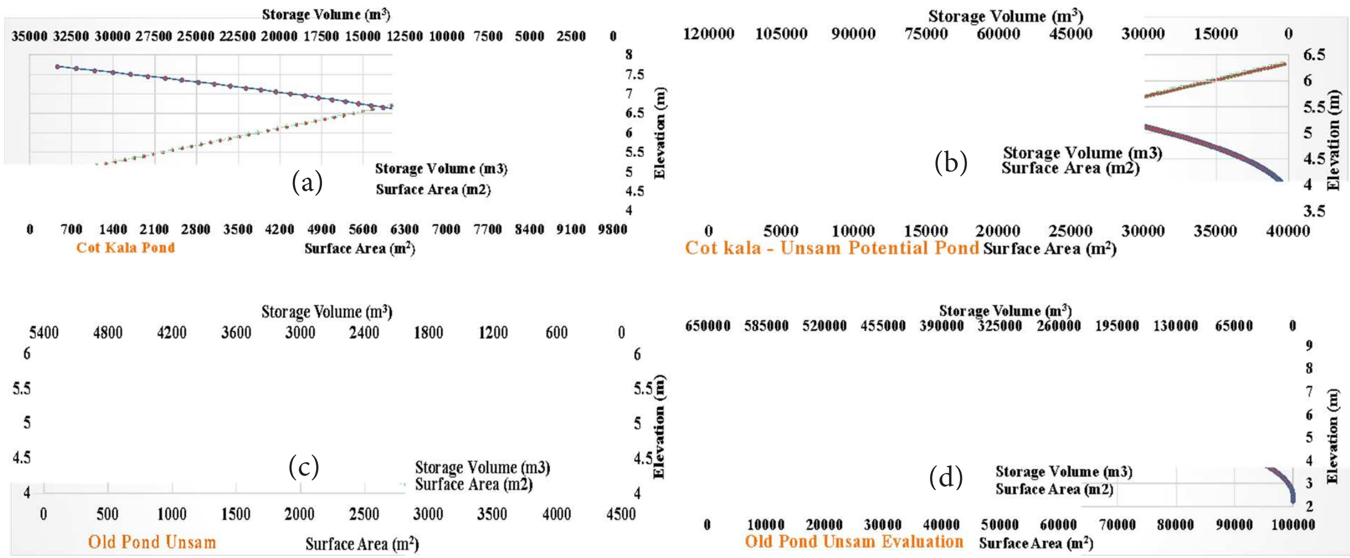

Figure 7. Relationship between elevation, area and volume Ponds

institutions, including Unsam campus, PTPN I, and IAIN Cot Kala.

Unsam currently has a new pond with an area of 3,221 m² and a depth of 1.27 m, with a storage capacity of 4,090.67 m³. However, this pond does not account for the inflow volume from SB-4, so it has not yet functioned to reduce runoff volume during heavy rainfall, which causes flooding at Unsam. The new pond only receives inflow from domestic wastewater generated by the community around Unsam through the drainage system. Based on the surface runoff model using HEC-HMS, the inflow volume from Junction-2 (JC-2) is 509,788.8 m³. Therefore, the old Unsam pond, with a capacity of 4,863.27 m³, is insufficient to accommodate runoff from the 2- and 5-year design storms with rainfall intensities of 113.18 mm/day and 144.90 mm/day (Figure 2), which generate surface runoff volumes of 509,789 m³ and 1,260,165.6 m³, respectively.

Hence, an evaluation of the old pond›s capacity is necessary to enable it to reduce surface runoff from the Unsam catchment (JC-2). A natural pond area of 90,120 m² with a depth of 5.90 m is required to store 526,902.85 m³ of runoff. The retention pond can be equipped with a sluice gate to regulate the water volume. Excess water can be discharged into the drainage system and directed towards the Langsa River system. However, the discharge control must consider the capacity of the drainage system to prevent the risk of flooding downstream of the pond. The relationship between area and storage capacity, along with the evaluation and potential of new retention ponds at Unsam, is shown in Figure 7.

Figure 7 illustrates several aspects related to the storage volume of Unsam›s natural retention ponds, including water availability and flow reduction. In Figure 7(a), it is shown that the storage volume of the IAIN Cot Kala pond at an elevation of +6.695 m+MSL has a volume of 14,530.72 m^3 with an area of 6,079.80 m^2. The dead storage is set at an elevation of +5.045 m+MSL with a volume of 327.99 m^3 and an area of 799.97 m^2, resulting in an effective storage volume of 14,202.73 m^3.

In Figure 7(b), the condition of the Cot Kala-Unsam pond is described through the relationship between area and storage volume at an elevation of +5.430 m+MSL. The storage volume reaches 44,262.82 m^3 with an area of 26,113.8 m^2. The dead storage is at an elevation of +3.99 m+MSL with a capacity of 1,001.80 m^3, yielding an effective storage volume of 43,261.02 m^3.

Figure 7(c) depicts the potential of the Cot Kala-Unsam pond in reducing flow volume. At an elevation of +5.458 m+MSL, the pond has an area of 26,575.90 m^2 and a storage volume of 45,843.51 m^3. The dead storage is recorded at 1,123.12 m^3 at an elevation of +4.00 m+MSL. The effective storage volume reaches 79,038.03 m^3 at an elevation of +5.99 m+MSL. The total storage volume of the pond is 103,681.34 m^3 with a maximum elevation of +6.31 m+MSL, while the pond bottom is at +3.70 m+MSL.

The evaluation of the old Unsam pond, as shown in Figure 7(d), demonstrates the relationship between area and storage volume at an elevation of +6.39 m+MSL. The storage volume is 252,947.43 m^3 with an area of 62,456.15 m^2. The dead storage is at an elevation of +2.79 m+MSL with a volume of 1,825.02 m^3, resulting in an effective storage volume of 526,902.85 m^3 at an elevation of +7.99 m+MSL. The total storage volume of the pond reaches 545,558.59 m^3 with an area of 90,120 m^2 at an elevation of +8.24 m+MSL, while the pond bottom is at +2.24 m+MSL. The reduction in design flow after evaluating the existing ponds and adding new ponds at Unsam is presented in Figure 8.

Figure 8 illustrates the reduction in flood discharge for the 2-year recurrence period after the evaluation and addition of potential ponds in the Unsam campus environment. At the location of the old pond, there is a 36.97% reduction in peak discharge in Figure 8 (a), while at the IAIN Cot Kala – Unsam pond location, there is a 33.82% reduction in peak discharge in Figure 8 (b). Additionally, there is a delay in peak discharge for 1-2 hours.

The pond evaluation conditions contribute positively to future water supply at the Unsam campus. However, in relation to the water needs from the pond, water quality testing from the pond water source is necessary to ensure that it is suitable for washing, bathing, and drinking purposes. The sampling points for water body samples are indicated in Figure 9.

Water body samples were subjected to water quality testing in the Laboratory of the Environmental Health and Disease Control Technical Center (BTKLPP) Class I in Medan. The testing covered physical, chemical, and biological parameters based on the clean water quality standards for river water according to Government Regulation No. 22 of 2021. Physical properties refer to characteristics that can be directly observed by the naked eye and other senses. Changes in the color and odor of water are indicators of a decline in water quality (Dai et al., 2020; Sukristiyono et al., 2021). The physical quality of water from the three ponds appears to be relatively good, as shown in Table 5.

The laboratory test results in Table 5 indicate that the water in the three ponds on campus is tasteless and odorless, and the turbidity values are relatively low. Total Dissolved Solids (TDS), which represent the amount of dissolved solid matter, serve as an indicator of the total particles or substances present, whether in the form of organic or inorganic compounds. High solid content is an indicator that hazardous contaminants, such as sulfate and arsenic bromide, may be present in the water. This condition arises when household or industrial waste has contaminated the water. The TDS value in the new pond is the highest at 122.8 mg/l. This is suspected to be due to the fact that the water source for this pond comes from domestic waste from the community around the Unsam campus.

Water is considered good if its temperature is not significantly different from the air temperature, which ranges between 20°C - 30°C. When the water temperature is below or above the air temperature, it indicates that the water is contaminated (Agudelo-vera et al., 2020). The measurements taken at the locations are relatively similar, around 37°C. This may be because the area around the pond is quite open, allowing a larger surface area of the water body to be directly exposed to sunlight, and the intensity of sunlight is quite high. Additionally, other factors affecting water temperature include land cover and vegetation on the pond banks. Total Dissolved Solids (TDS), which represent the amount of dissolved solid matter, serve as an indicator of the total particles or substances present, whether in the form of organic or inorganic compounds. The World Health Organization (WHO) states that as long as the water is categorized as fresh, the mineral content in the water will not have a negative impact on health. The laboratory test results for the chemical quality of the water from the three ponds are shown in Table 6.

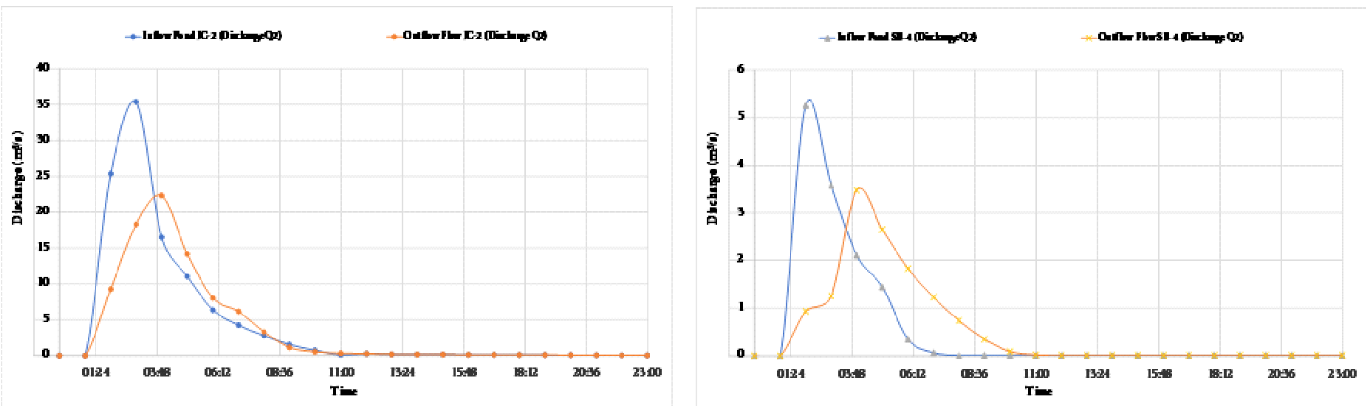

Figure 8. Reduction of Flood Discharge After and Before Ponds

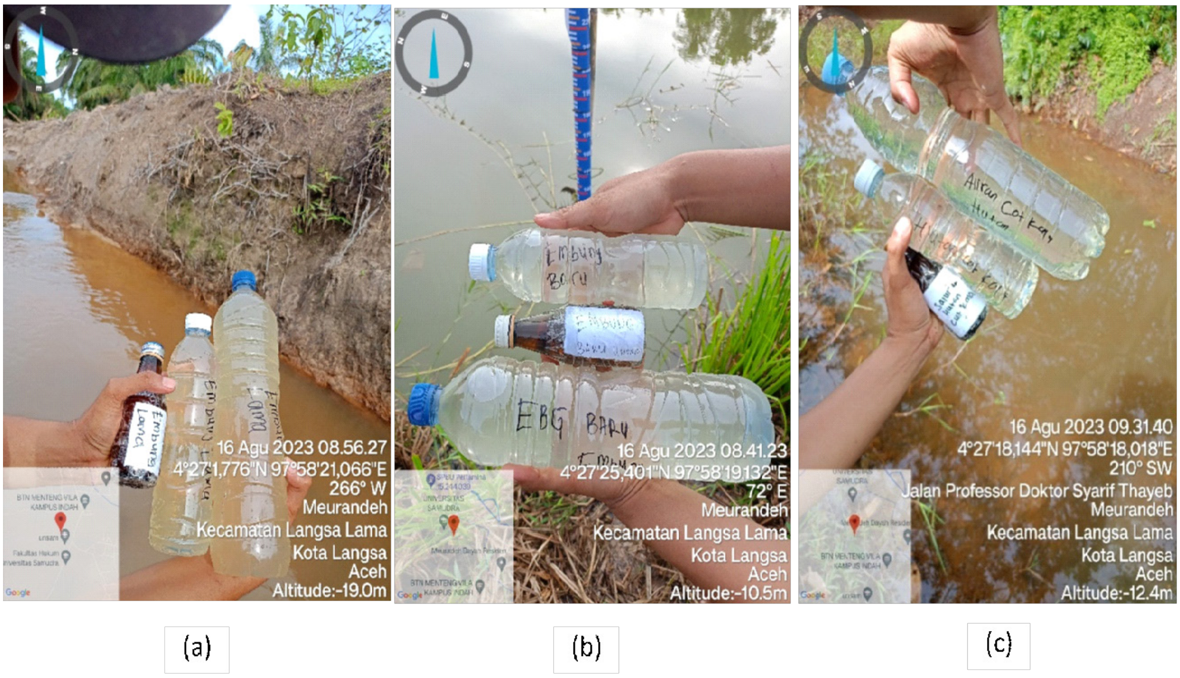

Figure 9. Unsam Campus Retention Ponds Water Sample

Table 5. Water Quality Physical Parameters in the Unsam Campus Retention Ponds

No.	Sampling Location	Kekeruhan (NTU)	Dissolved Solids (TDS) (mg/l)	Temperature (°C)	Flavor	Smell
1	Old Pond Unsam	1.22	28.88	27.3	Tasteless	Odorless
2	New Pond Unsam	1.29	122.8	27.4	Tasteless	Odorless
3	Hutan Cot Kala – Unsam Pond	1.28	70.5	27.3	Tasteless	Odorless
	Maximum Allowable Level	25	1000	Air Temperature	-	-
	Test Method	Tubidimetri	Elektrometri	Insitu	Organoleptis	Organoleptis

Table 6. Water Quality Chemical Parameters in the Unsam Campus Retention Ponds

No.	Sampling Location	PH	Flourida (mg/l)	hardness ($CaCO_3$) (mg/l)	Nitrit (NO_2)	Nitrat (NO_3)	Iron (Fe)	Mangan (Mn)	Zink (Zn)
1	Old Pond Unsam	6.3	<0.02	113.2	0.037	2.2	2.440	0.075	0.012
2	New Pond Unsam	5.9	<0.02	11.6	0.02	1	0.075	0.283	0.005
3	Hutan Cot Kala – Unsam Pond	6.9	< 0.02	110.4	0.013	0.5	0.957	0.048	0.011
	Maximum Allowable Level	6.5 - 8.5	1.5	500	0.06	10	0.3	0.4	0.05
	Test Method	Insitu	Spektrofotometri	SNI 06-6989.12-2004	Spektrofotometri	Spektrofotometri	APHA 3120B, 22 nd ed. 2012	APHA 3120B, 22 nd ed. 2012	APHA 3120B, 22 nd ed. 2012

pH value is a crucial factor that serves as an index for pollution. It has a direct effect on life within the ecosystem (Khatri & Tyagi, 2015). Iron (Fe) in the form of Fe3+ ions is highly soluble in water. Iron in water can cause disturbances such as a metallic taste and unpleasant odor, lead to a brownish discoloration on white clothes, and leave stains on bathroom fixtures and other equipment. Additionally, the presence of Fe in water can originate from the soil itself. Iron (Fe) is an essential metal required in certain quantities by living organisms, but it can become toxic when present in excess amounts (Zoroddu et al., 2019). Furthermore, water containing high levels of iron, when consumed, can induce nausea and damage the lining of the intestines, and in severe cases, even lead to death due to the erosion of the intestinal lining. Iron content exceeding 1 mg/l can cause irritation to the eyes and skin.

Hardness (CaCO3). Water hardness refers to the total content of Ca2+ and Mg2+ ions in water. Generally, hardness is expressed in terms of milligrams of calcium carbonate

($CaCO_3$) per liter. In household or industrial use, hardness is typically undesirable (Astuti et al., 2015; Verma, 2018). According to the Standard for Environmental Health Quality for Sanitation Needs, the maximum allowable limit for water hardness is 500 mg/l. Water with hardness above this threshold may lead to health issues. Potential consequences include cardiovascular disease and kidney stones (Nyoman et al., 2018). Laboratory analysis of water hardness in the three ponds revealed low values. All of these values are well below the maximum allowable limit according to hardness standards. This indicates that in terms of hardness level, the water from these three ponds is safe for consumption.

Nitrate (NO_3). Nitrate is one of the chemical parameters that disrupt water quality and affects the overall quality of the water (Amalia et al., 2021). Nitrate has the potential to flow towards lower water sources such as springs, rivers, and other water bodies, which can disrupt the nutrient levels in the water and directly impact its overall quality (Kane et al., 2016). Excessive levels of nitrate can lead to significant problems with water quality, accelerate eutrophication, and cause rapid growth of aquatic plants, affecting parameters such as dissolved oxygen levels, temperature, and others (Bhateria & Jain, 2016; M. F. Isma & Isma, 2019; World Health Organization, 2009). Based on the Indonesian Ministry of Health Regulation No. 32/MENKES/2017 on Standard Environmental Health Quality, all three nitrate concentration values are below the allowable threshold of 10.0 mg/l. The water quality standard values for all three rivers fall within Class 1, indicating that they can be used as a source of drinking water.

Nitrite is normally not found in drinking water, except in cases where the drinking water source is groundwater resulting from the reduction of nitrate by iron salts. Apart from groundwater, the presence of any nitrite in drinking water should raise suspicion of contamination. The established nitrite limit is 0.06 mg/l. The acute toxic effect of nitrite is methemoglobinemia, where more than 10% of hemoglobin is converted into methemoglobin (Mohanty et al., 2017). If this conversion exceeds 70%, it can be highly fatal. The significant influence of high levels of nitrite on the human body can lead to bloody diarrhea followed by convulsions, coma, and if not addressed promptly, death (Nadhila & Nuzlia, 2021). Upon examining the water quality test results, the nitrite content in the three ponds of Unsam campus remains below the established standard, making it still within safe tolerance levels for consumption as drinking water.

According to the Indonesian Ministry of Health Regulation No. 492/2010 regarding the requirements for drinking water quality, fluoride is an inorganic chemical substance directly related to health, and the maximum allowable level is 1.5 mg/L. Fluoride has beneficial effects in preventing dental caries at appropriate concentrations (Sfandy R et al., 2019). Health impacts may occur if the concentration of fluoride ions in drinking water exceeds safe levels for an extended period. This can lead to skeletal and spotted enamel damage in both children and adults. Conversely, a deficiency of fluoride in drinking water can lead to dental caries. In cases of severe poisoning, bone defects, paralysis, and even death may occur. Based on laboratory tests conducted on the three ponds of Unsam campus, all fluoride levels remain below the established standard, falling within the safe category for consumption.

The levels of heavy metals such as zinc (Zn), manganese (Mn), and iron (Fe) are usually sourced from waste pollution. Consumption of water contaminated with zinc (Zn) can lead to physiological disturbances, mortality, and the extinction of certain species (Khayan et al., 2017). The high risk of pollution in the Kaligarang river requires a detection system for water pollutants as an early warning of contamination. A deficiency of zinc in the human body can lead to decreased growth rate, reduced appetite and food intake, as well as other conditions like glossitis, alopecia, immune system disorders, impaired wound healing, pressure ulcers, burns, and more. Excessive zinc (Zn) levels, up to two to three times the Recommended Daily Allowance (RDA), reduce copper absorption. Exceeding up to ten times the RDA affects cholesterol metabolism, alters lipoprotein values, and appears to accelerate the onset of atherosclerosis. The minimum allowable zinc concentration for human consumption is 0.05 mg/l.

Iron (Fe) content in drinking water can cause nausea if consumed, and in large doses, it can also lead to damage to the intestinal walls, potentially resulting in death. Iron content exceeding 1 mg/L can cause irritation to the skin and eyes. If the solubility of iron in water exceeds 10 mg/L, it can cause an odor. In addition to its negative effects, iron also has positive impacts, as it is used in the formation of red blood cells. However, if it exceeds the limit set by the Ministry of Health, further treatment is necessary (Kustomo, 2022). The iron (Fe) content in the old Unsam pond is 2.440 mg/l, and in the IAIN Cot Kala – Unsam pond, it is 0.957 mg/l, both exceeding the standard limit of 0.3 mg/l.

A manganese (Mn) contaminant level greater than 0.5 mg/L can cause an unusual taste in groundwater and leave a brownish color on clothes after washing, in addition to potentially causing liver damage (Mekonin et al., 2022; Rahaman, 2018). According to the standard regulations of the Indonesian Ministry of Health No. 32/2017, the maximum allowable manganese (Mn) level in clean water is 0.5 mg/L (Ministry of Health Republic of Indonesia, 2017). In the research measurements, the average manganese content in the groundwater was 0.1 mg/L, still meeting the standard for clean water quality and deemed suitable for consumption by the public. Based on laboratory test results from the three ponds at Unsam campus, the manganese (Mn) content remains below the established standard.

In this study, water quality testing for biological parameters was conducted using indicators for Total Coliform and Escherichia Coli (E. Coli) bacteria content. The presence of coliform bacteria can originate from waste, agricultural residues, contamination with human/animal feces, and so forth (Lollino et al., 2015; Widyastuti & Haryono, 2016). The laboratory test results indicate that the water in both the old and new ponds at Unsam campus have been contaminated, as coliform bacteria were detected. On the other hand, the Cot Kala – Unsam pond was found to be uncontaminated, as seen in Table 7.

The Total Coliform parameter is useful in determining the quantity of Escherichia coli and aerobic bacteria present in the water. Escherichia coli bacteria generally originate from human feces, and they can infiltrate the soil and enter the groundwater system. Meanwhile, aerobic bacteria typically stem from decomposed animals or plants in the soil. These bacteria can be harmful if ingested, as they can disrupt the digestive system (Agus et al., 2019). The minimum allowable limit for Total Coliform is 1000 MPN/100 ml, and for Escherichia Coli, it is 0 MPN/100 ml. From the laboratory test results, it was observed that the old Unsam pond has been contaminated with a Total

Table 7. Water Quality Biological Parameters in the Unsam Campus Ponds

No.	Sampling Location	Total Coliform (MPN/100 ml)	Escherecia Coli (MPN/100 ml)
1	Old Pond Unsam	2200	330
2	New Pond Unsam	2200	170
3	Cot Kala – Unsam Pond	0	0
	Maximum Allowable Level	1000	0
	Test Method	APHA 9221B 23rd ed.2017	

Coliform count of 2200 MPN/100 ml and an Escherichia Coli count of 330 MPN/100 ml. This contamination arises from the residues of the palm oil plantation operated by PTPN I Langsa. Additionally, the new Unsam pond is contaminated with an Escherichia Coli count of 170 MPN/100 ml and a Total Coliform count of 2200 MPN/100 ml. This contamination is a result of domestic waste from the community entering the pond through the urban drainage system.

4. Conclusion

The hydrological conditions of the Unsam campus land have good potential to provide sufficient water volumes to meet the campus water demands. However, the current retention ponds are not yet capable of handling excess runoff from the catchment area, which flows into Unsam land from the surrounding plantation areas. The water demand on the Unsam campus is 3 m^3/day, while the potential storage capacity of the ponds can be optimized in the old Unsam pond area and the location between IAIN Cot Kala and Unsam. The flow discharge at SB-4 (Cot Kala – Unsam) is 132,501.6 m^3, while the flow volume from Junction-2 (JC-2) is 509,788.8 m^3. Currently, the old Unsam pond can only store a flow volume of 4,863.27 m^3. The capacity of the existing retention ponds indicates that the ponds are not yet able to manage the excess flow from the catchment area, especially from the surrounding plantation areas. Expanding and optimizing the retention ponds at the old pond location and the IAIN Cot Kala – Unsam area successfully reduced peak flow by 36.97% and 33.82%, with a peak time delay of 1–2 hours. This highlights the importance of evaluating and planning retention systems to mitigate flood risk and provide a more reliable water source for the campus. Reducing flood flow in the Unsam environment will have long-term positive impacts, such as reducing the risk of property damage due to waterlogging, which can reduce the cost of maintaining and repairing campus infrastructure.

The water quality from several retention ponds shows that not all of these water sources can be used as a clean water supply. Although the physical water parameters in the three potential retention ponds meet standard limits, chemical analysis indicates excessive levels of heavy metals such as Zinc (Zn) and Iron (Fe) in the old Unsam pond, exceeding the applicable standard limits. Biologically, contamination in the old Unsam pond, with Total Coliform and Escherichia Coli levels exceeding standards, and in the new pond, which is contaminated by domestic waste, necessitates improved water management practices. Technical measures to reduce biological contamination, especially Escherichia Coli, are urgently required to improve water quality and make it safer for use.

These findings emphasize that although retention ponds have the potential to support more sustainable water management on the Unsam campus, improving water quality through technical mitigation actions must be a priority before the water can be fully utilized. Continuous efforts to manage and monitor water quality and storage capacity are essential to achieving long-term goals aligned with the environmental sustainability of the campus. To support the sustainability of the Unsam campus and ensure the effectiveness of retention ponds as a water source and flood control measure, which also serves as a follow-up to future research, several recommendations can be made. These include an integrated water management approach, including adjusting the water storage capacity of retention ponds to ensure sufficient water supply during dry seasons and controlling flood runoff during the rainy season. Developing efficient water distribution infrastructure and installing real-time sensors to monitor water quality and quantity will also be key steps in ensuring sustainable water management. Implementing natural infiltration systems or technical systems can help filter pollutants and maintain water quality, and chemical or biological treatments using water treatment technologies such as aeration or microorganisms can clean the water from organic or chemical pollutants.

Additionally, educational campaigns to raise campus community awareness about water conservation should be continuously developed, including the efficient use of water and the optimization of green technologies, such as rainwater harvesting and groundwater recharge. In the long term, regular monitoring of the effectiveness of retention ponds, both in terms of storage capacity and water quality, must be conducted periodically, utilizing advanced technologies such as remote sensing and drones to provide accurate data and support evidence-based decision-making.

Acknowledgement

This research was funded by the LPPM-PM Lector Internal Research Grant at Samudra University through research contract Number 624/UN54.6/PG/2023 Samudra University in 2023

References

Agudelo-vera, C., Avvedimento, S., Boxall, J., Creaco, E., Kater, H. De, Nardo, A. Di, Djukic, A., Douterelo, I., Fish, K. E., Rey, P. L. I., Jacimovic, N., Jacobs, H. E., Kapelan, Z., Solano, J. M., & Pachongo, C. M. (2020). Drinking Water Temperature around the Globe : and Opportunities. *Water MDPI*, *12*(02), 1–19. https://doi.org/10.3390/w12041049

Agus, I. G., Kumala, H., Putu, N., Astuti, W., & Sumadewi, U. (2019). Uji Kualitas Air Minum Pada Sumber Mata Air di Desa Baturiti. *Higiene*, *5*(2), 101

Amalia, R. H. T., Tasya, A. K., & Ramadhani, D. (2021). Kandungan Nitrit dan Nitrat Pada Kualitas Air Permukaan. *Prosiding Seminar Nasional Biologi*, *1*, 679–688

Astuti, D. W., Rahayu, M., & Rahayu, D. S. (2015). Penetapan Kesadahan Total (CaCO3) Air Sumur di Dusun Cekelan Kemusu Boyolali Ddengan Metode Kompleksometri. *Jurnal*

Kesehatan Masyarakat (Journal of Public Health), *9*(2), 119–124. https://doi.org/10.12928/kesmas.v9i2.2273

SNI-03-7065-2005 tentang Tata Cara Perencanaan Sistem Plambing, (2005)

Bhateria, R., & Jain, D. (2016). Water quality assessment of lake water : a review. *Sustainable Water Resources Management*, *2*(2), 161–173. https://doi.org/10.1007/s40899-015-0014-7

Dai, W., Li, H., Chen, X., Xu, F., Zhou, Z., & ... (2020). Saltmarsh expansion in response to morphodynamic evolution: field observations in the Jiangsu Coast Using UAV. *Journal of Coastal ….* https://meridian.allenpress.com/jcr/article-abstract/95/SI/433/437584

Day, J. W., Cable, J. E., Cowan, J. H., & ... (2009). The impacts of pulsed reintroduction of river water on a Mississippi Delta coastal basin. *Journal of Coastal ….* https://doi.org/10.2112/SI54-015.1/192260

Florince, Arifaini, N., & Adha, I. (2015). Studi Kolam Retensi sebagai Upaya Pengendalian Banjir Sungai Way Simpur Kelurahan Palapa Kecamatan Tanjung Karang Pusat. *Jrsdd*, *3*(3), 507–520

Förster, S., Kneis, D., Gocht, M., & Bronstert, A. (2005). Flood risk reduction by the use of retention areas at the elbe river. *International Journal of River Basin Management*, *3*(1), 21–29. https://doi.org/10.1080/15715124.2005.9635242

Irwansyah, I., Isma, F., Ismida, Y., Isma, M. F., Sufahani, S. F., & Akbar, H. (2023). Effect of Stream River and Tidal on the Suspended Sediment Concentration of Kuala Langsa Estuary, Aceh, Indonesia. *ILMU KELAUTAN: Indonesian Journal of Marine Sciences*, *28*(1), 27–36. https://doi.org/10.14710/ik.ijms.28.1.27-36

Isma, F., & Purwandito, M. (2019). Estimasi Erosi dan Sedimentasi Lahan Pada DAS Langsa Berbasis Sistem Informasi Geografis (SIG). *Teras Jurnal : Jurnal Teknik Sipil*, *9*(1), 29. https://doi.org/10.29103/tj.v9i1.169

Isma, F., & Purwandito, M. (2020). *Pengangkutan Sedimen (teori , Aplikasi , dan Model Numerik)* (Issue December).

Isma, M. F., & Isma, F. (2019). Zona Kesesuaian Kualitas Air Di Estuari Langsa , Provinsi Aceh. *Seminar Nasional Ke-IV Fakultas Pertanian Universitas Samudra*, 105–115. https://ejurnalunsam.id/index.php/psn

Ismida, Y., Isma, F., Fajri, H., & Zevri, A. (2021). A Flood Water Level and Risk Analysis in Langsa River Aceh Province. *Advance in Social Science, Education and Humanities Research*, *576*(Icstms 2020), 439–446. https://www.atlantis-press.com/proceedings/icstms-20/articles?q=&author=&keyword=&title=&type=&page=1

Kane, S. N., Mishra, A., & Dutta, A. K. (2016). The effect of land use change on water quality: A case study in Ciliwung Watershed. *IOP Conference Series: Earth and Environmental ScienceJournal of Physics: Conference Series*, *755*(1). https://doi.org/10.1088/1742-6596/755/1/011001

Khatri, N., & Tyagi, S. (2015). Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. *Frontiers in Life Science*, *8*(1). https://doi.org/10.1080/21553769.2014.933716

Khayan, K., Husodo, H., Sudarmadji, S., & Sugandawaty, S. (2017). Usate of Filter Tube to Reduce Pb, Turbidity And Increase pH of Rain Water Flowing Through Zinc Rooftop House. *Jurnal Kesehatan Masyarakat*, *13*(1), 41–49. https://doi.org/10.15294/kemas.v13i1.9077

Kustomo. (2022). Chemometric Analysis of Iron, Manganese, and Zink Contents for Ground Water Quality Assessment around the Candi Industrial Estate of Semarang City. *Indonesian Journal of Chemical Science*, *11*(3). http://journal.unnes.ac.id/sju/index.php/ijcs

Lauda, N., Pradana, J., & Qomariyah, S. (2017). *Analisis perencanaan lahan kolam retensi di kelurahan tipes kota surakarta 1). September*, 904–911

Lollino, G., Arattano, M., Rinaldi, M., Giustolisi, O., Marechal, J. C., & Grant, G. E. (2015). Engineering geology for society and territory – volume 3: River basins, reservoir sedimentation and water resources. *Engineering Geology for Society and Territory - Volume 3: River Basins, Reservoir Sedimentation and Water Resources*, *3*(2013), 1–657. https://doi.org/10.1007/978-3-319-09054-2

Mekonin, W., Dejene, D., Lemma, B., & Addisu, T. (2022). Removal of Iron and Manganese from Groundwater by Using Aeration and Natural Sand Filtration Techniques. *Chemistry Africa*, *5*(2217–2226), 2217–2226. https://doi.org/10.1007/s42250-022-00486-2

Ministry of Health Republic of Indonesia. (2017). Indonesia Ministry of Health Decree Number 32 Year 2017 Concerning in Water Quality Standard for Hygien Sanitation, Swimming Pool, Solute Per Aqua and Public Bath. *Regulation of Ministry of Health Republic of Indonesia Nb. 32 Year 2017*, 1–20

Mohanty, A. K., Satpathy, K. K., & Prasad, M. V. R. (2017). Changes in sub-soil river water quality upon its open storage—a case study. *Environmental Monitoring and Assessment*, *189*(8). https://doi.org/10.1007/s10661-017-6095-z

Nadhila, H., & Nuzlia, C. (2021). Analisis Kadar Nitrit Pada Air Bersih Dengan Metode Spektrofotometri Uv-Vis. *Amina*, *1*(3), 132–138. https://doi.org/10.22373/amina.v1i3.492

Nandal, A., Kaushik, N., Yadav, S. S., Rao Neetu Singh, A. S., & Gulia, S. S. (2020). Water quality assessment of pond water of Kalanaur block, Rohtak, Haryana. *Indian Journal of Ecology*, *47*(1), 1–6

Nyoman, R. N., Amri, I., & Harun, H. (2018). Perbandingan Kadar Kesadahan Air PDAM dan Air Sumur Suntik Kelurahan Tondo Kota Palu Tahun 2017. *Jurnal Ilmiah Kedokteran*, *5*(3), 12–21. http://jurnal.untad.ac.id/jurnal/index.php

Rahaman, A. R. H. (2018). Contamination of arsenic , manganese and coliform bacteria in groundwater at Kushtia District , Bangladesh : human health vulnerabilities Aminur Rahman and Hafezur Rahaman. *Journal of Water and Health*, *16*(5). https://doi.org/10.2166/wh.2018.057

Sfandy R, Budiman, & Rismawati, N. (2019). Study Kualitas Air Pada Instalasi Pengolahan Air Vatutela PDAM Kota Palu. *Kolaboratif Sains*, *1*(1), 8

Singh, A. (2018). Managing the salinization and drainage problems of irrigated areas through remote sensing and GIS techniques. *Ecological Indicators*, *89*(December 2017), 584–589. https://doi.org/10.1016/j.ecolind.2018.02.041

Standar Nasional Indonesia. (2012). *Perencanaan sistem penyediaan air minum*.

Sukristiyono, S., Purwanto, R. H., Suryatmojo, H., & Sumardi, S. (2021). Analisis Kuantitas dan Kualitas Air dalam Pengembangan Pemanfaatan Sumber Daya Air Sungai di Kawasan Hutan Lindung Sungai Wain. *Jurnal Wilayah Dan Lingkungan*, *9*(3), 239–255. https://doi.org/10.14710/jwl.9.3.239-255

Trilita, M. N., Suryandari, W., & Handajani, N. (2020). Study of Hidrology Nunukan Raw Water Retention Basin in North Kalimantan. *Journal of Physics: Conference Series*, *1569*(4), 2–7. https://doi.org/10.1088/1742-6596/1569/4/042045

Ujianto, R., Wigati, R., Ardiansyah, I. R., & Kulsum, K. (2022). Perencanaan Desain Embung Untuk Kebutuhan Air Baku dan Pengendalian Banjir (Studi Kasus: Universitas Sultan Ageng Tirtayasa, Kampus Sindangsari). *Fondasi : Jurnal Teknik Sipil*, *11*(1), 66. https://doi.org/10.36055/fondasi.v0i0.13095

Verma, S. (2018). Assessment of water quality around coal - fired thermal power plant , Bathinda (Punjab), India. *Journal of Applied and Natural Science*, *10*(3), 915–924. https://doi.org/10.31018/jans.v10i3.1809

Widyastuti, M., & Haryono, E. (2016). Water quality characteristics of Jonge Telaga (Doline Pond) as water resources for the people of Semanu District Gunungkidul Regency. *Indonesian Journal of Geography*, *48*(2), 157–167. https://doi.org/10.22146/ijg.17595

World Health Organization. (2009). Nitrate and nitrite in Drinking-water. *Drinking Water*, *2*(2), 21

Zevri, A., & Isma, F. (2021). Studi Keseimbangan Air (Water Balanced) Daerah Aliran Sungai Asahan. *Teras Jurnal*, *11*(1), 1–16

Zoroddu, M. A., Aaseth, J., Crisponi, G., Medici, S., Peana, M., & Marina, V. (2019). The essential metals for humans : a brief overview. *Journal of Inorganic Biochemistry*, *195*(November 2018), 120–129. https://doi.org/10.1016/j.jinorgbio.2019.03.013