Water Quality Status of an Urban River in Jakarta – Nature-Based Solution Recommendations for Water Quality Improvement

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Abstract. The Park and Forest Service (Distamhut) of DKI Jakarta Province has a goal to increase the city's green open spaces by utilizing the city's river banks. This research evaluated the water quality of a river segment from the Cilangkap River, Sunter River Basin, and Ciliwung-Cisadane watershed. Located adjacent to an urban and residential area, the 1.19 km river segment received wastewater from domestic, agricultural, fisheries, and small-scale factory activities. Water samples are taken from 4 sampling points along the river during August 2022. Although utilized for fisheries and agriculture, the Pollution Index (IP) for Class III shows that the Pollution Index value is in the range of 0 < Plj 5.0, thus the river is lightly polluted. This paper also reviews several of the nature-based solution as recommendation for improving river water quality. Bioretention ponds, rain gardens, or surface-flow wetlands are the several alternatives that can be applied for improving urban river.

Keywords: Contaminated river, Lightly polluted conditions, Pollution index, River water quality, Nature-based solution

1 Introduction

Rivers are open streams with variable cross-section, longitudinal profile and slope. Each river has different characteristics and shapes [1]. The availability of water in rivers is a source of human life. Rivers whose ecosystems are maintained are very beneficial for humans. Environmental conditions and community behavior are mutually sustainable. Community behavior is formed from the surrounding environmental conditions, and environmental conditions are also influenced by people's behavior towards the environment. The decline in water quality can be caused by an increase in population, a lack of water absorption areas, and

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an increase in settlements on the banks of the river. In addition, it can be caused by the activity patterns of riverside communities, such as the use of rivers as waste disposal sites, both household waste and industrial waste. This decline in water quality causes the water to no longer be suitable for use, if the community continues to use the water, it will endanger public health [2].

The condition of river water in DKI Jakarta from upstream to downstream is generally getting worse in terms of physical quality, chemical quality and biological quality. Based on the River Pollution Index, the rivers in DKI Jakarta fall into the category of moderately polluted and heavily polluted [3]. BPS stated that in 2021, as many as 4,896 urban villages in Indonesia disposed of their waste into rivers, irrigation canals, lakes, or the sea and as many as 321 urban villages throw their waste into drainage channels [4]. The waste ends up in the sea or gets stuck on river banks and sluice gates, which is an eyesore. In addition to the problem of garbage, rivers are also used as waste disposal sites. This phenomenon not only occured in DKI Jakarta Province, as it is a very common sight to see sewers that lead to rivers throughout Indonesia. Liquid waste that is disposed of does not only come from households, but also from industries operating around the river. Disposal of waste into rivers can damage water quality and cause contamination of rivers by hazardous and toxic materials that have an impact on health problems. Contamination of water from domestic waste, agricultural waste, industrial waste, floods and droughts, or the impact of global warming disrupting the hydrological cycle and water management are factor that are challenging acess to clean water and sanitation for human needs [5]. Pollutant sources are divided into two, namely institutional and non-institutional. Institutional sources of pollution are sources of pollution from various types of activities with clear management, such as industry, commerce, buildings/offices, hospitals and others. Meanwhile, non-institutional pollutant sources are household activities or other activities for which it is not clear who is responsible for waste management, such as domestic waste and agricultural waste, waste dumped into rivers and erosion [6].

As a result of the human intervention earlier, the river lost its self-purifying ability. The loss of this ability causes the function of the river to decrease [7]. The river cannot be used as a water source unless it is treated first, unable to support an ecosystem, turning animals and plants in and around it unsafe to consume, and will be dangerous if used as a means of transportation or recreation [8,9,10]. Now the river only functions as a water-carrying channel. That function is slowly starting to disappear due to the increasingly poor condition of the river. The river is no longer able to accept the large water discharge, so when the rainy season arrives, it is flooded [11]. Therefore, it is necessary to take action to rehabilitate the river.

Several projects that have been implemented and succeeded are the ABC Waterworks project implemented by Singapore. One of the programs implemented is the Klang River Clean Up, flood management, and water body design. Now, apart from functioning as a source of raw water, the Klang River also functions as a popular recreational area [12]. In Indonesia, there has been an ongoing river rehabilitation project, namely the Citarum Harum Project, which was initiated by the West Java Provincial Government. The project, which has been implemented since 2019, is an acceleration program for controlling pollution and damage to the Citarum Watershed [13].

The Park and Forest Service (Distamhut) of DKI Jakarta Province has a goal to provide comfortable and sustainable green open spaces for residents. One form of its manifestation is the availability of urban forests that can be accessed by residents [14]. Several urban forests are crossed by rivers, one of which is the Cilangkap River Urban Forest which is located in Cipayung District, East Jakarta. However, the condition of the river in the Cilangkap City Forest is not necessarily suitable if it is directly integrated with green public open spaces. Looking at the example of the successful integration of public spaces and rivers in Singapore, river naturalization can be a solution to make the Cilangkap River Urban Forest a public space with rivers that can be used as recreational facilities for the community.

The Cilangkap River Urban Forest is one of the rivers that gets its water supply from the Sunter watershed, Ciliwung-Cisadane watershed. This river is located in the Cilangkap River Urban Forest which is directly adjacent to a residential area. Upstream to downstream of the river, there are domestic wastes and agricultural wastes that are dumped directly into the river. This results in a high pollutant load which causes a decrease in water quality. In addition, there is a tofu factory located downstream of the river that produces waste, which is directly discharged into the river without any processing, thus causing contaminated and murky water on the river. Therefore, it is necessary to test the quality of river water which can later helps to identify the pollution that occurs in the river water. This study aims to measure the current water quality status of the river and provide recommendations for suitable nature-based solutions to improve its water quality to be suitable for use as green public open spaces.

2 Method and Material

Field sampling was carried out three times. The first data collection was carried out in the first week to measure water samples in situ at three points. The second data collection was carried out in the third week to collect and measure water samples at four points along with submitting the preserved samples to an external environmental laboratory for ex-situ testing. The third data collection was carried out in the fifth week to track river paths and collect data on elevation, river depth, river width, garbage points and drain points.

The sampling of river water and preservation of samples refers to SNI 6989.157.2008 concerning the method of sampling surface water [15]. Sampling and sample testing was carried out in August 2022. The sampling process involved the selection of appropriate sampling points along the river, taking into consideration factors such as the location of pollution sources, flow patterns, and the overall characteristics of the river. Clean sampling equipment, including pre-cleaned 2 Litres plastic jars, 500-ml clear glass container (specifically for *E. Coli* analysis), and sampling poles, was used to collect water samples, ensuring that they were free from any contaminants that could affect the accuracy of the analysis.

During the sample collection phase, specific methods were followed to ensure proper representation of the water quality. These methods involved submerging the sampling bottle at designated depths (river surface to 0.5 *x* average depth), avoiding contact with sediments or surfaces that could introduce additional impurities, and ensuring a sufficient volume of water (2 Litres) was collected for Laboratory analysis.

To preserve the integrity of the water samples, appropriate measures were taken during handling, transportation, and storage. This included minimizing contact with air, protecting the samples from direct sunlight, and ensuring proper sealing in an air-tight cooler box and labeling of each sample to prevent any potential contamination or alteration of their properties.

Preservation techniques were employed as necessary, depending on the specific analysis requirements. This involved adding specific chemical preservatives, adjusting pH levels, or maintaining specific temperature conditions as specified by the standard. The preserved samples were then stored in controlled environments, such as cool and dark conditions, to minimize microbial growth and prevent any degradation or alteration of their properties.

The proper packaging and transportation methods were implemented to ensure the samples were protected during transit. This included using suitable containers, insulation, and following appropriate handling procedures to maintain the samples' integrity throughout the transportation process to the external laboratory.
Water Quality Analysis of river water includes physical, chemical, and biological parameters that are tested in-situ and ex-situ. The results of water quality measurements will be compared to the Class IV Water Quality Standards set by the Government Regulation of the Republic of Indonesia No. 22 of 2021 regarding the Water Quality Standards for Rivers. In-situ testing includes temperature, pH, and electrical conductivity [16] .

In-situ Testing, conducted for parameters:

1) Temperature, where measurement of the water temperature to determine the average temperature or significant temperature changes.
2) pH: Measurement of the acidity or alkalinity level of the water, which reflects the balance between hydrogen ions and hydroxide ions.
3) Electrical Conductivity, where measurement of the water's ability to conduct electrical current, which can indicate the amount of dissolved salts in the water.

Ex-situ Testing, conducted for parameters:

1) Turbidity, where measurement of the amount of solid particles dissolved or suspended in the water, which can affect water clarity.
2) Total Dissolved Solids (TDS), where measurement of the total amount of dissolved substances in water, including minerals, salts, metals, and organic compounds.
3) Total Suspended Solids (TSS), where measurement of the amount of solid particles suspended in water, including soil, silt, and organic particles.
4) Color, where measurement of the concentration of color in water, which can be caused by dissolved organic matter.
5) Dissolved Oxygen (DO), where measurement of the amount of oxygen dissolved in water, which indicates the health of the aquatic ecosystem.
6) Biochemical Oxygen Demand (BOD), where measurement of the amount of oxygen required by microorganisms to decompose organic matter in water.
7) Chemical Oxygen Demand (COD), where measurement of the amount of oxygen required to oxidize organic matter and oxidizable chemicals in water.
8) Sulfate, where measurement of the concentration of sulfate ions in water, which can come from industrial or natural activities.
9) Chloride, where measurement of the concentration of chloride ions in water, which can come from human or natural activities.
10) Nitrate, Nitrite, Ammonia, where measurement of the concentration of nitrogen in the form of nitrate, nitrite, and ammonium in water, which can be indicators of pollution.
11) Total Nitrogen, where measurement of the total amount of nitrogen in water, including organic and inorganic nitrogen.
12) Total Phosphates, where measurement of the total amount of phosphates in water, which can come from agricultural or domestic wastewater.
13) Iron, where measurement of the concentration of iron in water, which can come from natural sources or pollution.
14) Permanganate, where measurement of the chemical oxidation requirement in water using potassium permanganate.

15) Hardness, where measurement of the amount of metal ions such as calcium and magnesium in water, which can cause soap scum deposits.
16) Manganese, where measurement of the concentration of manganese in water, which can come from natural sources or industrial activities.
17) E. coli, where testing for E. coli bacteria as an indicator of human fecal contamination in water.

2.1 Sampling Location

The location of this test was carried out in Cilangkap River Urban Forest. This Cilangkap City Forest has an area of ±26.5 ha with a height of about 25-48 mdpl. It gets its water supply from the Sunter River Basin in the Cilangkap City Forest Area with a river length of ±1.19 km. This river receives domestic waste from people's homes and from factories, which may lead to water pollution. There are 4 river sampling locations in Cilangkap, the locations are shown in **Figure 1**.

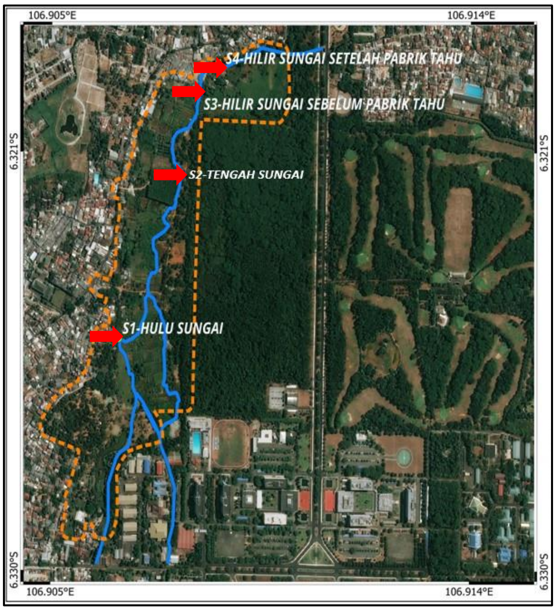

Fig. 1. Sampling Locations in Cilangkap River Urban Forest, Scale 1: 7006

Table 1. Sampling Locations Coordinates

Location	Location Coordinates
S1 – Upstream	6°19'31.4"S 106°54'25.6"E
S2 – Middle Stream	6°19'18.1"S 106°54'32.0"E
S3 – Downstream Before Factory	6°19'11.3"S 106°54'34.2"E
S4 – Downstream After Factory	6°19'09.5"S 106°54'36.4"E

Table 2. River Water Discharge

Location	b_1	b_2	h_1 (m)	h_2	h_3	A (m^2)	V (m/s)	Q (m^2/s)
Upstream	6	6.12	1.1	1.1	1.1	6.666	0.3	2
Middle Stream	4.8	5.7	0.88	0.88	0.88	4.62	0.1	0.462
Downstream Before Factory	4	4.15	1.03	1.03	1.03	4.19725	0.1	0.42
Downstream After Factory	6	6.12	0.8	0.8	0.8	4.848	0.1	0.489

2.2 Tools and Materials

There were a number of tools and ingredients which were used in taking sample as well as sample testing water by in situ. Tools and ingredients which were used for taking sample water can be seen on Table 3.

Table 3. Tools and Materials for Water Sampling

No.	Name	Amount	Unit	Function
A.	**Tool**			
1	Bucket	1	pc	Water sampling
2	Rope	1	pc	Water sampling
3	Dipper	1	pc	Water sampling
4	Meter	1	pc	Measuring the width and depth of the river
5	2L jerry can	10	pc	Storing water samples
6	Plastic funnel	1	pc	Transferring water samples to jerry cans
7	Stick	1	pc	Water sampling
8	Ice gel			Preservation of water samples
9	Dropper 10mL	1	pc	Moving liquid
10	Coller box	1	pc	Store and maintain water sample temperature
11	Durant 100mL	1	pc	Storing water samples
12	Durant 500mL	4	pc	Storing water samples
13	Pumpkin spray	1	pc	Washing tools
B.	**Materials**			
1	pH Paper	1	Pack	Measuring the pH of a water sample
2	H_2SO_4	50	mL	Preservation of water samples
3	Gloves	1	Pack	Protect hands when taking samples
4	Aquades	1	Liter	washing tools
5	Label and writing pads	1	Pack	Take notes measurement result

3 Results and Discussions

3.1 Measurement results

The results of water quality measurements will be compared with the Class IV Quality Standards Government Regulation of the Republic of Indonesia No. 22 of 2021 concerning River Water Quality Standards [16]. The classification or class of water used is the classification or class of water that has been stipulated in the Decree of the Governor of the Special Capital Region of Jakarta No. 582 of 1995. The classification of water used for the Cilangkap River Urban Forest is class D or class IV. According to the Decree of the Governor of the Special Capital Region of Jakarta No. 582 of 1995, Class D water can be used for agricultural purposes and urban businesses, such as the hydroelectric power plant industry [17]. Meanwhile, according to the Government Regulation No. 22 of 2021, Class IV water is used for irrigating plantations and/or other uses that require the same quality of water as those uses [16].

Table 4. Results of Upstream Water Quality Measurements

No.	Parameters	Concentration	Units	PP 22/2021		Result
				IV	Units	
A.	**Physical**					
1	Temperature	29.5	^{o}C	Dev 3	^{o}C	Good
2	pH	7.52		6-9		Good
3	Electrical Conductivity	313	µmhos/cm			
4	Turbidity	12	NTU			
5	TDS	155	mg/L	2000	mg/L	Good
6	TSS	12	mg/L	500	mg/L	Good
7	Color	10	Pt-CoUnit	-	Pt-Co Unit	Good
B.	**Chemical**					
1	DO	3.5	mg/L	Min. 1	mg/L	Good
2	BOD	5	mg/L	12	mg/L	Good
3	COD	37	mg/L	80	mg/L	Good
4	Sulfate (SO4)	3	mg/L	400	mg/L	Good
5	Chloride (Cl)	88	mg/L	600	mg/L	Good
6	Nitrate	<0.1	mg/L	20	mg/L	Good
7	Nitrite	<0.002	mg/L	-	mg/L	Good
8	Ammonia	4	mg/L	-	mg/L	Good
9	Total Nitrogen	6	mg/L	-	mg/L	Good
10	Total Phosphate	0.155	mg/L	-	mg/L	Good
11	Iron (Fe)	0.3	mg/L	-	mg/L	Good
12	Permanganate	12	mg/L			
13	Hardness (CaCO3)	102	mg/L			
14	Manganese (Mn)	0.2	mg/L	-	mg/L	Good

No.	Parameters	Concentration	Units	PP 22/2021 IV	PP 22/2021 Units	Result
C.	**Biological**					
1	E. Colli	2400	MPN/100mL			

Table 5. Results of Middle Water Quality Measurements

No.	Parameters	Concentration	Units	PP 22/2021		Result
				IV	Units	
A.	**Physical**					
1	Temperature	30.9	^{o}C	Dev 3	^{o}C	Good
2	pH	7.44		6-9		Good
3	Electrical Conductivity	317	µmhos/cm			
4	Turbidity	9	NTU			
5	TDS	151	mg/L	2000	mg/L	Good
6	TSS	7	mg/L	500	mg/L	Good
7	Color	9	Pt-CoUnit	-	Pt-Co Unit	Good
B.	**Chemical**					
1	DO	3.8	mg/L	Min. 1	mg/L	Good
2	BOD	4	mg/L	12	mg/L	Good
3	COD	29	mg/L	80	mg/L	Good
4	Sulfate (SO4)	<0.2	mg/L	400	mg/L	Good
5	Chloride (Cl)	80	mg/L	600	mg/L	Good
6	Nitrate	<0.1	mg/L	20	mg/L	Good
7	Nitrite	<0.002	mg/L	-	mg/L	Good
8	Ammonia	5	mg/L	-	mg/L	Good
9	Total Nitrogen	6	mg/L	-	mg/L	Good
10	Total Phosphate	0.163	mg/L	-	mg/L	Good
11	Iron (Fe)	0.4	mg/L	-	mg/L	Good
12	Permanganate	9	mg/L			
13	Hardness (CaCO3)	96	mg/L			
14	Manganese (Mn)	0.16	mg/L	-	mg/L	Good
C.	**Biological**	<0.002				
1	E. Colli	1500	MPN/100mL			

Table 6. Results of Downstream Before Factory Water Quality Measurements

No.	Parameters	Concentration	Units	PP 22/2021		Result
				IV	Units	
A.	**Physical**					
1	Temperature	30.8	^{o}C	Dev 3	^{o}C	Good
2	pH	7.45		6-9		Good
3	Electrical Conductivity	283	µmhos/cm			
4	Turbidity	12	NTU			
5	TDS	151	mg/L	2000	mg/L	Good
6	TSS	12	mg/L	500	mg/L	Good
7	Color	7	Pt-CoUnit	-	Pt-Co Unit	Good
B.	**Chemical**					

1	DO	3.6	mg/L	Min. 1	mg/L	Good
2	BOD	5.5	mg/L	12	mg/L	Good
3	COD	35	mg/L	80	mg/L	Good
4	Sulfate (SO4)	5	mg/L	400	mg/L	Good
5	Chloride (Cl)	6	mg/L	600	mg/L	Good
6	Nitrate	0.1	mg/L	20	mg/L	Good
7	Nitrite	<0.002	mg/L	-	mg/L	Good
8	Ammonia	4,74	mg/L	-	mg/L	Good
9	Total Nitrogen	7	mg/L	-	mg/L	Good
10	Total Phosphate	0.16	mg/L	-	mg/L	Good
11	Iron (Fe)	0.3	mg/L	-	mg/L	Good
12	Permanganate	12	mg/L			
13	Hardness (CaCO3)	97	mg/L			
14	Manganese (Mn)	0.2	mg/L	-	mg/L	Good
C.	**Biological**					
1	E. Colli	2400	MPN/100mL			

Table 7. Results of Downstream After Factory Water Quality Measurements

No.	Parameters	Concentration	Units	PP 22/2021		Result
				IV	Units	
A.	**Physical**					
1	Temperature	30.7	°C	Dev 3	°C	Good
2	pH	7.39		6-9		Good
3	Electrical Conductivity	326	µmhos/cm			
4	Turbidity	14	NTU			
5	TDS	163	mg/L	2000	mg/L	Good
6	TSS	21	mg/L	500	mg/L	Good
7	Color	12	Pt-CoUnit	-	Pt-Co Unit	Good
B.	**Chemical**					
1	DO	3.9	mg/L	Min. 1	mg/L	Good
2	BOD	4	mg/L	12	mg/L	Good
3	COD	27	mg/L	80	mg/L	Good
4	Sulfate (SO4)	2	mg/L	400	mg/L	Good
5	Chloride (Cl)	8	mg/L	600	mg/L	Good
6	Nitrate	<0.1	mg/L	20	mg/L	Good
7	Nitrite	<0.002	mg/L	-	mg/L	Good
8	Ammonia	4,69	mg/L	-	mg/L	Good
9	Total Nitrogen	6	mg/L	-	mg/L	Good
10	Total Phosphate	0.18	mg/L	-	mg/L	Good
11	Iron (Fe)	0.7	mg/L	-	mg/L	Good
12	Permanganate	10	mg/L			
13	Hardness (CaCO3)	106	mg/L			
14	Manganese (Mn)	0.9	mg/L	-	mg/L	Good

C.	**Biological**		
1	E. Colli	40	MPN/100mL

The measurement results show that the water quality upstream, middle, and downstream before and after the tofu factory still meets the set quality of standard thresholds. Thus, the river water is still in good condition according to its designation, which is to irrigate crops and/or other uses that require the same quality of water as that use. Based on the results of the interview with the person in charge of the urban forest, the river water has indeed been used by farmers for a long time to irrigate gardens. River water is taken manually using a bucket, and then the water is used to water the plants. Plants in the urban forest include kale, spinach, bitter gourd, chilies, and others.

Fig. 2. Agricultural Land at the river delta of Cilangkap Urban Forest area (Location **S1**)

In addition to agricultural land, the river water is also used for fish ponds. According to Government Regulation No. 22 of 2021, the allotment of the water for livestock must meet class III quality standards[16]. The Cilangkap River Urban Forest water does not meet the class III quality standards, so its river water cannot be used directly and requires processing first before it could be used for activities such as fish farming.

Fig. 3. Fishponds at the river delta of Cilangkap Urban Forest area (Location **S3**)

3.2 Water Quality Status of Cilangkap River Urban Forest

The status of water quality is the condition of water quality which describes the condition of river water which can be determined using the Pollution Index (PI) method which refers to the Decree of the Minister of Environment No. 115 of 2003 concerning Determination of Water Quality Status [18]. The following is the equation for the Pollution Index (PI):

$$PI_j = \sqrt{\frac{((Ci/Lij)_M^2) + ((Ci/Iij)_R^2)}{2}} \quad (1)$$

Information:
PI_j = Pollution index for designation j
Ci = Concentration of water quality parameters i
Lij = Concentration of water quality parameters listed in the quality standard
M = Maximum
R = Average

Table 8. Pollution Index Rating

Value Range	Status
$0 \leq Plj \leq 1.0$	Good
$1.0 \leq Plj \leq 5.0$	Light Polluted
$5.0 \leq Plj \leq 10$	Medium Polluted
$Plj > 10$	Heavy Polluted

Table 9. Water Pollution Index and Status Class IV

Sampling Point	Pollution Index	Status
S1 – Upstream	0.476	Good
S2 – Middle Stream	0.523	Good
S3 – Downstream before Factory	0.468	Good

S4 – Downstream after Factory	0.480	Good

Table 10. Water Pollution Index and Status Class III

Sampling Point	Pollution Index	Status
S1 – Upstream	3.947	Lightly Polluted
S2 – Middle Stream	4.289	Lightly Polluted
S3 – Downstream before Factory	4.210	Lightly Polluted
S4 – Downstream after Factory	4.189	Lightly Polluted

The pollution index of the four river points along with information on their quality status can be seen as follows. Table 8 shows that the overall Pollution Index (PI) value is in the range of $0 < Pl_j < 1.0$. Thus, the river is included in the category of rivers with water quality status in good condition. However, the PI for Class III shows that the PI value is in the range of $0 < Pl_j < 5.0$. Thus, the river is included in the category of rivers with a status of lightly polluted [17].

3.3 Water Quality Improvement of Cilangkap River Urban Forest

The Class IV designation of Cilangkap River Urban Forest means that the river is only suitable to be used for plant irrigations and is not recommended to be used for fishponds, because the river water does not meet Class III quality standards [16]. Therefore, the river water cannot be used directly for fish ponds, as it needs to be processed first. One way to improve water quality is nature-based solutions that are inspired and supported by nature, which are cost-effective, simultaneously deliver environmental, social and economic benefits and help build resilience. Nature-based solutions bring a greater variety natural features and processes to cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions. Nature-based solutions must bring benefit to biodiversity and support the delivery of multiple ecosystem services [19].

Several projects that used nature-based solutions have been implemented and succeeded. One of the example is the ABC Waterworks project implemented by Singapore. Some of the programs implemented on the project is the Klang River Clean Up, flood management and water body design. Currently, the Klang River functions as a source of raw water as well as a popular recreation area. A design feature of ABC Waterworks is natural treatment elements to retain and treat runoff before discharge into downstream waterways and bodies of water. With upstream planning and seamless integration with landscape and drainage systems, hydrological benefits and water quality improvements can be realized, in addition to other environmental benefits [12].

Nature-based solutions that can be applied in Cilangkap City Forest are bioretention ponds, rain gardens, and surface flow wetlands. A bioretention pond is designed to hold greater amounts of runoff that collect in larger areas. Plants that are placed around a designed collection area can survive times of wet and dry periods. The water is held within this area and slowly drains into the groundwater. Bioretention pond functions to maximize the volume of river water and runoff that can be accommodated, set aside pollutants, and recharge groundwater [12]. Rain gardens are often small and designed to reduce the impacts of stormwater runoff. stormwater enters the ground through a soil-based medium removes pathogens, and reduces nutrients, organic substances, and various heavy metals present in stormwater runoff. Generally, a rain garden will be placed near a swale where water is naturally directed. By layering rock and sand underneath the soil, the contaminants in the water can be dispersed and filtered through these elements before entering the groundwater [20]. Meanwhile, surface flow wetlands consist of shallow basins which are partially filled with soil, peat, or other media capable of supporting plant roots. Surface flow wetlands generally have a soil base, vegetation that appears above the water table, and the water surface above the substrate so that it inundates the plants. Surface flow can increase the detention time of water flow and remove pollutants [21].

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