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THE ASSESSMENT OF RIVER PERFORMANCE (CASE STUDY: PEPE RIVER, SURAKARTA)

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ABSTRACT
The performance of a river or river infrastructure is the capabilities of the river efforts to achieve the planned objectives. River infrastructure such as levee or dam is an infrastructure that is designed for a specific purpose. River infrastructures development objective can generally be grouped into two areas, namely to drainage at high flow (flood) in the rainy season and utilization at low flow (flow reliability) in the dry season. Questions that should be answered are to determine the performance of the river infrastructures and how to define the priority order of handling the improvement of the river performance.
The method to assess the performance of the river was conducted in two groups: assessing all the physical condition of the river and assessing the function of the river by using various indicators. The assessment of the river infrastructure functions carried out in accordance to the purpose of the infrastructure. The model of the assessment method which was developed is clarified to the river condition, hydrology and hydraulics analysis that conducted in small rivers in the upstream part of the Solo River rivers namely River Pepe which located in Surakarta City, Indonesia. The value of the river performance can be used to determine the river improvement priority sequence.
The research result shows that that the river performance of Pepe rivers is 73.87 %, it is indicates that the Pepe River is moderate performance. River performance between 60 to 80% needs a special maintenance to restore drainage function so that River Pepe needs special maintenance to improve the drainage function and physical condition.

Keywords: River Performance; Assessment; Pepe River

1. INTRODUCTION.
According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) the Earth’s freshwaters represent only 2.7% of the total water availability. Most of that, about 77.2% is found in polar caps, glaciers and icebergs, and the rest is distributed as: 22.4% stored in aquifers and groundwater; 0.36% in rivers, lakes and swamps, and 0.04% in the atmosphere (Rodrigues and Castro, 2008). Water on the river becomes crucial during wet and dry season. The problem during dry season consists of the quantity and quality of water. Both of them have strong relation to river ecosystem health (Pinto, 2014). In contrast during rainy season it always excesses of water.

The amount of surface water such as water on the lake and swam is transported mainly flows on the river. Rivers play an important role on transporting of water (Kaufman and

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Johnson, 2001). They transport water by gravity from headwaters to ocean. Topography of land surface becomes importance part of transporting water on the river. The performance of the river system should be known exactly during the operation of the river and river infrastructure (Nienhuis and Leuven, 2001). If the performance is well the river and river infrastructure will be operated normally and only need routine maintenance, but in contrast special maintenance or rehabilitation need to be done in worse river performance. The question is what the specific method to determine the river and river infrastructure performance.

River is a natural water flow or a place to storage the form of water drainage network along with water in it, from upstream to the estuary, with restricted right and left by a line of separation (Suyono and Tominaga, 1985). River is the combination of river stream and water flow. Rivers infrastructure is the physical infrastructure constructed for river management including supporting facilities (Indonesia Government Regulation No 38, 2011), such as: 1) Intake and water withdrawals structure, 2) Flood control structure, 3) Sediment control structure, 4) Protecting and strengthening riverbanks structure, 5) Regulating the flow direction structure, and 6) Equipment data monitor structure.

The objective of this research is to develop a river performance assessment method that can be used to the assessment of the river and river infrastructure performance. This study is intended to make a method for assessing the performance of the river and river infrastructure. Assessing river performance based on river condition and function is not developed formally in Indonesia. Some assessment methods develop based on the environment and ecological approach. Biological base river performance assessment basically is developed on watershed and biological river area. Approach assessment condition mainly assesses the water quality and river levels of pollutants.

The benefits of the performance assessment can be used to determine the priorities river and river infrastructure maintenance order and the benchmarking of restoration existing condition. At this time no standardized river assessment criteria in Indonesia, therefore the purpose of this research is to develop river performance assessment framework that can be used for the assessment of condition of the river and river infrastructure.

The assessment of river and rivers infrastructure performance in this study is specifically as a function of channel of drainage purpose. River functions as a provider of water and as a water storage as well as purification of water quality (Indonesia Government Regulation No 38, 2011) are not reviewed in this research. Rivers infrastructure performance assessment conducted to measure the ability of streams and rivers infrastructures/facilities to serve its function. Assessment of river physical condition as mentioned above is a powerful tool to evaluate the initial condition before river restoration taking place (Miller and Kochel, 2013).

The method to assess river performance in Indonesia become importance especially intended to make decision on maintenance priority scale on river and river infrastructure physical condition. In this moment a river and river maintenance priority scale is done by partial decision on a specific damage not systematic approach. The proposed river performance assessment method later used to determine the performance of physical condition and functions of Pepe River at Surakarta City. The application of this method will show the percentage of the performance by mean the function and condition of the river. In short by using an assessment results can be used to determine sequence of priority of rehabilitation or maintenance in case of limitation of funds condition.

2. METHODOLOGY/ EXPERIMENTAL

The study area is located in River Pepe, Surakarta City, Central Java, Indonesia. Selection of the river location is based on the river characteristic mainly on the river morphology, hydraulic and hydrology and the land use of river basin. The samples were also taken into consideration of river against chemical and biological context to consider the relation of river and watershed and also river disturbance. The river watershed and rural farmland will be very different from the river in urban areas and industrial sites. The selected river reach, about 15 km long from the junction, is on a segment of the river that does not have a reservoir to regulate the flow of water. The rivers have the natural flow conditions without setting the flow rate from the reservoir.

The research method in this study is the experimental method. It is started with the preparation of the river identify the river and river infrastructure components. Selection of the river component is based on the various river and river infrastructure component to get a technique of assessing the performance of the river and river infrastructure. The importance step of this research is developing the indicator and criteria base on the river and river infrastructure components. The last step is defining the indicator weight and making the assessment river streams method. River performance assessment is done by assessing the score.

River performance is good if all component of the river and river infrastructure functioning well and good physical condition. Otherwise bad river performance is all components of the river and river infrastructure is not functioning well and his physical condition was broken. In a simple stage of making the assessment method are as follows:

a. Identify of variables that affect the river and river infrastructures.
b. Analysis the relation of those variables in point 1 and grouped in different major component.
c. Determine the variables (as indicator of performance) that are sensitive to changes in the performance of the river and river infrastructures.
d. Conducting field research on the performance of a river reach is observed.
e. Find the magnitude of the effect of changes in the variables of the river and river infrastructures against performance index of rivers and river infrastructures.
f. Develop an assessment of river and river infrastructures.
g. Verify developed method at point 6 to selected rivers.
h. Refining and concluded the method and the results of the verification of the assessment method.

The assessment of the performance of the river and river infrastructure is limited by specifying the criteria and indicators of functions and physical condition of the river and river infrastructures. The other of river management such as the personnel, finance, facilities and method of river operation and maintenance do not assess. The assessment method is to determine the components of the river and river infrastructure. Each component has a performance indicator and criterion of rivers and river infrastructure that may perform well. Each component and sub component as the indicator then determined the specific criterion. River and river infrastructure criteria is focusing on the function as a drainage system.

Assessment the river physical condition are the assessing the structural condition based on the level of damage. If the damage is extensive then the criterion is bad. If the damage is lightweight in fair condition, while there is no damage or incidental damage then put in a good group. The assessment procedure based on the physical condition is undertaking the following criteria in Table 1.

Table 1. Physical river and river infrastructure condition

No	Score	Criteria	degree of damage
1	1	Bad	degree of damage > 60 %
2	2	Fair	degree of damage 20 – 40 %
3	3	good	degree of damage < 20 %

Source: (Indonesia Government Regulation No 20, 2010)

The percentage of river functions and river infrastructure conditions according to function performed by examining the function of the river and river infrastructure based its functions as a drainage system. Assessment function of the river is good if the river can serve as drainage system is well (according to the load discharge in the specified return period). If the river functioning is reduced so that the amount of freeboard is less than half the function of the building as a poor drainage system. The distribution of function of the river and river infrastructure is done by grouping on Table 2.

Table 2. Functioning of river and river infrastructure condition

No	Score	Criteria	Function of river/infrastructure
1	1	bad	Function < 60 %
2	2	fair	Function 80 – 60 %
3	3	good	Function > 80 %

Source: (Indonesia Government Regulation No 38, 2011)

The performance of river and river infrastructure is as a result of combination between condition and functioning of the river or river infrastructure. In many cases of river or river infrastructure have bad physical condition but still good serve, in contrast a good physical condition of river or river infrastructure do not have good function. The combination of river and river infrastructure are divided into nine criteria. River and river infrastructures combination indicator on physical condition and functioning of infrastructures as presented in Table 3.

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Table 3. Combination score physical and functional condition.

No	Score	Criteria		Description of Physical and functioning condition
		Physical	Function	
1	1	Bad	Bad	degree of damage > 60 %, function of infrastructure < 60 %
2	2	Fair	Bad	degree of damage 20 – 40 %, function of infrastructure < 60 %
3	3	Good	Bad	degree of damage < 20 %, function of infrastructure < 60 %
4	4	Bad	Fair	degree of damage > 60 %, function of infrastructure 80 – 60 %
5	5	Fair	Fair	degree of damage 20 – 40 %, function of infrastructure 80 – 60 %
6	6	Good	Fair	degree of damage < 20 %, function of infrastructure 80 – 60 %
7	7	Bad	Good	degree of damage > 60 %, function of infrastructure > 80 %
8	8	Fair	Good	degree of damage 20 – 40 %, function of infrastructure > 80 %
9	9	Good	Good	degree of damage < 20 %, function of infrastructure > 80 %

The score presented on Table 3 is based on function, its intended that higher score on functioning than physical condition. For example a river infrastructure which has bad physical condition but still has a good function is has higher score compared with a river infrastructure has the good physical condition but fair function condition.

The assessment method is done by giving a score every component or sub-component which is available on the field. Every component will contribute to the river performance based on the weight of the river and river infrastructure function mainly as a drainage system. Weights performance is calculated by the method of analytical hierarchy process. The weight factor is calculated by comparing the size of the relative importance of components compared with the other components. Standard weighting based on a scale ranging from 1 (mean the two things are equally important) to 9 (indicate the activity is very much more important than the others) to be used in the pairwise comparison matrix (Saaty, 1987). An evaluation sample consisting of n elements, with the pairwise comparison matrix is written as follows:

$$\begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \dots\dots & \dots\dots & \dots & \dots\dots \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix} \quad \dots\dots\dots [1]$$

Establishing priorities in the selection of AHP is done by calculating the eigenvector and eigenvalue through matrix operations. Eigenvector determines the ranking of the alternatives selected, while the eigenvalue provides an ensure of the consistency of the comparison process. Calculation column vector (Vj) is performed by the following equations:

$$Vj = Kij \times Wi \quad \dots\dots\dots [2]$$

Where Kij is a matrix of the form :

$$\begin{bmatrix} w_{11} & w_{12} & \dots & w_{1p} \\ w_{21} & w_{22} & \dots & w_{2p} \\ \dots & \dots & \dots & \dots \\ w_{n1} & w_{n2} & \dots & w_{np} \end{bmatrix} \quad \dots\dots\dots [3]$$

with the purpose/objective i = (1,2,3 ... , p) , and w is an alternative weighting 1 for the purpose 1, p represents a number of alternatives, and n is the number of destinations. Column vector, Vj, stating the final ranking of the alternatives tested in the analysis

The performance assessment of river and river infrastructure is based on the function and physical condition. The assessment of the river is conducted by the four component groups. Each group components consists of several sub-components with the weight of each factor. The calculation of the performance assessment of the river is done by calculating the performance of each sub-component. Each sub-component is given a score and multiplied by the weight factor. An example calculation on the performance of the sub-components River Side Slope (RSS) is as follows:

$$RSS = \frac{\sum(\frac{SRSS_i}{MSRSS} * LRSS_i)}{TLRSS} * WRSS \quad \ldots\ldots [4]$$

Where:
RSS = Performance of River Side Slope (%)
SRSSi = Score of River Side Slope location i
MSRSS = Maximum Score of River Side Slope location i
LRSSi = Distance of River Side Slope Location I (m)
TLRSS = Total Distance of River Side Slope (m)
WRSS = Weight factor of River Side Slope (%)

The river performance assessment on one component carried by summing the performance of each sub-component, then the result is multiplied by the weight factor. If one sub-component is not exist in river systems assessed, the standardization of weights applied to make adjustments of weighting factor to get balance the weighting factor for its component. The equation of river performance calculations is as follows:

$$RSF = \frac{(RSS+RBS+RCD+RDt)}{(WRSS+WRBS+WRCD+WRDt)} * WRSF \quad \ldots\ldots [5]$$

Where:
RSF = Performance of River Shortcut Floodway (%)
RSS = Performance of River Side Slope (%)
RBS = Performance of River Bad Slope (%)
RCd = Performance of Riparian Quality (%)
RDt = Performance of River Index Disturbance (%)
WRSS = Weight Factor of River Side Slope (%)
WRBS = Weight Factor of River Bad Slope (%)
WRCd = Weight Factor of Riparian Quality (%)
WRDt = Weight Factor of River Index Disturbance (%)
WRSF = Weight factor of River (%)

The assessment component of the river conducted by adding up all the components performance assessed. In another word performance calculations river infrastructure components should be performed for all sub-components. If the assessment component or sub-component is not completed then the performance value only takes into sub components by revised the weight factor. The overall assessment of the function and condition of the river is done by calculating the performance river/Shortcut/Floodway, river conservation infrastructures, utilization infrastructure and flood control infrastructure. The calculation is as shown in the following formula:

RIP = RSF + CsI + UtI + FCI .... [6]

Where:
RIP = River and River Infrastructure Performance (%),
RSF = Performance of River/Stream/Shortcut/Floodway (%),
XsL = Performance of Conservation infrastructures (%),
UtI = Performance of Utilization infrastructures (%).
FCI = Performance of Flood Control structures (%).

River and river infrastructure performance is the combination of the percentage of the weight of the function and the condition of both river and river infrastructure. The result of the assessment method can be one of these options:

1. if rivers and river infrastructure performance is very low (below 60 %) the river need to be rehabilitated;
2. if the rivers and river infrastructure has moderate performance (60-80%) the river need special maintenance to restore the function, and;
3. if the rivers and river infrastructure performance can perform well (above 80%) its indicate only need routine maintenance.

3. RESULTS

The assessment of river performance is based on the field observation and analysis condition of component of physical condition and function of river as a drainage system. There are many varieties of river infrastructures in the field. Assessment should take into account the possibility of all the infrastructures or groups of infrastructures. Indonesian Government Regulation No. 38 (2011) classifies into 3 groups of rivers infrastructures: (1) conservation, utility and flood control. Assessing the component of river and river infrastructures in this research is grouped as follows:

a. River/shortcut/Floodway
b. River Infrastructures
   1) Conservation infrastructures
   2) Utilization infrastructures
   3) Flood Control Infrastructures

This assessment method is made using four components river performance: (1) Conservation Infrastructures (CsI), (2) Utilization Infrastructures (UtI), (3) Flood Control Infrastructure (FCI). All components above are an indicator of the performance assessment of the river and rivers infrastructures. Assessed component of river/shortcut/ floodway need sub component for detail of assessing. The purpose of making the sub-component are to describe the performance in more accurate, Sub component as an indicators for calculate of the river/ shortcut/floodway consist of: (1) River side slope (RSS), (2) River bad slope (RBS), (3) Riparian Quality (RQt), River Index Disturbance (RDt). Component and sub-component which is rated the performance using a standard criterion as guidance. The explanation of the components and sub- components as indicators and criteria in judging the performance of the river presented at Table 4 (Indicator and Criteria of River Performance Assessment), as follows:

ISSN 2541-223X

Table 4. Indicator and Criteria of River Performance Assessment

Reference Number	Indicator		Criteria (physical condition and function)
	Component	Sub Component	
1.	River/shortcut/flood way (RSF)		Draining properly and good physical condition
1.a.		River side slope (RSS)	Land slide stability of river and side slope in draining water
1.b.		River bad slope (RBS)	River bad stability and sediment transport
1.c.		Riparian Quality (RQt)	Riparian changes quality of natural condition
1.d.		River Index Disturbance (RDt)	Disturbance level by human and animal
2.	Conservation Infrastructures (CsI)		Flow conservation / erosion and sedimentation control at the river bad
2.a.		Sediment control structure (SCS)	Total volume erosion and aggradation
2.b.		River bad stabilization structures (RBS)	The stability of the slope of the river bad
3.	Utilization Infrastructures (UtI)		Retrieval and Utilization of river water
3.a.		Free Intake (Fin)	Service water discharge
3.b.		Weir (Wi)	Setting the water level and water discharge
3.c.		Supply Reservoir (SRv)	the amount of water supply
3.d.		Pumping installation (Pum)	Pumping of Water
4.	Flood Control Infrastructure (FCI)		Control of water damage
4.a.		Levee (Lev)	Protection of flood
4.b.		Revetment/Lining (Rev)	Strengthening Slope stability
4.c.		River banks Protection.(Masonry/ Concrete)	Protection of landslides and slide erosion
4.d.		Krib	Guiding the flow and protecting the slide
4.e.		Groins/Jetty (Gro)	The ability to guide the flow

Reference Number	Indicator		Criteria (physical condition and function)
	Component	Sub Component	
4.f.		Side Spillway (SSw)	Dividing water
4.g.		Flow Regulation structure (FRS)	Regulating water
4.h.		Flood Control Reservoir/Detention/ Retention area (FCR)	Regulating peak discharge
4.i.		Hydraulic Monitor Equipment (HME)	Recording discharge

The assessment of river and river infrastructure is done by giving a weight each component of river and river infrastructure. River and river infrastructure performance is the combination of the percentage of the weight of the function and the condition of both river and river infrastructure. The purpose of giving the weighting factor is to provide the level of interest in accordance with the judging measurement function of the river and river infrastructures. Weight of the river and river infrastructures can be different that depend on the degree of interest function of the river and river infrastructures. The method of calculating the weight using hierarchy analytical process provides the possibility to distinguish the level of importance of the indicator compared to other indicators.

Total weight for the entire assessment of performance as a function of the drainage river is 100 %. Weight for each river and river infrastructure performance indicators calculated for the river and river infrastructures as a drainage functions. The result of the calculations of weights for each component is: (1) River/shortcut and floodway 39%, (2) Conservation Infrastructures 6%, (3) Utilization Infrastructures 11%, (4). Flood Control Infrastructure 44%.
The calculation results of weighted indicator in the assessment method stated that the two indicators are dominant in the measurement of the river infrastructure performance as the drainage system. It indicates that the river/shortcut/floodway and flood control infrastructure components is more important. Both of two components have high effect in the river as a function of the drainage system. Instead of two components that are not sensitive is the Conservation Infrastructures 6%, while Utilization Infrastructures is only 11%.
Calculation of weights for each component then detailed for sub components. A weighting factor in the component river streams/Shortcut/Floodway is grouped into 4 sub-indicators with the results weighted as follows: River Side Slope (7%), River bad Slope (9%), Riparian Quality (11%) and River Index Disturbance (12%). The weighting calculation in the method is described the Quality and River Riparian Disturbance Index states that more influence to the river functions as a drainage system. Weights calculation result for all components and sub-components of the river assessment is presented in Figure 1.

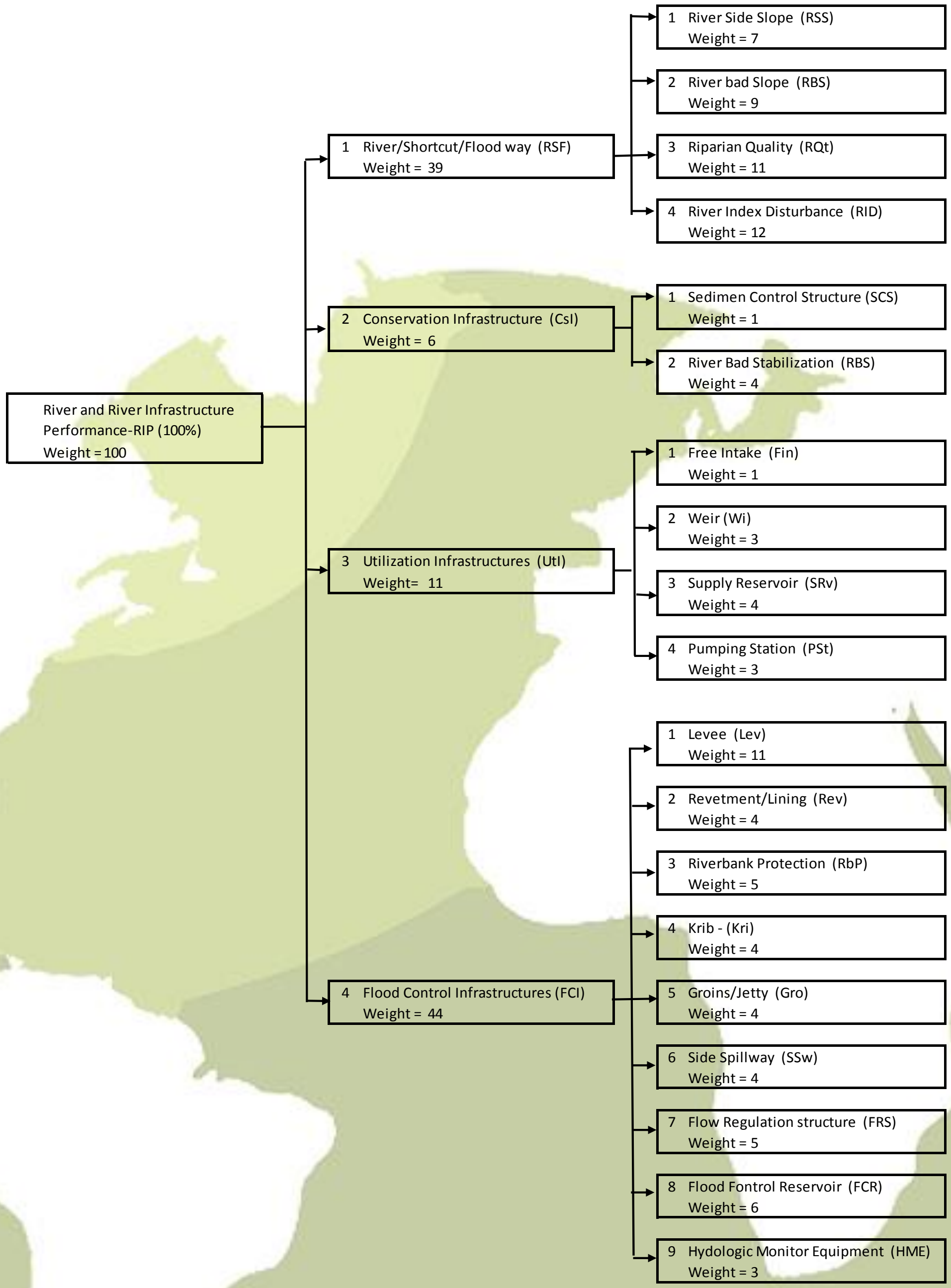

Figure 1 Weighting Factor of River and River Infrastructure Assessment (%)

The assessment method is developed using the indicator and criteria in assessing and giving a weights to each indicator, then applied to assess the performance on small rivers. The assessed river is located in Pepe River. This river is a second order river so that it is affected by back water from Bengawan Solo as the main river. Assessment is done on the field and continued at desk on hydraulic and hydrology analysis.

The research result on Pepe River shows that that the river performance of Pepe is 73.87 %. The result shows that the river performances as a drainage system do not have all similar components and sub components as designed on assessment criteria. With the difference in components and sub-components of the standard weighting in the

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standard method it is necessary to adjust the weight becomes relative weights. That particular weight is only valid in the local rivers were assessed. The assessment was used the specific weight.

If one the component is not complete and needs correction of weights, the standard of weight should be distributed into the other component groups concerned. If the rivers assessed do not have the score of a component, the weight of these components is distributed proportionally to each sub-component. In accordance with the method of performance assessment, the final result of the Pepe River's drainage system is presented in Table 5.

Table 5 The River Assessment of Pepe River

No	Component	Sub Komponen	Standart Wight (%)		Pepe River				
					Avg Score	Relative Weight (%)		Performance (%)	
1	2	3	4		5	6		7	
1	River (PoR)		38.9			38.9		25.4	
1.1.		River Side Slope (RSS)		7.1	2.0		7.1		1.6
1.2.		River bad Slope (RBS)		8.8	6.2		8.8		6.0
1.3.		Riparian Quality (RQt)		10.6	6.7		10.6		7.8
1.4.		River Index Disturbance (RID)		12.4	7.2		12.4		9.9
2	Conservation Infrastructure (Poc)		5.6			5.6		3.9	
2.1.		Sedimen Control Structure (SCS)		1.4					
2.2.		River Bad Stabilization (RBS)		4.2	6.3		5.6		3.9
3	Utilization Infrastructures (PoU)		11.1			11.1		10.0	
3.1.		Free Intake (Fin)		1.3					
3.2.		Weir (Wi)		3.3	8.1		11.1		10.0
3.3.		Supply Reservoir (SRv)		3.9					
3.4.		Pumping Station (PSt)		2.6					
4	Flood Control Infrastructures (PoF)		44.4			44.4		34.6	
4.1.		Levee (Lev)		10.6	7.7		16.3		13.8
4.2.		Revetment/Lining (Rev)		4.0	7.1		15.1		11.8
4.3.		Riverbank Protection (RbP)		5.0	6.2		13.1		8.9
4.4.		Krib - (Kri)		3.7					
4.5.		Groins/Jetty (Gro)		3.6					
4.6.		Side Spillway (SSw)		3.9					
4.7.		Flow Regulation structure (FRS)		4.8					
4.8.		Flood Fontrol Reservoir (FCR)		5.8					
4.9.		Hydologic Monitor Equipment (HME)		3.0					
	Sum		100.0	100.0		100.0	100.0	73.87	73.87

4. DISCUSSION

Table 5 shows that the river performance assessment has value 73.87 %. That value is in 60-80% of performance classification result which indicates that the river performance is a moderate performance. Using that value indicate that the Pepe river should be improve with special maintenance to restore the function. The lowest score is on the River Side Slope value (2), it is indicated that the river side slope is situated on clay so that it is unstable and may not have function properly. The second lowest score is 6.2 in the river bad slope and river bank protection score. This score represents erosion upstream reach and aggradation at downstream. It also need riverbank protection at many place as indicated on the lows riverbank protection score.

The performance assessment method is very effective in determining the ranking of repairing and maintenance of rivers and river infrastructure. Further analysis can be performed with scores determination to assess the sub-components as an indicator condition that requires improvement. The weakness of this assessment method is the implementation of the evaluation system is still highly subjective judgment in calculating the scores. Assessment in a field by field personnel need training in the perception awarding scores on each function and condition of the existing buildings on the ground. Furthermore, in order that this method is more applicable in the field, it needs to be made cards stated the condition assessment functions of rivers and streams of the building which is appropriate with format capability field officers.

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5. CONCLUSION

Based on developed assessment method and trials assessment of river performance test at river Pepe in Surakarta, Central Java found that the river performance is moderate (73,87 %). This result points out that the Pepe River needs a special maintenance program to restore the drainage function.

The main concern of this research is the generating of river component and river infrastructure component as an indicator of assessment. For further research need improvement especially the indicators of riparian quality and river index disturbance. The weakness of this report is lack of expert argument on setting up the weight of indicator so that still need of improvement quality.

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