Selection of Sediment Retention Structure Type in Coastal Reservoir (Case Study of Terboyo Retention Pond, Semarang)

Deddy Susanto, Slamet Imam Wahyudi, Soedarsono Soedarsono

Civil Engineering Department of Sultan Agung Islamic University, Semarang, INDONESIA

E-mail: deddypp5@gmail.com

| Submitted: November 13, 2024 | Revised: November 15, 2024 | Accepted: December 28, 2024 |

| Published: September 18, 2025 |

ABSTRACT

To overcome the problem of flooding and tidal flooding in the city of Semarang, especially in the eastern part of Semarang, the Semarang-Demak Toll Road was built which is integrated with the sea wall. The sea wall is planned to prevent sea water from entering the land area, however, the sea wall will also block the direct flow of several rivers to the sea so that a fairly large coastal reservoir is needed. As in general, coastal reservoirs and retention ponds often experience sedimentation problems which have an impact on the economic value of the reservoir concerned, while in the planning of coastal reservoirs and retention ponds in general they are not equipped with sediment retaining structures. From this study, the results of the selection of the right type of sediment retaining structure to be applied in coastal reservoirs were obtained. The selection of the type of sediment retaining structure in this study used the AHP (Analytical Hierarchy Process) method, which is a decision support model that involves experts who have knowledge and experience in planning or implementing retention ponds or sedimentation in river estuaries. From the results of the global priority analysis above, the weight of each alternative sediment retaining structure is obtained, namely a fixed dam of 33.21%, a vertical movable dam with an upper opening of 31.35%, without a sediment retaining structure of 19.61%, a vertical movable dam with a lower opening of 15.84%. From the results of the AHP analysis above, the highest weight was obtained, which was then used as a decision maker to choose the type of building with the highest value, namely a sediment retaining structure in the form of a permanent dam.

Keywords: coastal reservoir; sediment retention; AHP; fixed dam; movable dam.

INTRODUCTION

In areas with relatively low land areas such as along the north coast of Java, the main problem in handling floods is flooding due to rainwater that cannot be discharged directly into the sea and is coupled with seawater flooding that enters the land area or is called rob flooding. [1], as also stated [2] that land subsidence can also cause flooding. The flood disaster that impacted public infrastructure was caused by (1) the geographical location of the city of Semarang, (2) changes in land use, (3) embankments to prevent overflowing river water not functioning, (4) flooding from the southern part of Semarang, (5) high rainfall intensity, (6) high tide or rob, (7) not smooth or blocked channels [3]. Meanwhile, the condition of rob flooding in the city of Semarang, especially in the Kaligawe area, causes disruption to transportation, economic activities, industrial environments, residential environments and educational environments as well as health facilities, so it needs to be handled immediately. With these conditions, handling will be more appropriate with handling the polder system [4], [5]. With retention ponds on the coast, it can reduce seawater intrusion into the land [6], as well as [7] who said that embankments and pumps are one of the efforts to prevent flooding in the area.

To overcome the problem of flooding and tidal flooding in the city of Semarang, especially in East Semarang, the Semarang-Demak Toll Road was built which is integrated with the sea wall. The sea wall is planned to prevent sea water from entering the land area; however, the sea wall will also close the direct flow to the sea of several rivers so that a large retention pond is needed [8]. The retention pond functions to accommodate water from the river flow that is closed by the sea wall, before the water is pumped into the sea. The size of the reservoir volume will greatly affect the

pISSN 2302-4240
eISSN 2655-2086
Volume 14, Issue 3, September 2025, pp.0856-0864
DOI: http://dx.doi.org/10.32832/astonjadro.v14i3.18176 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

performance of the water pump [9]. There are two rivers that enter the retention pond, namely the Tenggang River and the Sringin River.

With this very vital purpose, the retention pond that will be built in the Semarang - Demak Toll Project Section 1 needs to be designed carefully so that the retention pond can work properly according to the plan. As in general, coastal reservoirs or in this case retention ponds often experience sedimentation problems which have an impact on the economic value of the reservoir in question [10].

In principle, the sedimentation process in retention ponds is influenced by 3 categories, namely delta deposits which mainly consist of coarse material, fine sediment deposition from homogeneous flow, transportation and deposition of sediment which is usually fine from stratified flow [11].

AHP or Analytical Hierarchy Process is a decision support model. This decision support model will describe complex multi-factor or multi-criteria problems into a hierarchy [12]. The AHP method is one method to help prioritize various choices using several criteria (multi criteria). Due to its multi-criteria nature, AHP is quite widely used in compiling decision-making priorities.

In the design of coastal reservoir planning and retention ponds, such as in the Terboyo retention pond, in general, there is no planned building or sediment control system. With this research, it is hoped that the selection of the right type of sediment retaining structure will be obtained to be applied in coastal reservoirs.

RESEARCH METHODS

Location

The research location is the planned Terboyo retention pond located on the Semarang - Demak Toll Road Section 1, in the administrative area of Semarang City, Central Java Province. There are 2 rivers that enter the Terboyo retention pond, namely the Tenggang River and the Sringin River (Figure 1). The sediment retention structure is planned to be placed at the mouth of the two rivers before entering the retention pond.

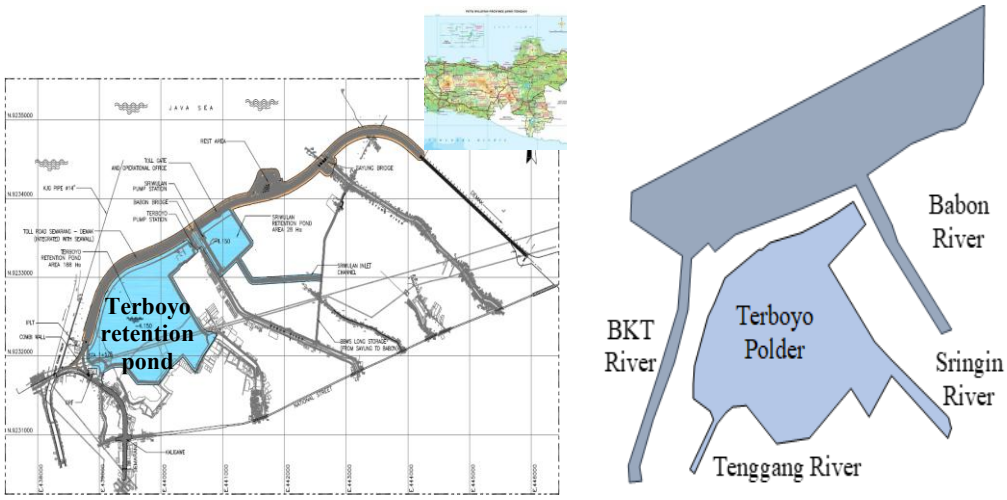

Figure 1. Research location and retention pond scheme

Method

The selection of the type of sediment-retaining structure in this study used the AHP (Analytical Hierarchy Process) method, which is a decision-support model. This decision support model will describe complex multi-factor or multi-criteria problems into a hierarchy [13]. In addition to being multi-criteria, AHP is also based on a structured and logical process [14]. Likewise, [15] selected the type of dam building with a moving gate using the AHP method.

Data for filling out the AHP was carried out by distributing questionnaires to experts who had experience and knowledge in fields related to coastal reservoirs/retention ponds and/or sediment

handling in the downstream/estuary, including from the Pemali-Juana River Basin Center (BBWS), Bengawan Solo BBWS, Brantas BBWS, Coastal Engineering Center, Sabo Engineering Center and the Public Works and Spatial Planning Office of Central Java Province.

The questionnaire is compiled based on a hierarchical structure, which must decompose into the objectives of an activity, identify several options, and formulate a criterion for determining priorities. In this study there are 5 criteria, namely ease of construction implementation, construction costs, ease of operation and maintenance of sediment retaining structures, ease of operation and maintenance of retention ponds and water flow barriers. While the alternative handling methods in general are without retaining structures and with sediment retaining structures. Sediment retaining structures that can be grouped into 2 types, namely in the form of permanent dams and movable dams. Movable dams can be categorized again into upper opening movable dams and lower opening movable dams. Fixed dams can be in the form of check dams or other structures that function to hold sediment, while upper opening movable dams are dam structures with an upper threshold whose elevation is regulated, and lower opening dams are structures whose elevation can be raised or lowered at the lower threshold.

So overall, the handling method in the hierarchical structure according to Figure 2, is without sediment retaining structures, permanent dams, lower opening vertical movable dams and upper opening vertical movable dams.

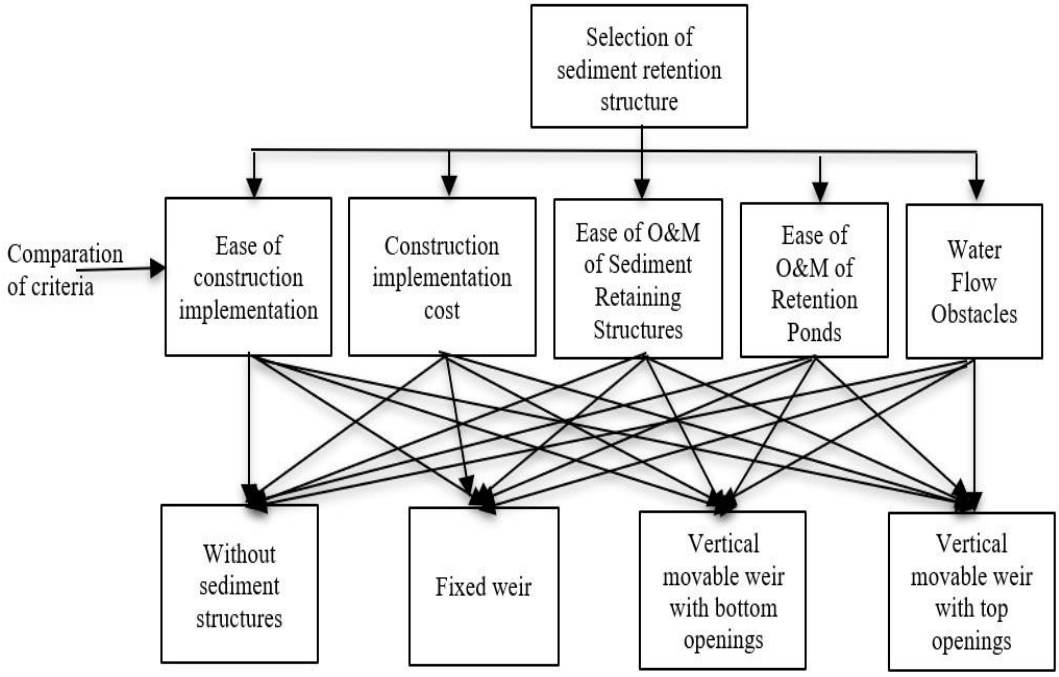

Figure 2. Hierarchical structure

The stages of research implementation are according to the flow chart in Figure 3 below.

pISSN 2302-4240
eISSN 2655-2086
Volume 14, Issue 3, September 2025, pp.0856-0864
DOI: http://dx.doi.org/10.32832/astonjadro.v14i3.18176 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

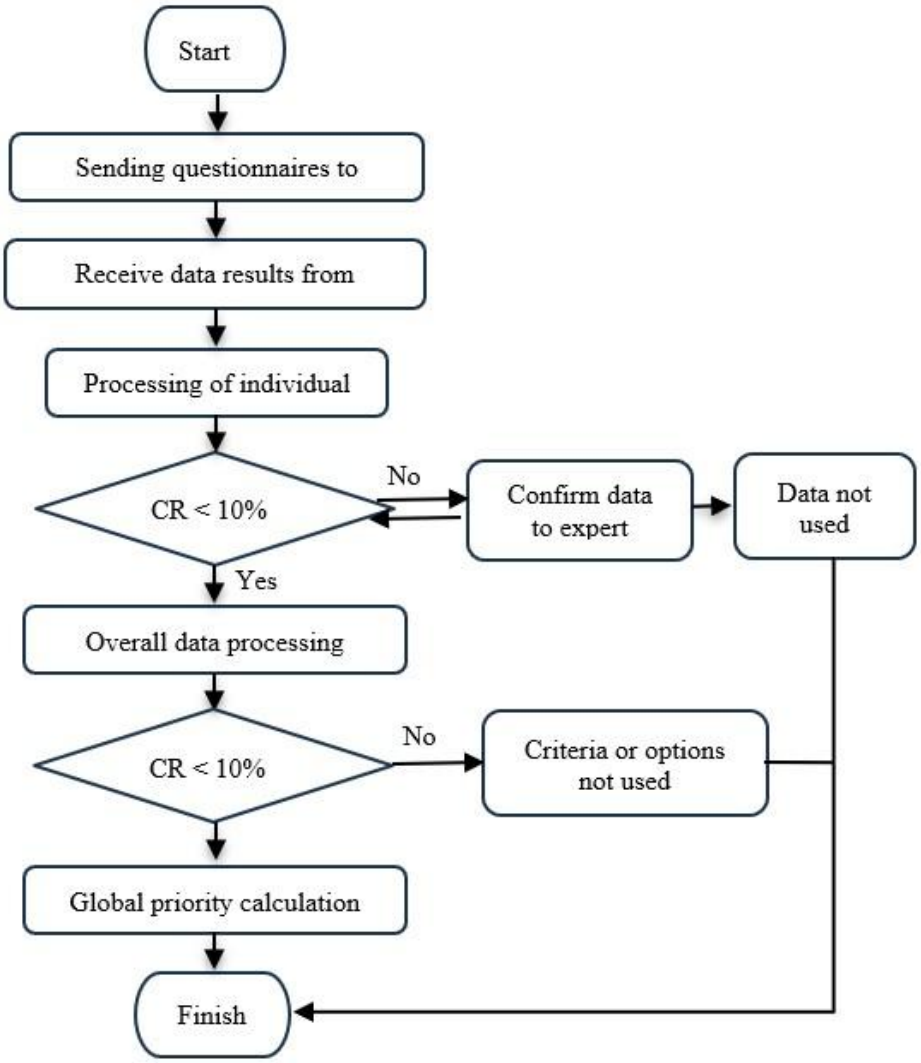

Figure 3. Flow chart

Data Analysis

The results of the questionnaire from the experts in the initial stage were processed individually for each choice of criteria and choice of type of sediment retaining structure. From individual processing, if a consistency ratio (CR) of more than 10% is obtained, confirmation is made with the expert. If there is an error in sending data, a revision is made, in which case the CR value is > 10%, the data is not processed further. Furthermore, overall data processing is carried out, in which if there are results with CR> 10%, the criteria or choice of type of sediment retaining structure are not used. In the final stage, global priority processing is carried out.

RESULTS AND DISCUSSION

In this study, there are five criteria, namely ease of construction implementation, construction costs, ease of operation and maintenance of sediment retaining structures, ease of operation and maintenance of retention ponds and water flow barriers. While the alternative handling methods are without retaining structures, fixed dams, lower opening vertical movable dams and upper opening vertical movable dams

From the data from filling out the questionnaire by the experts, the next step is two stages of assessment or comparison between elements, namely comparison between criteria and comparison

between choices for each criterion. Comparison of each criterion to determine the weight of each criterion. On the other hand, the comparison between choices for each criterion is intended to see the weight of a choice for a criterion [16].

Criteria Value Matrix

After conducting a pairwise comparison between criteria, the following results were obtained

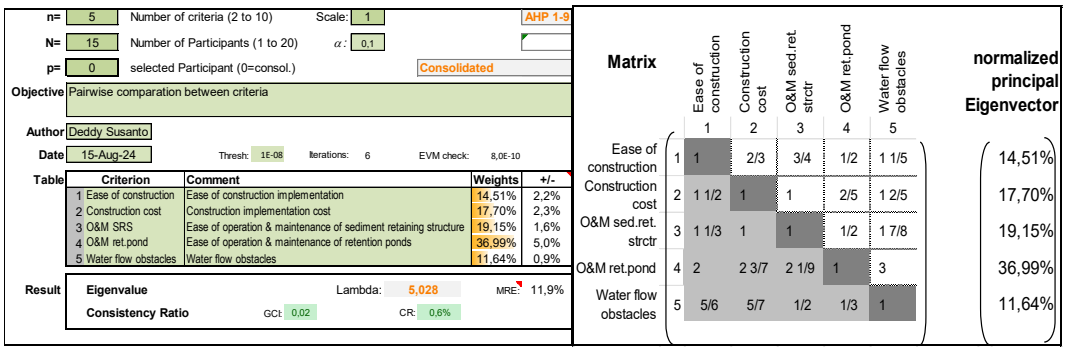

Figure 4. Results of comparison of criteria

From the results of the comparison of criteria, it can be concluded that the consistency ratio (CR) result = 0.6% is smaller than 10%. This indicates that the comparison process between criteria provides consistent results. Ease of operation and maintenance of retention ponds is most prioritized compared to other criteria with a value of 36.99%, ease of operation and maintenance of sediment retaining structures of 19.15%. construction costs of 17.70%, ease of construction implementation of 14.51% and water flow resistance of 11.64%. The basis for the choice of experts, the consideration of the service life of the coastal reservoir which must be comparable to the cost of construction so that the ease of operation and maintenance of retention ponds is considered to be the most important.

Criteria for Ease of Construction Implementation with Alternative Sediment Retaining Structures

From the calculation of paired comparisons between alternative sediment retaining structures with the criteria for ease of construction, the following results were obtained:

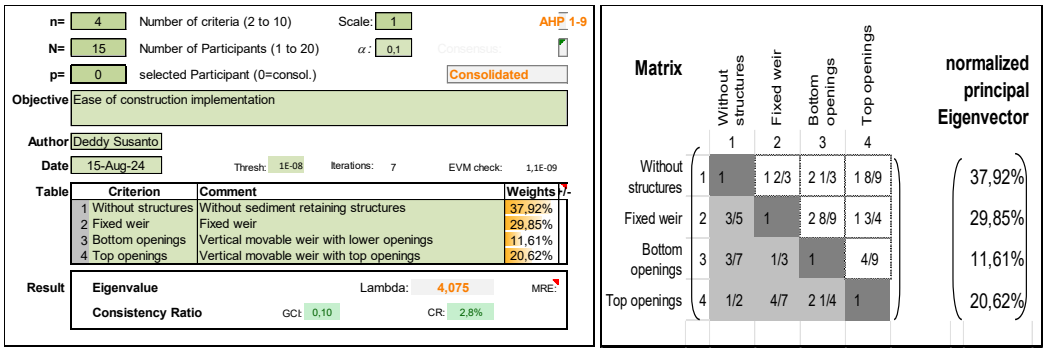

Figure 5. Results of comparison of ease of construction implementation

From the results of the comparison of ease of construction implementation, the result of CR = 2.8% is obtained which is smaller than 10%. This indicates that the comparison process between alternative methods of handling sediment retaining structures with the criteria of ease of construction implementation provides consistent results. Handling without sediment structures is preferred compared to other handling alternatives with a value of 37.92%, while fixed dams are 29.85%, vertical movable dams with upper openings are 20.62% and vertical movable dams with lower openings are 11.61%.

ASTONJADRO

pISSN 2302-4240
eISSN 2655-2086

Volume 14, Issue 3, September 2025, pp.0856-0864
DOI: http://dx.doi.org/10.32832/astonjadro.v14i3.18176 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Criteria for Construction Implementation Costs with Alternative Sediment Retaining Structures.

From the calculation of paired comparisons between alternative sediment retaining structures with the criteria of construction implementation costs, the following results were obtained:

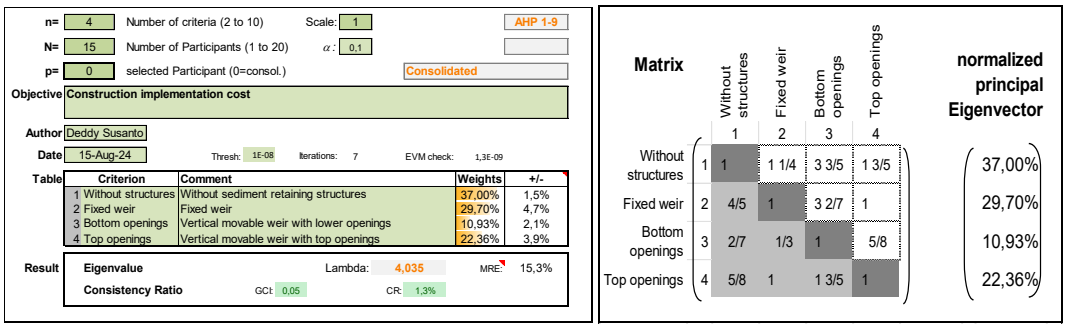

Figure 6. Results of comparison of construction implementation costs

From the results of the comparison of construction implementation costs, the result of the consistency ratio (CR) = 1.3% is obtained, which is smaller than 10%. This indicates that the comparison process between alternative methods of handling sediment retaining structures with the criteria of construction implementation costs provides consistent results. Handling without sediment structures is preferred with a value of 37.00%, while fixed dams are 29.70%, upper opening vertical movable dams are 22.36% and lower opening vertical movable dams are 10.93%.

Criteria for Ease of Operation and Maintenance of Sediment Retaining Structures with Alternative Sediment Retaining Structures

From the calculation of paired comparisons between alternative sediment retaining structures with the criteria for ease of operation and maintenance of sediment retaining structures, the following results were obtained

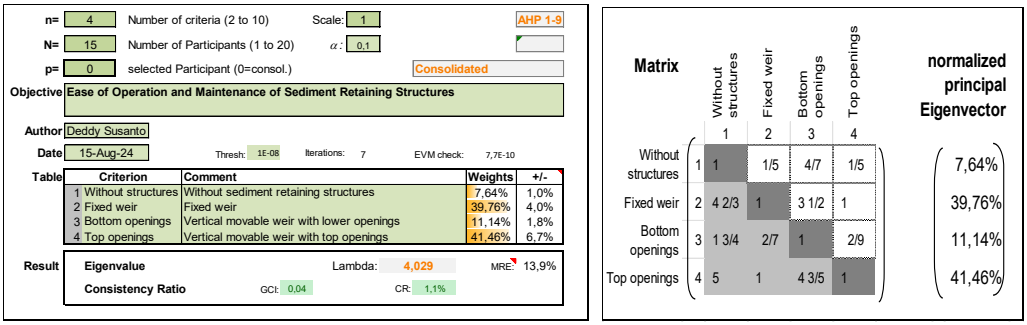

Figure 7. Comparison results of the criteria for ease of operation and maintenance of sediment retaining structures

From the results of the comparison of the criteria for ease of operation and maintenance of sediment retaining structures, the result of CR = 1.1% was obtained, which is less than 10%. This indicates that the comparison process between alternative methods of handling sediment retaining structures with the criteria for ease of operation and maintenance of sediment retaining structures provide consistent results. Handling with a vertical movable weir with a top opening is preferred compared to other handling alternatives with a value order of 41.46%, while a fixed weir is 39.76%, a vertical movable weir with a bottom opening is 11.14% and without a sediment retaining structure is 7.64%. The basis for the choice of experts, among the choices of sediment retaining structures, a fixed weir has ease of maintenance because there are no parts that must be moved either vertically or horizontally so that it will only focus on the sediment on the upstream side of the weir.

Criteria for Ease of Operation and Maintenance of Retention Ponds with Alternative Sediment Retention Structures.

From the calculation of a pairwise comparison between alternative sediment retaining structures with the criteria for ease of operation and maintenance of retention ponds, the following results were obtained:

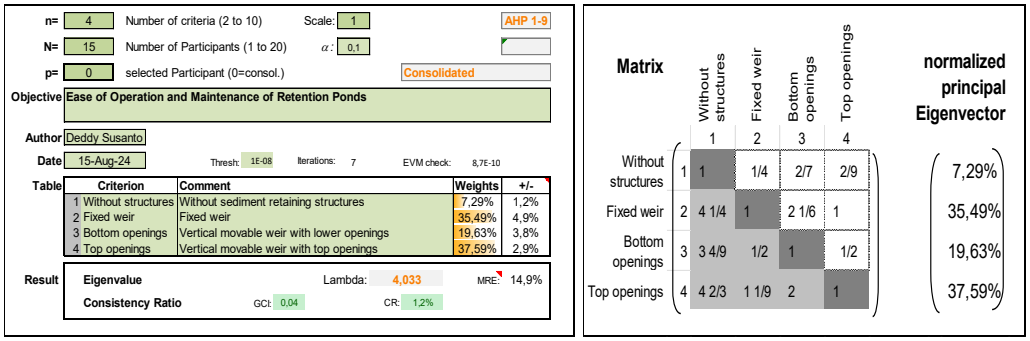

Figure 8. Results of comparison of criteria for ease of operation and maintenance of retention ponds

From the results of the comparison of criteria for ease of operation and maintenance of retention ponds, it can be concluded that the CR result = 1.2% which is smaller than 10% indicates that the comparison process between alternative methods of handling sediment retaining structures with criteria for ease of operation and maintenance of retention ponds provide consistent results. Handling with a vertical movable weir with a top opening is preferred compared to other handling alternatives with a value of 37.59%, while a fixed weir is 35.49%, a vertical movable weir with a bottom opening is 19.63% and without a sediment retaining structure is 7.29%. The basis for the choice of experts is the consideration of ease during operation because the presence of a top opening can maximize the elevation of retained sediment during the dry season.

Criteria for Water Flow Obstacles with Alternative Sediment Retaining Structures.

From the calculation of a pairwise comparison between alternative sediment retaining structures with criteria for water flow obstacles, the following results were obtained:

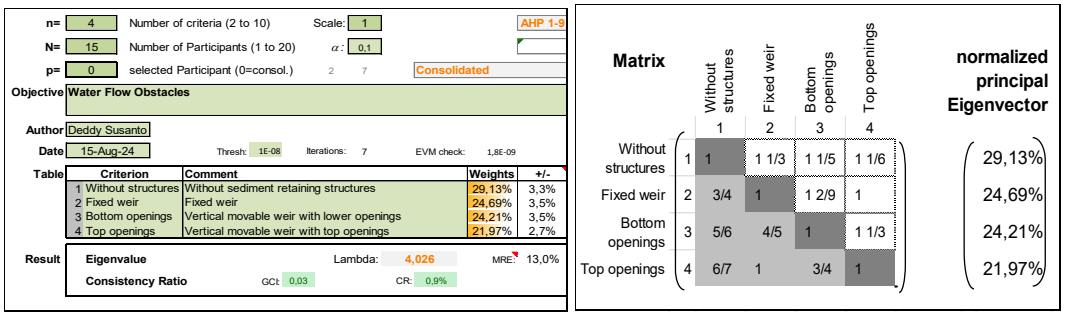

Figure 9. Results of comparison of water flow resistance criteria

From the results of the comparison with the flow resistance criteria, it can be concluded that the CR result = 0.9% is smaller than 10%. This indicates that the comparison process between alternative methods of handling sediment retaining structures with water flow resistance criteria provides consistent results. Handling without sediment retaining structures is most preferred compared to other handling alternatives with a value of 29.13%, while fixed weirs are 24.69%, lower opening vertical movable weirs are 24.21%, and upper opening vertical movable weirs are 21.97%.

Global Priority

pISSN 2302-4240
eISSN 2655-2086
Volume 14, Issue 3, September 2025, pp.0856-0864
DOI: http://dx.doi.org/10.32832/astonjadro.v14i3.18176 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Global priority is the weight of the alternative multiplied by the weight of the priority criteria. The results of the calculation are as follows:

Table 1. Results of global priority calculations

	Ease of construction implementation	Construction costs	Ease of operation and maintenance of sediment retaining structures	Ease of operation and maintenance of retention ponds	Water flow barriers	Conclusion
Criteria weight	**14,51%**	**17,70%**	**19,15%**	**36,99%**	**11,64%**	
Without retaining structures	37,92%	37,00%	7,64%	7,29%	29,13%	**19,61%**
Fixed dam	29,85%	29,70%	39,76%	35,49%	24,69%	**33,21%**
Lower opening vertical movable dam	11,61%	10,93%	11,14%	19,63%	24,21%	**15,84%**
Upper opening vertical movable dam	20,62%	22,36%	41,46%	37,59%	21,97%	**31,35%**

From the results of the global priority analysis above, the weight of each alternative sediment retaining structure is obtained, namely a fixed weir of 33.21%, a vertical movable weir with an upper opening of 31.35%, without a sediment retaining structure of 19.61% and a vertical movable weir with a lower opening of 15.84%. From these results, it can be concluded that the right type of sediment retaining structure is a fixed weir

CONCLUSION

From the results of the analysis, the choice without a sediment retaining structure is a priority in the criteria of ease of construction implementation, construction costs and water flow obstacles. The basis for this choice by experts is because without a sediment retaining structure, it will be easier to implement construction, more efficient in construction costs and facilitate water flow, however, these three criteria are considered not to be the criteria with the highest weight. The ease of operation and maintenance of the retention pond is the criterion with the highest weight with the consideration of the service life of the coastal reservoir which must be comparable to the cost of construction. Furthermore, the ease of operation and maintenance of the sediment retaining structure is the next priority. Of the two criteria with the highest weight, the vertical movable weir with an upper opening is a priority. As for the analysis of global priority calculations, the highest weight is obtained for the choice of permanent dams, so it can be concluded that the type of sediment retaining structure that is appropriate to be applied in a retention pond system or coastal reservoir in general is to use a sediment retaining structure in the form of a permanent dam.

ACKNOWLEDGEMENTS

The author would like to thank the Sultan Agung Islamic University of Semarang for facilitating this research and to the Pemali Juana BBWS, Brantas BBWS, Bengawan Solo BBWS, Coastal Engineering Center, Sabo Engineering Center, Central Java Disputaru and other parties for their participation in this research.

REFERENNCES

[1] Harwitasari, D., & van Ast, J. A. (2011). Climate change adaptation in practice: People's responses to tidal flooding in Semarang, Indonesia. *Journal of Flood Risk Management*, *4*(3), 216–233. https://doi.org/10.1111/j.1753-318X.2011.01104.x

[2] Darmo Yuwono, B., Andreas, H., & Zainal Abidin, H. (2021). *Assessing the Impact of Flood Induced by Sea Level Rise and Land Subsidence in Semarang City*.

[3] Sahid Wismana Putra, I., Hermawan, F., & Utomo Dwi Hatmoko, J. (n.d.). *Penilaian Kerusakan dan Kerugian Infrastruktur Publik Akibat Dampak Bencana Banjir di Kota Semarang*.

[4] Ikhwanudin, Wahyudi, S. I., & Soedarsono. (2020). Simulation of Catchment Area, Water Storage and Pump Capacity in Polder Drainage System. *IOP Conference Series: Earth and Environmental Science*, *498*(1). https://doi.org/10.1088/1755-1315/498/1/012073

[5] Susanto, D., Wahyudi, S. I., & Niam, M. F. (2021). Correlation between Pump Discharge and Operational Cost of Polder System: Case Study of Pekalongan Regency. *IOP Conference Series: Materials Science and Engineering*, *1144*(1), 012058. https://doi.org/10.1088/1757-899x/1144/1/012058

[6] Mo, Y., Jin, G., Zhang, C., Xu, J., Tang, H., Shen, C., Scheuermann, A., & Li, L. (2021). Combined effect of inland groundwater input and tides on flow and salinization in the coastal reservoir and adjacent aquifer. *Journal of Hydrology*, *600*. https://doi.org/10.1016/j.jhydrol.2021.126575

[7] Widada, S., Zainuri, M., Yulianto, G., Satriadi, A., Jati Wijaya, Y., & Helmi, M. (2020). Mitigation of floodwaters inundation due to land subsidence in the coastal area of Semarang City. *IOP Conference Series: Earth and Environmental Science*, *530*(1). https://doi.org/10.1088/1755-1315/530/1/012006

[8] Suprayogi, H., Rudyanto, A., Bachtiar, H., & Limantara, L. M. (2018). Critical-phase sea dike construction of NCICD program in Jakarta as national capital city. *IOP Conference Series: Earth and Environmental Science*, *162*(1). https://doi.org/10.1088/1755-1315/162/1/012020

[9] Suripin. (2004). *Sistem Drainase Perkotaan yang Berkelanjutan*. Yogyakarta Andi.

[10] Pomázi, F., & Baranya, S. (2020). Comparative assessment of fluvial suspended sediment concentration analysis methods. *Water (Switzerland)*, *12*(3). https://doi.org/10.3390/w12030873

[11] Fan, J., & Morris, G. L. (1992). *Res Sedimentation, II: Reservoir Desiltation and Long-Term Storage capacity* (Vol. 118).

[12] Anirudh K. M, & Manoj K. S. (2020). *Implementation of the AHP in construction project management*. www.erpublication.org

[13] Boudreau-Trudel, B., & Zaras, K. (2012). Comparison of Analytic Hierarchy Process and Dominance-Based Rough Set Approach as Multi-Criteria Decision Aid Methods for the Selection of Investment Projects. *American Journal of Industrial and Business Management*, *02*(01), 7–12. https://doi.org/10.4236/ajibm.2012.21002

[14] Susila, W. R., & Munadi, E. (2007). *Application of Analytical Hierarchy Process on Prioritizing Research Proposal* (Vol. 16, Issue 2).

[15] Adi, H. P., Wahyudi, S. I., & Ni'Am, M. F. (2020). Decision Support System for Selecting Type of Moveable Dam Gate to Handle Tidal Flood Issued (A Case Study in the Parid River, Cilacap, Indonesia). *Journal of Physics: Conference Series*, *1625*(1). https://doi.org/10.1088/1742-6596/1625/1/012043

[16] Basak, I., & Katz, J. M. (1993). Group Decision Making Using The Analytic Hierarchy Process. In *Mathl. Compat. Modelling* (Vol. 17, Issue 415).