Sedimentation Rate Analysis in Ponre-Ponre Dam and Estimate the Service Age of the Dam

Ajiz Muhammad Khaerul, Farouk Maricar, Subhan Mustari

Abstract: ***Sediment is the result of erosion process, either in the form of surface erosion, trench erosion, or other types of soil erosion. The increase of percentage of sediment in dam which increases rapidly each time, causing dam dredging and affecting dam capacity and service age of dam. This study discusses sedimentation sediment volume, sedimentation rate, sediment distribution, and estimated service age of Ponre-Ponre Dam in Bone, South Sulawesi. Sediment volume of sediments deposited at each elevation is marked by reduced dam volume. Sedimentation rate that occurs based on the sediment volume that stays every year. The service age of the dam is indicated by the reduction of the dam's dead reservoir. The volume of sediments occurring at the Ponre-Ponre Dam in 2016 reached 8.7965437 X10^{6}m^3. The rate sedimentation that occurred around 1.2566491 X10^6 m^3/year. The dam's planned service age is 50 years old but the measurement results does not support. By comparing the actual sedimentation rate with the reservoir planning data, if there is conformity it is necessary to do maintenance and if there is a faster estimate than the actual plan then it needs to be done sediment handling that occurs.***

Keywords: Dam, Reservoir, Sediment, Service age

I. INTRODUCTION

The rain fall to the surface of the soil, flowing to lower places and after experiencing various kinds of resistance due to gravity, eventually overflow into sea or lake. The river is steep due to rainfall discharges which causes a rapid rise in the water and significantly erodes the riverbed. Thus, the residue from the eroded riverbed become the sediment in the river as we as in the reservoir. The sediment content increases especially during raining seasons [1]. The present of sediment in a river and reservoir has attracts many researchers in the field of hydraulics, fluid dynamics, environment and hydrology [2, 3, 4]. The maintenance and treatment of the river to meet the geographic factor and demand of various human needs result changes in flow patterns.

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This result in changes in the river channels in horizontally and vertically. Changes in flow patterns will include changes in forces and changes in sediment transport in the river. Transverse river structures such as weir, sabo dam, sand pocket, and dams are some of the buildings that influence changes in river behaviour. Besides that, reservoir impoundment also reported to have significant impact on natural flow regime of rivers [5].

The increase in sediment percentage in sediment building along the river which increases rapidly at all times which causes siltation of the reservoir and affects the reservoir capacity and the service life of the reservoir [2, 6, 7]. Besides that, decreases in storage capacity may cause uncertainly risk such as flood if sudden increase of water level due to heavy rainfall [8, 9]. Therefore, it is necessary to maintenance or adds sediment control structures. Ponre-ponre Dam is considered in this study. Ponre-ponre Dam is located in Bone District. The 55 m high dam with a clean (effective) capacity of 60.76648624 X106 cubic meters is located on the Tinco river, a tributary of the Walanae River, which is administratively located in Kahu and Libureng sub-districts. Bone Regency, about 70 km from Makassar. This study determine the volume of sediment, the rate of sedimentation and the effect of sediment on the service life of the reservoir

II. RESEARCH METHODOLOGY

The considered location in this study is at Ponre-Ponre Dam.Figure 1 illustrates the flow of the study in the schematic format. The information and data is collected based on reservoir topographic map, data of the area of the reservoir inundation area, reservoir capacity data and ponre-ponre dam bathymetry data. All mention four resources are come from source BBWS Pompengan Jeneberang. The information of the dam:

Name of Dam: Ponre Ponre

The location of the dam is in: Tompobulu Village, Kec. Libureng, Kab. Bone

Type of Dam: Urugan Dam

Purpose and Benefits of Dam: Irrigate irrigation area.

Storage Capacity: 60.76648624 m^3

Dead storage capacity: 8.3 X10^{6}m^3

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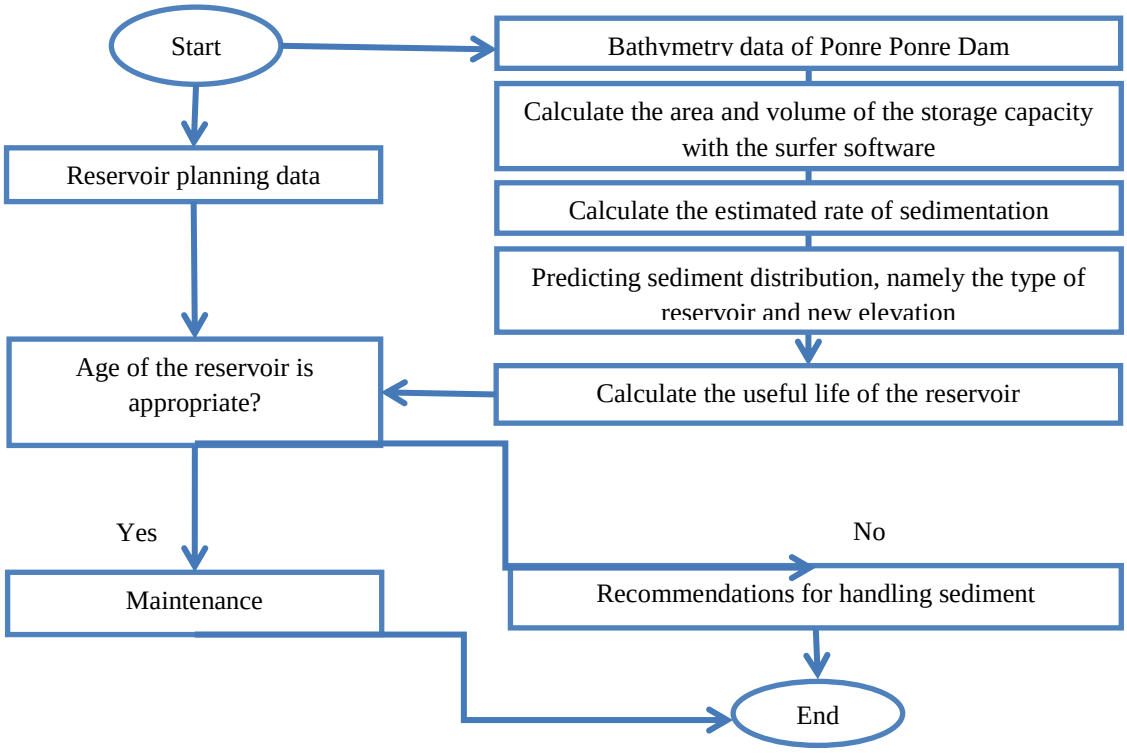


Fig. 1 Schematic diagram of the flow of the study

1. Calculate the area and volume of storage at each elevation with bathymetry data sourced from BBWS Pompengan Jeneberang by using Surfer 8 software.
2. Calculate the analysis of reservoir volume. This stage finds out the amount of sediment that stays in the reservoir that results formation of dead reservoir. This because not all the sediment that reaches the reservoir will stays in the reservoir. The calculation will be analyzed the amount of sediment that enters and stays into the ponre-ponre dam.
3. Calculate the analysis of estimated sedimentation rates. The sediment volume and sedimentation rate are determined based on the measurement results in order to determine the regression equation to estimate the volume of the reservoir.
4. Predict the distribution of ponre-ponre dam sediments. Determine the type of reservoir by connecting the depth and capacity of the reservoir and the new elevation of the ponre.ponre dam can be obtains.
5. Analyzing the Age Prediction of the Ponre-Ponre Dam. Calculate and predict the remaining age for the reservoir to be able to operate.

III. RESULTS AND DISCUSSION

Reservoir sedimentation is an important parameter in the planning and management of the reservoir because some of the available volume will be filled with sediment deposits so that the effective volume will be reduced. In addition, sediment can stay in the outlet of the extraction so that it will disrupt the operation of the reservoir. The lifespan of the reservoir is calculated based on the estimation of sediment deposits until it reaches the taking threshold.

Analysis of Sediment Volume

The reservoir storage volume is calculated based on contour lines in the form of closed polygons with Surfer software so that it can be calculated the extent and volume of the reservoir.Table 1 tabulated the sediment volume up to 2012, 2013, 2015 and 2016 from 2009. The sediment volume that stays at each elevation is characterized by reduced surface area of elevation and volume of storage.

Table. 1 Sediment Volume up to 2012, 2013, 2015 and 2016 from 2009

	2009 - 2012		2009 - 2013		2009 - 2015		2009 - 2016	
Elevation	**Area**	**Sediment Volume**	**Area**	**Sediment Volume**	**Area**	**Sediment Volume**	**Area**	**Sediment Volume**
165	0	0	0	0	0	0	0	0
175	0.019087	0.048876	0.020994	0.053404	0.024861	0.05778	0.024881	0.057803
180	0.014296	0.78768	0.036998	0.790302	0.089886	0.867178	0.090119	0.921447
185	0.127746	0.953715	0.150866	0.960626	0.246574	1.462962	0.250117	1.679569
190	0.137201	2.366552	0.157557	2.958036	0.174768	3.436725	0.224446	3.960137
195	0.103798	3.061832	0.145673	3.787653	0.163001	4.08884	0.228516	4.350369
200	0.094666	3.660046	0.128346	3.870355	0.279652	3.99315	0.432342	4.248316
205	0.069026	4.318395	0.085146	5.244146	0.095523	7.870321	0.146596	8.736405
210	0.425617	4.908865	0.576494	5.203728	0.713043	6.315646	0.73447	7.00835
215	0.004628	5.799544	0.010117	5.86225	0.043021	6.876544	0.59091	8.091556
216	0.00193	5.906453	0.00237	5.914808	0.004052	7.478654	0.016306	8.796544

Sedimentation Volume and Sedimentation Rate Estimation

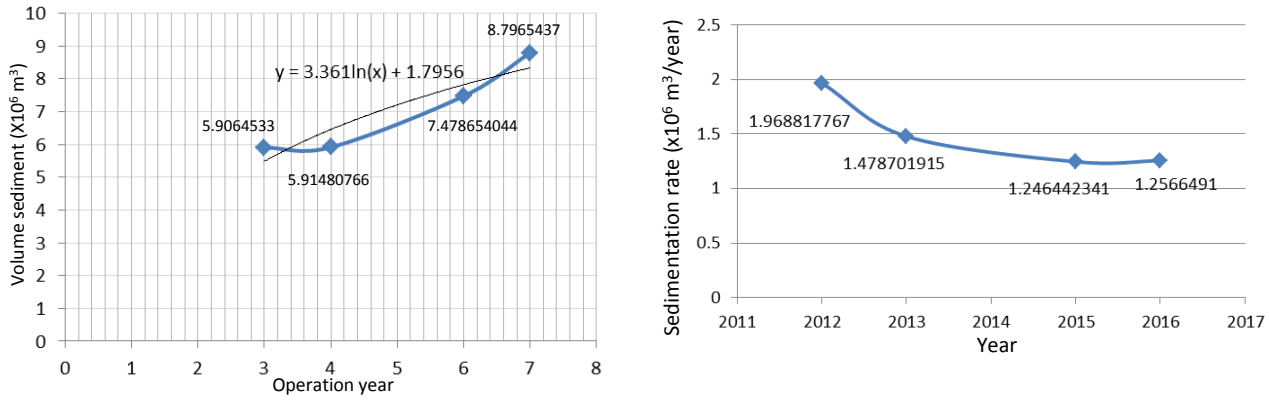
Sedimentation rate in the reservoir can be calculated based on sediment volume from the measurement results. The amount of sediment volume collected can be calculated from changes in reservoir storage capacity. Figure 2(a) shows the Cumulative Volume Curves for Actual Sedimentation of Ponre-Ponre Dam Based on Reservoir Operation Year. Besides that Figure 2(a) also presents as a sedimentation volume regression chart. Based on the curve, the regression line equation y = 3.361ln (x) + 1.7956 is obtained so that to estimate the future sedimentation volume of the Ponre-Ponre Reservoir is used. The estimation of sedimentation volume and rate can be determining from the shape of the curve that matches the distribution of sedimentation volume data starting in 2009 to 2016 as shown in the graph in Figure 2(b).

Prediction of Sediment Distribution in Ponre-Ponre Dam

Sediment distribution predictions using empirical methods are based on observations and measurements in the field. The stages in the calculation of sediment distribution are as follows:

1. Determination of Reservoir Type

One factor that influences the distribution of sediment deposits is the shape of the reservoir. The m value is defined as the slope line that is plotted between the initial depth data and the initial reservoir capacity data. The value of m is not linear and depending on the capacity of each elevation. If the value of m is not in a straight line then the form of the type of the dominant slope line is used or the value of m is in the tendency of stay. From the result in Figure 3, the Ponre-Ponre reservoir type based on the empirical method curve reduces the area of the inundation to estimate the reduction in capacity as long as the sediment deposited in the reservoir is type I with a value of m = 3.751563 which means the form of Lake reservoir.



(a) (b)

Fig. 2 The graph of (a) Cumulative Volume Curves for Actual Sedimentation and (b) Actual Sedimentation Rate Curve of Ponre-Ponre Dam

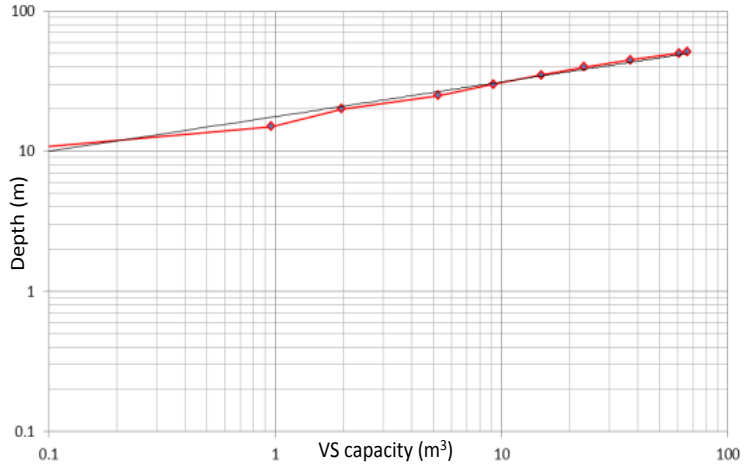


Fig. 3 Determination of the type of Ponre-Ponre Dam

2. Sediment Distribution

The distribution of sediment deposits in the reservoir is influenced by the shape of the reservoir and the sediment material carried by the water and the reservoir operating pattern. Table 2 tabulates the distribution of sedimentation in 2016.

Table. 2 Distribution of Sedimentation in 2016

		2016	
Elevation	**Depth (%)**	**Volume (x10^6 m^3)**	**Distribution (%)**
216	100	8.796544	100
215	98.03922	8.736405	99.31634
210	88.23529	8.091556	91.98562
205	78.43137	7.00835	79.67163
200	68.62745	4.350369	49.45544
195	58.82353	4.248316	48.29529
190	49.01961	3.960137	45.01924
185	39.21569	1.679569	19.09351
180	29.41176	0.921447	10.4751
175	19.60784	0.057803	0.657116
165	0	0	0

3. Sediment Deposition Pattern

Basically the sedimentation pattern in the reservoir varies greatly depending on hydrological conditions, sedimentary characteristics (grain size), reservoir geometry, and reservoir operating patterns. To find out the sediment deposition pattern that occurs that is by describing the base profile of the reservoir each year which consists of cross sections and longitudinal pieces. Transverse profile is divided into 3 types which are,

a. The profile is crossed upstream

b. Transverse profile downstream

c. The profile is crossed between the upstream and downstream

Based on the above, the sediment deposition pattern that occurs in the ponre-ponre dam is the Wedgeshaped deposits sedimentation pattern.

Determination of New Elevation Value of Ponre-PonreDam

To determine the estimated sediment distribution in the Ponre-Ponre Dam based on the empirical method, it is necessary to determine the new zero elevation of the reservoir near the dam of the Area Reduction Method. Following is the New Elevation Determination of Ponre-Ponre Dam:

Cumulative sediment in 2016 = 8,7965437 X10^{6}m^3

Surface Height from the base of the Initial Reservoir = 216 m - 165 m = 51 m

From the graphs in Figure 4 of Fh's value and P in 2016

Relative Depth (p0) = 0.43

So that p0 x H = 0.43 x 15 = 6.45m

Elevation Dam design = + 165 m

Sediment elevation stays in the reservoir = +165 m + 6.45 m = + 171.45m

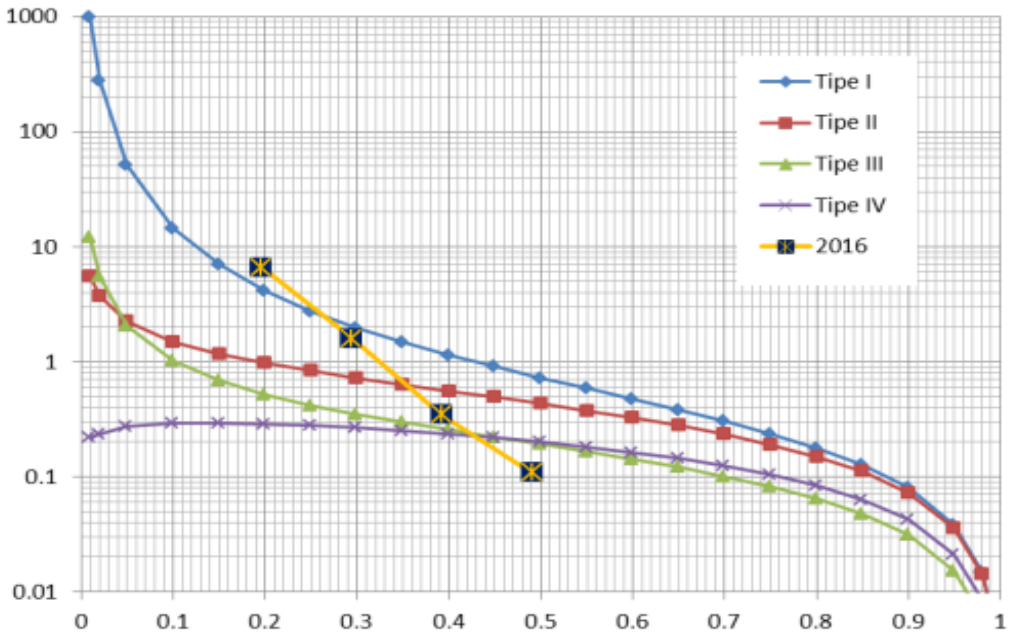


Fig. 4 Graph of Fh Value and P in 2016

The Age of Ponre-Ponre Dam

To find out the remaining useful life of Ponre-Ponre Dam, the calculation is done using a volume approach. For calculations using the volume approach can be seen as follows:

The 2016 volume entered at elevation 194 m = 4.33 X106 m3

Sediment storage volume = 8.3 X106 m3

The volume of dead storage has been filled = 8.3 X106 m3 - 4.33 X106 m3 = 3.97 X106 m3

Sediment rate entered in the dead reservoir = (8.3 - 4.33) / 7 = 0.567 m3 / year

So, the remaining age of the ponre-ponre dam = (4.33 / 0.567) = ± 8 years

Efforts to Handle Reservoir Sedimentation

If sedimentation occurs more quickly with the results of the analysis, then the effort that needs to be done to extend the operating life of the ponre-ponre dam is by dredging or by building sediment retention upstream. Technical implementation of dredging is done in a way:

- Suck sediment deposits in front of the intake with a dredger device and disposed of in a sediment reservoir (bank spoil) which is outside a pool of reservoirs downstream of the dam.
- Sediments that have been in the sediment storage (spoil bank) that have dried up are then discarded to empty the sediment reservoir (bank spoil).

IV. CONCLUSIONS

The volume of the sedimentin the Ponre-Ponre Dam increases and result the capacity of the reservoir to decrease. The sediment volume increases from year 2012 to 2016, which is from 5,9064533 $X10^6$ m^3 to 8,7965437 $X10^6$ m^3.Sedimentation rate in 2012 reached 1,9688,17767 $X10^6$ m^3 / year while, Sedimentation rate in 2016 reached 1.2566491 $X10^6$ m^3 / year. The remaining useful life of the Ponre-Ponre Dam is faster than the planning of the reservoir thus, more serious maintenance is needed such as the construction of sediment retention or dredging in the reservoir.

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REFERENCES

1. J. Y. Mei, B. P. Mao, "Study on characteristics of water-sediment transport in Chenglingji-Wuhan reach of the middle Changjiang river before and after the Three Gorges Reservoir impoundment", *Journal of Basic Science and Engineering*, vol. 15,
2. Pingping Luo, Bin He and Kaoru Takara, "Sustainability and Life Span of Japanese Reservoirs-Statistic analysis of sedimentation condition in Japan," *2011 International Symposium on Water Resource and Environmental Protection*, Xi'an, 2011, pp. 2125-2128.
3. A. Reani, Hanafi, Misdi, Triantisto and A. Setiadi, "Quality Water for Relative Hydroelectric Life Assesment," *2006 IEEE 8th International Conference on Properties & applications of Dielectric Materials*, Bali, 2006, pp. 486-489.
4. W. Sweet, "China's big dams," *in IEEE Spectrum*, vol. 38, no. 9, pp. 46-51, Sept. 2001.
5. Y. Yang, W. Wang, D. Cheng and H. Yang, "Reservoir impoundment influence on river flow regime," *2011 International Symposium on Water Resource and Environmental Protectio*n, Xi'an, 2011, pp. 1087-1089.
6. S. S. Karapetyan and B. M. Mamikonyan, "The measuring of dynamic parameters of unctioning water storage dams," *Proceedings. 2005 International Conference Physics and Control, 2005., Saint Petersburg*, Russia, 2005, pp. 853-858.
7. G. L. Morris, J. Fan, Reservoir Sedimentation Handbook: Design and Management of Dams Reservoirs and Watersheds for Sustainable Use, New York:McGraw-Hill, 1998.
8. N. M. Dhandre, P. D. Kamalasekaran and P. Pandey, "Dam parameters monitoring system," *2016 7th India International Conference on Power Electronics (IICPE)*, Patiala, 2016, pp. 1-5.
9. M. J. Alias and O. M. Yusof, "Real time reservoir operation information system displaying elevation — Storage curve using hydrographic survey data," *2011 IEEE Control and System Graduate Research Colloquium*, Shah Alam, 2011, pp. 86-89.