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Impact of River Infrastructure on Sediment Distribution to Maintain Reservoir Lifespan: A Case of the Bili-Bili Reservoir, Jeneberang Basin, Indonesia

Mursyid Hasnawi[1 a)], Ritnawati[2], Mahyuddin[3], La Ode Agisaqma[4], Muhammad Subri[5]

[1,2,3,4,5] *Department of Civil Engineering, Faculty of Engineering, Muslim University of Indonesia, Makassar City, 90231, Indonesia*

[a)] Corresponding author: mursyid.hasnawi@umi.ac.id

Abstract. This study investigates the impact of river infrastructure on sediment distribution in the Bili-Bili Reservoir. Bathymetric data obtained using an echo-sounding sonar system were processed with Surfer 14 to analyze reservoir bottom morphology, storage capacity, and sediment accumulation. Hydrological modeling with NRECA calibration was combined with field measurements to estimate sediment inflow and storage loss. Results show cumulative sedimentation increased by 42% (1997–2005), 33% (2005–2011), and 25% (2011–2017), with a peak deposition of 21.74 × 10^6 m^3 in 2005. Following the construction of sabo dams, consolidation dams, and check dams in 2011, sedimentation rates decreased by 57% relative to 2005. Reservoir capacity declined from 365 × 10^6 m^3 in 1997 to 264 × 10^6 m^3 in 2017, reducing the effective service life by approximately 6.5 years. The remaining lifespan of the reservoir in 2017 was 24 years and 4 months, compared to the original design life. These findings emphasize that periodic dredging (every four years), monthly sediment removal at the consolidation dam, and sediment trapping in the Jeneberang watershed are essential to sustain reservoir performance.

Keywords: Sedimentation, River Infrastructure, Reservoir Capacity, Bili Bili Dam

INTRODUCTION

Reservoir sedimentation remains one of the most critical challenges [1],[4] in water resources management worldwide [5], [6]. Excessive sediment deposition reduces effective storage capacity, diminishes flood control and water supply reliability, and shortens the operational lifespan of hydraulic infrastructure [7]. This problem is particularly severe in volcanic and mountainous regions, where steep slopes and intense rainfall accelerate soil erosion and sediment transport [8], [9]. In Indonesia, several multipurpose reservoirs face serious sedimentation threats, with implications for regional water security and disaster risk reduction [10], [11].

The Bili-Bili Reservoir, constructed in 1997 along the Jeneberang River in South Sulawesi, was initially designed with a 50-year operational lifespan and a sediment storage capacity of 29 × 10^6 m^3 [12], [13]. However, subsequent events, most notably the 2004 caldera wall landslide at Mount Bawakaraeng, drastically increased sediment inflow, accelerating capacity loss [14]. The Jeneberang watershed is characterized by rugged volcanic terrain, with elevations ranging from approximately 100 m in the lowlands to over 2,830 m above sea level at the Bawakaraeng caldera rim [15]. Slopes in the upper catchment frequently exceed 40 60%, producing unstable geomorphic conditions prone to landslides and erosion [16], [17]. In addition, the basin receives annual rainfall exceeding 3,000 to 4,000 mm, intensifying surface runoff and sediment transport into the reservoir [18]. These combined factors, steep topography, friable volcanic deposits, and high rainfall, make the Bili-Bili catchment one of the most sediment-prone basins in Indonesia. Between 1997 and 2017, cumulative sediment deposition exceeded 100×10^6 m³, reducing the reservoir's capacity from 375×10^6 m³ to 264×10^6 m³ [19]. These changes threaten the reservoir's ability to provide irrigation, raw water supply, and flood control [20] for Gowa Regency and Makassar City [21].

Previous studies on the Jeneberang Basin have investigated erosion rates, sediment budgets, and bathymetric changes in the reservoir [12], [13], [19]. While valuable, most of these works have examined general sediment trends or single interventions in isolation. Limited research has explicitly quantified the integrated effect of multiple river infrastructures, including sabo dams, consolidation dams, and check dams, on sediment reduction and reservoir lifespan [22], [23]. This represents a critical gap, given that sediment control in volcanic catchments requires a layered system of upstream, midstream, and downstream structures [24].

This study addresses that gap by analyzing long-term bathymetric and hydrological data to evaluate the evolution of sediment distribution in the Bili-Bili Reservoir from 1997 to 2017. Specifically, it aims (i) to assess changes in sedimentation patterns before and after the construction of river infrastructure, (ii) to quantify the effectiveness of these interventions in reducing sediment inflow, and (iii) to evaluate the implications for reservoir management and sustainable operation. By integrating bathymetric surveys, hydrological modeling, and field data, the study provides new insights into the role of sediment control infrastructure in extending reservoir service life in sediment-prone tropical basins.

METHODS

Study Area

The Jeneberang River Basin, located in South Sulawesi, Indonesia, is a critical catchment area for regional water resources. The Bili-Bili Reservoir, constructed along the Jeneberang River within Gowa Regency, serves essential roles in flood control, irrigation, and urban water supply. The basin is dominated by mountainous topography and volcanic deposits, conditions that strongly influence sediment transport processes toward the reservoir. Major sediment control infrastructures were completed in 2011 to mitigate sedimentation, and a bathymetric survey was conducted in 2017, as shown in Figure 1.

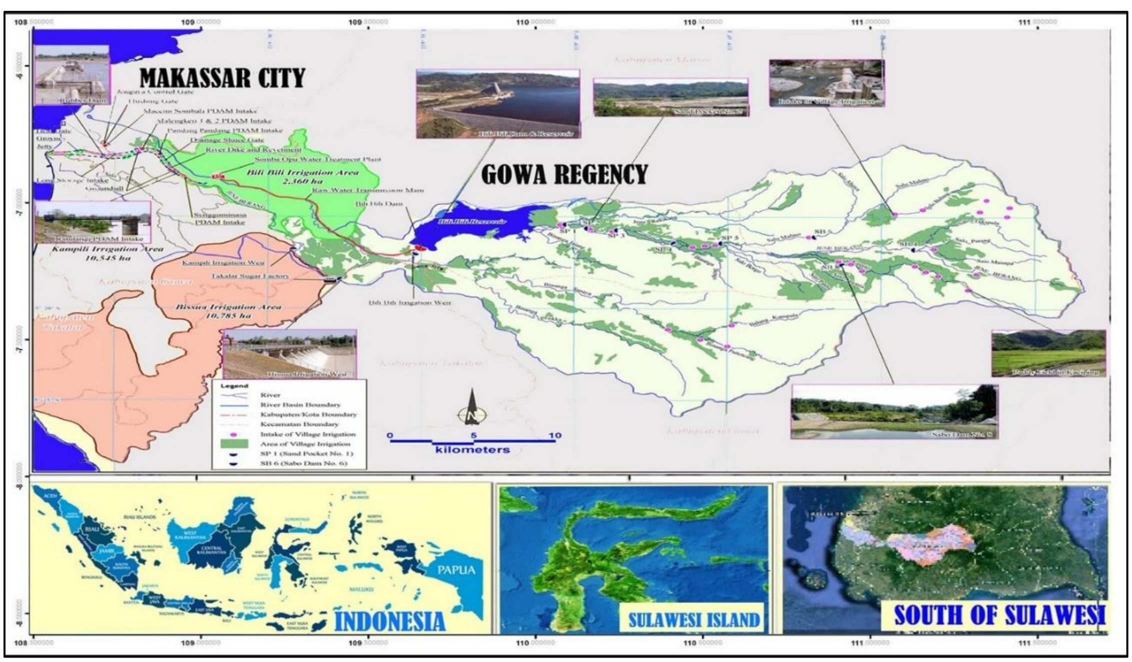


FIGURE 1. General map of the Jeneberang river basin and river infrastructure

The Jeneberang watershed, Gowa Regency, was managed after the Bili Bili Dam was built in collaboration with the Japan International Cooperation Agency (JICA), and it was designed as a multifunctional dam. The Infrastructure of the river basin Jeneberang to control sediment transport is in **FIGURE 2.**

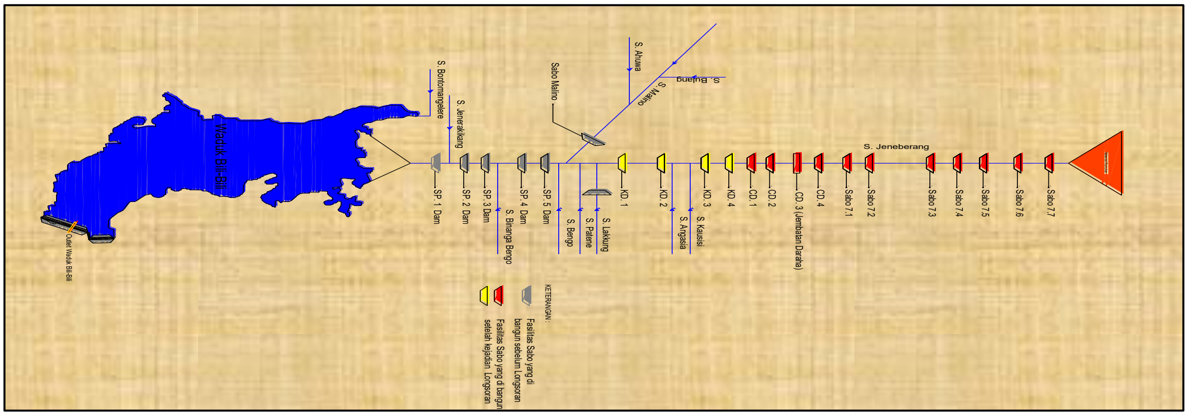


FIGURE 2. Map of the Location of the river infrastructure of the Jeneberang watershed.

The spatial arrangement of sediment control infrastructure along the Jeneberang River demonstrates a layered system designed to intercept different sediment fractions. Sabo dams in the upstream segment capture coarse debris from the Bawakaraeng caldera landslide, consolidation dams in the midstream stabilize the riverbed and trap medium-sized sediment. At the same time, checking dams closer to the reservoir reduces fine sediment inflow. This sequential configuration significantly decreases the sediment load entering the Bili-Bili Reservoir, consistent with monitoring data showing a 57% reduction in sedimentation after the infrastructure was completed in 2011. Despite its effectiveness, limitations remain, particularly in retaining fine particles, emphasizing the need for regular maintenance and complementary monitoring approaches such as bathymetric surveys and remote sensing. River infrastructure in the Jeneberang River Basin captures [18]–[19] bottom and floating sediments carried by river discharge. The following is the sediment capacity captured by river infrastructure in **TABLE 1.**

TABLE 1. Summarizes sediment volumes captured by infrastructure.

No	Location	Sediment Volume m^3	Percentage %
1	Upper Stream River Basin	29.561.034	36.2
2	Middle Stream River Basin	49.989.195	61.1
3	Down Stream River Basin	2.190.000	2.7
		81.740.229	`100

Bathymetric Data Processing

Bathymetric data were processed [20] – [21] in Surfer 14 using kriging interpolation with cross-validation to control error and ensure accuracy of contour representation. The dataset was refined by removing outliers and duplicate depth measurements to enhance accuracy and reliability. All equations presented in this study are consistently formatted and sequentially numbered to facilitate clarity and ease of reference.

NRECA Calibration

The calibration and validation of the NRECA model were adjusted using observed discharge data from the Bili-Bili Dam inflow and outflow gauging stations (1997–2017). Calibration was carried out until the Nash-Sutcliffe Efficiency (NSE) exceeded 0.8, while validation was confirmed with an independent subset of years. Inflow and outflow data were obtained from the Jeneberang River Basin Authority.

Based on the NSE value approaching 1, the three model calibration result parameters will be used to calculate the discharge with the NRECA model at the intake or outlet of the river basin of the Jeneberang area. [22].

$$NSE = 1 - \frac{\Sigma_{t=1}^{T}(Q_0^t - Q_m^t)^2}{\Sigma_{t=1}^{T}(Q_0^t - Q_m^t)^2} \quad (1)$$

where NSE is the coefficient of Nash-Sutcliffe. $Q0t$ = discharge of observation results at time t, Qmt is the discharge of model results at time t, Q_0 = average discharge of observation results.

Sediment Load Estimation

The methodology used is the reservoir volume and capacity method, namely, the difference between the increase in discharge in the reservoir and the increase in sediment discharge. To analyze this, it is necessary to calculate the floating sediment load and the bottom sediment load [23]. The equation is as follows:

Qs = 0,0864 CQw (2)

Where Qs is the sediment transport discharge (tons/day), Qw is the River discharge (m3/s), and 0.864 = Unit conversion

Based on the list of elevations and areas, the volume of space can be calculated using the truncated pyramid formula [24] as follows.

V = (A1 + A2 + (A1 . A2) 0.5) x H/3 (3)

V is Volume, A1 is Bottom area, A2 is Top area, and H is Height or difference in elevation between the top and bottom areas. [25].

Reservoir Volume

To calculate the volume between contour intervals, the following formula can be used:

$$V_1 = \frac{1}{3}(H_{i+1} - H_i)\left(A_i + A_{i+1} + \sqrt{A_1}A_{i+1}\right) \quad (4)$$

Where V1 is the Volume of the reservoir between two contour lines (m3), V is the reservoir of volume (m3) H I is the Elevation of the first contour line (m), H i+1 is the Elevation of the second contour line (m), AI is Area of the first contour area (m2), Ai+1 is The area of the second contour area (m2).[26]

Reservoir Lifespan

Reservoir lifespan was estimated using a volume-based approach. [27]

$$Sediment\ rate\ entering\ dead\ reservoir = \frac{Control\ Elevation - Based\ elevation}{\Delta H\ volume\ of\ years}$$

$$Age\ of\ use = \frac{Total\ of\ volume\ sediment\ in\ last\ years}{Total\ of\ Sediment\ rate\ entering\ dead\ reservoir\ of\ years} \quad (5)$$

RESULTS AND DISCUSSION

Hydrological Simulation

The inflow of the Jeneberang River into the Bili-Bili Reservoir consists of water and substantial sediment loads. Water availability in the watershed, estimated through NRECA calibration, indicated an average inflow discharge of 24.07 m³/s in 2017. In contrast, the outflow released through the reservoir spillway reached 44.80 m³/s. (FIGURE 3)

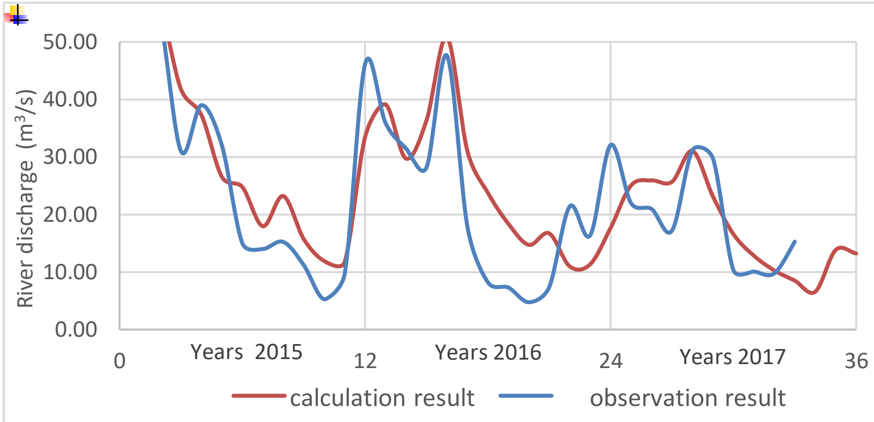


FIGURE 3. Jeneberang watershed area using NRECA calibration.

The comparison between calculated and observed discharge for 2015 to 2017 indicates that the NRECA model adequately reproduces the hydrological behavior of the Jeneberang River. Prominent peaks in 2016 are well simulated, while moderate discrepancies appear during low-flow periods and certain high-flow events. Overall performance was satisfactory, with a Nash–Sutcliffe Efficiency (NSE) exceeding 0.80 and a coefficient of determination (R^2) above 0.85, confirming good agreement between simulation and observation. These results demonstrate that the model is sufficiently robust for sediment transport assessment and reservoir inflow prediction, although further refinement is recommended to improve accuracy under extremely low flow conditions. Complementing these findings, other studies have shown that river morphological stability resulting from dam construction is influenced by regime theory [28] and sediment transport morphological stability [29]. Investigations into rake and rib structures in hydroelectric power plant sand traps further support these insights [30]. In contrast, the hydraulic performance of sand traps during flushing operations in the Pengasih irrigation network yielded comparable outcomes [31]. Despite these advances, most existing research remains site-specific and narrowly focused on structural or hydraulic components, without fully integrating the long-term morphodynamic responses of rivers and reservoirs. This limitation underscores the need for holistic approaches combining robust hydrological modeling, morphological theory, and sediment transport simulations to enhance predictive capacity and improve sediment management strategies under changing hydrological and climatic conditions.

River infrastructure of the Bili-Bili Dam System

The river infrastructure developed in the Jeneberang Basin, including sabo dams, groundsills, and other sediment control structures, is estimated to have retained approximately 81.74 million m^3 of sediment, effectively reducing sediment inflows to the Bili-Bili Reservoir by about 57%. These measures have been crucial in delaying the storage capacity reduction rate and extending the reservoir's functional lifespan. However, their effectiveness is not constant; during periods of extreme rainfall events, volcanic debris flows, and climate variability, the performance of these infrastructures declines significantly. This highlights the necessity for continuous monitoring**,** periodic maintenance, and regular upgrading to ensure that they can cope with future hydrological extremes and sustain reservoir operations in the long term [11]–[12], [20], [25], [31]. River Control Infrastructure within the Jeneberang Basin:

1. Main Dam (Bili-Bili Dam)
   Type: Rockfill embankment, 73 m high and 750 m long.
   Functions: multipurpose reservoir serving irrigation, water supply, hydropower, and flood control.
2. Sabo Dams (Check Dams)
   Constructed upstream after the 2004 Mount Bawakaraeng landslide.
   Purpose: trap volcanic debris and sediments before reaching the reservoir.
   Estimated sediment retention: approximately 81.74 million m^3 (about 57% reduction of sediment inflow).
3. Groundsills and River Training Structures
   Installed along the Jeneberang River.
   Functions: stabilize the riverbed, reduce erosion, and regulate sediment transport.
4. Spillway and Diversion Facilities

Designed to discharge floodwaters and sediment-laden flows safely.
Crucial for flood management and ensuring the safety of the reservoir.

5. Watershed Protection Measures
Include riverbank protection, dikes, and reforestation programs.
Aim: reduce erosion and sediment yield from degraded catchment areas.

6. Sediment and Hydrological Monitoring System
Bathymetric surveys have been conducted since 1997 and supported by sediment gauging stations.
Functions: monitor storage loss, detect sedimentation patterns, and support operational planning.

Overall, this network of infrastructures has proven effective in delaying reservoir storage reduction. Still, their efficiency decreases during extreme rainfall events and under climate variability, highlighting the need for regular maintenance and upgrading to sustain long-term reservoir performance.

Sediment Distribution

Bathymetric data were acquired using sonar-based echo sounding. Figure 4 illustrates the measurement paths applied to map the storage of the Bili-Bili Reservoir, together with a representative cross-sectional profile of the reservoir bed. (TABLE 2)

FIGURE 4. Map the location of the Echo Sounding storage route of the Bili-Bili reservoir storage.

The bathymetric map illustrates detailed contour lines and cross-sectional survey routes used to evaluate sediment accumulation in the Bili-Bili Reservoir. The dense grid of sounding tracks ensures adequate spatial coverage, enabling accurate interpolation of the reservoir bottom morphology. The results reveal clear patterns of sediment deposition concentrated in the upstream zone, gradually tapering toward the dam site. This distribution reflects the natural settling process, where coarse materials are deposited near river inlets while finer particles are transported downstream. Such bathymetric evidence supports the volumetric estimates of storage loss, confirming that sedimentation is spatially heterogeneous and primarily controlled by inflow dynamics.

The cross-sectional profiles (L–R) from 1997 to 2017 demonstrate a consistent rise in reservoir bed elevation, confirming substantial sediment accumulation. Upstream sections show moderate aggradation, while the mid-reservoir zone records the most pronounced elevation increase, reflecting its role as the primary deposition area. Downstream sections near the dam also indicate progressive infilling by fine sediments, with some profiles exceeding 100 m elevation by 2017. This spatial pattern highlights a typical deltaic progression: coarse sediment settling upstream, transitional deposits mid-reservoir, and finer material transported to the intake zone. The results corroborate volumetric estimates of storage loss and emphasize the urgency of targeted dredging and continuous monitoring to safeguard reservoir capacity.

TABLE 2. Cross-section of the base profile of the Bili-Bili reservoir.

Section L-R	Distance m	Accumulation m	Bili- Bili Reservoir Base Cross-section of Profile 1997	2005	2008	2009	2011	2017
0-0	0	0	42.50	61.06	61.75	61.56	61.64	61.09
1 - 1	428	428	42.50	62.35	61.74	62.13	62.47	62.8
2 - 2	362	790	49.11	62.55	62.14	62.51	62.92	65.28
3 - 3	338	1128	49.69	62.82	62.54	63.01	63.67	65.03
4 - 4	365	1493	52.08	63.02	63.34	63.55	65.06	65.96
5 - 5	349	1842	54.83	63.52	64.04	64.77	65.67	65.67
6 - 6	535	2377	56.01	64.55	64.34	66.51	67.17	68.3
7 - 7	406	2783	58.87	65.6	68.87	69.03	71.06	71.99
8 - 8	229	3012	65.58	68.58	72.01	71.5	74.48	75.59
9 - 9	502	3514	60.47	70.6	74.95	75.52	77.4	75.09
10 - 10	405	3919	64.45	74.02	75.65	76.44	77.75	78.13
11 - 11	463	4382	73.39	77.62	77.52	77.28	78.54	78.8
12 - 12	403	4785	67.48	80.34	79.58	81.66	82.24	82.48
13 - 13	457	5242	77.62	83.33	81.58	85.09	85.23	85.25
14 - 14	450	5692	77.17	84.13	84.09	87.36	86.51	86.84
15 - 15	365	6057	82.76	86.13	86.36	90.42	89.07	88.89
16 - 16	379	6436	80	86.51	87.92	91.13	92	93
17 - 17	404	6840	89.6	89.86	88.45	92.76	94.37	95.37
18 - 18	382	7222	90.4	89.61	89.32	94.99	97.24	98
19 - 19	266	7488	93.2	90.43	94.86	96.56	97.84	99.99
20 - 20	718	8206	100.5	101.7	102.3	102.98	101.04	102.67
21 - 21	210	8416	-	104	103.2	105.98	102.44	102.99
22 - 22	326	8742	-	105.6	105.6	105.56	103.12	105.43

The cross-sectional profiles (L–R) from 1997 to 2017 demonstrate a consistent rise in reservoir bed elevation, confirming substantial sediment accumulation. Upstream sections show moderate aggradation, while the mid-reservoir zone records the most pronounced elevation increase, reflecting its role as the primary deposition area. Downstream sections near the dam also indicate progressive infilling by fine sediments, with some profiles exceeding 100 m elevation by 2017. This spatial pattern highlights a typical deltaic progression: coarse sediment settling upstream, transitional deposits mid-reservoir, and finer material transported to the intake zone. The results corroborate volumetric estimates of storage loss and emphasize the urgency of targeted dredging and continuous monitoring to safeguard reservoir capacity. Based on echo-sounding measurement data, the annual sediment volume that entered and settled in the Bili-Bili reservoir until 2017 was 13.23×10^6 m³, as shown in TABLE 3.

TABLE 3. Comparison of the amount of measurement data on sediment accumulation with data from Echo Sounding.

No	Inflow (m^3)	Storage Capacity (10^6 m^3)	Sediment Volume (m^3/years)	Sediment Accumulation (m^3)	Echo sounding (m^3)	Error %	Years
1	1705.11	375.000	995.708	995.708	0	0	1997
2	1141.36	360.388	6.967.834	27.576.005	44.677.520	38.2	2005
3	1206.94	339.097	9.810.077	54.151.241	61.968.408	12.6	2008
4	1281.63	320.839	10.746.075	64.897.321	75.236.144	13.7	2009
5	1247.18	298.257	12.632.172	89.077.895	84.818.146	4.95	2011
6	1383.21	264.345	13.232.254	101.156.684	104.155.840	8.89	2017

Hydrological and bathymetric data from 1997 to 2017 indicate progressive storage loss in the Bili-Bili Reservoir. Reservoir capacity declined from 375×10^6 m³ in 1997 to 264×10^6 m³ in 2017, reflecting severe sedimentation. Annual sediment inflow increased from less than 1×10^6 m³ in 1997 to more than 13.232×10^6 m³ in 2017. Cumulative sediment deposition exceeded 101 × 10^6 m³, consistent with echo sounding measurements of 104 × 10^6 m³, with error margins below 10% after 2008. The data confirm accelerated sedimentation following the 2004 caldera landslide, with peak deposition observed in 2008–2009. After completion of sediment control infrastructure in 2011, discrepancies between calculated and observed values decreased markedly, demonstrating improved measurement reliability. Nonetheless, the long-term trend highlights ongoing capacity loss that threatens the reservoir's designed lifespan, underscoring the importance of sustained sediment management and monitoring.

Reservoir Capacity Loss

Reservoir capacity decreased from 375 × 10^6 m³ (1997) to 264 × 10^6 m³ (2017). Cross-sectional analysis confirms rising bed elevation, with deposition concentrated mid-reservoir. The reservoir's operational life is now projected at 24 years from 2017, 6.5 years shorter than design.

The decline in sedimentation rates after 2011 can be attributed to completing major sediment control infrastructure. Sabo dams in the upstream basin reduced direct sediment inflow by capturing large volumes of debris, while consolidation dams and check dams in the midstream further minimized sediment transport. This layered infrastructure system explains the 57% reduction in sedimentation rate compared to 2005 levels. These findings suggest that integrated sediment control infrastructure can significantly extend reservoir lifespan for other watersheds in Indonesia with volcanic origins and similar sediment hazards. **FIGURE 3** to **9** illustrate these processes, and their interpretation highlights the spatial redistribution of sediment rather than merely volumetric changes. The profile cross-section extending from the bottom of the reservoir shows an increase in elevation each year due to sediment deposition in **FIGURE 5**.

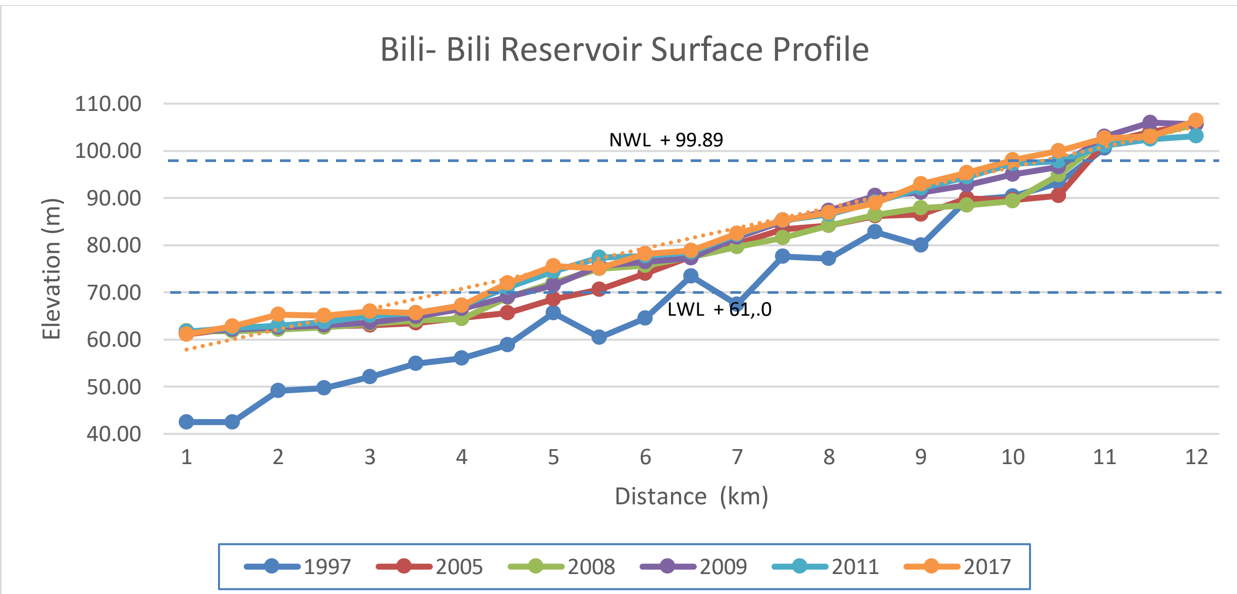
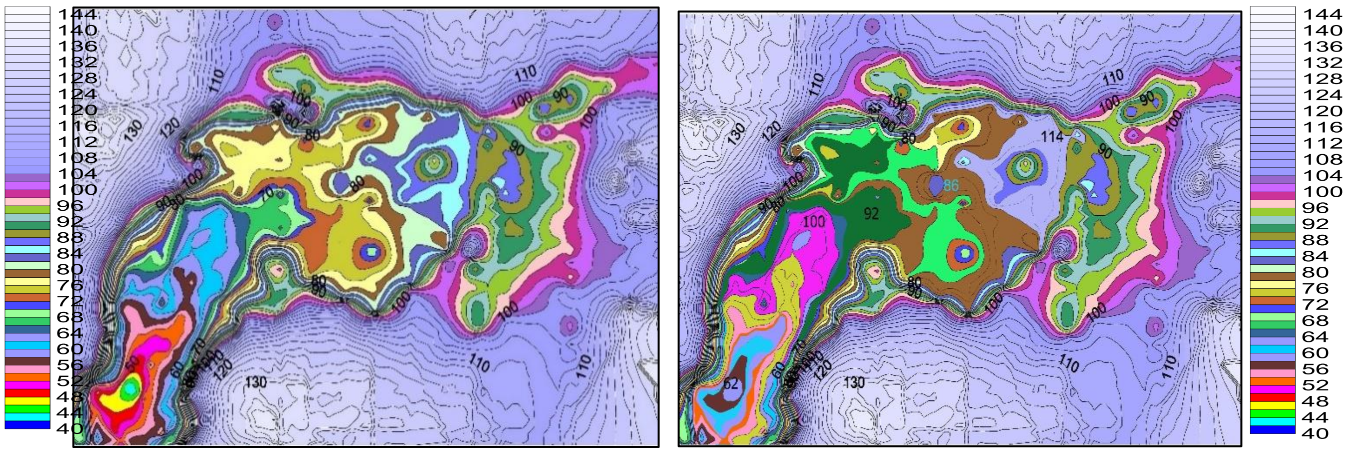


FIGURE 5. Cross-sectional profile of the Bili Bili reservoir.

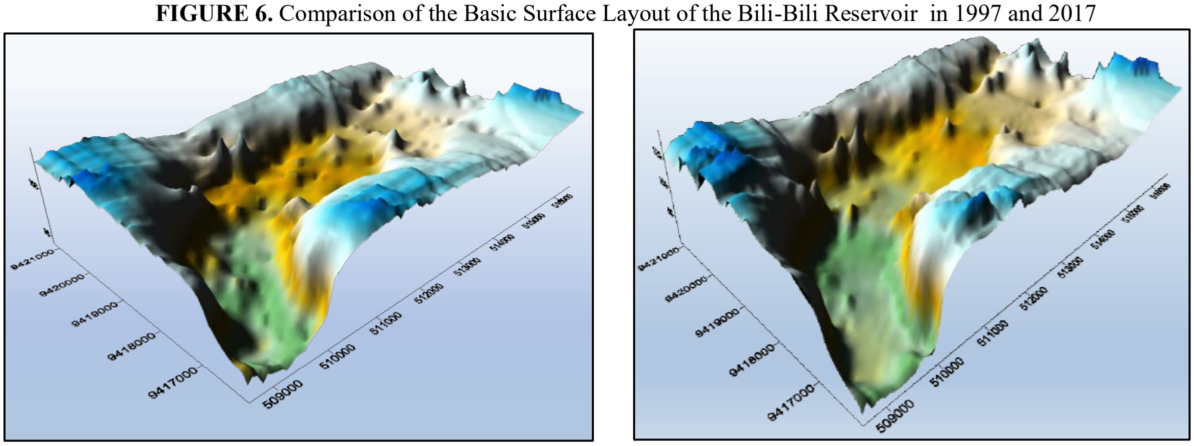
The longitudinal profiles (1997–2017) show a continuous rise in bed elevation across the Bili-Bili Reservoir. Upstream sections experienced rapid aggradation after the 2004 caldera landslide, while fine sediments progressively filled mid- and downstream zones. By 2017, elevations in several sections increased by more than 20 m, significantly reducing adequate storage between LWL (+61.0 m) and NWL (+99.89 m). This deltaic pattern confirms that sedimentation remains the primary driver of capacity loss despite the partial reduction achieved by sediment control infrastructure after 2011

Sediment deposited in 2017 shows that sedimentation in the dead reservoir is relatively high compared to years ago. For practical raw water storage, irrigation, and reservoir flood storage tends to be normal. 6 Comparison of the Basic Surface Layout of the Bili-Bili Reservoir in 1997 and 2017



(a) (b)

FIGURE 6. Comparison of the Basic Surface Layout of the Bili-Bili Reservoir in 1997 and 2017



(a) (b)

FIGURE 7. Comparison of the Basic Surface Layout 3D of the Bili-Bili Reservoir in 1997 and 2017.

Bili-Bili Reservoir Basic Surface Layout and 3D Model Comparison 1997and 2017. The provided figures illustrate significant geomorphological and bathymetric changes within the Bili-Bili Reservoir over two decades, from 1997 to 2017. This comparative analysis, derived from the basic surface layout (Figure 6) and the corresponding 3D visualizations (Figure 7), highlights critical issues relevant to the reservoir's operational longevity and hydraulic performance.

The comparative assessment of the 1997 and 2017 layouts and 3D models of the Bili-Bili Reservoir demonstrates pronounced geomorphological changes driven by sedimentation processes. Over two decades, the expansion of shallow zones and the infilling of deep pockets have resulted in substantial bathymetric flattening and effective storage loss. This topographic leveling is particularly evident in the inlet zones and along the main flow paths, where sediment accumulation is most concentrated.

The observed alterations are consistent with conditions in tropical reservoirs characterized by high catchment erosion rates, intensive land-use change, and strong sediment trapping efficiency. Furthermore, the potential increase in rainfall intensity during the study period may have accelerated erosion and sediment transport, amplifying deposition within the reservoir basin.

Reservoir Lifespan

Calculations are carried out using the volume approach. For calculations using the volume approach, it can be seen as follows:

The volume against the control elevation (+65.00) is obtained (from the measurement results).

Volume in 2017 = 46.000.000 m^3

Sediment Storage Volume = 29.000.000 m^3

Dead reservoir volume has been filled = 46.000.000 – 29.000.000 = 17.000.000 m^3

Volume exceeds dead reservoir storage = 17.000.000 m^3

Sediment rate entering the dead reservoir storage $= \frac{46.000.000 + 17.000.000 - 29.000.000}{18 \text{ year}}$

= 1.888.888 m^3 / year

Age of use of the Bili Bili reservoir $= \frac{46.000.000}{1.888.888}$ = 24.3

= 24 years, 4 months

Implications

Amid global climate warming, the hydrological cycle intensification has led to more extreme droughts and floods [32], increasing erosion and sediment transport into rivers and reservoirs. These findings highlight critical implications for reservoir operation and sustainability. The reduction of adequate capacity undermines flood attenuation potential, elevating downstream flood risk. Similarly, the diminished storage volume compromises water supply reliability for municipal, industrial, and agricultural needs, particularly during dry seasons. In addition, sediment deposition threatens the longevity of critical infrastructure, including intake facilities and power generation units, by clogging and reducing hydraulic efficiency. Overall, the analysis underscores the urgency of integrating sediment management strategies, catchment rehabilitation, and adaptive reservoir operation to ensure the long-term functionality of the Bili-Bili Reservoir.

The cross-section L1–R1, located near the weirs at 62.9 m, lies near the reservoir crest gate and represents the principal water distribution route**. Figures 8** and **9** clearly illustrate progressive sediment deposition along this section, as indicated by the gradual rise in base elevation. This morphological change directly reduces the effective conveyance capacity and poses a risk to the operational reliability of the reservoir. The critical position of this cross-section underscores the necessity of continuous monitoring and sediment management to safeguard both hydraulic performance and downstream water supply functions.

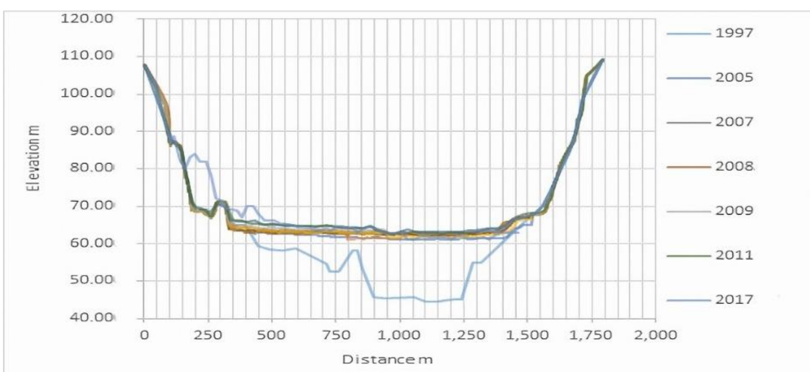


FIGURE 8. The profile cross-section L1 – R1

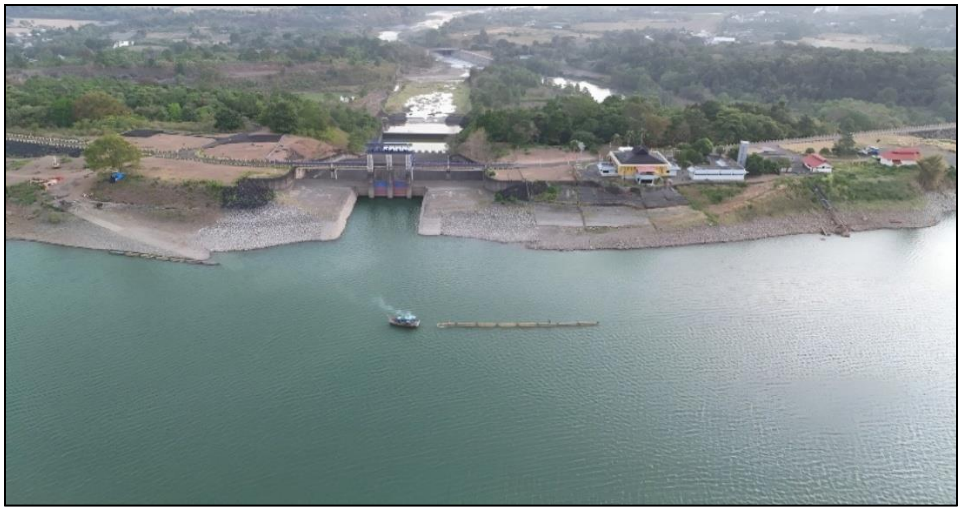


FIGURE 9. The map shows the profile cross-section position near the crested gate of the Bili-Bili reservoir.

River infrastructure development, such as sabo dams and consolidation dams, reduced sediment transport. Sandbags as sediment traps minimize sediment inflow (bottom sediment and floating sediment) into the reservoir, so the water storage volume allows more water to be stored to meet the needs of reservoir operation. If the base elevation rises, the reservoir capacity will decrease. However, the volume of water inflow continues to increase. Then, the incoming water will be discharged again if it passes the peak crest limit—percentage of reservoir sedimentation to reservoir capacity in 2017, as shown in **TABLE 4.**

TABLE 4. Percentage of reservoir sedimentation to reservoir capacity in 2017.

No.	Reservoir capacity	Volume $10^6 m^3$	Elevation m	Sedimentation $10^6 m^3$	total $10^6 m^3$	%
			100 - 101.6	3.983		
1	Flood control	41	99.5 - 100	3.454	7.43	6.5
			90 -99.5	10.320		
	Effective Reservoir capacity (Irrigation and Raw water)		80-90	10.261		
			70-80	35		
2		305	67-70	15.537	61.331	53.79
			60-65	30		
			50-60	8.89		
3	Dead reservoir water	29	40-50	7.1	46	40.35
		375			114	100

It is essential to address water storage reduction and sedimentation processes. [33] To ensure that the Bili-Bili Reservoir continues to provide sustainable benefits for communities in South Sulawesi, particularly in Gowa Regency and Makassar City. Developing and implementing effective sediment management strategies is therefore critical to maintaining reservoir functionality and extending its operational lifespan.

CONCLUSION

This study demonstrates that river infrastructure in the Jeneberang Basin effectively reduced sediment inflow to the Bili-Bili Reservoir by approximately 57%, confirming its role in extending operational performance and sustaining water supply. Sediment accumulation increased by 42% (1997–2005), 33% (2005–2011), and 25% (2011–2017), peaking in 2005 at 21.74×10^6 m³/year, which contributed to a storage decline from 365×10^6 m³ in 1997 to 264.35×10^6 m³ in 2017. The construction of sabo dams, consolidation dams, check dams, and sand pockets since 2005 has significantly mitigated sedimentation, reducing the rate to 2.79×10^6 m³/year. Despite these efforts, the reservoir's lifespan was shortened by 6 years and 6 months compared to design expectations. These results highlight the need for integrated sediment management strategies to secure long-term reservoir functionality, including periodic dredging and catchment rehabilitation.

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