iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** IV **Month of publication:** April 2024

DOI: https://doi.org/10.22214/ijraset.2024.59812

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue IV Apr 2024- Available at www.ijraset.com

A Workable Approach to Calculate the Rate of Silting in Small and Hillside Dams in the Rambiara watershed in Jammu and Kashmir

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Abstract: In temperate regions, building small dams and hillside reservoirs is a popular solution to irregular and unevenly distributed rainfalls. Furthermore, it is advised that rural communities use these tiny hydraulic structures as a means of adapting to climate change. They are essential to the water resources' survival. These dams could, however, act as sinks for material from upstream. In order to better understand siltation and the proper operation of these essential structures, it would be helpful to monitor and measure the amount of sediments in minor dams. The bathymetry or topographical surveys needed for this control and these measurements are too costly for the people in charge of these minor dams. In this regard, the triangulation of the estimated silted level is a straightforward and inexpensive method that is proposed in this work. This technique is based on measuring the accessible silted level in the dam directly. This new approach is contrasted with an alternative that is based on the dam's original Elevation-Capacity curve and is typically employed when the bathymetry is unachievable. The bathymetry and electrical tomography findings from both of them were compared, confirming the proposal method's status as the most accurate. Consequently, this approach is suggested as a novel, straightforward, and easy way to assess the degree of silting in minor dams and hillside reservoirs.
Keywords: Small Dams, Evaluate Silting, Bathymetry, Triangulation

I. INTRODUCTION

Since the strategy of building hillside and small dams was first conceived in the United States and improved upon by the Italians, many countries, have quickly adopted it due to its low cost and adaptability to marginal and mountainous areas. The mobilization of surface water is not a recent method in certain structures were long ago constructed to fulfil particular purposes. In the highlands since 1980.

The International Commission on Large Dams classifies small and hillside dams as those that can hold up to one million cubic meters of water, have embankments up to a height of roughly 15 meters, and have a catchment area of up to tens of square kilometres. These particular structures provide genuine development potential by regulating flow and supplying water, which helps maintain rural villages on their current location. Since they can be used for a variety of purposes, including household use, irrigation, groundwater recharge, flood mitigation, animal watering, fishing, and more, small dams have actually been proven to be extremely vital to the well-being of the communities. In fact, they are essential for both climate change adaptation and sustainable growth. Hydrologists advise that only dams with a lifespan of more than 30 years be used for irrigation or drinking water valuations. However, the lakes created by these dams, which act as sediment traps across their catchments, are severely endangered by siltation, which shortens their lifespan. In actuality, siltation is a very old and natural phenomena; the bibliography gives us examples of two such dams, Kebbar in Iran in 1300 AD and Marib in Yemen, which were built 1100 years ago. Siltation not only shortens life expectancy but also increases the size of floods and increases downstream risk. Moreover, the growing pressure of silts on the wall endangers the stability of the embankment.

Controlling siltation is therefore a necessary step to achieve global values for the rate of erosion or the amount of sediment produced in watersheds. For the administration and optimization of these structures, this control is crucial. Additionally, it permits changing the dam's filling curve (Height-Volume Curve), which could be replaced by later deposits.

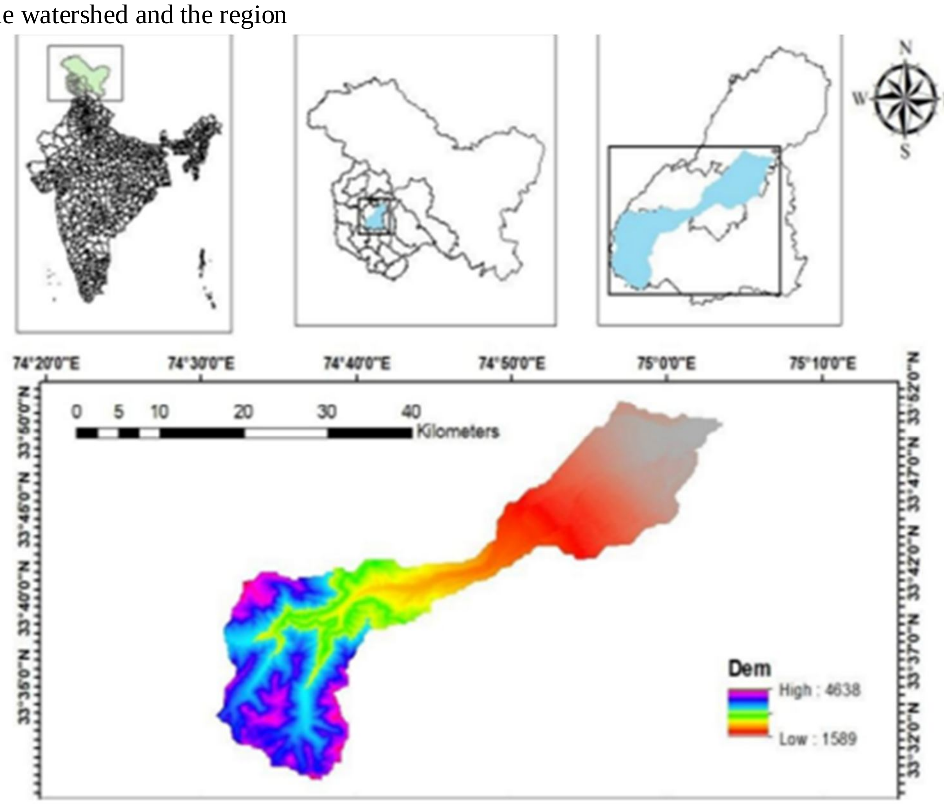
Numerous studies have examined siltation, sediment production, and erosion. Most efforts have been made to create workable models and monographs for each location, with an emphasis on characterizing and regionalizing siltation. Some scholars focus on identifying and evaluating the rate of erosion based on the watershed's geometric, hydrological, lithological, geomorphological, and climatic features.

To measure sediment transport and determine erosion rates, a variety of modeling tools are available. Depending on the region, one of them, the Revised Universal Soil Loss Equation (RUSLE), is frequently used as a base to create particular models. Models like the watem/sedem, EPM model, SATEEC, AGQ, and PISA require a substantial amount of data for every watershed, which makes it challenging for tiny watersheds where there are no monitoring stations. Thus, bathymetry and other direct measurement techniques are more trustworthy. Several techniques are used to compute the silted volume following a bathymetric survey: Kolmogorov, the average height technique, and the general method

In this study, we offer a straightforward and inexpensive direct measurement approach for estimating the volume of siltation in hillside reservoirs and small dams. In actuality, we have made an effort to avoid the limitations of empirical equations and to approximate the bathymetric principle, which is regarded as a trustworthy method. The foundation of this proposed technique, known as TESL (Triangulation of the Estimated Silted Level), is a study of a few prominent locations within the silted surface. We have used seven hillside reservoirs in the Rambiara watershed region with this unique technique. Furthermore, we have confirmed and validated its findings using trustworthy techniques including electrical tomography and bathymetry.

II. STUDY AREA

Several earthen dams situated on the watershed comprise the study area. Rambiara Watershed in the southern Kashmir Valley of Jammu & Kashmir. It has a moderate climate. There is a small and highly uneven water surface. Water flows vary greatly throughout the year. When there is flooding, the runoff occurs very briefly; occasionally, it happens quite quickly and violently due to the topography of the watershed and the region



Location map of the study area.

A. *Commonly Used Direct Measurement Methods to Determine Rate of Siltation*

Without the use of modeling or empirical formulas, a direct assessment of the rate of silting is conducted by surveying the study area and taking current measurements.

1) *Bathymetry Survey*

The foundation of the bathymetric technique is a straightforward comparison of the morphology of the reservoirs at two distinct points in time: the dam's construction and the survey. Position and depth measurements are the two types of essential measurements involved in a bathymetric map.

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2) Remote Sensing

It is predicated on the recurrence of comparable satellite photos over dammed areas at regular intervals of two to five years. The utilization of remote sensing technology facilitates the computation of the current storage capacity, which is juxtaposed with the initial capacity. The gradual decrease in capacity is ascribed to the deposition of silt. The use of remote sensing techniques to estimate sedimentation is limited to lakes and reservoirs where frequent fluctuations in water level occur.

3) Calculating the Volume of Siltation

There are various ways in which we might use the bathymetry survey and remote sensing data. They are all predicated on the antiquated techniques for computing volumes between elevated profiles.

4) Kolmogorov Method

This technique is based on averaging survey profiles from two regions, Pa and Pb, and a fake profile, Pc. And is explained in the following equation

$$Sc = \frac{Sa \times lc}{la} .^{(2)} \; Vab = V1 + V2 .^{(3)} \; Vab = \frac{Sb + Sc}{2} \times h1 + \frac{Sc \times h2}{2}$$

B. The Method of Average Height

This method, as its name implies, is based on the surface that divides survey profiles Pa and Pb, shown in Figures, and the average silted heights on those profiles.

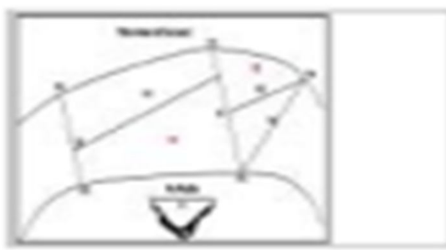


Diagram of the Kolmogorov method

Diagram of the average height method

$$Vab = Sab \times \frac{ha + hb}{2}$$

C. The General Method

This approach considers both the inclination of sections Pa and Pb on Figure as well as the silted sections on the survey profiles.

$$Vab = \left(Sa \times \mathrm{Sin}\alpha_a \times La\right) + \left(Sb \times \mathrm{Sin}\alpha_b \times Lb\right)$$

Today, surveying of the silted areas is automatically integrated into specialized software to compute the volume of sediment in dams instantly and readily thanks to advancements in topographic software and remote sensing.

D. Method for Determining the Silting Volume: Examining the Dam's First Elevation-Area-Capacity Curve

Today, surveying of the silted areas is automatically integrated into specialized software to compute the volume of sediment in dams instantly and readily thanks to advancements in topographic software and remote sensing.

E. Method for Determining the Silting Volume: Examining the Dam's First Elevation-Area-Capacity Curve

In actuality, determining a reservoir's storage capacity requires knowledge of the area-capacity curve. Before the reservoir area fills, the area contained by each contour line is planimetered to create an area capacity curve. The reservoir's surface area and storage capacity are rated in relation to the elevation of the water's surface by means of graphical area and capacity curves.

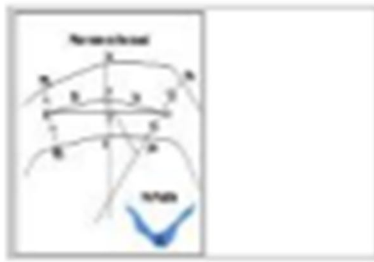


Diagram of the general method.

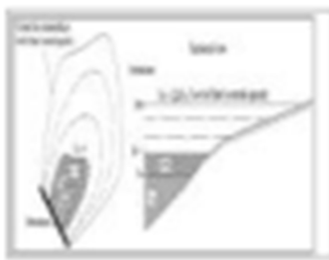
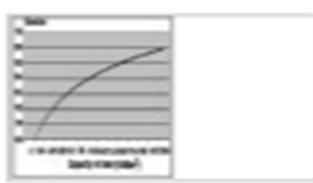


Diagram explaining the initial elevation capacity curve components.

Data of the elevation-capacity curve.



Example of elevation capacity curve

The manager of small dams typically uses the dam's original elevation-area-capacity curve to determine the silting volume when survey bathymetry is not technically or financially feasible.

We measured the amount of silt directly on the embankment with one or two workers, and we plotted this level on the elevation-capacity curve to determine the volume of "silt." However, this method is predicated on the idea that silting is similar to water. It implies that the sediments are moving horizontally across the dam's basin, which raises serious questions.

F. The New Proposal Method: Triangulation of the Estimated Silting Leve

It is not always feasible to use remote sensing and bathymetric surveys in small dams and hillside lakes. Therefore, to predict silting and track its progress in minor dams, a straightforward and less expensive method is required. Building an approximated digital elevation model using TIN (triangulated irregular network) is the suggested approach. A TIN, which is composed of randomly distributed nodes and lines with three-dimensional coordinates (x, y, and z) arranged in a network of non-overlapping triangles, is a vector-based representation of the actual land surface or lake bottom.

We had inspected a few accessible sites on the surface of the dam in order to generate this estimated digital elevation model for the silted surface: The three survey stations on the embankment and additional easily accessible spots on the silt's surface are depicted in Figure; however, due to the drop in water level, it is advised to survey the silting level during the autumn.

These few locations actually allow us to create an approximated digital elevation model, which we can then overlay with a data-driven horizontal plan that represents the dam's usual capacity. The new capacity of the dam following siltation is represented by the difference between the horizontal plan and the estimated digital elevation model. The difference between the initial capacity and the newly computed capacity is the sediment's volume.

III. CONCLUSIONS

The sustainable development of hillside lakes and small dams, which are typically found in vulnerable landscapes with little economic activity, is essential. Since recurrent drought times primarily affect temperate areas, the construction of these dams for water conservation comes next. Nevertheless, siltation poses a serious threat to these tiny hydraulic structures, reducing their longevity and impairing their intended outcome. The problem of dam silting is not new, in actuality. Because of their age, it has afflicted and will continue to torment the management of these structures. Since this is a natural occurrence, prevention is still the most effective means of reducing its effects.

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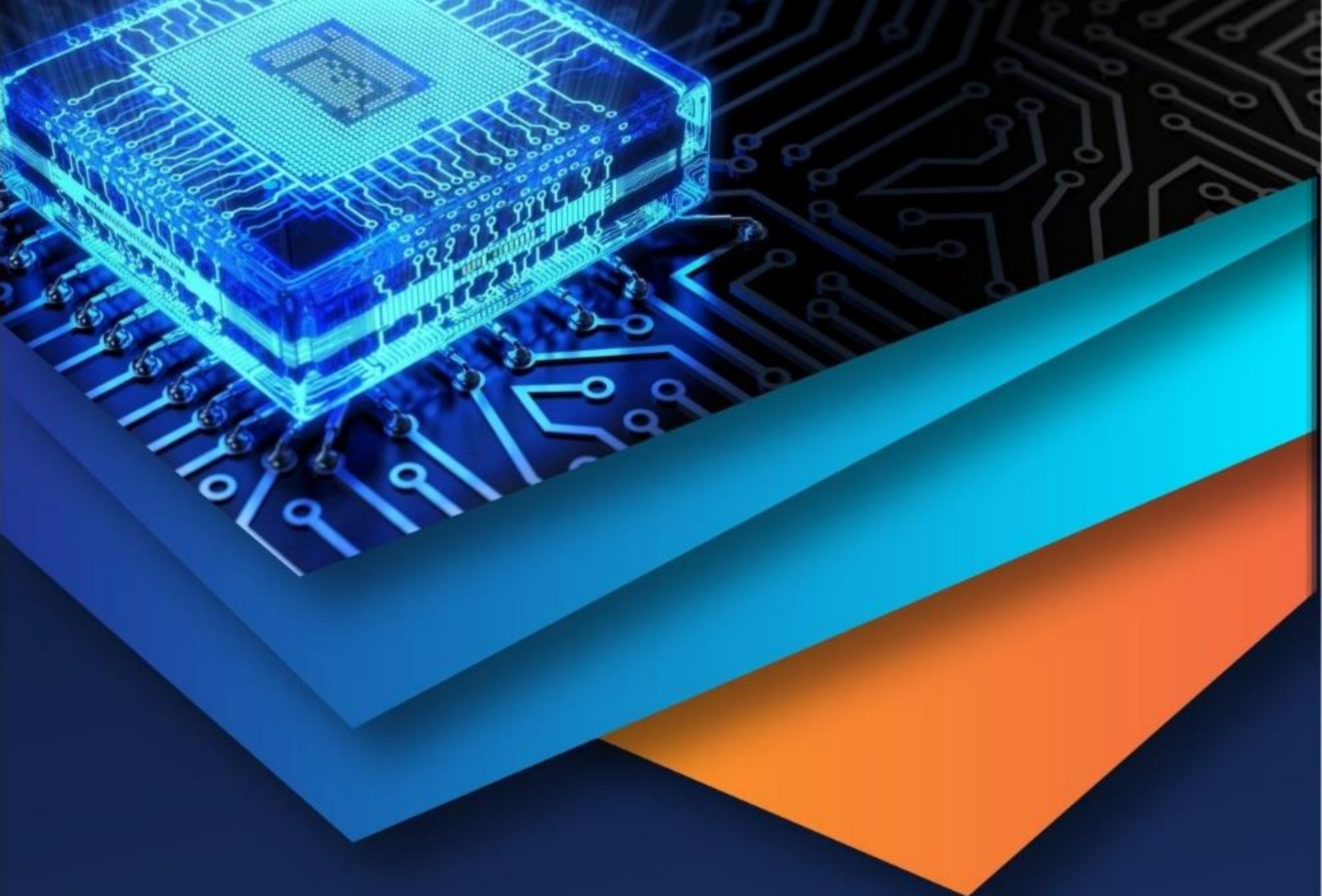

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