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Evaluating Optimal Relationships for Estimating Suspended Sediment Discharge in the Balaroud River

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Abstract

The transport of sediment in rivers is a crucial aspect of hydraulic engineering and environmental management. This study focuses on suspended sediment transport in the Balaroud River, a significant tributary of the Dez River in northern Khuzestan Province, Iran. We evaluated various sediment transport equations, including those by Rouse (1937), Lane & Kalinske (1941), Brooks (1958), Bagnold (1966), and Yang (1996), to determine the most accurate model for estimating suspended sediment load in this river. Data spanning from 2007 to 2020, collected from the Khuzestan Water and Power Authority (KWPA), were analyzed to compare these models against measured sediment loads. The Rouse method proved to be the most reliable, achieving approximately 80% accuracy in estimating suspended sediment load. The modified Yang equation followed with about 60% accuracy, while accuracy for Brooks' method was around 49%. Conversely, the Bagnold (1966) and Lane & Kalinske (1941) models demonstrated significantly lower accuracies of 21% and 12%, respectively. The study reveals that Rouse and Yang equations align better with the Balaroud River's conditions, marked by its sandy substrate and the influence of the Balaroud dam on flow dynamics. The findings underscore critical discrepancies among the evaluated equations and the necessity for case-specific assessments to enhance sediment transport predictions. This research highlights the importance of selecting models tailored to the unique characteristics of each river system for effective sediment management and environmental conservation. Recommendations include prioritizing the Rouse equation for similar rivers and pursuing further research to develop models suited to diverse sediment transport dynamics.

Introduction

Sediment transport is a critical process that involves the movement of solid particles, or sediment, driven by gravitational forces and the displacement of fluids. This phenomenon is particularly significant in river systems, where sediments are transported from one location to another during the flow of water. The movement of sediments occurs in various forms, including bed load and suspended load, with the specific mode of transport influenced by factors such as sediment availability and flow rate. Rivers play a pivotal role in shaping landscapes through the erosion of bedrock and surrounding slopes, contributing to the formation of new sediments. These riverine sediment processes are influenced by water flows and flash floods, with sediments transported by water often being larger than those carried by air due to the higher density and viscosity of water. In typical river systems, the largest sediments transported are usually sand and gravel; however, during flood events, larger rocks may also be mobilized. The transport of sediments by water flow can lead to the development of complex erosion patterns and the creation of floodplains (Burbank, 2002).

Effective management of sediment transport is essential for reducing flood damage in rivers, which is a primary objective in water resource management. To achieve this goal, it is imperative to thoroughly examine the processes of flow, bed erosion, sediment transport, and deposition (Strahler et al., 1950).

Evaluating the various relationships for calculating sediment discharge and comparing them is of critical importance from the perspective of river engineering. This subject aids in the optimal design of hydraulic structures, effective flood management, and the prediction of river bed evolution. Furthermore, these analyses allow engineers to better understand the impacts of projects on aquatic ecosystems and adopt the necessary measures for environmental protection and water quality improvement. Ultimately, these studies lead to the sustainable development of water systems and the reduction of risks associated with erosion and sedimentation.

This research focuses on examining the different relationships for more accurately estimating the suspended sediment load in the Balaroud River, in order to identify the most suitable model for estimating the sediment discharge in this river. It is important to note that changes in riverbed elevation are closely tied to the river's bed load transport, and while the primary objective of this study is to quantify the suspended sediment load, there is a close relationship between the suspended load and bed load. By obtaining an understanding of the suspended sediment load, it is possible to provide a reasonably realistic estimate of the bed load transport as well, through the use of appropriate bed load transport coefficients. Identifying these relationships can assist in the detection and prediction of riverbed elevation changes, proactive measures to reduce bed degradation, and the mitigation of risks arising from scour around bridge piers and the undermining of embedded structural foundations. The results of this study can provide support to water engineers and managers in the realm of sediment management and the design of hydraulic structures in this region.

One of the significant challenges faced in the construction and maintenance of dams is sedimentation within reservoirs. Sedimentary materials enter dam reservoirs from the erosion of riverbeds and upstream watersheds, manifesting as washed load, suspended load, and bed load. These sediments settle in the reservoir due to changes in hydraulic conditions, leading to a reduction in storage capacity and various operational issues, including turbine disruption, clogging of intakes, and increased pressure on dam structures. Consequently, regular management and control measures are essential to mitigate sedimentation impacts and ensure the longevity of dam infrastructure (Aryaei & Lashkar-Ara, 2023 & Abasi Zade Bagheban and Lashkar-Ara, 2020).

Dams alter the flow characteristics of rivers, causing a portion of the sediments in transit to settle within the reservoir. Sediments are generally categorized into three types: bed load, suspended load, and wash load. Bed load typically settles at the upstream end of reservoirs, while finer sediments remain suspended and can move closer to the dam structure before eventually settling (Khastar-Boroujeni et al., 2019). Understanding the physical and behavioral characteristics of cohesive sediments is crucial for predicting their transport and deposition dynamics. One key parameter in this context is the settling velocity of sediment particles, which is influenced by factors such as particle size, turbulence, ambient temperature, and concentration of suspended sediments (Shadorvan et al., 2018).

The literature on sediment transport highlights the complexity of interactions between water flow and sediment particles, with significant implications for water quality and environmental health. Suspended sediments can lead to water pollution and the transport of contaminants, necessitating effective management practices to preserve aquatic ecosystems (Muste et al., 2005). Various empirical and semi-empirical models have been developed to estimate sediment loads, yet discrepancies between model predictions and field observations remain a challenge, underscoring the need for more precise approaches to sediment transport analysis.

The total sediment load comprises both suspended and bed loads, with the alluvial load consisting of finer materials. Accurately predicting alluvial load is challenging, as it is influenced more by watershed characteristics than by river hydraulics. Consequently, sediment discharge estimation has been a focal point of research, leading to numerous equations and models aimed at improving predictive accuracy (Shafai Bajestan, 2013).

Accurate prediction of suspended sediment discharge is essential for effective water resource management and environmental sustainability. The growth of rivers, deltas, coastal regions, and undersea fans depends on the entrainment and suspension of sand and gravel. An entrainment relation is usually used to determine both the concentration close to the bed and the upward vertical distribution of sediment in the water column, which is crucial for forecasting a vertical profile of suspended sediment concentration. However, both phases, particularly near-bed concentration, are fraught with ambiguity. Limited associations have been assessed for gravel suspension, particularly in bedrock and mountain rivers, with most entrainment relations based on a small amount of grain size-specific data (Birkhoff, 2015).

Recent advancements in computational techniques, especially artificial neural networks (ANNs), have shown significant potential for enhancing predictive performance by analyzing nonlinear relationships and capturing intricate patterns within datasets. For instance, a comprehensive study by Sedaei and Shahedi (2012) compared empirical methods to the Multilayer Perceptron (MLP) neural network technique for predicting suspended sediment discharge in the Armand River, located within the Karoon Basin of Iran. Their findings indicated that MLP models, when configured with critical hydrological parameters such as velocity, area, and depth, yield more accurate estimations than traditional empirical methods. This research underscores the urgent need for innovative modeling approaches to effectively address increasing demands for precision in sediment estimation and enhance water resource management strategies.

In conclusion, it can be noted that previous studies have not approached sediment load estimation comprehensively; rather, they have focused on sediment transport as isolated case studies. In some of these investigations, rainfall data has even been used to measure sediment levels. This paper aims to evaluate and identify the most effective equations for predicting suspended sediment transport in the Balaroud River. By analyzing various sediment transport models and their applicability to specific river conditions, this research seeks to improve sediment management practices, ultimately contributing to the preservation of aquatic ecosystems and water resources.

The innovation of present study lies in its comprehensive assessment of different sediment transport equations under the unique conditions of the Balaroud River, which may lead to the development of more accurate and efficient models in the field of sediment transport. The findings of this research will provide valuable insights into the dynamics of sediment transport and enhance the understanding of sediment management in river systems.

Materials and Methods

The study area for this research is the Balaroud River, a significant tributary of the Dez River located in northern Khuzestan Province, Iran. The watershed of the Balaroud River spans over 37.872 square kilometers, with a perimeter of 150 kilometers and an average elevation of 716.75 meters. It is situated within the Alvar-e-Garmsiri District (Hosseiniyeh City) and the central part of Andimeshk County. The region experiences an average annual temperature of 23 degrees Celsius, with average annual precipitation recorded at 30 millimeters, contributing to a total annual precipitation of 378 millimeters. The geographical coordinates of the Balaroud River area, according to the UTM coordinate system, are as follows: North 3601770 *m* to 3654377 *m* and East 235576 *m* to 260746 *m*. The geographical location of the Balaroud River as shown in Fig. (1).

This context provides essential background information for understanding the hydrological and environmental characteristics of the Balaroud River, which are crucial for the study of sediment transport and management in the region.

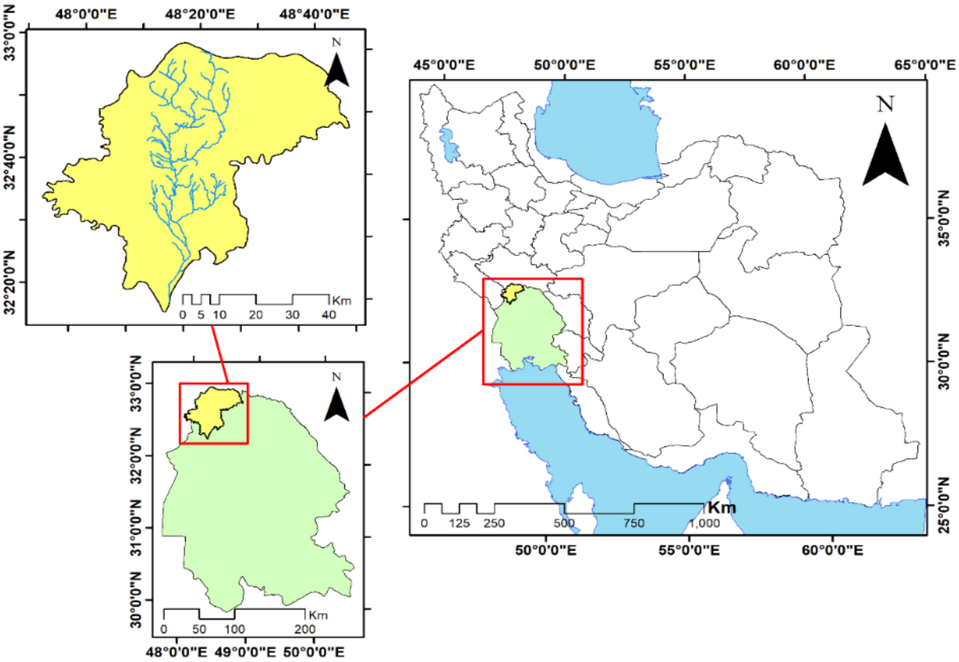

Fig. 1- Geographical location of the Balaroud River – Andimeshk, Khuzestan, Iran.

Table 1- Summary of Data Used in Suspended Load Calculations for the Balaroud River (2007-2020)

Sediment discharge (*Ton/Day*)	Flow discharge (m^3/s)	Depth (*m*)	D_{50} (*mm*)	D_{90} (*mm*)	Slope %	*R* (*m*)	*V* (*m/s*)	Section area (m^2)	Section width (*m*)
44951.81	7.02 ~ 4916	1.71 ~ 4.99	24.16	64.24	0.00397 ~ 0.005078	0.160 ~ 2.862	0.3 ~ 1.90	14.09 ~ 370.74	82.52 ~ 121.90

To conduct this research, statistical data obtained from the Khuzestan Regional Water Company was utilized, specifically from the hydrometric and sediment gauging station at Dukouheh during the period from 2007 to 2020. This data was used to evaluate the equations of Rouse (1937); Lane & Kalinske (1941); Brooks (1958); Bagnold (1966) and Yang (1996), along with graphical analyses. It is important to note that the hydrological method was employed to estimate and determine the observed values of suspended sediment load in the river.

In this method, the concentration of suspended materials (*C*) is initially measured in milligrams per liter at the sediment gauging stations, along with the corresponding volumetric flow rate (Q_W) measured in cubic meters per second over a long-term statistical period. The suspended load (Q_S) is then calculated in kilograms per year using the suspended load equation. In other words, using hydrometric and sediment data, and considering that sediment discharge is a function of flow rate, a equations between Q_W and Q_S is extracted. Using long-term volumetric flow data from the river, the long-term suspended load of the river is estimated.

$$Q_s = 0.0864\ C\ Q_w \tag{1}$$

If the concentration of suspended solids in a specific cross-section at a given time is denoted by *C*, and the velocity of the fluid passing through this cross-section is equal to v, then the suspended sediment load can be expressed as follows:

$$q_s = \int_a^d Cv\,dy \tag{2}$$

In which, a depth is the distance the distance from which the dispersed material is still in motion, and d is the flow depth. After statistical monitoring and correctness, as well as removing suspicious cases, the collected data was used for testing in the calculations of transfer equations. The results from the studies detailed below will inform the current research.

Rouse (1937) introduced an innovative formula that takes into account the effects of distortion and the concentration of suspended sediments across a complete distribution. This formula enables the calculation of sediment concentration for various sizes of non-cohesive particles and is expressed as:

$$\frac{C}{C_a} = \left(\frac{d-y}{y}\frac{a}{d-a}\right)^Z \tag{3}$$

$$Z = \frac{\omega}{\beta k u_*} \tag{4}$$

In which : C represents the weight density of the suspended material, C_a is the average concentration of the dispersion, and d is the flow depth. The variable y denotes the depth at a specific location where the sediment concentration is equal to C. The height a represents the distance from the bed to the surface of the object, above which the Rouse equation is valid; below this height, the equation is not applicable. Some researchers suggest a value of an equal to 5% of the flow depth, expressed as a = 0.05d (Fig. 2). In Equation (4) the particle fall velocity, denoted as ω, is influenced by the Von Kármán (1921) constant k, which is approximately 0.4 for clear water. The shear velocity u_* is defined by $(gRS)^{0.5}$. Additionally, the Rouse number Z indicates the relationship between particle size and sediment concentration profiles within the channel depth. Smaller particle sizes contribute to more uniform concentration profiles, while larger particle sizes result in greater variability. The variable β is also considered, which is treated as a dimensionless quantity by most researchers. Van Rijn (1984) proposed the following ratio to estimate β :

$$\beta = 1 + 2\left(\frac{\omega}{u_*}\right)^2 \qquad 0 < \frac{\omega}{u_*} < 1 \tag{5}$$

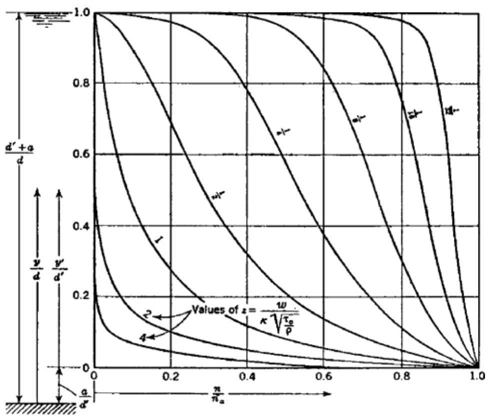

Fig. 2- Suspended-load distribution according to Rouse (1937)

Chanson (1999) proposed a method that allows for the determination of the amounts C_a and *a* through analysis. This method is detailed in equations (6), (7), and (8), which outline the related relationships and computational techniques involved.

$$C_a = \frac{2.457}{\upsilon}\left(\frac{V^2}{(G_s - 1)g}\right)^{1/3}(\tau_* - 0.047) \quad (6)$$

$$a = 1.375\left(D_{50}\left(\frac{(G_s - 1)g}{\upsilon^2}\right)^{1/3}\right)^{0.7} \times \sqrt{\tau_* - 0.047} \quad (7)$$

$$\tau_* = \frac{\tau_0}{\gamma_w (G_s - 1) D_{50}} \quad (8)$$

In this context, C_a represents concentration (weight), *d* is the average bed constant, and D_0 refers to the mean particle size, defined as the diameter at which 50% of the weight of the particles is finer. Furthermore, G_s denotes the specific density of the grains, $\tau 0$ represents the frictional shear stress, γ_w indicates the specific weight of water (in newton per cubic meter), and μ signifies the synthetic viscosity. Among the parameters utilized to determine *C* is the fall velocity, which is calculated using the Ruby equation, as defined in equations (9) and (10) (Rubey, 1933).

$$\omega = F\left[D g (G_s - 1)\right]^{1/2} \quad (9)$$

$$F = \left[\frac{2}{3} + \frac{36\nu^2}{gD^3(G_s - 1)}\right]^{1/2} \quad (10)$$

Lane & Kalinske (1941); utilizing the perspectives presented by Rouse (1937) proposed an equation to determine the suspended sediment load carried by water flow in rivers as follows:

$$q_s = \gamma_w q C_a p_L \exp\left(\frac{15\omega a}{U \times D}\right) \quad (11)$$

Where q_s represents the suspended load per unit width (N/s-m), *q* is the flow rate per unit width, γ_w denotes the specific weight of water (N/m³), and P_l is a parameter obtained from Figure (3). To utilize the plotted curve $n/D^{1/6}$, it is necessary to specify the ratio, where *n* is the Manning coefficient evaluated for the river under consideration. Once the value of the daily sediment load q_s in tons is determined, it can be calculated based on the equation (12).

$$Q_s = 8.64 q_s B \quad (12)$$

In this context, Q_s refers to the daily suspended sediment load (measured in tons per day), and *B* represents the width of the river (measured in meters).

Brooks (1958) introduced Equation (13) for estimating suspended load in rivers based on the concentration distribution equation.

$$\frac{q_s}{\gamma_w \; q \; C_{md}} = F(K\frac{V}{U_*}, Z_1) \quad (13)$$

In which, q_s the suspended load per unit width (N/s-m), q the flow rate per unit width (m^3/s-m), *F* is the transfer function, Z_1 and the modified exponent of the concentration distribution equation is derived from the Figure (4). The weight concentration at C_{md} a distance of 0.5d is determined based on the following equation:

$$C_{md} = C_a\left(\frac{a}{d - a}\right)^{Z1} \quad (14)$$

V is the average flow velocity (m/s), which is obtained from the following equation

$$V = 6.261 U_* Log\left(\frac{R}{D_{65}}\right) \quad (15)$$

In which: *R* is the hydraulic radius of the flow (*R=A/P*), a is the cross-sectional area (m), and D_{65} the diameter corresponding to 65% of the weight of sediment particles (m). The amount of q_s daily suspended load in tons (Q_s) is calculated using the following equation:

$$Q_s = 8.64 q_s B \quad (16)$$

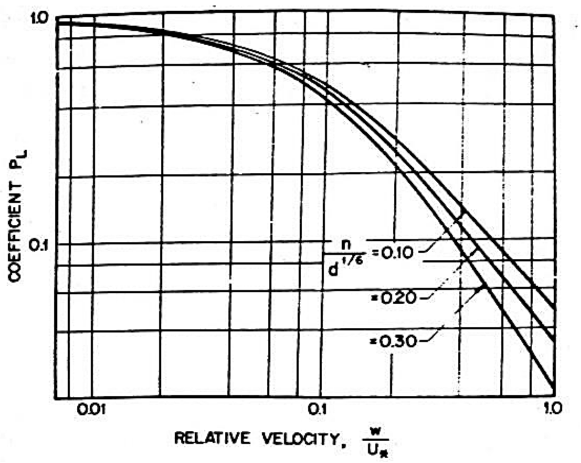

Fig. 3- The PL parameter estimation in Lane and Kalinske (1941)

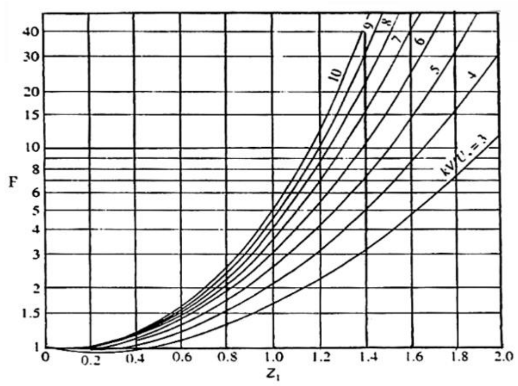

Fig. 4- The F parameter estimation in Brooks (1958) study

Bagnold (1966) sediment transport equation is founded on the principle of energy conservation. The sediment load is transported through various mechanisms. As a first approximation, Bagnold classified the load into bedload and suspended load. The immersed weight of the bedload is balanced by momentum transfer from solid-solid collisions, whereas the immersed weight of the suspended load is counterbalanced by upward momentum transfer from fluid turbulence.

The available flow power ω represents the common energy supply to both transport mechanisms. For bedload transport, the bedload work rate is given by q_b tan(a), while the bedload transport rate is expressed as follows:

$$q_b = \frac{e_b}{\tan\alpha}\omega \qquad (17)$$

Where q_b is the bedload transport rate expressed in terms of the immersed weight of the load, e_b is the bedload transport efficiency, tanα is the coefficient of dynamic bedload friction, and ω is the total available flow power, which can be expressed in terms of the boundary shear stress τ_0 and the mean flow velocity $\bar{U}$ as follows:

$$\omega = \tau_0 \overline{U} \qquad (18)$$

For suspended-load transport, the work rate is defined as $q_S \frac{\omega}{\overline{U}_S}$, while the transport rate is expressed as follows:

$$q_s = \omega \frac{e_s U_s}{W}\left(1 - e_b\right) \qquad (19)$$

In this context, q_s represents the suspended-load transport rate, also expressed in terms of immersed weight, e_s denotes the suspension efficiency; W is the terminal fall velocity of suspended sediments; and $\overline{U}_S$ is the mean transport velocity of suspended sediments. By adding equations (17) and (19), we obtain Bagnold (1966) expression for the total transport rate q:

$$q = q_b + q_s = \left(\frac{e_b}{\tan\alpha} + \frac{e_s \overline{U_S}}{W}(1-e_b) \right)\omega \tag{20}$$

This expression has a clear physical significance regarding the sediment transporting power of the fluid.

Yang (1996) modified his main equation for rivers with highly concentrated suspended materials, which is applied in this paper as follows:

$$\begin{aligned} LogC_t &= 5.165 - 0.153 Log \frac{\omega_m D_{50}}{\upsilon} - \\ 0.297 Log \frac{u_*}{\omega} &+ \left(1.780 - 0.36 Log \frac{\omega_m D_{50}}{\upsilon} - \right. \\ \left. 0.48 Log \frac{u_*}{\omega_m} \right) &Log \left[\frac{VS}{\omega_m} \frac{\gamma_m}{\gamma_s - \gamma_m} \right] \end{aligned} \tag{21}$$

In which C_t weight concentration of sediment in ppm, V is kinematic velocity of sediment-laden flow, γ_m is special weight of sediment laden flow and ω_m is particle fall velocity. Here's a polished version of your text to enhance clarity and flow:

An ideal equation for predicting sediment transport would accurately forecast measured sediment values over the entire statistical period or a significant portion of it, with reduced error compared to other equations. To facilitate comparison between estimates derived from empirical equations and observational data, the Mean Absolute Error (MAE) and the Root Mean Square Error (RMSE) indices were used. These statistical tools quantify the accuracy of sediment transport predictions relative to actual measured values, enabling a more effective assessment of the performance of various sediment estimation models.

$$MAE = \frac{\sum |O_t - E_t|}{n} \tag{22}$$

$$RMSE = \sqrt{\frac{\sum (O_t - E_t)^2}{n}} \tag{23}$$

Where, O_t is the calculated value (observations) and E_t is the computed value. In addition, the total number of n is calculated.

Results and Discussion

Rivers are generally classified into two categories: sandy rivers and alluvial rivers, based on the sediment size distribution and the physical characteristics of their beds. Sandy rivers typically consist of heterogeneous particles, including fine, medium, and coarse grains. This variability in particle size and shape presents greater challenges for sediment transport. In such rivers, flow patterns are more complex, and particles may interact unpredictably, complicating the calculations related to sediment load. Furthermore, changes in hydraulic conditions in sandy rivers necessitate the use of accurate and advanced models to predict sediment behavior. In contrast, alluvial rivers, which are usually composed of more uniform sand particles, provide a more favorable condition for calculations. The uniformity of particles in these rivers makes sediment movement and transport more predictable, thus facilitating sediment load modeling. In other words, in alluvial rivers, one can achieve higher accuracy in estimating sediment loads using standard hydraulic models. Rivers located at the onset of floodplains, particularly those in zone 2, exhibit specific characteristics that significantly impact the transport and deposition of materials. These rivers typically enter low-gradient zones due to sudden decreases in flow slope, where this change in slope can lead to abrupt and significant sediment deposition. Under such conditions, flow velocity changes drastically, and when water reaches the low-gradient areas, it loses its capacity to carry and transport sediment particles. This sudden reduction in flow velocity causes larger and heavier particles to settle first, resulting in sediment accumulation in the riverbed.

The Balaroud River, located at the beginning of Zone 2 in the downstream mountainous regions, experiences a gradual decrease in slope as one moves further downstream, particularly near the hydrometric station. In these areas, coarse sediments settle as bed load. Additionally, the Balaroud reservoir dam, constructed on this river, captures the entire sediment load, allowing only a small fraction of suspended sediments to pass downstream through its flood discharge system. Since the hydrometric station is positioned downstream of the Balaroud reservoir dam, these characteristics facilitate the application of relationships typically used in alluvial rivers for estimating suspended sediment discharge in this river as well.

This study evaluated the effectiveness of several equations proposed by Rouse (1937), Lane and Kalinske (1941), Brooks (1958), Bagnold (1966), and Yang (1996) for estimating suspended sediment discharge in the Balaroud River. In the first step, annual weighted discharge values of the Balaroud River were calculated using these various equations, with the observed values for corresponding years presented in the bar chart shown in Figure (5).

In the second step, power regression methods were employed to assess the accuracy and efficiency of the relationships used in this research. The compatibility of the data obtained from these sediment estimation equations was evaluated using recorded data on the volume of suspended sediments (in kg/year) for each statistical year from 2007 to 2020. Additionally, to further examine the accuracy and efficiency of each equation, scatter plots comparing computed values against observed data were generated and are displayed in Figure (6).

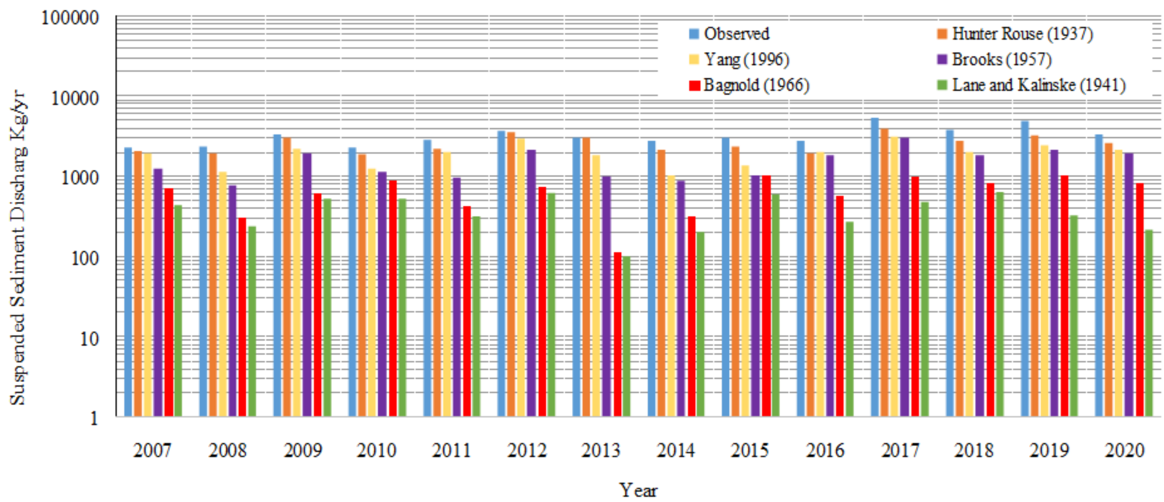

Fig. 5- Comparison of Annual Suspended Sediment Weight Based on Various Estimation Equations and Observations from the Balaroud Hydrometric Station

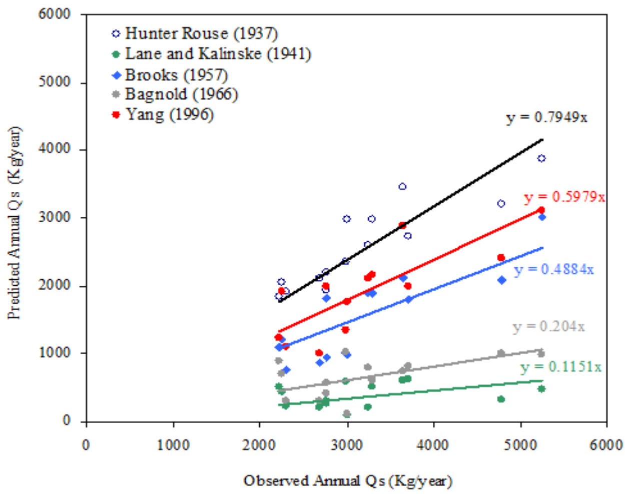

Fig. 6- Scatter Plot of Computed Values versus Observations for Suspended Sediment Estimation Methods

Among the methods assessed, the Rouse (1937) equation was recognized as one of the most accurate, demonstrating a deviation of approximately 20.5 percent from observed values. In contrast, the Yang (1996) and Brooks (1958) equations estimated sediment loads that were 40 percent and 51 percent lower than the predicted values, respectively, for the years 2007 to 2020. Additionally, the Bagnold (1966) equation yielded an average estimation that was 80 percent lower than the observed sediment loads, while the Lane & Kalinske (1941) equation predicted, on average, 88 percent less than the observed values. The comparison of the results from these equations indicates that the primary reason for these discrepancies relates to the specific characteristics of the Balaroud River and its sandy bed. As mentioned earlier, the Balaroud River is classified in zone 2; however, the construction of the Balaroud reservoir dam has altered its characteristics due to the reservoir established upstream of the dam. Inaccuracies in sediment load estimation may arise from limitations regarding the size range of materials considered in different methods. Equations developed based on data from sandy bed rivers may yield poorer results when applied to similar sandy conditions. Furthermore, the presence of coarse sediments and the dynamic behaviors of water flow in different river zones can affect the observed discrepancies among the results. Error plot diagrams and accuracy assessments of the equations, particularly radar plots, illustrate the disparities and relative accuracy of the various equations in estimating suspended sediment load (Fig. 7). The Rouse (1937) equation showed the least error, indicating its effectiveness under the specific conditions of the Balaroud River, while the highest error rate was associated with the Lane & Kalinske (1941) equation.

Based on the obtained results, it is recommended that the Rouse (1937) equation be favored for estimating suspended sediment discharge in rivers with characteristics similar to those of the Balaroud River. Additionally, further research is necessary to optimize accuracy through the development and validation of equations tailored to specific applications.

Fig. 7- Radar Chart Analysis of Error Metrics (RMSE, MAE) for Various Methods in Estimating Mean Annual Suspended Sediment

Conclusions

The present study investigates various equations for estimating suspended sediment load in the Balaroud River and demonstrates that the accuracy of these equations varies significantly. The results indicate that the Rouse (1937) equation was identified as the best option, exhibiting only a 20% deviation from the observed values. In contrast, other equations such as Yang (1996) and Bagnold (1966) underestimated sediment loads by 40% and 51%, respectively, while the Bagnold (1966) and Lin and Kalinski (1941) equations predicted sediment loads that were 80% and 88% lower than actual values. These discrepancies are primarily linked to the specific characteristics of the Balaroud River and its sandy bed, as well as the impact of the Balaroud dam on the river's hydrological features. Limitations related to the range of particle sizes in various equations also contribute to these inaccuracies. Therefore, utilizing equations that align with the specific conditions of the riverbed is crucial.

Consequently, it is recommended that the Rouse (1937) equation be employed for estimating suspended sediment load in rivers with characteristics similar to those of the Balaroud River. Furthermore, additional research is essential to optimize accuracy and to develop and validate suitable equations under specific river conditions.

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