

# Stone Quarries and Hydrological Regime of Roshi with Emphasis on Sedimentation

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**Abstract:** Nepal is a country with many mountains, situated in Hindukush Himalayas. Stone quarrying is currently accompanying the rapid expansion of physical infrastructure in the Roshi River and its tributaries. This study aims to establish the discharge and suspended sediment rating curve of the Roshi River. It also includes the impact of the stone quarries in the Roshi River during operation and non-operation at the upper Roshi watershed, Nepal. The data includes stage data, measurement of discharge, and suspended sediment in the years 2022 and 2023. The regression analysis was conducted with the development of a discharge rating curve having a coefficient of determination  $R^2 = 0.83$ . The suspended sediment rating curve of the annual and monsoon, of the year 2022 was developed with a coefficient of determination of 0.23 and 0.39 respectively. The average suspended sediment concentration at tributary Roshi is 203.04 percent higher than at upstream. The increase in average suspended sediment concentration at main Roshi concerning tributary Roshi is 14.25 percent. Further, the decrease in average suspended sediment concentration due to the non-operation of the stone quarry in January 2023 concerning December 2022 is 52.13 percent in tributary Roshi and 12.59 percent in the main Roshi River. Furthermore, the increase in SSC during the operation of stone quarry including monsoon contribution is 682.97 percent higher than during non-operation. The increase in SSC during the operation of stone quarry excluding monsoon contribution is 64.34 percent higher than during non-operation. The study will facilitate Panauti hydropower and the concerned authorities of Panauti to adopt various measures to control sediment discharge from stone quarries at Roshi for sustainable development of the Roshi watershed.

**Keywords:** Discharge, Stage, Stone Quarry, Suspended Sediment Rating Curve

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## 1. Introduction

Nepal is a country with many mountains, situated in Hindukush Himalayas. The Nepalese River's steep slope, intense flow turbulence, and boulder-infested sediment during the rainy season make it difficult to monitor discharge and sediment. Year-round variations in flow, measurements are therefore quite challenging. Planning and designing water resource projects require accurate data on water quantity and quality, in terms of spatial and temporal variability. The selection of appropriate instruments and methods to monitor discharges and sediment must take into account the site's location, terrain, and flow characteristics. The most prevalent issue found in several hydropower installations is

sedimentation. The relatable problem in the Nepalese rivers is boulder-laden sediment, flash floods, rapids, and turbulent flows. A massive amount of sediment is generated, transported, and deposited every year during monsoon season. Roshi River in Kavre district also experiences a huge amount of sediment transport in the monsoon season. Most of the sediment studies carried out in Nepal are of fluvial and road development but not of the quarry. Stone quarry problems are proliferating in various locations of the Roshi watershed in the Kavre district. There is a sedimentation problem in the headworks of Panauti Hydropower. The construction of roads, river training works, and the deposition of spoil in river banks are some of the sources of sediment in the Roshi River.

The delivery of sediment from a landslide to a stream in a drainage basin near Wong Chuk Hong, China was studied.

The study includes the monitoring of suspended sediment by manual sampling during storm events followed by concentration calculations [1]. The two hills streams Galundi and Pokhare situated in the central, and their discharge and sediment were measured. The representative sample was periodically taken from January to September from dry seasons and rainy seasons. The stream velocity was measured by float method and sediment sampling by taking a 1 L grab sample from the middle depth of the stream [2]. Assessed sediment load for one year in the Langtang River of Rasuwa district, Nepal. The sample was collected for four seasons pre-monsoon, monsoon, post-monsoon, and winter. The collection was weekly in pre-monsoon and post-monsoon, daily in monsoon, and bi-weekly in winter seasons. The sampling was conducted by depth integration method followed by filtration and oven-drying [3]. Determined sediment discharge utilizing sediment rating curve of North Sumatra, watershed Indonesia. The discharge, sediment, and water level data were collected from the field [4]. Generated sediment rating curves from long-term sediment concentration data by various methods and indicated the method of reducing associated errors. The long-term sediment, gauge height, and discharge data of Kabeli River a major tributary of Trishuli River from (2010 to 2018) were analyzed using Ordinary Least Square, Duan Ferguson, and the Optimization method [5]. Studied sediment transport in the Koshi River by comparing the previous and recent measurement data. Different measurement methods were adopted, in earlier days depth-averaged samplers were used but recently surface of bank samples was practiced [6]. Analyzed the discharge and sediment data to establish hydrographs and flow duration curves, carried out flood frequency analysis, flood magnitude, and discharge variability study of Koshi basin [7]. Evaluated sediment load of the Adji-Chai River in Tabriz Iran. The discharge and suspended sediment data were analyzed for the development of the relationship between discharge and sediment for dry seasons and wet seasons using regression analysis. Further applied the Buckingham  $\Pi$ -theorem dimensional analysis to derive the equation of bed load [8]. Studied sediment in the sub-catchment of the Pangani River basin, Tanzania. The depth integrating sampler D-74 to calibrate the sub-daily automatic sediment pumping sampler (ISCO6712) was used [9]. Applied ANN, SVM, and regression model for the prediction of runoff and sediment yield in the Kankaimai watershed of Nepal. The performance of the model was evaluated by root mean square, correlation coefficient, and coefficient of efficiency [10]. Studied rainfall, discharge, and sediment dynamics of two small watersheds Arnigad and Bansigad in the lesser Himalayas, India. The data used are tipping-bucket rain gauge and ordinary rain gauge for rainfall data. The discharge data were collected using a broad crested weir with a 120° gauge and V-Notch for low flows. The grab sample method was applied to collect suspended sediment data [11]. Studied climate change's impact on the discharge of the upper Roshi River which is the primary source for the Kavre Valley integrated water supply project.

The 'abcd' hydrological model was applied against climatic variables projected by the statistical downscaling model for the prediction of future scenarios [12]. Studied the challenges and opportunities that existed in the hydropower sector of Nepal. The problem associated with sediment in developing hydropower in Nepal has been stated [13]. Fluvial morphology and sediment transport of Malekhu situated in the lesser Himalayas, central Nepal have been studied. The ten river transects were surveyed for cross-section and longitudinal profiles. The suspended sediment samples were collected from each transect and analyzed and their concentrations were found out. Further conducted the river bed material sampling by using Wolman's pebble count for establishing grain size distribution. Furthermore, the velocity and discharge using Manning's and continuity equation using hydraulic parameters [14]. Hydraulic parameters for sediment transport and prediction of suspended sediment in the Kali Gandaki river basin, Himalaya, Nepal were studied. The study area is located at Setiben, Syangja 5 km upstream of the hydropower dam. The key hydraulic parameters included bed shear stress, specific stream power, flow velocity, and discharge associated with the transport size of the boulder [15]. The impact of Roshi river sand on hydraulic turbine material was studied by collecting sand samples from 20 different locations that included proposed hydropower project sites and confluences. The importance and critical role of the size, shape, and hardness of sand in the erosion of hydraulic turbines have been mentioned [16]. The sediment source and transport, the interaction of tectonics, monsoon seasonality, and strong relief provide an ideal environment for sediment in the Nepalese Himalayas. The daily suspended sediment data of 12 stations of major rivers were analyzed with formulation of the relationship of sediment transport with daily river discharge precipitation as well as with morphometric parameters [17]. Assessed the role of limestone quarries as a sediment source in the tropical Maracas-Saint Joseph River catchment, measuring both suspended and bed load to determine the impact of limestone quarries on the river system [18]. Quantified the variation of runoff and sediment load due to anthropological actions such as land use and check dam construction in the Xichuwan River catchment in China [19]. The suspended sediment samplers and their classification based on various parameters such as working principle, accuracy, specifications, availability, depth requirement, and cost were reviewed and put forward the general overview of mechanical samplers USP-61, and USD-49, optical sensors such as OBS and LISST, acoustic sensors such as ASTM and ADV, and in brief other sensors such as impact sensors, nuclear sensors, and conductivity sensors [20]. Investigated the effects on sediment load due to hydrological extremes and human intervention in Nepal's Kali Gandaki river basin [21]. Estimated suspended sediment rating curves and mean suspended-sediment loads of Wabash River and Big Blue River in Indiana. The flow duration, the rating curve method (FDRC) method to estimate the mean suspended load, and several alternative methods of estimating parameters of the

suspended- sediment rating curve [22]. Sediment variability and development of suspended sediment rating curve of Celone River Italy, analyzing the 12 months data at high, normal, and low flows [23]. Studied the contribution of suspended sediment during the storm and non-storm periods from an undisturbed and human-disturbed portion of the small mountainous watershed Faga'alu located in Tutuila, American Samoa. Suspended sediment yield for 142 storms was calculated by measuring discharge, turbidity, and suspended sediment concentration downstream of the quarry [24]. Assessed the suspended rating curve and turbidity-based approach for estimating suspended sediment loads in two river basins Bandon and Owanabue, Ire-land. The linear logarithmic regression and the power curve method were adopted in these two basins [25]. Compared the four soft computing artificial intelligence approaches ANN, ANFIS, WANN, and conventional SRC for estimating the SSL of two rivers Flathead River and Santa Clara River USA. The performance of each model is evaluated by using performance evaluation techniques such as coefficient of correlation, Nash Sutcliffe efficiency coefficient, Root mean square error, and Mean absolute percentage error [26]. Studied the pattern and trend analysis of the Yangtze River in China and the Eel River in the USA utilizing sediment rating curves [27]. The spatial variations of suspended sediment rating curves in the middle Yellow River of China using power and linear models to fit the daily flow and suspended load [28].

Stone quarrying is currently accompanying the rapid expansion of physical infrastructure in the Roshi River and its tributaries. However, the discharge of sediment from stone quarries and its quantification has not been done in the Roshi watershed. The studies on the impact of quarry in the contribution of fluvial sedimentation in the Roshi watershed have become essential. Additionally, the heterogeneity of development and multi-user agriculture, irrigation, water supply, cremation, and hydropower makes it difficult to assess the sediment yield that each LULC is contributing. The hydrological impact may be surface hydrology or groundwater hydrology. The sediment loads from anthropogenic activities can be found in the tributaries of Roshi as well as in the main Roshi River. The stone quarry is critical in contributing sediment, and the study of discharge and sedimentation and the impact of stone quarry plays a vital role in hydrological disaster management. In today's climate change setting, it's become critical to investigate climate change's impact on sediment and quarry impact too. Suspended sediment is an important factor in determining water quality. Streams and rivers carry enormous amounts of sediment in storms than in low flow periods. Both stream flow and sediment concentration continually change. If the quantity of flowing water and the amount of sediment it carries at different flow conditions is known, the tonnage of sediment that past the site during the day, during a storm, or even during the whole year can be computed. The majority of the research focuses on water supply and its sources to fulfill the demand for water for three municipalities Dhulikhel,

Banepa, and Panauti. The earlier study doesn't incorporate the quarry and its risk assessment, and susceptibility to deteriorating the riverine condition of River Roshi. This study aims to determine the discharge and suspended sediment quantity and the development of discharge and suspended sediment rating curves. It also includes the impact of the stone quarries during operation and non-operation in the Roshi River at the upper Roshi watershed, Nepal.

## 2. Materials and Methods

### 2.1. Study Area

Roshi watershed lies in Kavre district, Bagmati province central development region of Nepal. It covers an area of 84.4 sq. km. It extends 27° 34' 27.72 N to 27° 34' 29.12"N and 85° 29' 54.86"E to 85° 29' 57.31" E. Roshi River is one of the important and holy rivers that lies in Panauti Municipality. The main tributaries of the Roshi River are Roshi, Kalanti, and Lilawati which meet 500m above the headworks of Panauti hydropower. Roshi water has been used for various purposes. It includes hydropower, irrigation, drinking water, and traditional water mills. Panauti Hydropower with an installed capacity of 2.4 MW, the oldest hydropower is also situated in the Roshi watershed. Roshi River is the tributary of the Sunkoshi River which in turn tributary of the Koshi River. Currently, 11 stone quarries are running in the Roshi watershed 3 in Kalanti, and 8 in Roshi upstream area. The climate of Kavre district is sub-tropical to temperate but most regions have sub-tropical climates. The mean annual rainfall in the watershed based on Khopasi station is 1315.5 mm. Roshi joins the Sunkoshi downstream at Kusheswar Mahadev Dumja. The Roshi watershed with its district map is shown in Figure 1.

### 2.2. Discharge Measurement and Sample Collection

The study employs the compiling of primary and secondary data. The primary data includes the collection of field data from Roshi River that comprises the stage data, measurement of discharge, and suspended sediment. The suspended sediment data is obtained by sampling followed by suspended sediment analysis in the laboratory. The measurement of discharge was carried out at the gauge station of Main Roshi. The suspended sediment sampling was carried out upstream and downstream of tributary Roshi, Kalanti, Lilarwati, and the main Roshi gauge station. The discharge and suspended sediment were measured in the year 2022 when the quarry was in operation and also in January 2023 when the quarry was not in operation. In the year 2022, the measurement was carried out once every month for 12 months. The measurement was carried out for 31 days in the month of monsoon (August-September) and in winter (December) 2022. During the non-operation of a quarry that is in January 2023, it was measured for 9 days. The Roshi watershed was delineated by using QGIS. The discharge data and suspended sediment data obtained from the lab were analyzed and the discharge rating curve and sediment rating curve were developed. The

suspended sediment sampling at the main Roshi gauge station and lab setup is shown in Figure 2.

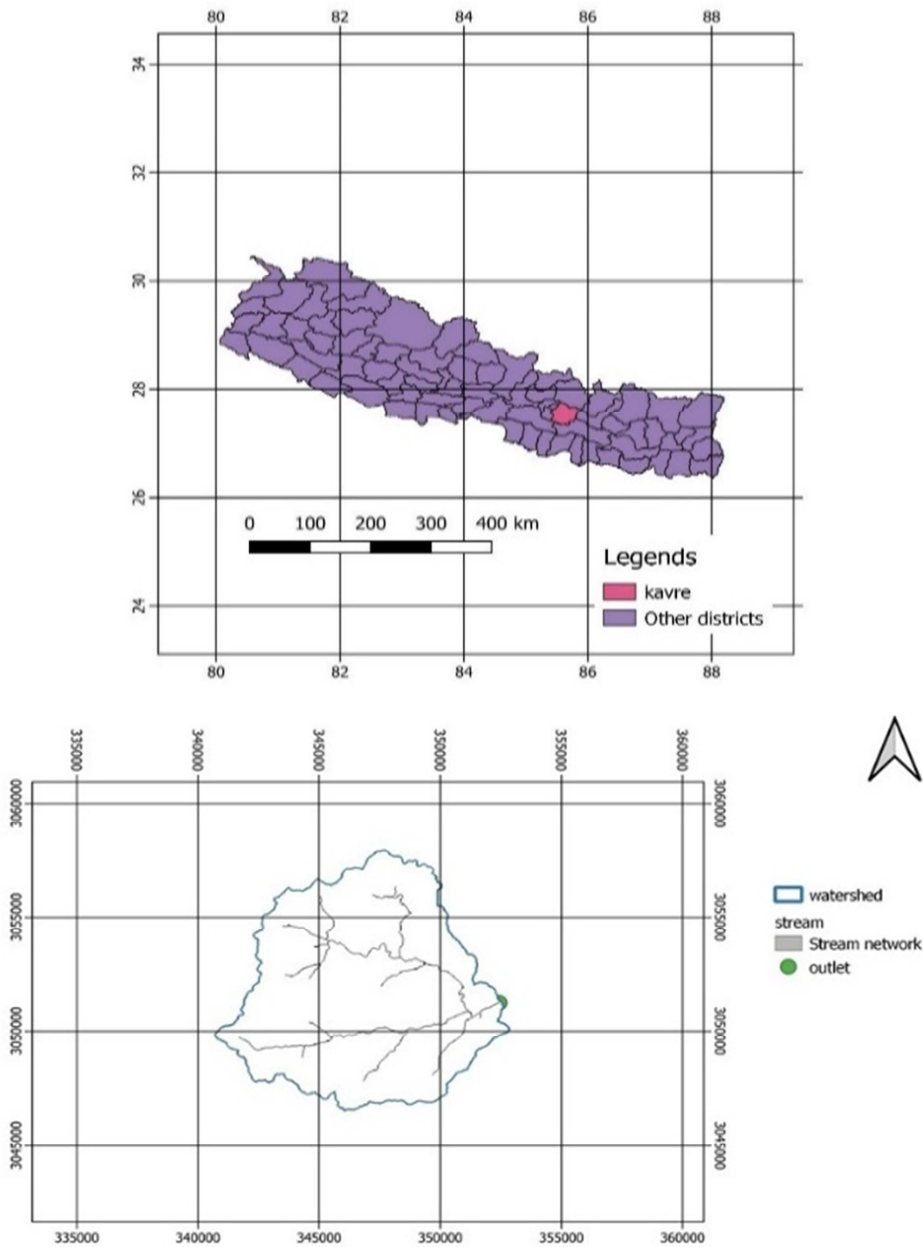


Figure 1. Study area Kavre district and Roshi watershed.



Figure 2. Sediment sampling in Roshi River and lab setup.

### 3. Results and Discussion

#### 3.1. Discharge Rating Curve

The stage data and measured discharge of the year 2022,

were plotted and the discharge rating curve was obtained with a coefficient of determination  $R^2 = 0.83$ . The relationship between stage and discharge and its curve is shown in Figure 3.

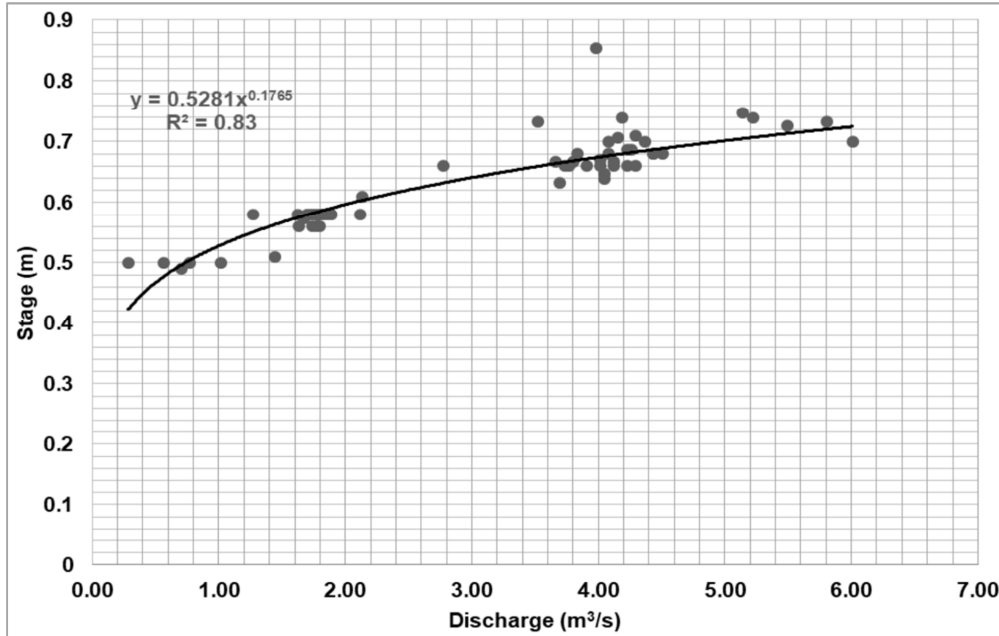


Figure 3. Discharge rating curve of the River Roshi of the year 2022.

#### 3.2. Suspended Sediment Rating Curve

The discharge and suspended sediment of the main Roshi were used to establish a suspended sediment rating curve. The annual and monsoon-suspended sediment rating curve of the year 2022 was plotted. The coefficient of determination of annual and monsoon-suspended sediment rating is 0.23 and 0.39, respectively. The annual and monsoon-suspended

sediment rating curve is shown in Figures 4 and 5 respectively.

#### 3.3. Comparison of Suspended Sediment of Main Roshi and Its Tributaries

The suspended sediment upstream and downstream of tributaries Roshi, Lilawati, Kalanti, and gauge station of main Roshi in December 2022 are plotted and compared.

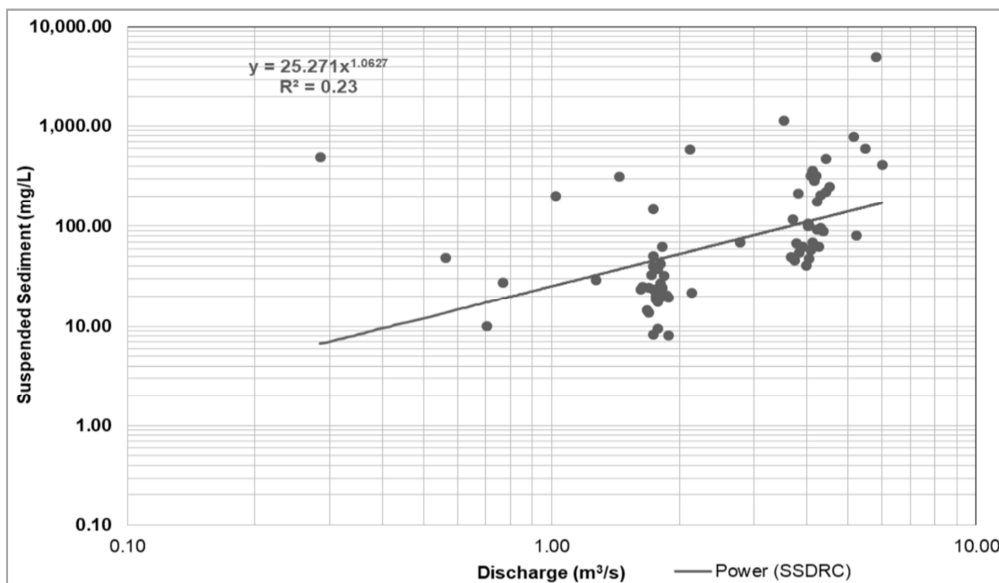


Figure 4. Suspended sediment rating curve of 2022.

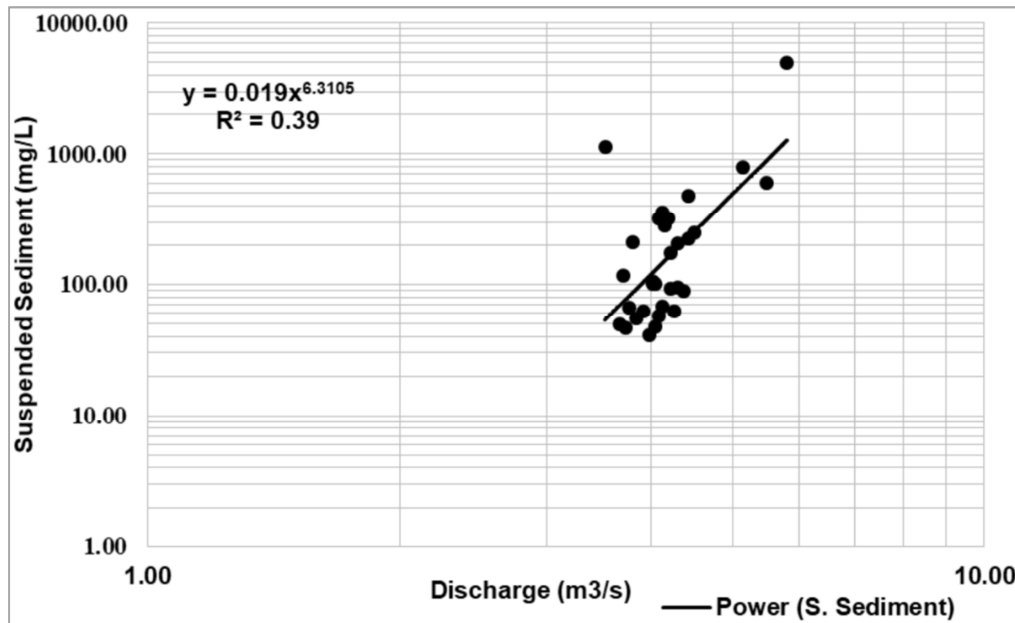


Figure 5. Suspended sediment rating curve of Monsoon 2022.

### 3.3.1. Upstream and Downstream of Tributary Roshi

The average suspended sediment upstream is 11.17 mg/L whereas it is 33.85 mg/L at downstream. The comparison of suspended sediment upstream and downstream of Roshi indicated

that suspended sediment is higher downstream than upstream. The percentage increase in average suspended sediment was found to be 203.04 percent. Figure 6 shows the suspended sediment upstream and downstream of tributary Roshi.

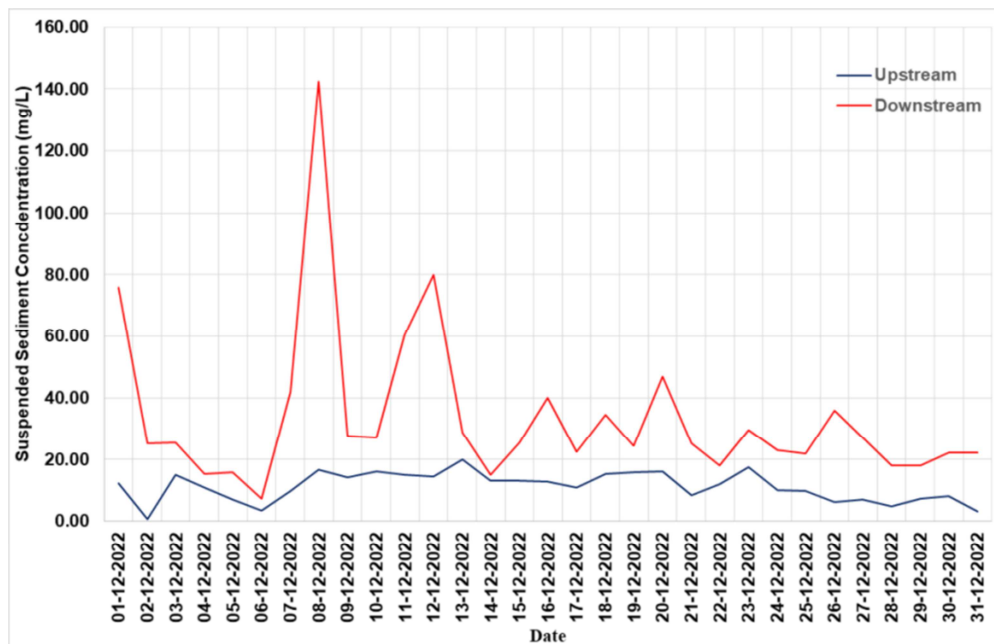


Figure 6. Comparative chart of suspended sediment upstream and downstream of tributary Roshi.

### 3.3.2. Main Roshi and Its Tributaries

The average suspended sediment concentration in the Roshi gauge station in Dec 2022 is 28.62 mg/L and downstream of tributaries Roshi, Lilawati and Kalanti are 33.85, 15.38, and 23.26 mg/L. The tributaries Roshi have high concentration whereas Lilawati has low. The concentration of suspended sediment fluctuates at the gauge station. The concentration at

the gauge station depends on the discharge and suspended sediment of its tributaries. The fluctuation is due to various reasons like human intervention such as the diversion of water to water mills, fishing by local people, and construction activities upstream like road and river training works. The washing of vehicles upstream also increases the suspended sediment concentration. Figure 7 shows the suspended sediment concentration at Roshi gauge station and its



tributaries in Dec 2022.

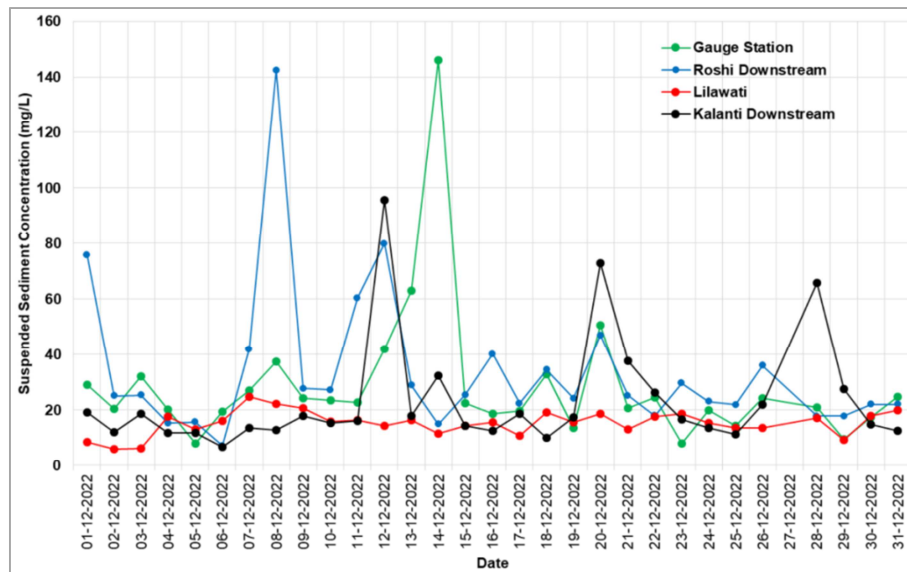


Figure 7. Graph showing suspended sediment concentration at Roshi Gauge station and its tributaries in Dec 2022.

### 3.4. Suspended Sediment Downstream of Tributary Roshi and Main Roshi When the Quarry Was Not in Operation

The average suspended sediment concentration downstream of tributary Roshi and Main Roshi during non-operation of the quarry is 22.25 mg/L and 25.42 mg/L.

The increase in average suspended sediment concentration at main Roshi concerning tributary Roshi is 14.25 percent. The decrease in average suspended sediment concentration due to the non-operation of the stone quarry in Jan 2023 concerning Dec 2022 is 52.13% in tributary Roshi and 12.59% in main Roshi. The suspended sediment in the tributary Roshi and main Roshi gauge station are shown in Figure 8.

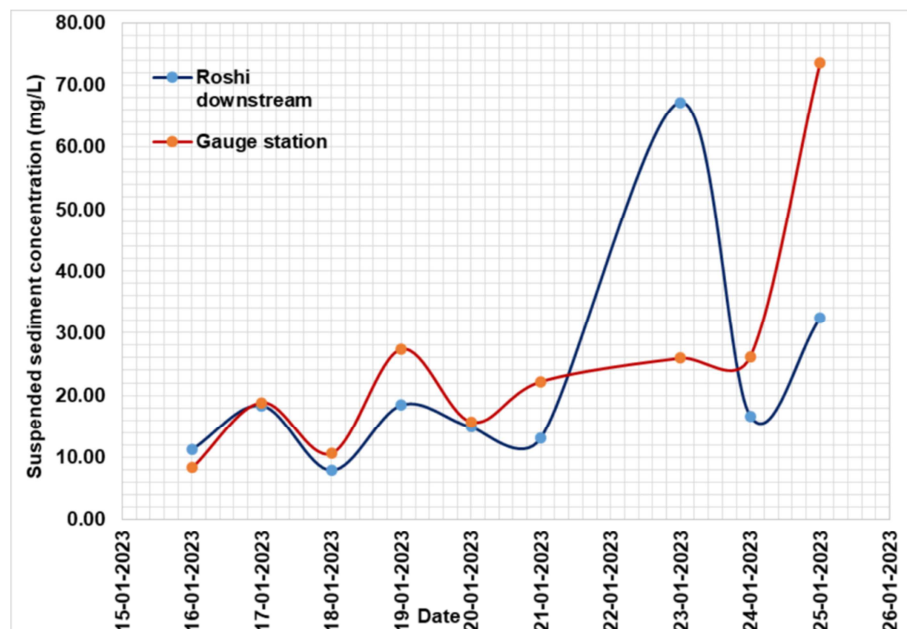


Figure 8. Suspended sediment downstream of tributary Roshi and Main Roshi at gauge station when the quarry was not in operation in January 2023.

### 3.5. Suspended Sediment Downstream of Tributaries Roshi, Kalanti, and Main Roshi Gauge Station When the Quarry Was Not in Operation

The average suspended sediment downstream of tributary

Roshi and Kalanti is 22.25 and 86.52 mg/L whereas it is 25.42 mg/L at gauge station. The suspended sediment in tributary Kalanti was high during the non-operation of the quarry due to road construction and river training works that were ongoing upstream of the Kalanti River. Suspended sediment

downstream of tributaries Roshi and Kalanti and the main Roshi gauge station are shown in Figure 9.

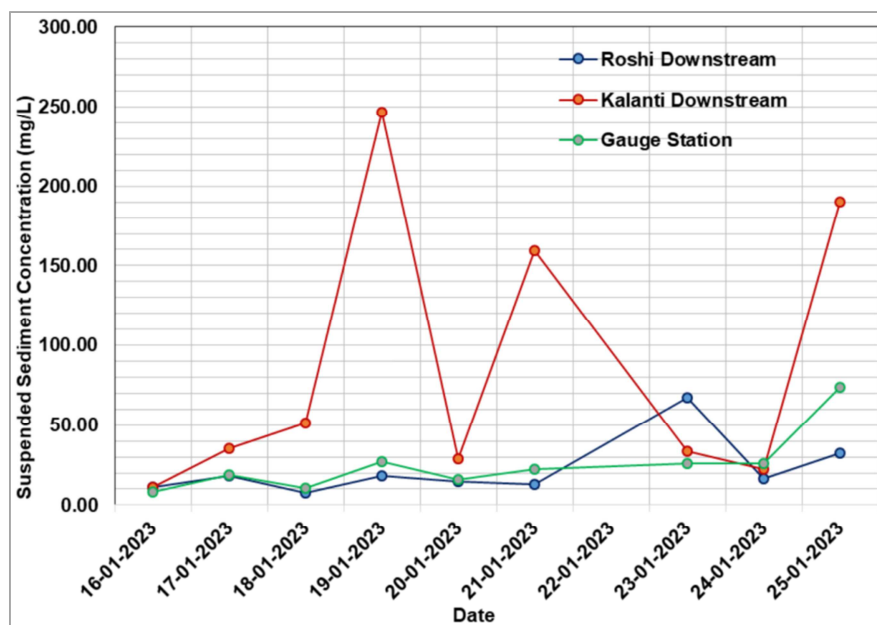


Figure 9. Suspended sediment downstream of tributaries Roshi and Kalanti and Roshi Gauge station in January 2023 when the quarry was not in operation.

### 3.6. Suspended Sediment in the Main Roshi During Operation and Non-Operation of Stone Quarries

The average suspended sediment contributed by all phenomena (including the stone quarry and monsoon) during the operation of the quarry in the year 2022 was found to be 199.03 mg/L. The average suspended sediment concentration

during the non-operation of the quarry in January 2023 was 25.42 mg/L. It is found that during the operation of the quarry including monsoon, the quarry contributes 682.97 % higher than during non-operation. The suspended sediment in the main Roshi gauge station (including the stone quarry and monsoon) and during the non-operation of the quarry is shown in Figure 10.

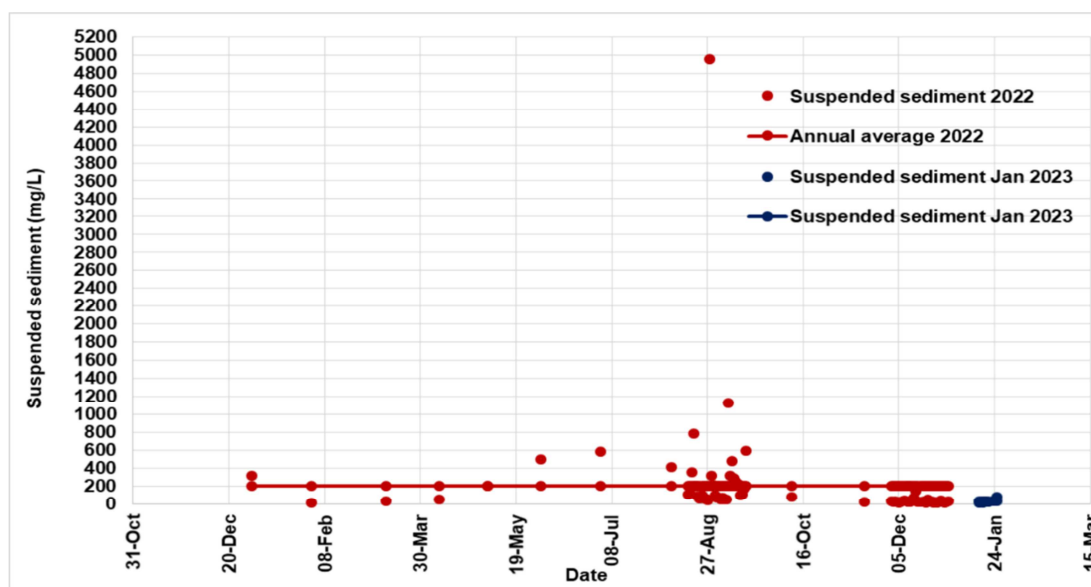


Figure 10. Suspended sediment in Main Roshi gauge station (including stone quarry and monsoon) in 2022 and during non-operation of quarry January 2023.

The average suspended sediment contributed by all phenomena (including stone quarry and excluding monsoon) in the year 2022 was found to be 41.78mg/L. The average suspended sediment concentration during the non-operation of

the quarry in January 2023 was 25.42 mg/L. It is found that during the operation of the quarry (excluding monsoon), SSC is 64.34 % higher than during non-operation. Suspended sediment concentration (excluding monsoon) and during



non-operation of the quarry is shown in Figure 11.

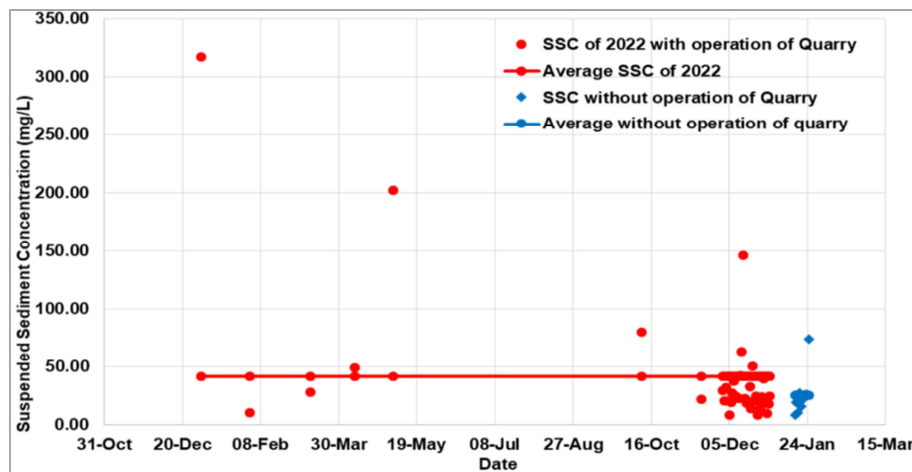


Figure 11. Suspended sediment concentration (excluding monsoon) of 2022 and during non-operation of stone quarry January 2023.

Research on discharge and suspended sediment is carried out in various parts of the world. The study comprises the development of the discharge rating curve, flow duration curve, suspended sediment rating curve, and also the impact of suspended sediment in hydropower and other hydraulic structures. The impact of quarries on river morphology, hydrology, and environment has also been carried out. The C and N content in the sediment sample and its color indicated that the sediment was derived from landslides, indicating the connectivity of hill slopes and channel systems [1]. The development of the relationship between discharge and sediment concentration of Galundi and Pokhara Khola [2]. The calculation of the sediment concentration of Langtang River is its seasonal and diurnal variation followed by a hysteresis loop [3]. Derivation of the sediment rating curve for the river of Sumatra watershed, Indonesia [4]. The OLS is a more common method of constructing SSRC, the Optimization was best suited for generating SSRC for the Himalayan Rivers [5]. The composition of the coarse, medium, and fine percentage of sediment in Koshi River, adoption of measurement methods in the past and the present, stated that in the past depth-averaged samplers were used but recently surface samples from the bank have been practiced [6]. Establishment of hydrographs, flow duration curve, and the study carried out on flood frequency analysis, flood magnitude, and discharge variability stating that 56% of discharge and sediment at Chatara are contributed by the western part of the Koshi basin and also mentioned that ~100 million tonnes of sediment are transported by Koshi at Chatara [7]. Analyzing and developing of discharge and suspended sediment relationship for dry seasons and wet seasons using regression analysis of Adji –Chai River Iran and also application of Buckingham  $\Pi$ -theorem for dimensional analysis to derive the equation of bed load [8]. An excellent rating curve could be developed from one hydrological sediment sampling program data [9]. The ANN model is computationally more intensive and SVM could be an efficient alternative for runoff and sediment yield

prediction [10]. Calculation of bed load, total dissolved solid, and denudation rate of two watersheds Aringad and Bansigad followed by development of rating curve [11]. The seasonal analysis showed a slight increase in discharge in pre-monsoon, monsoon, and winter but a slight decrease in post-monsoon in Roshi and there is no evidence of climate change causing a deficit in extreme flows that impact water sources of KVIWSP provided water infrastructure function properly [12]. Despite the adequate availability of surface water, several water resources projects have not yielded the expected output primarily due to sedimentation problems which were underestimated at the design stage in most of the hydropower of Nepal. Nepalese watersheds have generally been acknowledged to be the highest in the world and little reliable data on actual sediment production is available [13]. Malekhu Khola situated in the lesser Himalayas is sixth order stream with the mature stage of erosion having an eroding tendency, the concentration increases with the increase of discharge and watershed area, and the sediment is contributed due to increment in velocity, mining activities, and local tributaries [14]. The Artificial Neural Network was more satisfactory in predicting the daily suspended sediment rate and annual suspended sediment load compared to other models such as the multiple regression model, non-linear multiple regression model, general power model, log transform model in Kali Gandaki river basin, Himalaya, Nepal [15]. The larger sand particles of size 300–425 microns have a higher impact than sand particles of less than 90 microns in the erosion of the turbine [16]. The interaction of tectonics, monsoon seasonality, and strong relief provides an ideal environment for sediment in the Nepalese Himalayas. The suspended sediment concentrations vary systematically through seasons and asynchronously to river discharge displaying the hysteresis effect. All rivers showed similar erosion behavior in terms of the drainage area and sediment flux independent of location, size, and catchment characteristics. The erosion in the lesser Himalayas ranged from 0.2 to 2mm/yr. Nepal Himalayas have limited sediment

supply and the hill slope as a contributing source is transport limited [17]. The limestone quarry disproportionately contributes 2.1 Mgha-1 yr-1 suspended sediment load in the tropical Maracas- Saint Joseph River catchment and bed load is also contributed from the quarry [18]. The anthropogenic intervention accounted for 47 and 81% of the change in runoff and sediment load, respectively, with the balance attributed to climate variability in the Xichuwan River catchment in China [19]. And also discovered catchment's yearly discharge and sediment load have been dropping dramatically. Though optical and electronic sensors are standard nowadays mechanical devices are still in use [20]. Due to human interference such as landslides and road development, and hydrological extreme that includes changing precipitation patterns caused by climatic variability, contributed to the extreme sediment load that correlates significantly positively with successive 3-day precipitation in Nepal's Kali Gandaki river basin [21]. The parameters of the suspended-sediment rating curves obtained for the bias-corrected, transformed linear model by linear least squares are more precise than parameter estimates obtained for the non-linear model by either non-linear least squares or weighted non-linear least squares. Also, weighted non-linear least squares significantly improves the estimates of rating curve parameter and calculation of mean suspended sediment load in a non-linear model [22]. The Celone River transports 94% of total suspended materials during high flows and only 0.1% were transported during low flow conditions [23]. In the mountainous watershed, Faga'alu suspended sediment concentration downstream of the quarry was significantly higher in both storm and non-storm periods. Also, 10.1% of human-induced sub-watershed contributed 87% of SSYEV. The annual suspended sediment yield from human-disturbed watersheds is higher than undisturbed sub-watersheds like 1.1% quarry area of the total watershed contributed 36% of SSYEV [24]. The stage-separated power curve and the general power curve were most accurate for Bandon and Owanabue River, Ireland [25]. Among the four models, ANN, ANFIS, WANN, and conventional SRC the WANN model exhibited the most accurate one to estimate SSL and satisfactorily mimic the hydrological phenomenon in Flathead River and Santa Clara River USA [26]. Though the conventional suspended sediment power rating curve is a popular method for trend analysis, the study of the Yangtze River in China and the Eel River indicated discharge-normalized power equation is best suited [27]. The SRC regression coefficient varies with drainage area and basin slope but these parameter responses are remarkably different in different watersheds due to underlying surface characteristics like sediment availability, erodibility, and grain size distribution in Yellow River China [28].

It has been observed in the Roshi gauge station the concentration of suspended sediment downstream is lower than upstream. The lower value of suspended sediment concentration is due to clean water discharge from tributaries that reduced the concentration of the main river below the confluences. During fishing, local people make small local materials dams using stone

and boulders making small poundage and minimizing the sediment downstream. There are water mills in Roshi River these watermills divert the water by making local dams to run the mill. This local dam creates a small poundage that also reduces the sediment downstream.

## 4. Conclusion

A natural factor that contributes to suspended sediment in Roshi is rain erosion and flood. Anthropogenic activities constitute stone quarries and land uses. The land uses that contribute to sediment are agriculture and construction activities like road construction and river training works. The deposition of debris from stone quarries in the river banks contributes to sediment in the Roshi. The anthropogenic impact of quarry on sedimentation is significant in deteriorating river health. This study identified a quantitative relation between stone quarry activities and their impact on generation, production, and transport of sediment which is essential for formulating policies and programs for better sediment management. A long-term study of stone quarry impact on Roshi River with a comparison of before-after quality assessment is recommended to solidify the relation between anthropogenic activities and river sedimentation. The study will facilitate Panauti hydropower and the concerned authorities of Panauti to adopt various measures to control sediment discharge from stone quarries at Roshi for sustainable development of the Roshi watershed. Further monitoring and research studies on stone quarries in the Roshi watershed are required to understand better the anthropogenic impact of stone quarries due to sedimentation in the Roshi River.

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