SEDIMENT FLOW CHANGES INDUCED BY DAMS IN PAMBA RIVER

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ABSTRACT

The Pamaba River is the third longest river in Kerala after Periyar and Bharathappuza. The length of the river is 176 Km. The total catchment area of river basin is 2235 km².

The Pamba river and its tributaries have eleven dams which are constructed mainly for Hydroelectric projects and Water Supply and Irrigation projects such as “Sabarigiri”, “Kakkad”, “Maniyar”, and ”Pamba irrigation project”. Many of these dams are constructed in different periods. The dams have significant effects in the flow of sediments through the rivers. The effect of dams on sediment flow is studied by analyzing the sediment load data and discharge load data from three gauging stations such as Kaloppara, Thumpamon and Malakkara. These data are collected from Central Water Commission. The data during Monsoon season, for six months, from June to November is analysed from the beginning to till date. Yearly data from these three stations were also compared to study the variation of sediment load with discharge and the gradual change in sediment flow rate.

Keywords: Dam, Discharge Load, Pamba River, Run Off, Sediment Flow, Sediment Load.

1. INTRODUCTION

Sediment transport in rivers is associated with a wide variety of environmental and engineering issues. Effective management of sediment in rivers is becoming increasingly important from an economic, social and environmental perspective. Adverse impacts of increased sediment deposition can result in increased flooding and resulting property damage, contamination of water supplies, loss of crops, social dislocation and temporary homelessness, and even loss of life.

Natural river reaches are usually in a state of morphological equilibrium, where the sediment inflow on average balances the sediment outflow. Reservoirs can upset this equilibrium by slowing or halting the movement of water and allowing sediment to settle, thereby preventing the movement of sediment downstream. This is an important issue for many rivers around the world.

Soil erosion in the upstream river basins, its transport, and deposition play a major role in understanding many activities of global significance. The recent activities of man in changing river courses and construction of dams across natural rivers have significantly altered the sediment yield regime. In estuarine and coastal zones, which are major sinks of sediment, alteration of the natural sediment supply can cause considerable changes in ecosystem propagation.
Sediment transport from northern rivers is highly influenced by the SW monsoon, whereas both the southwest and northeast monsoons control the sediment yield of southern rivers. About 90 - 95 % of the sediment load is carried by the monsoon river flows and few particular days in monsoon supplies bulk of the annual sediment load transported by the rivers.

Pamba River is selected as the representative hydrologic regime for detailed studies about the sediment flow changes that is caused by the construction of dams.

2. PAMBA RIVER

Kerala is the land of rivers and backwaters. There are 44 rivers cut across Kerala with its innumerable tributaries and branches. The Pamba river is the third longest river in Kerala after Periyar and Bharathappuza.

Pamba originates at Pulachimalai hill in the Peerumedu plateau in the Western Ghats at an altitude of 1650 meters and flows through Ranni, Kozenchery, Thrivalla, Chenganoor, Kuttanadu, Karthikappally and Ambalappuzha Taluk and finally empties into the Vembanadu lake. The river shares its northern boundary with the Manimala river basin, while it shares the southern boundary with the Achankovil River basin. Pamba has many rivers combining it starting from Kakkiyar, Azhuthayar, Kakkatar and Kallar all its tributaries. The length of the river is 176 Km. The total catchment area of river basin is 2235 km\(^2\). The basin experiences good rainfall, moderate temperature and humid atmosphere. The SW and NE monsoon have great influence over the climatic condition. The normal daily temperature varies from 22.6\(^0\)C to 32.7\(^0\)C as per IMD. Average annual rainfall varies from 2276 mm to 4275 mm.

The Pamba is considered as the Dakshina Ganga (Southern Ganges) due to its association with Kerala’s Largest Pilgrim Centre - Sabarimala.

2.1. TRIBUTORIES OF PAMBA RIVER

The following are the tributaries of Pamba River.

1. Azuthayar.
2. Kakkiyar
3. Kakkatar
4. Kallar
5. Perunthenaruvi
6. Madatharuvi
7. Thanugattithodu
8. Kozithodu
9. Varattar

2.2. SALIENT FEATURES OF PAMBA RIVER

Location: Latitude: 09\(^0\)-24’. Longitude: 77\(^0\)-10’E

Basin Area: 2235 km\(^2\). Length of main stream: 176 Km

Origin of river: Pullichimala

Average annual rainfall: 3600mm

2.3. DAM

A dam is a hydraulic structure constructed across a river to store water on the upstream side. It is an impervious or fairly impervious barrier put across a natural stream so that the reservoir is formed. Due to the construction of dams water level in the river at its up-stream side is very much increased and a large area may be submerged depending up on the water spread of the reservoir so formed.

2.4. DAMS IN PAMBA RIVER

Kakki dam, Anathodu dam, Pamba dam, Gavi dam, Kallar dam, Mooziyar dam, Upper mooziyar dam, Meenar 1, Meenar 2, Veluthodu (Kakkad) dam, Maniyar dam.
3. SEDIMENTS

Sediment is defined as fragmented material formed by physical and chemical weathering of rocks. Sediment (sometimes called “silt” or “alluvium”) is comprised of solid particles of mineral and organic material that are transported by water. In river systems the amount of sediment transported is controlled by both the transport capacity of the flow and the supply of sediment.

Sediment transport study includes movement of huge boulders down mountain sides, to diffusion of colloid-sized material in groundwater systems. Transport is driven by gravity, and drag forces between the sediment and surrounding fluid (air or water).

3.1. CLASSIFICATION OF SEDIMENTS

Sediment can be classified as 1. Deposited sediments, 2. Suspended sediments.

Deposited sediment is that found on the bed of a river or lake. The “suspended sediment load” refers to the fine sediment that is carried in suspension and this can comprise material picked up from the bed of the river (suspended bed material) and material washed into the river from the surrounding land (wash load). The wash load is usually finer than the suspended bed material. In contrast, the “bed load” comprises larger sediment particles that are transported on the bed of the river by rolling, sliding or saltation.

Suspended sediment is found in the water column where it is being transported by water movements. Most rivers will transport sediment in each of these “load” forms, according to the flow conditions. Suspended sediment is also referred to as suspended matter, particulate matter or suspended solids. Generally, the term suspended solids refers to mineral + organic solids, whereas suspended sediment should be restricted to the mineral fraction of the suspended solids load.

3.2. TYPES OF SEDIMENT TRANSPORT

Sediment transport is a direct function of water movement. During transport in a water body, sediment particles become separated into three categories:

3.2.1. (1) Suspended material

Suspended materials include silt + clay + sand; the coarser, relatively inactive bedload and the saltation load. Suspended load comprises sand + silt + clay-sized particles that are held in suspension because of the turbulence of the water.

The suspended load is further divided into the wash load.

Wash load is generally considered to be the silt + clay-sized material (< 62 µm in particle diameter) and is often referred to as “fine-grained sediment”. The wash load is mainly controlled by the supply of this material (usually by means of erosion) to the river.

The amount of sand (>62 µm in particle size) in the suspended load is directly proportional to the turbulence and mainly originates from erosion of the bed and banks of the river. In many rivers, suspended sediment (i.e. the mineral fraction) forms most of the transported load.
3.2.2. (2) Bed load

Bed load is stony material, such as gravel and cobbles that moves by rolling along the bed of a river because it is too heavy to be lifted into suspension by the current of the river. Bed load is especially important during periods of extremely high discharge and in landscapes of large topographical relief, where the river gradient is steep (such as in mountains). It is rarely important in low-lying areas.

Measurement of bed load is extremely difficult. Most bed load movement occurs during periods of high discharge on steep gradients when the water level is high and the flow is extremely turbulent. Such conditions also cause problems when making field measurements.

3.2.3. (3) Saltation load

Saltation load is a term used by sedimentologists to describe material that is transitional between bedload and suspended load. Saltation means “bouncing” and refers to particles that are light enough to be picked off the river bed by turbulence but too heavy to remain in suspension and, therefore, sink back to the river bed. Saltation load is never measured in operational hydrology.

4. FACTORS AFFECTING RIVER’S VELOCITY

A river’s velocity refers to the speed at which a river moves water through its channel. The velocity of a river is determined by many factors, including the shape of its channel, the gradient of the slope that the river moves along, the volume of water that the river carries and the amount of friction caused by rough edges within the riverbed.

4.1. CHANNEL SHAPE

The shape of the channel affects the velocity of a river. Around the perimeter of the river, at the sides and along the river bed friction is created as water flows against the edges. Water flowing through a wide, deep river channel encounters less resistance than water flowing in a narrow, shallow channel, since a smaller proportion of the total water molecules will be slowed by the river's edges. The center of the river experiences the greatest velocity.

4.2. VOLUME

The volume of water that flows through a river within a given amount of time -- also known as the discharge -- also affects its velocity. As the volume of water in a river increases, through smaller streams flowing into it, for example, the velocity of the river increases. An increase in water volume can also affect a river's velocity in the long term; this is because the increasing mass of water is capable of causing more erosion, resulting in a wider, deeper river channel that allows water to flow more freely.

4.3. SMOOTH AND ROUGH CHANNEL

Rough river channels are those which contain a large quantity of rocks, pebbles and boulders, either at the bottom of the river or embedded within its sides. A great deal of friction is created between water molecules and these stones as the river flows past them; in rough channels, the resistance caused by this friction reduces the river's velocity. In a smooth river channel, with fewer pebbles and rocks, velocity is higher as there is less friction causing energy to be expended as it flows.

4.4. GRADIENT

The gradient of a river refers to how steep its slope is; this also has a significant effect on the velocity of a river. When a river flows down a steep slope, the gravitational force that pulls the water downwards is stronger than it would be on water flowing down a gentle slope, resulting in the river having a greater level of velocity. The velocity of the flowing waters of a nearby river depends on local rainfall amounts and elevation. Scientists and engineers define velocity as how fast an object's position changes as time passes. An object moving in a straight line, in a river for example, has velocity equal to the distance it moves divided by the time of travel of that object. A common unit for velocity is feet per second. By using a few tools we can calculate the velocity of a river.

5. RAINFALL IN KERALA

The major rainfall season in Kerala is from June to October (Monsoon Period).

The Kerala State, situated in the humid tropics lies between 8° 18’ and 12° 48’ N and 74° 52’ and 77° 22’ E. Based on the topography, the state can be divided into three well-defined natural landforms: the lowlands with altitude less than 7.5 m; midlands with altitude between 7.5 and 75m; and the highlands with altitudes greater than 75 m. The state is a narrow strip of land with width varying from 30 km in the north and south to about 130 km in the central region. The Western Ghats forms a continuous mountain wall on the eastern border of the state while Arabian Sea is the margin to west.
5.1. MONSOON PERIOD (JUNE TO OCTOBER)
A major part of India (excluding Jammu and Kashmir and South Eastern parts) gets more than 75% of rainfall due to monsoon winds which originate in the Indian Ocean and proceed to the sub continent. The monsoon wind advancing from south – western direction breaks up into two distinct branches.

Bay of Bengal branch, Arabian Sea branch.

The Arabian Sea branch touches Kerala while the Bay of Bengal branch reaches the North – Eastern states of India.

The average annual rainfall for the State is about 3000 mm. It ranges in the lowland, from 900 mm in the south to 3500 mm in the north; in the midland, from 1400 mm to 4000 mm; and in the highland, from 2500 mm to 6000 mm (CWRDM, 1995). About 65% of this rainfall is received during the southwest (SW) monsoon and 25% during northeast (NE) monsoon. However, for the southern parts, NE monsoon is active compared to the northern Kerala.

6. INFILTRATION

Infiltration may be defined as the downward movement of water from soil surface into the soil mass. When rainwater falls on the ground, a small part of it is initially absorbed by the top thin layer of soil so as to replenish the soil – moisture deficiency, and thereafter, excess water infiltrates downwards to join ground water. So infiltration is the entry of water into the soil through soil surface. Once water enters into the soil, the process of transmission of water into the soil, known as percolation takes place thus removing the water from near the surface to down below.

6.1. FACTORS AFFECTING INFILTRATION

1. Condition of entry surface: Vegetation cover versus bare land
2. Permeability/Percolation characteristics of soil formation
3. Temperature.
4. Intensity and duration of rain fall
5. Movement of men and animals.
6. Change due to human activity
7. Quality of water
8. Presence of ground water table

7. RUN – OFF

The term “run – off “ is used for water that is on the “run” or in a flowing state in contrast to the water held in depression storage and water evaporated in the atmosphere. The run off of a catchment area in any specified period is the total quantity of water draining into the stream or into a reservoir in that period. This can be expressed as in centimeters of water over a catchment or the total water in cubic meters or Hectare – meter for a given catchment. Run-off is broadly classified into three types. They are

1. Surface run-off
2. Sub surface run-off
3. Base flow.

8. DAM CONSTRUCTION

The construction of dams and other hydraulic structures is one of the oldest branches of engineering. Dams and diversions are constructed and operated for a wide variety of purposes including residential, commercial, and agricultural water supply; flood and/or debris control; and hydroelectricity production. Regardless of their purpose, all dams trap sediment to some degree and most alter the flood peaks and seasonal distribution of flows, thereby profoundly changing the character and functioning of rivers. By changing flow regime and sediment load, dams can produce adjustments in alluvial channels, the nature of which depends upon the characteristics of the original and altered flow regimes and sediment loads.

9. ANALYSIS

The Discharge data and sediment load data from three gauging station of Central Water commission were analyzed. The gauging stations are Kalloppara, Malakkara and Thumpamon. Out of these three, Kalloppara is the gauging station nearer to Vembanadu lake. Then comes Malakkara and Thumpamon.
The data from Kallooppara gauging station were analyzed first. Starting from the year 1986 for Monsoon season i.e. from June to November, the data were considered up to 2010. At first the data for each month in monsoon season for the year 1986 were analyzed. It was found that the sediment load is more in June as the discharge increase. But the sediment load was decreased for the month of August even though the discharge is more than in June. The reason is that as the rain fall decreases the surface run off from the catchment area of river will decrease. But there will be base flow which is the water that percolates down through the surface soil. The base flow will be free of sediment.

After Kallooppara the data from Malakkara gauging station were analysed. The cases were very similar to Kallooppara. In June 1986 for a discharge of 300 cumecs the sediment load in the year 1986 for the month of June was 0.045tons/m³. In August it became 0.035tons/m³. Again it increased in September to a value of 0.065tons/m³ then in November it became 0.03tons/m³. These values were almost same up to the year 1992. But for the year 2010 it became 0.03 tons/m³. We can see that the quantity of sediment decreased as the years passed.

But during the month of October there will be heavy rainfall which will again increase the surface runoff and hence increase of sediment load. Then gradually the discharge and sediment load decreases as the rainfall intensity decreases.

This is the general flow condition up to the year 2010. But the main change noted was that, there is considerable decrease in sediment load. The rate of decrease of sediment load is more when the data analysed at an interval of four years. i.e. after considering the data in 1992 the data checked for the year 1996. Then the change in sediment load was considerable.

For example, for a discharge value of 300 cumec the sediment load in the year 1986 for the month of June was 0.045tons/m³. In August it became 0.035tons/m³. Again it increased in September to a value of 0.065tons/m³ then in November it became 0.03tons/m³. These values were almost same up to the year 1992. But for the year 2010 it became 0.03 tons/m³. We can see that the quantity of sediment decreased as the years passed.

The analysis of data from Thumpamon gauging station also gave the same result. The sediment load is gradually decreasing. This is mainly due to the effect of dams.
But we can find that as the river crosses Kallooppara gauging station the sediment load is increasing than at Malakkara and Thumpamon. The reason is that for any river there will be catchment area. The water reaching to the river from the catchment area through small streams. The runoff from the catchment area will catch the loose soil particles as sediment.

10. CONCLUSION

The effect of dams on sediment flow through rivers were studied by selecting Pamba river, using the discharge data and sediment load data which were collected from three gauging stations namely Kallooppara, Thumpamon, and Malakkara of Central Water commission.

This project verified how the quantity is varying after the construction of dams in this river. Considering the year of starting of construction of dams in this river and in its tributaries, and also the year of completion of these dams the sediment load data and discharge data were analysed graphically.

Starting from the year 1986 to 2010 the data were analyzed for the monsoon season (From June to November). It was found that during the month of June the sediment load and discharge were more, but for the month of August discharge was more but there was decrease in sediment load. The reason is that in August the rainfall intensity will be less, so the surface run off will be less hence the sediment flow will be less. But there will be base flow which will increase the discharge rate. Usually base flow will be free of sediments.

Again there was increase in discharge load as the intensity of rainfall increased hence there was increase in sediment load also. During the month of November both discharge and sediment load were decreasing.

This is the general condition of flow. But it was found that the sediment load quantity is gradually decreasing as years pass. When the data analyses for the year of 2010, there was about 50% reduction in sediment load than for the year of 1986. This is mainly due to the effect of dams in this river and in its tributaries.

Out of the three gauging stations of Central Water Commission, the first one is Thumpamon. Then comes Malakkara, and Kallooppara is nearer to Vembanadu lake. On analyzing the data graphically it was found that even though there was decrease in sediment load quantity with years the sediment load is increasing when the flow reaching Kallooppara gauging station. This shows that from the catchment area in that region the sediment load is more with runoff. This may be due to the soil conditions, topography of that location, construction activities etc. In Thumpamon more than 50% area is covered by forest. So the sediment load quantity will be less. Almost similar condition was observed at Malakkara also. But the sediment load is more at Kallooppara. In this condition also we can observe that there is reduction in sediment load quantity. This is mainly due to the effect of dams. Since there was a change in sediment load observed at Kallooppara there is scope of further study that what the causes of increasing sediment load there are and even though there is increase in sediment load a common reduction can be observed. It also arising the need of further experimental study during monsoon season in the catchment area.

11. REFERENCES

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