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Investigation of Flushing Phenomena in a Reservoir

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Abstract— Sediments eroded from the catchment area plays key role in diminution of reservoir efficiency and overall performance. Sediment concentration depends upon many factors i.e. topography of catchment area, vegetation cover intensity of rainfall and duration of rainfall etc. Most reservoirs in the world have lost their major storage capacity due to sediment deposition and inadequate flushing phenomena. Sediments can be removed by flushing process. In order to observe the flushing phenomena and its characteristics experiments have been performed on a one dimensional model located in Hydraulic laboratory of Civil Engineering Department, University of Engineering & Technology Taxila. Sluice gate having circular opening was installed at the bottom of the dam model. Sand having 1200 kg/m^3 density and 0.75mm mean size diameters was used as sediment. Chanel having dimensions (20m x 1m x 0.75m) was modified as a reservoir model. Experimental results indicated that the rate of sediment flushing is dependent on the discharge, flushing channel width and water surface profile.

Index Terms— sediment concentration; flushing; modeling; experiments; Sluice gate; water surface profile;reservoir model;discharge

1 Introduction

IMpounding of inflow from upstream catchment areas of the reservoir carries sediments. finer sediment are carried out by the flow in suspension are called as suspended particles while heavier sediments travel on bed known as bed load. In reservoir generally water has lesser velocity and turbulence which intimately results in deposition of heavier sediments along the bed. Longer time is required by the suspended particles to settle down in the reservoir bed. Sediments establish delta formation after entering into the reservoir. The gradient of sediment bed profile gradually changes and is a function of particle size and its characteristics. River sedimentations have bad impacts on the very useful functions of reservoir; as a result huge economic loss arises. Reservoir efficiency worldwide has been reduced because due to loss in storage capacity the power generation, water usage for water supply and irrigation has been affected. Deposition of sediments near power intakes produces wear and tear of turbine due to their momentum may cause huge financial losses. Deposited sediment in reservoir may cause high risk to the stability of dam (Hal crow Report 2001). Deposition of sediments in reservoirs depends upon many factors i.e. nature of upstream catchment area, flow characteristics, seismic activity, and urbanization etc. catchment characteristics also contributes effectively in deposition of sediment. For medium size reservoirs situated in hilly areas sediment will reach more rapidly in reservoirs which are located in hilly areas due to steep slope of the river bed and fine sediment size (Zhang et al. 1976). Better management of existing reservoir is very important as it is very expanses to construct the new reservoir due to its higher economical and financial aspects. Building new reservoir takes usually took much time period and due to huge environmental losses, it is not advisable to build huge reservoir in order to reduce the storage loss due to depositions of sediments in the reservoir. Major reservoirs in the world have lost their storage capacity annually drastically due to sediment depositions.

So need of the hour is to adopt a feasible mechanism for removal of these deposited sediments. Approximately loss of 1% storage capacity is being observed annually due to concentration of deposited sediment. (Yoon.1992 and Mahmood .1987).

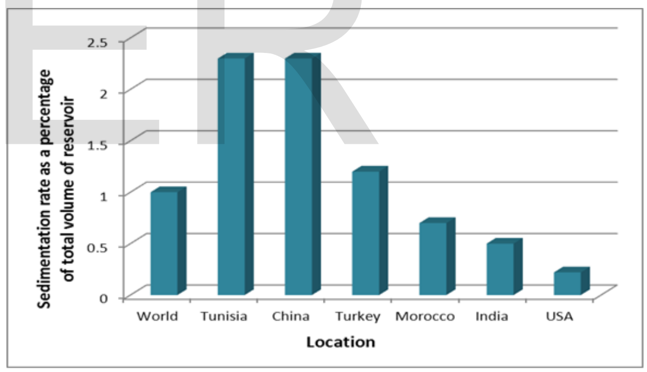

Fig.1 (Janssen .1999) worldwide deposition of sedimentation

Major reservoirs of Pakistan i.e. Tarbela and Mangla have lost up to 28.23% and 20.54% of gross storage capacity respectively (Hydrographic survey, WAPDA 2005). Different methods are used for controlling the sediment depositions in reservoirs. Watershed management (by providing vegetation and check dams) is very useful technique in controlling the sediment depositions in the reservoir. Dredging and excavation is a mechanical method adopted for sediment removal but it is not preferable due to its high cost. Now a days removal of deposited sediment is carried out by hydraulic method know as flushing. Flushing technique is in practice since many decades. Flushing is very effective method for the removal of sediment deposited in the narrow reservoir. Flushing is basically the removal of sediments from reservoirs by using low level outlets.

Brandt [1] highlighted that flushing is carried out to remove

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sediments by eroding them while sluicing is carried out to remove arriving sediments towards reservoir not considering the conditions of drawdown. Lai and Shen (1996) has described two types of flushing

a) Use of high flows to flush the sediment deposited in the reservoir

b) Allow higher sediment concentrated flow during floods

2 Experimental Methodology

A rectangular channel made of concrete having dimensions (20m x 1m x 0.75m) located in hydraulic laboratory Department of Civil Engineering U.E.T Taxila was adjusted to model a reservoir. A dam model is constructed in the middle of the concrete flume using 4.75mm thick plastic sheet. A sluice gate having circular opening composing of 0.065 m radius was constructed. Initially marble pieces were used as sediment but due to lesser velocity flushing process couldn't be successful. Keeping in mind the velocity limitations sand having specific weight of 1200 kg/m³ and mean diameter of 0.75 mm was used as sediment. Sediments were paved up to 2.4m length from the dam having 4inch height. Sediments were paved by using T shaped device. The discharge was controlled by the regulation of valve installed just before the initial silting basin. A notch was constructed in the down stream silting basin to prevent the back water effect.

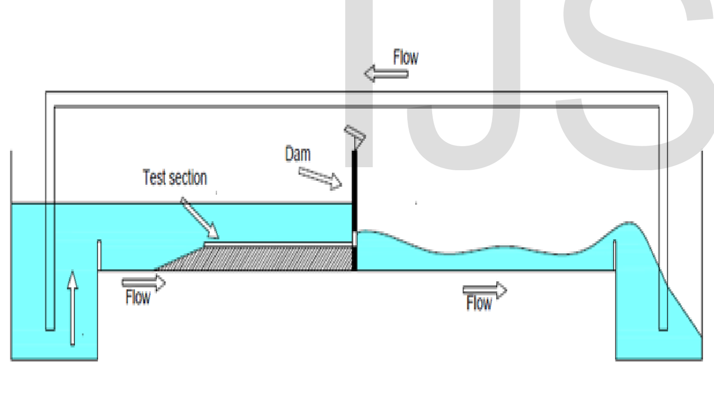

Fig. 1.a (Cross section of Experimental model)

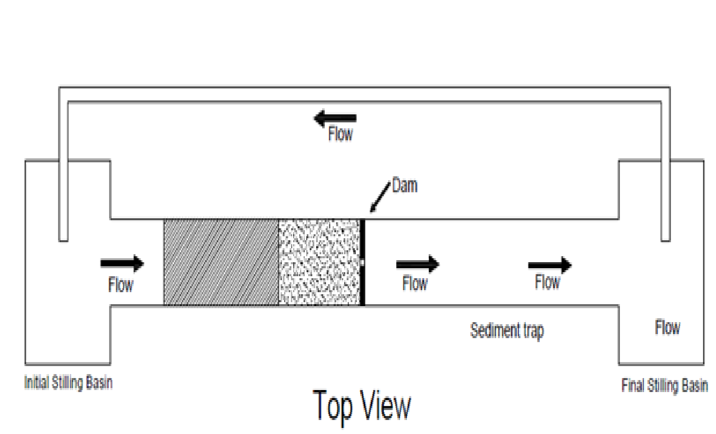

Fig. 1.b (Top view of Experimental model)

The dead storage 0.16 m deep was constructed by using the coarse aggregate to control the submergence at the d/s face the dam section which is built at the center of rectangular channel. The wall of final silting basin was removed to prevent the back water effect. Flushed sediment were calculated by using analytical method, upstream side of the reservoir was divided into grids having dimension (1'x 1'). Sediment bed profile was generated by using the data obtained by these grids.

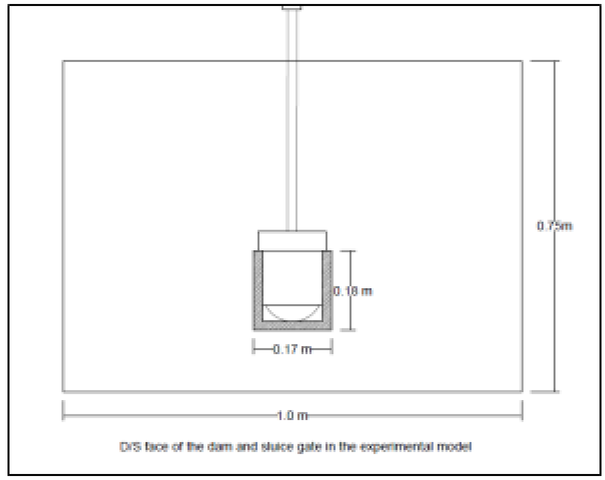

Fig. 2.a (View of sluice gate from downstream)

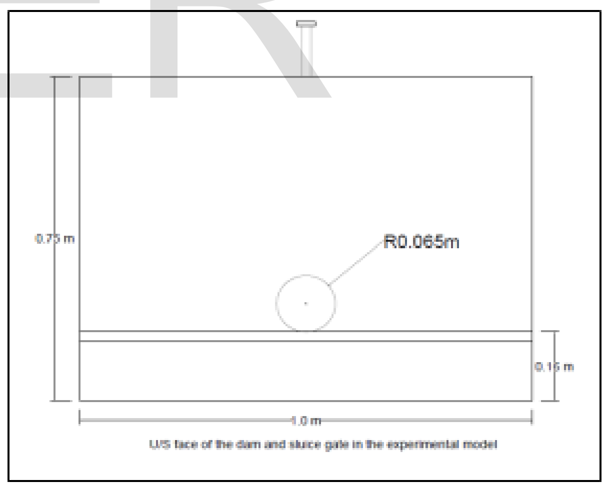

Fig. 2.b (View of sluice gate from Upstream)

Summary of Experimental Data							
Flow	Inflow discharge (m3/s)	Exp.No.	Radius of circular gate opening(m)	Initial deposit depth of sediment (m)	Length of sediment section (m)	Initial bed slope(%)	Running time(min)
1	0.014	1,2,3,	0.065	0.06	2.4	0	75
2	0.01	4,5,6	0.065	0.06	2.4	0	75

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3 Results and Discussions

Experiments have been performed and a clear pattern of sediments flushing was observed. Initially the circular gate outlet was opened at moderate manually. Gauges were used to measure water depth at the upstream end of the reservoir. Initially the flushed sediments were deposited along the wall of the channel then gradually a bullet type pattern was observed at a distance of 24ft from the dam outlet opening. It was observed during experiments that the position of these sediment patterns is dependent on outflow discharge, nature of sediment type and flushing duration.

Fig. 3.a (D/S Sediment pattern formed at a distance of 24 feet from dam)

Fig. 3.b (Layout Plan of D/S Sediment pattern formed at a distance of 24 feet from dam)

The trapezoidal shape was attained during flushing because of sediment scouring, initially no specific pattern was observed at the upstream face of the dam during flushing but later on trapezoidal pattern was observed. The downstream pattern of the flushed sediments are plotted and is highlighted in the figure 3.a.

Downstream sediments pattern is dependent upon the width of the channel and its geometry. Upstream sediment section was divided into grids and then sediment bed profile was plotted by using the measured values obtained from grids. By using these grids the flushed sediments are calculated.

Total flushing duration for all experiments were around 75 min. sediment were eroded very effectively as shown in Figures 4.a & 4.b. sediment bed profile was generated by using these analytical grid system adopted.

Fig. 4.a U/S sediment profile after Flushing Grid No.1 and 2

Fig. 4.b U/S Sediment profile after Flushing Grid no.3, 4, 5, and 6

Two inflows were used for simulation. During 1st flow a clear pattern were started to bluid at a distance of approx 17 feet from the face of the dam, the clear pattern of eroded sediment were appeared during first 10-15 min and enhanced gradually. Lesser amount of sediments was eroded as compared to 2nd flow having higher values of discharge then initial flow.

It was observed that during the 2nd flow the sediment pattern at the downstream end of the reservoir appeared earlier then 1st flow. But these patterns were appeared at larger distance i.e. 24 feet from the face of the reservoir.

Flushed sediment is the function of outflow sediment discharge and flushing duration, a graph is plotted between the flushing duration, water depth at the upstream face of the dam and sediment outflow discharge and highlighted in figure 5.a & 5.b.

It was observed during experiments that initially lesser amount of sediment were flushed. The amount of flushed sed-

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iments were increased gradually. Time, taken by each experimental run was around 70 min.

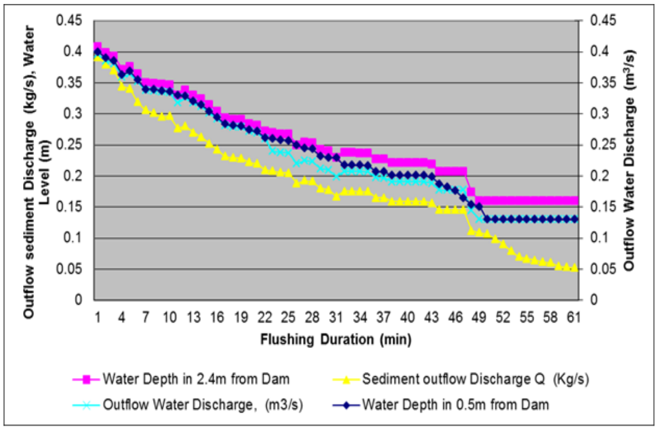

Figure 5.a Relationsship of flushing duration, outflow sediment Discharge (Kg/s) and outflow water Discharge (when inflow Q= 0.010 m^3/s)

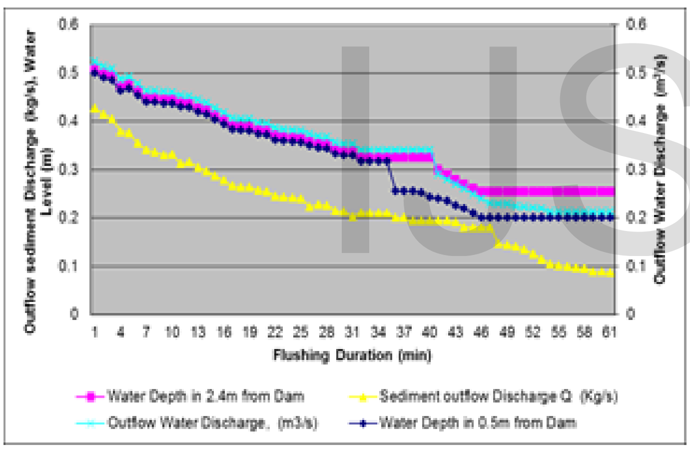

Figure 5.b Relationsship of flushing duration, outflow sediment Discharge (Kg/s) and outflow water Discharge (when inflow Q= 0.014 m^3/s)

4 Conclusion and Recommendations

During experiments it was found that the flushed sediments are related with discharge, flushing duration, sediment characteristics, flow pattern, and flushing width. It is recommended that the experimental study in detail should be conducted to observe the flushing pattern of reservoirs located at the same river. Environmental impact of flushed sediments on downstream species of living organism should also be studied in detail.

It was found during experiments that during initial 10-15 min of the flushing operation cumulative flushed volume of sediments was approx. forty percent and it enhance gradually. Higher amount of sediments were eroded during 2nd flow as it has higher value of discharge and lesser time is taken by the sediment to flush.

The process of flushing observed during experiment was well in line with the literature. Bullets shaped of the deposited sediment were also observed.

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