Prediction of Sedimentation Pattern in Run-of-the-River Projects using HECRAS Model

Ravi Raj[1]

[1]Affiliation not available

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Ravi Raj[1], Neena Isaac[2], Pratibha Warwade[3]

[1]Indian Institute of Technology Delhi, India

[2]Central Water and Power Research Station Pune, India

[3]Central University of Jharkhand Ranchi, India

E-mail cez198244@civil.iitd.ac.in

Introduction

Hydropower is one of the cheapest and preferred sources of electric generation (Chaudhary et al., 2019). East and North-East India are fully dependent on hydroelectric power projects for power supply. These projects are termed as run-of-the-river projects as in these schemes, power is generated from the force of water flowing due to relatively higher change in elevation of a stream. The rivers in these regions suffer a very common problem of sedimentation (Isaac and Eldho, 2019, 2016). These rivers carry an enormous amount of sediment load, which could lead to non-functionality of the reservoirs within a few years of operation. So, it is necessary to figure out proper sediment management schemes for optimal use of the reservoir (Boyd and Gibson, 2016). In this study, a typical Himalayan River reach was selected and modelled in HEC-RAS (Hydrologic Engineering Center - River Engineering System) version 5.0.3 to study long term sedimentation pattern and to identify the worst condition sedimentation profile so that a proper sediment management plan could be introduced to increase the life of such reservoirs.

Materials and Methods

A typical Himalayan reach of 5.4 Km length had been selected as run-of-the-river project in this research. The study area was a part of preliminary research of a bilateral international hydro-power project between India and Nepal on Arun-III river conducted in CWPRS, Pune. The project complex consists of 59 m high concrete gravity dam with 6 numbers of sluice spillways with crest at 808 m elevation, and one overflow spillway with crest at 840 m elevation from mean sea level. The storage capacity of the reservoir is 13.94 and 8.29 Mm3 at FRL (Full reservoir level) and MDDL (Minimum draw down level) respectively.1D (one dimensional) mathematical model in HEC-RAS was set up to simulate the sedimentation analysis. The datasets required were a) Topographic data in the form of cross-sections b) Hydraulic data in the form of hydrograph and water levels and c) Sediment data in the form of load inflow as well as gradation curves. All the datasets were provided by CWPRS (Central Water and Power Research Station) Pune, India. The flow and sediment load data were available for 2009-2012 for this study. To get the worst condition sediment profile flow data were processed in two ways. So, monsoon flow data was used as yearly flow data in numerical modelling as 98% of total load comes in monsoon (May-Oct) only. Sediment rating curves were developed for May 2009 - April 2012 period as well as for the critical year (2010) with 0.69 and 0.72 coefficient of

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correlation (R2 value). Suspended load was increased to 120% to account for bed load, and gradation curve was also prepared to simulate quasi-unsteady flow in HEC-RAS.

Results and Discussion

A steady flow simulation was done with a set of three 'n' (Manning's roughness coefficient) values (0.040, 0.045 and 0.048) to set up the 1D model for further processing. In this analysis it was observed that the simulated water level was matching with greater accuracy with observed water levels for 'n' value equal to 0.045. Out of eight sediment transport equations, Ackers-White equation was selected for this study because it predicted sediment load with greater accuracy (84%) when compared with the observed load. In the first simulation for sediment load prediction two sets of flow and sediment loads were incorporated. In the first set, 10 years (2010-2019) of critical flow hydrograph with four years (2009-2012) sediment rating curve; and in the second set, 12 years (2010-2021) flow hydrograph with four years (2009-2012) sediment rating curve had been processed. Both the simulations were performed at MDDL level as these computations were performed for monsoon seasons. The output of these two simulations were shown in Figure 1 and Figure 2 respectively.

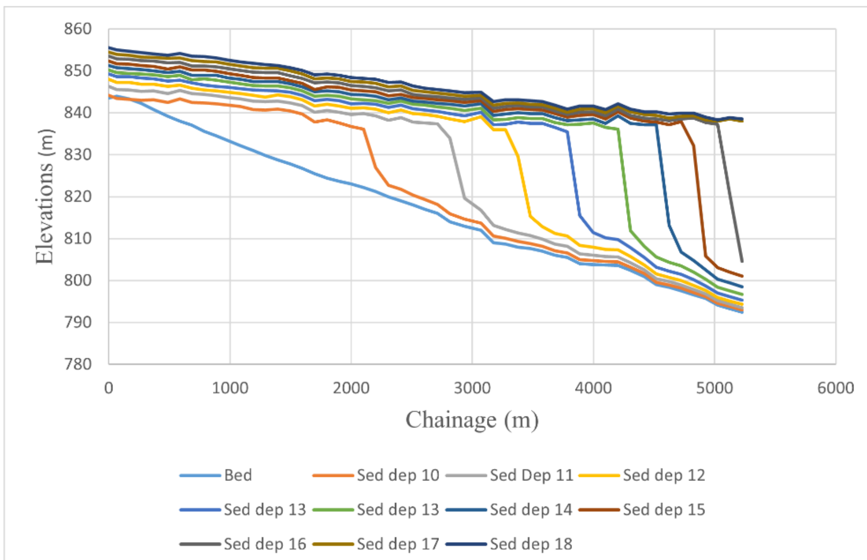

Figure 1. Simulated sediment pattern for critical flow condition

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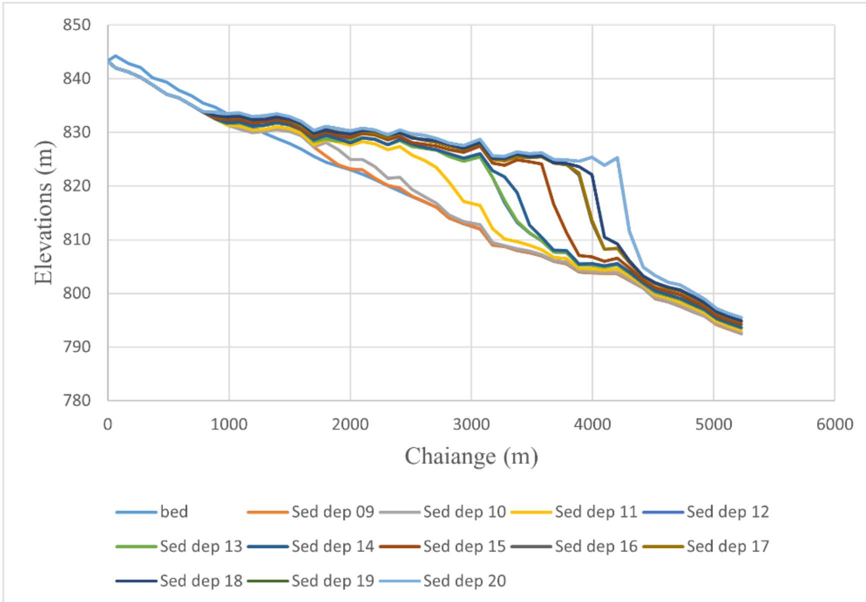

Figure 2. Simulated sediment pattern for normal flow condition

The chainage distance of the river reach was plotted on x-axis and bed elevation with each simulation was plotted on y-axis. Analyzing these two plots Figure 1 and Figure 2, the reservoir got stabilized when the reservoir was operated for 10 years with critical flow condition at MDDL. The worst condition sedimentation profile estimated using numerical model could be used to perform flushing analysis for optimal use of reservoir performances. This could be done using different combination of flushing durations and discharges to get the best possible way for flushing in physical modelling by constructing prototypes of the river steams.

Conclusions

- The deltaic pattern of sediment deposition was observed in the upstream reaches of the reservoir. The advancement of delta deposition towards the dam axis was observed to be at very low rate when the reservoir operation was performed at MDDL.
- In eight years of reservoir operation, sediment deposition level touched the crest level (808 m elevation) and in nine years stabilized at an elevation of 828 m.
- The worst condition sedimentation profile could be used to perform flushing analysis for optimal use of reservoir performances.

Acknowledgement

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