NUMERICAL MODELING OF SEDIMENT DEPOSITION IN HEADWATER RESERVOIRS

by

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Dedicated to

my Father

Late Sh. S. L. Vaidya

CERTIFICATE

This is to certify that the thesis entitled **NUMERICAL MODELING OF SEDIMENT DEPOSITION IN HEADWATER RESERVOIRS** submitted by Ms. Poonam Binjolkar to the Indian Institute of Technology Delhi for the award of Doctor of Philosophy in Department of Civil Engineering, is a record of bonafide research work carried out by her under my supervision and guidance.

The thesis work in my opinion has reached the requisite standard, fulfilling the requirements for the said degree. The results contained in this thesis have not been submitted, in part or full, to any other university or Institute for the award of any degree or diploma.

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ABSTRACT

The accurate assessment of sedimentation is essential to ascertain the viability of a river basin project as incorrect assessment of the rate of sedimentation and deposition pattern within the reservoirs may undermine the very existence of the dam/reservoir. Geomorphological parameters of the reservoir catchment, flow conditions and reservoir regulation influence the deposition of sediments within the reservoirs. A methodology consisting of determination of geomorphological parameters using GIS, a hydrological water balance model for determining water levels on 10-daily and monthly basis in a reservoir, a 2-D hydrodynamic model for flow investigation and a 2-D sediment transport model for investigating sediment deposition pattern within reservoirs is presented for qualitative and quantitative assessment of reservoir sedimentation. The hydrodynamic model incorporates the effect of turbidity currents and plunging phenomenon. The sediment transport model consists of two sub models, namely, suspended sediment transport and bed load transport models, and accounts for the cohesiveness character of sediment and the change in bed profile. Solutions were obtained numerically using the MacCormack two step predictor corrector scheme for the hydrodynamic model and the upwind scheme for the suspended sediment transport model. The capability of these models have been demonstrated with the application of developed models to the Tilaiya and the Tenughat reservoirs, the headwater reservoirs of the Damodar river basin. Results reveal good agreement for sediment deposition within the reservoirs generally having R^2 value of 0.9 and above for the sediment bed level in case of both the reservoirs.

The analysis of various geomorphological parameters namely, length, area, perimeter, drainage density, drainage frequency, basin circularity, basin elongation, relief, ruggedness number, Shape index, Gravelius index using GIS for the Tilaiya and

the Tenughat reservoir catchments reveals that the Tilaiya catchment is elongated drainage basin with low drainage density, whereas the Tenughat catchment is comparatively less elongated with low basin elongation and higher circulation. It appears that there is some influence of geological structures in its lower reaches. The upper reaches covering low order streams with comparatively low bifurcation ratio appear to be rocky and less susceptible to erosion. The error associated with the values obtained for various geomorphological parameters is restricted up to 5%.

The hydrodynamic model provides various flow parameters such as the flow field and the depth as input to the sediment transport model. The model was calibrated by adjusting the Manning's roughness coefficient. The changes in bottom roughness due to cohesive and noncohesive sediments were accounted for by varying the roughness coefficient in different zones of the reservoir. Model results agree closely with the observed values of water level. The hydrological mass balance model was utilized for obtaining 10-daily and monthly water level variations. These water levels were used in hydrodynamic model for calibrating model parameter and as an input to the suspended sediment transport model.

The sediment transport model comprising suspended sediment transport and bed load transport models, yields reliable results in predicting the sediment transport and bed level changes across the reservoir bed. The study demonstrates that the sediment deposition in reservoirs significantly depend on the hydraulic conditions in the reservoir and flow variables. The incoming sediment load, both suspended and bedload, cohesiveness of sediment particles and settling velocity of suspended sediments influence sediment deposition in reservoirs significantly. The two different approaches adopted for settling velocities clearly demonstrates that the sediment deposition of cohesive sediments is well defined using median floc diameter approach as compared to the one based on particle size diameter. Further, spatial variation of critical shear stress is also established. The wide variation in eddy diffusivity has been observed to result in negligible variations in the bed profiles across the reservoir cross sections.

In case of cohesive sediments, the settling velocities though negligibly small, are found to increase with the concentration of cohesive sediments. The settling velocity increases with the concentration of cohesive sediments resulting in comparatively more deposition of these sediments. In case of Tilaiya reservoir, the sediment concentration being very less, the settling velocities of cohesive particles are very small, and thus has resulted in low deposition of these sediments.

Formation of turbidity currents have also been investigated and is has been found that no turbidity currents are formed in any of the two study reservoirs. However, some indication of development of such currents at maximum water level in Tilaiya reservoir with negligibly small sediment concentration establishes the fact that the turbidity currents are not generated only in those reservoirs which are on heavily sediment laden rivers, but also in reservoirs on rivers with low sediment condition. The main reason of non formation of the turbidity currents in these reservoirs may however, be attributed to the water level or the depth of flow and hence the topography of the reservoir.

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