Investigation of Climate Change Impact on Reservoir Capacity and Water Supply Reliability

Jianchun Victor Huang, Ph.D., P.E., Paula W. Makar, M.S., P.E.
Hydraulic Engineers, Sedimentation and River Hydraulics Group, 86-68240

Summary

This study assesses the impacts of projected climate changes on flow and sediment loads into reservoirs. This is a joint research between the Bureau of Reclamation (Reclamation) and the United States Army Corps of Engineers (USACE). Reclamation selected Bighorn Lake in MT and WY and Elephant Butte Reservoir in NM. USACE selected Garrison Reservoir in ND and Cochiti Reservoir in NM.

Based upon climate change simulations, the expected changes in mean annual temperature (°C) and precipitation (%) in the two basins are slightly different. Compared with the historical data from 1940 to 1999, annual temperature in the Rio Grande Basin will increase by 2.5°C and 4.3°C in the near future (2010-2039) and far future (2040-2069), respectively; and annual precipitation will decrease by 1.9% and 3.1%; respectively. In the Missouri Basin, annual temperature will increase by 2.3°C and 3.4°C in the near and far futures; respectively, and annual precipitation will increase by 3.0% and 4.1%; respectively.

A total of 112 projections were divided into five categories: q1 (wetter, more warming), q2 (wetter, less warming), q3 (drier, more warming), q4 (drier, less warming), and q5 (average). These five climate conditions provide average and extreme scenarios for reservoir sedimentation management and water operations.

Hydrologic responses were simulated using the Rio Grande and Missouri Basin applications of the VIC hydrologic model obtained from the University of Washington. Results are calibrated by monthly naturalized flows in four locations in the Rio Grande Basin and six locations in the Missouri Basin. The VIC applications were further improved by model calibration and bias correction. The existing VIC model was calibrated to a larger area with a spatial resolution of 1º, and the difference between observed and the VIC-simulated hydrologic conditions is apparent. In this study the VIC model was first calibrated to naturalized data at four gages in the Rio Grande and six gages in the Bighorn River Basins, respectively, by adjusting the soil properties in each of the sub-basins. The difference between observed and the VIC simulated flows was further reduced by a bias correction method first applied to monthly mean flows in each of the 12 months in a year and then to annual mean flows. Results show that under the average climate change scenario (q5), annual flow into Elephant Butte reservoir will decrease by 7% and 9 % in the near future and far future, respectively. Under drier and more warming scenario (q3), annual flow there could decrease by 13% and 20% in the near future and in the far future, respectively. Annual flows into Bighorn Lake will increase by 4% (near future) and 8% (far future) under the average scenario (q5), 9% in the near future under wetter and more warming scenario (q1), and 13% in the far future under wetter and less warming scenario (q2).

Differences exist in the modeled month-to-month pattern of the annual hydrographs between Rio Grande Basin and Missouri Basin. In the Rio Grande Basin, the modeled hydrographs show a reduction in the duration of the spring runoff, with decreases of flow in June, continuing through

most of the winter season. In the Missouri Basin, the modeled annual hydrographs show more consistent increase of flow in each month.

The centroid date of the mean annual hydrograph will shift in both the Rio Grande Basin and in the Missouri Basin. At Elephant Butte Reservoir, the centroid date will shift by 5 and 10 days earlier in the average scenario (q5) in the near and far futures, respectively, and in the drier and more warming scenario (q3) it could shift by 7 and 12 days earlier in the near and far futures, respectively. At Bighorn Lake, the centroid date will shift by 1 day in the average scenario (q5), and 2 days in wetter scenarios (q1 - wetter, more warming or q2 - wetter, less warming) in both near and far futures.

Total sediment loads at Rio Grande at San Marcial (USGS gage 08358400) and Bighorn River at Kane (USGS gage 06279500) were calculated using the BORAMEP program. BORAMEP calculated the total sediment load (measured and unmeasured load) based on the hydraulic properties, measured suspended load, and bed material gradation. Total sediment rating curves were developed for two scenarios: dry and wet years; and dry, normal, and wet years based on annual flow rates during the years when the sediment loads are available. The sediment rating curve developed by the USACE was used at Shoshone River at Lovell (Gage ID 06285100). Sediment load into Elephant Butte Reservoir was calculated by the discharge and sediment rating curves at the Rio Grande at San Marcial gage. Sediment load into Bighorn Lake was calculated by adding up sediment loads at Bighorn River at Kane and Shoshone River at Lovell. Initial sediment rating curves were used to compute historical sediment loads at Rio Grande at San Marcial and at Bighorn River at Kane, and results were compared with the reservoir capacity losses in these two reservoirs. The sediment rating curves were adjusted after the comparison so that the total change in mass of sediment within the reservoir equaled the total mass of sediment transport for the same time period.

Sediment loads at Elephant Butte Reservoir will decrease in the average scenario q5 in the near future (97 thousand acre-ft (TAF)) and in the far future (91 TAF), compared with the historical condition (99 TAF) in 30 years. In the wetter and less warming scenario (q2), the sediment load could increase to 106 TAF in the near future and 113 TAF in the far future.

Sediment loads at Bighorn Lake will increase in the average scenario q5 to 59 TAF in both near and far futures, compared with historical condition (51 TAF) over 30 years. In the wetter and more warming scenario (q1), the sediment load could increase to 69 TAF in the near future and 71 TAF in the far future.