Bear Creek Reservoir Hydrologic Scenario Development

The point of articulation between the control regulation and the in-lake standard (chlorophyll or phosphorus) is the allowable phosphorus load, which becomes the starting point for TMAL development. The allowable load defines a target for implementation of watershed controls, if needed, such that the water quality standard in the lake is not exceeded. Because load is the product of flow and concentration, the allowable load can be defined for only one hydrologic scenario at a time.

The Division has no specific guidance for establishing the hydrologic scenario to be used in developing lake TMALs. It is common practice in TMDL development to rely on the median flow condition. A median annual inflow could be applied to lakes, although it would involve the implicit assumption that the magnitude of the inflow does not affect the likelihood of attaining the in-lake standard. In Colorado control regulations, hydrologic scenarios were chosen originally from a very limited set of years where loads and flows had been measured.

For example, the hydrologic scenario in the Lake Dillon Control Regulation corresponds to the annual inflow observed in 1982 (212,000 AF/y) during the Clean Lakes study. This scenario was used to develop load estimates consistent with attainment of the phosphorus standard. The control regulation acknowledges explicitly that if flows are higher than 212,000 AF/y, "the total phosphorus loading and inlake concentrations are expected to be exceeded." Because the inflow is close to the median for the period of record, the control regulation implicitly accepts the possibility of frequent exceedances. (In practice, the phosphorus standard has been exceeded only two times in more than 20 years.)

Hydrologic scenarios in the other two control regulations (Chatfield and Cherry Creek reservoirs) also were defined, at least initially, by a reference year from the original Clean Lakes studies. For Chatfield Reservoir, the hydrologic scenario was changed significantly as a result of technical review in the mid-1990s. An annual inflow of 261,000 AF/y was selected apparently assuming that it ensured a once-in-10-year exceedance frequency for the standard. (In practice, higher loads have not necessarily resulted in higher in-lake concentrations.)

The control regulation for Bear Creek Reservoir does not define a hydrologic scenario, possibly because allowable load is not specified either. Older documents from the Clean Lakes study are more forthcoming on the subject. In the 1992 revision of the Clean Lakes document, 41,827 AF/y is used to compute loads; it is described as the "annual total inflow to the reservoir during the monitoring period." In fact, the provenance is a little mysterious because the inflow reported for the monitoring period (Apr-88 through Mar-89) was only 32,916 AF. Both flows are larger than the median (28,891 AF/y). Clearly, there is both incentive and opportunity to develop a new hydrologic scenario that can be justified on the basis of site-specific information

The period of record for Bear Creek Reservoir is relatively brief; flow records from the USACE begin in July 1977. Computed inflows for calendar years 1978-2006 are shown in Figure 1, and the median is 28,891 AF/y. The flow record back to 1928 can be approximated using data from the USGS gage on Bear Creek at Sheridan. The years prior to 1977 appear to have been drier in general (median of about 17,000 AF/y), but the range of flows was essentially the same as that observed more recently (Figure 2).

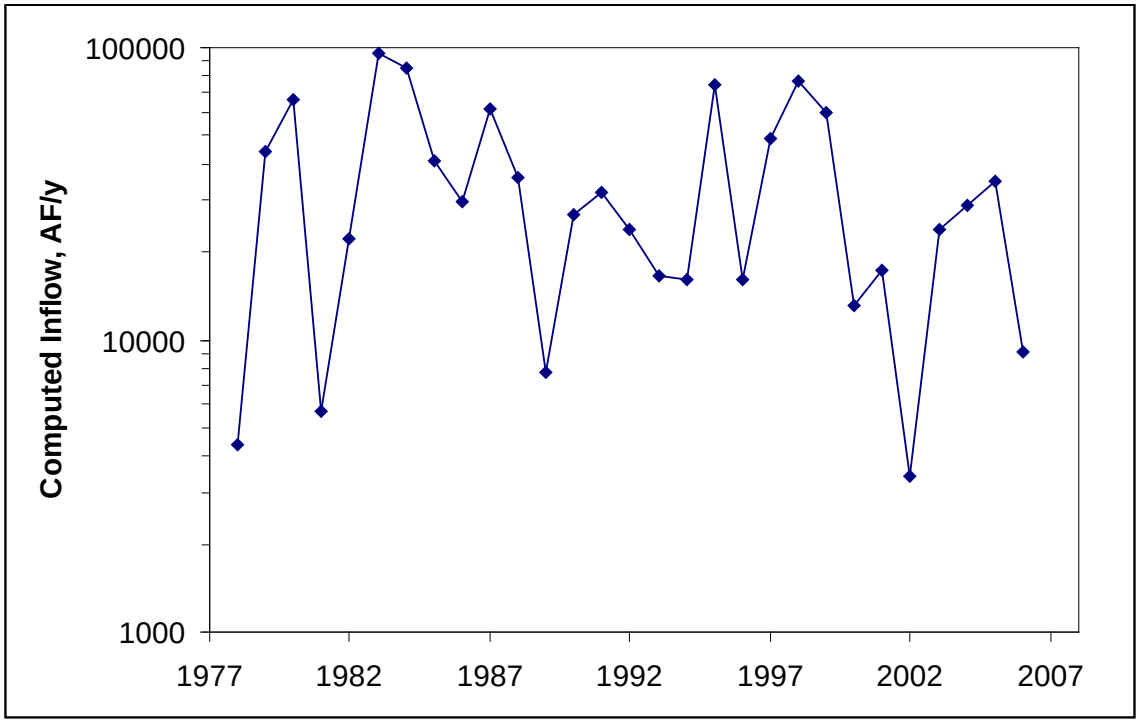

Figure 1. Computed annual inflow (AF/y) from USACE, shown on a log scale for 1978-2006.

The second consideration in choosing the flow scenario is the relationship between inflow volume and annual average phosphorus concentration (Figure 3). If there is no strong relationship, the choice of hydrologic scenario has little influence on the exceedance probability for the standard. In other words, the median inflow volume would be a good choice.

At best, there is a weak, non-linear relationship between chlorophyll and inflow volume in Bear Creek Reservoir (Figure 3). Chlorophyll tends to be suppressed at the highest inflows, perhaps related indirectly to residence time. The mechanism responsible for the suppression of algal abundance is less important than the recognition that there is a threshold inflow above which response seems altered. In this case, inflows greater than 35-40,000 AF/y should be avoided when determining the allowable load for the reservoir. The median would serve the purpose well.

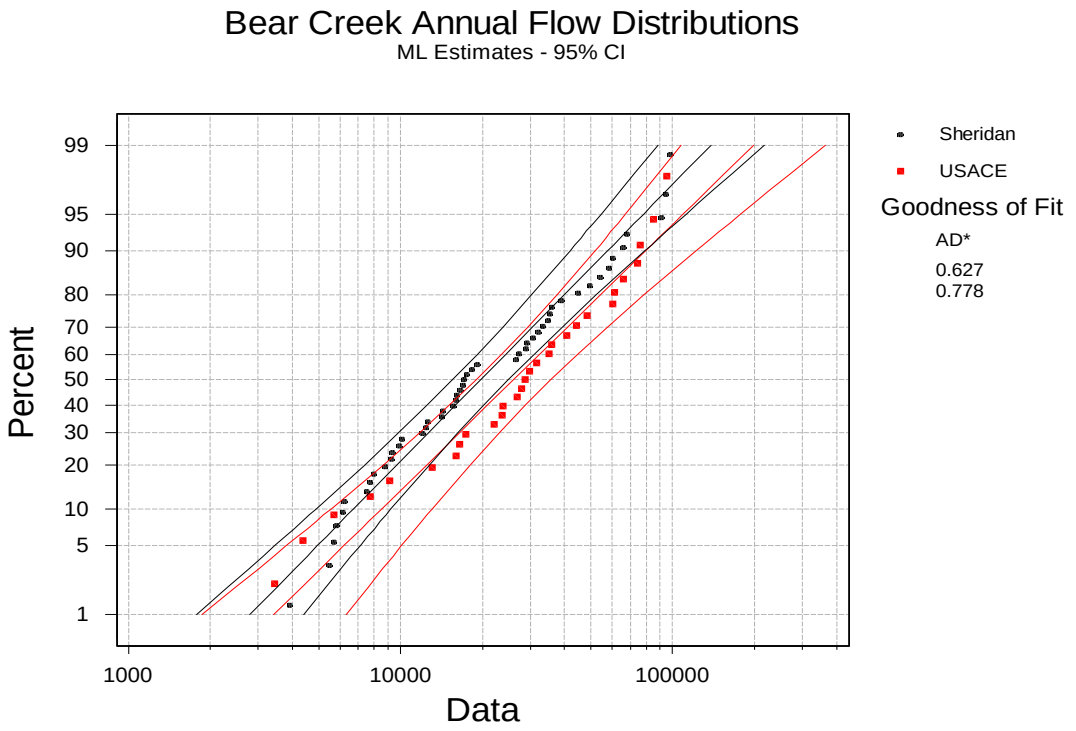

Figure 2. Cumulative probability distributions for annual flows (AF/y) in Bear Creek. The USGS gage at Sheridan (1928-1976) represents conditions prior to construction of the reservoir. Computed inflow (USACE 1978-2006) to the reservoir is shown for comparison.

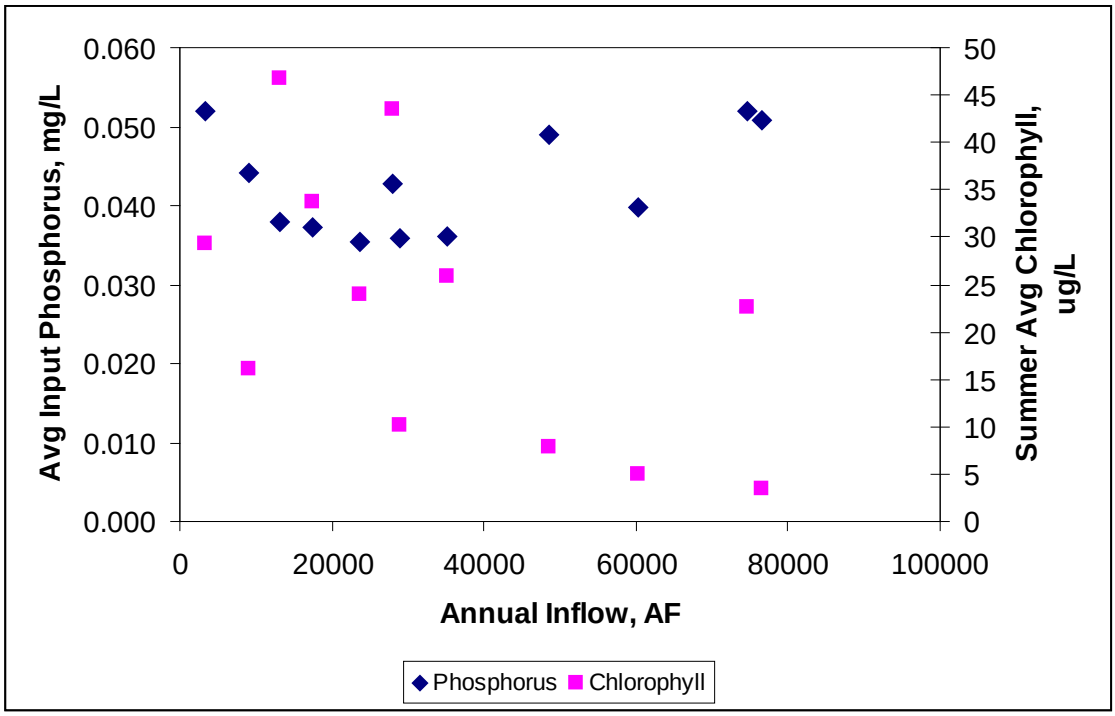

Figure 3. Relationship between average input phosphorus concentration and inflow volume, and between summer average chlorophyll and inflow volume. Data prior to 1995 were excluded because loads and concentrations were substantially higher than what has been observed in recent years.

Recommendation

The Division recommends the median annual inflow (28,891 AF/y) as the hydrologic scenario for developing the allowable load estimate. The recommendation is based on the conclusion that the annual average concentration of phosphorus in the inflow is largely independent of inflow volume and on the observation that algal abundance tends to be suppressed at inflows much larger than the median. The observation that algal abundance is suppressed at high flow could be useful later stage in the regulatory process in the sense that it might be incorporated in an explicit margin of safety, or it could influence determination of exceedance frequency.