23. Appendix K. Other Drawdown Scenarios Analyzed

Other drawdown scenarios are analyzed in this appendix.

Table 23-1. Scenarios analyzed for Reservoir Drawdown.

Scenario Number	Description
1	• Reopen old river diversion tunnel at Copco 1 and use this to drain reservoir beginning Nov 15, 2019 • Copco 1 is limited to 3 ft/day of drawdown. • Begin drawdown of J.C. Boyle and Iron Gate beginning Nov 15, 2019
2	• Do not use low level outlet at Copco 1, instead notch from top beginning Nov 15, 2019. • Notching of Copco 1 is at a rate of 6ft /wk. The notching will be two 20 ft wide sections, in alternating 12 ft high sections. • Begin drawdown of J.C. Boyle and Iron Gate beginning Nov 15, 2019 using low level outlets
3	• Do not use low level outlet at Copco 1, instead notch from top beginning Jan 1, 2019. • Notching of Copco 1 is at a rate of 6ft /wk. The notching will be two 20 ft wide sections, in alternating 12 ft high sections.
4	• Use low level outlet at Copco 1 and notch from top beginning Nov 15, 2019. • Notching of Copco 1 is at a rate of 6ft /wk. The notching will be two 20 ft wide sections, in alternating 12 ft high sections.
5	• Use low level outlet at Copco 1 and notch from top beginning Jan 1, 2019. • Notching of Copco 1 is at a rate of 6ft /wk. The notching will be two 20 ft wide sections, in alternating 12 ft high sections. • Begin drawdown of J.C. Boyle and Iron Gate beginning Jan 1, 2020
6	• Use low level outlet at Copco 1 and notch from top beginning Nov 15, 2019. • Limit drawdown rate at Copco I to 1 ft/d for upper 50 ft of reservoir, 3 ft/d below that • Notching of Copco 1 is at a rate of 6ft /wk. The notching will be two 20 ft wide sections, in alternating 12 ft high sections. • Begin removal of J.C. Boyle beginning Feb 15, 2020
7	• Use low level outlet at Copco 1 and notch from top beginning Jan 1, 2020 • Limit drawdown rate at Copco 1 to 1 ft/d for upper 50 ft of reservoir, 3 ft/d below that • Notching of Copco 1 is at a rate of 6ft /wk. The notching will be two 20 ft wide sections, in alternating 12 ft high sections. • Begin removal of J.C. Boyle beginning Jan 1, 2020

The following are common to all scenarios:

- Existing Low Level Outlet Capacities at Iron Gate and J.C. Boyle will be used.
- Iron Gate drawdown is begun at same time as Copco Reservoir
- Iron Gate drawdown rates are limited to 10 ft/day of drawdown
- Deconstruction of J.C. Boyle and Iron Gate embankments will not begin until after May 1.

23.1. Scenario 1

This scenario assumes drawdown begins Nov 15, 2019 and only the low level outlets are used to drain J.C. Boyle, Copco 1, and Iron Gate reservoirs.

The results of the hydrologic reservoir routing are shown in Figure 23-5 to Figure 23-2. The reservoir elevations in the 3 larger reservoirs are shown for 3 years: a dry year (2001), and median year (1976), and a wet year (1984). These were defined as years that had a 10%, 50%, and 90% exceedance in terms of flow volume between March and June. The daily exceedance values for reservoir elevations are also shown in the figures.

Because the flows commonly exceed the low level outlet capacity in the winter and spring, the reservoirs refill to some extent depending upon whether it is a dry, median, or wet year. In the dry year, J.C. Boyle does not refill more than a few feet; Copco 1 refills to about 2520 ft, and Iron Gate refills to about 2200 ft. In the median year, J.C. Boyle refills to about 3760 ft, Copco 1 to about 2575 ft, and Iron Gate to about 2225 ft. In a wet year, all three reservoirs overtop their spillway, or come very close to overtopping their spillway.

Because of its Iron Gate is an earthen dam, it cannot be overtopped at any time during the deconstruction. There has not been any event that would exceed the elevation 2240 feet at Iron Gate after May 1 based upon the hydrologic simulations using the period of record 1961 – 2008. After June 15, the Iron Gate reservoir can be maintained at an elevation of below 2190. Iron Gate Dam must not create any significant reservoir pool after Dec 1 to eliminate the possibility of a flood wave being created by a partially removed earthen dam.

The results of the sediment transport analysis for the years 2001, 1976, and 1984 are shown in Figure 23-7, Figure 23-8, and Figure 23-9, respectively. The concentrations are given below Iron Gate dam. There are significant dilution effects as tributaries enter downstream and this will be discussed later.

During a dry year, high concentrations may persist all the way well into the spring. The high concentrations are of shorter duration during a median year, but there are spikes of high concentration as the reservoir refills and empties.

During a wet year, there are spikes of concentration during period where the reservoir is draining, but there are also period where the reservoir is filling and the

concentrations decreases to low. When the reservoirs finally drain completely in June and July, the concentrations remain high until August.

The amount of sediment eroded from each of the reservoirs under a dry, median, and wet year is shown in Figure 23-11. If dam removal occurs during a wet year, up to 56 % of the reservoir sediment would be eroded, whereas, about 38% of the sediment would be eroded if removal were to occur during a dry year. The remaining sediment is expected to stabilize upon the terraces. The erosion resistance of the dried sediment increased by more than 10 times based upon the erosion tests in Appendix D. Report on Erodibility Characteristics of Reservoir Sediment by Agricultural Research Service.

The sediment left on the terraces will also consolidate significantly. It is expected the thickness of the sediment left behind will decrease by about 40%. The volume will decrease by a larger amount and there will be significant cracking of the sediment. The cracking will allow preferential flow paths to form within the sediment and the overland flow during rain storms will create rills in the sediment. Stabilization of sediment is a primary reason why aggressive re-vegetation of the reservoir is necessary. Once grasses and other native species colonize the reservoir sediment, erosion will be significantly reduced.

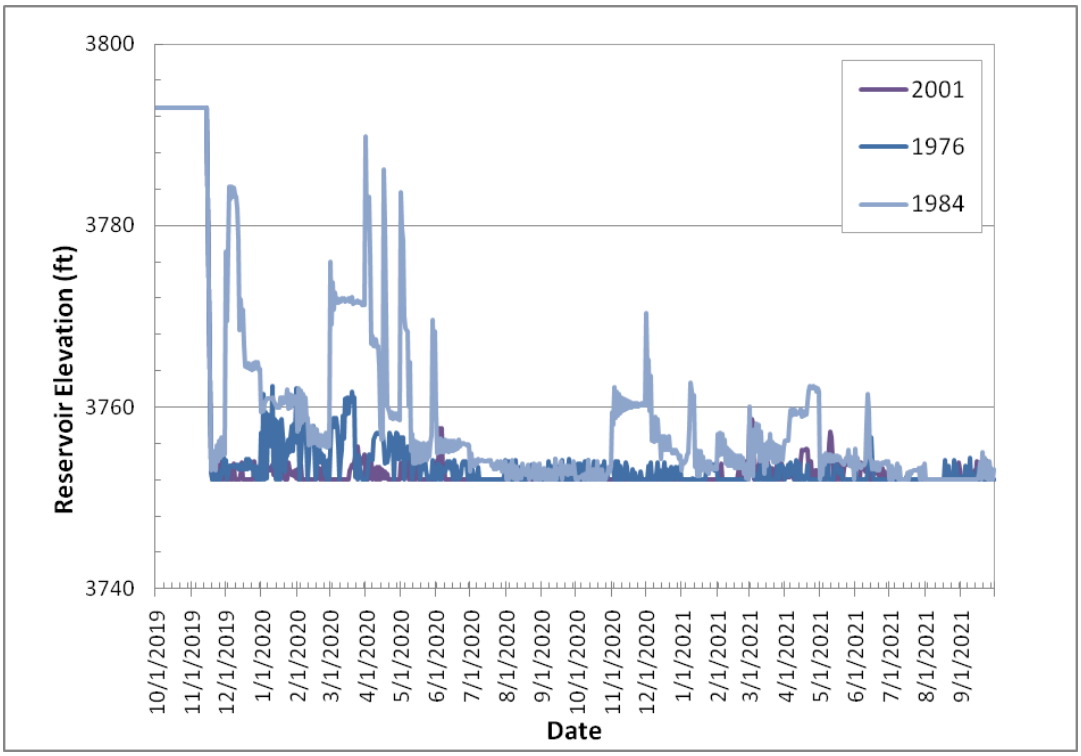

Figure 23-1.JC Boyle elevation for typical dry (2001), median (1976), and wet(1984) years for Scenario 1.

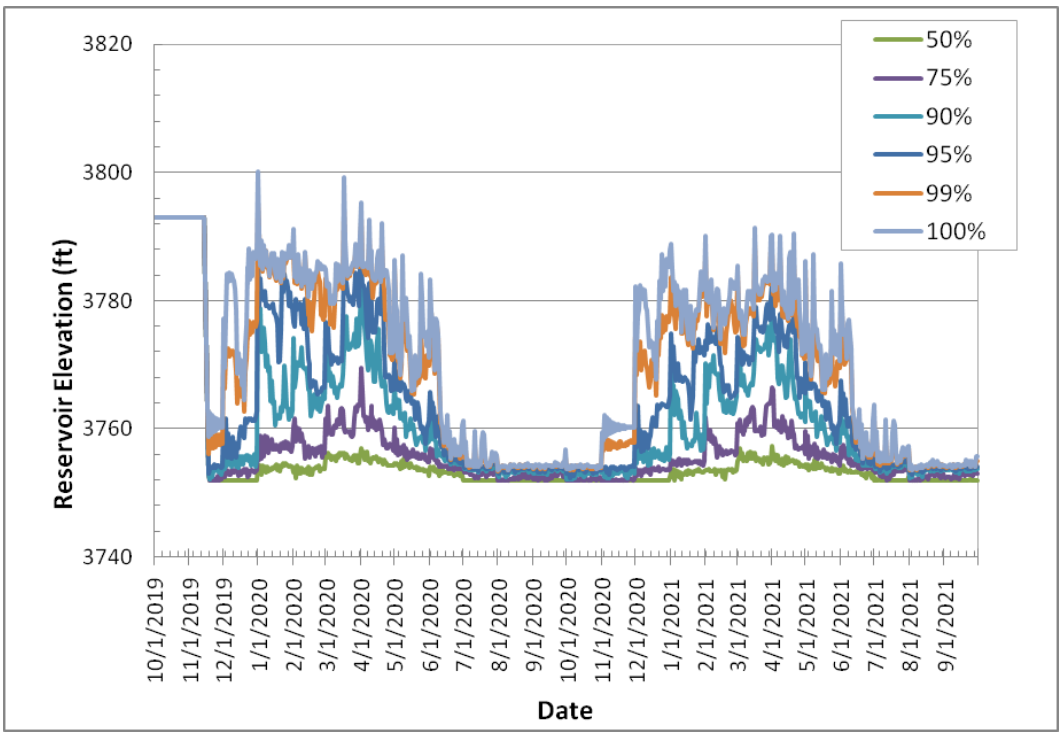

Figure 23-2. J.C. Boyle Non-Exceedance Elevations for all years from 1961 to 2008 for Scenario 1.

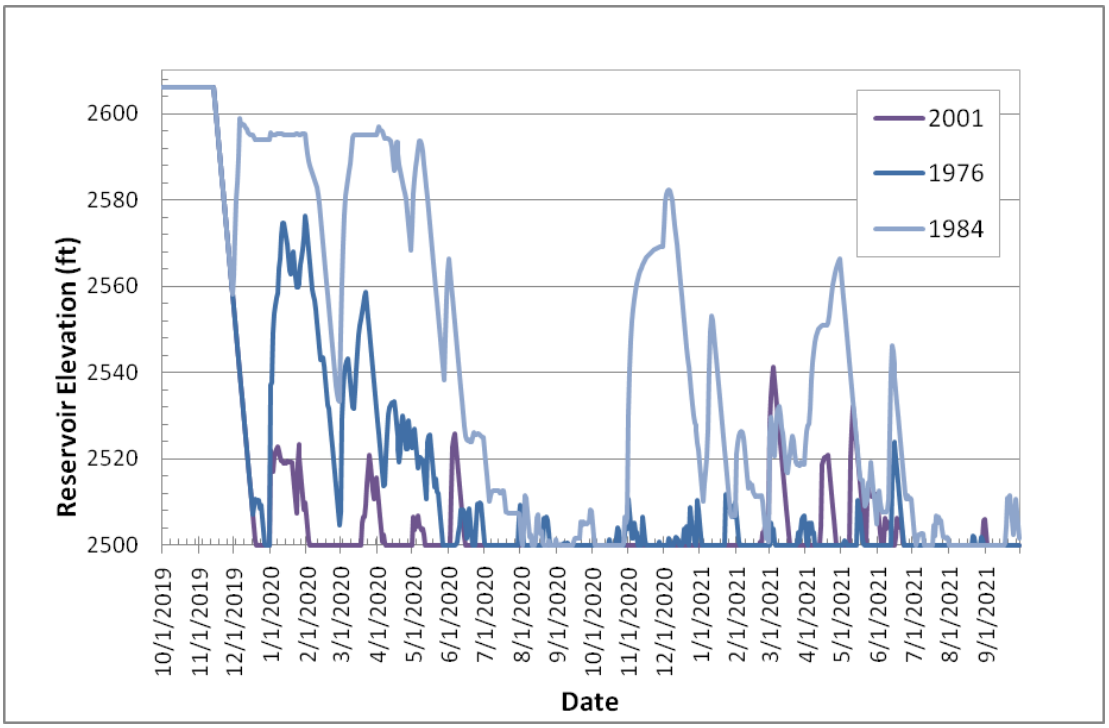

Figure 23-3. Copco 1 elevation for typical Dry (2001), Median (1976), and Wet (1984) years for Scenario 1.

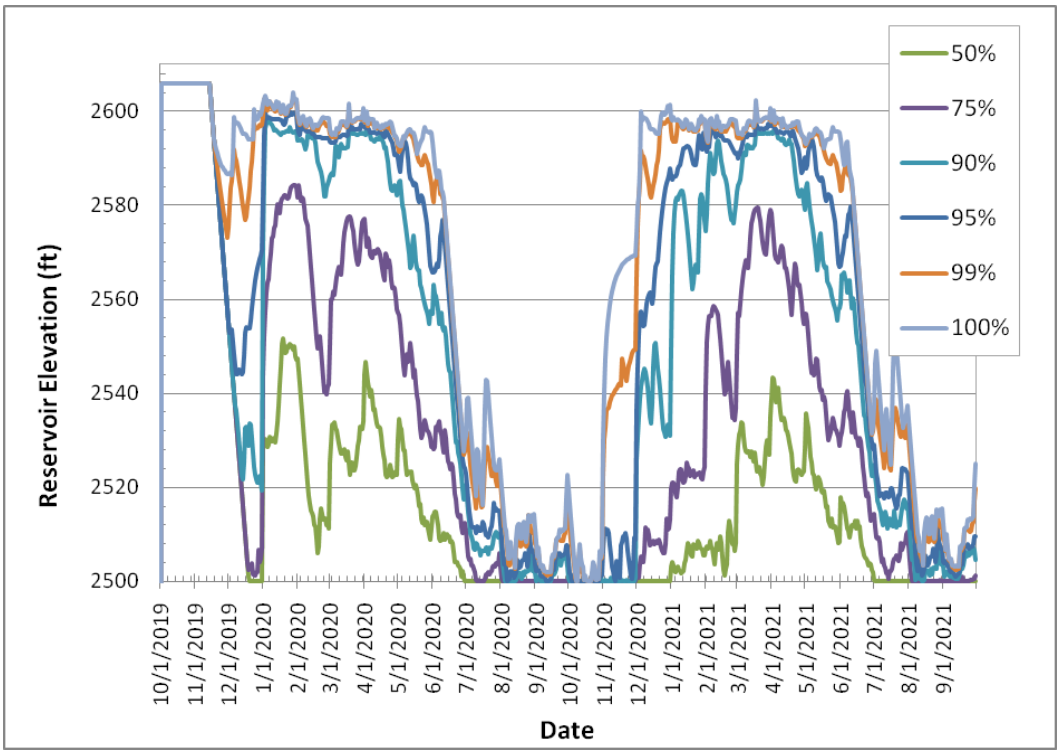

Figure 23-4. Copco 1 non-exceedance elevations for all years from 1961 to 2008 for Scenario 1.

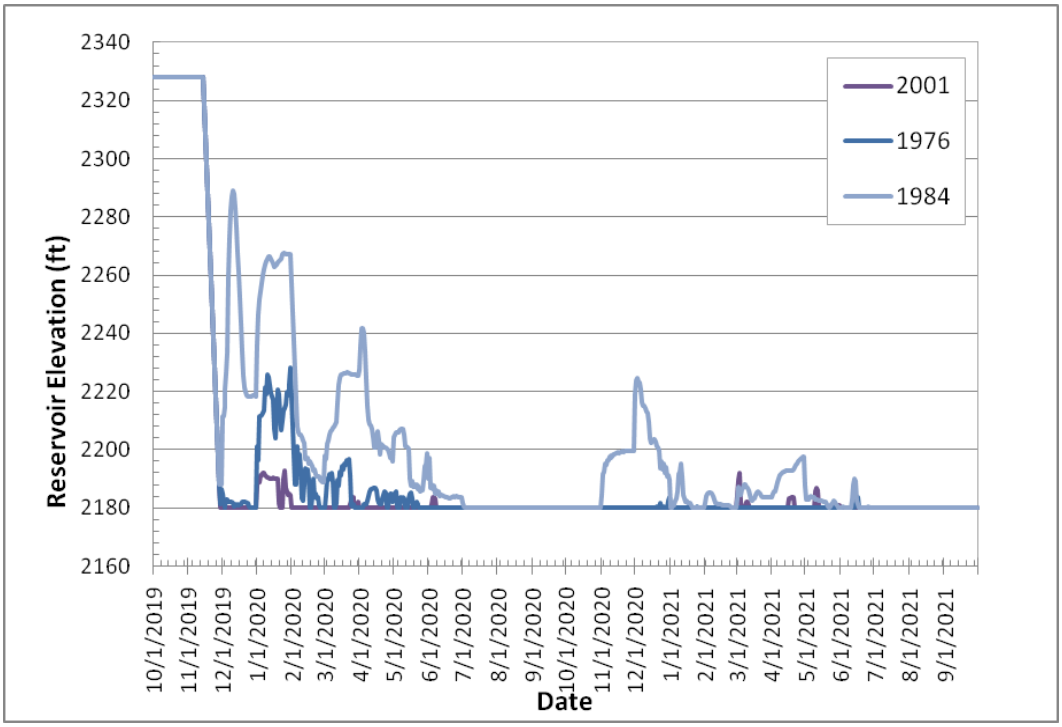

Figure 23-5. Iron Gate elevation for typical Dry (2001), Median (1976), and Wet (1984) years for Scenario 1.

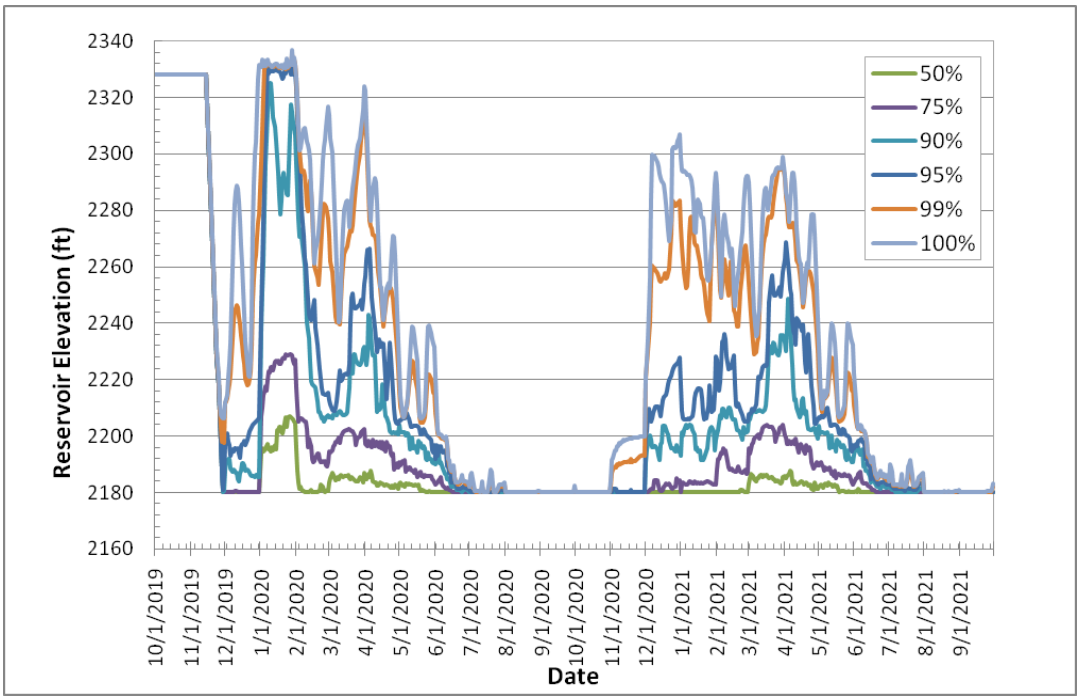

Figure 23-6. Iron Gate Non-Exceedance Elevations for all years from 1961 to 2008 for Scenario 1.

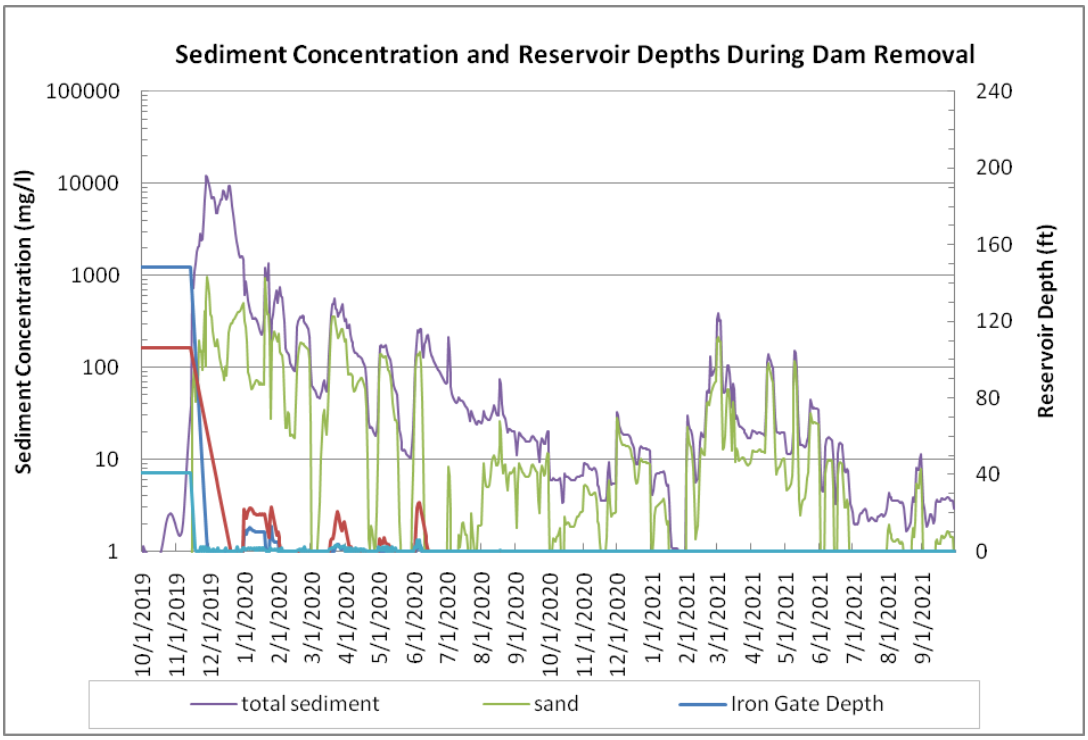

Figure 23-7. Simulated reservoir depths and sediment concentration below Iron Gate for WY 2001 (Dry year) for Scenario 1.

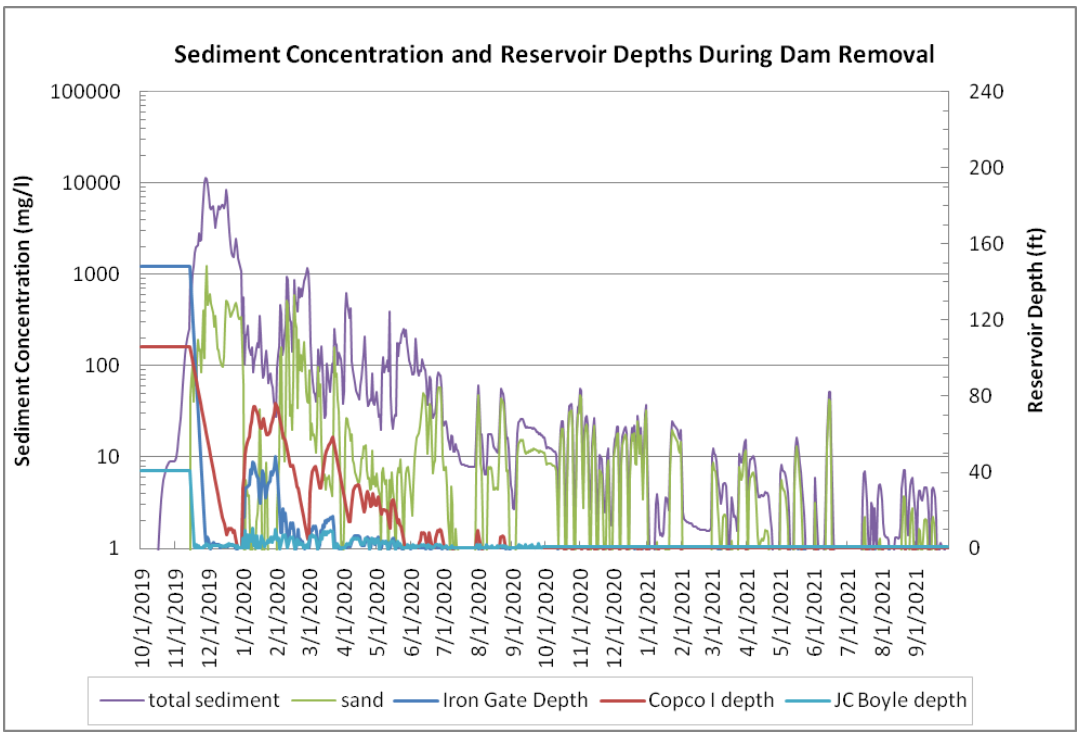

Figure 23-8. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1976 (median year) for Scenario 1.

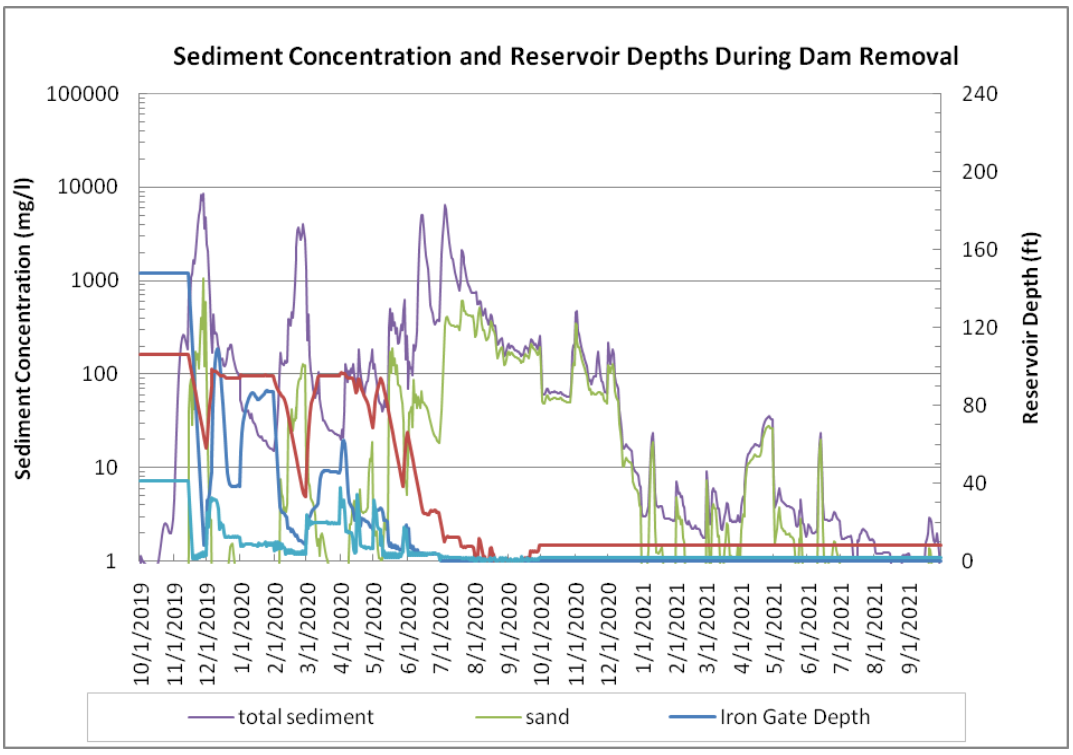

Figure 23-9. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1984 (wet year) for Scenario 1.

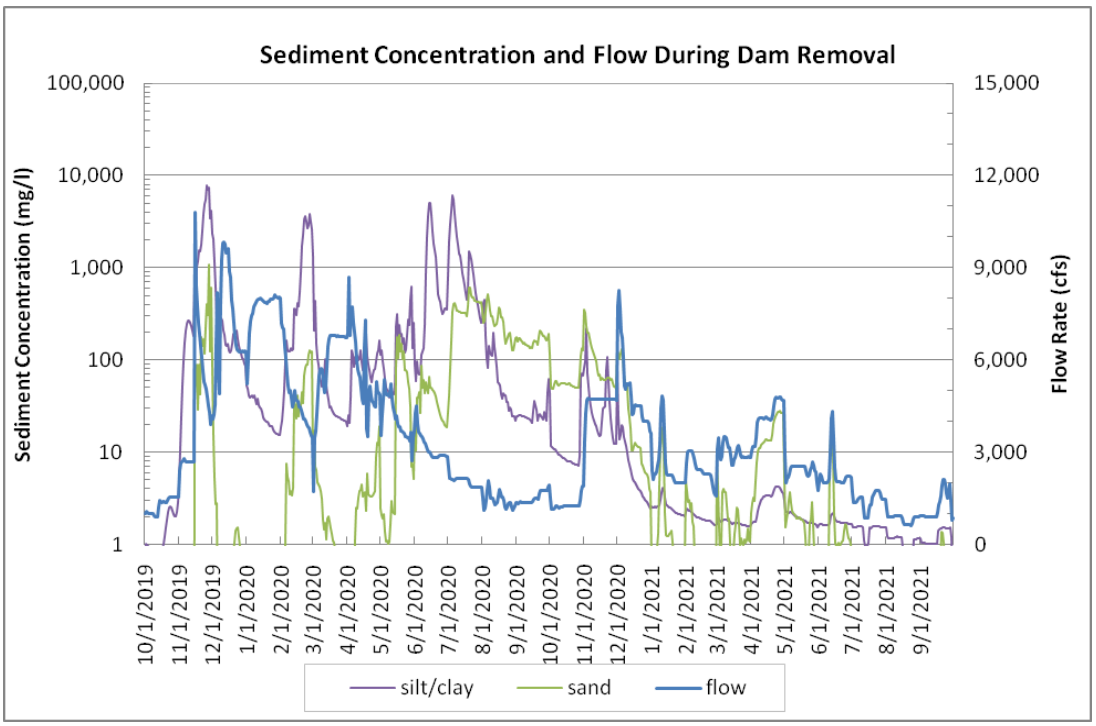

Figure 23-10. Simulated flows and sediment concentration below Iron Gate for WY 1984 (wet year) for Scenario 1.

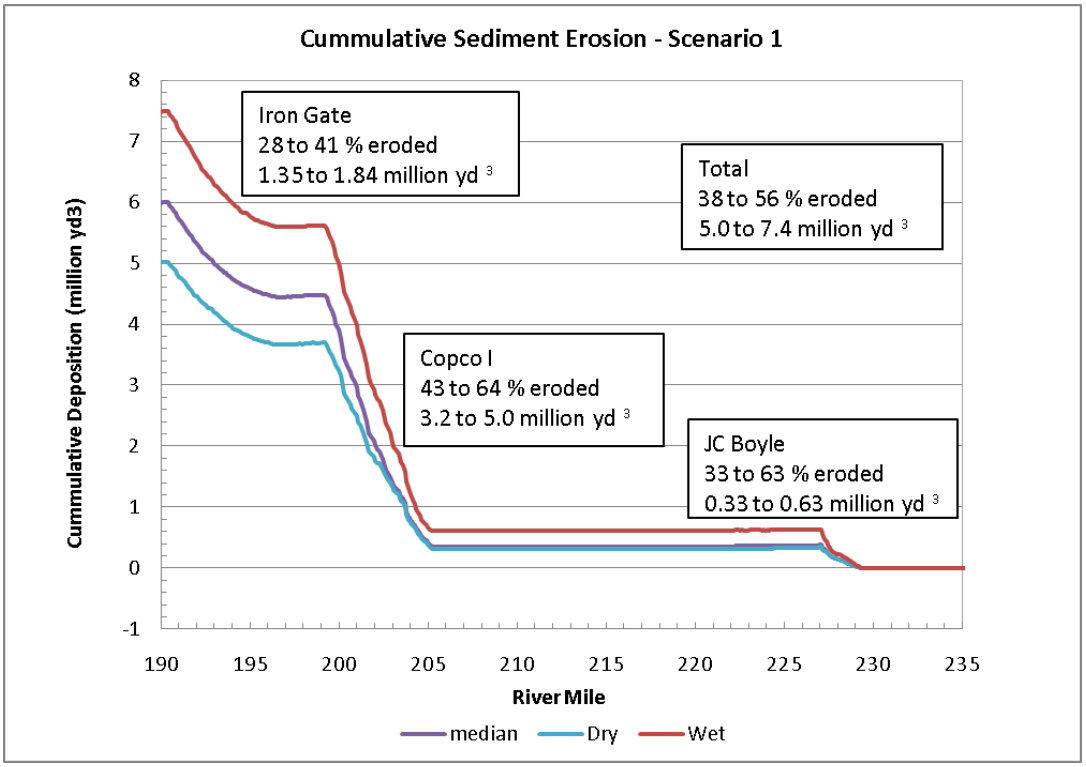

Figure 23-11. Volume of sediment erosion for Scenario 1 for the dry, median, and wet year types for Scenario 1.

23.2. Scenario 2

Scenario 2 assumes that the drawdown begins Nov 15, 2019, but that instead of using the low level outlet at Copco 1, Copco 1 Dam is notched from the top. The concrete of the dam is removed at a rate of 6 ft/week. Therefore is takes over 3 months to remove Copco 1 Dam and then the reservoir cannot refill after this time. The reservoir elevations at Copco and Iron Gate reservoirs for the dry, median and wet water years are shown in Figure 23-12 and Figure 23-13. The non-exceedance reservoir elevations for Iron Gate are shown in Figure 23-14.

The reservoir elevation at Copco I is essentially controlled by the notching. Iron Gate reservoir show slightly more refilling because the Copco 1 is now storing less water and allows higher flows to reach Iron Gate.

The peak concentrations for Scenario 2 are slightly lower than for Scenario 1 because the reservoir elevation at Copco I decreases slower under Scenario 2 than 1 and therefore sediment is eroded at a slower rate.

Because Copco 1 does not refill during the spring runoff, the concentrations after April are significantly lower for Scenario 2 than Scenario 1.

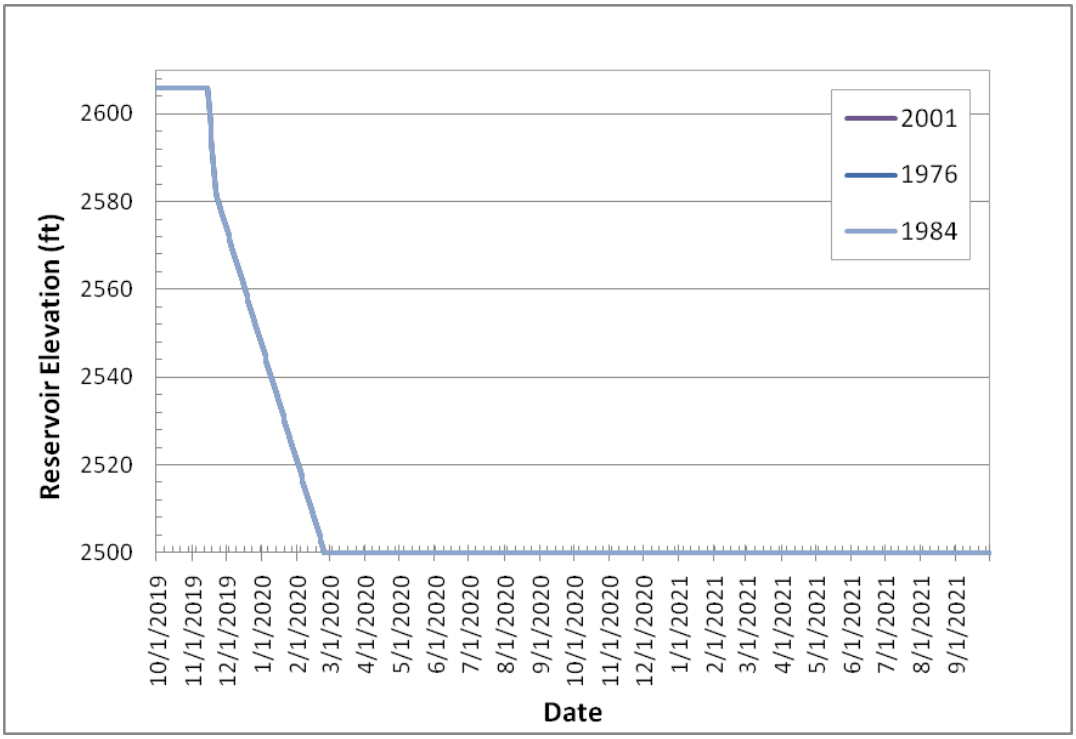

Figure 23-12. Copco 1 elevation for Typical Dry (2001), Median (1976), and Wet (1984) years for Scenario 2.

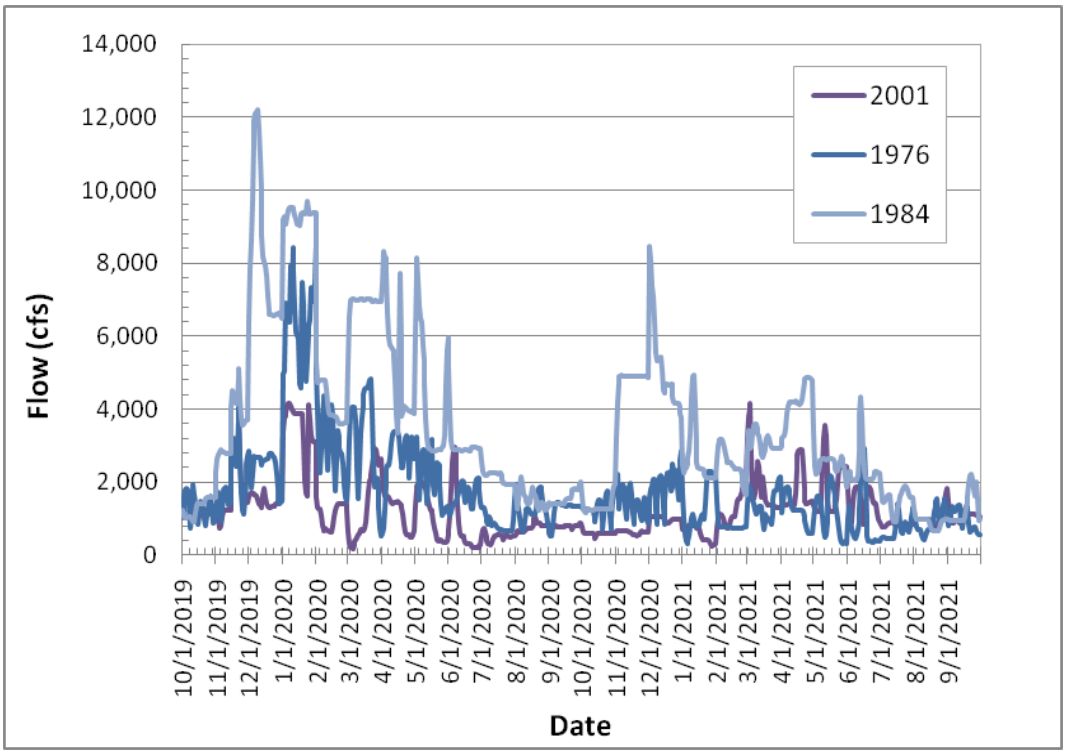

Figure 23-13. Iron Gate elevation for typical Dry (2001), Median (1976), and Wet Years for Scenario 2.

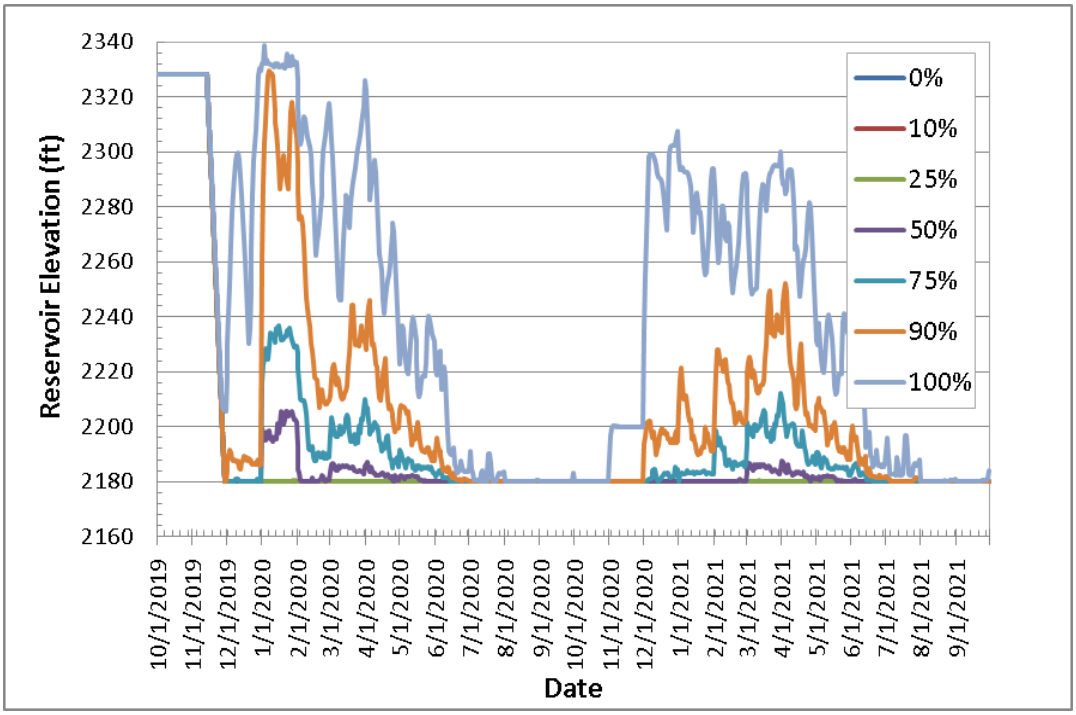

Figure 23-14. Iron Gate Non-Exceedance Elevations for all years from 1961 to 2008 for Scenario 2.

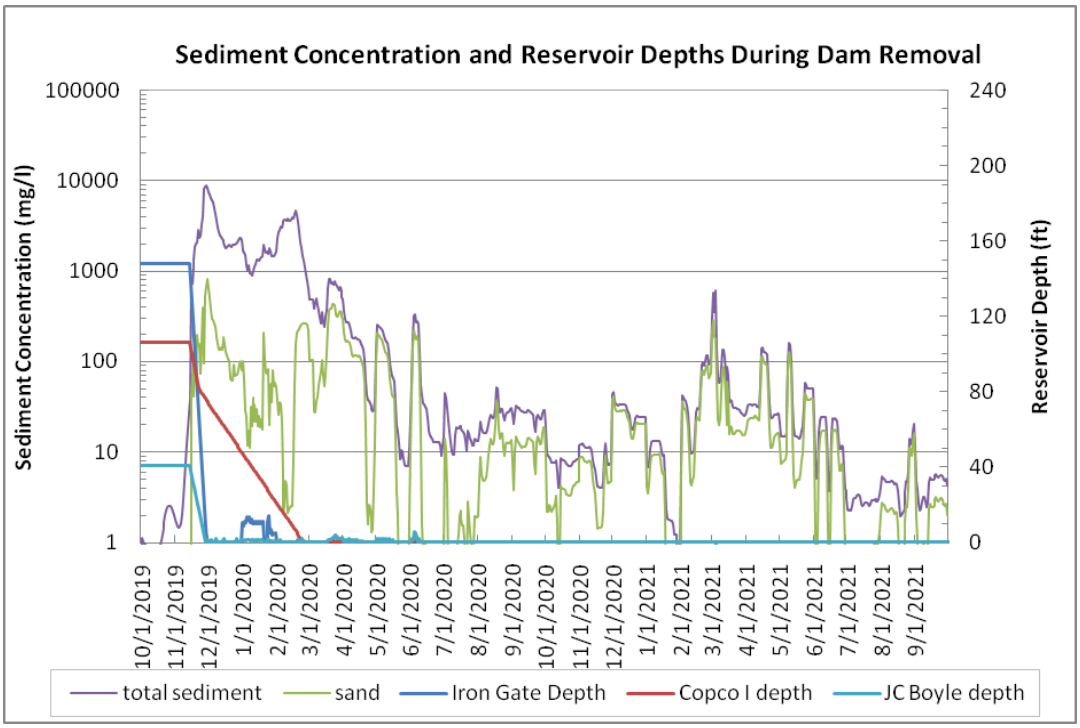

Figure 23-15. Simulated reservoir depths and sediment concentration below Iron Gate for WY 2001 (Dry year) for Scenario 2.

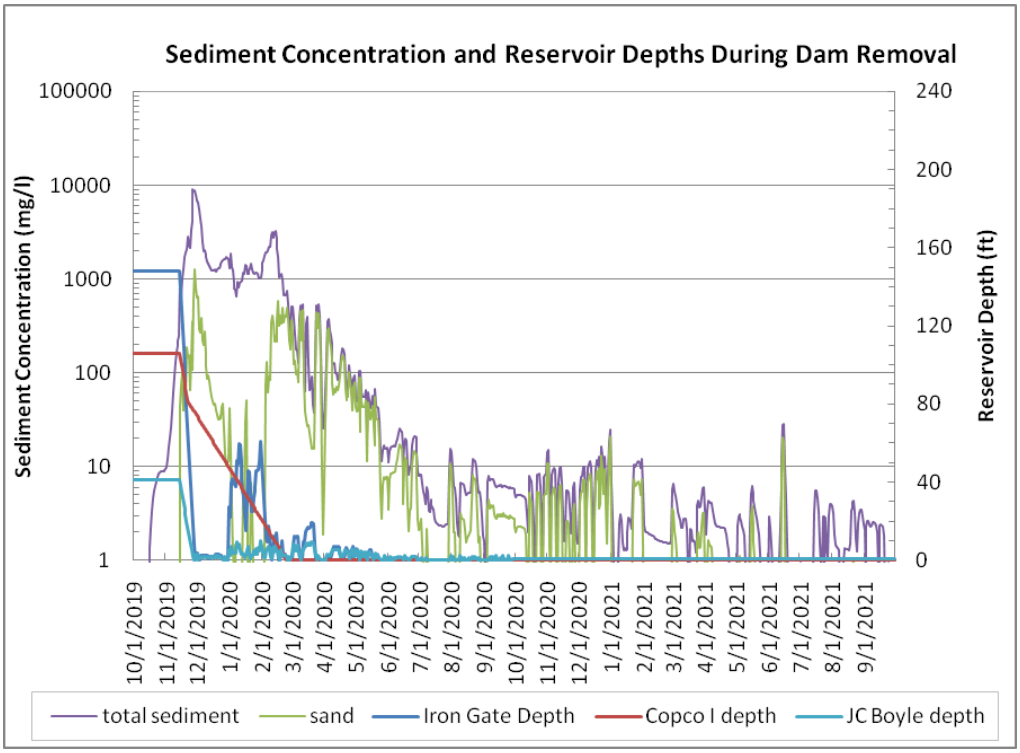

Figure 23-16. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1976 (median year) for Scenario 2.

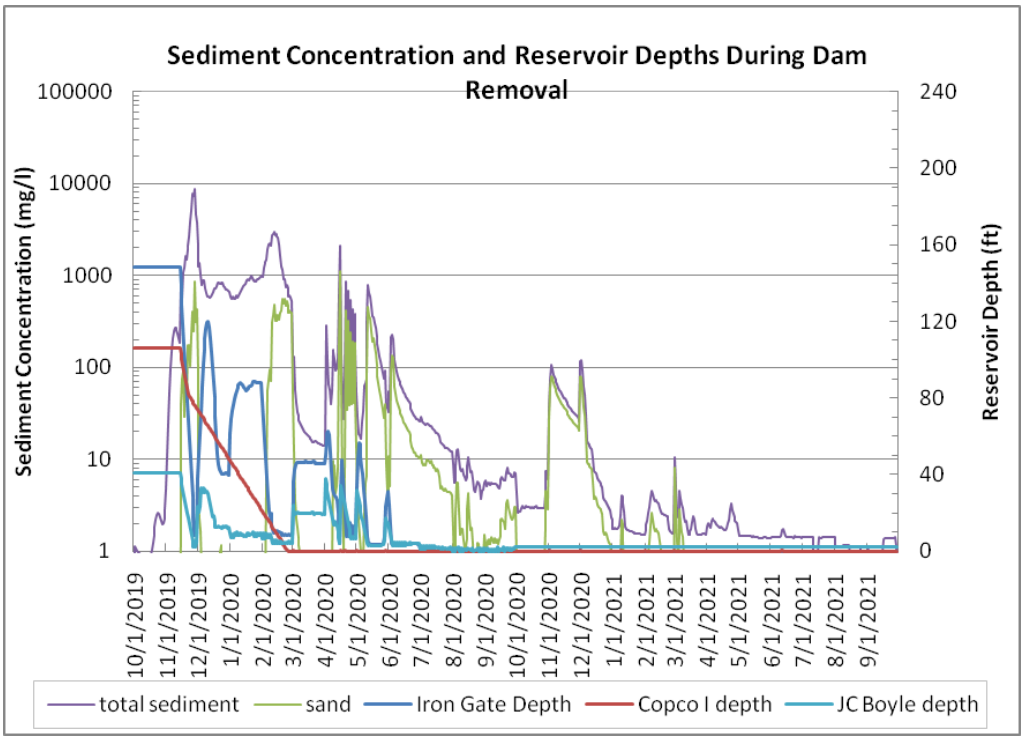

Figure 23-17. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1984 (Wet year) for Scenario 2.

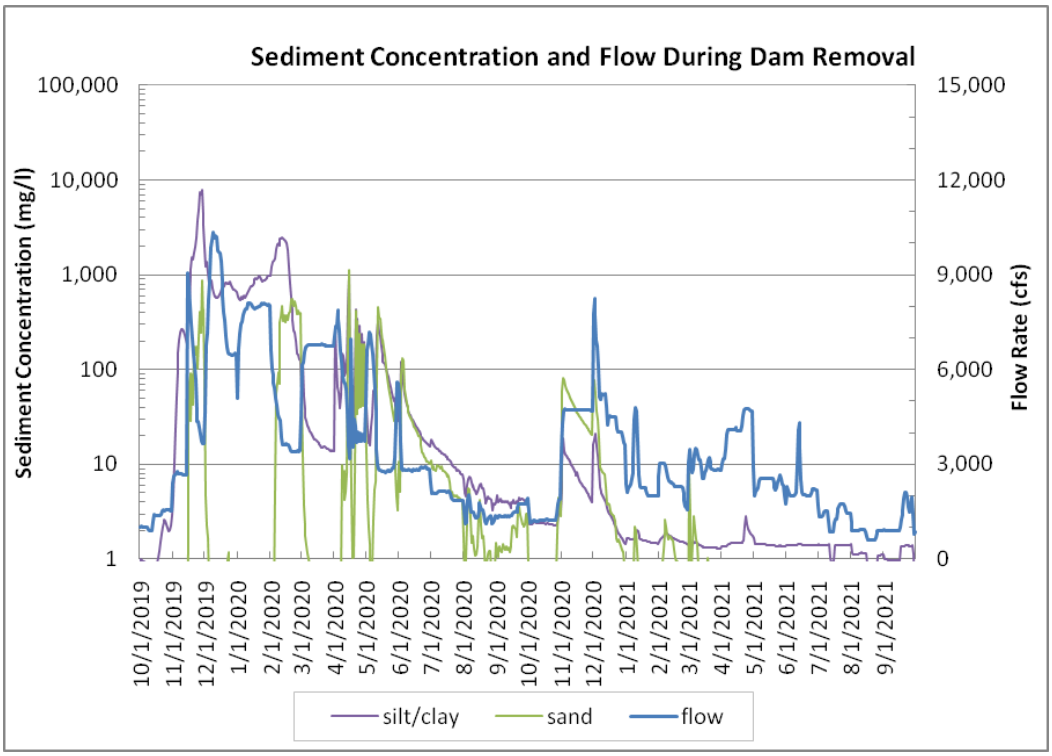

Figure 23-18. Simulated flows and sediment concentration below Iron Gate for WY 1984 (Wet year) for Scenario 2.

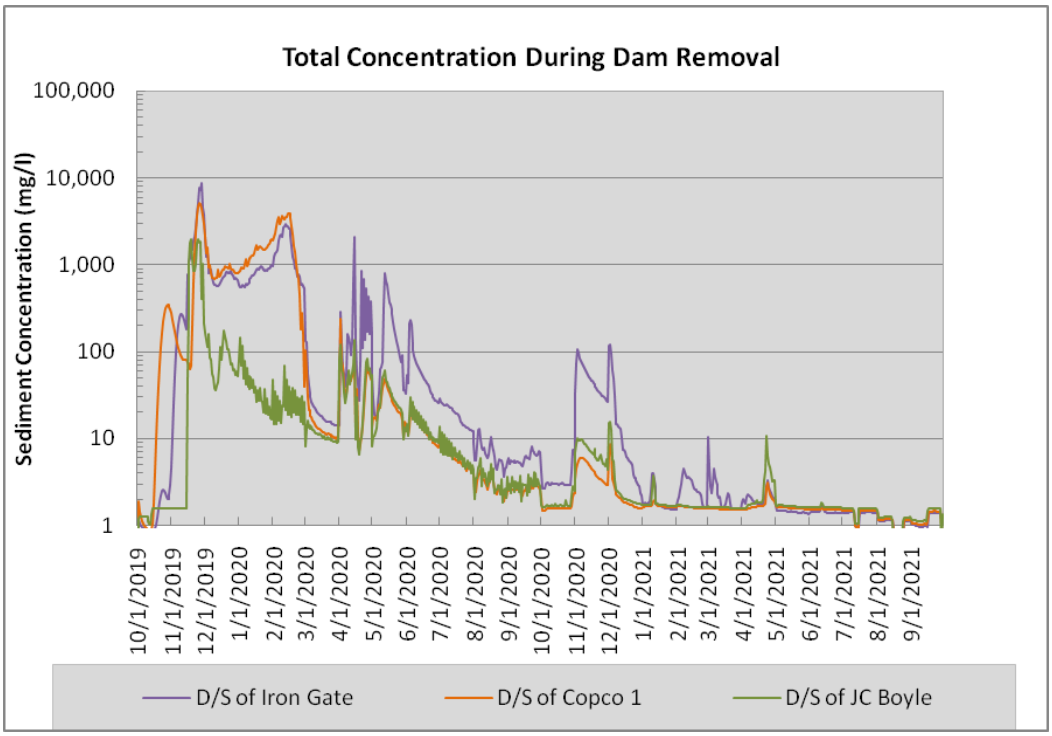

Figure 23-19. Simulated sediment concentrations below J.C. Boyle, Copco 1, and Iron Gate for WY 1984 (Wet year) for Scenario 2.

23.3. Scenario 3

Scenario 3 assumes that drawdown commences Jan 1, 2020. The low level outlet is used to drain J.C. Boyle and Iron Gate reservoirs, and Copco 1 is removed as in Scenario 2, being notched from the top. The low level outlet at Copco 1 is not used.

Copco 1 is not drawdown until the beginning of April and therefore the sediment concentrations remains high until then. Copco 1 does not refill after that date and concentrations quickly decrease after drawdown.

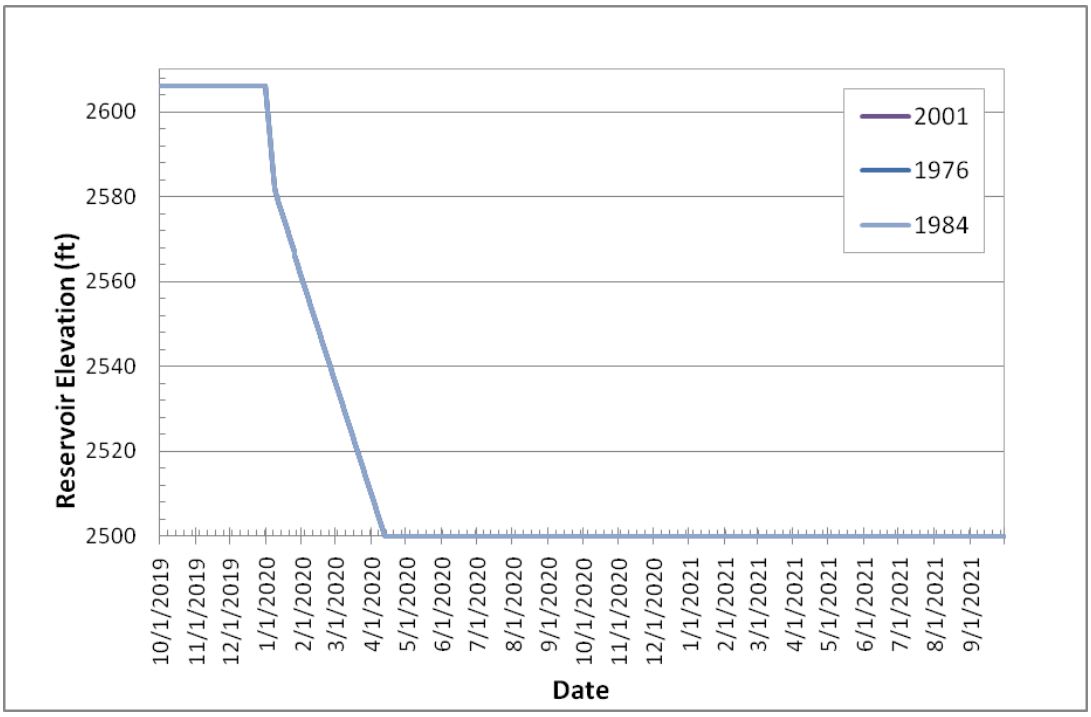

Figure 23-20. Copco 1 elevation for typical Dry (2001), Median (1976), and Wet Years for Scenario 3.

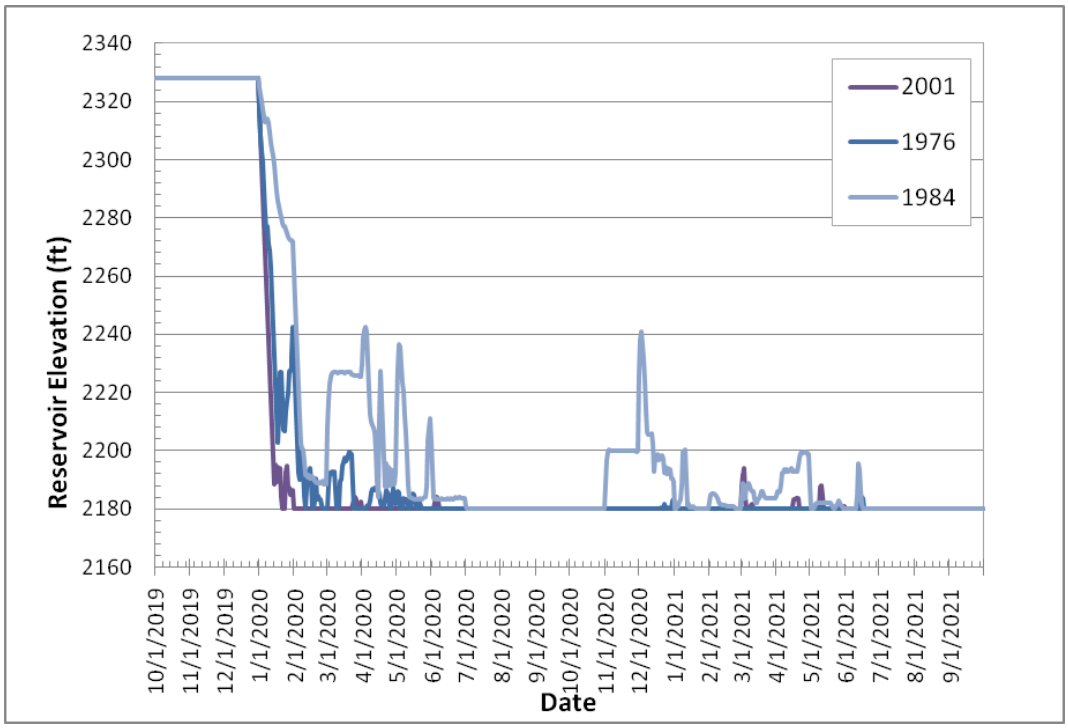

Figure 23-21. Iron Gate elevation for typical Dry (2001), Median (1976), and Wet (1984) years Scenario 3.

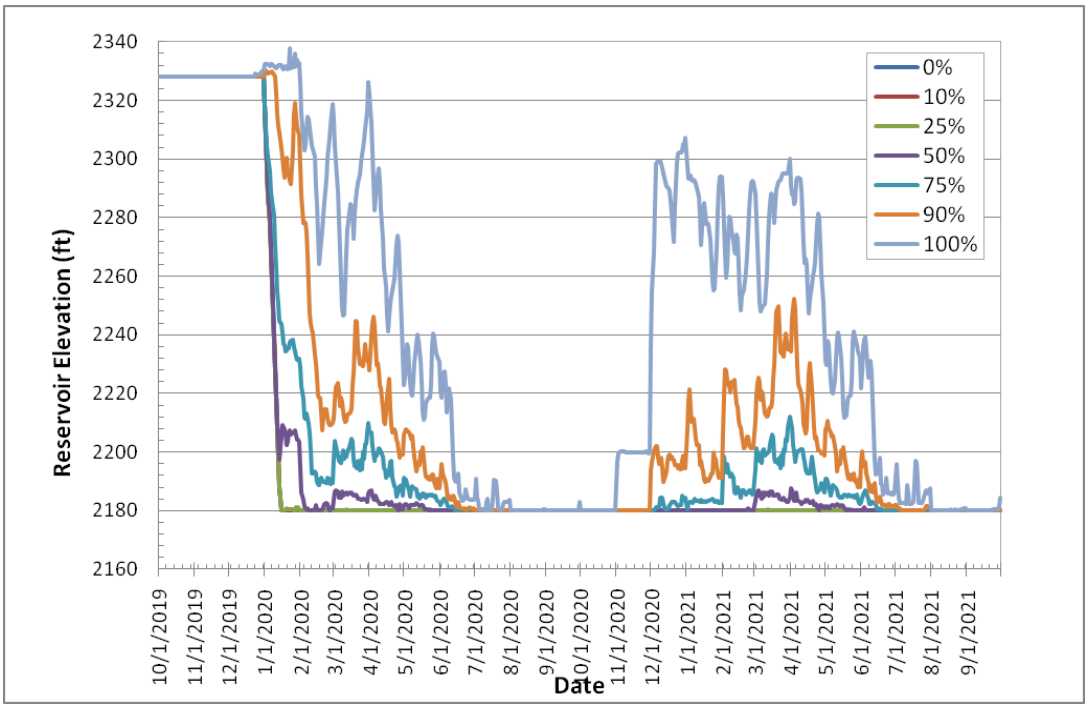

Figure 23-22. Iron Gate Non-Exceedance Elevations for all years from 1961 to 2008 Scenario 3.

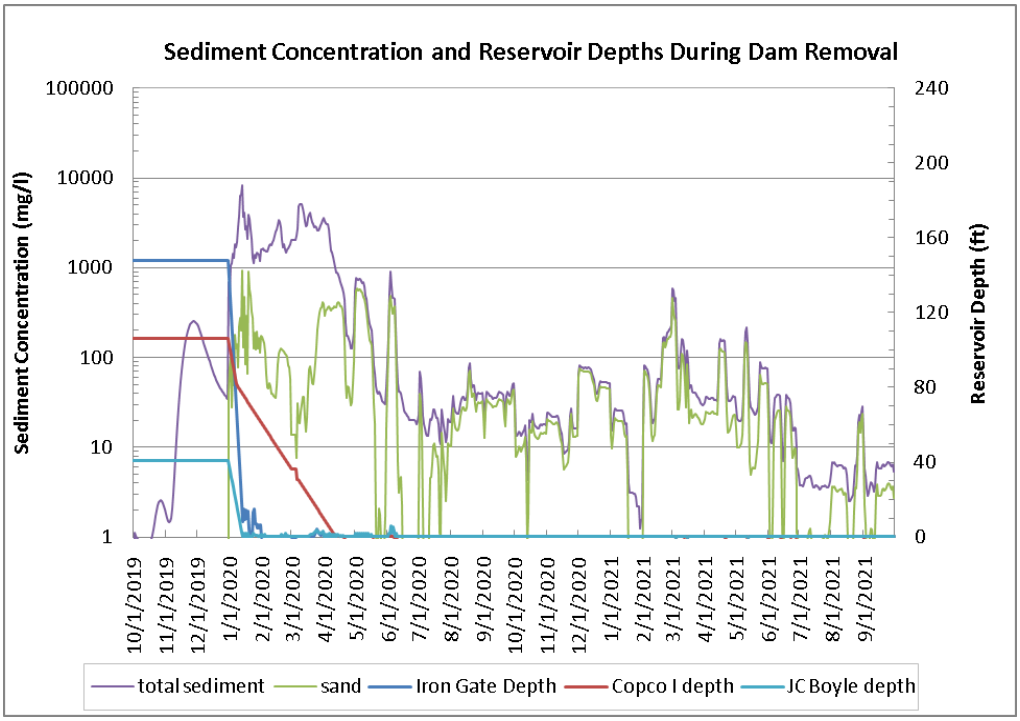

Figure 23-23. Simulated reservoir depths and sediment concentration below Iron Gate for WY 2001 (Dry year) Scenario 3.

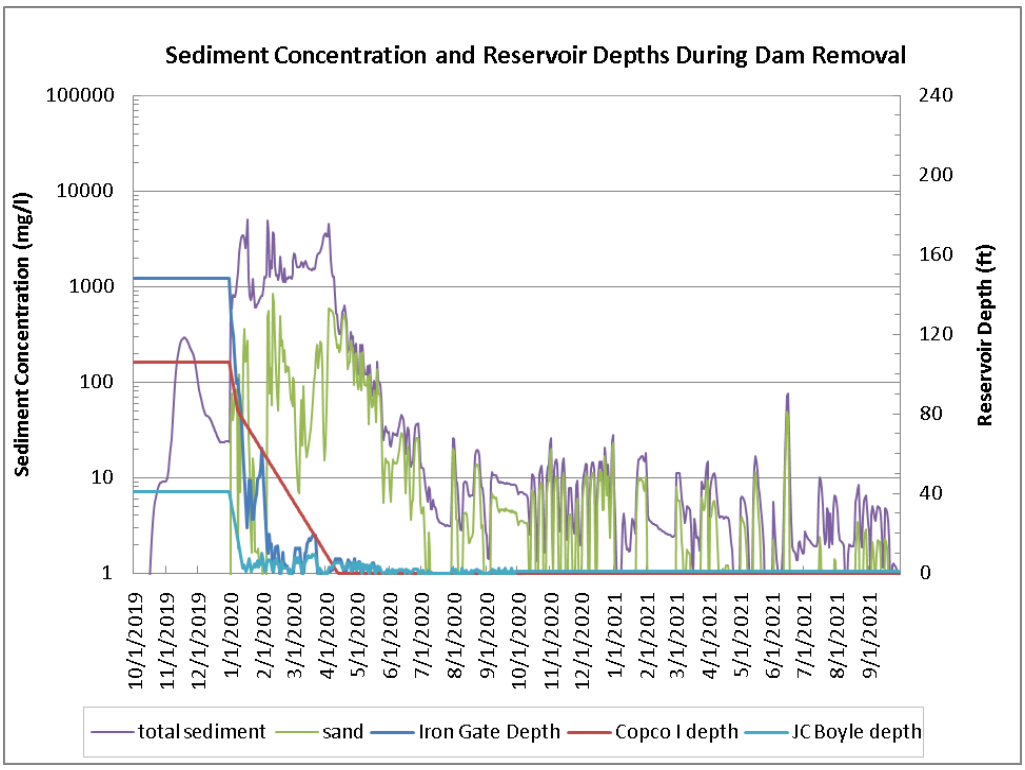

Figure 23-24. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1976 (median year) Scenario 3.

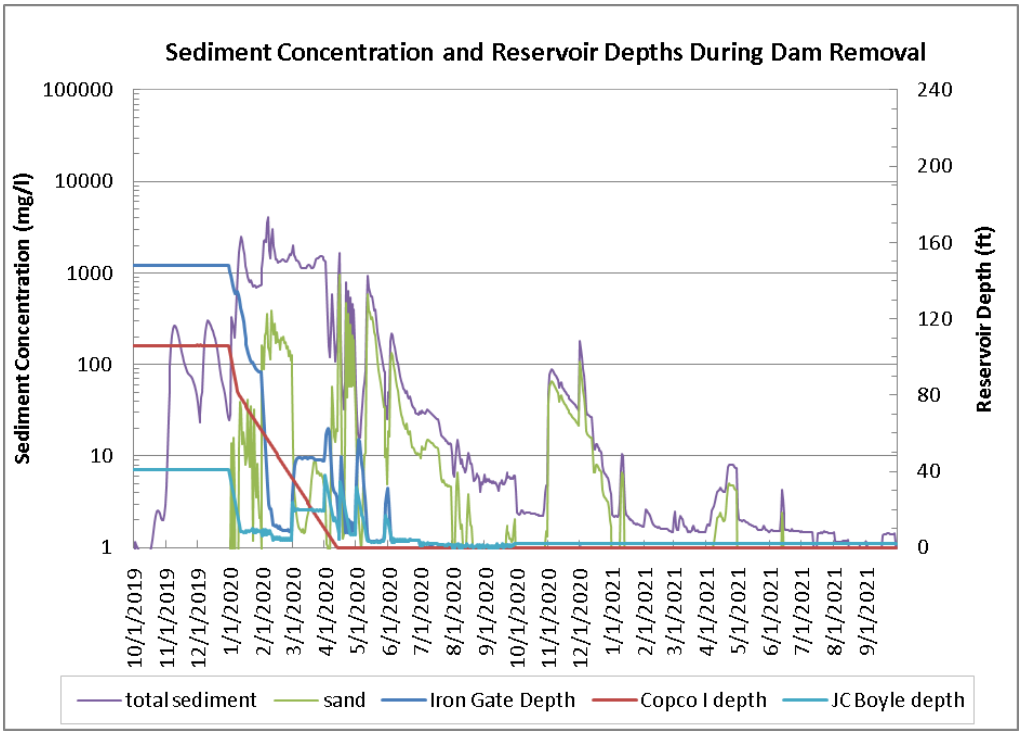

Figure 23-25. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1984 (wet year) Scenario 3.

23.4. Scenario 4

Scenario 4 assumes that the low level outlet of Copco 1 is used to empty the reservoir and in addition Copco 1 is notched from the top at a rate of 6ft/wk. Therefore, the dam is removed to the existing stream bed by the end of February. The results for the reservoir routing are shown in Figure 23-26, Figure 23-27, and Figure 23-28. The results for J.C. Boyle are essentially the same for all Scenarios.

Copco 1 does not refill because the dam is removed by March 1. This eliminates the large spikes in concentration that occurred under Scenario 1 when the reservoir refills and then empties. The results for the sediment concentrations are given in Figure 23-29, Figure 23-30, and Figure 23-31 for the dry, median, and wet years.

There are still smaller spikes in concentration due to the refilling of Iron Gate in the wet year, but the concentration is below 1,000 mg/l downstream of Iron Gate after March 1 for all water year types.

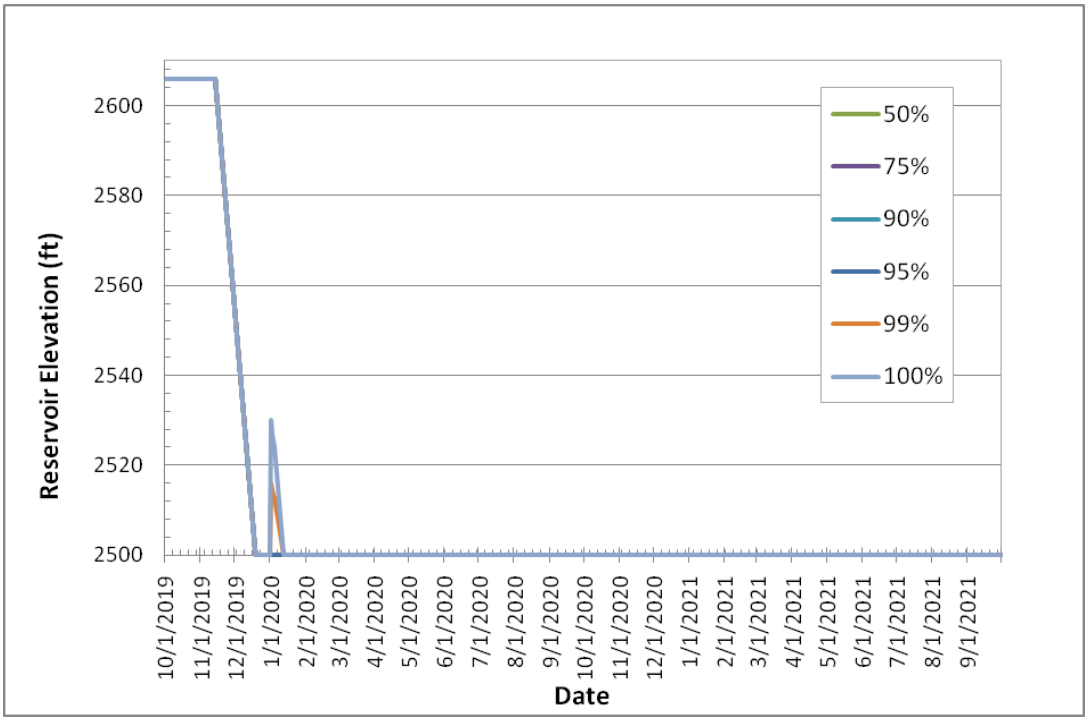

Figure 23-26. Copco 1 Non-Exceedance Elevations for all years from 1961 to 2008 for Scenario 4.

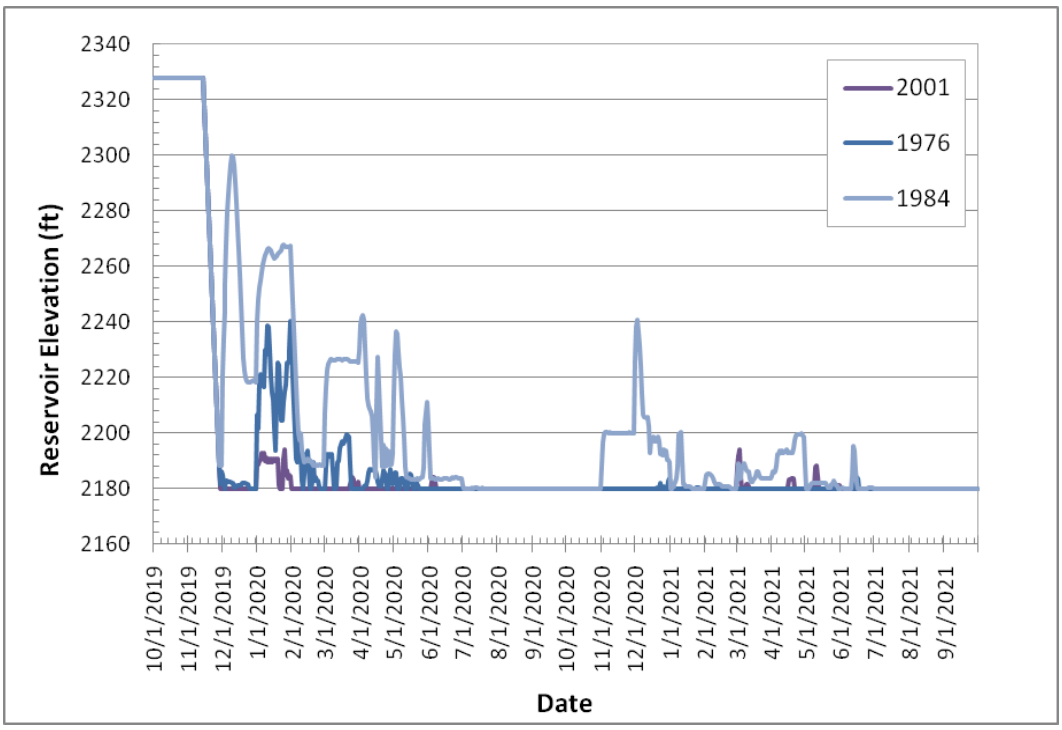

Figure 23-27. Iron Gate reservoir elevations for typical Dry (2001), Median (1976), and Wet (1984) years for Scenario 4.

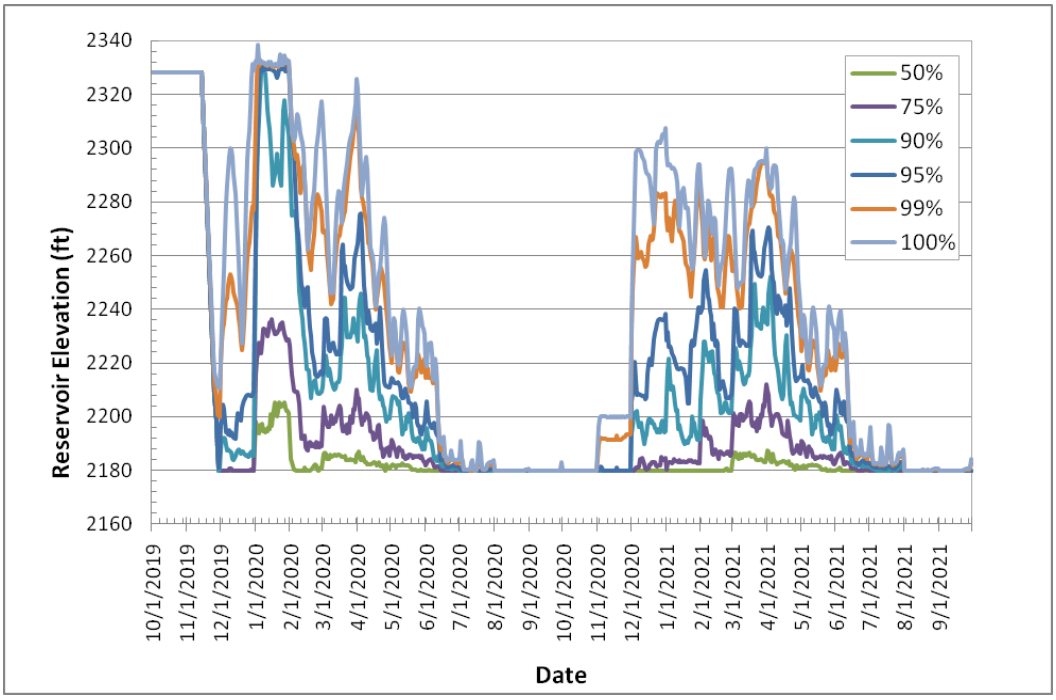

Figure 23-28. Iron Gate Non-Exceedance Elevations for all years from 1961 to 2008 for Scenario 4.

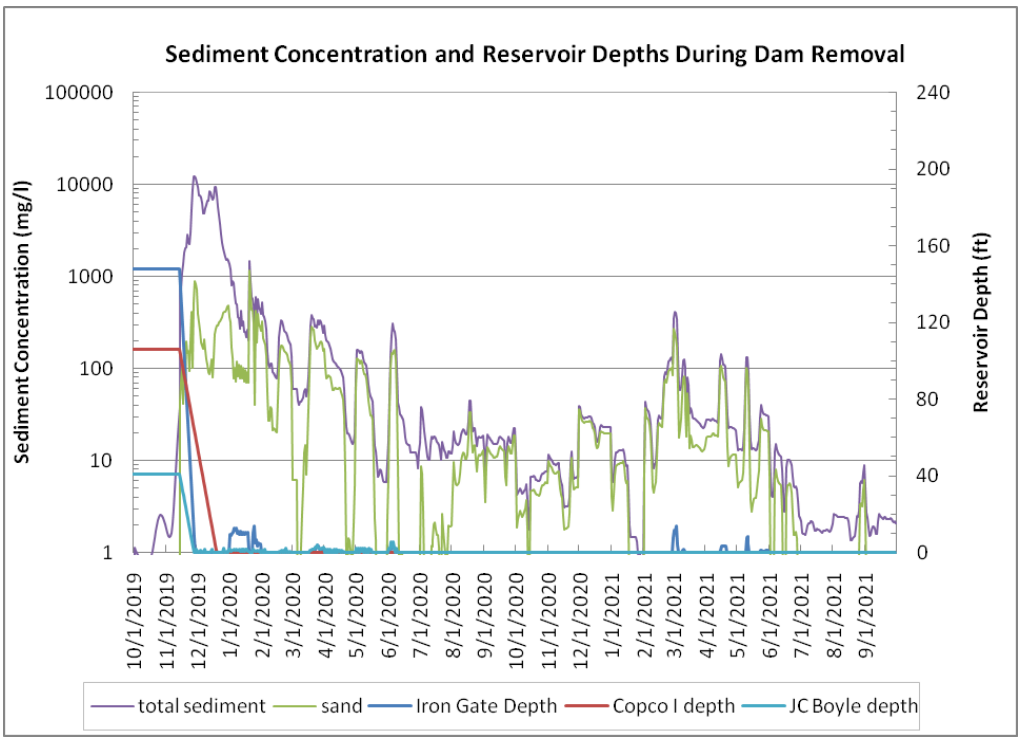

Figure 23-29. Simulated reservoir depths and sediment concentration below Iron Gate for WY 2001 (Dry year) for Scenario 4.

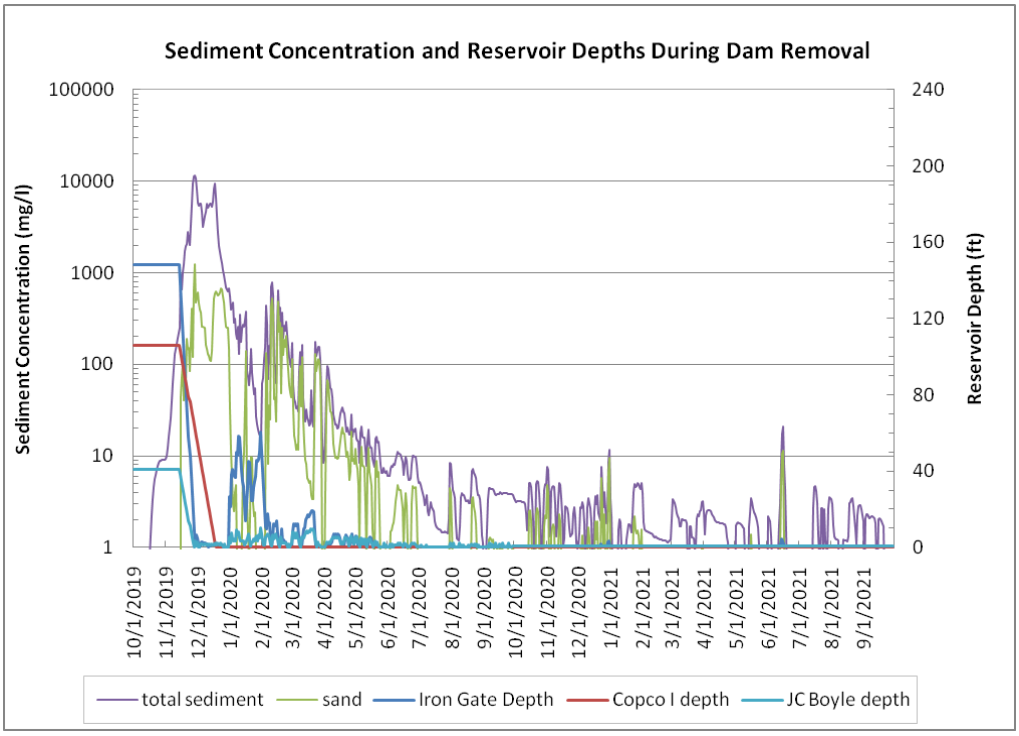

Figure 23-30. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1976 (median year) for Scenario 4.

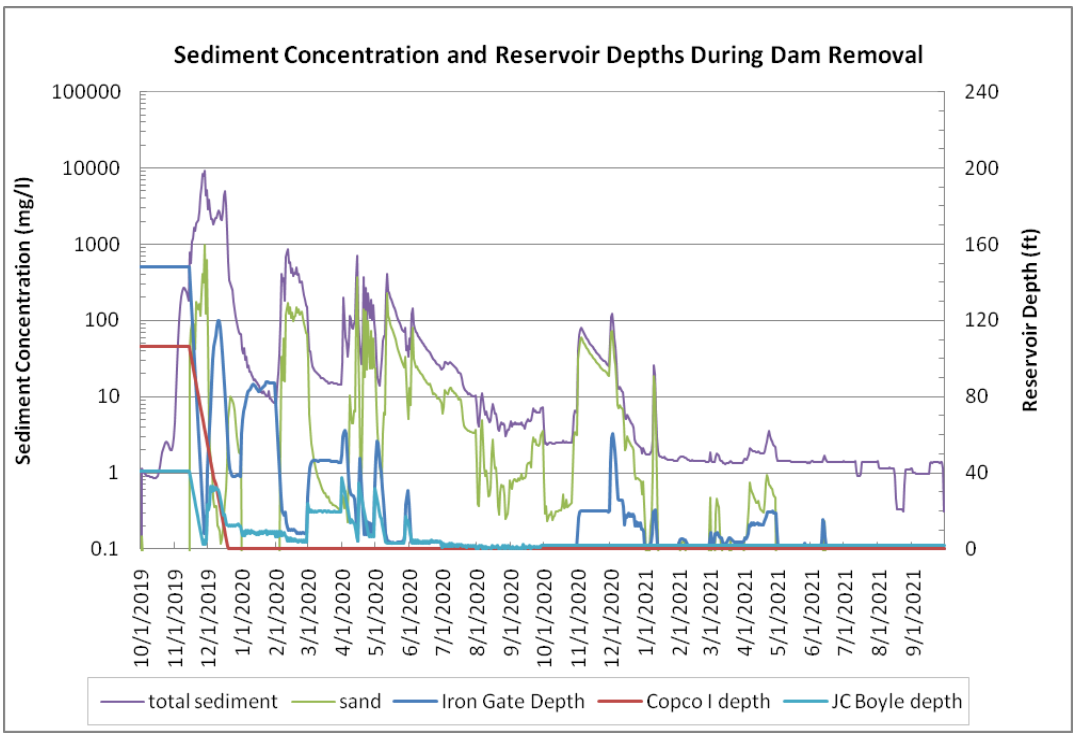

Figure 23-31. Simulated Reservoir Depths and Sediment Concentration below Iron Gate for WY 1984 (wet year) for Scenario 4.

23.5. Scenario 5

Scenario 5 assumes drawdown commences on Jan 1, 2020. The low level outlet of Copco 1 is used and in addition Copco 1 is notched from the top at a rate of 6ft/wk. Therefore, the dam is removed to the existing stream bed by mid April. The results for the reservoir routing are shown in Figure 23-26, Figure 23-27, and Figure 23-28.

Copco 1 drains more quickly for Scenario 5 than scenario 3 because the low-level outlet tunnel is used in addition to notching Copco 1 from the top. Because Copco 1 is drawdown faster in Scenario 5 than 3, the peak concentrations are higher and the concentrations are of shorter duration. The results for the sediment concentrations are given in Figure 23-29, Figure 23-30, and Figure 23-31 for the dry, median, and wet years.

There are still smaller spikes in concentration due to the refilling of Iron Gate in the wet year.

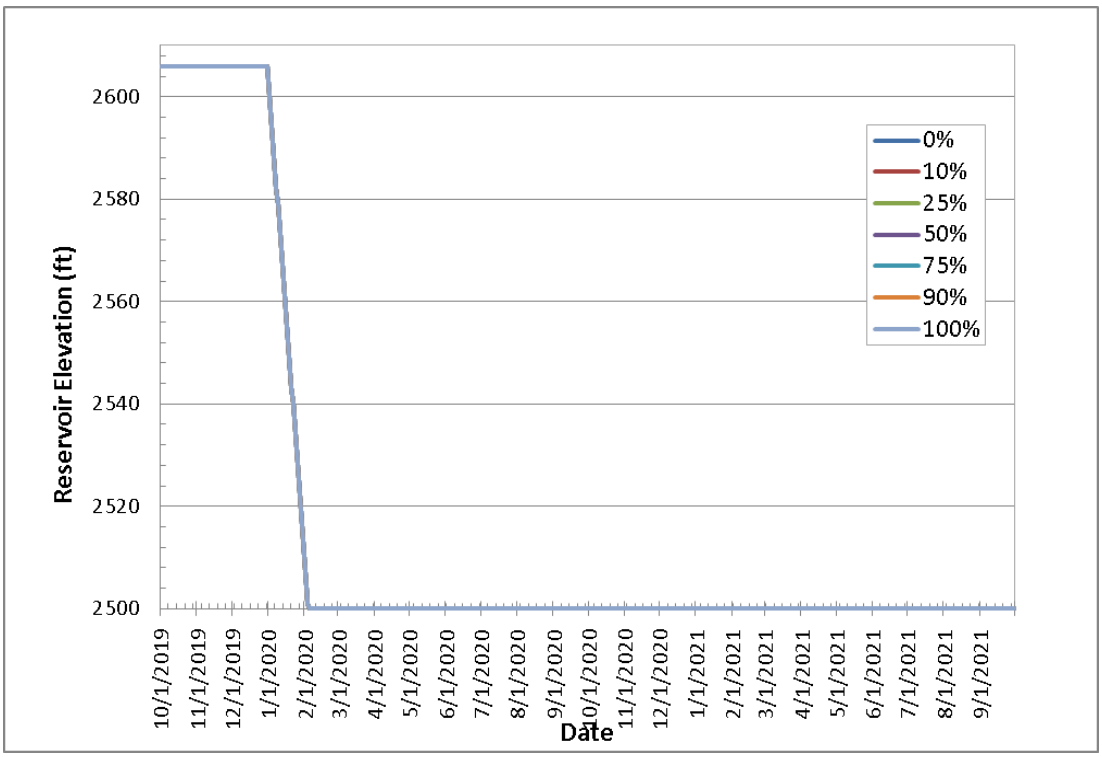

Figure 23-32. Copco 1 Non-Exceedance Elevations for all years from 1961 to 2008 for Scenario 5.

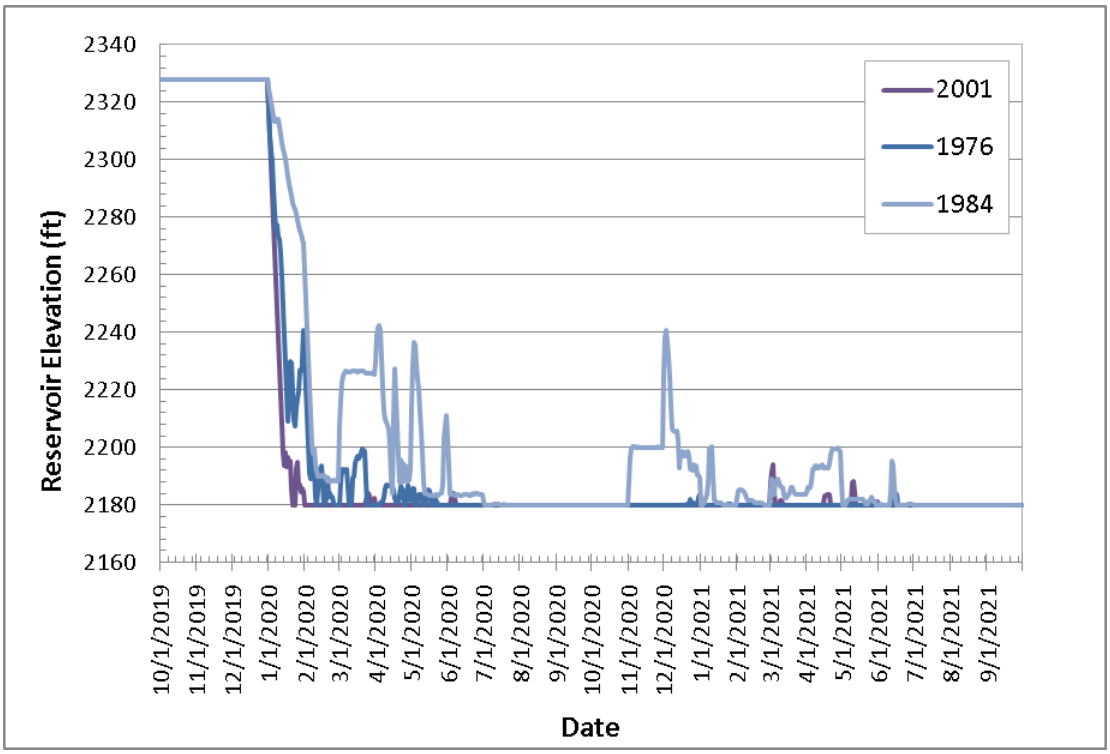

Figure 23-33. Iron Gate reservoir elevations for typical Dry (2001), Median (1976), and Wet (1984) years for Scenario 5.

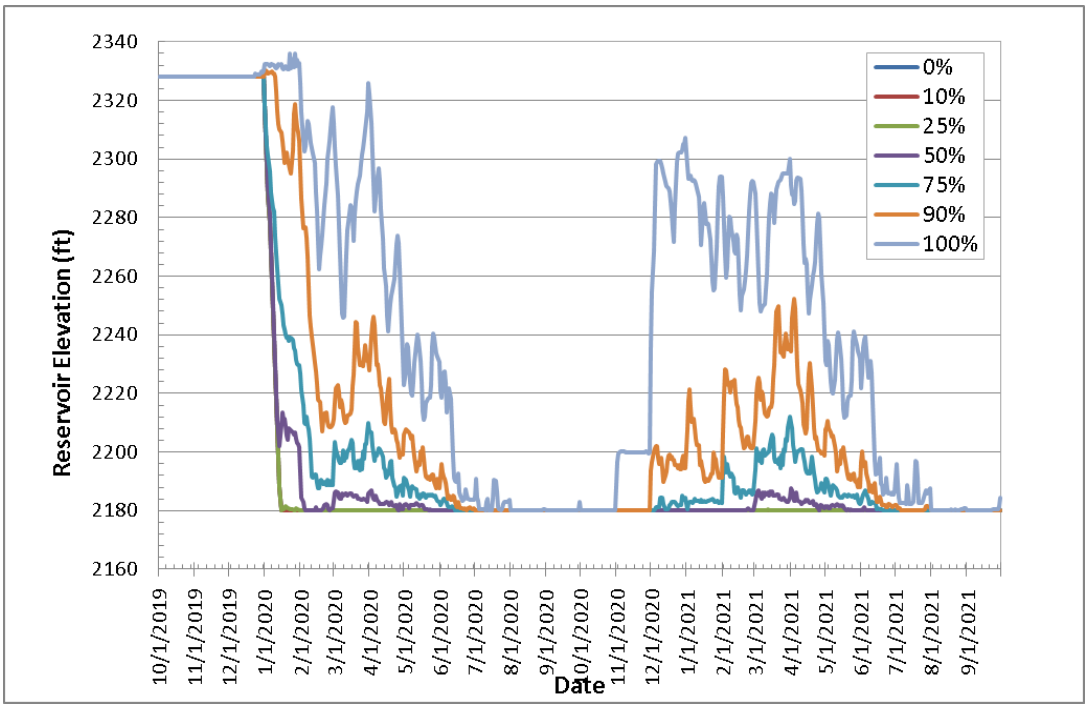

Figure 23-34. Iron Gate Non-Exceedance Elevations for all years from 1961 to 2008 for Scenario 5.

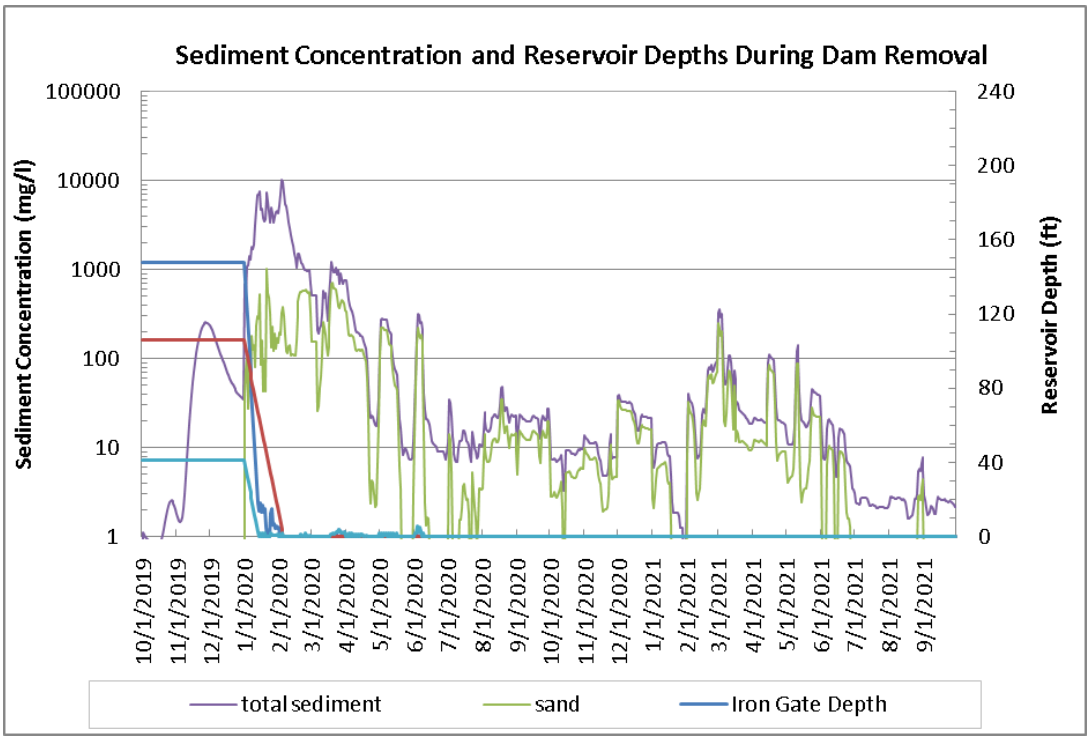

Figure 23-35. Simulated reservoir depths and sediment concentration below Iron Gate for WY 2001 (Dry year) for Scenario 5.

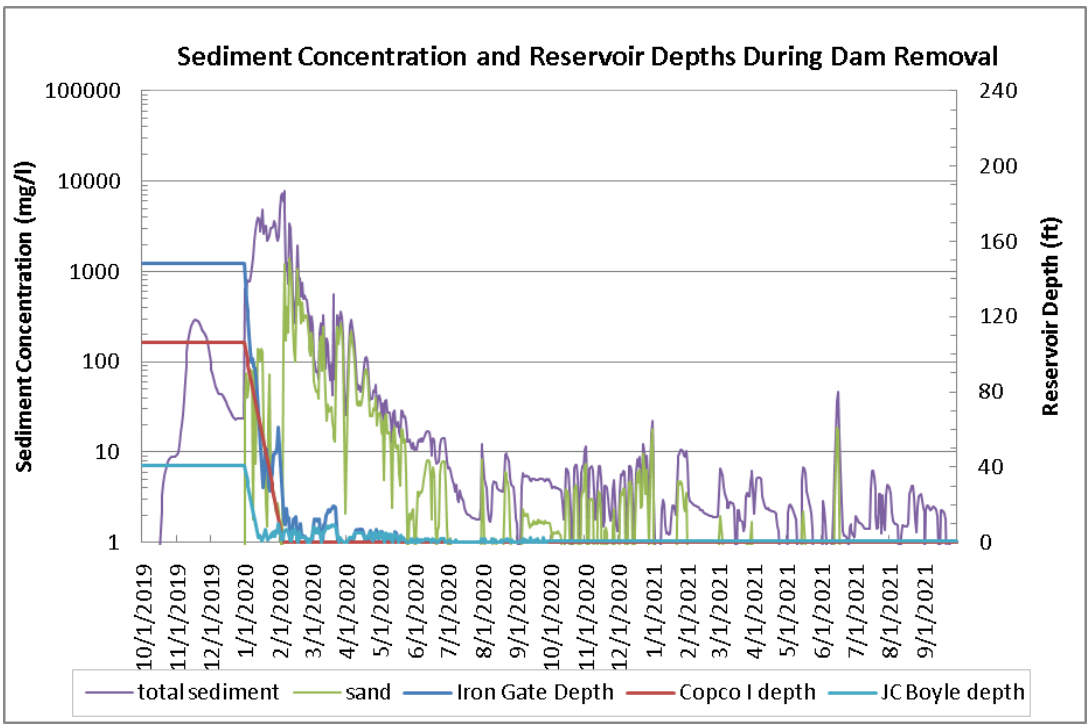

Figure 23-36. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1976 (Median year) for Scenario 5.

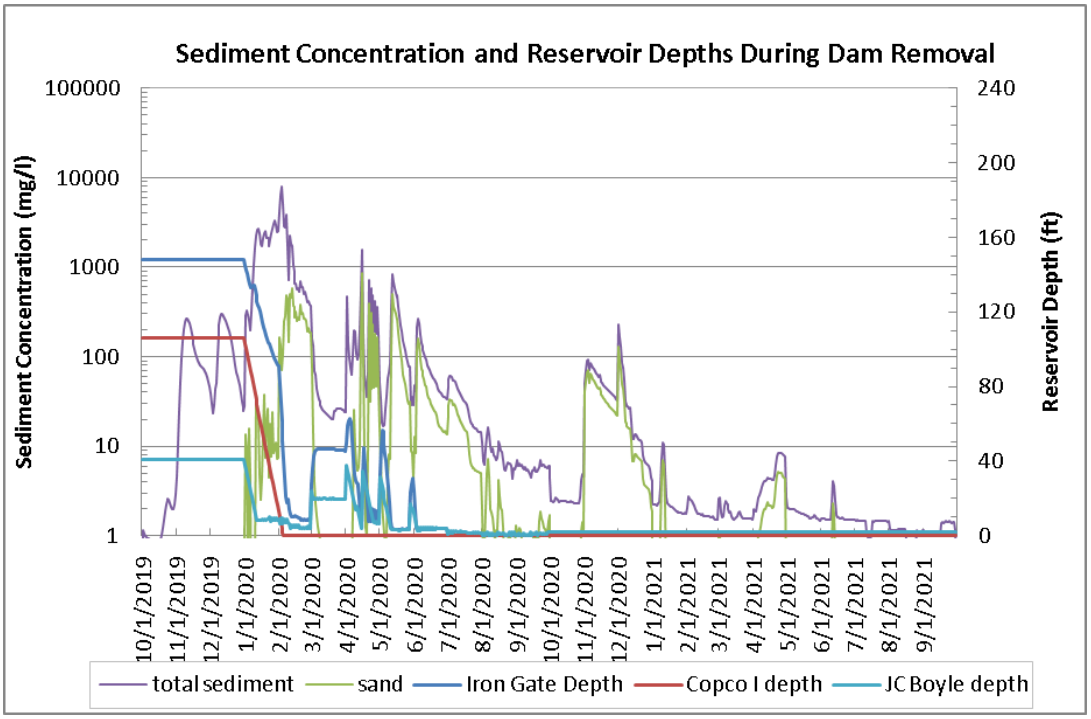

Figure 23-37. Simulated Reservoir Depths and Sediment Concentration below Iron Gate for WY 1984 (wet year) for Scenario 5.

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23.6. Scenario 6

Scenario 6 assumes drawdown commences on Nov 15, 2019. The low level outlet of Copco 1 is used and in addition Copco 1 is notched from the top at a rate of 6ft/wk. Therefore, the dam is removed to the existing stream bed by Mar 1, 2020. The drawdown rate is limited to 1 ft/day for the upper 50 feet of the reservoir and 3 ft/d below that. Drawdown at J.C. Boyle is assumed to begin Feb 15, 2020. The reservoir elevations for J.C. Boyle are shown in Figure 23-38.

The results for the sediment concentrations are given in Figure 23-39, Figure 23-40, and Figure 23-41, and for the dry, median, and wet years.

The results are similar to Scenario 2, but there is a small spike in concentration when J.C. Boyle is finally emptied in early March. The spike in concentration lasts only 1 day. In dry years, it can exceed 1,000 mg/l, but the high concentrations quickly recede.

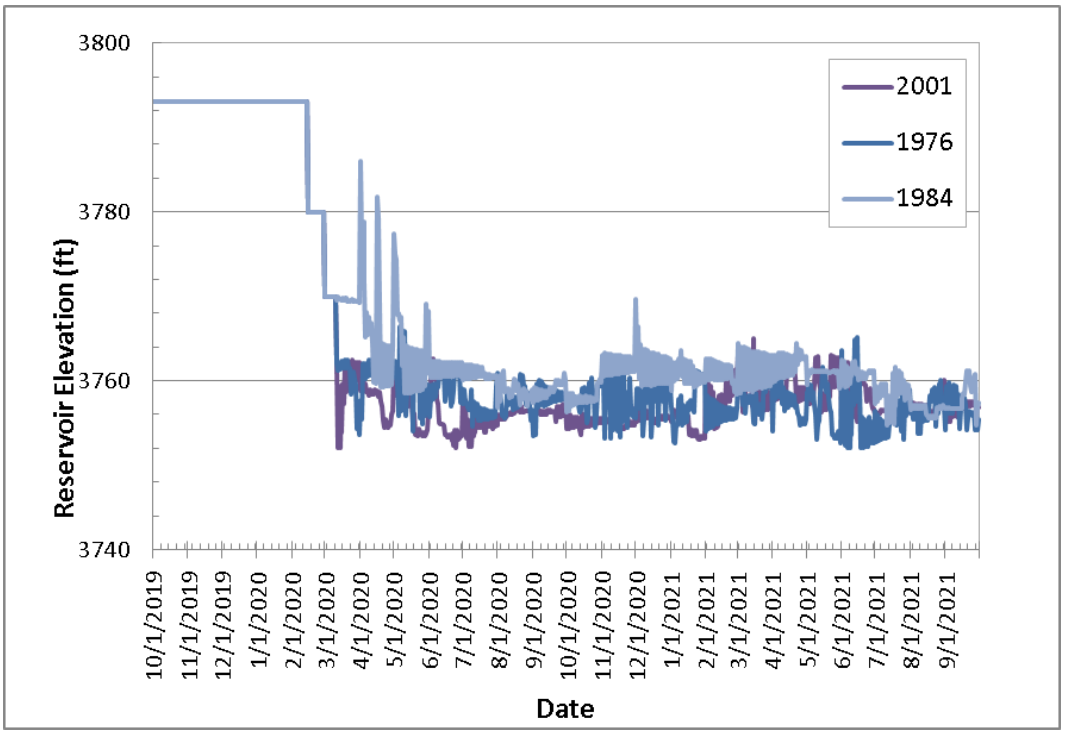

Figure 23-38. J.C. Boyle Elevations for dry, median, and wet year for Scenario 6.

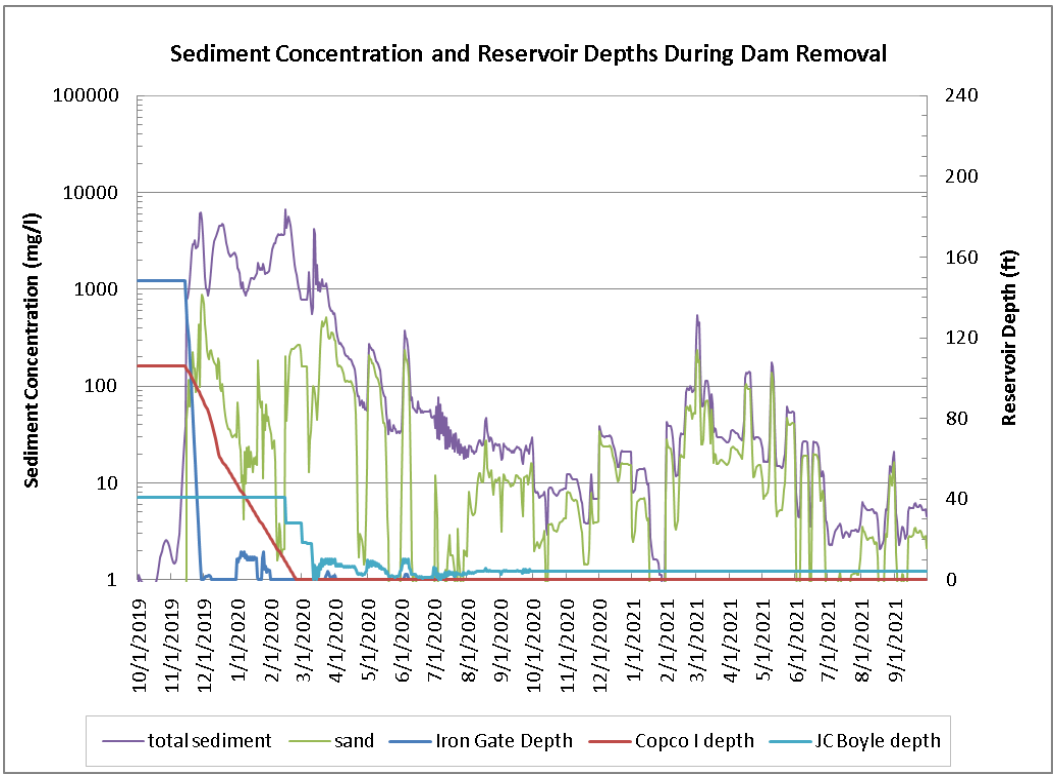

Figure 23-39. Simulated reservoir depths and sediment concentration below Iron Gate for WY 2001 (Dry year) for Scenario 6.

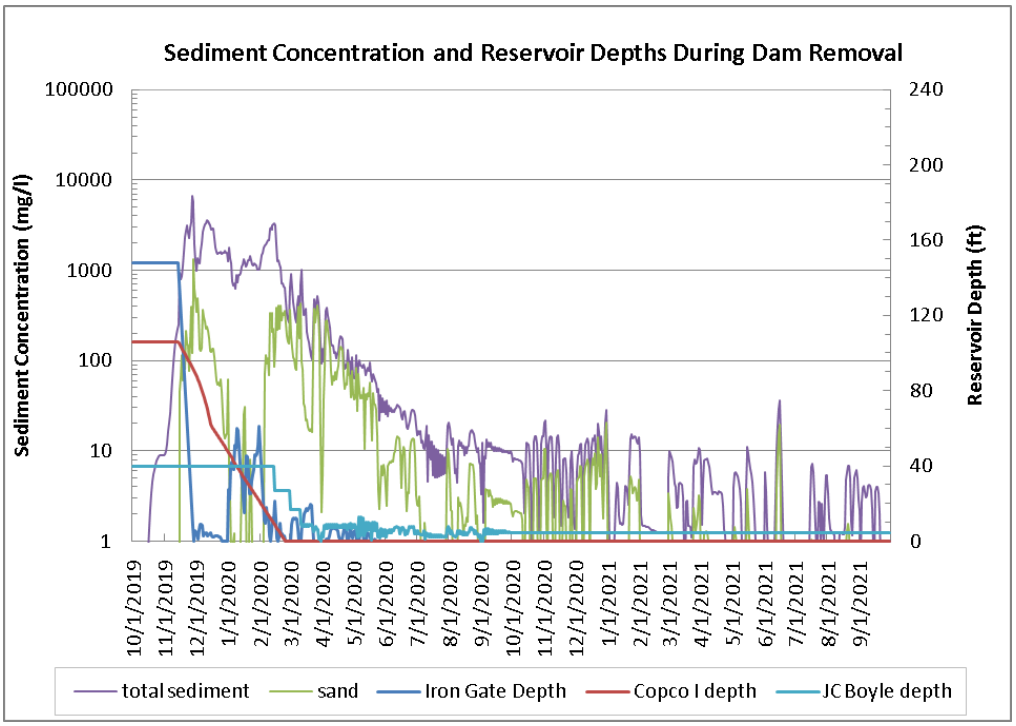

Figure 23-40. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1976 (median year) for Scenario 6.

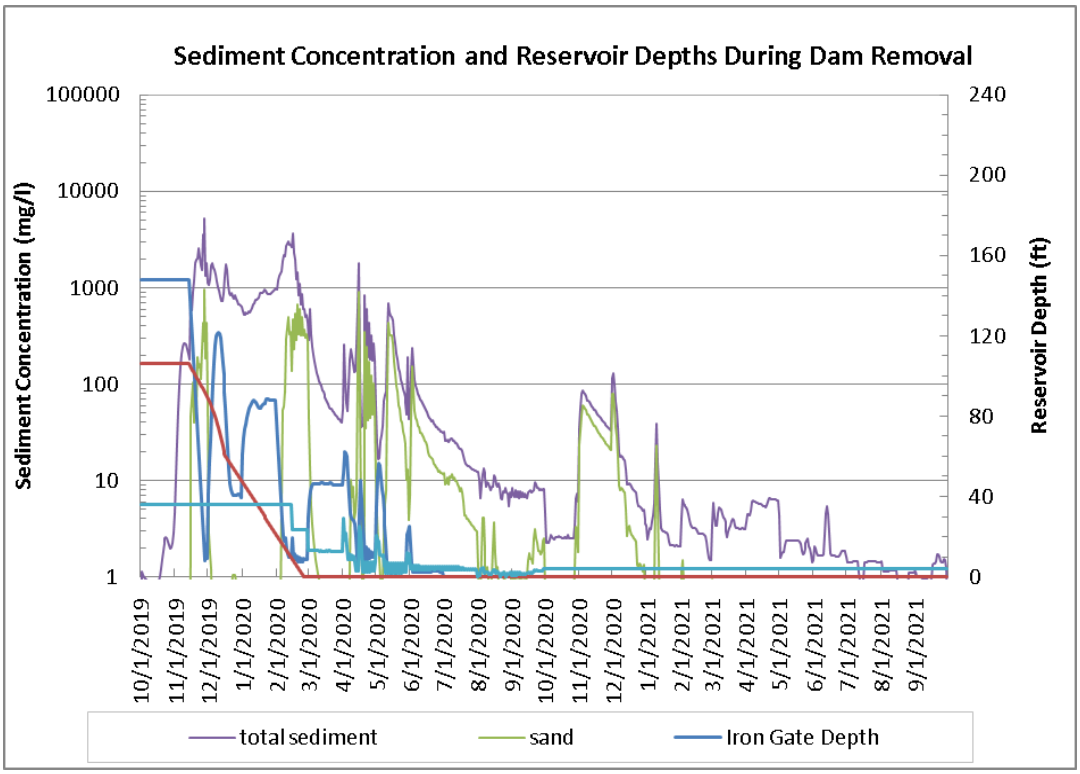

Figure 23-41. Simulated Reservoir Depths and Sediment Concentration below Iron Gate for WY 1984 (wet year) for Scenario 6.

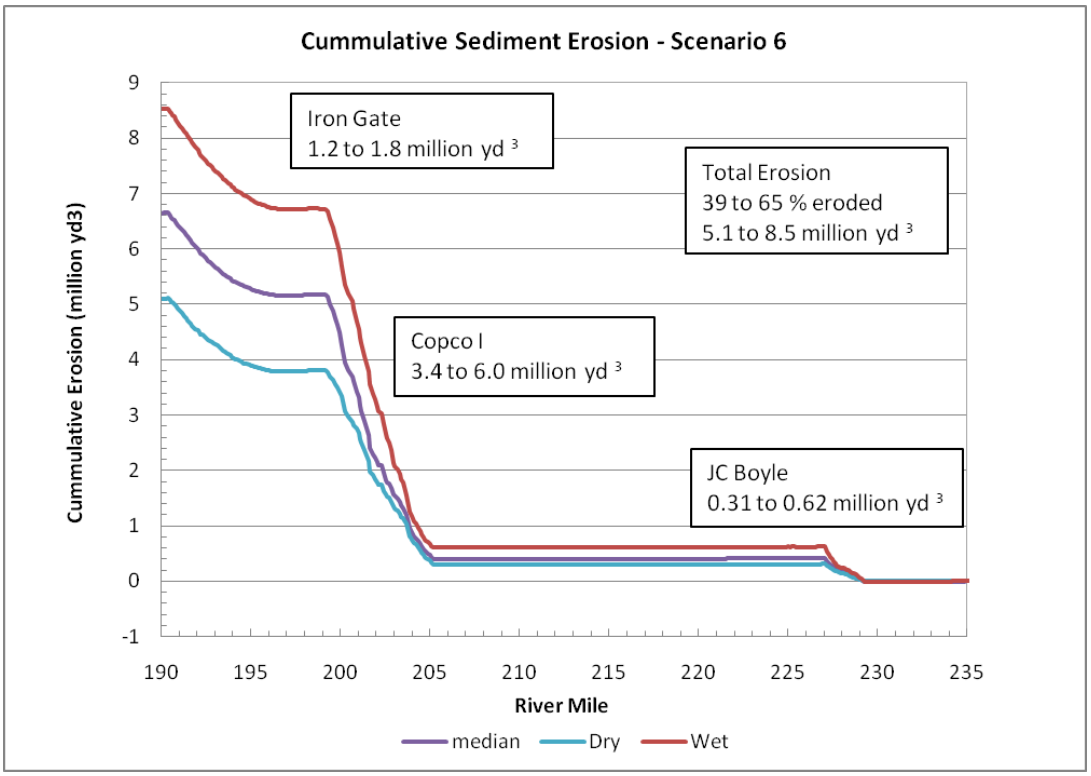

Figure 23-42. Cumulative sediment erosion for Scenario 6.

23.7. Scenario 7

Scenario 7 assumes drawdown for all three reservoirs commences on Jan 1, 2020. The low level outlet of Copco 1 is used and in addition Copco 1 is notched from the top at a rate of 6ft/wk. Therefore, the dam is removed to the existing stream bed by mid April 2020. The drawdown rate is limited to 1 ft/day for the upper 50 feet of the reservoir and 3 ft/d below that. Drawdown at J.C. Boyle is assumed to occur in a manner similar to Scenario 6, but begins Jan 1, 2020. The reservoir elevations for J.C. Boyle are shown in Figure 23-38.

Sediment Concentrations

The results for the sediment concentrations at Iron Gate are given in Figure 23-39, Figure 23-40, and Figure 23-41, and for the dry, median, and wet years. The results are similar to Scenario 3.

There are slightly elevated concentrations in November prior to the start of drawdown. There are fines in the upper portion of the reservoirs that are mobilized upon model start up and carried through the system. It doesn't reflect reality, but is due to probably putting fine material too far upstream in the reservoir where velocities are still high enough to mobilize it.

A comparison between Scenario 7 and background concentrations for dry, median, and wet years at Seiad Valley, Orleans and Klamath stream gages is given in Figure 23-48, Figure 23-49, and Figure 23-50, respectively. The concentrations due to dam removal generally decrease in the downstream direction. The maximum concentrations at Iron Gate are approximately 8,000 mg/l under a dry water year, 6,000 mg/l under a median water year, and 4,000 mg/l under a wet water year. The maximum concentrations correspond to maximum drawdown rates or to the last portion of reservoir evacuation. It is expected that the maximum concentrations are under predicted because the model does not represent the variability that will existing during drawdown. For example, bank failure is assume to occur gradually during the drawdown process. In reality, a large bank failure may occur and suddenly add a large volume of sediment to the river. This high concentration will quickly dissipate but may cause a rapid spike in concentration. The concentrations in the plot are best interpreted as daily average concentrations that may vary significantly throughout the day.

The maximum concentrations at Seiad Valley decrease to approximately 2,000 to 3,000 mg/l under dry, median, and wet conditions. During the period Jan 1 to April 15, the concentrations are usually above 1,000 mg/l during the dry years, above about 700 mg/l for the median and wet years. The main difference between the dry, median, and wet is more on the duration of the higher concentrations. The concentrations under the dry water year are more often near the maximum concentration, whereas, under the wet water year, the concentrations are commonly just below 1,000 mg/l. The background concentrations at Seiad valley

are expected to be less than 100 mg/l during months of Jan to Apr, but may spike to above 1,000 mg/l during wet water years as sediment is contributed from tributaries.

The maximum concentrations at Orleans are just above 1,000 mg/l for all water year types. Again, the main difference between dry, median, and wet is the duration that concentrations are near the maximum concentration. The background concentrations at Orleans will typically be around 100 mg/l, but will spike to around 1,000 during high flow events.

The maximum concentrations at Klamath are variable between water years. For the median and wet year, the maximum concentrations are due to high background concentrations pushing the concentrations to over 1,000 mg/l. The concentrations due to dam removal are expected to be around 700 to 800 mg/l at Klamath for the median and dry years and will occur near the end of Iron Gate drawdown in January and the end of Copco drawdown in April.

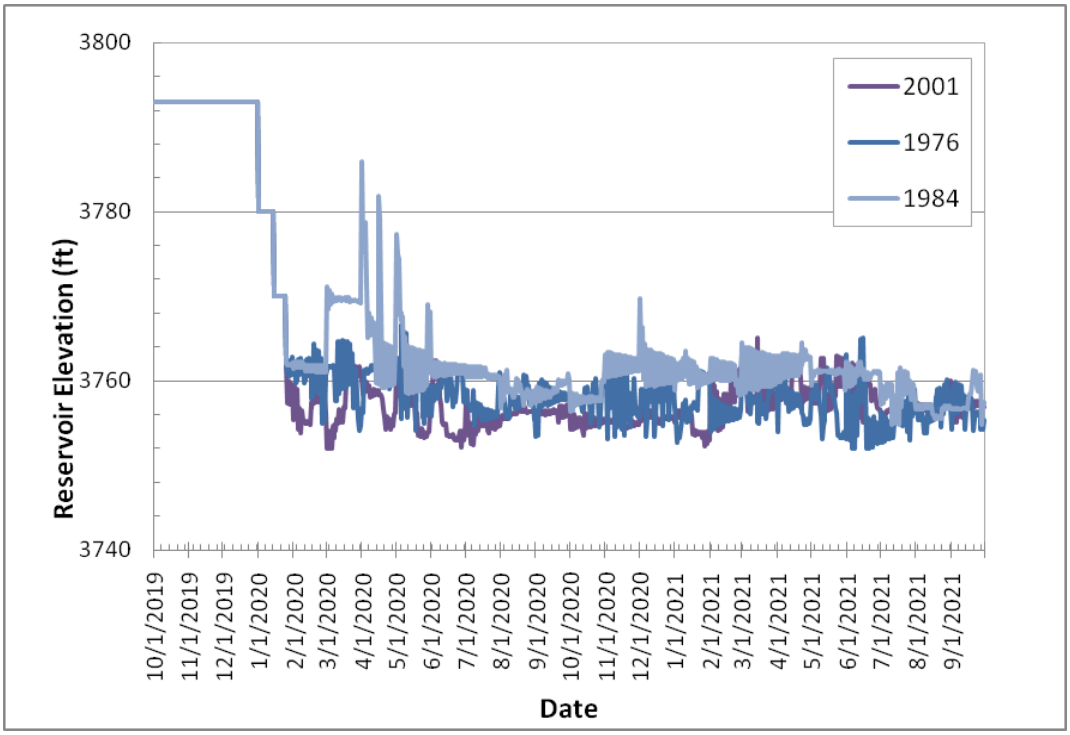

Figure 23-43. J.C. Boyle Elevations for dry, median, and wet year for Scenario 7.

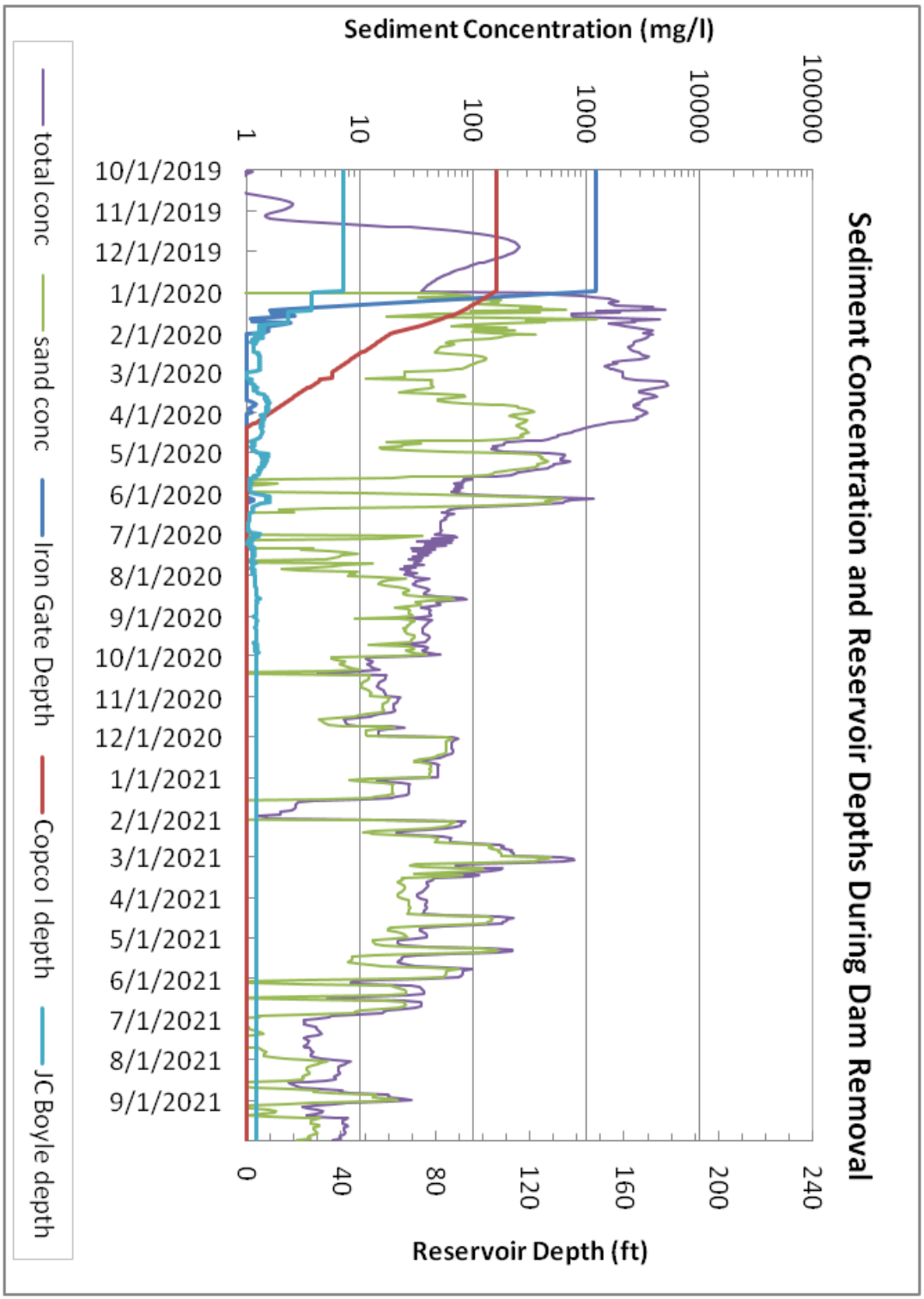

Figure 23-44. Simulated reservoir depths and sediment concentration below Iron Gate for WY 2001 (Dry year) for Scenario 7.

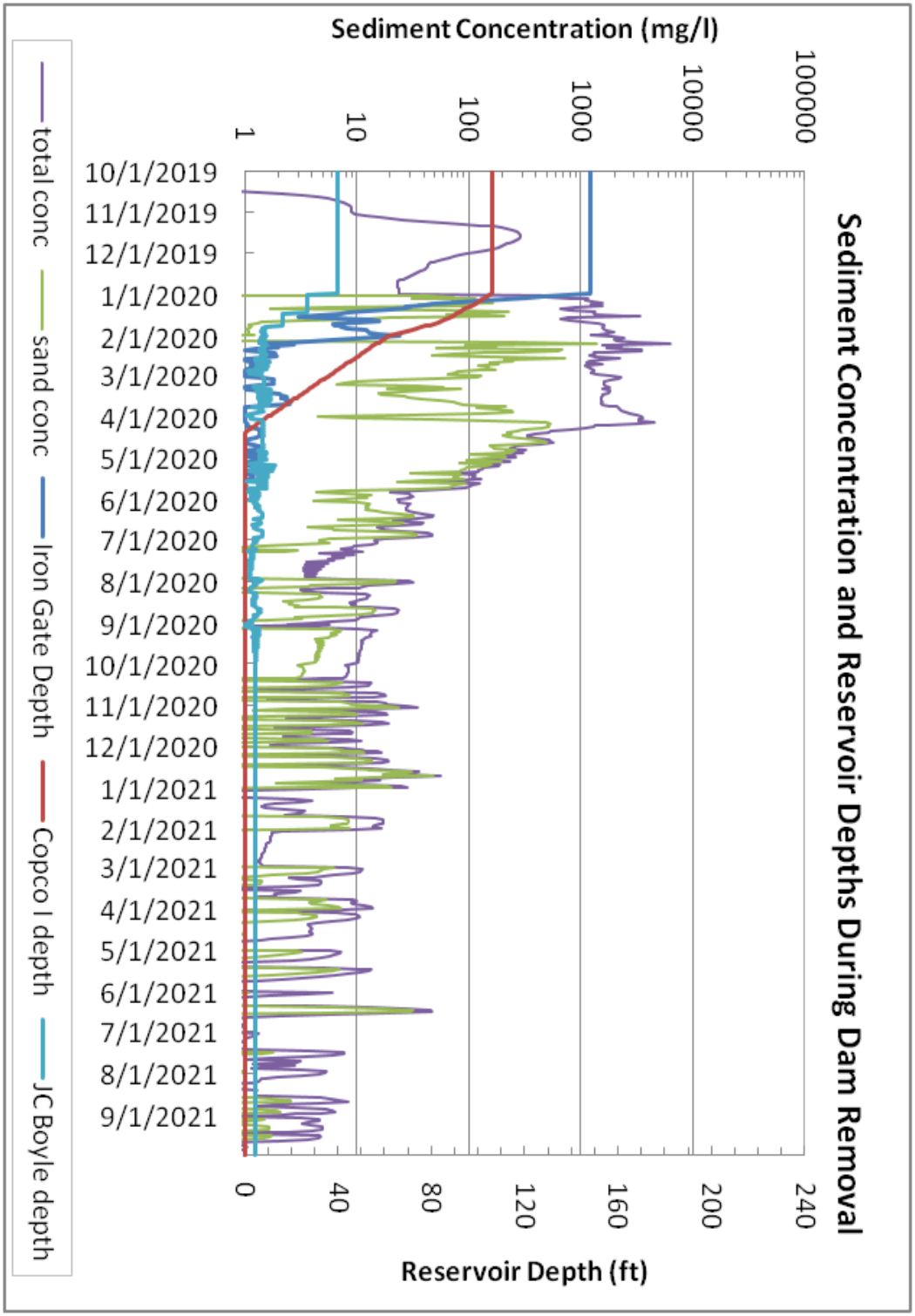

Figure 23-45. Simulated reservoir depths and sediment concentration below Iron Gate for WY 1976 (median year) for Scenario 7.

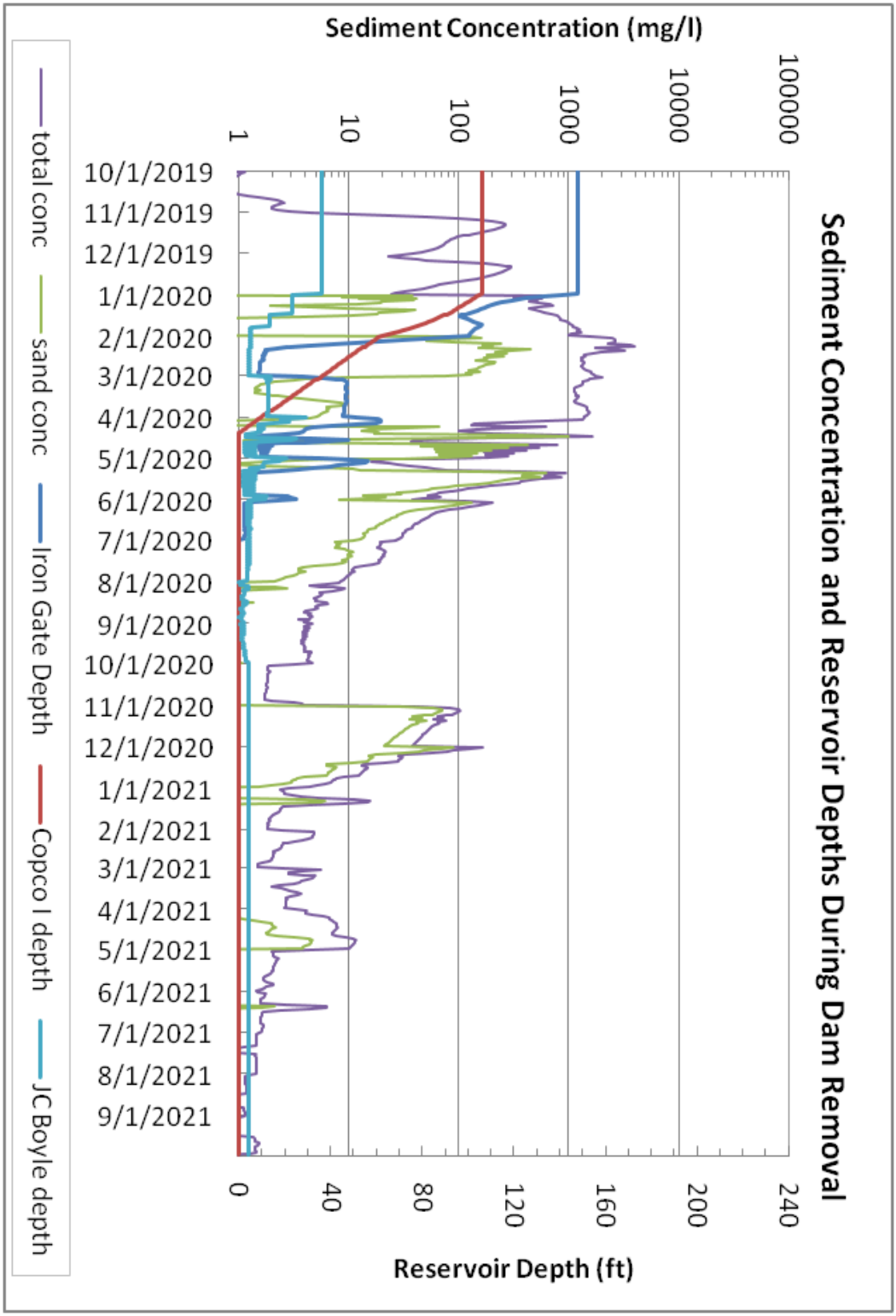

Figure 23-46. Simulated Reservoir Depths and Sediment Concentration below Iron Gate for WY 1984 (wet year) for Scenario 7.

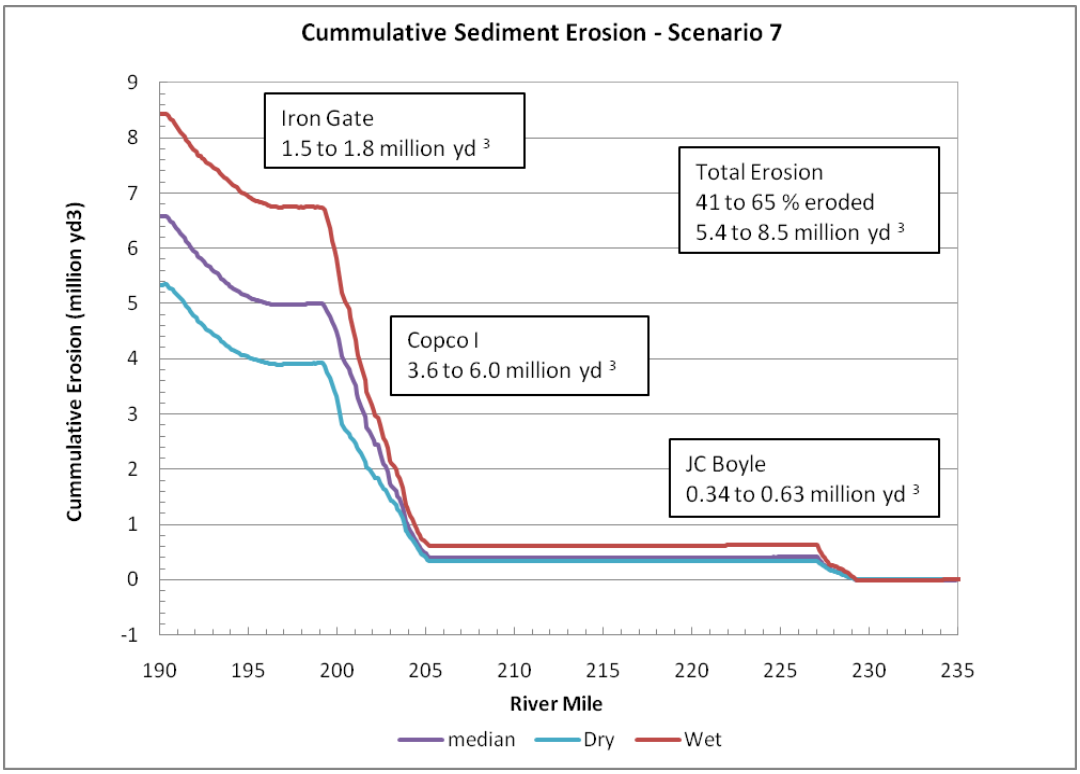

Figure 23-47. Volume of sediment erosion for Scenario 7.

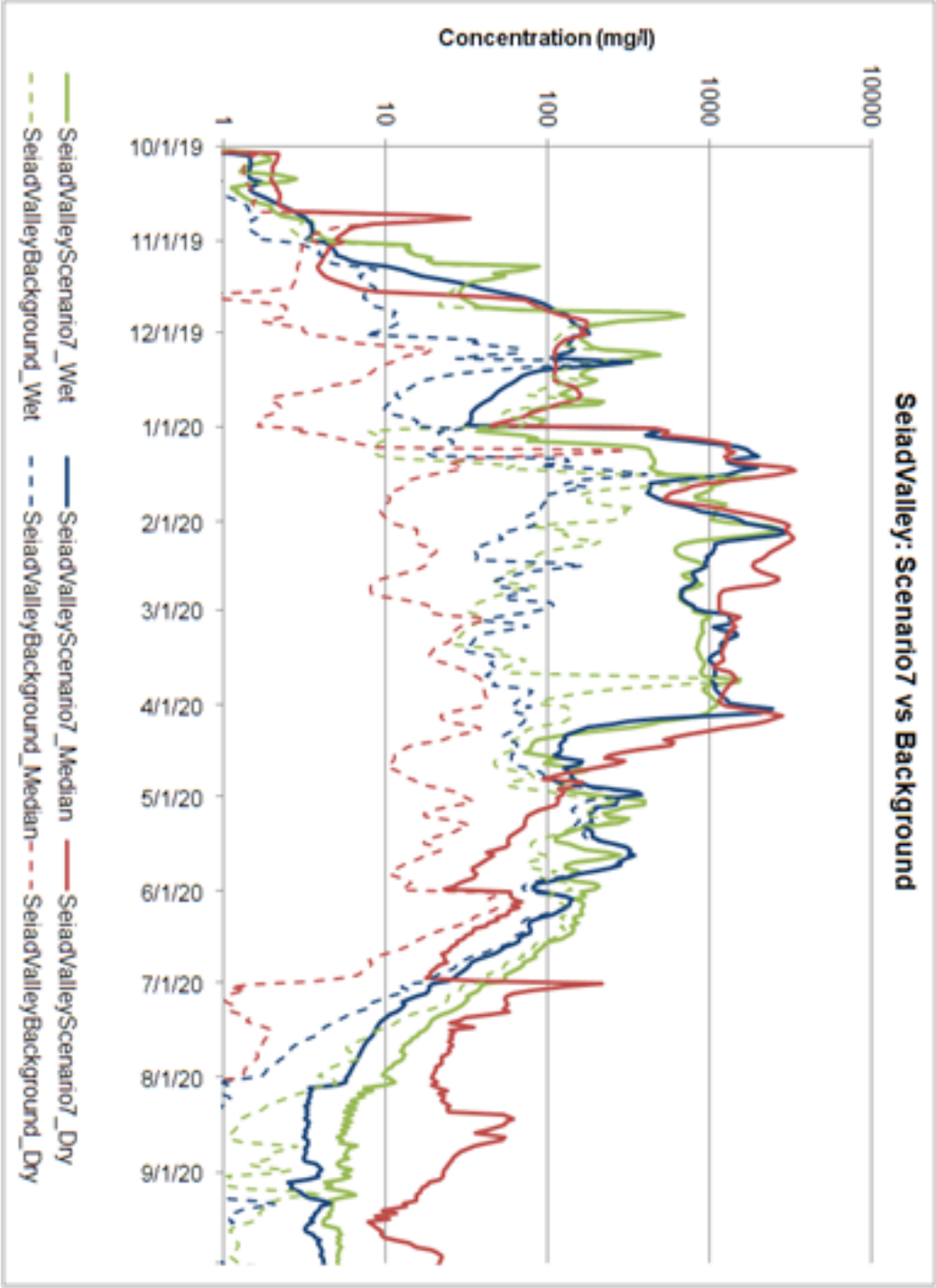

Figure 23-48. Sediment Concentrations at Seiad Valley for Scenario 7 and for Background conditions for dry, median and wet years.

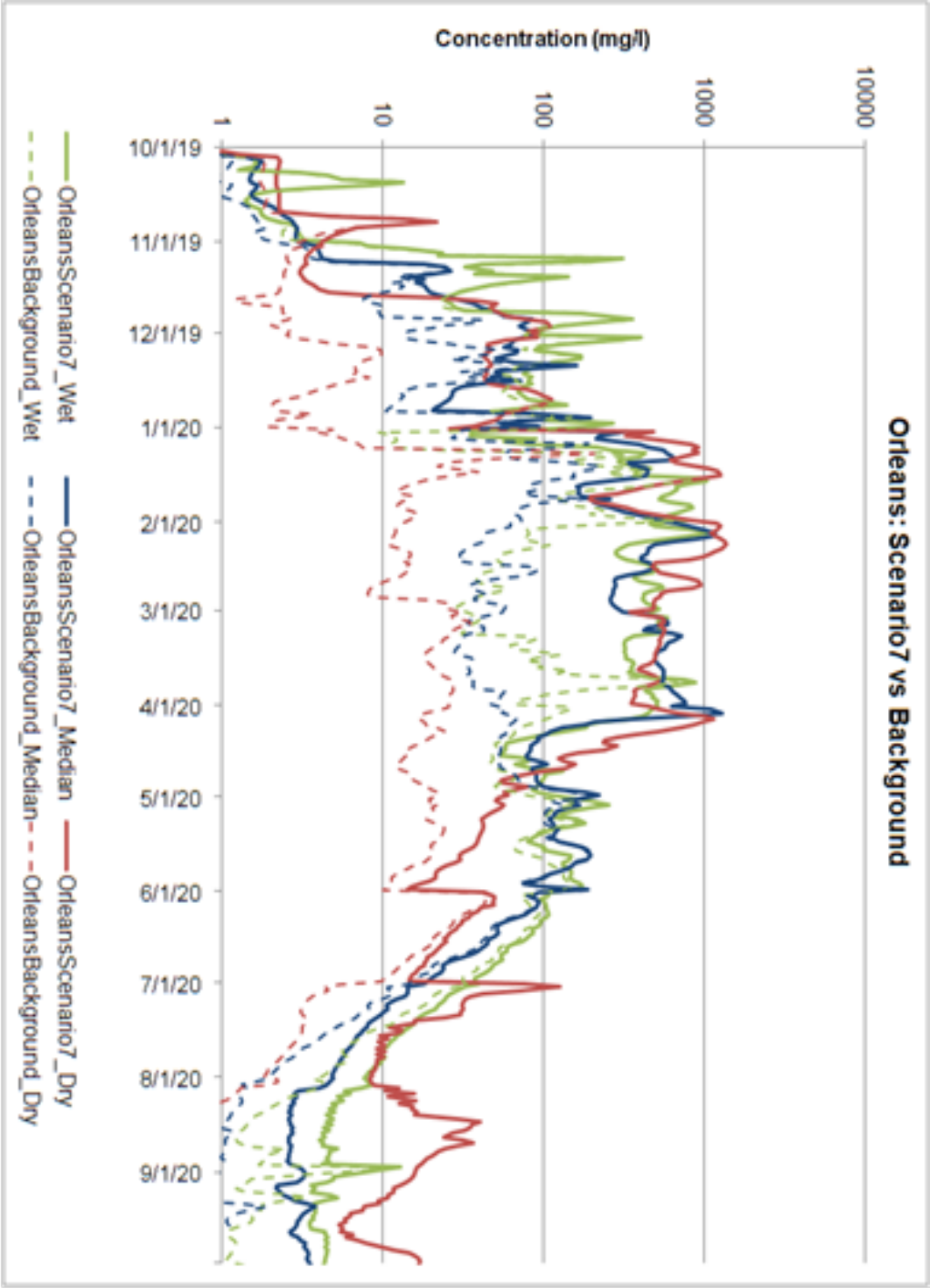

Figure 23-49. Sediment Concentrations at Orleans for Scenario 7 and for Background conditions for dry, median and wet years.

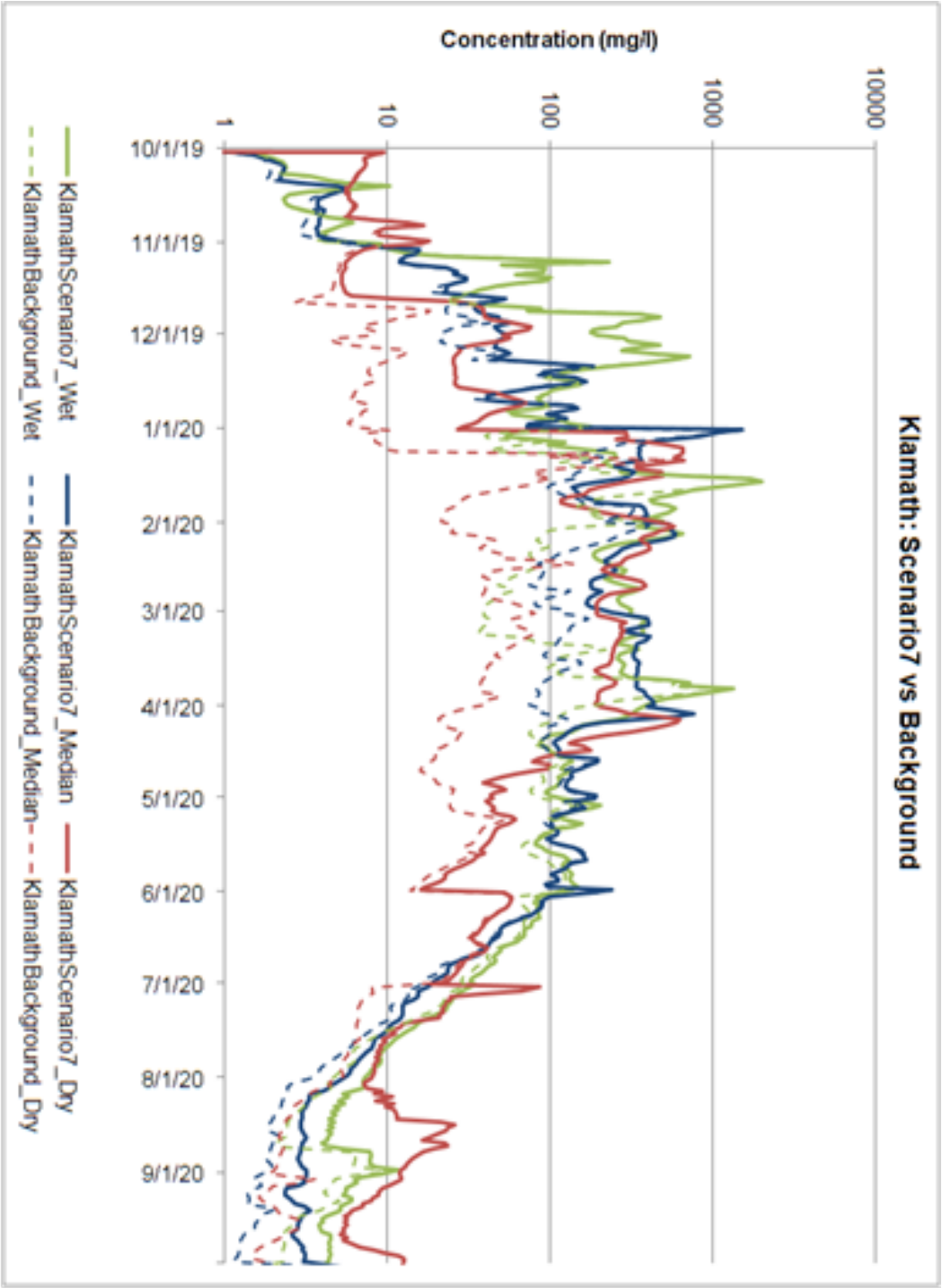

Figure 23-50. Sediment Concentrations at Klamath for Scenario 7 and for Background conditions for dry, median and wet years.

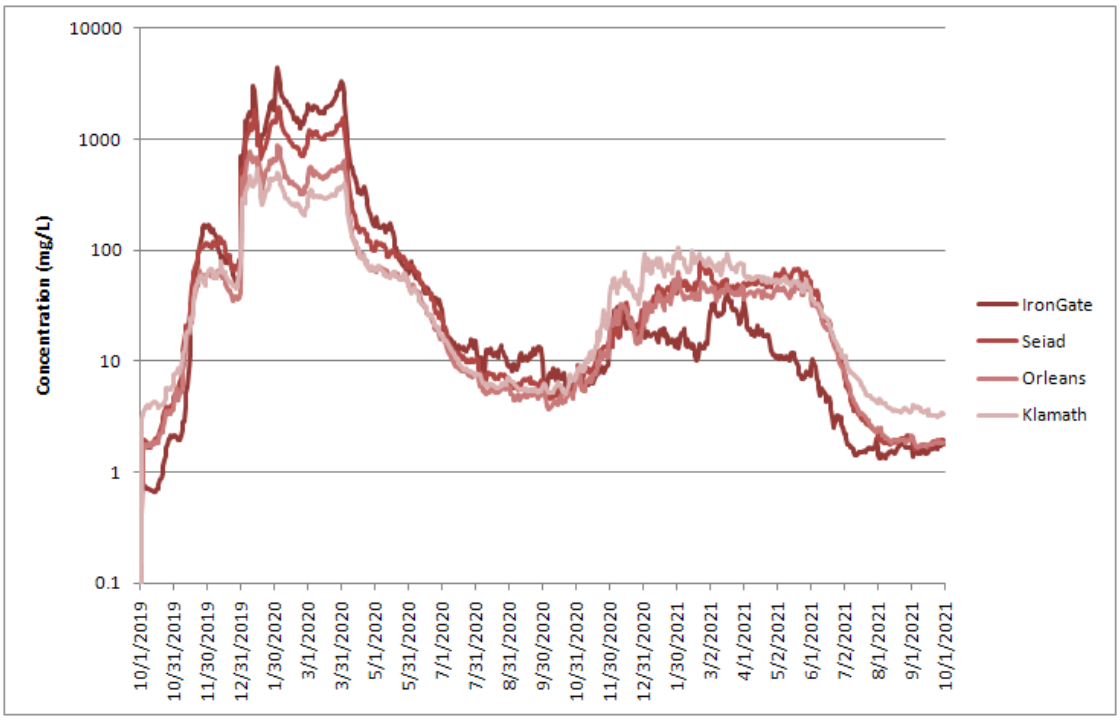

Figure 23-51. Sediment Concentrations at stream gage locations for Scenario 7 at 50% exceedance levels.

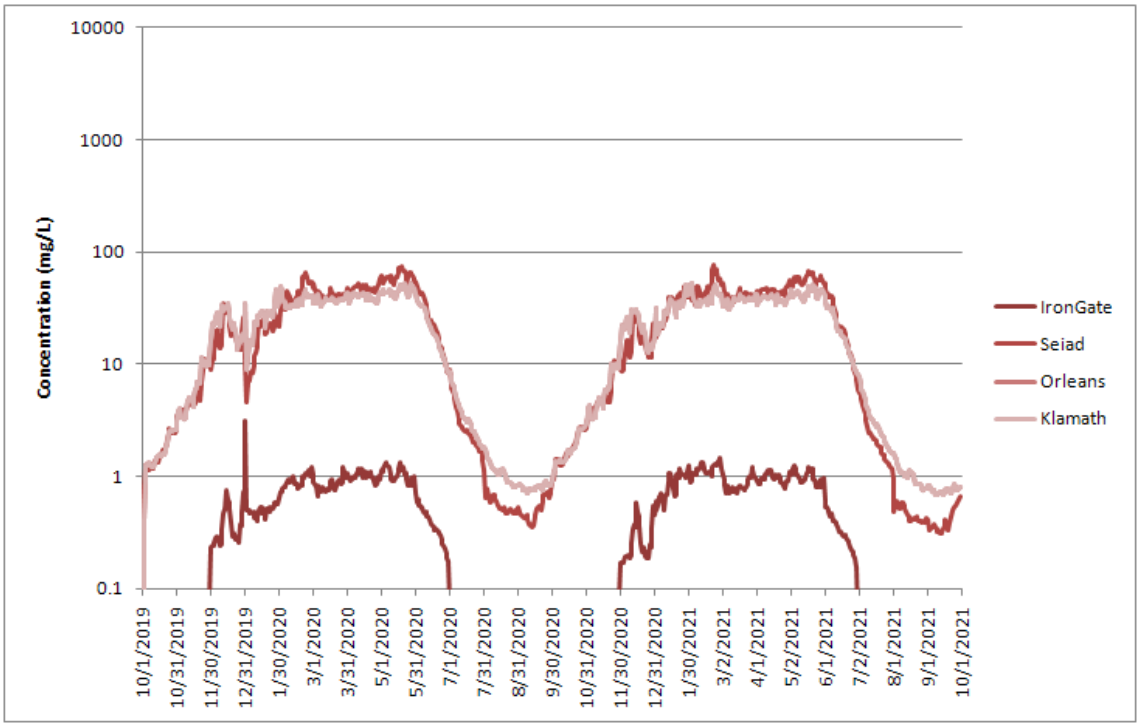

Figure 23-52. Sediment Concentrations at stream gage locations for background conditions at 50% exceedance levels.

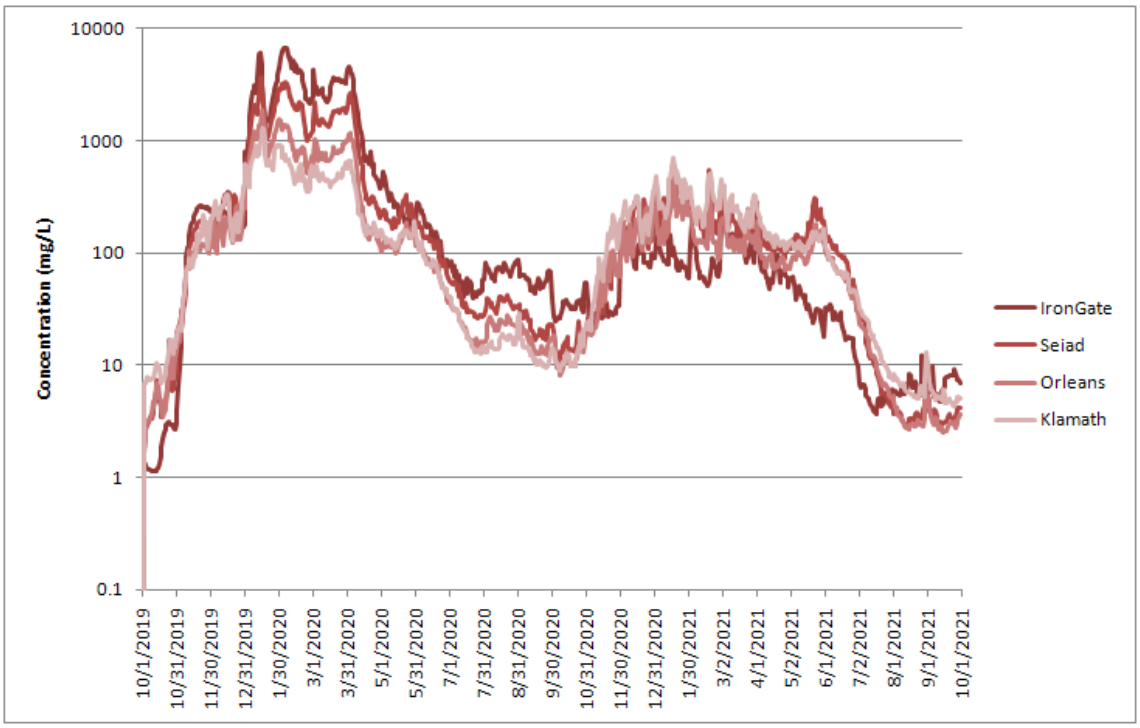

Figure 23-53. Sediment Concentrations at stream gage locations for Scenario 7 at 10% exceedance levels.

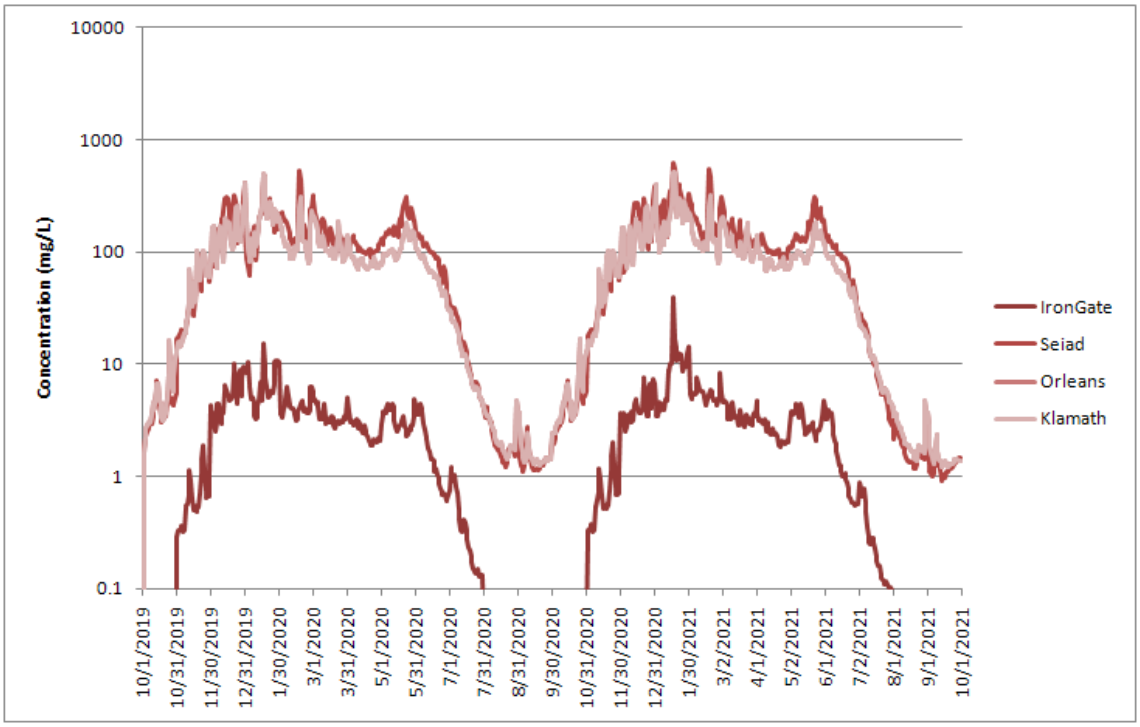

Figure 23-54. Sediment Concentrations at stream gage locations for background conditions at 10% exceedance levels.

23.8. 1D Model Sensitivity

One of the main model uncertainties was the sediment angle of repose.

Angle of Repose

The angle of repose is varied from 15 degrees to 5.7 degrees. The effect on the erosion volumes and concentration is significant. The angle of repose is likely the most important model parameter. When the angle of repose is decreased to 5.7 degrees (a slope of 10H:1V), significantly more sediment is eroded than when an angle of repose of 15 degrees is assumed. This is because a large portion of the reservoir slopes are steeper than 10%. Therefore, the sediment simply falls into the river channel with no applied shear stress.

The peak sediment concentrations are similar when an angle of repose of 5º is used, but the concentrations remain above 1,000 mg/l and 100 mg/l for a significantly longer period of time.

Geotechnical tests indicated that the angle of repose was above 25º, but Strauss (2010) indicated that this is likely an upper estimate and that the actual value could be significantly lower. Samples indicated the samples rapidly increase in shear strength when drained. As a simple test, the container in Figure 5-42 was tipped at a 4:1 slope a day after placement. The slope was maintained and the sediment did not show any significant movement. Therefore, as long as the sediment is freely drained, the sediment should maintain slopes of 4:1 or greater shortly after drawdown. The sediment will have very little strength when it is first saturated and an angle of repose of 5º is considered, but as the sediment drains, the angle of repose will quickly increase and it is not likely that the angle of repose remains at 5º for more than a few weeks.

It is possible that the sediment does slump toward the river channel for a period of time that is longer than predicted in the sediment model. The model assumes bank failure occurs instantaneously when in reality, the sediment may tend to act similar to a very viscous liquid for a period of time. The sediment may slowly slump into the river channel and be carried away. The duration of impacts shown in Figure 23-56 is not considered likely, but because of the large uncertainties in the project, such a scenario cannot be discounted. Water quality permits should consider potential extensions in the duration of impacts over those presented as best estimates.

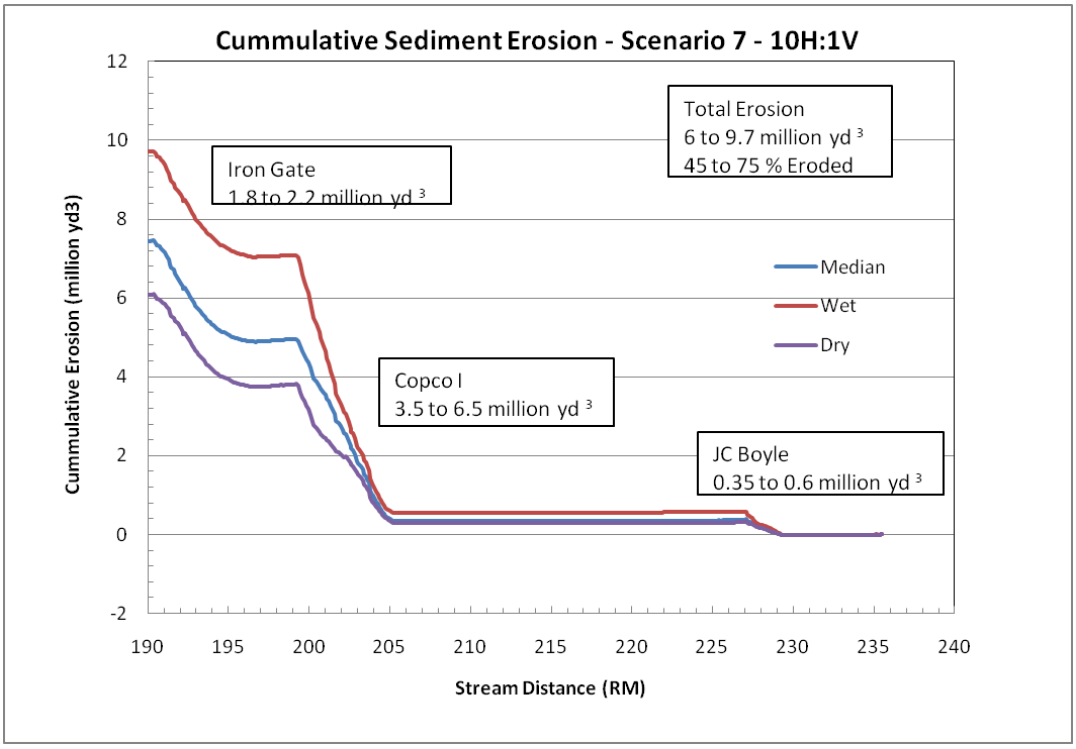

Figure 23-55. Sensitivity of Erosion Volumes to changes in Angle of Repose.

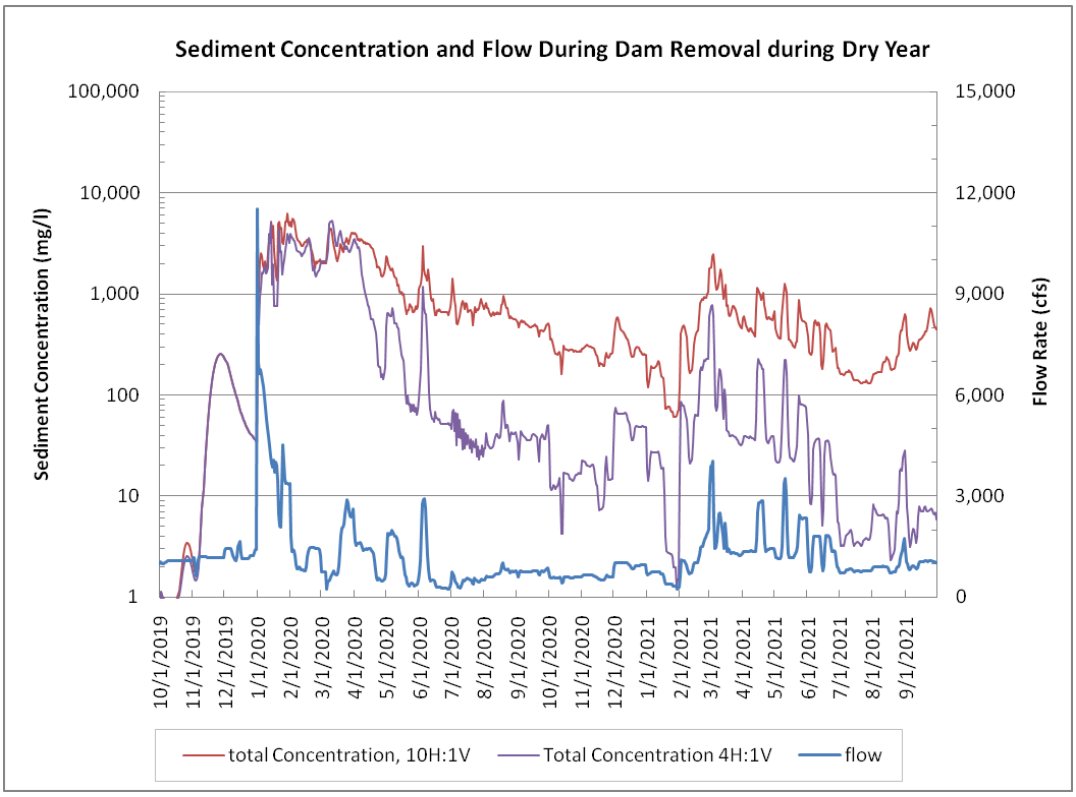

Figure 23-56. Sensitivity of model results to angle of repose of sediment.

23.9. Summary of Drawdown Model Results

The most important differences between the dam removal scenarios are the timing and magnitude of the sediment concentrations during the year of removal. There are expected to be no significant differences between the scenarios in terms of the long term impacts to sediment transport.

The sediment concentrations of all seven scenarios at the 5% exceedance level are shown in Figure 23-57. The 5% exceedance is computed on a daily basis and represents the concentration that is exceeded only 5 % of the time for a given day.

The magnitude of the sediment concentrations are greatest for the scenarios that have the higher drawdown rates at Copco 1 (Scenarios 1, 4, and 5). The peak concentrations are near or above 10,000 mg/l for several weeks. The magnitude of the concentrations that have smaller drawdown rates at Copco 1 peak at around 8,000 mg/l and this last only for a few days.

The durations of the concentrations above 1,000 mg/l are greatest for the scenarios that have lower drawdown rates at Copco 1 (2, 3, 6, and 7). The concentration remains above 1,000 mg/l for about 4 months.

The scenario that does not allow notching of Copco 1 (Scenario 1) shows high concentrations into June and July during wet years, whereas, all the other scenarios do not experience high concentrations past April.

If the drawdown of Copco 1 is not begun until Jan 1 and the drawdown rates are limited to 1ft/day or less, there will be high concentrations throughout March and into April.

The number of days above various concentration thresholds for given months are shown in Figure 23-58 to Figure 23-61. The exceedance levels in these charts refer to percent likelihood that concentrations will exceed the concentration threshold for a given number of days.

A comparison between just Scenario 6 and 7 is shown in Figure 23-62 and Figure 23-63, where the 5% and 50% exceedance concentrations for each day are shown. Scenario 6 has high concentrations at 50% exceedance levels between Nov 15 and March 1. Scenario 7 has high concentrations at a 50% exceedance level between Jan 1 and mid April.

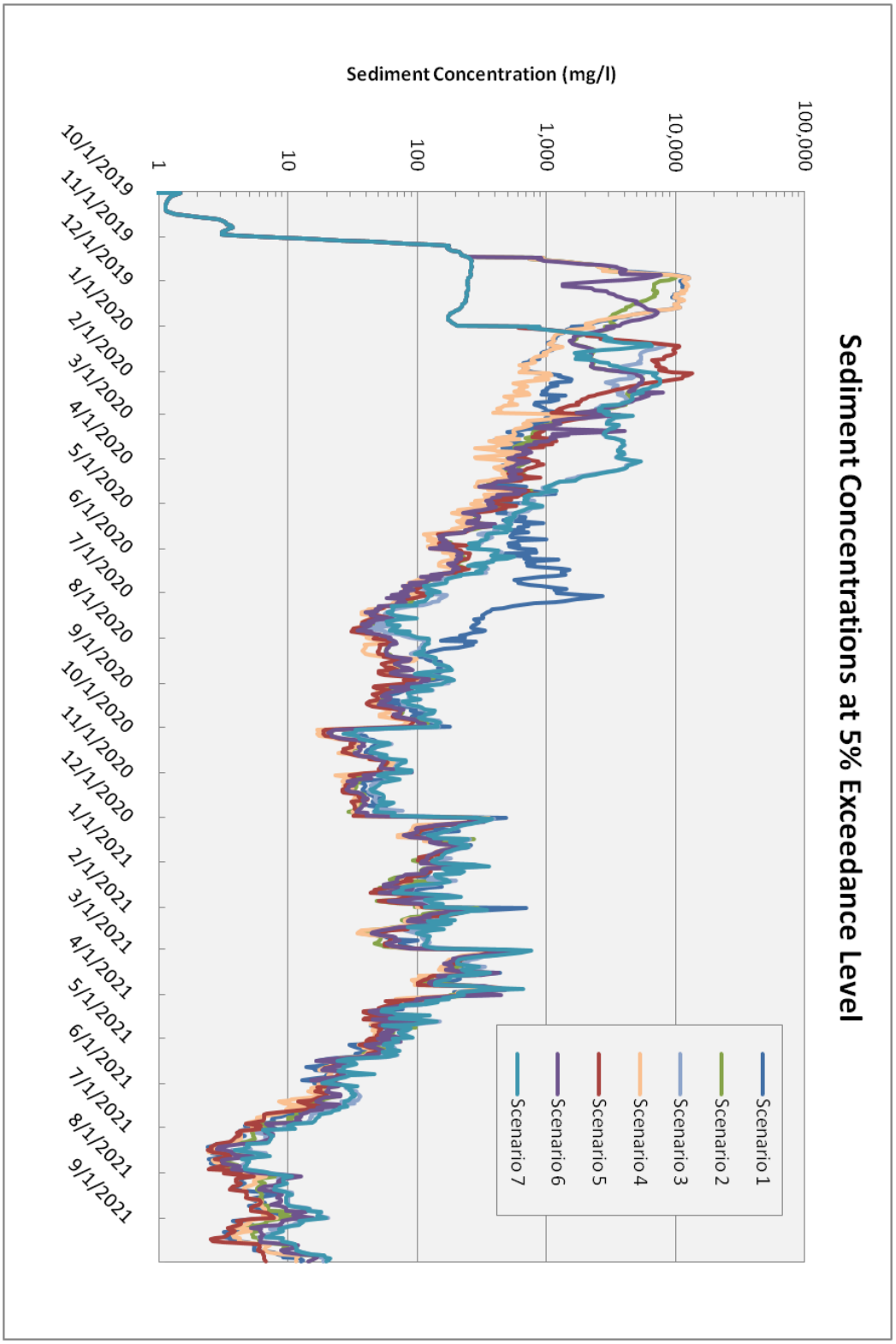

Figure 23-57. Sediment Concentration at 5% Exceedance Level for all Scenarios.

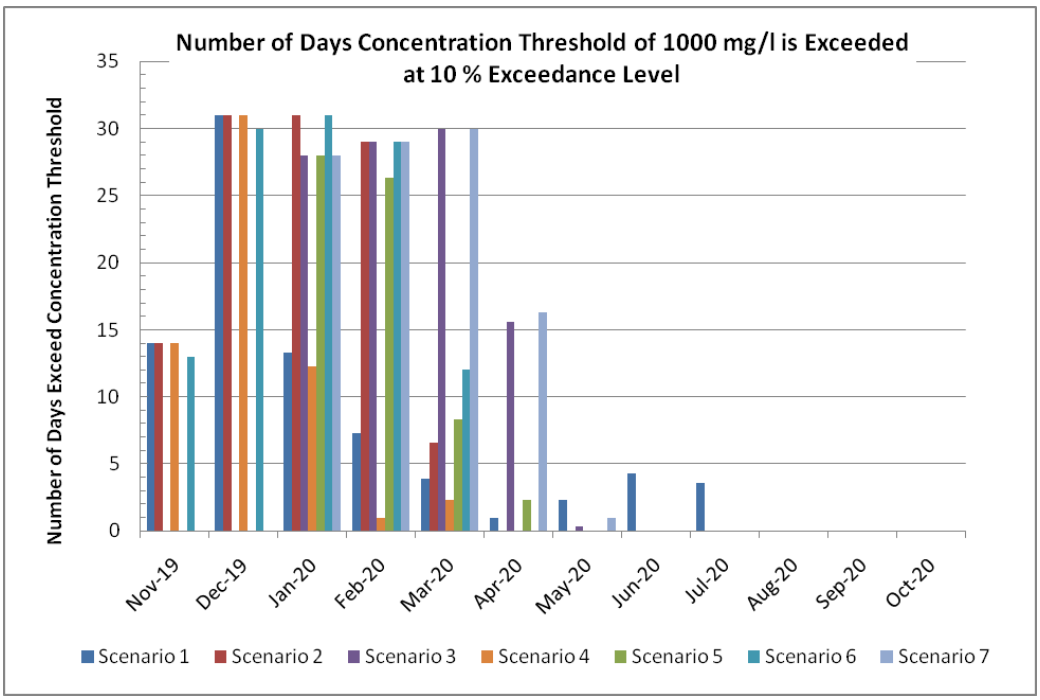

Figure 23-58. Number of Days Concentration Threshold of 1000 mg/l is Exceeded at a 10% Exceedance Level.

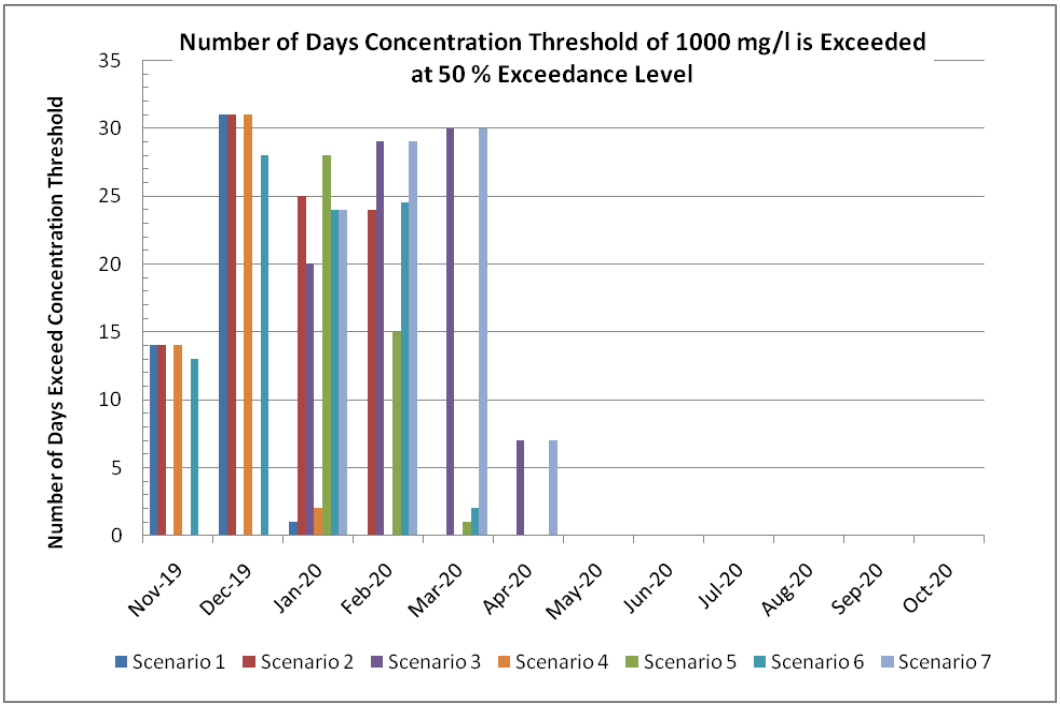

Figure 23-59. Number of Days Concentration Threshold of 1000 mg/l is Exceeded at a 50% Exceedance Level.

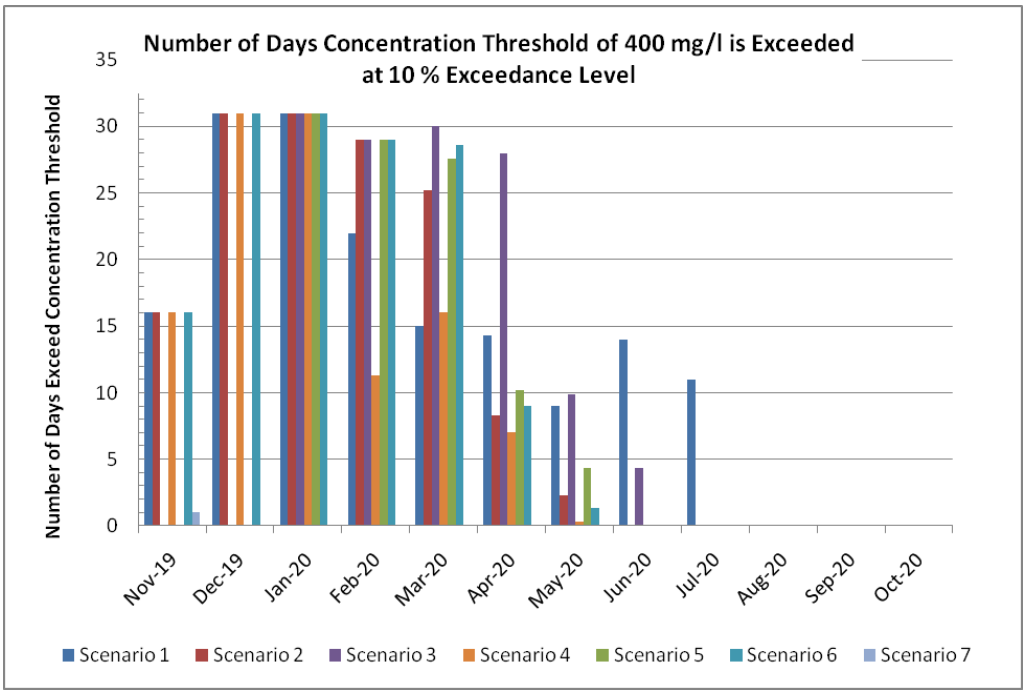

Figure 23-60. Number of Days Concentration Threshold of 400 mg/l is Exceeded at a 10% Exceedance Level.

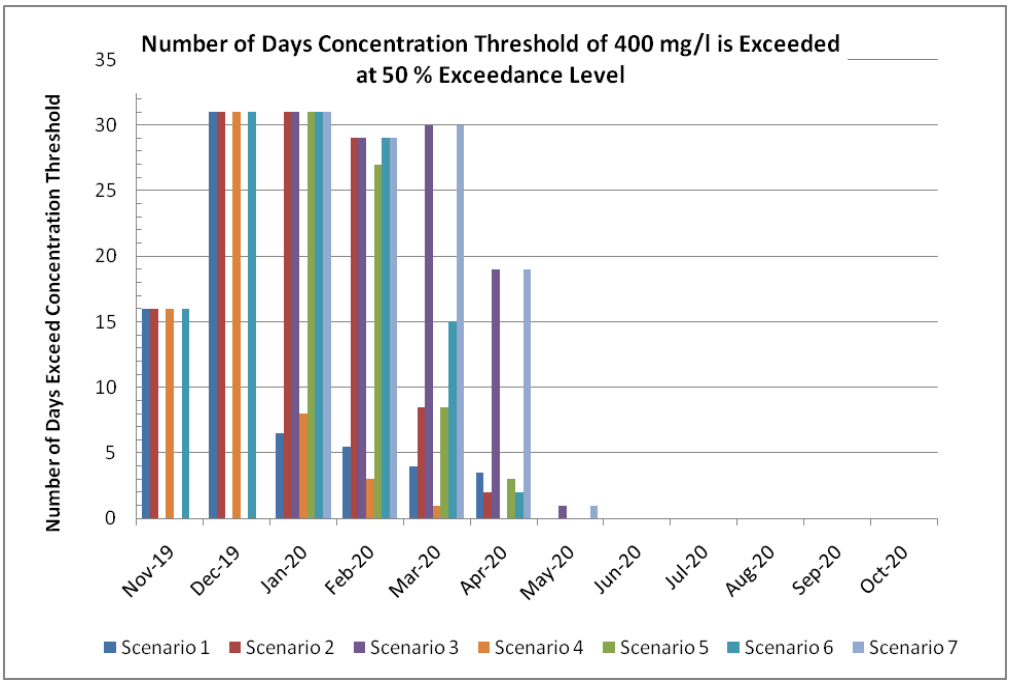

Figure 23-61. Number of Days Concentration Threshold of 400 mg/l is Exceeded at a 50% Exceedance Level.

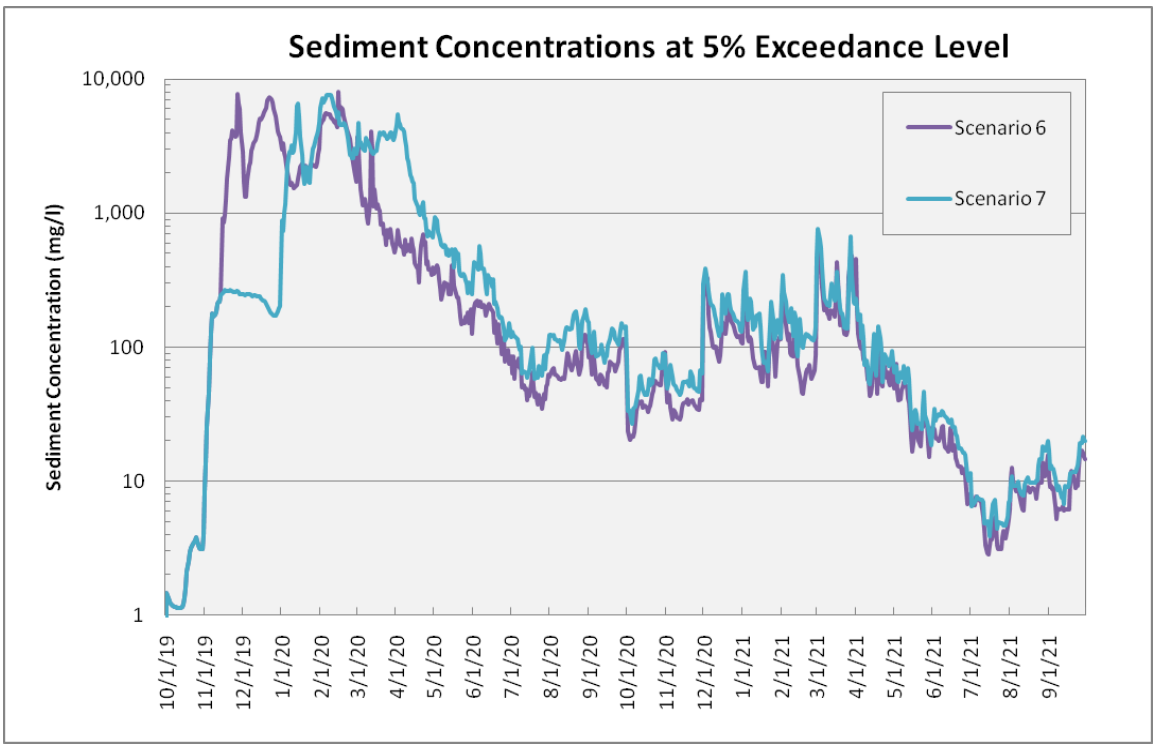

Figure 23-62. Comparison between Scenario 6 and 7 at 5% exceedance level.

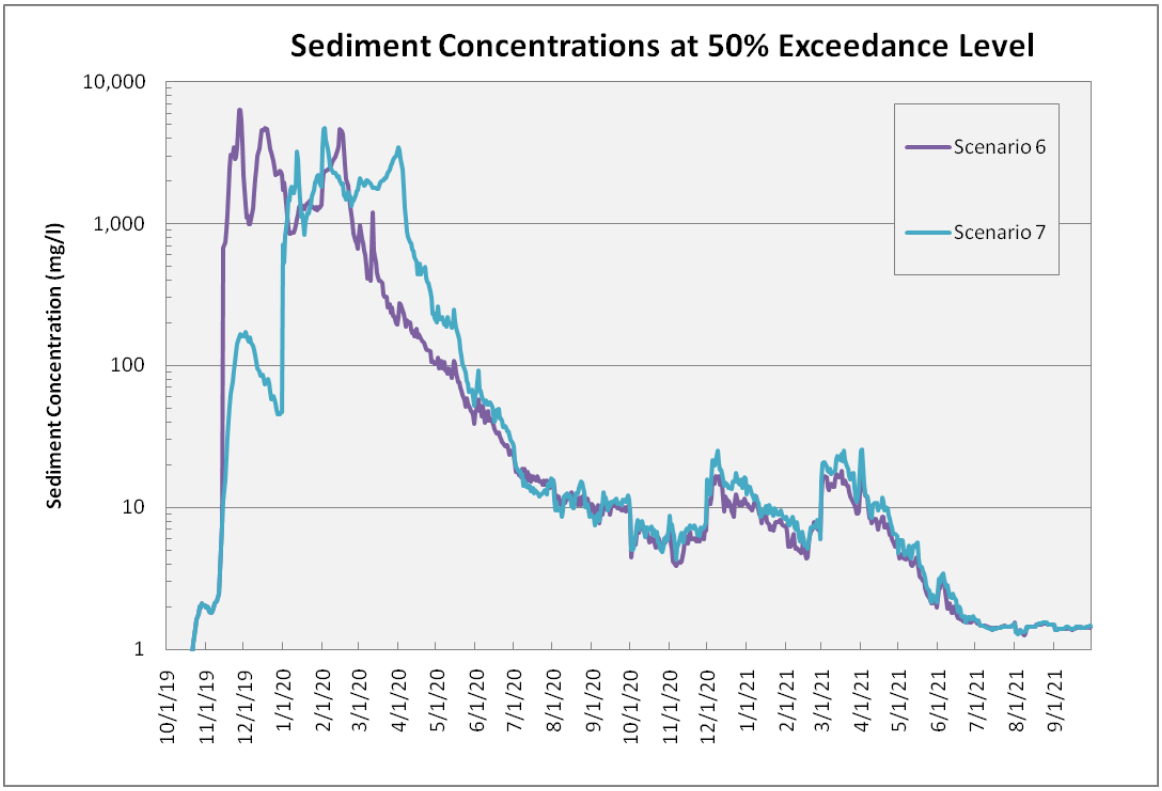

Figure 23-63. Comparison between Scenario 6 and 7 at 50% exceedance level.