TECHNICAL MEMORANDUM

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Date:	August 24, 2020
Subject:	**Silver Lake Reservoir Complex Master Plan Water Quality Model – Final (Revised)**

ES. Executive Summary

The Silver Lake Reservoir Complex (SLRC), composed of Silver Lake and Ivanhoe Reservoirs, is a large and historic piece of water infrastructure located in the Silver Lake neighborhood of Los Angeles. Historically used by the Los Angeles Department of Water and Power (DWP) for potable water storage, the function of the SLRC changed in 2008 when Silver Lake Reservoir was removed from potable water service. The SLRC Master Plan (SLRCMP) initiative was undertaken beginning in 2018 to allow the Silver Lake community and the City of Los Angeles to consider ways to repurpose the reservoirs as a public amenity. The SLRCMP is a planning document that seeks to create a clear, bold design for the future of the SLRC as a hybrid space for expanded wildlife habitat and human recreational uses. A key component in the plan is predicting the future impacts to water quality due to both the SLRCMP projects and other planned future activities.

The SLRC Water Quality Model was created to predict water quality impacts in both Silver Lake and Ivanhoe Reservoirs with the goal of maintaining a level of water quantity and quality that can support the future uses of the site. The model, a zero-dimensional mass balance model, was built to mimic the processes that drive water quantity and quality in the SLRC, and it was calibrated against historic water level and water quality data. Four scenarios were constructed which evaluate isolation baseline conditions without Pollock Well water (Scenario 1), existing baseline conditions including Pollock Well water (Scenario 2), future conditions following the implementation of planned DWP aeration, recirculation, and stormwater capture projects (Scenario 3), and conditions following the implementation of the SLRCMP projects which will include habitat enhancement and treatment wetlands (Scenario 4). Impacts to water quality were measured against specific numeric pollutant limits established as water quality goals for the SLRC.

The results from the model indicated that the addition of wetlands will provide a significant water quality benefit for phosphorus, nitrogen, chlorophyll, and algae. **Table E-1** and **Table E-2** show some of the results from the water quality model. Nitrogen peaks, above the goal of 1 milligram per liter (mg/L), in Scenarios 2 and 3 were reduced to peaks of less than 0.3 mg/L in Scenario 4. Phosphorus, which plays an important role in the generation of chlorophyll-a, was reduced by 87 percent in Silver Lake Reservoir and by 91 percent in Ivanhoe Reservoir due to the presence of treatment wetlands. Algae coverage was reduced 75 percent in both reservoirs. The model also indicated there would be a meaningful reduction in dissolved solids and in total coliform bacteria due to the treatment wetlands in Scenario 4. Over the twenty-year timespan of the model, total coliform limits were predicted to be exceeded in Ivanhoe Reservoir on fourteen days in Scenario 3 due to stormwater runoff from the future stormwater capture project. This was reduced to just one day in Scenario 4. The reductions in nutrients and bacteria highlight the importance of including wetlands in the SLRCMP.

Table E-1 Ivanhoe Reservoir Water Quality Modeling Results Summary

Pollutant	Limit	Type	Scenario 2	Scenario 3	Scenario 4
Total Nitrogen	1 mg/L	Maximum*	2.2 mg/L	1.6 mg/L	0.3 mg/L
Total Phosphorus	0.1 mg/L	Maximum*	0.053 mg/L	0.080 mg/L	0.019 mg/L
Chlorophyll-a	20 µg/L	Maximum*	11.3 µg/L	15.3 µg/L	5.2 µg/L
Dissolved Oxygen	5 mg/L	Minimum	7.9 mg/L	7.9 mg/L	7.9 mg/L
Total Copper	22 µg/L	Maximum	4.3 µg/L	19.6 µg/L	16.1 µg/L
Total Lead	11 µg/L	Maximum	0.4 µg/L	5.9 µg/L	4.7 µg/L
Total Coliform Bacteria	1,000 MPN per 100 mL	Days in Exceedance of Limit	0 days	14 days	1 day

* Following initial depreciation period

Table E-2 Silver Lake Reservoir Water Quality Modeling Results

Pollutant	Limit	Type	Scenario 2	Scenario 3	Scenario 4
Total Nitrogen	1 mg/L	Maximum*	1.2 mg/L	1.2 mg/L	0.2 mg/L
Total Phosphorus	0.1 mg/L	Maximum*	0.058 mg/L	0.080 mg/L	0.019 mg/L
Chlorophyll-a	20 µg/L	Maximum*	12.0 µg/L	15.4 µg/L	5.2 µg/L
Dissolved Oxygen	5 mg/L	Minimum	7.9 mg/L	7.9 mg/L	7.9 mg/L
Total Copper	22 µg/L	Maximum	8.0 µg/L	19.7 µg/L	16.7 µg/L
Total Lead	11 µg/L	Maximum	0.8 µg/L	5.9 µg/L	4.9 µg/L
Total Coliform Bacteria	1,000 MPN per 100 mL	Days in Exceedance of Limit	0 days	1 day	0 days

* Following initial depreciation period

The water quality benefits from wetlands are only achievable over the long term if continuous, comprehensive maintenance is sustained, especially for floating treatment wetlands, which require specialized maintenance. Following the completion of the SLRCMP, a Wetlands Maintenance Plan will need to be developed. The Wetlands Maintenance Plan should not only describe the maintenance requirements but also specify future funding to guarantee a sustaining source of financial support for wetlands maintenance.

1. Introduction

The Silver Lake Reservoir Complex (SLRC) Master Plan (SLRCMP) led by Hargreaves Jones will identify elements to improve both the recreational and ecological functions of the SLRC. For successful implementation, the planning effort needs to identify and meet water quality objectives that balance the beneficial uses of the waterbodies for both humans and wildlife. Water quality objectives will need to be met into the future, long after the projects identified in the Master Plan are completed. CWE developed a water quality model to estimate the future condition of water quality within the SLRC. This technical memorandum (TM) describes the assumptions, the data inputs, the calculations, and the results of the SLRC Water Quality Model.

The SLRC Water Quality Model accounts for inputs and outputs on a daily basis. The model takes the form of a spreadsheet mass balance model that estimates the in-lake concentrations of nutrients and contaminants of concern over time. Inflows, outflows, and their associated nutrient and contaminant concentrations were calculated for each daily time step. Additionally, transformations and removal of nutrients and contaminants within the SLRC were simulated based on rates from scientific and engineering literature.

The model performs calculations on Silver Lake Reservoir and Ivanhoe Reservoir separately, treating each reservoir as a well-mixed waterbody, which eliminates the need for lateral, longitudinal, or vertical discretization. **Figure 1-1** shows the location of the Silver Lake and Ivanhoe Reservoirs. The well-mixed waterbody assumption allowed the model to be conceived as a zero-dimensional model with two cells, one for Silver Lake Reservoir, and one for Ivanhoe Reservoir, and to assume the same water quality properties (both inputs and degradation) throughout each reservoir, both horizontally and vertically. The well-mixed assumption is valid for the scenarios with recirculation because the recirculation project will induce mixing. There are drawbacks to assuming a well-mixed system for the isolation and current scenarios because no mechanical mixing will be incorporated, and mixing will be dependent on dispersion, diffusion, and potential lake turnover. A concentration gradient will be expected at the Pollock Well inflow location. Bird loadings are assumed to be evenly distributed, but loadings will likely be higher near the shoreline. Without site-specific monitoring data measuring the gradients, assumptions would need to be made for dispersion and diffusion for each constituent of concern. A more complex model would be needed than the zero-dimensional mass approach to calculate the spatial distribution of nutrients and contaminants.

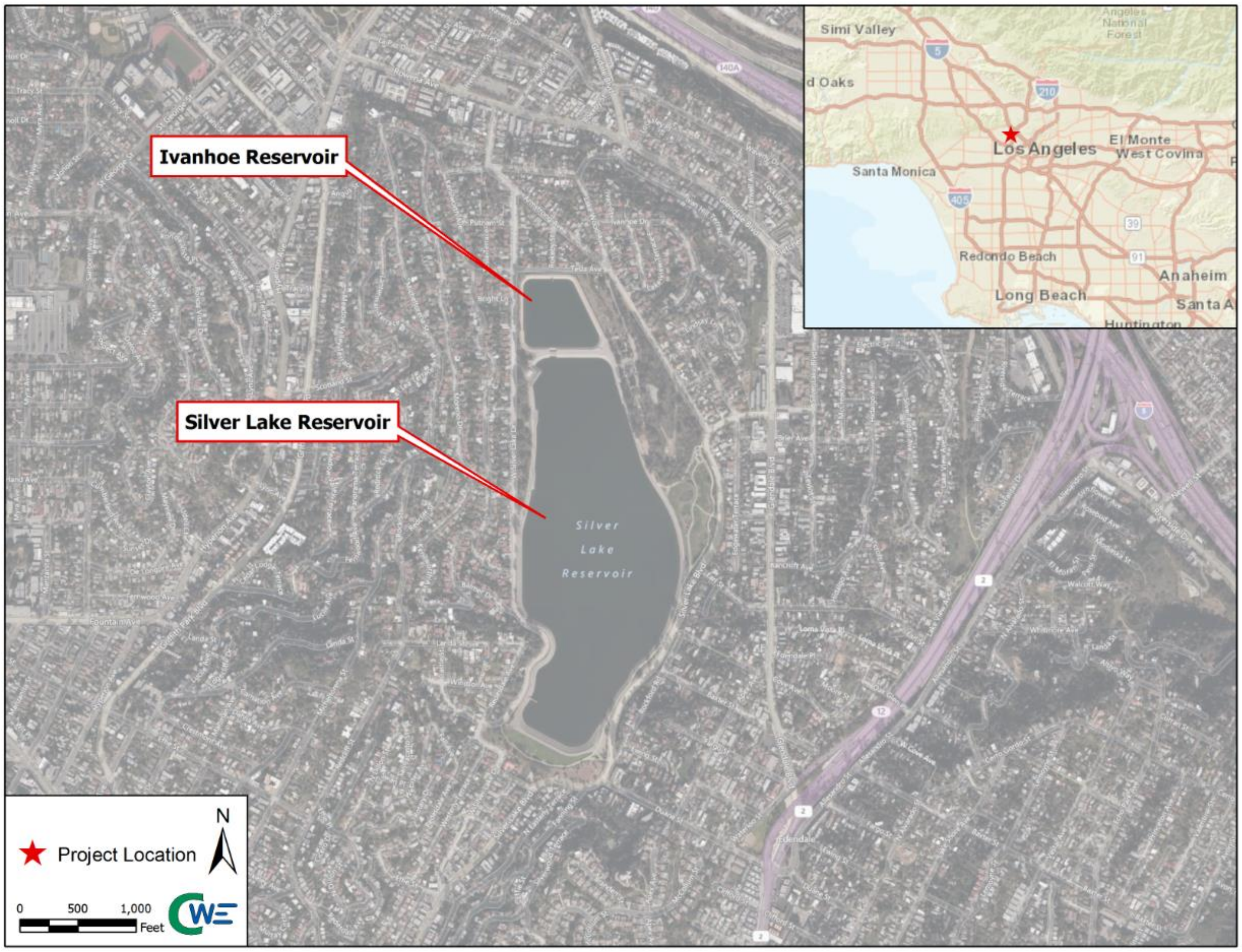

Figure 1-1 Project Location

1.1 Water Quality Goals of the SLRC

Water Quality Objectives are established by the Los Angeles Regional Water Quality Control Board's Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties (Basin Plan), but they can also be established by the United States Environmental Protection Agency (EPA) if a waterbody is on the 303(d) list of impaired waterbodies. The SLRC is not on the 303(d) list, but other nearby reservoirs, including Echo Park Lake, are on the 303(d) list, and it is reasonable to assume that Water Quality Objectives similar to those in other nearby reservoirs will likely be established for the SLRC sometime in the future. The SLRCMP effort should plan for these potential future water quality objectives. Water quality goals noted in **Table 1-1** were assumed to apply to the SLRC Water Quality Model. These goals were similar to the numerical water quality limits that were established for Echo Park Lake (Echo, 2009).

Table 1-1 Water Quality Goals of the SLRC

Pollutant	Related Numerical Limits Not To Exceed
Algae, Ammonia, Eutrophic, Odors	➢ Total Nitrogen: 1 mg/L ➢ Ammonia-N: 2.15 mg/L (30-day average) ➢ Ammonia-N: 5.95 mg/L (one-hour average) ➢ Total Phosphorus: 0.1 mg/L ➢ Chlorophyll-a 20 µg/L ➢ Dissolved Oxygen: ≥5 mg/L (single sample one foot from bottom)
Copper	➢ 22 µg/L
Lead	➢ 11 µg/L
pH	➢ 6.5 to 8.5
Trash	➢ Zero
Total Coliform	➢ 10,000 MPN/100 mL (single sample) ➢ 1,000 MPN/100 mL (single sample, Fecal/Total ≥ 0.1) ➢ 1,000 MPN/100 mL (geometric monthly mean)
E. coli	➢ 235 MPN/100 mL (single sample) ➢ 126 MPN/100 mL (geometric monthly mean)
Enterococci	➢ 104 MPN/100 mL (single sample) ➢ 35 MPN/100 mL (geometric monthly mean)

In addition to meeting the numerical limits, the SLRC must meet various narrative goals established in the Basin Plan, including minimizing stagnant water, reducing odor, and distributing dissolved oxygen throughout the SLRC.

The goal of the modeling effort was to evaluate the effects on water quality from the projects proposed in the SLRCMP and from the planned projects proposed by the Los Angeles Department of Water and Power (DWP), noted in **Section 1.2**. The goal of the treatment wetlands project from the SLRCMP is to evaluate whether water quality limits listed in **Table 1-1** will exceeded within the waterbodies during any modeled time period.

1.2 Modeling Scenarios

The SLRC Water Quality Model performed water quantity and water quality calculations across four alternative scenarios. The scenarios incorporate existing baseline conditions, future conditions following the implementation of planned DWP projects, and conditions following the implementation of the Master Plan projects. Existing conditions incorporate the refill operations from non-potable well water from Pollock Well. Three planned DWP projects, the Aeration Project, the Recirculation Project, and the Stormwater Capture Project, are included in the DWP Project Baseline Scenario. The Master Plan projects include the addition of treatment wetlands, as well as different slope paving configurations and different refill operation procedures. The four scenarios are described in **Table 1-2**.

Table 1-2 Model Scenarios

Model Scenario	Description of Model Inputs
1 – Isolation Baseline Scenario	➢ Precipitation falling on SLRC ➢ Bird droppings ➢ Atmospheric deposition
2 – Existing Baseline Scenario	➢ Precipitation falling on SLRC ➢ Bird droppings ➢ Atmospheric deposition ➢ Pollock Well Water
3 – DWP Project Baseline Scenario	➢ Precipitation falling on SLRC ➢ Bird droppings ➢ Atmospheric deposition ➢ Pollock Well Water ➢ Aeration and Recirculation Projects ➢ Stormwater Capture Project Flows
4 – Master Plan Proposed Scenario	➢ Precipitation falling on SLRC ➢ Bird droppings ➢ Atmospheric deposition ➢ Pollock Well Water ➢ Aeration and Recirculation Projects ➢ Stormwater Capture Project Flows ➢ Treatment Wetlands

The four model scenarios are depicted in **Figure 1-2**, **Figure 1-3**, **Figure 1-4**, and **Figure 1-5** on the following page.

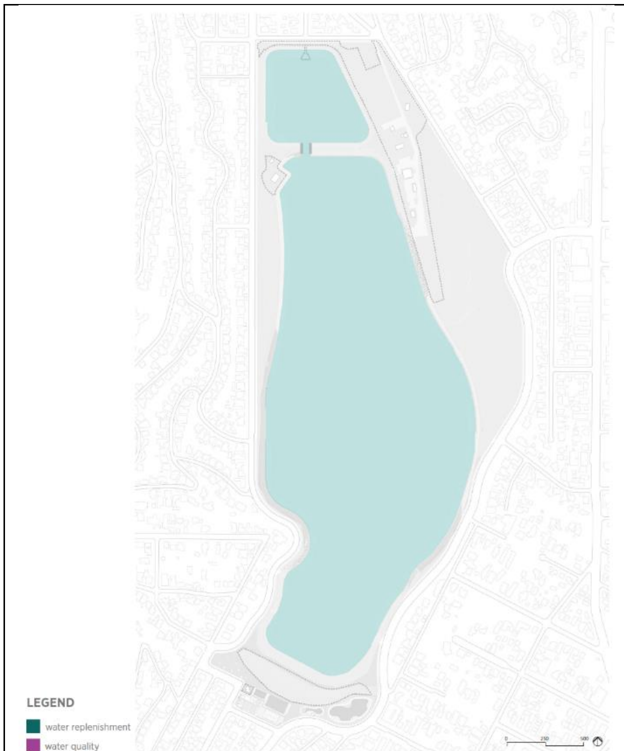

Figure 1-2 Scenario 1

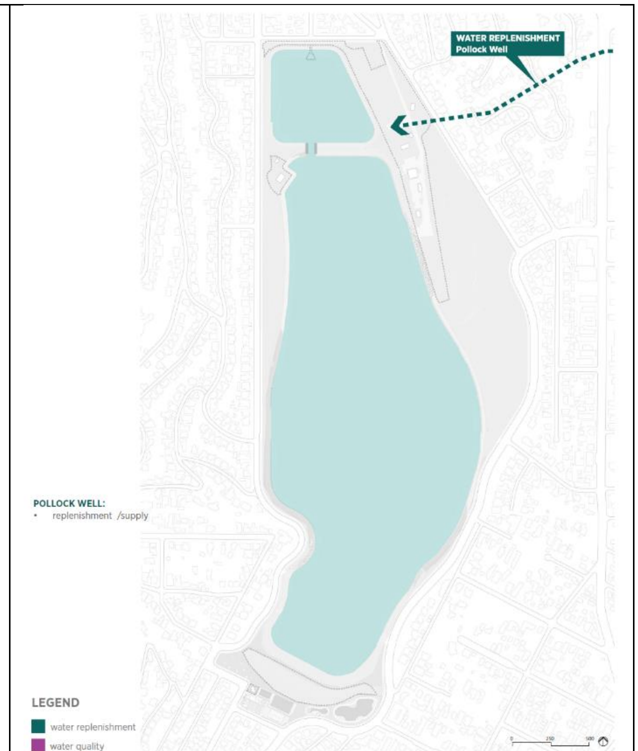

Figure 1-3 Scenario 2

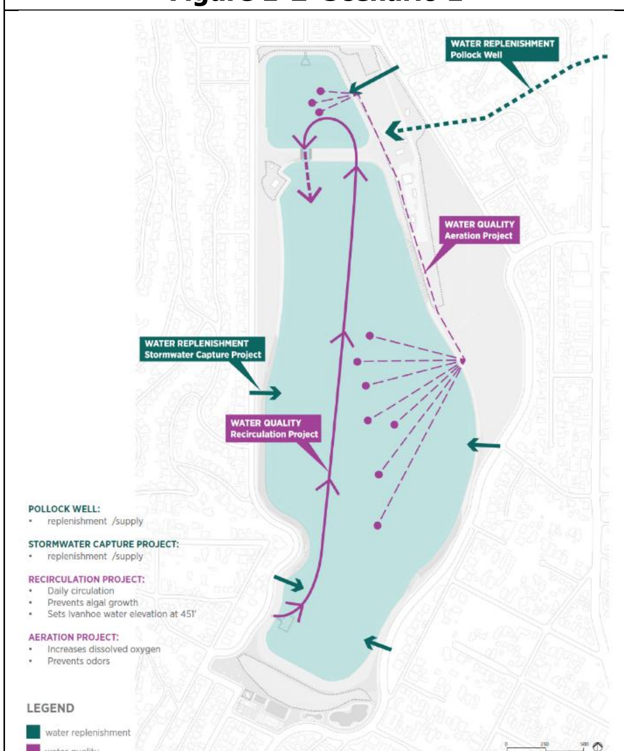

Figure 1-4 Scenario 3

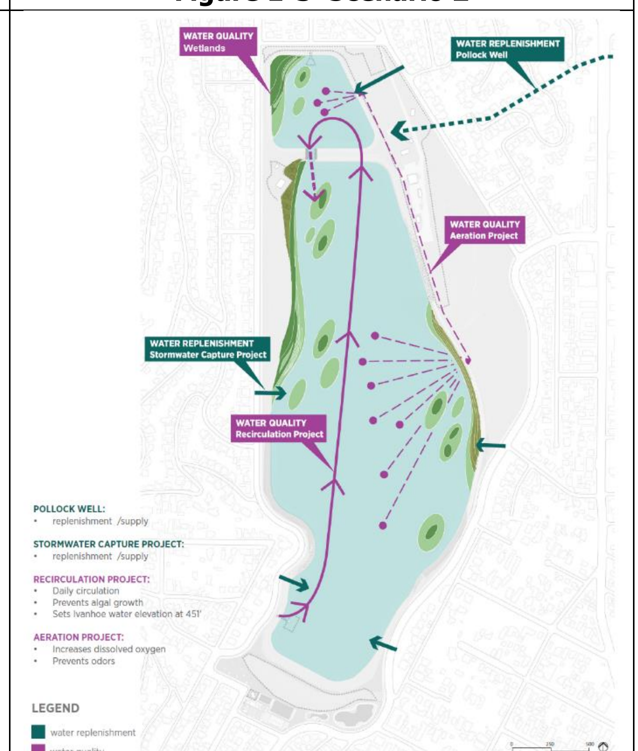

Figure 1-5 Scenario 4

2. Water Quantity Data

Water supply to the reservoirs from different sources had to be determined prior to development of water quality model. The quantity of water from each source was calculated to provide a foundation for the water quality calculations. Hydrology, topography, bathymetry, operations procedures, geotechnical information, and biological processes affected the daily water balance within the SLRC. **Table 2-1** lists the sources of water entering and exiting the modeled system for each scenario.

Table 2-1 Water Quantity Input and Output Sources

Source	Data	Data applicable to Scenario:			
		1	2	3	4
Inputs	Precipitation	X	X	X	X
	Pollock Well water		X	X	X[1]
	Stormwater Capture Project runoff			X	X
Input/Output	Overflow from Ivanhoe to Silver Lake	X	X	X	X
	Recirculation from Silver Lake to Ivanhoe			X	X
Output	Exfiltration	X	X	X	X
	Evaporation	X	X	X	X
	Transpiration				X
	Overflow to Ballona Creek (Silver Lake only)	X	X	X	X
	Maintenance Discharge (Silver Lake only)		X	X	X

[1] Pollock Well flow rate and operating procedure will be altered due to the SLRCMP projects.

2.1 Scenario 1 – Isolation Baseline

The Isolation Baseline Scenario (Scenario 1) required modeling for precipitation, exfiltration, and evaporation. The starting water surface elevation for Scenario 1 in the model was set at 451 feet above mean sea level (AMSL), per the National Geodetic Vertical Datum of 1929 (NGVD29). A stage-storage curve was developed based on contours from existing survey data from DWP (2019). The volume between the sectional areas represented by contours was calculated using the conic approximation method. The model inputs are summarized in the following sections.

2.1.1 Precipitation

The model simulated rainfall falling on the SLRC for twenty years by incorporating rain gage data. The precipitation data collected at Los Angeles County Public Works (LACPW) rain gage 716 was used. This gage is located in downtown Los Angeles on Ducommun Street, three miles from the SLRC. Though the rain gage data has been collected since the 1800s, the rainfall data used in the model spanned twenty water years (October to September), from 1999-2000 to 2018-2019. **Figure 2-1** graphs the twenty years of rainfall data used in the model. The volume of daily precipitation was calculated as the daily precipitation depth multiplied by the area of the reservoirs at the top of bank.

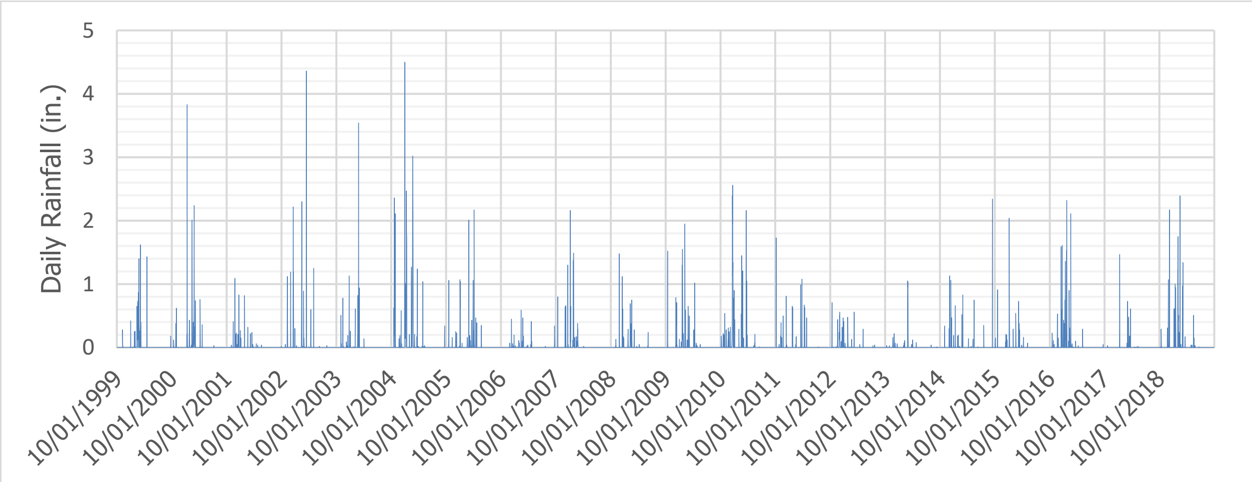

Figure 2-1 Daily Rainfall

2.1.2 Exfiltration

Exfiltration is related to wetted surface area, and to the perviousness of the surface. Both reservoirs have paved side slopes of 30 vertical feet, but the bottom of Silver Lake Reservoir is composed of compacted clay material and the bottom of Ivanhoe Reservoir is lined with asphalt concrete. The side slopes extend to an approximate elevation of 428 AMSL in both reservoirs. The bottom of Silver Lake Reservoir is not flat, but rather graded to drain to a low point in the center at elevation 414 AMSL. Ivanhoe Reservoir's bottom slopes to the southwest to an elevation of 422 AMSL.

A previous water balance evaluation for the SLRC concluded that Silver Lake Reservoir loses almost 150 acre-feet of water per year via exfiltration, which accounts for water lost due to infiltration into the ground and leakage through existing valves, gates, and piping systems (Black & Veatch, 2016). The conclusion was an average of two sources of information: an analysis of historic water surface elevations in Silver Lake Reservoir, and one hydraulic conductivity value from an earlier geotechnical report.

Exfiltration losses in the Black & Veatch memo were estimated by calculating the overall water losses based on the changes in reservoir water surface elevation during periods with little precipitation inputs and during the time when Silver Lake Reservoir was isolated from the distribution system, and then subtracting the evaporative losses from the overall losses. The result, averaged across three periods between 2008 and 2014, was an average exfiltration loss of 82 acre-feet per year (AFY).

The Black & Veatch memo then compared the exfiltration loss value to a hydraulic conductivity value found in a 2013 geotechnical report (DWP, 2013). The report cited a hydraulic conductivity value of 0.0001 centimeters per second (194 AFY) to be used for the design of a groundwater control system during construction of a bypass waterline beneath Silver Lake Reservoir. According to the 2013 geotechnical report, the hydraulic conductivity value was "based on field and laboratory permeability test results," though the report did not include permeability testing data or the permeability test location. Regardless, since the report was created before Silver Lake Reservoir was drained for construction of the bypass line, the permeability test was almost certainly not an in-situ test on the bottom sediments of Silver Lake Reservoir. The utility of this value to determining the exfiltration rate of Silver Lake Reservoir should have been negligible. Nevertheless, the Black & Veatch memo increased the estimate of exfiltration losses by 80% from 82 AFY to 150 AFY based on this hydraulic conductivity value from the 2013 geotechnical report.

The purpose of the Black & Veatch memo was to understand how much refill water is needed to maintain reservoir levels in the SLRC. Given the uncertainty involved in percolation rates, it was appropriate to use an exfiltration rate value at the high end of a range of possible values, as this would provide a conservative (high) estimate for replacement water needs. However, the SLRCMP Water Quality Model requires the most accurate, rather than the most conservative, characterization of the physical and chemical properties of the SLRC. Given the lack of in-situ percolation test data, it is therefore more appropriate to use the exfiltration rate calculated from the historic water surface elevation evaluation, which was 82 AFY.

The exfiltration rate cited by the Black & Veatch memo was based on a unit rate per surface area of the reservoirs. The memo cited a surface area for Silver Lake Reservoir of 78 acres, which is roughly the size of Silver Lake Reservoir at the top of bank. The same memo showed that Ivanhoe Reservoir loses approximately 56 acre-feet of water per year via exfiltration. However, the evaluation was based on an erroneously large area for Ivanhoe Reservoir of 29 acres. Had the previous evaluation used the surface area of Ivanhoe Reservoir at the top of bank, approximately eight (8) acres, the analysis would have shown exfiltration losses for Ivanhoe Reservoir at about nine (9) AFY.

Table 2-2 summarizes the corrections made to the exfiltration values which were used in the SLRCMP Water Quality Model.

Table 2-2 Corrected Exfiltration Values

	Black & Veatch Memo	Corrected Values
Silver Lake Exfiltration Losses	150 AFY	82 AFY
Silver Lake Area	78 acres	77 acres
Ivanhoe Area	29 acres	8.3 acres
Ratio: Ivanhoe Area to Silver Lake Area	0.372	0.107
Ivanhoe Exfiltration Losses	56 AFY	9 AFY

The Black & Veatch memo assumed a constant value for exfiltration throughout the year, which is a situation that could only occur if the wetted surface area remained unchanged throughout the year, i.e. that the water surface elevation remained constant. However, the SLRCMP Water Quality Model must be able to account for a wide range of water surface elevations, including situations where the reservoirs are almost dry. For the SLRCMP Water Quality Model, the 82 AFY exfiltration rate was divided by the square footage of the bottom of each reservoir to determine the volume of exfiltration per square foot through the semi-permeable reservoir bottoms. The exfiltration rate through the semi-permeable bottom of the reservoir was calculated to be 0.005 feet per day for Ivanhoe Reservoir, and 0.003 feet per day for Silver Lake Reservoir. Exfiltration under the semi-impermeable side slopes was assumed to exist due to cracks in the slope paving, but at a rate of only a tenth of the rate for the reservoir bottom.

The exfiltration volume is the sum of the exfiltration through the semi-permeable bottom and the exfiltration through the semi-impermeable side slopes, assumed to occur at a rate of 0.1 times the rate through the semi-permeable bottom. Exfiltration was calculated for each day given the surface area and the semi-impervious area fraction of the previous day, according to the following formula:

$$EX_n = i\,(SA_{n-1})\,(1 - IMP_{n-1}) \;+\; 0.1\,i\,(SA_{n-1})\,(IMP_{n-1})$$

- EX_n = Volume of exfiltration losses on day n, in acre-feet per day
- i = exfiltration rate through the semi-permeable bottom, or feet per day (0.005 ft/d for Ivanhoe Reservoir, 0.003 ft/d for Silver Lake Reservoir)
- SA_{n-1} = Surface area, in acres, on day n-1
- IMP_{n-1} = Semi-impervious area fraction, unitless, on day n-1

The first term in the equation represents the volume of exfiltration losses through the semi-permeable bottom, and the second term in the equation represents the volume of exfiltration losses through the semi-impermeable side slopes.

The bulk of the exfiltration in the model occurred through the semi-permeable bottom sediments of the two reservoirs. When the water level was above the bottom of the slope paving, the daily exfiltration rate only varied between 0.024 and 0.025 acre-feet per day for Ivanhoe Reservoir, and between 0.225 and 0.228 acre-feet per day for Silver Lake Reservoir.

2.1.3 Evaporation

Evaporative losses are the most significant outflow in the SLRC. Evaporation is a variable factor based on atmospheric conditions at the water surface (temperature, humidity, wind, etc.). Unlike exfiltration losses, evaporation losses vary by season: in the summer months, the SLRC loses more water than during winter months.

Seasonal evaporation losses were calculated through an analysis of water surface elevations over time at both Silver Lake and Ivanhoe Reservoirs. The water surface elevations, which originated from a dataset given to CWE by DWP (2020), covered a period between 2008 and 2019. The dataset included information from both before and after the draining of Silver Lake Reservoir for the construction of the water bypass line. The water surface elevations of both Silver Lake and Ivanhoe Reservoir are graphed in **Figure 2-2**.

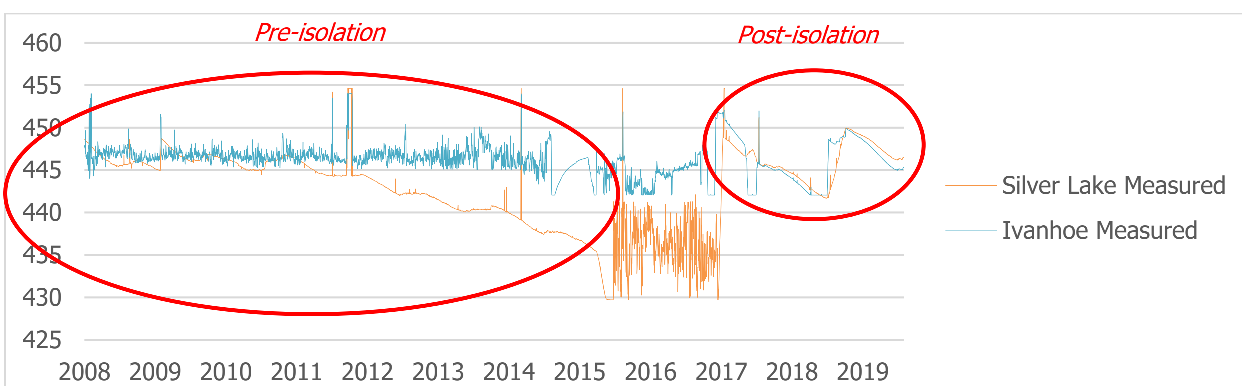

Figure 2-2 Water Surface Elevations 2008-2019

Before the bypass line construction project, Ivanhoe Reservoir was still used for potable water storage, and Silver Lake Reservoir was still connected to the potable water system for refill purposes. After the bypass line construction was completed, both Ivanhoe Reservoir and Silver Lake Reservoir were disconnected from the potable water system, and the water surface elevation fluctuated with evaporation and exfiltration losses and precipitation gains.

Table 2-3 shows the monthly change in the volume of Silver Lake Reservoir due to the combination of exfiltration and evaporation. Negative numbers indicate a decrease in the volume of the reservoir. The numbers were calculated by taking the volume difference between the beginning of the month and the end of the month and subtracting the volume of precipitation that fell that month.

Table 2-3 Monthly Exfiltration and Evaporation in Silver Lake Reservoir (ac-ft)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008						-49	-56	-44	-32	-32	-19	-10
2009	2	3	-18	-27	-26	-21	-55	-50	-41	-41	-24	-10
2010	-4	-4	-20	-25	-12	-13	-22	-43	-15	-6	-14	6
2011	1	-4	5	-15	-24	-29	-37	-31	-27	-25	-8	-11
2012	-3	-8	-5	-9	-18	-26	-30	-29	-30	-32	-2	-16
2013	-8	-9	0	-27	-25	-27	-28	-24	-16	-2	16	-9
2014	-2	21	-29	-17	-28	-25	-32	-36	-36	-20	-16	-23
2015	-2	-9	-22	-28	-24	-27	-34	-52	*	*	*	*
2016	*	*	*	*	*	*	*	*	*	*	*	*
2017	*	*	*	*	*	*	-45	-46	-46	**	**	-27
2018	-10	-22	-11	-29	-27	-32	-40	-47	-38	-27	-29	-16^
2019	-12^	-2^	-26^	-32	-28	-26	-40	-43	-42	-39	-24	-16

* Period of time when Silver Lake was being emptied, was empty, or was being refilled

** Period of time when stored water from Ivanhoe was pumped into Silver Lake

^ Value accounts for additional Pollock Well refill water

To convert the evaporation and exfiltration volumes into instantaneous rates (in inches per day (in/d)) applicable in the model at any time period or water surface level, the numbers from **Table 2-3** were divided by the number of days in each month and by the average areal extent of Silver Lake in each month calculated from the DWP survey information (2019). The result is tabulated in **Table 2-4**.

Table 2-4 Monthly Exfiltration and Evaporation in Silver Lake Reservoir (in/d)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2008						-0.27	-0.30	-0.24	-0.18	-0.17	-0.10	-0.06
2009	0.01	0.02	-0.10	-0.15	-0.14	-0.12	-0.29	-0.26	-0.22	-0.22	-0.13	-0.06
2010	-0.02	-0.02	-0.11	-0.14	-0.07	-0.07	-0.12	-0.23	-0.08	-0.03	-0.08	0.03
2011	0.00	-0.03	0.03	-0.08	-0.13	-0.16	-0.20	-0.17	-0.15	-0.13	-0.05	-0.06
2012	-0.02	-0.05	-0.03	-0.05	-0.10	-0.14	-0.16	-0.16	-0.17	-0.18	-0.01	-0.09
2013	-0.04	-0.05	0.00	-0.15	-0.14	-0.15	-0.15	-0.13	-0.09	-0.01	0.09	-0.05
2014	-0.01	0.13	-0.16	-0.10	-0.15	-0.14	-0.18	-0.20	-0.21	-0.11	-0.09	-0.13
2015	-0.01	-0.06	-0.12	-0.16	-0.14	-0.16	-0.20	-0.30	*	*	*	*
2016	*	*	*	*	*	*	*	*	*	*	*	*
2017	*	*	*	*	*	*	-0.24	-0.25	-0.25	**	**	-0.14
2018	-0.06	-0.13	-0.06	-0.16	-0.15	-0.18	-0.22	-0.26	-0.22	-0.15	-0.17	-0.09^
2019	-0.07^	-0.01^	-0.13^	-0.17	-0.15	-0.14	-0.21	-0.23	-0.23	-0.21	-0.13	-0.08

* Period of time when Silver Lake was being emptied, was empty, or was being refilled

** Period of time when stored water from Ivanhoe was pumped into Silver Lake

^ Value accounts for additional Pollock Well refill water

Table 2-3 and **Table 2-4** include both exfiltration and evaporation processes. Exfiltration accounts for an annual loss of approximately 82 AFY from Silver Lake Reservoir, equivalent to a constant loss of 0.035 in/d. The evaporation rates were determined by averaging the values from **Table 2-4** and subtracting the exfiltration loss of 0.035 in/d from each month. The averaging was performed separately for the pre-isolation period and for the post-isolation period. The results are shown in **Table 2-5** and **Figure 2-3** for both the post-isolation ("Post") and pre-isolation ("Pre") periods.

Table 2-5 Silver Lake Average Evaporation Rate Per Month (in/d)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Post	-0.026	-0.037	-0.062	-0.131	-0.113	-0.127	-0.188	-0.210	-0.199	-0.145	-0.115	-0.070
Pre	0.023	0.026	-0.034	-0.085	-0.089	-0.118	-0.165	-0.175	-0.123	-0.088	-0.019	-0.023

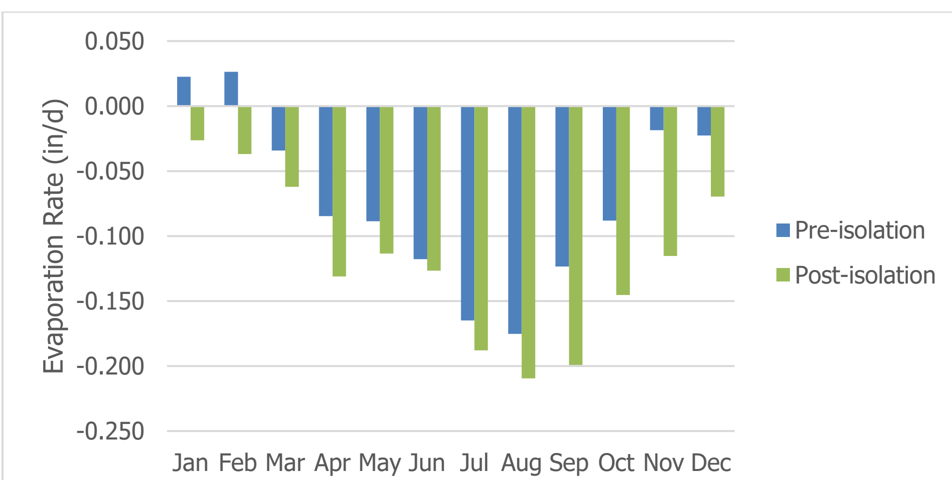

Figure 2-3 Silver Lake Calculated Monthly Evaporation Rate

The water surface elevation methodology for determining evaporation rates indicated that the evaporation rate before Silver Lake was isolated from the potable water system was very low in November and December on average and that in January and February the rates were negative (shown as positive values in **Figure 2-3** indicating an increase in the volume of the reservoir). There are several potential explanations for this result, including metering error, groundwater flows into the reservoir, unknown discharges into the reservoir from the potable water system, and others. Regardless, this inexplicable evaporation result was not found in post-isolation Silver Lake. For this reason, and because post-isolation Silver Lake is the best approximation for current baseline conditions for the model, the post-isolation monthly average evaporation rates are used in the model.

The exfiltration, evaporation, and precipitation inputs as described in the sections above were included in the SLRC Water Quality Model, and the modeled water surface elevation was compared to the measured water surface elevation in both reservoirs. The comparison started in December 2017, in the post-isolation period, after the work to disconnect the Ivanhoe Reservoir water supply pipeline from Rowena Reservoir was completed and water surface elevations in both Silver Lake and Ivanhoe Reservoirs were equalized. **Figure 2-4** shows that the model matched the measured data quite well between December 2017 and December 2018, which is when the reservoirs began to be refilled with Pollock Well water for the first time. The water surface elevation of Ivanhoe Reservoir was likely lower than 442 feet after September 2018, but the metered data seems unable to record a water surface elevation lower than 442 feet.

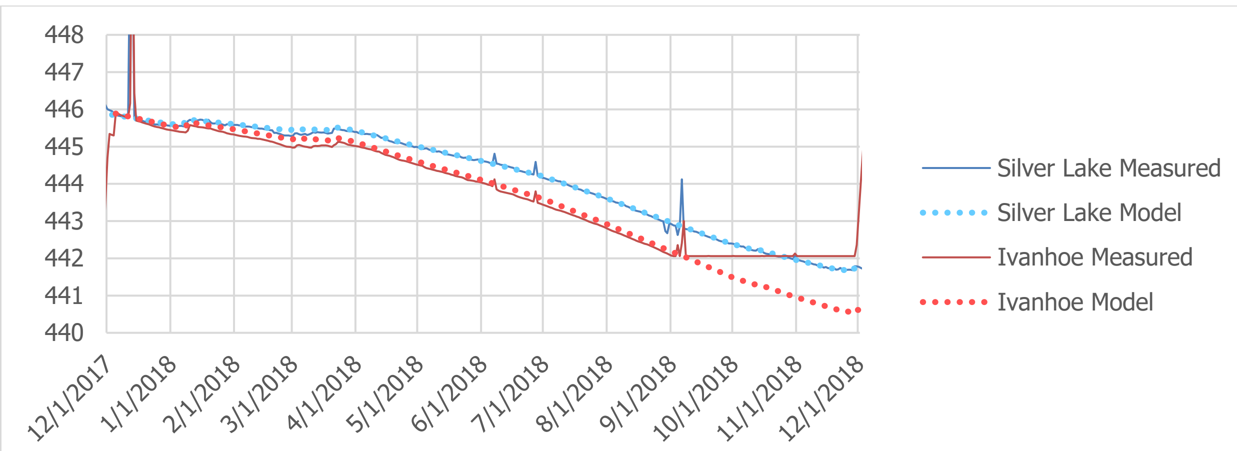

Figure 2-4 Measured vs. Modeled Water Surface Elevations – Dec 2017 to Dec 2018

After the first Pollock Well water refill concluded in March 2019, the modeled data and the metered data once again showed agreement, as seen in **Figure 2-5**.

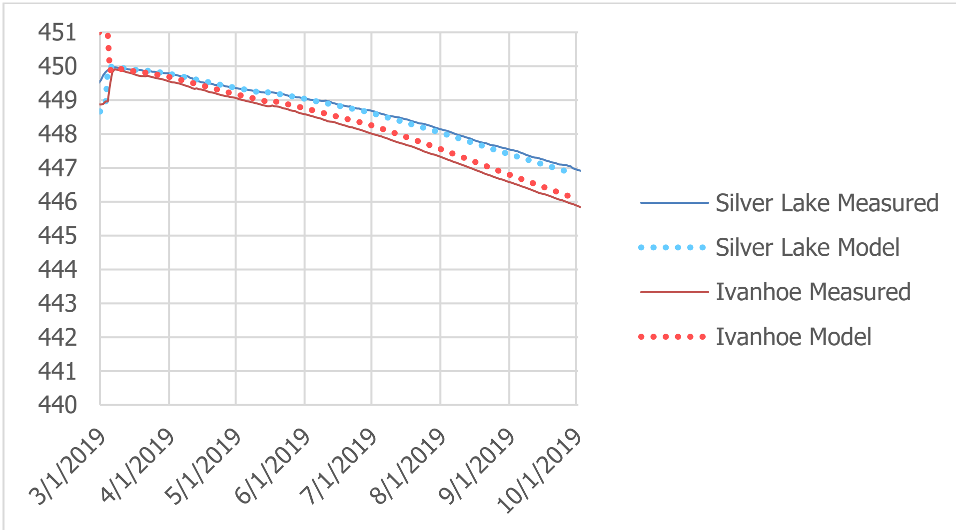

Figure 2-5 Measured vs. Modeled Water Surface Elevations - Mar 2019 to Oct 2019

2.1.4 Scenario 1 Water Quantity Results

Scenario 1 (Isolation Baseline) assumes that only rainfall adds water to the reservoir and no water from Pollock Well Field or stormwater runoff enter the SLRC. Water is lost through evaporation and exfiltration and the water level decreases over time. **Figure 2-6** shows the water surface elevations calculated by the model for Silver Lake and Ivanhoe Reservoirs. Without additional water from Pollock Well or from the Stormwater Capture Project, the water elevation in both reservoirs falls below the elevation of the bottom of the slope walls (elevation 428 AMSL) in a span of seven years. Precipitation falling within the reservoir complex continues to accumulate, providing a source of water to exfiltrate and evaporate for the remainder of the 20-year modeling period.

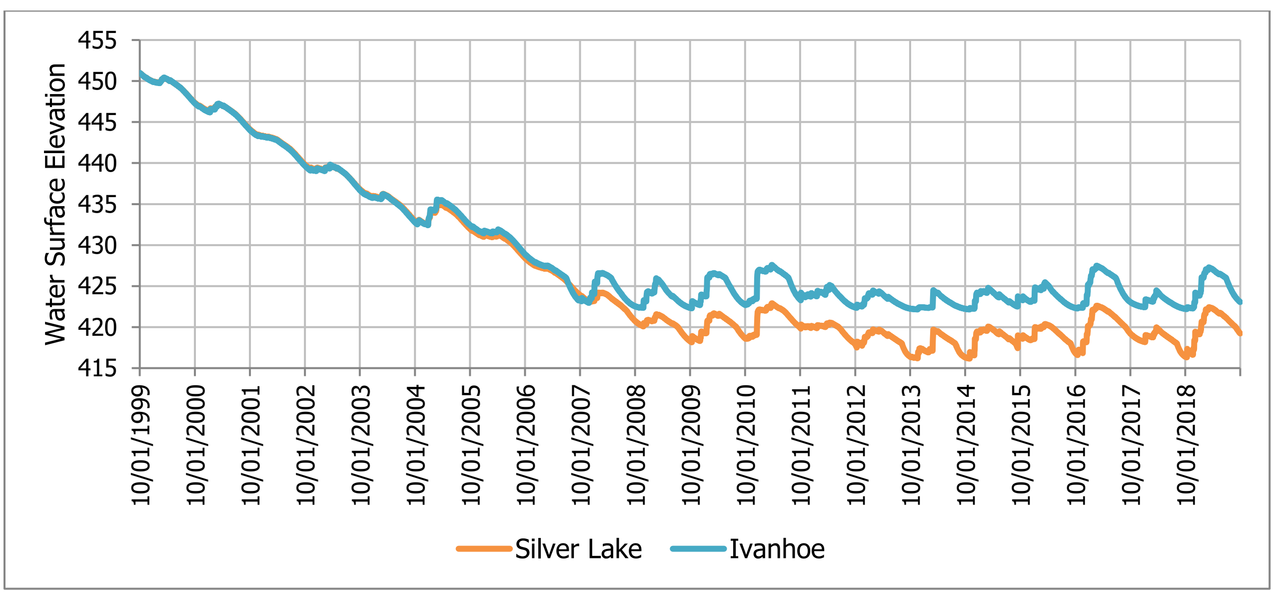

Figure 2-6 Scenario 1 Water Surface Elevations

The SLRC Water Quality Model was run for a typical rain year, a wet year, and a dry year. For each scenario, the surface elevation of Silver Lake Reservoir was set at 446 on October 1, and water surface elevation was examined on September 30 of the following year. The annual precipitation for each water year since the 1900-1901 water year was determined from historic rain gage data, and each water year was ranked according to its annual precipitation. The typical wet year was chosen to be 2010-2011 (22.9″ of rain, 87th percentile), the typical dry year was 2015-2016 (8.2″ of rain, 13th percentile), and the typical average year was 2005-2006 (13.45″ of rain, 53rd percentile).

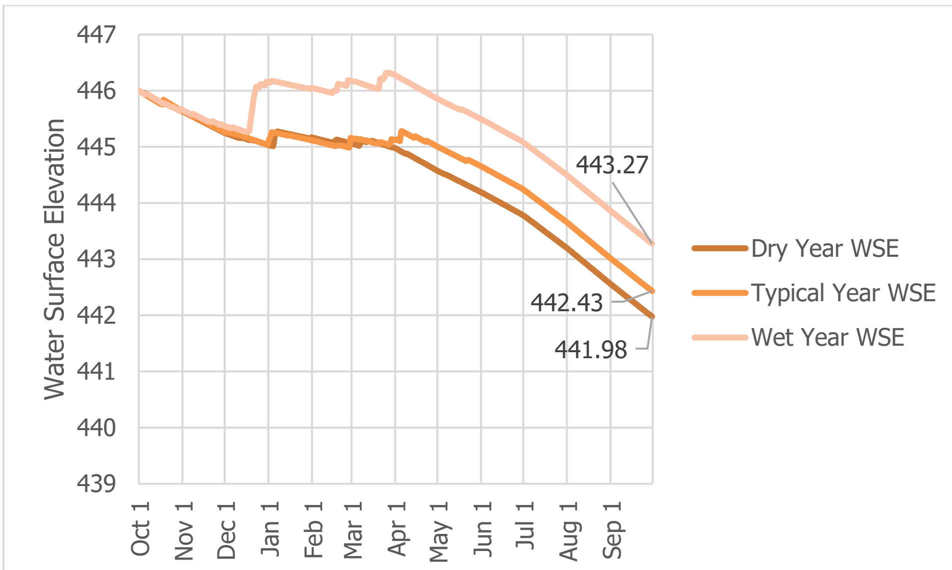

Figure 2-7 Scenario 1 in a Dry, Wet, or Typical Year

Figure 2-7 shows that over the course of a typical year, the water surface elevation in Silver Lake Reservoir dropped to 442.43 (3.57 feet). For the wet year, the drop was only to 443.27 (2.73 feet). For the dry year, the drop was to 441.98 (4.02 feet).

2.2 Scenario 2 – Existing Baseline Scenario

The Existing Baseline Scenario (Scenario 2) used the same inputs as in the Isolation Baseline Scenario (Scenario 1), but with the addition of refill operations from Pollock Well water. The addition of external water to the system allowed water to regularly, though not continuously, spill over from Ivanhoe Reservoir into Silver Lake Reservoir. The following sections characterize Pollock Well water and the Ivanhoe Spillway.

2.2.1 Pollock Well Water

The SLRC is currently filled via treated groundwater pumped from Pollock Well #3 from the DWP Ripple Street Yard northeast of the SLRC. The groundwater is treated with granular activated carbon (GAC) before being pumped to the SLRC. Pollock Well water currently enters the SLRC through a gatewell structure east of both reservoirs. The gatewell structure can divert flows to both Ivanhoe Reservoir and

Silver Lake Reservoir through two different pipes. When the Silver Lake Reservoir gate is closed during refilling operations, water spills over the Ivanhoe Spillway, at elevation 451, to enter Silver Lake Reservoir. An assumption used in the model was that Pollock Well water was added only to Ivanhoe Reservoir and not to Silver Lake Reservoir, which matches the planned operation. This assumption kept the Ivanhoe Reservoir elevation constant at 451 during refill operations in Scenario 2, though exfiltration and evaporation processes lowered the water surface elevation during time steps without Pollock Well refill.

Under current operating procedures, Pollock Well water is pumped into the SLRC at a peak rate of approximately three cubic feet per second (cfs). The pump is switched on when the water level in Silver Lake Reservoir falls below elevation 440, and it is switched off when the water level rises above elevation 451. The SLRC Water Quality Model included Pollock Well water as a constant daily inflow under Scenario 2 at the current operating rate of three cfs during refill operations, or a volume of approximately six AF per day. Under current operating procedures, the model predicted that five refill periods would be required over the 20-year span of the model. **Figure 2-8** shows these refill periods on a timeline, and **Table 2-6** identifies the total days required for the pump to be on and the total volume pumped from Pollock Well for each refill period.

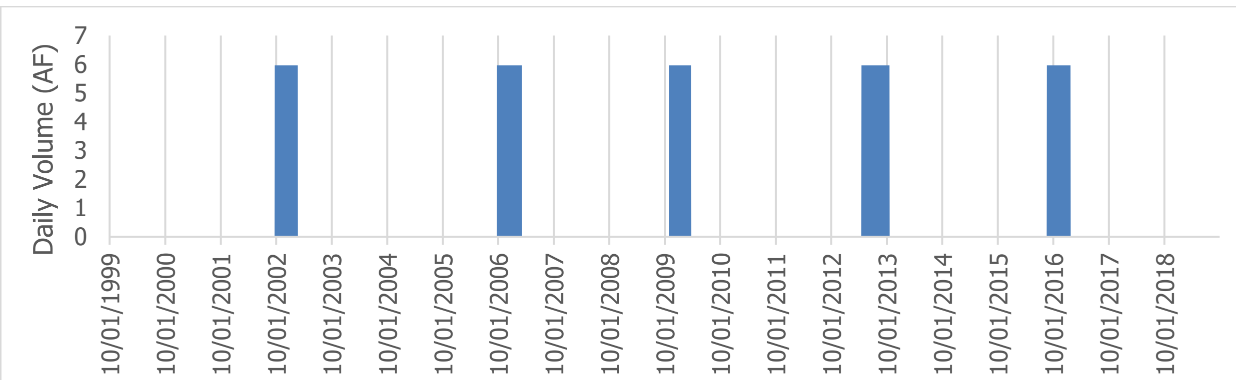

Figure 2-8 Pollock Well Time Series - Scenario 2

Table 2-6 Refill Periods - Scenario 2

Refill Number	Start Date	End Date	Total Days	Total Volume (AF)
1	September 21, 2002	February 20, 2003	153	913
2	September 22, 2006	March 5, 2007	165	984
3	October 29, 2009	March 24, 2010	147	877
4	April 17, 2013	October 19, 2013	186	1,110
5	August 19, 2016	January 22, 2017	157	937

The frequency of refill periods, time for the pump to be switched on, and total volume pumped vary depending on the precipitation gains and evaporation/exfiltration losses to the system. Refill operations were triggered on average about 36 months following the end of the previous refill period, and refill operations lasted 5.3 months on average. The total volume added to the SLRC per each refill period averaged to 964 AF.

2.2.2 Overflow from Ivanhoe Reservoir

Ivanhoe Spillway, located between Ivanhoe Reservoir and Silver Lake Reservoir, is a 50-foot-wide concrete spillway set at an elevation of 451. Ivanhoe Reservoir has a volume of approximately 160 AF below elevation 451. The spillway functions as a broad crested weir between Ivanhoe Reservoir and Silver Lake Reservoir. The wide width of the spillway does not constrict flows, but rather allows volumes of water greater than the capacity of Ivanhoe Reservoir to pass easily to Silver Lake Reservoir without retention. In the SLRC Water Quality Model, if the sum of all daily inputs and existing storage minus the sum of all daily outputs to Ivanhoe Reservoir resulted in a volume greater than 160 AF, the difference was diverted to Silver Lake Reservoir.

Under Scenario 2, Ivanhoe Spillway was dry on all days except those where refill operations from Pollock Well occurred. During refill operations, Ivanhoe Spillway remained dry for the first two weeks while Pollock Well water first refilled Ivanhoe Reservoir before spilling over to Silver Lake Reservoir.

2.2.3 Scenario 2 Water Quantity Results

The water surface elevations calculated by the model are shown for both Silver Lake and Ivanhoe Reservoirs in **Figure 2-9**. The five refill periods are indicated as the sharply rising portions of the time series graphs. The rise occurs for Ivanhoe Reservoir over the course of two weeks, while for Silver Lake Reservoir, the rise lasts for about six months.

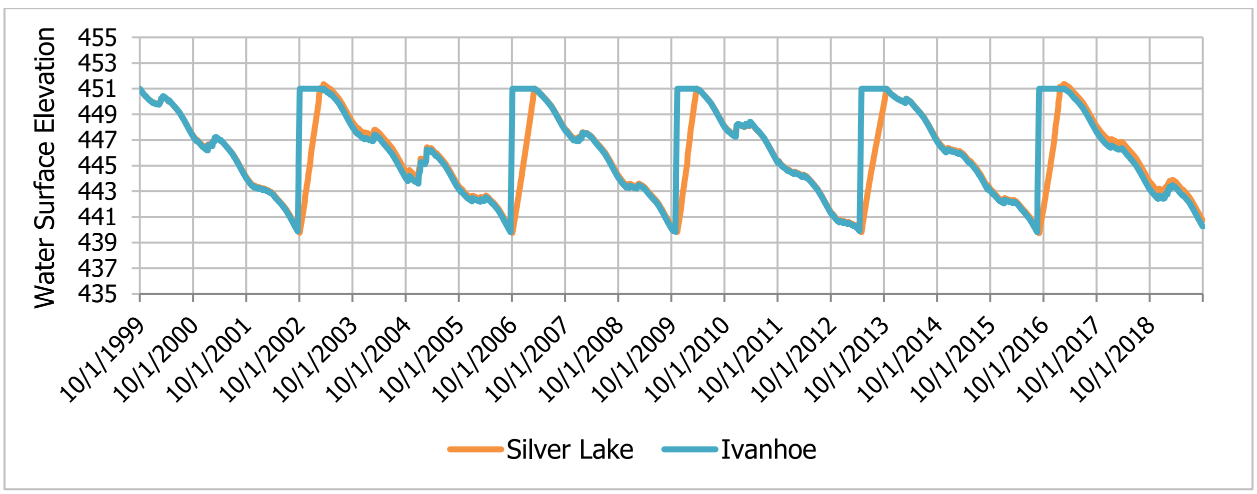

Figure 2-9 Scenario 2 Water Surface Elevations

Table 2-7 summarizes the water balance in the entire SLRC over the course of the entire 20-year modeled period from 1999 to 2019. **Figure 2-10** displays the same information in bar graph format. No additional analysis of the dry year, wet year, and typical year was performed for Scenario 2, as the results are the same as in Scenario 1.

Table 2-7 Scenario 2 Water Balance Summary

Water Year	Exfiltration	Evaporation	Precipitation	Pollock Well
	AF	AF	AF	AF
1999-2000	-93	-293	90	0
2000-2001	-92	-286	124	0
2001-2002	-92	-279	39	60
2002-2003	-92	-291	139	853
2003-2004	-92	-287	73	0
2004-2005	-92	-284	288	0
2005-2006	-92	-278	96	54
2006-2007	-92	-290	25	931
2007-2008	-92	-287	92	0
2008-2009	-92	-279	66	0
2009-2010	-92	-289	113	877
2010-2011	-92	-288	163	0
2011-2012	-92	-282	67	0
2012-2013	-92	-283	50	996
2013-2014	-92	-292	38	113
2014-2015	-92	-284	77	0
2015-2016	-92	-278	58	257
2016-2017	-92	-291	142	680
2017-2018	-92	-286	35	0
2018-2019	-92	-280	140	0
Total	**-1,841**	**-5,707**	**1,913**	**4,821**
Average Annual	**-92**	**-285**	**96**	**241**

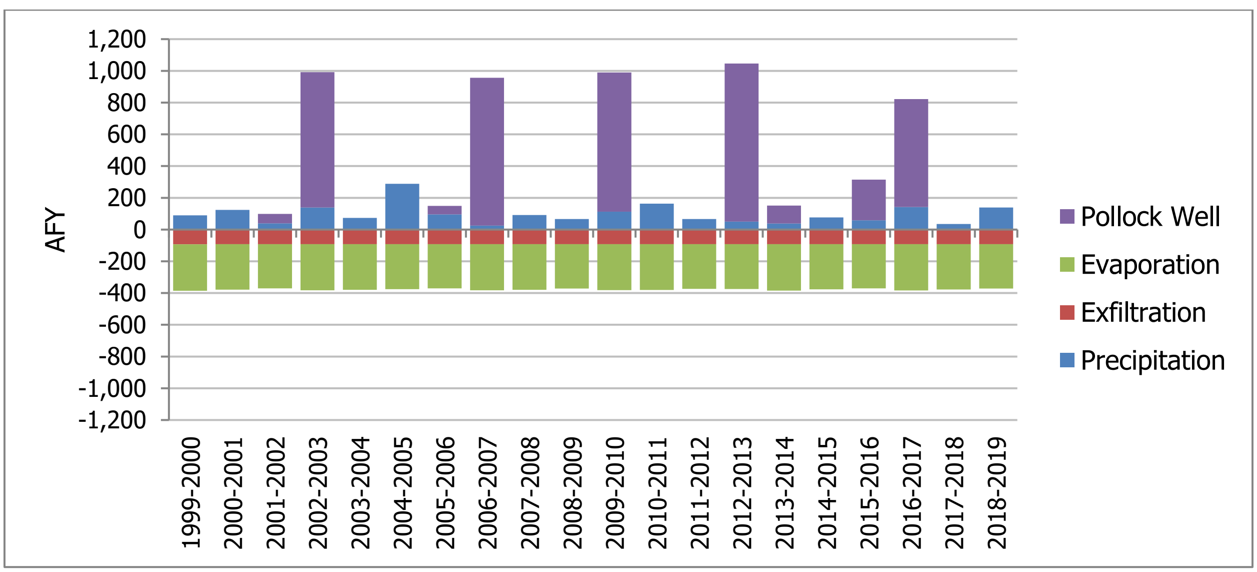

Figure 2-10 Scenario 2 Water Balance Summary

2.3 Scenario 3 – DWP Project Baseline Scenario

The DWP Project Baseline Scenario (Scenario 3) includes all the elements from the Existing Baseline Scenario (Scenario 2) and adds the effects of the planned DWP projects, which are outside the scope of the SLRCMP. Scenario 3 represents the conditions of the SLRC prior to the implementation of the SLRCMP projects.

2.3.1 Stormwater Capture Project

The Stormwater Capture Project will capture stormwater runoff from five locations in the neighborhoods surrounding the SLRC and divert the runoff to five discrete locations within the SLRC. Four locations will discharge to Silver Lake Reservoir, and one location will discharge to Ivanhoe Reservoir, as shown in **Figure 2-11** and described in Tetratech (2019). The captured stormwater runoff will enter a pretreatment structure best management practice (BMP), which will remove sediment and debris from runoff up to a design flow limit. The portion of runoff above the design flow limit of the BMP but below the capture capacity of the system's catch basins will pass through the BMP's internal bypass untreated. Pretreatment BMPs are typically sized to treat the runoff from an 85th percentile 24-hour design storm. Though these BMPs are efficient at removing trash and large sediment from runoff up to the 85th percentile design storm, they do not provide treatment up to the standards defined in **Table 1-1**.

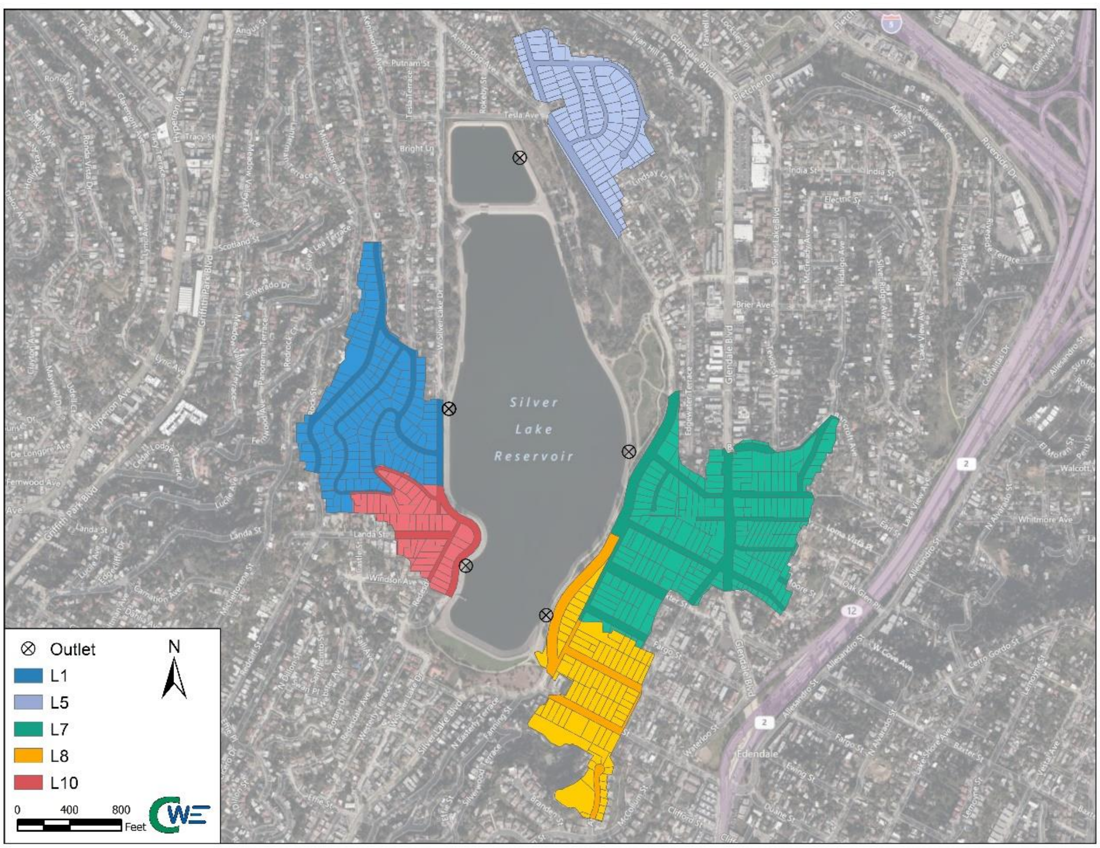

Figure 2-11 Stormwater Capture Drainage Areas

The SLRC Water Quality Model included runoff from each drainage area tributary to the five discharge locations, as shown in **Figure 2-11**. The design 24-hour storm volumes were calculated for each drainage area using the MODRAT methodology described in the LACPW Hydrology Manual. Attributes for each drainage area are listed in **Table 2-8**, along with calculated values for the 85th percentile, 24-hour rainfall event.

Table 2-8 Drainage Area Attributes

Attribute	L1	L5	L7	L8	L10
Area (ac)	27.3	18.7	42.8	20.5	10.8
Flowpath Length (ft)	2,660	1,780	2,600	2,000	1,700
Flowpath Slope (ft/ft)	0.064	0.053	0.065	0.075	0.085
Impervious %	43%	40%	44%	48%	45%
85th percentile Rainfall (in)	1.0	1.0	1.0	1.0	1.0
85th Percentile Peak flow (cfs)	2.4	1.9	3.9	2.3	1.3
85th Percentile Volume (AF)	1.02	0.67	1.63	0.84	0.42

Captured runoff was partitioned into a treated portion and a bypass portion. The treated portion was limited to the 85th percentile 24-hour design storm volume, and the bypass portion accounted for runoff above the 85th percentile 24-hour design storm volume but below the 10-year 24-hour design storm volume. Runoff in excess of the 10-year design storm volume will not enter the proposed diversion system and will instead follow pre-project drainage patterns. The runoff volume on every storm day was calculated and added to the SLRC.

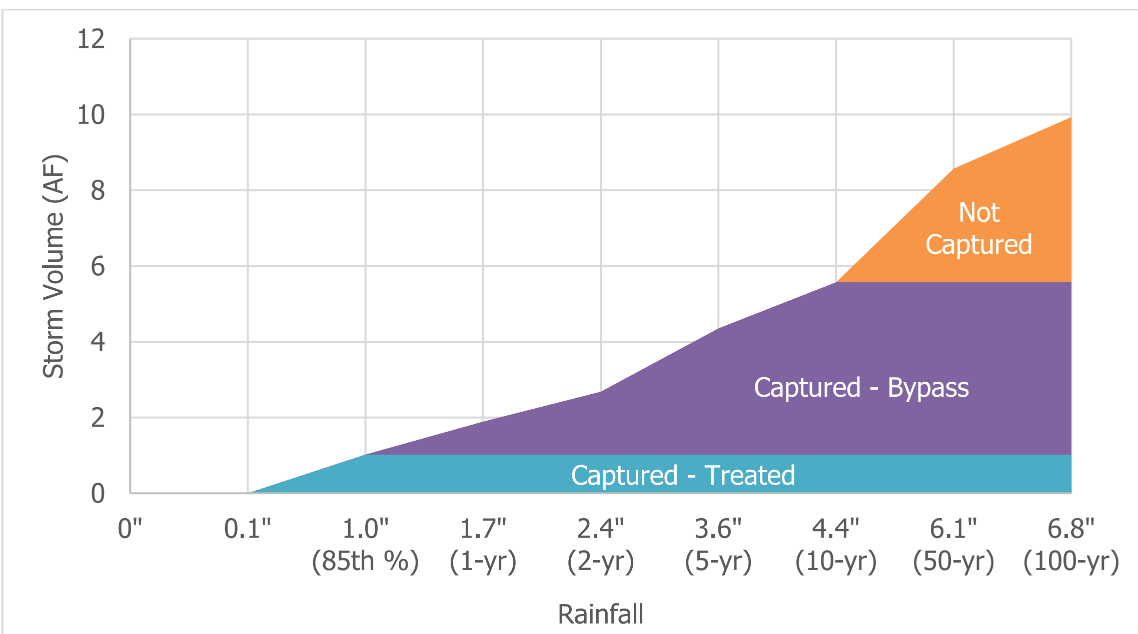

Figure 2-12 Captured Volume for Area L1

Figure 2-12 shows the partitioning of runoff from the Stormwater Capture Project for Drainage Area L1, which is presented here as representative of all five drainage areas captured by the Stormwater Capture Project. The figure shows how rainfall was converted into runoff for each storm event.

- First, no runoff is assumed to occur for daily rainfall amounts less than a tenth of an inch.
- Second, daily rainfall amounts between a tenth of an inch and one-inch (the 85th percentile 24-hour storm volume for this location) produce runoff that is fully captured and treated by the pretreatment BMP at Area L1.
- Third, daily rainfall amounts greater than one inch produce more runoff than can be treated by the pretreatment BMP. In these situations, the portion of the runoff equivalent to a one-inch storm (1.02 AF) is assumed to be captured and treated, while the portion of the runoff above this threshold is assumed to be captured and bypassed around the treatment system.
- Fourth, for daily rainfall amounts greater than 4.4 inches (the 10-year 24-hour storm volume for this location), only the portion of runoff below the 10-year storm volume (5.57 AF) is assumed to be captured, while the portion above this amount is not captured by the diversion system. Over the 20 years of rainfall record used in the Water Quality Model, a rainfall event greater than the 10-year storm occurred only once (December 29, 2004).

2.3.2 Recirculation and Refill

The DWP Recirculation project will take water from the south end of Silver Lake Reservoir and pump it to the north end of Ivanhoe Reservoir continuously. Two pumps will each operate for 12 hours a day at a rate dependent on the water level in Silver Lake Reservoir, typically between 850 and 1,400 gallons per minute (GPM), according to design plans (Black & Veatch, 2018). This operation procedure was accounted for in the water quality model under Scenario 3.

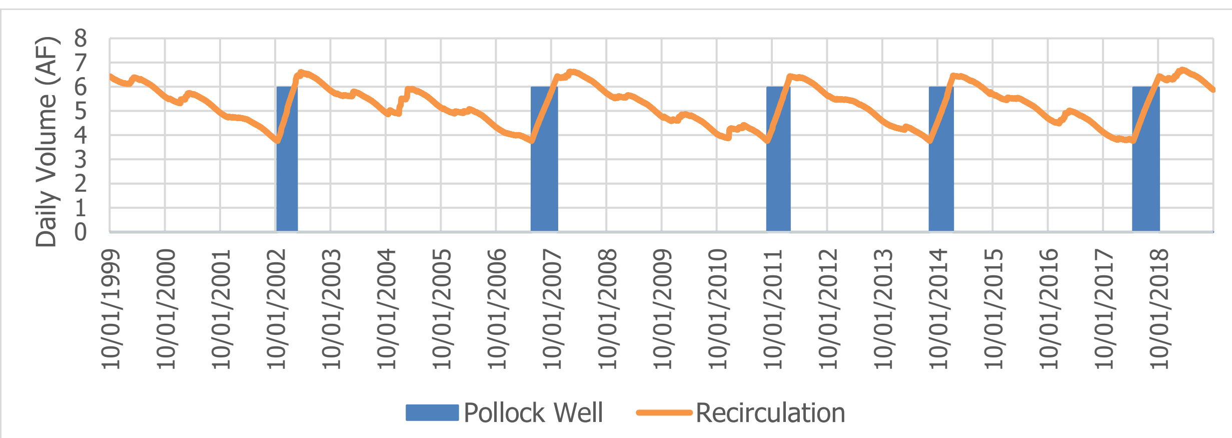

Figure 2-13 Recirculation and Refill - Scenario 3

Figure 2-13 shows the daily recirculation volume conveyed by the Recirculation Project, along with the refill period timeline under Scenario 3. The recirculation rate depends on the water level in Silver Lake Reservoir: as the head difference increases between Silver Lake Reservoir and Ivanhoe Reservoir, the pump operates less efficiently. Following refill operations, the head difference between the two reservoirs decreases and the pump operates efficiently once again, pumping at a higher flow rate.

The figure also shows Pollock Well refill periods. The number of refill periods over the 20-year modeled time period remains the same at five under both Scenario 2 and Scenario 3, but the average length of time between refills increases from approximately 36 months under Scenario 2 to approximately 41 months under Scenario 3 due to the additional water from the Stormwater Capture Project. The total length of time to perform the refill remained at about five months, but the average volume per refill decreased from 964 AF under Scenario 2 to 885 AF under Scenario 3. **Table 2-9** summarizes the refill periods under Scenario 3.

Table 2-9 Refill Periods – Scenario 3

Refill Number	Start Date	End Date	Total Days	Total Volume (AF)
1	November 8, 2002	March 8, 2003	121	722
2	July 14, 2007	December 20, 2007	160	955
3	October 26, 2011	March 15, 2012	142	847
4	September 1, 2014	January 26, 2015	148	883
5	May 21, 2018	November 7, 2018	171	1,020

2.3.3 Scenario 3 Water Quantity Results

The water surface elevation calculated by the model are shown for both Silver Lake and Ivanhoe Reservoirs in **Figure 2-14**. The five refill periods are indicated as the sharply rising portions of the time series graphs for Silver Lake Reservoir. Due to the constant flow from the Recirculation Project, the level in Ivanhoe Reservoir remains constant at elevation 451.

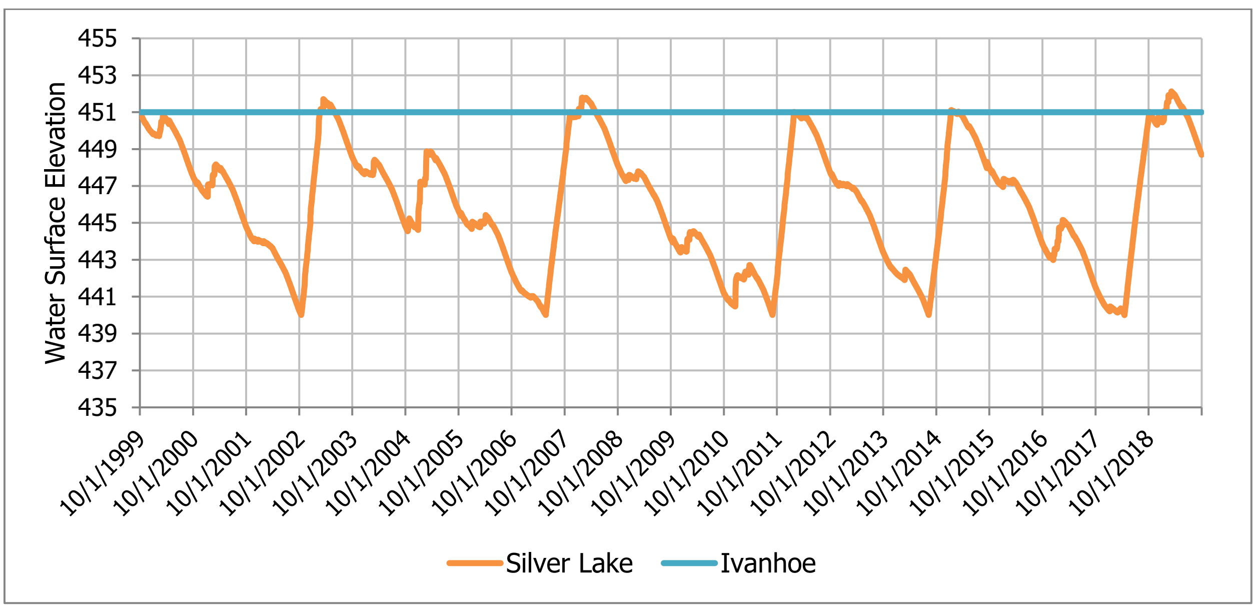

Figure 2-14 Scenario 3 Water Surface Elevations

Table 2-10 summarizes the water balance in the entire SLRC over the course of the entire 20-year modeled period from 1999 to 2019. The table shows a total Stormwater Capture Project contribution of 1,141 AF over 20 years, or about 57 AF per year. **Figure 2-15** provides the same information in bar graph format.

Table 2-10 Scenario 3 Water Balance Summary

Water Year	Stormwater Capture Project			Exfil-tration	Evapo-ration	Precipi-tation	Pollock Well
	Treated	Bypass	Total				
	AF	AF	AF	AF	AF	AF	AF
1999-2000	43	8	51	-93	-294	90	0
2000-2001	46	30	76	-92	-289	124	0
2001-2002	19	0	19	-92	-283	39	0
2002-2003	54	39	93	-92	-291	139	722
2003-2004	30	15	45	-92	-290	73	0
2004-2005	104	87	191	-92	-290	288	0
2005-2006	41	13	54	-92	-287	96	0
2006-2007	10	0	10	-92	-282	25	471
2007-2008	41	13	55	-93	-294	92	483
2008-2009	32	3	35	-92	-289	66	0
2009-2010	54	12	66	-92	-284	113	0
2010-2011	66	34	99	-92	-282	163	0
2011-2012	35	4	39	-92	-291	67	847
2012-2013	23	0	23	-92	-288	50	0
2013-2014	19	0	19	-92	-282	38	179
2014-2015	37	8	45	-92	-291	77	704
2015-2016	26	6	32	-92	-289	58	0
2016-2017	60	24	84	-92	-284	142	0
2017-2018	16	2	19	-92	-283	35	794
2018-2019	64	21	85	-92	-295	140	227
Total	**820**	**321**	**1,141**	**-1,843**	**-5,758**	**1,913**	**4,427**
Annual Average	**41**	**16**	**57**	**-92**	**-288**	**96**	**221**

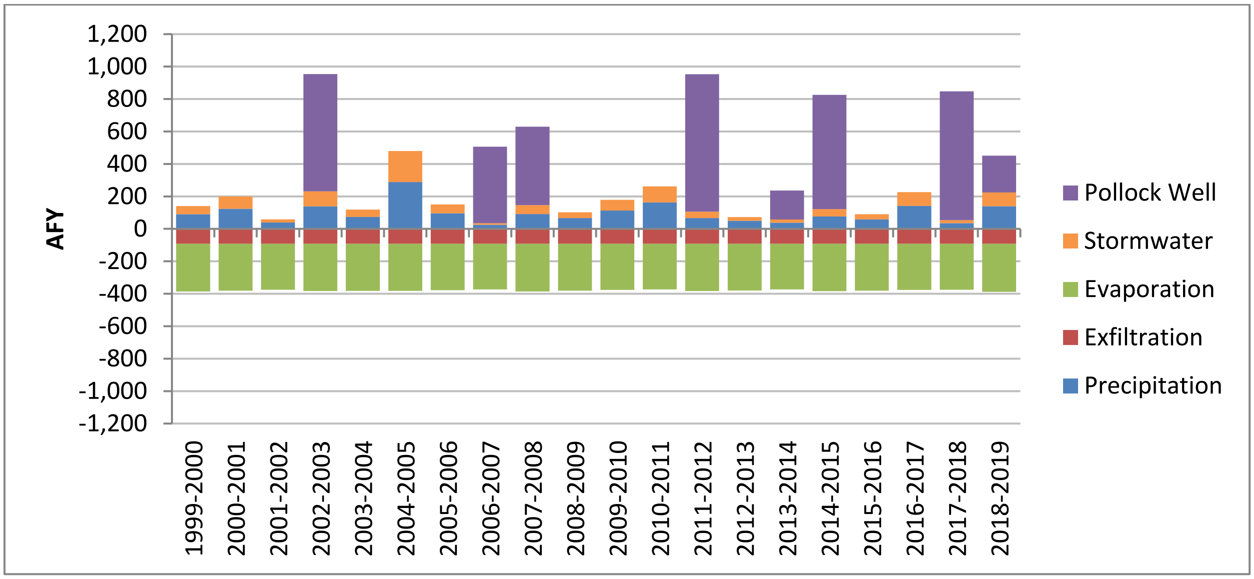

Figure 2-15 Scenario 3 Water Balance Summary

For Scenario 3, the water surface elevation for a wet year, typical year, and dry year were 444.36, 442.81, and 441.99, respectively, as shown in **Figure 2-16**. The drop was 1.64 feet, 3.19 feet, and 4.01 feet, respectively. The presence of the Stormwater Capture Project resulted in more water entering the system, especially during wet years. For example, the peak water surface elevation in the wet year under Scenario 3 is 447.71 in March, while at the same point in time for Scenario 1 and 2 it was only 446.40. However, the decrease in water levels in Silver Lake Reservoir during the dry months is slightly accelerated in Scenario 3 when compared with Scenarios 1 and 2, so much so that during the dry year, even though more volume of water entered the system due to the Stormwater Capture Project, the ending water surface elevation in Silver Lake Reservoir is about equal to the Scenario 1 and 2 elevation. In all scenarios, both Ivanhoe and Silver Lake Reservoirs lose water due to exfiltration/evaporation. However, in Scenario 3, water lost from Ivanhoe Reservoir is replaced by water from Silver Lake Reservoir via the Recirculation Project. Therefore, in Scenario 3, water leaves Silver Lake Reservoir both through evaporation/exfiltration and through replacement of Ivanhoe Reservoir water, which hastens the drop in water levels.

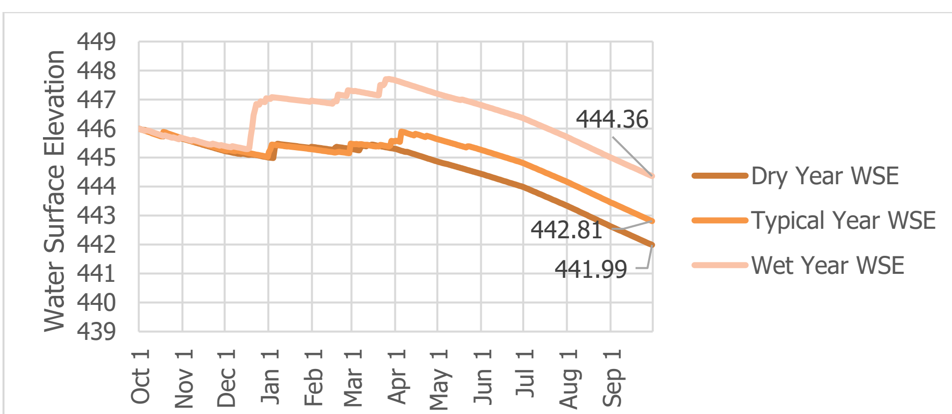

Figure 2-16 Scenario 3 in a Dry, Wet, and Typical Year

2.4 Scenario 4 – Master Plan Proposed Scenario

The Master Plan Proposed Scenario (Scenario 4) includes all the elements from the DWP Project Baseline Scenario (Scenario 3) and adds the effects of the Master Plan projects. The Master Plan project that will have the most effect on water quality is the addition of wetland plants and habitat, illustrated in **Figure 2-17**, which will have a positive effect on water quality if properly maintained.

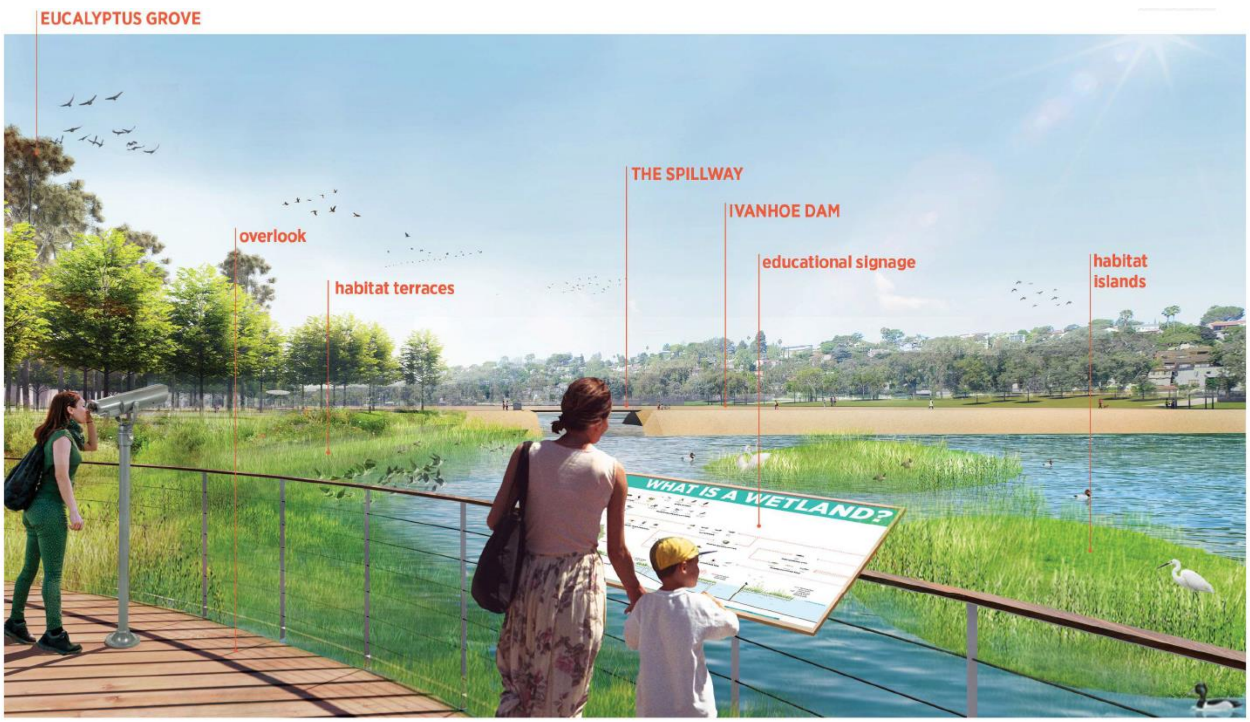

Figure 2-17 Master Plan Wetlands (Hargreaves Jones)

The SLRCMP calls for the addition or rehabilitation of 23 acres of habitat, including 11 acres of wetland and transition habitats. **Figure 2-18** shows the interaction between proposed wetland habitat areas and the water from the SLRC. Water will be pumped from the reservoirs to the wet meadow habitat zones which will then flow through the emergent wetlands back into the reservoirs. The water will be treated through sedimentation of suspended solids and filtration as it moves through each of the wetland zones. The wet meadows will go through wetting and drying cycles daily as reservoir water is pumped into them and then allowed to drain out. Transition habitat zones will also be irrigated with reservoir water on a separate cycle appropriate for the drought-tolerant, coastal scrub planting palette envisioned there.

In the SLRC Water Quality Model, the wetland and transition habitat areas were divided between Ivanhoe Reservoir and Silver Lake Reservoir, with two acres of wetland and transition habitat added to Ivanhoe Reservoir and nine acres of wetland and transition habitat added to Silver Lake Reservoir.

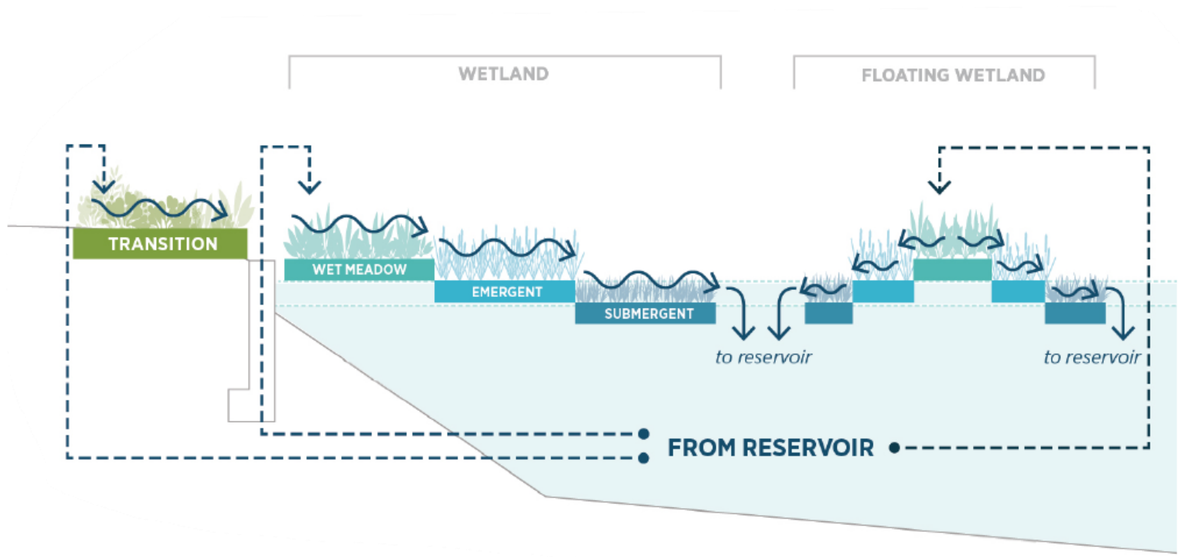

Figure 2-18 Wetland Irrigation Concept

Given the irrigation concept for the SLRC, the wetland and transition habitat areas in Scenario 4 will mimic the water quality processes from treatment wetlands. Treatment wetlands use biological processes to remove nutrients through transformation and uptake by microbes and plants. Nutrients are assimilated and absorbed into organic and inorganic sediments and converted into gas through volatilization. Both above-water and submerged aquatic plants take up and remove nutrients from both sediment and the water column.

Floating treatment wetlands are built upon artificial platforms that allow aquatic plants to grow in deeper water than is typical of wetland plants. Plant roots grow in the water column, which allows for direct uptake of nutrients and for a biofilm to develop that enhances nutrient uptake and transformation. The floating rafts are planted with native plants and are anchored to stay in one area but can rise and fall with changes in water elevation. Studies have shown floating treatment wetlands are as effective as conventional flow-through wetlands at nitrogen and phosphorus removal (Tanner et al., 2011). A study by the International Institute for Sustainable Development showed enhanced phosphorus uptake and cattail root growth in floating treatment wetlands in a lake with high phosphorus concentration compared to a lake with a lower phosphorus concentration, which shows that floating wetland treatments are effective at phosphorus removal regardless of the eutrophication state of the waterbody.

The effectiveness of wetlands at improving water quality has been demonstrated locally at Echo Park Lake, in which 68% of total nitrogen and 77% of total phosphorus was estimated to be removed by the wetland treatment system (USEPA, 2012).

The water quality processes from treatment wetlands were included in the SLRC Water Quality Model in Scenario 4, along with all the elements from Scenario 3. The sections below describe the additional model inputs processes that were used in Scenario 4.

2.4.1 Transpiration

Transpiration describes the process of water being released to the atmosphere as water vapor through the stomatal apertures of plants. Water balance equations for agriculture combine evaporation and transpiration into one term, evapotranspiration, covering water vapor losses through both the soil and crops. Evaporation losses are generally a larger component of evapotranspiration for land-based crops; however, in wetland systems, transpiration can account for between 50% and 90% of the total evapotranspiration losses, especially during growing seasons (Bachand, 2014).

The Master Plan wetlands projects will replace a portion of the open water surface area of the SLRC with floating wetlands containing plants whose roots will be immersed in water. The floating wetland plants will be assumed to be in growing season constantly. It is reasonable to assume that transpiration processes added in Scenario 4 will replace the open water evaporation processes in the wetland areas and the net water balance effects of the wetlands will be negligible. Transpiration was modeled as a separate factor in the SLRC Water Quality Model for water quality mass balance purposes.

2.4.2 Change in Pollock Well Water Operations

Under operating conditions proposed by the SLRCMP, Pollock Well water will need to be pumped into the SLRC continuously at a seasonally variable rate to maintain a water level in Silver Lake Reservoir between elevation 445 and elevation 447. Seasonally-variable evaporation rates and precipitation change vastly from one year to the next and the Pollock Well water input to the system must be used to counterbalance the uncontrollable evaporation, precipitation, and exfiltration outputs to maintain the narrow range of water surface elevations.

Under existing conditions, Pollock Well water is pumped through a portable GAC treatment facility at a high rate during each refill period. The GAC treatment facility is then hauled away to be cleaned and used at another facility. The frequent pumping required by the SLRCMP to allow wetlands to grow will require a permanent GAC treatment facility to treat the groundwater from Pollock Well. It is beyond the scope of the SLRCMP to design a GAC treatment facility for the future Pollock Well flows into the SLRC, but there are certain design requirements for such a facility. One such requirement is that the GAC media material will need to be continually wet to reduce bacterial growth on the media, to prevent channeling, and to ensure filter efficiency. During times when the reservoir elevation is low, continuous flows through the GAC media will be achievable, but even during times when the reservoir elevation is high, sporadic pumping of water through the GAC media will be required every three to six hours. The exact operational details for the pump and GAC system will be determined at a future time during the design phase of the SLRCMP projects.

In the SLRC Water Quality Model, the operation structure of the future Pollock Well was set to run at 300 GPM for 24 hours a day (1.326 ac-ft/day) when the water level was below elevation 445.5, and 300 GPM for two hours a day (0.1105 ac-ft/day) when the water level was above elevation 445.5. The 300 GPM for two hours a day can be structured in real life so that the pump runs for an hour every 12 hours, or for half an hour every six hours, or however DWP Operations wishes to do it so that the media stays wet but not too much water flows to the SLRC. This operating scheme resulted in no days with water below elevation 445, but 887 days with water level above 447, many in the very rainy water year of 2004-2005.

2.4.3 Other Discharges

When water levels in Silver Lake Reservoir rise above elevation 454, water will start to flow into the overflow spillway structure located on the west side of the reservoir. The overflow weir structure is connected to a 36-inch pipe that tunnels underneath the hillside to the west of Silver Lake Reservoir and discharges to a storm drain tributary to Ballona Creek. However, the SLRC Water Quality Model never predicted a water surface elevation above 454 in its 20-year modeled timespan, so this capability was never used. A provision in the Quality Assurance Project Plan (QAPP) called for a maintenance discharge if exceedances of water quality limits established in **Table 1-1** were exceeded on any day within the modeled time span. Maintenance discharges, however, never became necessary over the 20-year modeled timespan.

2.4.4 Scenario 4 Water Quantity Results

The water surface elevation calculated by the model are shown for both Silver Lake and Ivanhoe Reservoirs in **Figure 2-19**.

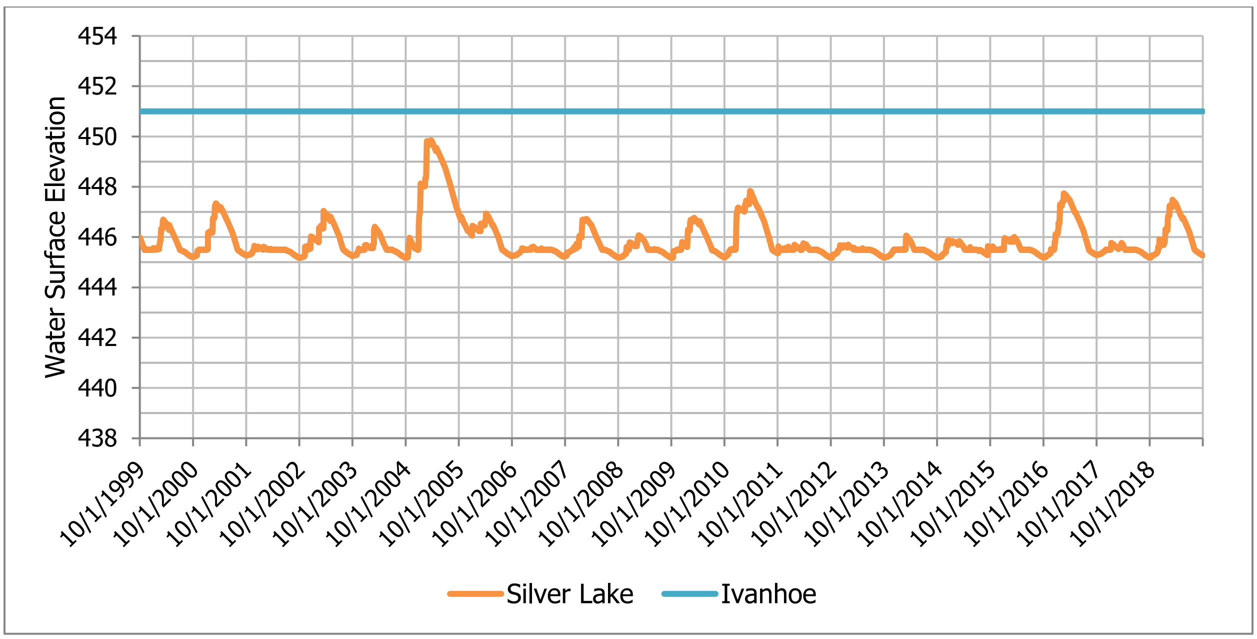

Figure 2-19 Scenario 4 Water Surface Elevations

The change in Pollock Well operations is apparent from the water surface elevation data shown in **Figure 2-19**. The frequent refills offset the effects of evaporation and exfiltration such that the water surface elevation in Silver Lake Reservoir is usually between elevation 445 and elevation 447. Particularly rainy seasons sometimes lift the water surface elevation above elevation 447. The model allowed the water surface to rise above the elevation 447 limit without a discharge. Under this operating procedure, areas close to the water such as the kayak launch, certain observational platforms, and wetlands terraces may become inundated for weeks or months at a time, which may be unacceptable depending on the other goals of the Master Plan projects.

Table 2-11 Scenario 4 Water Balance Summary

Water Year	Stormwater Capture Project			Exfil-tration	Evapo-ration	Trans-piration	Precip-itation	Pollock Well
	Treated	Bypass	Total					
	AF	AF	AF	AF	AF	AF	AF	AF
1999-2000	43	8	51	-95	-251	-37	90	186
2000-2001	46	30	76	-95	-251	-37	124	189
2001-2002	19	0	19	-94	-250	-37	39	315
2002-2003	54	39	93	-95	-251	-37	139	158
2003-2004	30	15	45	-95	-251	-37	73	256
2004-2005	104	87	191	-95	-254	-37	288	65
2005-2006	41	13	54	-95	-252	-37	96	88
2006-2007	10	0	10	-94	-250	-37	25	338
2007-2008	41	13	55	-95	-251	-37	92	232
2008-2009	32	3	35	-94	-250	-37	66	280
2009-2010	54	12	66	-94	-251	-37	113	204
2010-2011	66	34	99	-95	-251	-37	163	135
2011-2012	35	4	39	-95	-250	-37	67	260
2012-2013	23	0	23	-94	-250	-37	50	309
2013-2014	19	0	19	-94	-250	-37	38	324
2014-2015	37	8	45	-94	-250	-37	77	281
2015-2016	26	6	32	-95	-250	-37	58	270
2016-2017	60	24	84	-95	-251	-37	142	169
2017-2018	16	2	19	-94	-250	-37	35	315
2018-2019	64	21	85	-95	-251	-37	140	169
Total	**820**	**321**	**1,141**	**-1,891**	**-5,016**	**-740**	**1,913**	**4,544**
Annual Avg	**41**	**16**	**57**	**-95**	**-251**	**-37**	**96**	**227**

Table 2-11 summarizes the water balance in the entire SLRC over the course of the entire 20-year modeled period from 1999 to 2019. The table shows an average of 227 AF of Pollock Well water required, which is less than in Scenario 2 but more than in Scenario 3. The difference from Scenario 3 is due to the fact that at the 20-year mark, the ending water surface elevation was several feet lower than the beginning water surface elevation. If Pollock Well water refilled the SLRC to eliminate the drop in water surface elevation, the quantities of Pollock Well water in Scenario 3 and Scenario 4 would be similar.

Figure 2-20 shows the information from **Table 2-11** in bar graph format. The wild annual fluctuations that characterize Scenario 2 and Scenario 3 due to refill operations are removed in Scenario 4 due to the change in Pollock Well operations.

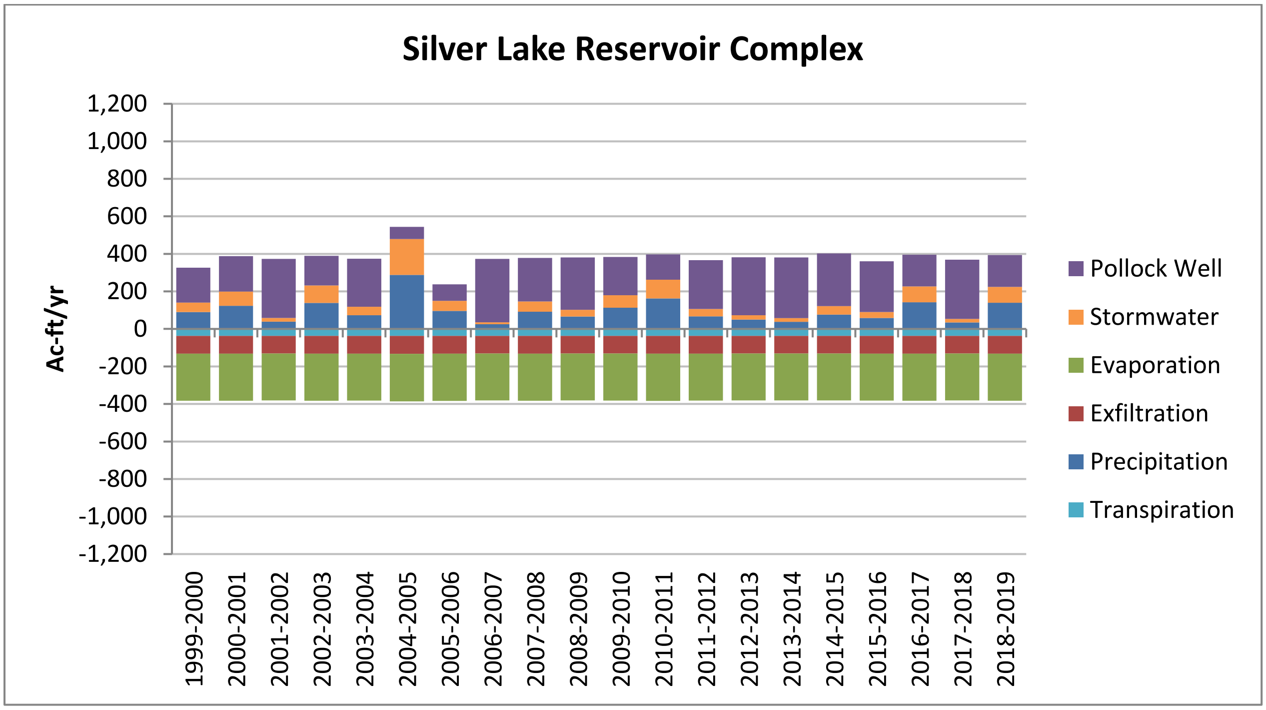

Figure 2-20 Scenario 4 Water Balance Summary

As shown in **Figure 2-21**, the end-of-year water surface elevations in Silver Lake Reservoir were similar across the dry year, typical year, and wet year. But during the wet year, the water surface elevation was higher after rainfall events, especially after a particularly wet mid- to late-December of that year that saw over 11 inches of rain fall over the course of two weeks.

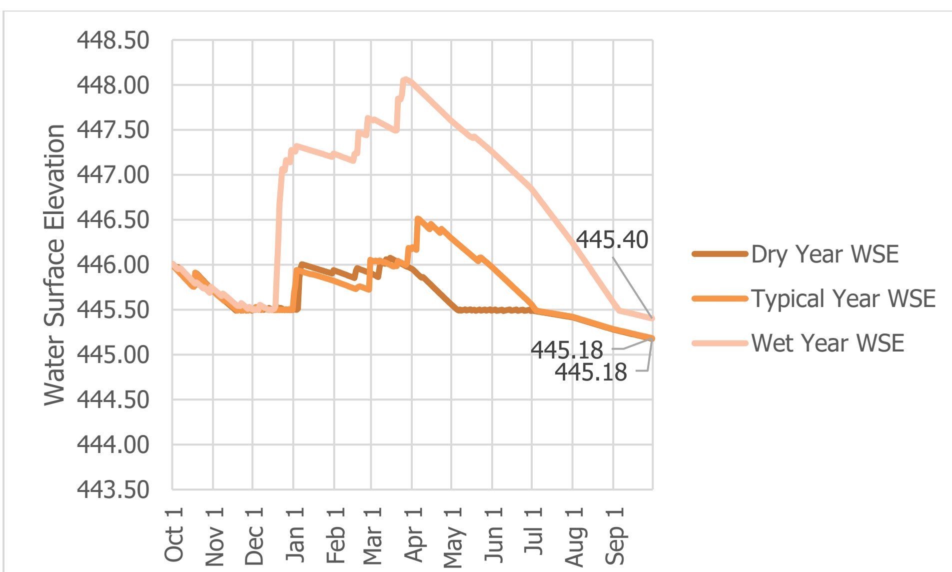

Figure 2-21 Scenario 4 in a Dry, Wet, and Typical Year

The similarity of water surface elevations among dry, typical, and wet years by the end of the year for Scenario 4 is due to the variable Pollock Well input. During the dry year and the typical year, the water surface elevation stayed within the recommended two-foot range (445 to 447) 100% of the time. During the wet year, the water surface elevation rose above 447 in December and did not drop below 447 until June.

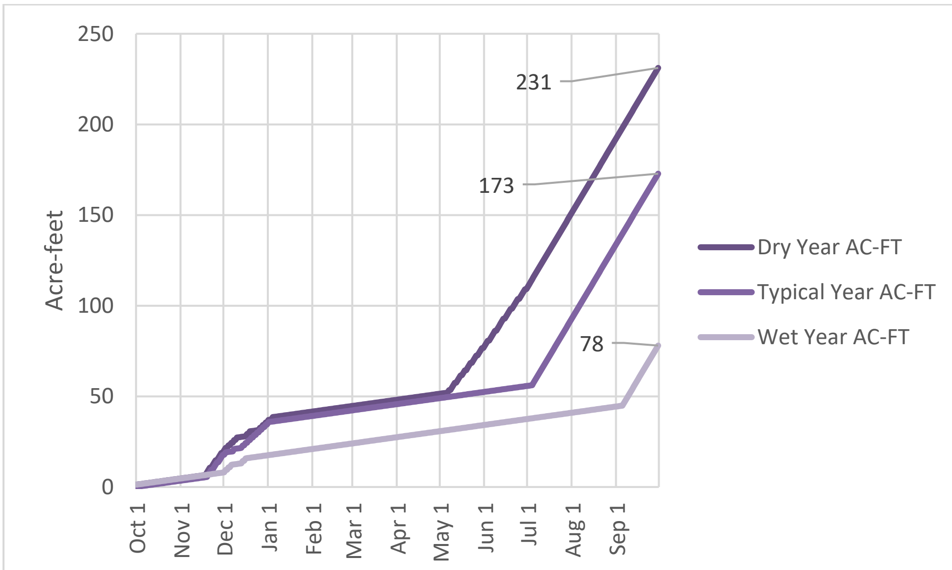

Figure 2-22 Cumulative Volume of Pollock Well Water Used

Figure 2-22 shows the cumulative volume of Pollock Well water added to the SLRC over the course of the typical dry year, typical wet year, and typical average year. Over the course of the year, 78 AF of Pollock Well water was added during the wet year, 173 AF during the typical year, and 231 AF during the dry year. The majority of flows from Pollock Well would be required during the summer months, but the timing of the start of the constant (or near-constant) 300 GPM flow would vary depending on the amount of rainfall in the year. The dry year required the constant replenishment period to begin at the beginning of May, the typical year at the beginning of July, and the wet year at the beginning of September.

2.5 Water Quantity Summary

The water quantity portion of the SLRC Water Quality Model calculated each component as a daily volume input or output, and calculated the volume, water surface elevation, and surface area of both Ivanhoe Reservoir and Silver Lake Reservoir on a daily basis for each modeled scenario. These numbers served as the basis for calculations in the water quality portion of the model, described in **Section 3**.

3. Water Quality Data

Each input source of water has specific physical properties and transports certain constituents. The properties and constituents include temperature, dissolved oxygen, sediment, salinity, bacteria, and other pollutants. The concentration of constituents and pollutants within the SLRC depends not only on the quantity and concentration of inflow water sources, but also on physical, chemical, and biological processes that occur within the reservoir system. The SLRC Water Quality Model was based on mass balance relationships. The mass balance relationship assumes the mass of each constituent during each time step equals the mass input minus the mass output. The mass output of a constituent can be due to outflow, decay, absorption, or sedimentation.

3.1 Temperature

Most chemical and biological rates are dependent on water temperature. The SLRC Water Quality Model includes a calculated average reservoir water temperature for each modeled day. The water temperature time series was calibrated using water quality data collected by DWP at the surface of Ivanhoe Reservoir and Silver Lake Reservoir and air temperature data to determine an average daily water temperature.

The water temperatures were measured approximately bi-weekly at or near the water surface for Silver Lake and Ivanhoe Reservoirs from January 2018 to April 2019. The surface temperature measurements reflect the maximum temperature observed in the water column. To determine an average temperature in each reservoir for the model, thermocline effects were considered (Gorham and Boyce, 1989). Temperature with depth measurements during different seasons for four lakes in Los Angeles County (Peck Lake, El Dorado Park Lake, Puddingstone Reservoir, and Lake Sherwood) were reviewed to determine the average temperature change with depth during different seasons (Los Angeles Area Lakes, 2012). The thermocline was more pronounced in summer months compared to winter months, as shown in **Figure 3-1**. During winter months, the average lake temperature was 1.3 degrees Celsius lower than the surface temperature. During summer months, the average lake temperature was 3.2 degrees Celsius lower than the surface temperature. The measured surface water temperature for Silver Lake and Ivanhoe Reservoirs were adjusted by these amounts to determine the average temperature for the model. No data for these lakes were reported for spring and fall, so the average between winter and summer was used (2.3 degrees Celsius) to adjust the measured surface temperature.

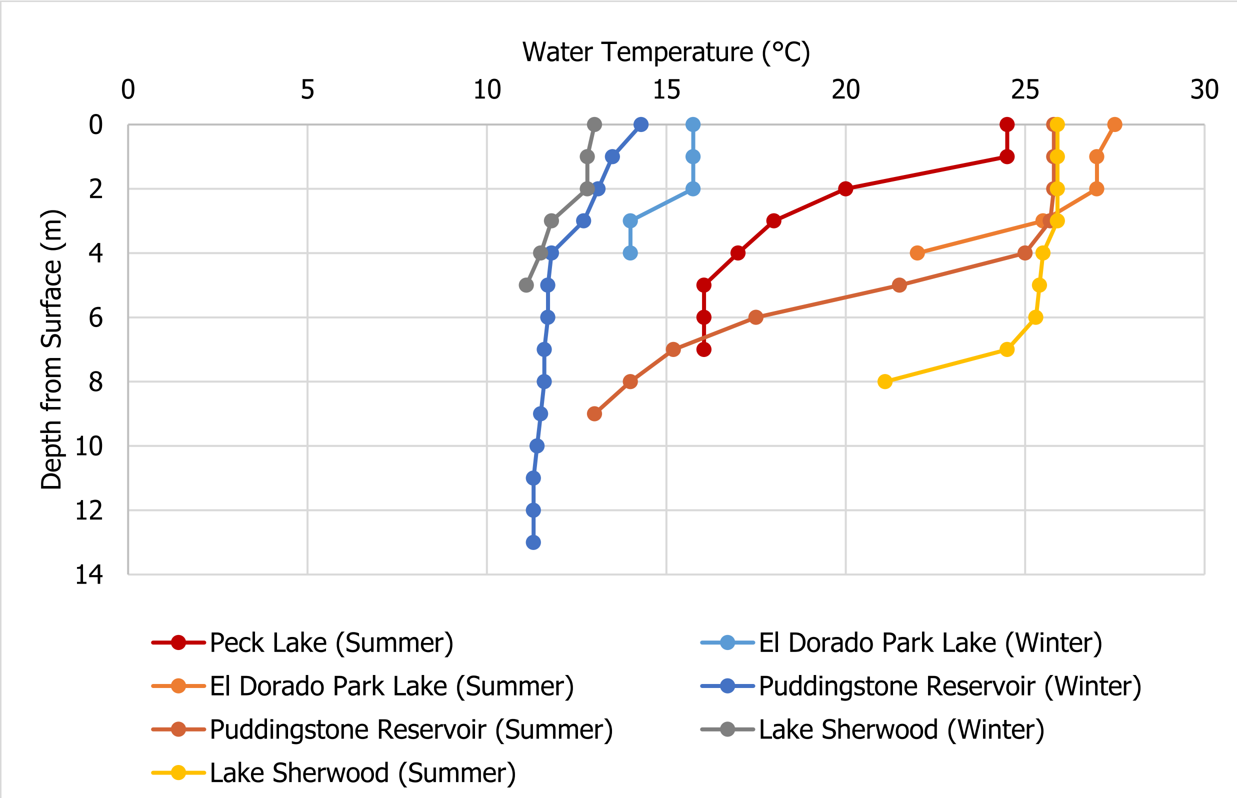

Figure 3-1 Water Temperature at Varying Depths in Los Angeles County Lakes

Once the surface measurements were converted to average water temperature measurements, a linear relationship was found relating the average water temperatures to the minimum daily air temperature. Linear relationships for both Silver Lake and Ivanhoe Reservoirs with r^2 values of 0.9 were found using a running-average of eight days (four days prior and three days post) for the minimum daily air temperature. A running average of eight days (four days prior and three days post) was used to reduce the daily fluctuations in the average daily water temperature time series. The water temperature is expected to fluctuate less than the air temperature due to the higher heat capacity of water over air.

The daily minimum and maximum air temperatures from Station USW00093134 in Downtown Los Angeles are plotted with the measured water surface and calculated average water temperatures of Silver Lake and Ivanhoe Reservoirs in **Figure 3-2**. The water temperature time series was used in calculations for bacteria decay and dissolved oxygen in all four model scenarios.

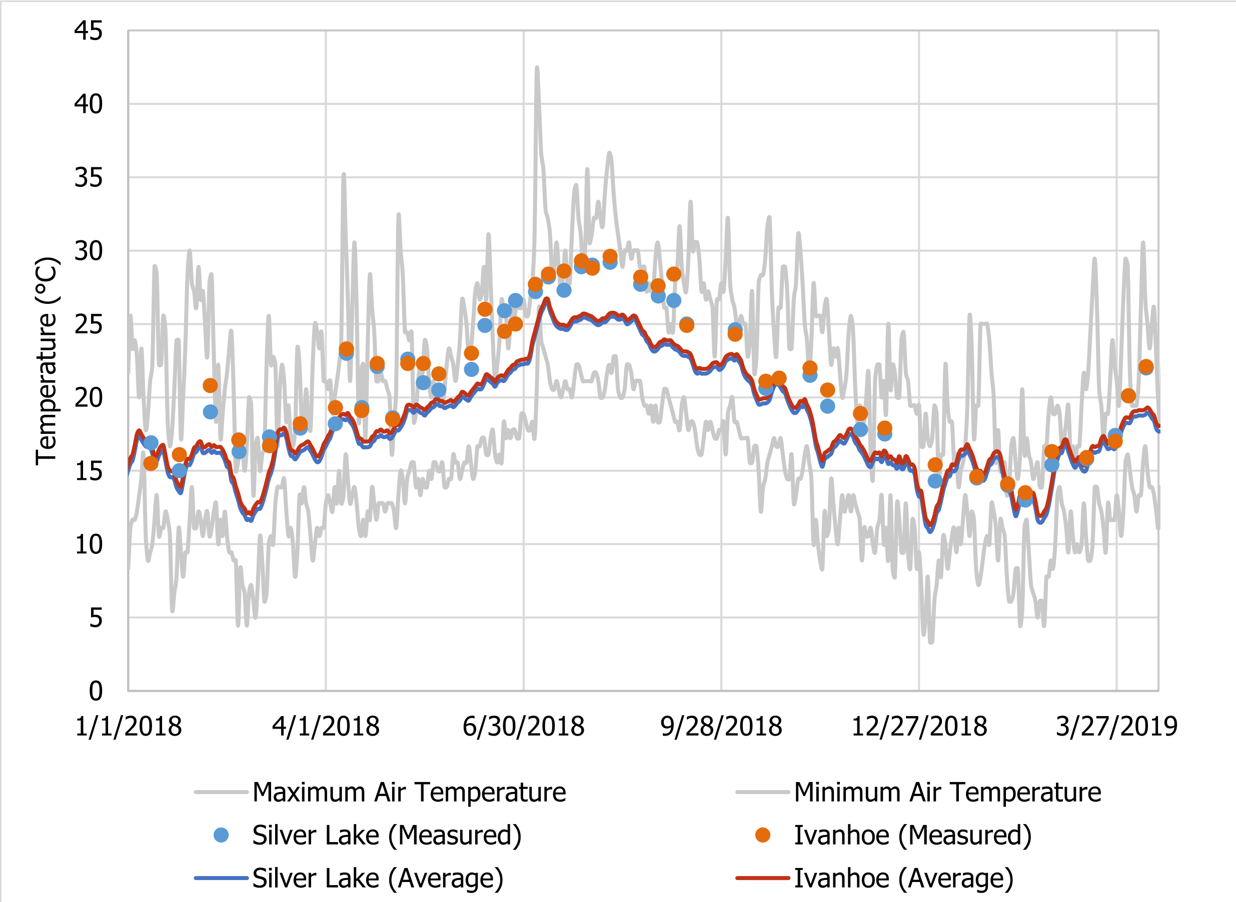

Figure 3-2 Average and Measured Temperatures

The water temperature in each reservoir was adjusted using a mass balance for stormwater inflows in Scenarios 3 and 4. The temperature of the stormwater inflow was assumed to be 15.5 degrees Celsius based on an average value from stormwater monitoring data collected by CWE in Los Angeles County over four years.

3.2 Suspended Solids and Sediment

Suspended solids and sediment affect the fate and transport of chemical pollutants in water and contribute to sediment loading in the reservoir. Chemical pollutants tend to adsorb to suspended solids, and therefore the fate and transport of pollutants is dependent on the transport of suspended solids.

Scenarios 1 and 2 do not include any sources of suspended solids, and therefore suspended solids were not modeled in these two scenarios. Suspended solids and sediment will enter the SLRC through the five proposed outflow pipes from the Stormwater Capture Project, and were modeled in Scenarios 3 and 4. Though the Stormwater Capture Project will construct pretreatment Best Management Practices (BMPs), sediments finer than 2.4 millimeters will pass through the pretreatment filtration devices and enter the SLRC (Contech, 2019). Flows greater than the 85th percentile design storm will bypass the BMPs to enter the SLRC untreated. The BMP suspended solids removal efficiency for each time step in the model was calculated using a relationship of the removal efficiency to the percent of the design flow rate for a typical CDS unit (Contech, 2017):

$$Removal\ Efficiency\ (\%) = -19.145(fraction\ of\ design\ flow\ rate) + 100.92$$

The total suspended solids concentration expected from the five catchment areas in the model were calculated using event mean concentrations (EMCs) by land use from the Los Angeles County 1994-2000 Integrated Receiving Water Impacts Report (2000). The land use in the five catchment areas consisted of mixed residential and transportation, and the EMCs for each catchment area were weighted using the percentage of each land type. **Table 3-1** summarizes the expected total suspended solids concentration in runoff for each catchment.

Table 3-1 Total Suspended Solids Concentration by Catchment

Catchment	Total Suspended Solids (mg/L)
L1	65.9
L5	66.4
L7	66.3
L8	67.6
L10	67.0

Suspended solids settle in the SLRC based on particle size. An average settling velocity of 0.9 m/day was used in the model to account for the suspended solids leaving the water column (Dortch and Gerald, 1995 and WPCF, 1990).

3.3 Total Dissolved Solids

The dissolved solids content of a waterbody, which includes dissolved salts, is key to its aquatic ecological health. Dissolved solids enter the SLRC through the Stormwater Capture Project and Pollock Well water, and the SLRC will have a certain dissolved solids content as an initial condition. The mass of dissolved solids entering the SLRC from precipitation was assumed to be insignificant compared to the concentrations in runoff and Pollock Well water.

3.3.1 Initial SLRC Total Dissolved Solids Concentration

Specific conductance measurements were taken by DWP at each reservoir on a bi-weekly schedule from January 2018 to April 2019. The dissolved solids content in the SLRC was estimated from the water quality data via a formula that translates specific conductance, measured in microsiemens per centimeter (µS/cm), to a dissolved solids concentration in milligrams per liter (mg/L). A conversion factor of 0.70 was used to convert specific conductance to a total dissolved solid concentration (Gilmore and Luong, 2016). The total dissolved solid concentration calculated from the measurements is shown in **Figure 3-3**. Pollock Well water was added to the SLRC in October 2018 and February 2019. The Pollock Well water dissolved solids concentration was higher than the average concentration in the SLRC. This addition of water is the most likely cause of the slight rise in total dissolved solids seen in the figure. The decrease observed near the end of March 2019 appears to be a measurement or recording error. The last measured values for Silver Lake and Ivanhoe Reservoirs taken on April 9, 2019, were used in the model for the initial reservoir concentrations. The initial total dissolved solids (TDS) concentration in Silver Lake and Ivanhoe Reservoirs were 388 and 431 mg/L, respectively. The last measured values were used because of the increasing trend observed in the data. Using the average values could underestimate the initial values for the model.

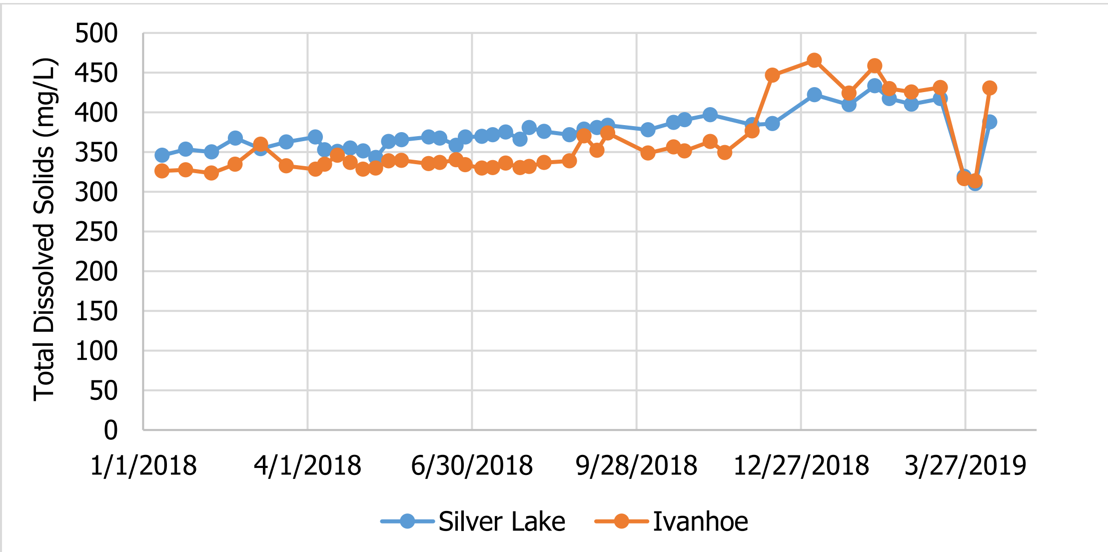

Figure 3-3 SLRC Total Dissolved Solids Concentration

3.3.2 Pollock Well Water Total Dissolved Solids Concentration

The TDS concentration of Pollock Well GAC-treated effluent from DWP monitoring data on October 10, 2018, and February 12, 2019, were given as 100.5 and 418 mg/L, respectively. The October 10th concentration is likely too low as the total dissolved solids concentration in the reservoirs increased above 400 mg/L with the addition of the well water. Additionally, GAC-treatment typically does not remove dissolved solids from water, and groundwater typically has higher dissolved solids content than surface water (State Water, 2017). Therefore, the February 12th concentration of 418 mg/L was used in the model for the Pollock Well water TDS concentration.

3.3.3 Stormwater Capture Project Total Dissolved Solids Concentration

The TDS concentration in the Stormwater Capture Project runoff was estimated using EMC data, which was weighted by land use within the tributary areas. **Table 3-2** summarizes the expected total dissolved solids concentration in runoff from each catchment.

Table 3-2 Total Dissolved Solids Concentration by Catchment

Catchment	Total Dissolved Solids (mg/L)
L1	54.7
L5	55.1
L7	55.0
L8	55.8
L10	55.4

3.3.4 Losses of Total Dissolved Solids in the SLRC

Dissolved solids leave the modeled system as overflow, exfiltration, and plant uptake via transpiration. Losses to exfiltration, overflow to Ballona Creek, and overflow from Ivanhoe to Silver Lake Reservoir are modeled in all four scenarios. Recirculation of dissolved solids from Silver Lake to Ivanhoe Reservoirs is modeled in Scenarios 3 and 4. Losses through plant uptake via transpiration are modeled in Scenario 4.

In Scenario 4, it is assumed that plant detritus will be removed during ongoing maintenance of the wetlands, and therefore the dissolved solids taken up by the plants will not be resuspended in the water column.

3.4 Coliform Bacteria

Pathogens, measured as total coliform, *E. coli*, and Enterococci, enter the SLRC from the Stormwater Capture Project flows and bird droppings.

3.4.1 Coliform Bacteria from Bird Droppings

Typical birds observed at SLRC include Canada Geese, Ruddy Ducks, American Coot, and California Gulls. The average daily bird counts were estimated from SLRC data from the Los Angeles Audubon Society and Cornell Lab of Ornithology, and are provided in **Table 3-3**. Two to three days from each month over one year, from March 2019 to February 2020, were averaged by season. Seasons were defined as winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November).

Table 3-3 Average Daily Bird Counts by Season

Bird Species	Winter	Spring	Summer	Fall
Canada Goose	3	1	9	1
Ruddy Duck	233	46	3	214
American Coot	59	3	1	117
California Gull	272	86	59	46

The mass of average daily droppings per bird are given in **Table 3-4** (Scherer et al., 1995).

Table 3-4 Average Daily Bird Droppings

Bird Species	Average Daily Droppings (grams/bird/day)
Canada Goose	81.6
Ruddy Duck	18.0
American Coot	13.5
California Gull	15.6

Fecal coliform loading for all bird species was estimated based on 9 x 10^6 MPN per 250 grams of droppings (Hussong et al., 1979), as shown in **Table 3-5**.

Table 3-5 Daily Fecal Coliform Loading in (MPN/day) by Season

Bird Species	Winter	Spring	Summer	Fall
Canada Goose	8,812,800	2,937,600	26,438,400	2,937,600
Ruddy Duck	150,984,000	29,808,000	1,944,000	138,672,000
American Coot	28,674,000	1,458,000	486,000	56,862,000
California Gull	152,755,200	48,297,600	33,134,400	25,833,600
Total	341,226,000	82,501,200	62,002,800	224,305,200

Fecal coliform levels were assumed to be 20% of the total coliform levels for the model (Thomann and Mueller, 1987). Only total coliform levels were modeled, and it was assumed that if total coliform levels were below numerical limits, then *E. coli* and Enterococci levels would also be below numerical limits.

3.4.2 Coliform Bacteria from Stormwater Capture Project Flows

Total coliform bacteria concentrations from the Stormwater Capture Project flows were estimated from EMC data weighted by land use in each catchment. **Table 3-6** summarizes the expected total coliform concentration in runoff from each catchment.

Table 3-6 Total Coliform Concentration by Catchment

Catchment	Total Coliform Concentration (MPN/100mL)
L1	133,870
L5	159,140
L7	153,980
L8	214,050
L10	182,970

3.4.3 Removal of Coliform Bacteria in SLRC

Total coliforms are transported in overflow to Ballona Creek and overflow from Ivanhoe to Silver Lake Reservoirs in all scenarios. In Scenarios 3 and 4, total coliforms are recirculated from Silver Lake to Ivanhoe Reservoir.

The survival, fate, and distribution of bacteria within natural waters are influenced by sunlight, temperature, salinity, predation, nutrients, and toxic substances. In all four scenarios, the change in total coliform concentrations within each reservoir was modeled with a decay rate (k) using the equation:

$$C = C_o e^{-kt}$$

In Scenarios 1, 2, and 3, the removal of total coliform bacteria was modeled using a decay rate (k) value of 1.0 per day at 20 degrees Celsius. In Scenario 4, the decay rate (k) was increased to 1.36 and 1.97 per day for Silver Lake and Ivanhoe Reservoirs, respectively, based on the expected bacterial removal by the wetlands in each reservoir. The decay rates were calculated by weighting the surface area covered by wetlands in each reservoir with a higher decay rate (k) of four per day (Thomann and Mueller, 1987). The decay rate (k) in all scenarios was adjusted for water temperature (Thomman and Mueller, 1987; Vymazal, 2005), using the equation:

$$k_T = k_{20°C} 1.07^{T-20}$$

3.5 Metals

Copper and lead concentration limits of 22 µg/L and 11 µg/L, respectively, have been established as goals for the project. Copper and lead enter the SLRC through the Stormwater Capture Project runoff and Pollock Well water, atmospheric deposition, and the SLRC has an initial concentration of each on the first day of the model.

3.5.1 Initial SLRC Copper and Lead Concentrations

SLRC metal concentration data was unavailable, so the concentrations of copper and lead in Pollock Well GAC-treated effluent were assumed to apply to the SLRC for the initial concentrations within the SLRC. The measurements taken on October 10, 2018, and February 12, 2019, were averaged, and the copper and lead concentrations were calculated to be 2.6 µg/L and 0.23 µg/L, respectively.

3.5.2 Atmospheric Deposition

Dry atmospheric deposition will contribute to copper and lead loading in the SLRC. A study of the Santa Monica Bay watershed showed that atmospheric deposition can be a significant source of contaminants in the Los Angeles region (Stolzenbach et al., 2001). The SLRC Water Quality Model accounts for dry atmospheric deposition by incorporating seasonal deposition values, as given in **Table 3-7** (Stolzenbach et al., 2001). Seasons were defined as winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November). The flux was converted to a mass loading by multiplying by the surface area of water in each reservoir for each day of the model.

Table 3-7 Atmospheric Deposition of Copper and Lead

Season:	Spring	Summer	Fall	Winter
Copper	0.44 µg/(m^2-day)	0.03 µg/(m^2-day)	0.66 µg/(m^2-day)	0.03 µg/(m^2-day)
Lead	0.26 µg/(m^2-day)	0.01 µg/(m^2-day)	0.35 µg/(m^2-day)	0.02 µg/(m^2-day)

3.5.3 Pollock Well Water Copper and Lead Concentrations

Monitoring data for copper and lead in Pollock Well GAC-treated effluent was averaged to determine concentrations of the metals expected in Pollock Well water additions to SLRC. An average copper concentration of 2.6 µg/L and an average lead concentration of 0.23 µg/L were calculated and were assumed to be constant concentrations for Pollock Well water additions in Scenarios 2, 3, and 4.

3.5.4 Stormwater Capture Project Copper and Lead Concentrations

Concentrations of copper and lead in runoff have been estimated from regional EMC data for area weighted land use in each catchment. **Table 3-8** summarizes the expected total copper and lead concentrations in runoff from each catchment.

Table 3-8 Total Copper and Lead Concentrations by Catchment

Catchment	Total Copper Concentration (µg/L)	Total Lead Concentration (µg/L)
L1	26.2	10.8
L5	27.5	10.8
L7	27.2	10.8
L8	30.4	10.7
L10	28.8	10.7

3.5.5 Metal Partitioning and Removal from SLRC

Within the SLRC, metals adsorb to suspended solids and sediments, which settle, and also leave the water column through uptake by plants and algae. Metal partitioning was included in the model to distinguish the dissolved and adsorbed fractions of the metals (Thomann and Mueller, 1987). The dissolved fraction was calculated in two different ways: using conversion factors and partitioning.

Conversion factors were used to estimate the expected dissolved fractions within the water column (EPA, 1999). A conversion factor of 0.960 was used to convert total copper to dissolved copper. The conversion factor for lead is dependent on water hardness, which is related to total dissolved solids concentration. The conversion factor for lead is calculated using the equation:

$$Lead\ conversion\ factor = 1.46203 - LN(Hardness)(0.14572)$$

Hardness is given in mg/L with a maximum hardness value of 400 mg/L (EPA, 1999). The TDS concentration multiplied by 0.7 was used as a surrogate for hardness in the conversion factor calculation. The conversion factor of 0.7 was supported by water quality data collected in Los Angeles County over four years by CWE for monitoring sites along the Rio Hondo and San Gabriel River.

The absorbed fractions of the metals to suspended solids and algae were also calculated using an average partition coefficient (Kp) value of 10^5 L/kg for both copper and lead for partitioning to sediment and algae in Scenarios 1, 2, and 3 (Thomann and Mueller, 1987). Partition coefficients (Kp) of 109,100 and 124,100 L/kg for Silver Lake and Ivanhoe Reservoirs, respectively, were used in Scenario 4. The wetland areas provide additional sorption and uptake of metals from the water column, therefore the partition coefficients were calculated by increasing the base value in relation to the surface area covered by wetlands in each reservoir. The absorbed fraction was calculated using the equation (Thomann and Mueller, 1987):

$$Absorbed\ Fraction = \frac{\mathrm{Kp\ (Suspended\ Solids + Algae\ Concentration)}}{\mathrm{(1 + Kp\ (Suspended\ Solids + Algae\ Concentration))}}$$

Only the dissolved fraction of the metals is transported within and out of the SLRC. Dissolved copper and lead leave the SLRC as exfiltration and overflow. Particulate metals within the SLRC adsorb to suspended solids and algae and then settle to the reservoir bottom.

3.6 Nutrients and Algae

Excessive growth of cyanobacteria (blue-green algae) and other forms of algae (hereafter referred to using the umbrella term "algae") can deplete dissolved inorganic carbon and raise pH, causing water quality impacts. When the algal blooms die off, dissolved oxygen can be depleted causing a dead zone. Algal blooms also degrade recreational opportunities and contribute to public health risks through dermal contact or ingestion, as some algal blooms are classified as harmful algal blooms (HABs) that release toxins. Both algal blooms and HABs affect the appearance of the waterbodies by forming mats or scum on the surface, by turning the water green or blue, and by producing foul-smelling odors.

Eutrophication, or the enrichment of nutrients in a waterbody, can lead to excessive algae growth. Heavy nutrient loading can also lead to other detrimental impacts like excessive mosquito and midge fly larvae. Nutrients, including nitrogen and phosphorus, enter the SLRC from four sources: Stormwater Capture Project flows, bird droppings, atmospheric deposition, and Pollock Well water.

3.6.1 Initial Nitrogen and Phosphorus Concentrations in SLRC

The initial nitrogen concentration in both Ivanhoe and Silver Lake Reservoirs was assumed to be 2.3 mg/L, which was the average of the GAC-treated Pollock Well effluent concentrations on February 12, 2019, and October 10, 2018.

The initial phosphorus concentration for each reservoir was determined from averaging the chlorophyll-a concentrations measured within the reservoirs from January 2018 to April 2019 and applying an empirical formula to calculate phosphorus concentrations (Rast and Lee, 1978). The calculated phosphorus concentrations from the chlorophyll-a measurements are shown in **Figure 3-4**. The initial phosphorus concentrations in Silver Lake and Ivanhoe Reservoirs for the model were calculated to be 0.04 and 0.02 mg/L, respectively.

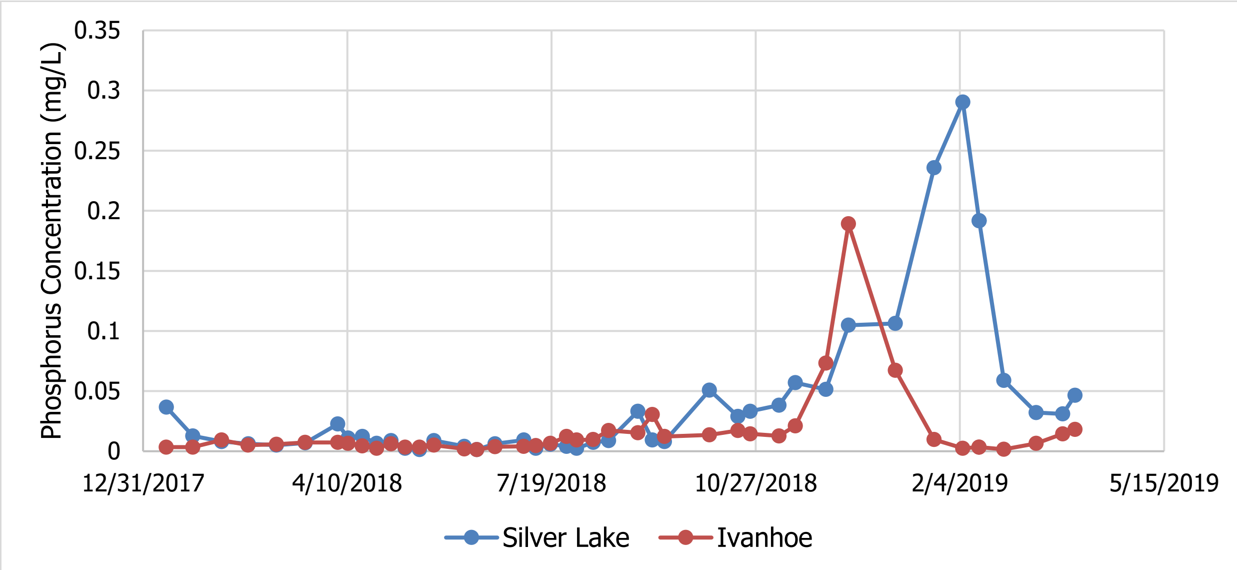

Figure 3-4 Calculated Phosphorus Concentrations

3.6.2 Nitrogen and Phosphorus from Bird Droppings

The average daily bird count and average daily bird droppings were given in **Table 3-3** and **Table 3-4**. The phosphorus content of droppings was estimated to be 1.87% of the dry weight of droppings (Scherer et al., 1995). **Table 3-9** provides the daily phosphorus loading by season and bird type.

Table 3-9 Daily Phosphorus Loading in (g/day) by Season

Bird Species	Winter	Spring	Summer	Fall
Canada Goose	4.6	1.5	13.7	1.5
Ruddy Duck	78.4	15.5	1.0	72.0
American Coot	14.9	0.8	0.3	29.5
California Gull	79.3	25.1	17.2	13.4
Total	**177.2**	**42.9**	**32.2**	**116.4**

The nitrogen content of droppings was estimated to be 2.65% of the dry weight of droppings (Bazely and Jefferies, 1985). **Table 3-10** provides the daily nitrogen loading by season and bird type.

Table 3-10 Daily Nitrogen Loading in (g/day) by Season

Bird Species	Winter	Spring	Summer	Fall
Canada Goose	6.5	2.2	19.5	2.2
Ruddy Duck	111.1	21.9	1.4	102.1
American Coot	21.1	1.1	0.4	41.9
California Gull	112.4	35.6	24.4	19.0
Total	**251.1**	**60.8**	**45.7**	**165.2**

Phosphorus and nitrogen loadings in the model were divided between Silver Lake and Ivanhoe Reservoirs based on the surface area of each reservoir.

3.6.3 Atmospheric Deposition

Dry atmospheric deposition will contribute to nutrient loading in the SLRC. A study of the Santa Monica Bay watershed showed that atmospheric deposition can be a significant source of contaminants in the Los Angeles region (Stolzenbach et al., 2001). The SLRC Water Quality Model accounts for dry atmospheric deposition by incorporating seasonal deposition values, as given in **Table 3-11**. Nitrogen values are from a study conducted within the Ballona Creek Watershed (Burian et al., 2002). Phosphorus values specific to the Ballona Creek Watershed were not available. Phosphorus values from a study of dry deposition in an urban area were used in the model (Decina et al., 2018). The nitrogen values in this study closely resembled the Ballona Creek Watershed nitrogen values, therefore an assumption was made that the phosphorus values would be similar. Seasons were defined as winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November). The flux was converted to a mass loading by multiplying by the surface area of water in each reservoir for each day of the model.

Table 3-11 Atmospheric Deposition of Nitrogen and Phosphorus

Season:	Spring	Summer	Fall	Winter
Nitrogen	3.9 mg/(m^2-day)	1.1 mg/(m^2-day)	1.1 mg/(m^2-day)	3.9 mg/(m^2-day)
Phosphorus	0.7 mg/(m^2-day)	0.7 mg/(m^2-day)	0.7 mg/(m^2-day)	0.7 mg/(m^2-day)

3.6.4 Nitrogen and Phosphorus Concentrations in Pollock Well Water

Nitrogen concentrations of GAC-treated Pollock Well effluent on February 12, 2019, and October 10, 2018, were averaged to determine the expected nitrogen concentration of 2.3 mg/L. No data was provided for phosphorus concentrations in the effluent, and the model assumes no phosphorus contributions from the Pollock Well water.

3.6.5 Nitrogen and Phosphorus from Stormwater Capture Project Flows

Nitrogen and phosphorus concentrations from the Stormwater Capture Project flows were estimated per regional EMC data attributable to land use. **Table 3-12** summarizes the expected total nitrogen and phosphorus concentrations in runoff from each catchment.

Table 3-12 Total Nutrient Concentration by Catchment

Catchment	Total Nitrogen Concentration (mg/L)	Total Phosphorus Concentration (mg/L)
L1	3.1	0.3
L5	3.0	0.3
L7	3.1	0.3
L8	3.0	0.3
L10	3.0	0.3

3.6.6 Removal of Nitrogen and Phosphorus in the SLRC

Within the SLRC, nitrogen and phosphorus will leave the water column through settling. A settling rate of 10 m/yr was used for both nitrogen and phosphorus (Lee, 2019; Thomann and Mueller, 1987). In addition to settling, nitrogen and phosphorus will be removed from the SLRC by the wetlands in Scenario 4. Removal rates of 0.11 mg/L per day for nitrogen and 0.21 mg/L per day for phosphorus were adjusted based on the surface area covered by wetlands in each reservoir (Rousseau et al., 2004). The model does not include secondary effects from detritus because it is assumed the wetland foliage will be maintained.

3.6.7 Algae and Chlorophyll-a

Algae can cause anaerobic conditions to form by depleting dissolved oxygen. Algae growth is measured via chlorophyll-a concentrations. The model calculates the chlorophyll-a concentrations based on an empirical relationship of phosphorus concentration and chlorophyll-a (Rast and Lee, 1978):

$$Log_{10}(Chlorophyll - a) = 0.76Log_{10}(Phosphorus) - 0.259$$

The chlorophyll-a concentration is given in µg/L and phosphorus concentration in mg/m^3. The chlorophyll-a concentration was converted to algal biomass using a multiplication factor of 67 (Raschke, 1993). The surface area of each reservoir covered by algae was estimated by dividing the mass of algae in each reservoir by the average density of algae biomass and dividing by an assumed depth of one inch. The density of algae biomass was assumed to be 0.57 g/cm^3 (Hu, 2014).

3.7 Dissolved Oxygen

Dissolved oxygen concentrations are a key metric to estimate the overall health of the SLRC. Sources of dissolved oxygen include reaeration from the atmosphere, aquatic plant photosynthesis, and denitrification. Oxygen will also be added to the SLRC by the Aeration and Recirculation Projects. The Aeration Project will install an air compressor, a blower, tubing, and twenty diffusers (fourteen at the bottom of Silver Lake Reservoir, six at the bottom of Ivanhoe Reservoir) that will bubble air up from the bottom of the reservoirs. The Recirculation Project will continuously recirculate water from the bottom of Silver Lake Reservoir at the south end and pump it to Ivanhoe Reservoir at the north end; the increased splashing from water entering Silver Lake Reservoir from Ivanhoe Spillway due to the Recirculation Project will increase aeration. These projects are modeled in Scenarios 3 and 4.

Dissolved oxygen levels decrease due to the oxidation of carbonaceous and nitrogenous material, sediment oxygen demand, and aquatic plant respiration. The daily dissolved oxygen mass balance in each reservoir was calculated using the following equation (Thomann and Mueller, 1987):

$$Volume\left(\frac{dc}{dt}\right) = reaeration + (photosynthesis - respiration) - oxidation\ of\ CBOD, NBOD \\ - sediment\ oxygen\ demand + oxygen\ input\ \pm oxygen\ transport$$

Reaeration is calculated using wind speed and is limited by the saturated dissolved oxygen concentration. The saturated dissolved oxygen concentrations were estimated based on water temperature in Kelvin using the equation (Weiss, 1970):

$$DO = 1.42905 \exp\left[-173.4292 + 249.6339\left(\frac{100}{T}\right) + 143.3483\left(ln\left(\frac{T}{100}\right)\right) - 21.8492\left(\frac{T}{100}\right)\right]$$

The saturated dissolved oxygen concentration was adjusted for salinity by multiplying by the Weiss salinity factor, calculated using the equation (Weiss, 1970):

$$F_S = exp\left\{Salinity\left[-0.033096 + 0.014259\frac{T}{100} - 0.0017000\left(\frac{T}{100}\right)^2\right]\right\}$$

Salinity in parts per thousand was calculated using the specific conductance (SC) using the following equation (USGS, 1981):

$$Salinity = 5.572x10^{-4}(SC) + 2.02x10^{-9}(SC)^2$$

The dissolved oxygen transfer coefficient (K_L) from wind was calculated using the average wind speed (WS) with the following equation (Thomann and Mueller, 1987):

$$K_L = 0.728(WS)^{1/2} - 0.317(WS) + 0.0372(WS)^2$$

The volumetric reaeration coefficient (K_a) was calculated using the following equation (Thomann and Mueller, 1987):

$$K_a = \frac{K_L(Surface\ Area)}{Volume}$$

The daily reaeration dissolved oxygen concentration due to wind was calculated using the following equation, where DO_0 is the deficit calculated by subtracting the actual dissolved oxygen concentration from the saturated concentration (Thomann and Mueller, 1987):

$$DO = DO_0 e^{-K_a t}$$

The production of dissolved oxygen by photosynthesis was calculated using the equation (Thomann and Mueller, 1987):

$$DO = [a_{op}G_{max}(1.066)^{T-20}P]G(I_a)$$

Where a_{op} is the ratio of dissolved oxygen per chlorophyll-a concentration, which was assumed to be 0.25, G_{max} is the maximum growth rate of phytoplankton, which was assumed to be 1.5 per day, P is the chlorophyll-a concentration in µg/L, T is water temperature in degrees Celsius, and $G(I_a)$ is the light attenuation factor, which was assumed to be 0.5.

The amount of dissolved oxygen consumed by respiration of plants and algae was estimated using the following formula with the same values for a_{op} and P as described for photosynthesis (Thomann and Mueller, 1987):

$$DO = a_{op}0.01(1.08)^{T-20}P$$

The deoxygenation rate (K_d) for the biochemical oxygen demand (BOD) was assumed to be 0.3 per day and was adjusted for water temperature using the following equation (Thomann and Mueller, 1987):

$$K_d = 0.3(1.047)^{T-20}$$

The decline in BOD was modeled using the following equation (Thomann and Mueller, 1987):

$$BOD = BOD_0 e^{-K_d t}$$

The sediment oxygen demand (SOD) was assumed to be 0.07 g $O_2/(m^2 day)$, which is the typical value for mineral soils (Thomann and Mueller, 1987). The SOD was adjusted for water temperature using the following equation (Thomann and Mueller, 1987):

$$SOD = SOD_{20}(1.065)^{T-20}$$

The oxygen inputs and transport into and out of the reservoirs were accounted for using a mass balance of concentrations and volumes of flows.

3.8 Not Modeled

Trash and polychlorinated biphenyls (PCBs) were not modeled in the SLRC Water Quality Model.

3.8.1 Trash

The water quality goals in **Table 1-1** cite a limit for trash at zero. Sources of trash in waterbodies are from stormwater runoff and from aerial deposition from wind. The only source of trash applicable to the SLRC Water Quality Model is through the Stormwater Capture Project. However, the Stormwater Capture Project will have pretreatment units designed to fully capture trash. Trash production in the watersheds tributary to the Stormwater Capture Project is expected to be approximately 100 cubic feet per storm event, based on EMCs by land use. Aerial deposition of trash lies outside the scope of the Water Quality Model. Therefore, the model assumes that no trash will enter the SLRC.

3.8.2 Polychlorinated Biphenyls (PCBs)

PCBs previously were widely used as dielectric and coolant fluids and have been classified as persistent organic pollutants. PCBs have low water solubility and are typically found adsorbed to sediments or in fish tissue. PCBs can enter the SLRC from Stormwater Capture Project flows, but PCBs are not expected due to the lack of industrial land uses in the watershed. PCB accumulation was not modeled within the SLRC Water Quality Model.

4. Results

The results for each modeled constituent are presented in the following sections. Data for all four scenarios described in **Table 2-6** are presented on separate graphs for Ivanhoe and Silver Lake Reservoirs. No overflow goes into Ballona Creek in any of the scenarios, so no results are presented for Ballona Creek.

4.1 Suspended Solids

Suspended solids enter the SLRC from Stormwater Capture Project flows in Scenarios 3 and 4. No suspended solids enter the SLRC in Scenarios 1 and 2, therefore no suspended solids concentrations were modeled for these scenarios. **Figure 4-1** shows the Ivanhoe Reservoir TSS concentration for Scenarios 3 and 4. The Silver Lake Reservoir TSS concentrations are shown in **Figure 4-2**. Concentrations spike due to inflows from rain events, and then concentrations decrease due to settling. The suspended solids accumulate as part of the bottom sediment in each reservoir. The suspended solids concentrations in Scenario 3 and 4 are both very similar in each reservoir, with only a slight decrease observed in Scenario 4. This difference is due to slight variations in the volume of water in each reservoir in each scenario. The model does not include any additional removal of suspended solids due to the wetlands in Scenario 4.

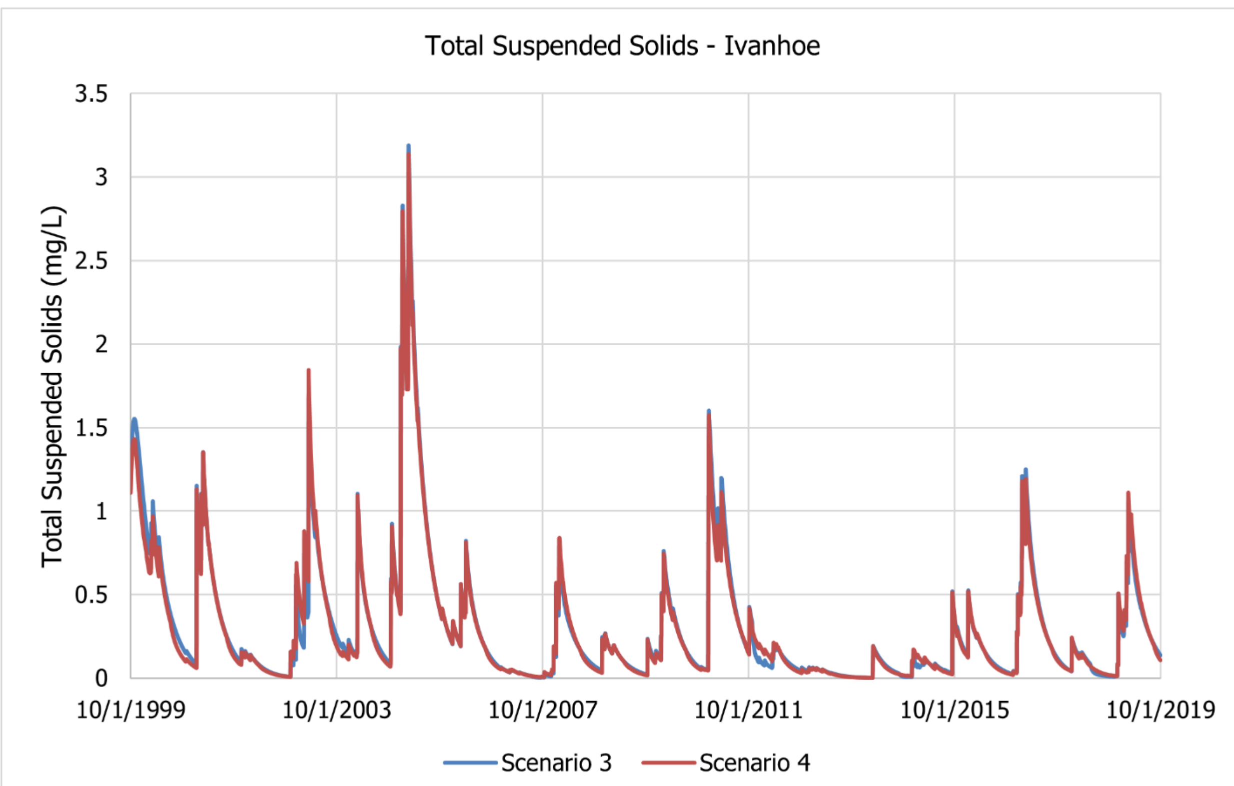

Figure 4-1 Suspended Solids Concentration in Ivanhoe Reservoir

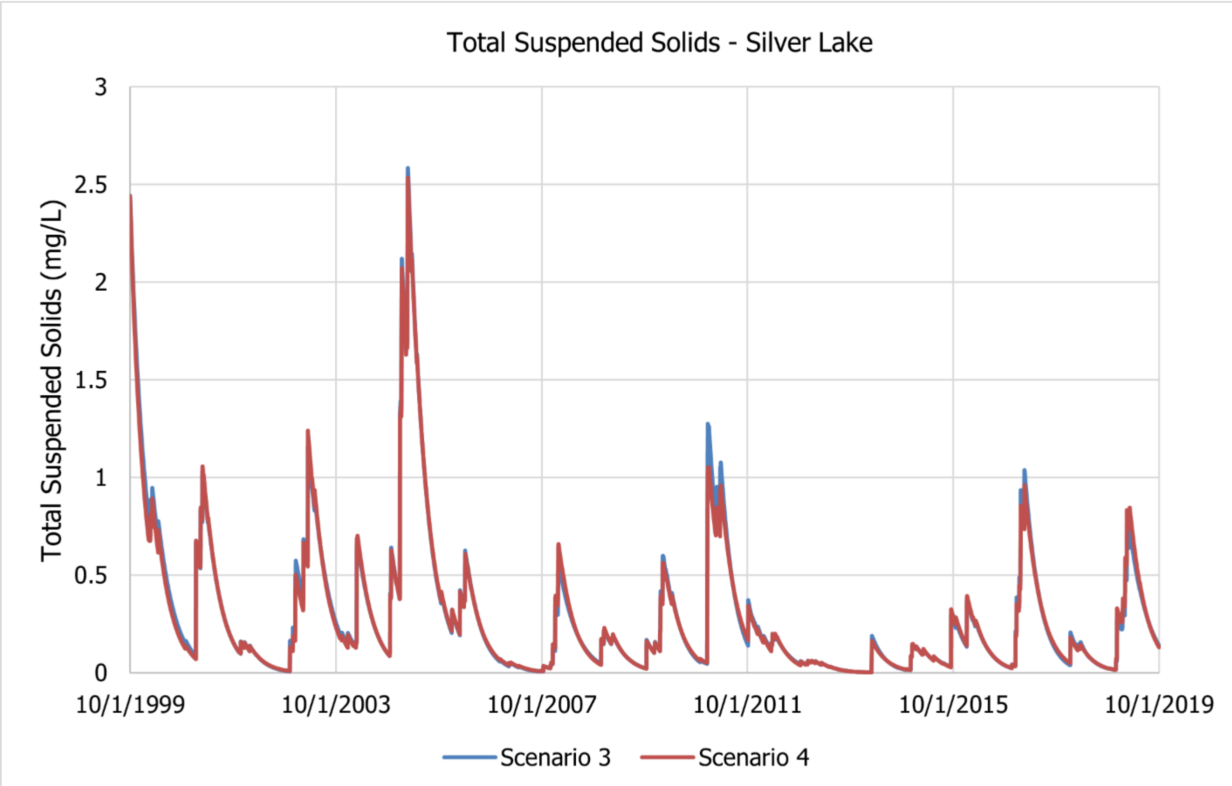

Figure 4-2 Suspended Solids Concentration in Silver Lake Reservoir

Sediment occasionally needs to be removed from most reservoirs to maintain the design capacity. However, it is unlikely that sediment will need to be removed from the SLRC within the twenty-year modeled timespan due to the slow rate of sediment accumulation expected. The rate of accumulation of sediment in the model was approximately 0.0001 AFY for Ivanhoe Reservoir and 0.0009 AFY for Silver Lake. Based on these rates, the sediment volume is of Ivanhoe Reservoir and Silver Lake is negligible over the expected life-cycle of the project. As an illustration of the small size of the predicted sediment loading rates, at a rate of 0.0001 AFY, it would take approximately 21,000 years to fill up just one percent of the volume of Ivanhoe Reservoir, and at a rate of 0.0009 AFY, it would take approximately 28,000 years to fill up just one percent of the volume of Silver Lake Reservoir.

The sediment accumulation rate is influenced by the sediment removal efficiency of the pretreatment CDS unit, which was estimated to be greater than 90% for the sum of all storm events. **Figure 4-3** shows the volume of settled suspended solids in Ivanhoe Reservoir, and **Figure 4-4** shows the volume of settled suspended solids in Silver Lake Reservoir.

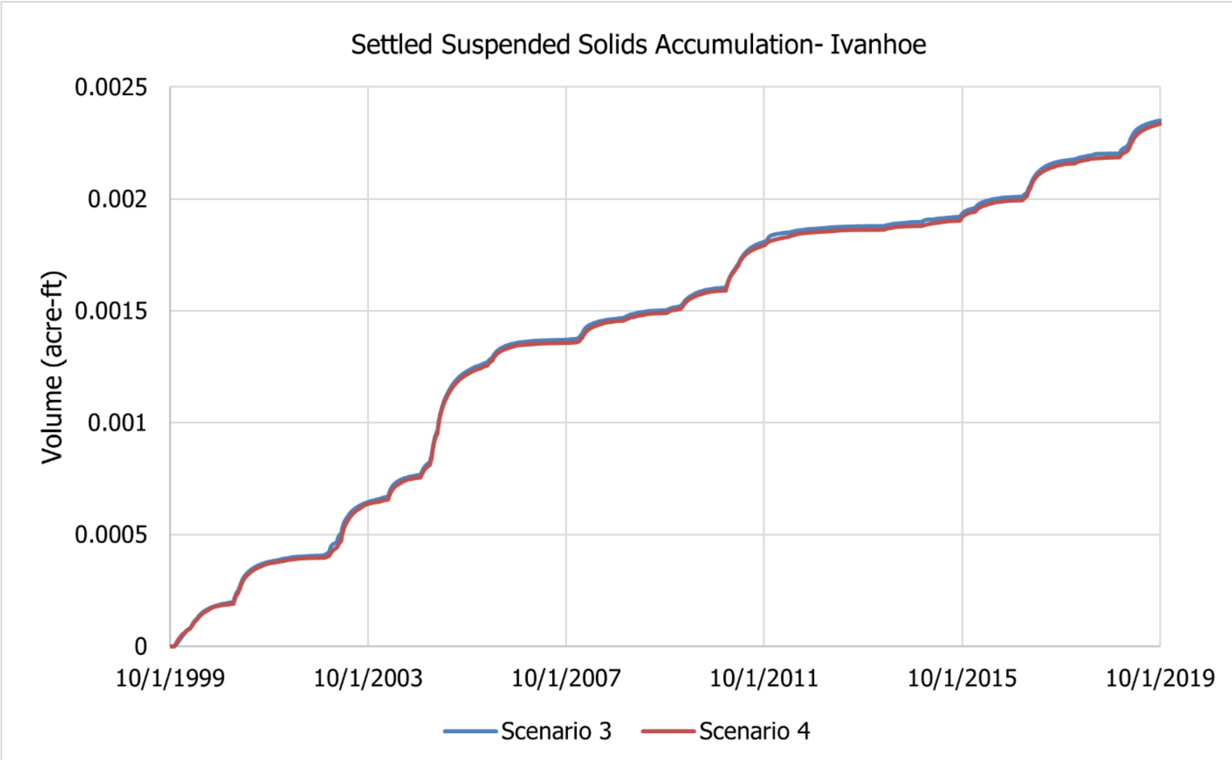

Figure 4-3 Accumulation of Sediment in Ivanhoe Reservoir

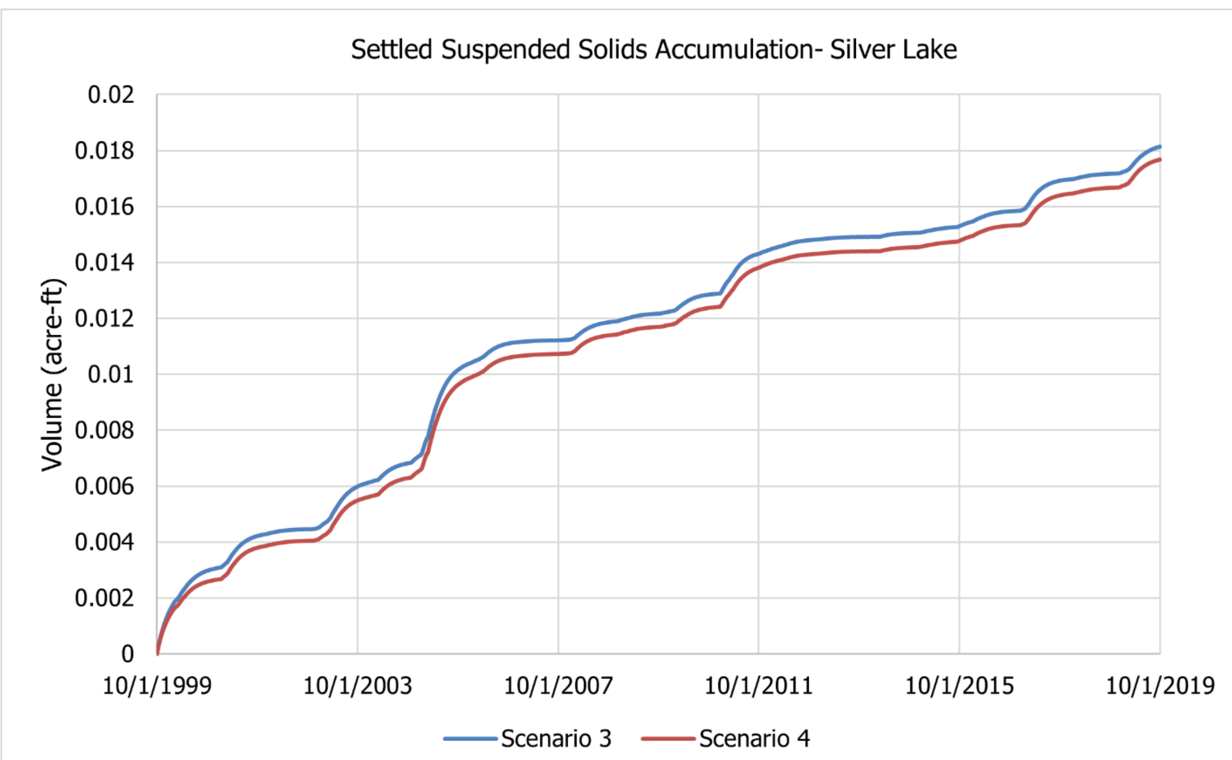

Figure 4-4 Accumulation of Sediment in Silver Lake Reservoir

4.2 Dissolved Solids

Dissolved solids enter the SLRC in Pollock Well water in Scenarios 2, 3 and 4 and in Stormwater Capture Project flows in Scenarios 3 and 4. There are no sources of dissolved solids entering the SLRC in Scenario 1. Each reservoir has an initial concentration of dissolved solids. Dissolved solids are removed in exfiltration in all scenarios and by plant uptake through transpiration by the wetlands in Scenario 4. Precipitation falling on the SLRC increases the volume in the reservoirs, which reduces the concentration of dissolved solids. Dissolved solids are transported in overflow and recirculation within the SLRC. The Ivanhoe Reservoir TDS concentrations for all four scenarios are shown in **Figure 4-5.** The Silver Lake Reservoir TDS concentrations are shown in **Figure 4-6**. **Figure 4-6** has a logarithmic y-axis. Spikes in TDS concentrations were observed in Scenario 1 due to the volume decreasing from evaporation and exfiltration, which causes the concentration (mass per volume) to increase. The concentration decreases to almost zero after October 2008 due to losses of mass to exfiltration in Scenario 1, which does not have any additional inputs of dissolved solids from the initial concentration in each reservoir. For these reasons, Scenario 1 was excluded from the charts below.

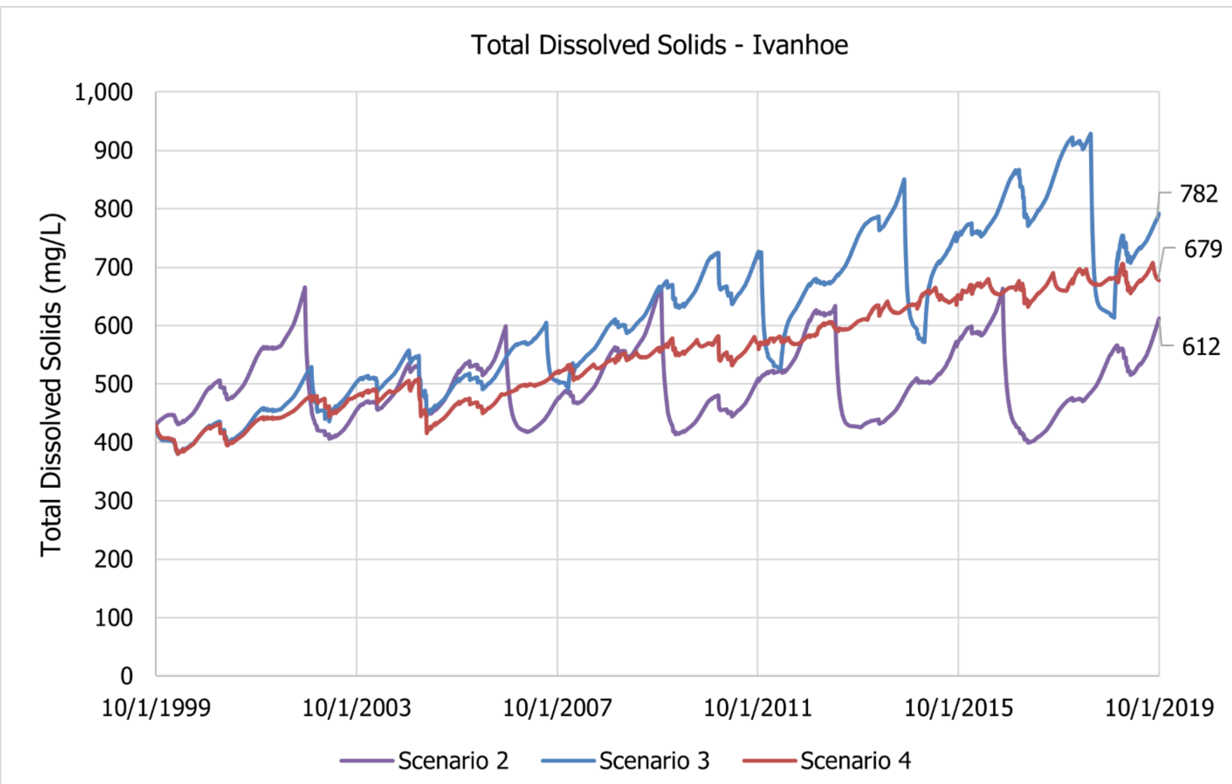

Figure 4-5 Dissolved Solids Concentration in Ivanhoe Reservoir

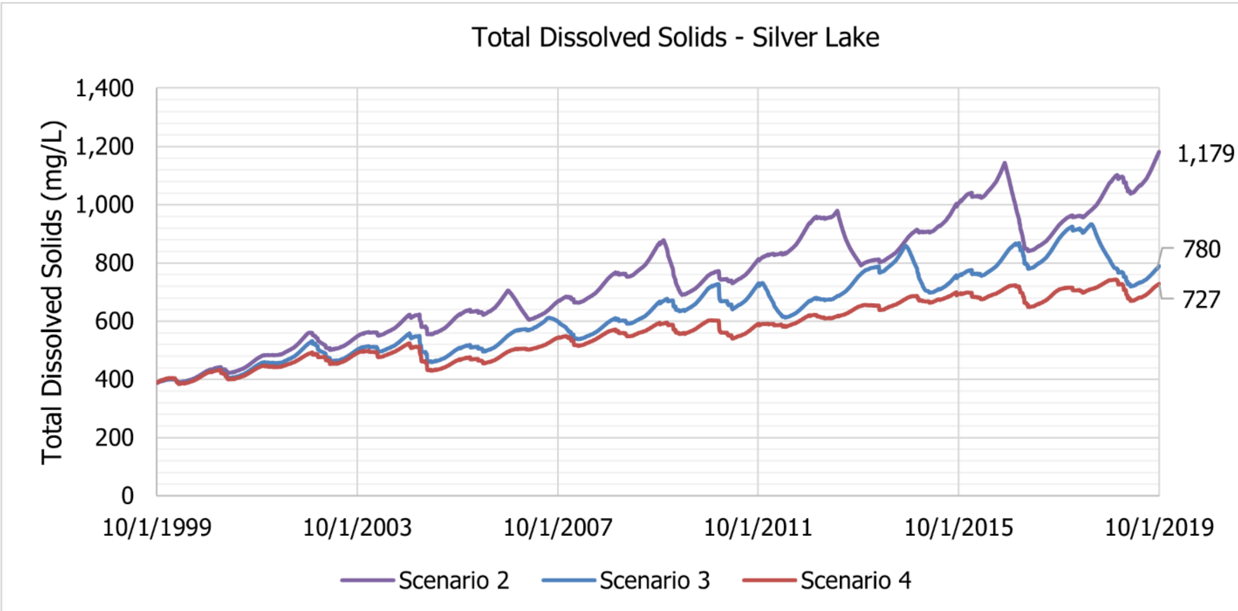

Figure 4-6 Dissolved Solids Concentration in Silver Lake Reservoir

Figure 4-7 gives context for the modeled TDS concentrations. Though TDS concentrations will increase with time in Silver Lake Reservoir, the model predicted that the TDS concentration after 20 years under Scenario 4 conditions will still be within the range of drinking water standards (less than 1,000 mg/L), and less than the TDS limits set for other bodies of water that receive urban runoff in Southern California such as the Los Angeles River.

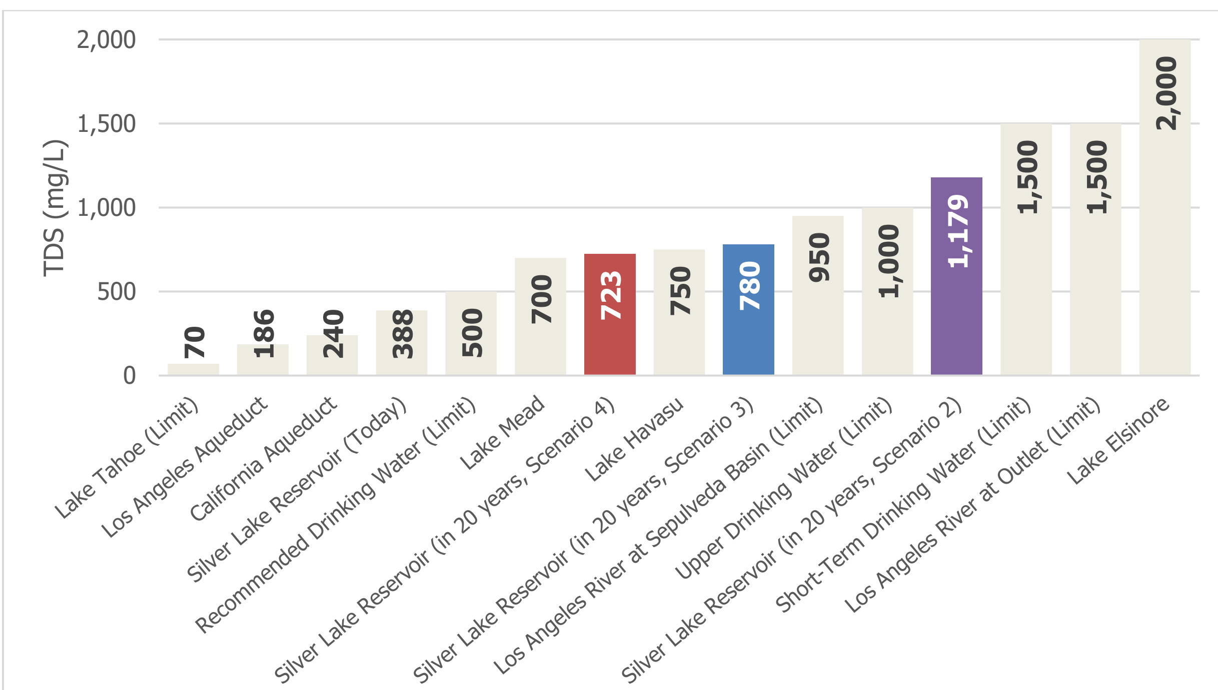

Figure 4-7 TDS Concentrations in Various Waterbodies

4.3 Bacteria

Bacteria, measured as total coliform, enter the SLRC from bird droppings in all scenarios and from Stormwater Capture Project flows in Scenarios 3 and 4. The Ivanhoe Reservoir total coliform concentrations for all four scenarios are shown in **Figure 4-8** and the Silver Lake Reservoir concentrations are shown in **Figure 4-9**. Total coliform concentrations for Scenarios 1 and 2 with only bird loadings are well below the limit of 1,000 MPN/100mL.

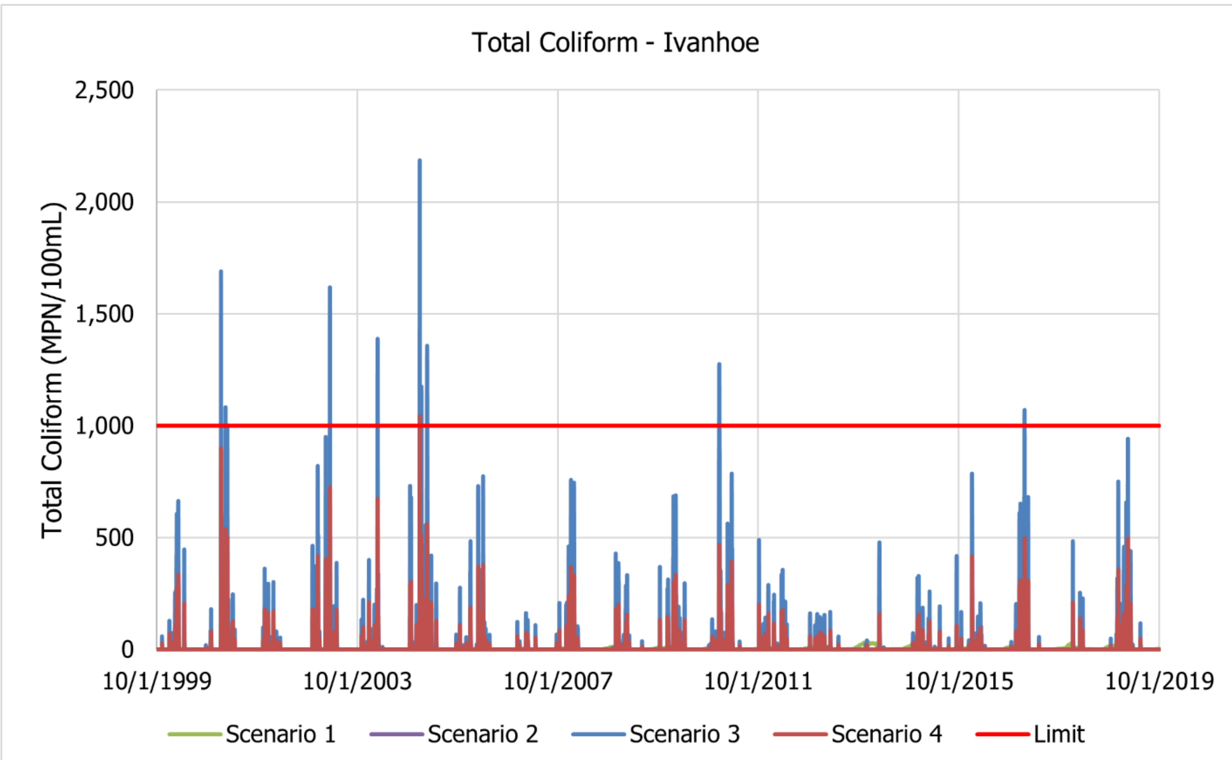

Figure 4-8 Total Coliform Concentration in Ivanhoe Reservoir

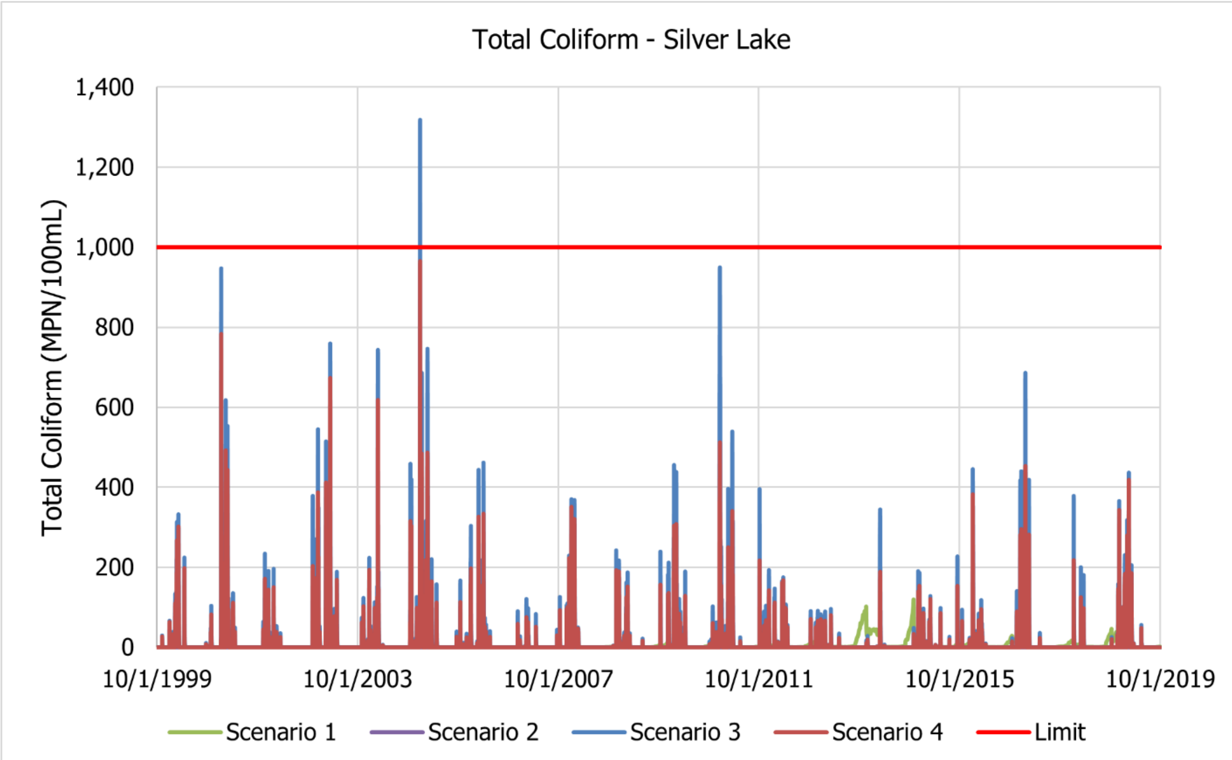

Figure 4-9 Total Coliform Concentration in Silver Lake Reservoir

Bacteria concentrations in Scenario 3 occasionally exceed the limit due to large storm events. The model predicted that there would be a total of 15 exceedances over the course of 20 years; 14 exceedances within Ivanhoe Reservoir and one exceedance within Silver Lake Reservoir. Bacteria concentrations in Scenario 4 approach the limit but only exceed the limit once, and only in Ivanhoe Reservoir. This attenuation of 93% of the potential exceedance days is attributable to the wetland treatment systems.

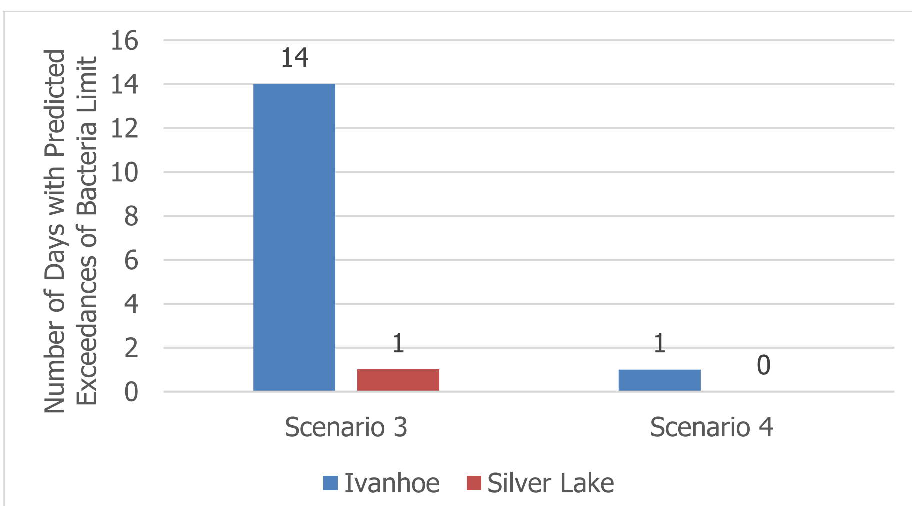

Figure 4-10 Bacteria Limit Exceedances

4.4 Copper

Copper enters the SLRC in Pollock Well water in Scenarios 2, 3, and 4 and in Stormwater Capture Project flows in Scenarios 3 and 4. Each reservoir has an initial concentration of copper. Dissolved copper leaves the SLRC in exfiltration and overflow and is transported within the SLRC in overflow in all scenarios and by recirculation in Scenarios 3 and 4. The Ivanhoe Reservoir total copper concentration for all four scenarios are shown in **Figure 4-11**, and the Silver Lake Reservoir concentrations are shown in **Figure 4-12**. **Figure 4-13** shows the dissolved copper concentration for all four scenarios for Ivanhoe Reservoir. **Figure 4-14** shows the Silver Lake Reservoir dissolved copper concentrations. **Figure 4-12** has a logarithmic y-axis. The dissolved copper concentrations are dependent on suspended solid and algae concentrations but were typically 96-97% of the total copper concentration. The spikes observed in Scenario 1 are due to decreases in volume of water in the reservoirs, which increases the concentration. Scenario 1 exceeds the copper concentration limit of 22 µg/L. The other three scenarios are below the limit.

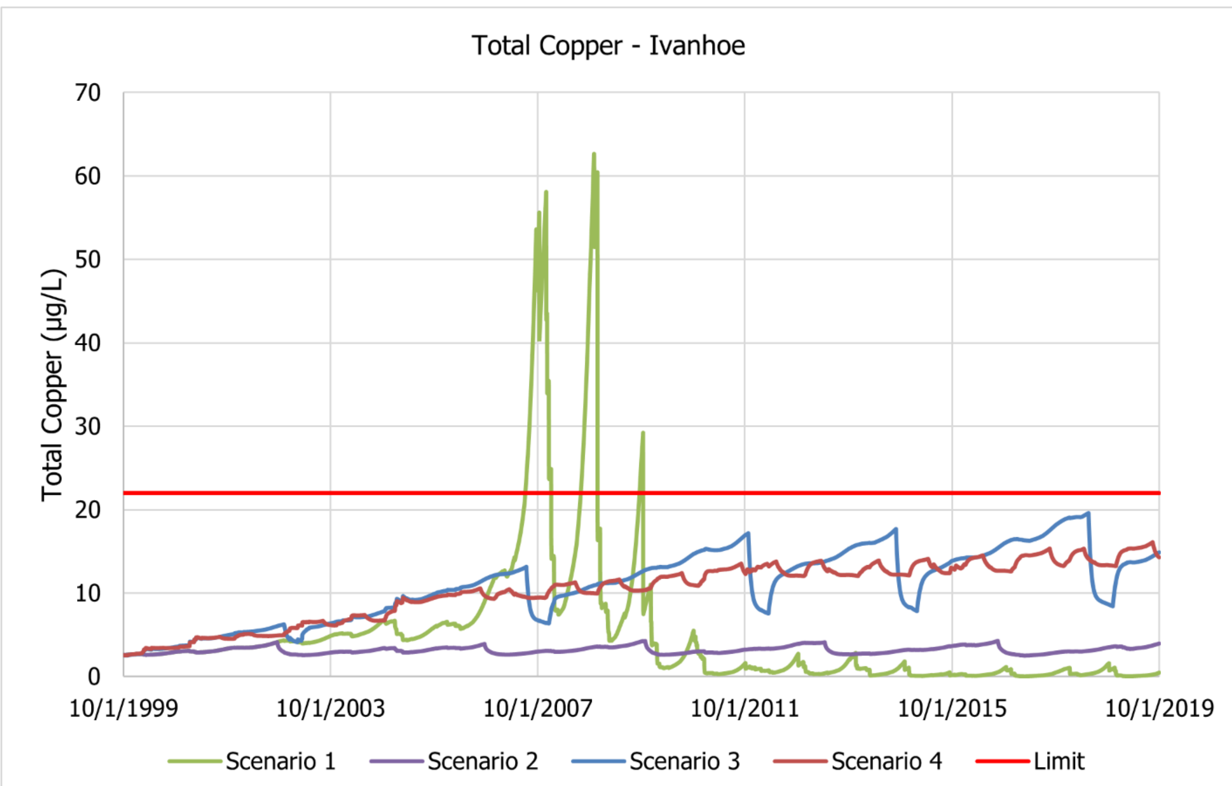

Figure 4-11 Total Copper Concentrations in Ivanhoe Reservoir

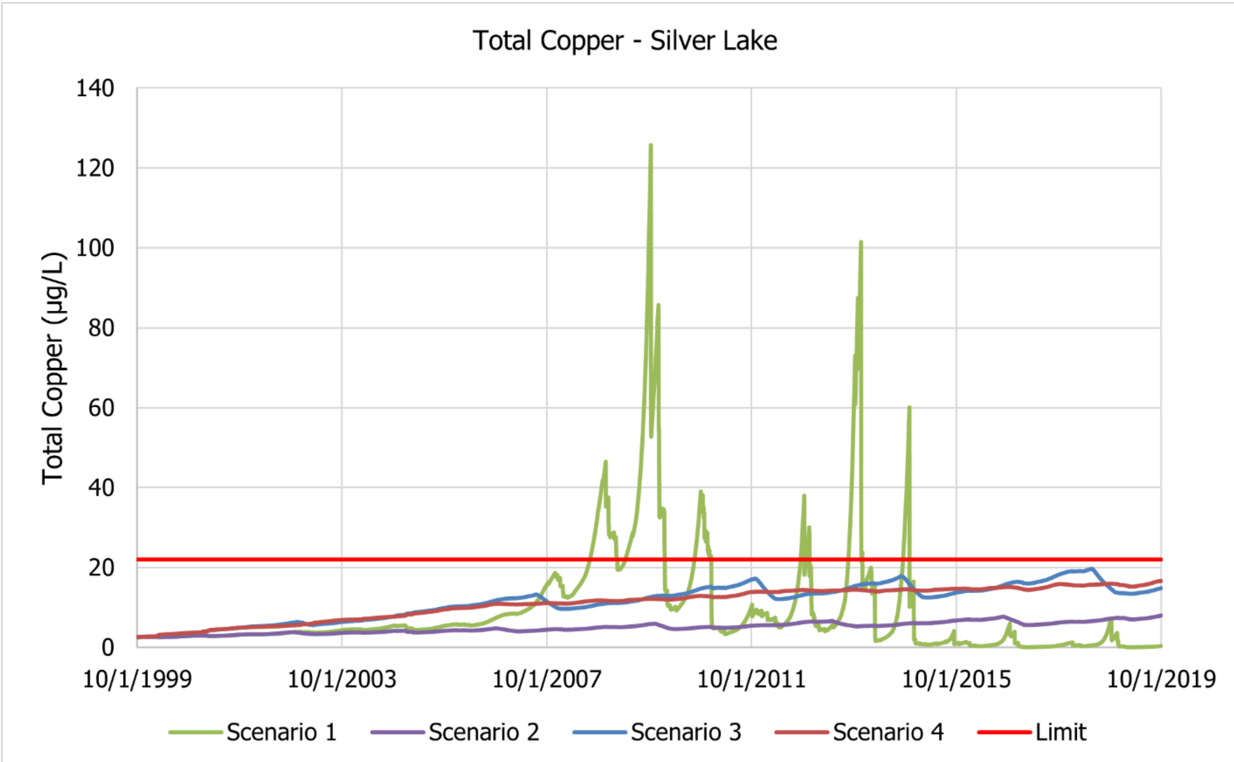

Figure 4-12 Total Copper Concentrations in Silver Lake Reservoir

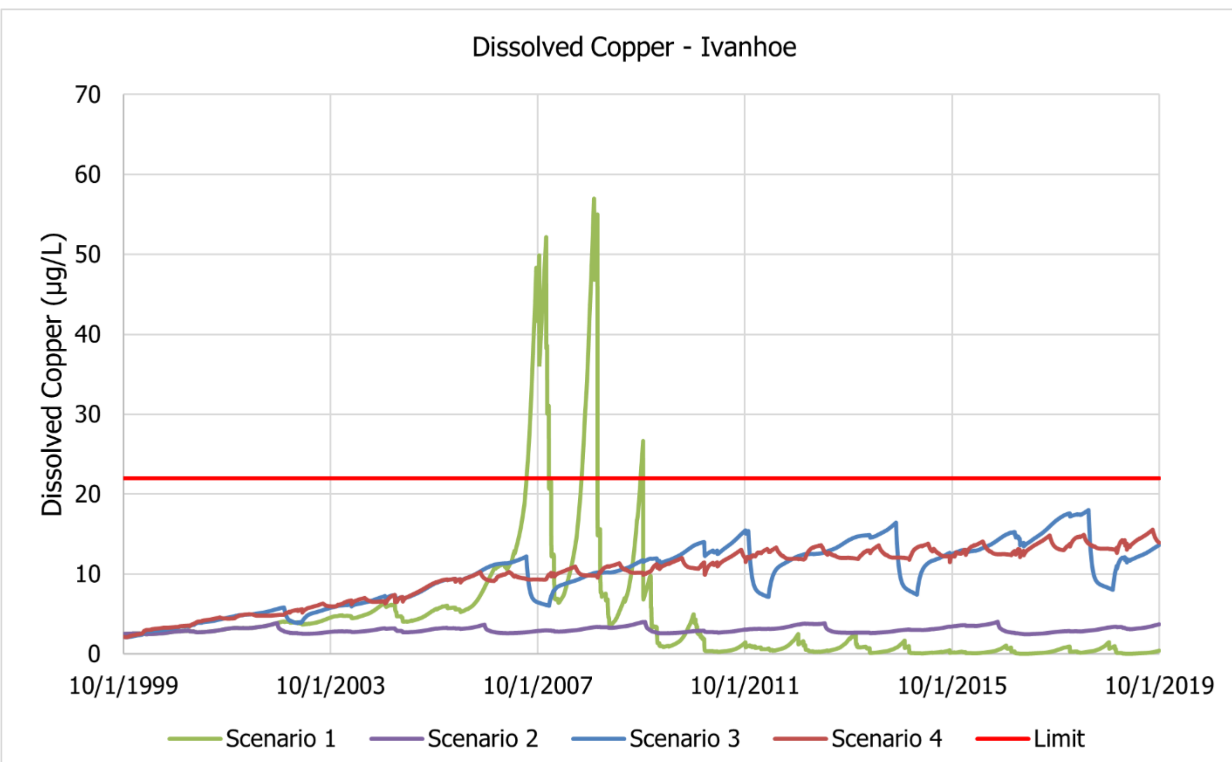

Figure 4-13 Dissolved Copper Concentrations in Ivanhoe Reservoir

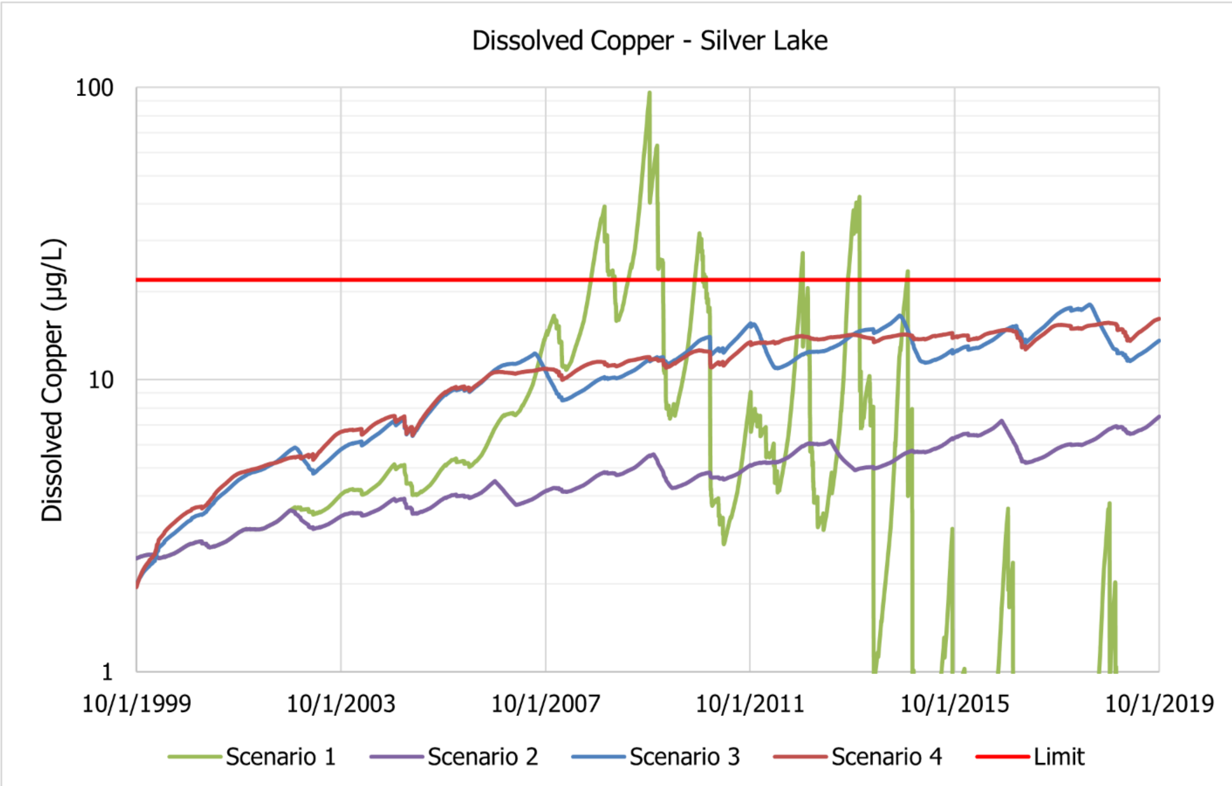

Figure 4-14 Dissolved Copper Concentrations in Silver Lake Reservoir

4.5 Lead

Lead enters the SLRC in Pollock Well water in Scenarios 2, 3, and 4 and in Stormwater Capture Project flows in Scenarios 3 and 4. Each reservoir has an initial concentration of lead and inputs from daily atmospheric deposition. Dissolved lead leaves the SLRC in exfiltration and overflow and is transported within the SLRC in overflow in all scenarios and by recirculation in Scenarios 3 and 4. The Ivanhoe Reservoir total lead concentrations for all four scenarios are shown in **Figure 4-15.** The Silver Lake Reservoir total lead concentrations are shown in **Figure 4-16**. The Ivanhoe Reservoir dissolved lead concentrations for all four scenarios are shown in **Figure 4-17. Figure 4-18** shows the Silver Lake Reservoir dissolved lead concentrations. The dissolved lead concentrations are dependent on suspended solid and algae concentrations but were typically 96-97% of the total lead concentration. The spikes observed in Scenario 1 are due to decreases in volume of water in the reservoirs, which increases the concentration. Scenario 1 exceeds the lead concentration limit of 11 µg/L in October 2009 and November 2013 for Silver Lake Reservoir, but the other three scenarios are below the limit for the duration of the model.

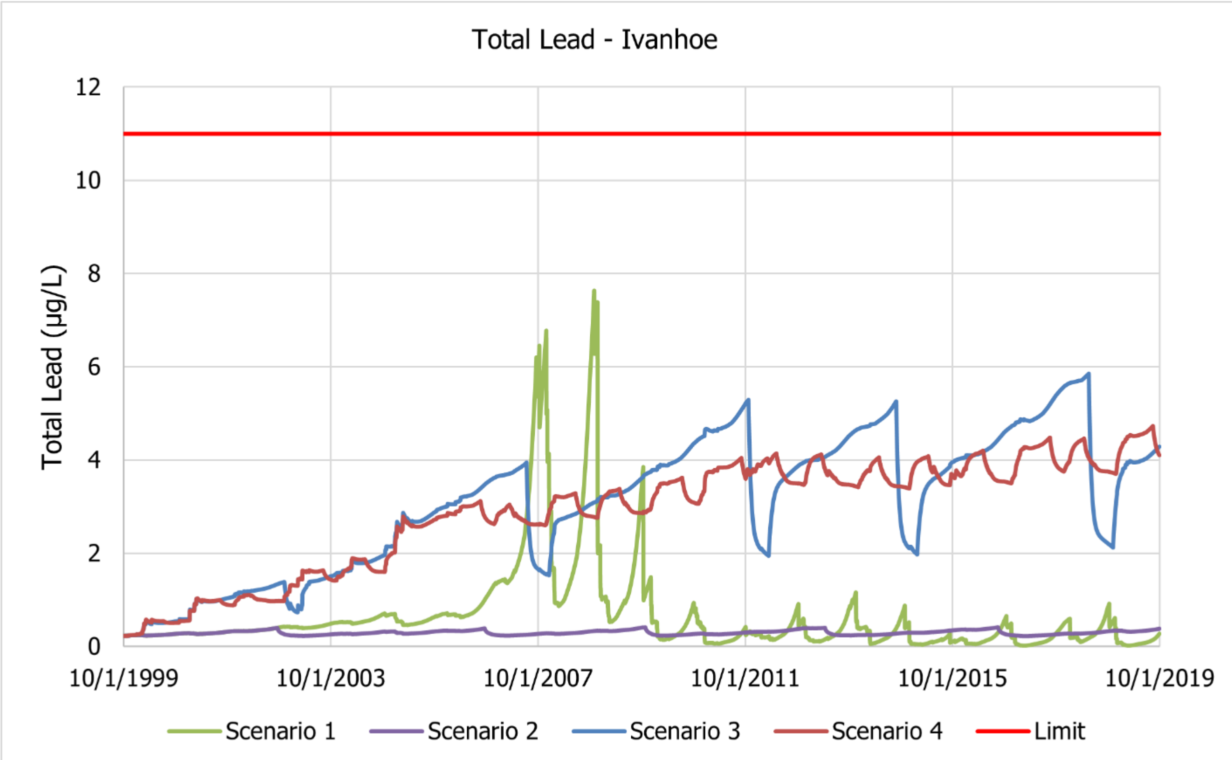

Figure 4-15 Total Lead Concentration in Ivanhoe Reservoir

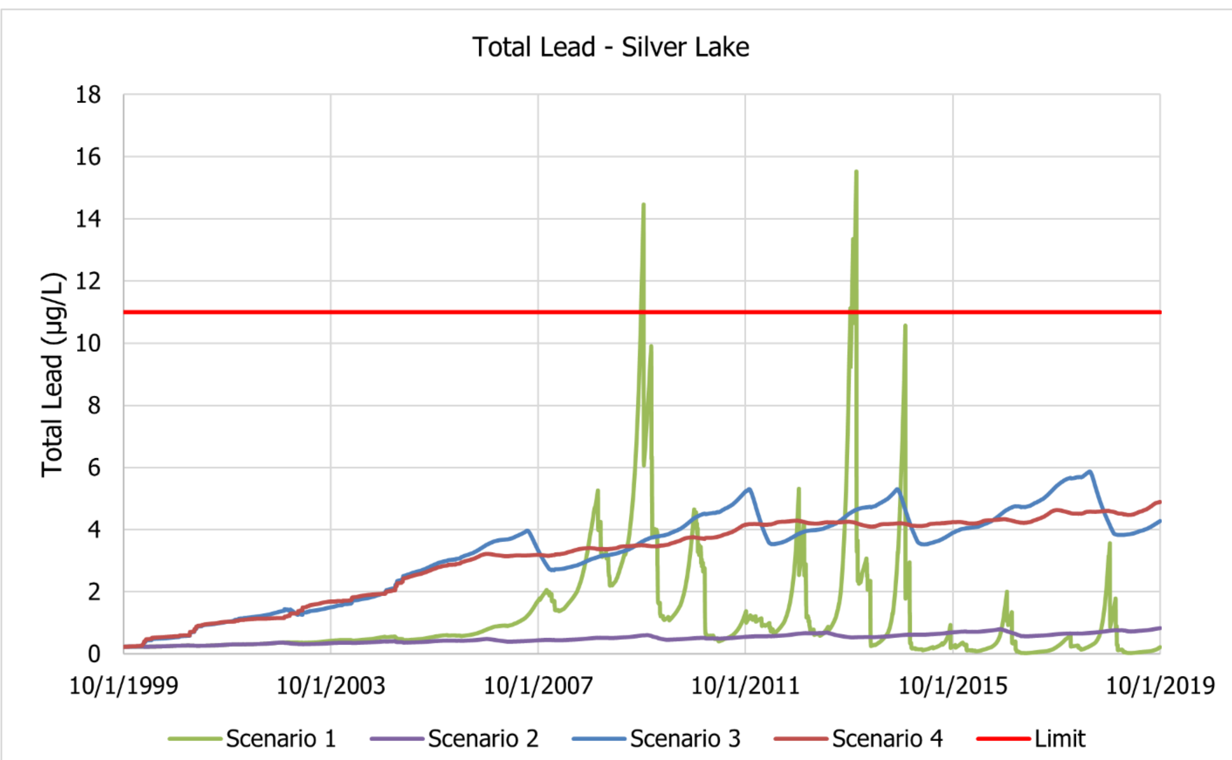

Figure 4-16 Total Lead Concentration in Silver Lake Reservoir

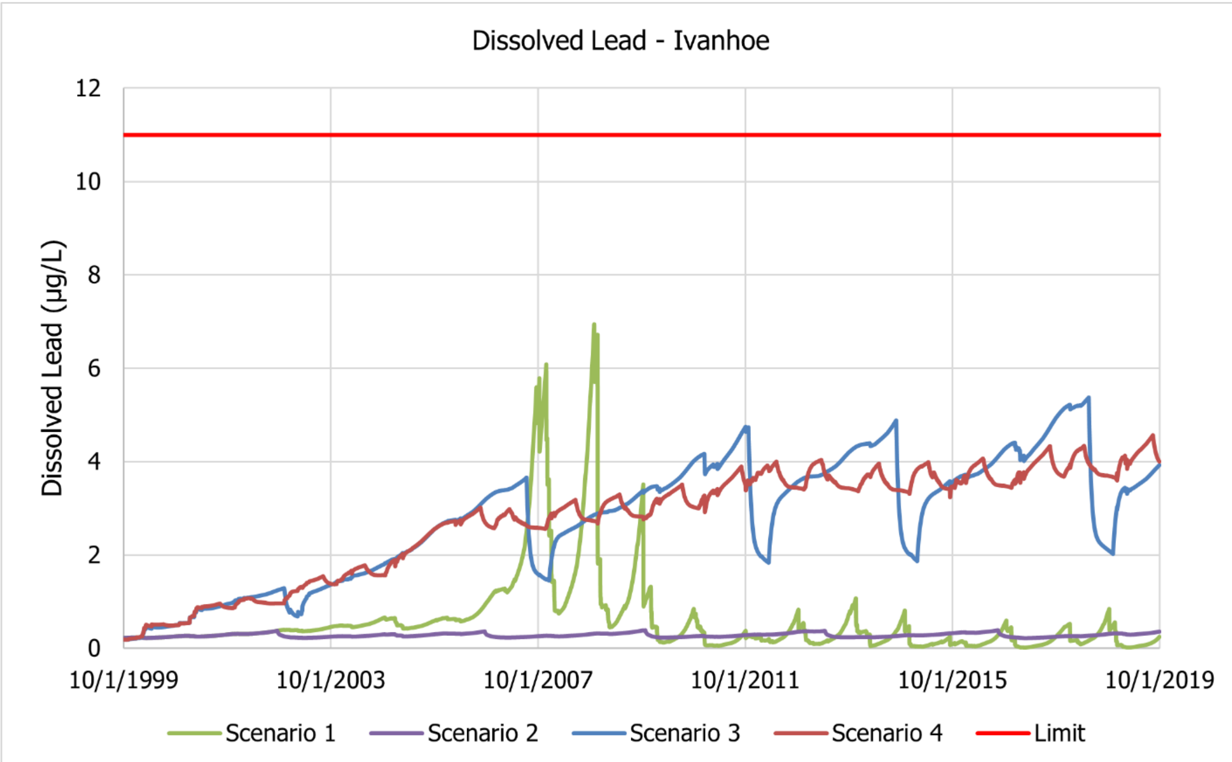

Figure 4-17 Dissolved Lead Concentration in Ivanhoe Reservoir

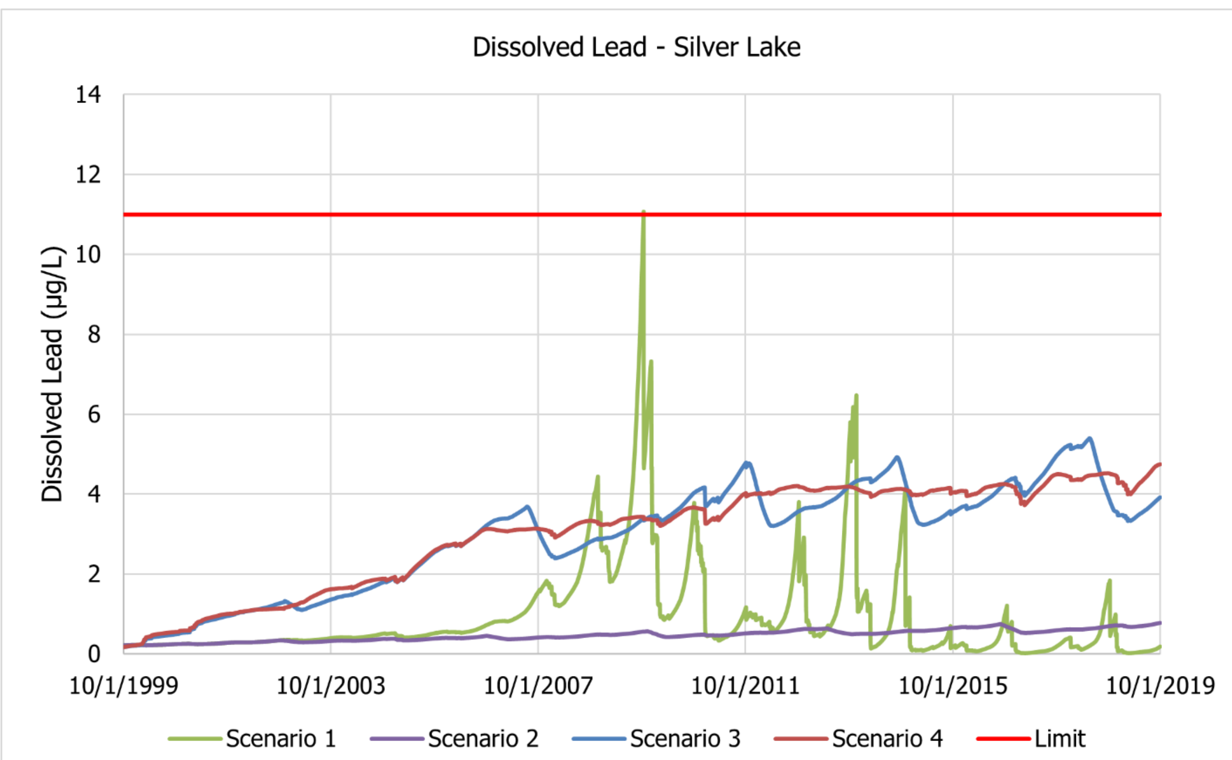

Figure 4-18 Dissolved Lead Concentration in Silver Lake Reservoir

4.6 Nitrogen

Nitrogen enters the SLRC from bird droppings and atmospheric deposition in all scenarios, from Pollock Well water in Scenarios 2, 3 and 4, and from Stormwater Capture Project flows in Scenarios 3 and 4. **Figure 4-19** shows the total nitrogen concentration for all four scenarios at Ivanhoe Reservoir. **Figure 4-20** shows the Silver Lake Reservoir total nitrogen concentrations. **Figure 4-19** and **Figure 4-20** have a logarithmic y-axis. Nitrogen concentrations exceed the limit of 1 mg/L in Scenarios 2 and 3 due to additions of Pollock Well water, which has a nitrogen concentration of 2.3 mg/L. These exceedances were not observed in Scenario 1 because there is no Pollock Well water injections in Scenario 1. Only two measurements of Pollock Well water were available, which had wide range of 0.2 to 4.4 mg/L, so if additional monitoring data becomes available for Pollock Well water, the nitrogen concentration of Pollock Well water should be adjusted in the model. The wetlands in Scenario 4 reduce the nitrogen concentration in the SLRC. The spikes observed in Scenario 1 are due to seasonally high bird loadings into smaller volumes of water.

Total nitrogen is a summation of nitrate, nitrite, and total Kjeldahl nitrogen, which includes ammonia. The model does not include speciation of nitrogen, and therefore ammonia levels are assumed to be below the numeric target when total nitrogen levels are below numeric targets.

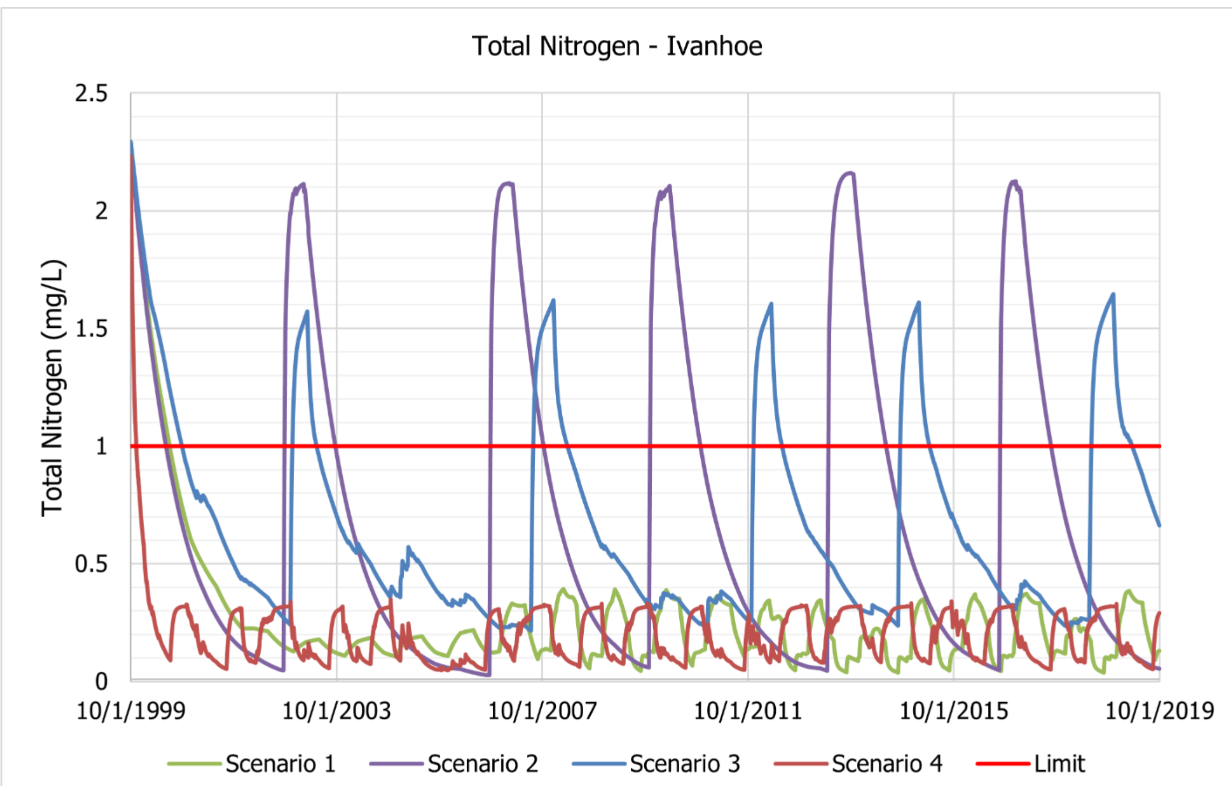

Figure 4-19 Total Nitrogen Concentration in Ivanhoe Reservoir

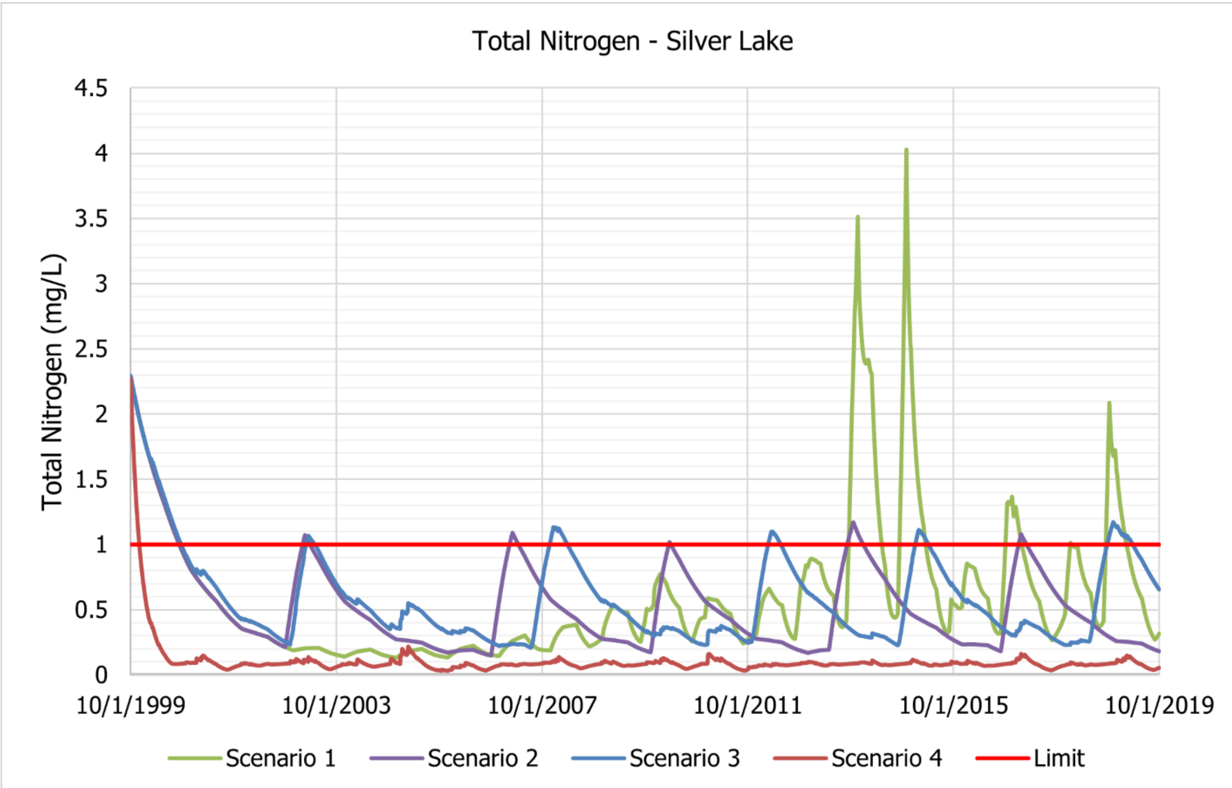

Figure 4-20 Total Nitrogen Concentration in Silver Lake Reservoir

4.7 Phosphorus

Phosphorus enters the SLRC from bird droppings and atmospheric deposition in all scenarios and from Stormwater Capture Project flows in Scenarios 3 and 4. **Figure 4-21** shows the total phosphorus concentration in Ivanhoe Reservoir for all four scenarios. **Figure 4-22** shows the Silver Lake Reservoir concentrations. **Figure 4-22** has a logarithmic y-axis. Phosphorus concentrations exceed the limit of 0.1 mg/L in Scenario 1 due to seasonally high bird loadings into smaller volumes of water.

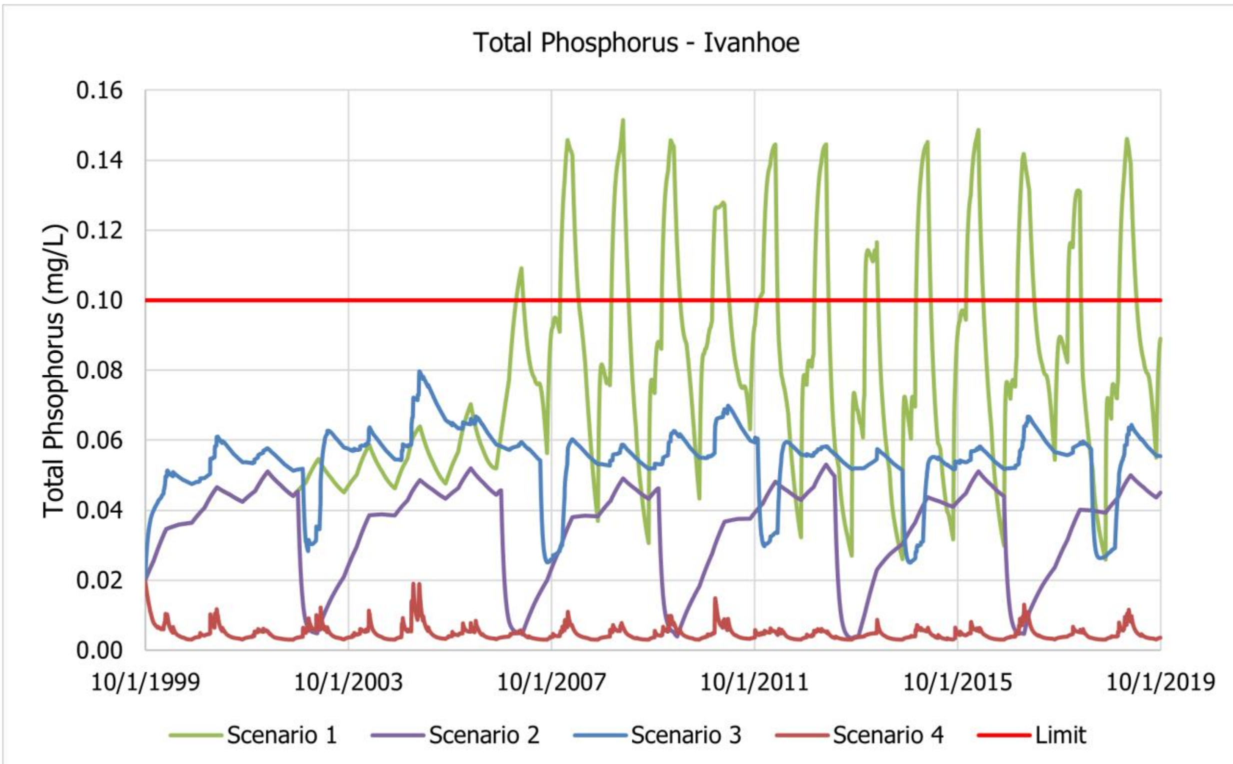

Figure 4-21 Total Phosphorus Concentration in Ivanhoe Reservoir

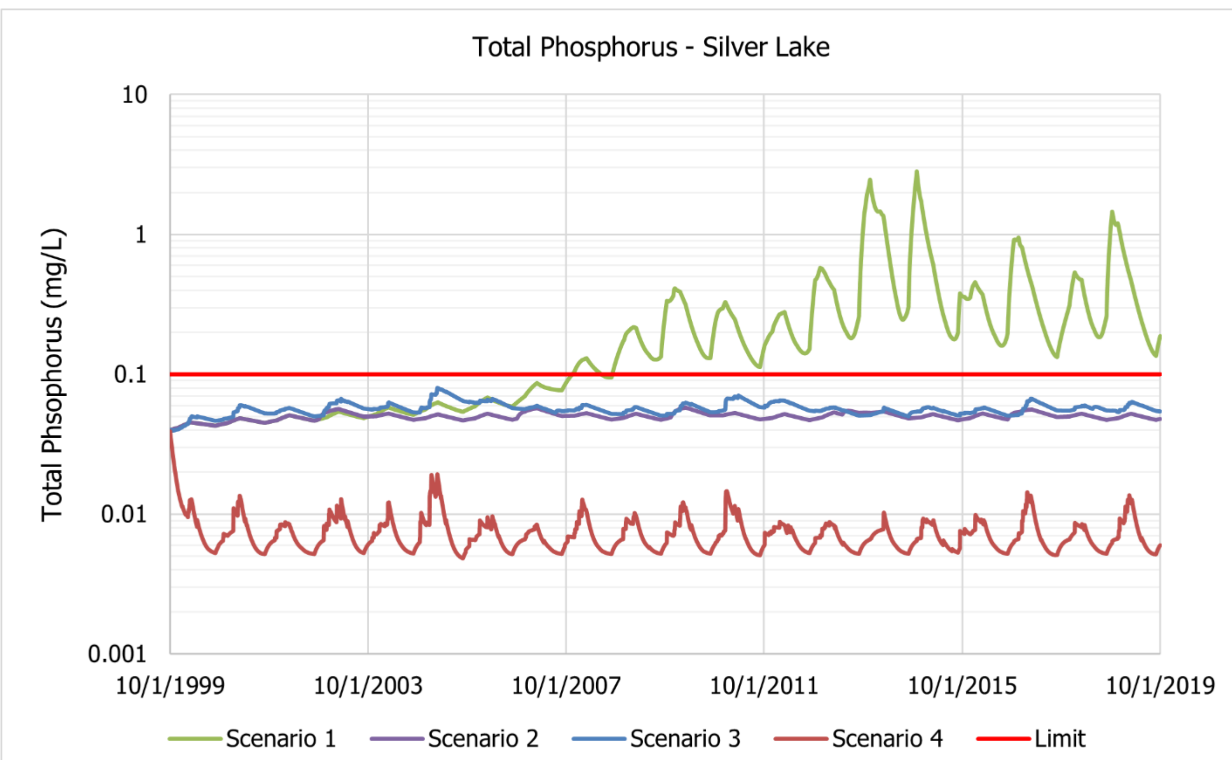

Figure 4-22 Total Phosphorus Concentration in Silver Lake Reservoir

4.8 Chlorophyll-a

The chlorophyll-a concentration for all four scenarios for Ivanhoe Reservoir is shown in **Figure 4-23,** and the Silver Lake Reservoir concentrations are shown in **Figure 4-24**. **Figure 4-24** has a logarithmic y-axis. The chlorophyll-a concentration is calculated from the phosphorus concentration, and therefore the same peaks are observed in Scenario 1 due to seasonal bird loadings into smaller volumes of water.

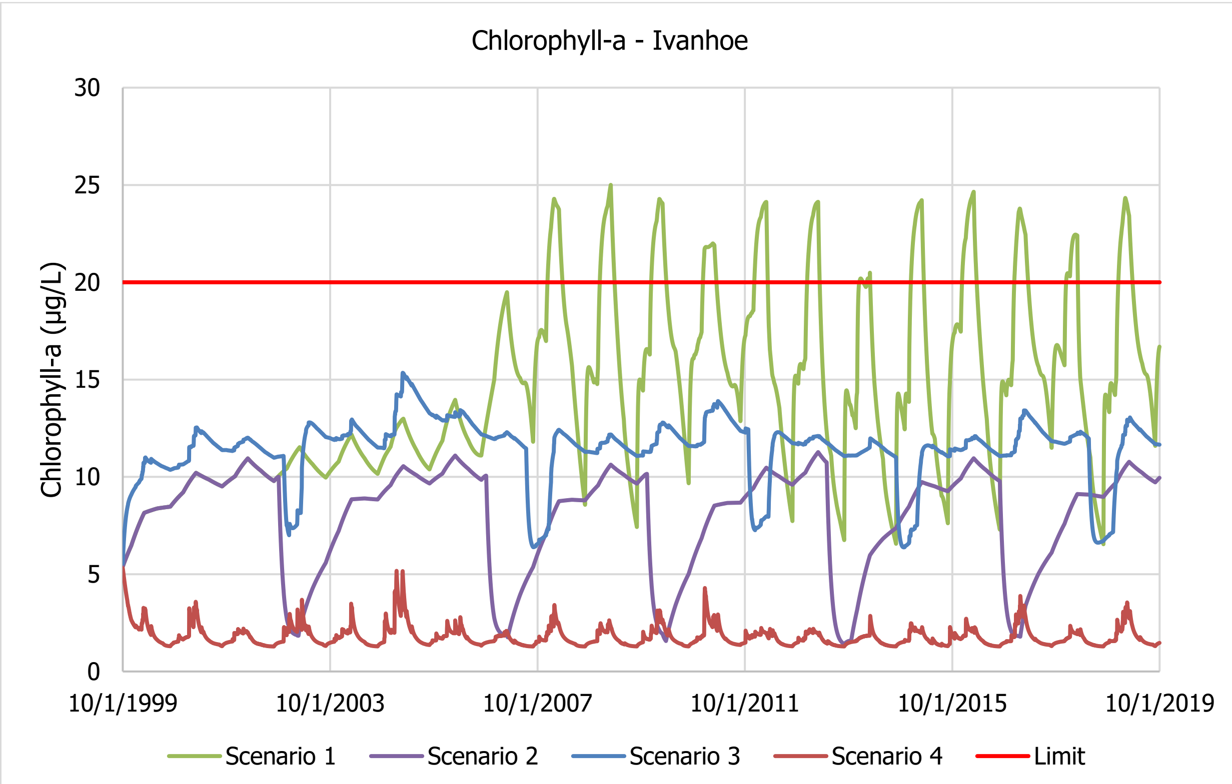

Figure 4-23 Chlorophyll-a Concentration in Ivanhoe Reservoir

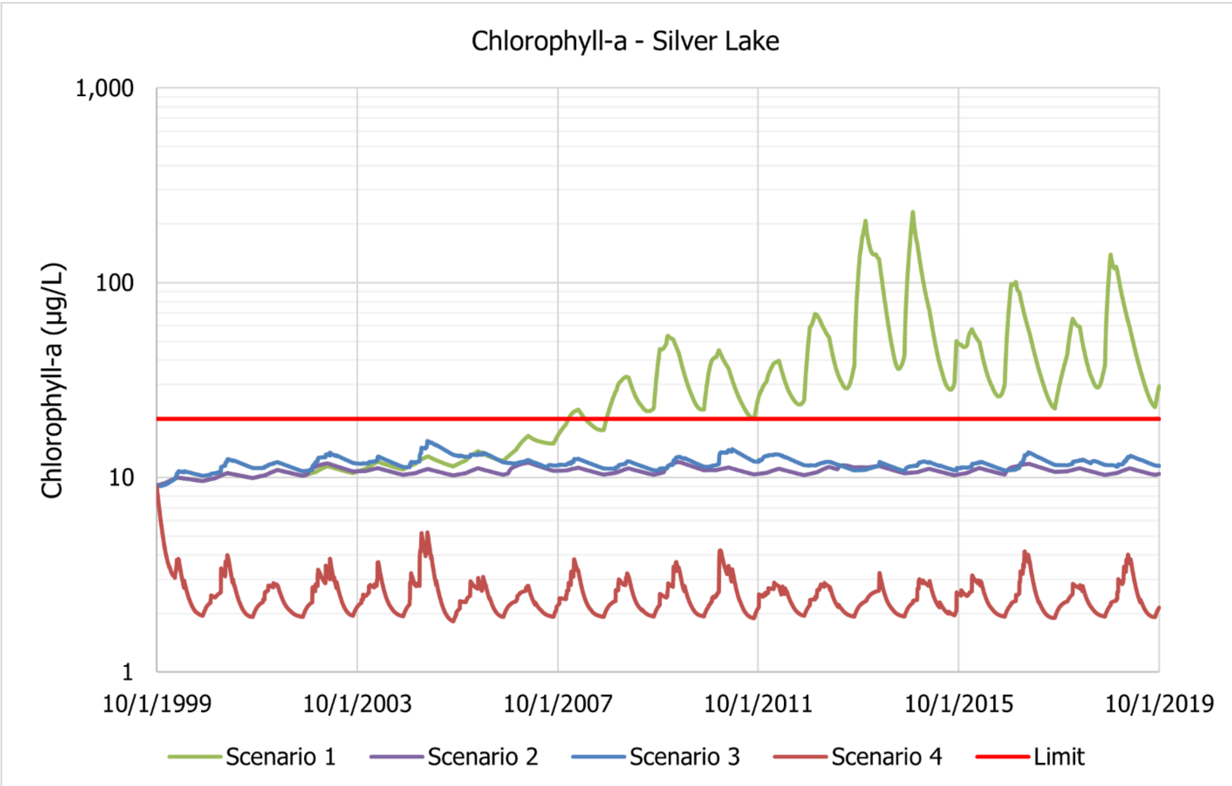

Figure 4-24 Chlorophyll-a Concentration in Silver Lake Reservoir

4.9 Algae

The algae concentration calculated in the model is based on the assumption that each reservoir is well-mixed, but in reality, algae will be concentrated near the surface of each reservoir. The surface area covered by algae was estimated by assuming an average thickness of algae and density. The percentage of the surface covered by algae for the duration of the model for all four scenarios for Ivanhoe Reservoir is shown in **Figure 4-25** and for Silver Lake Reservoir is shown in **Figure 4-26**. Less than 0.1% of the surface is covered in algae throughout all four scenarios. It is more likely that this algae will be spread throughout the upper portion of water column. Although the chlorophyll-a limit is exceeded in Scenario 1 in Silver Lake Reservoir, which would indicate an algal bloom is possible, the surface area covered was still less than 0.1%. In both reservoirs, the amount of water surface covered with algae was reduced from about 0.04% in Scenario 3 to 0.01% in Scenario 4 due to the presence of wetlands. In Silver Lake Reservoir, this would reduce the algae coverage from about 1,200 square feet to about 300 square feet.

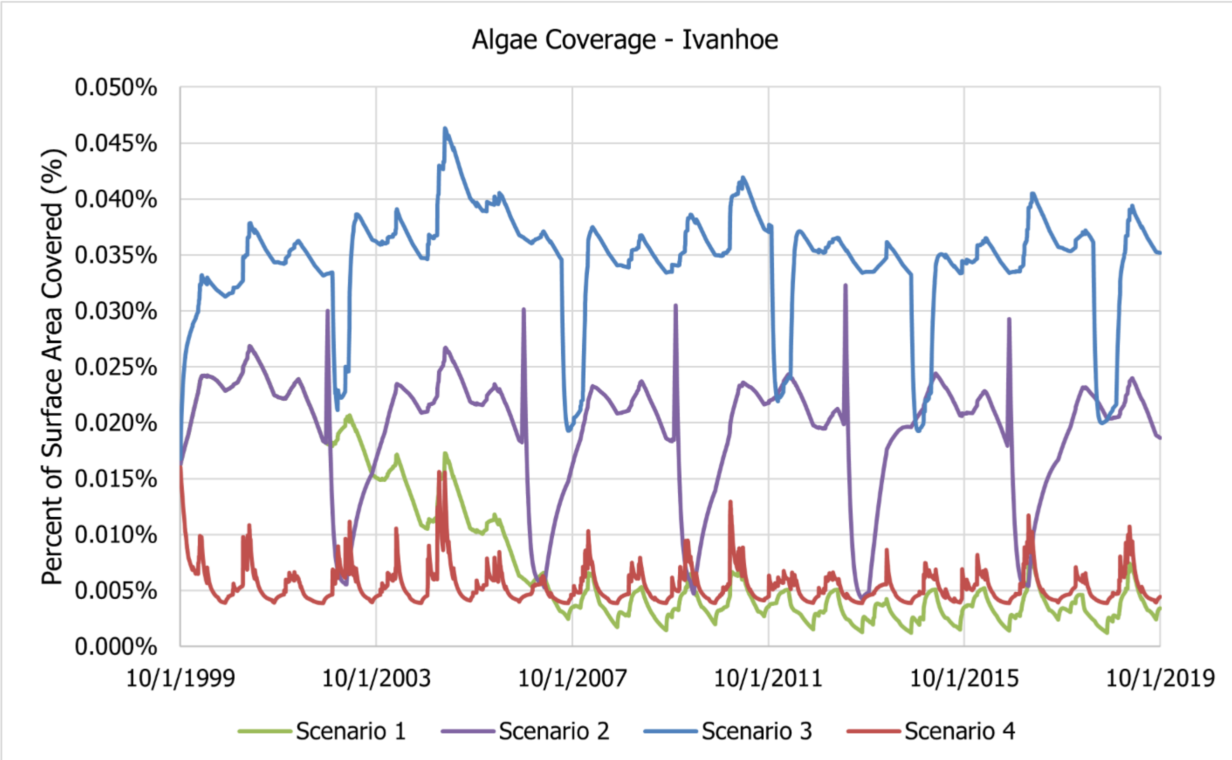

Figure 4-25 Algae Surface Area Coverage in Ivanhoe Reservoir

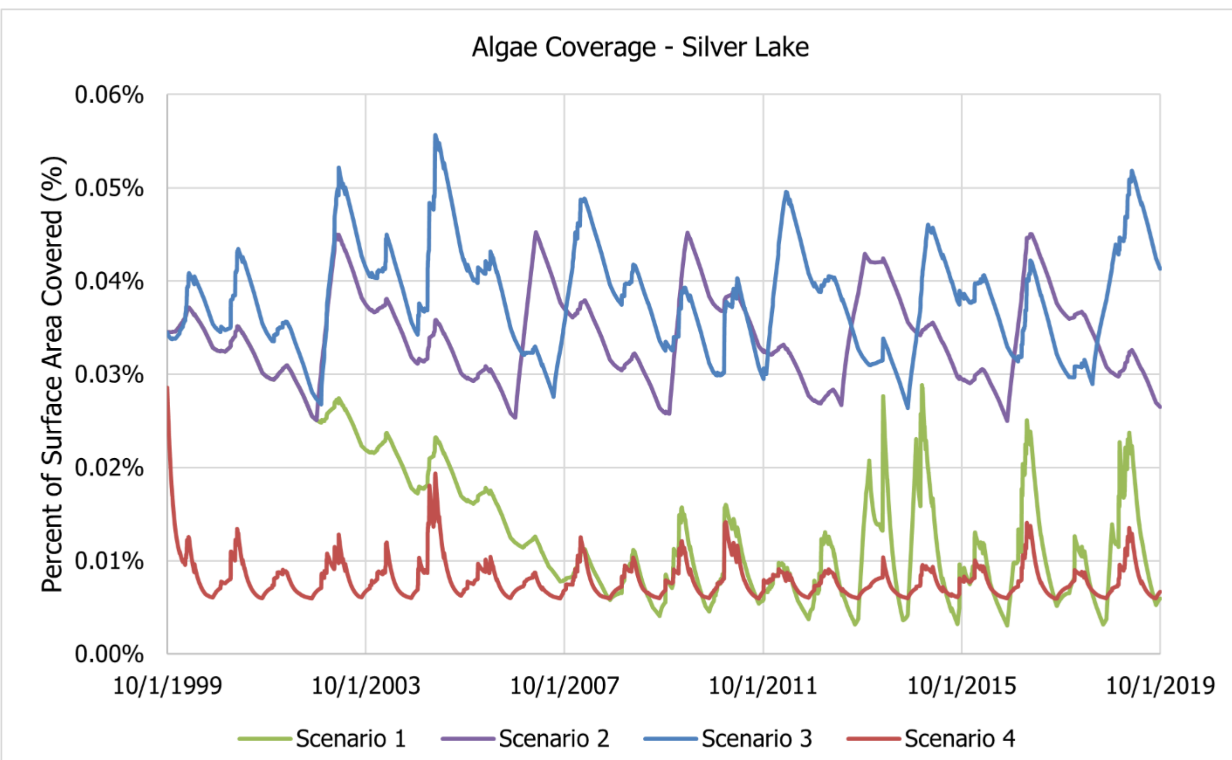

Figure 4-26 Algae Surface Area Coverage in Silver Lake Reservoir

4.10 Dissolved Oxygen

The dissolved oxygen concentration in the SLRC is determined by reaeration from wind, photosynthesis and respiration of aquatic plants and algae, biochemical oxygen demand within the reservoirs, dissolved oxygen content and biochemical oxygen demand of inflows and outflows, and water temperature. The dissolved oxygen concentrations for Ivanhoe Reservoir are shown in **Figure 4-27,** and **Figure 4-28** shows the Silver Lake Reservoir concentrations. A dissolved oxygen concentration below 5 mg/L indicates an impaired waterbody. The dissolved oxygen concentrations remain above 5 mg/L for all four scenarios. Seasonal fluctuations are due to changes in water temperature because colder water has a higher saturated dissolved oxygen concentration than warmer water. The Silver Lake Reservoir dissolved oxygen concentration in Scenario 1 decreased below the other scenarios due to the increase in dissolved solids concentration in October 2007, which increases salinity and decreases the saturated dissolved oxygen concentration.

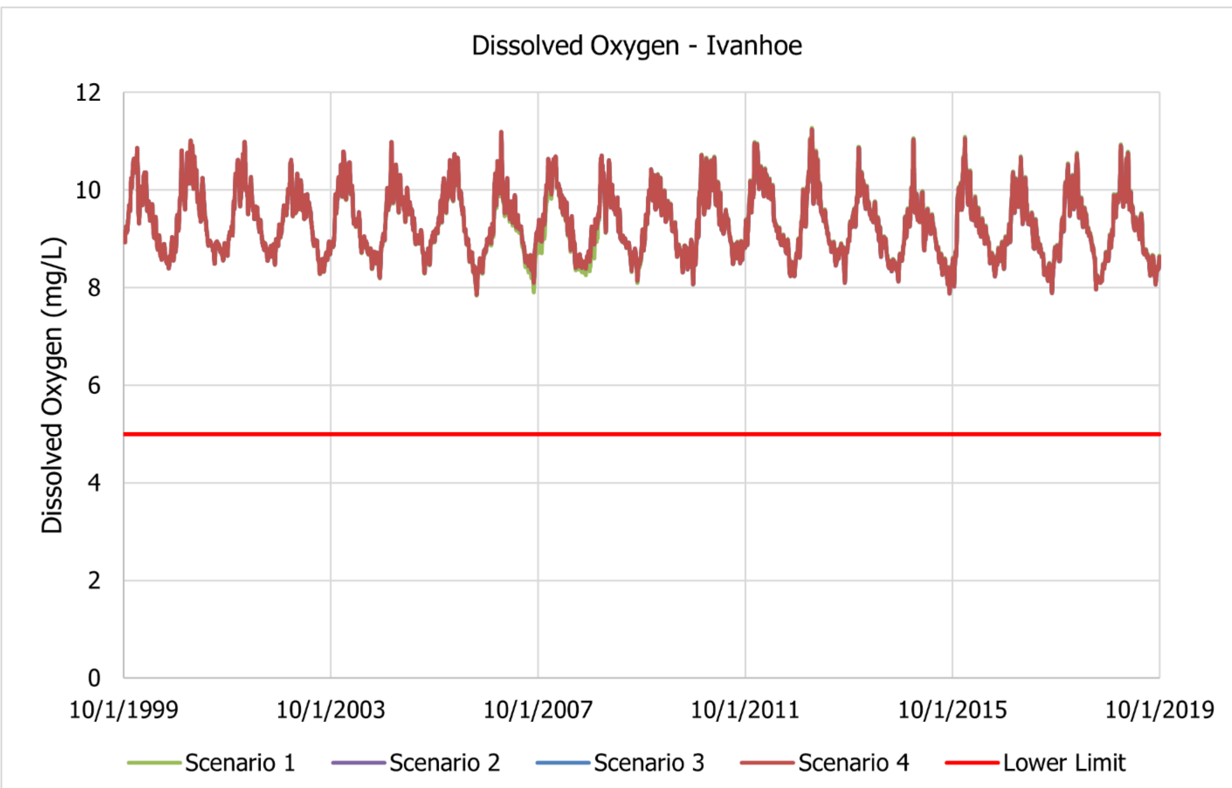

Figure 4-27 Dissolved Oxygen Concentration in Ivanhoe Reservoir

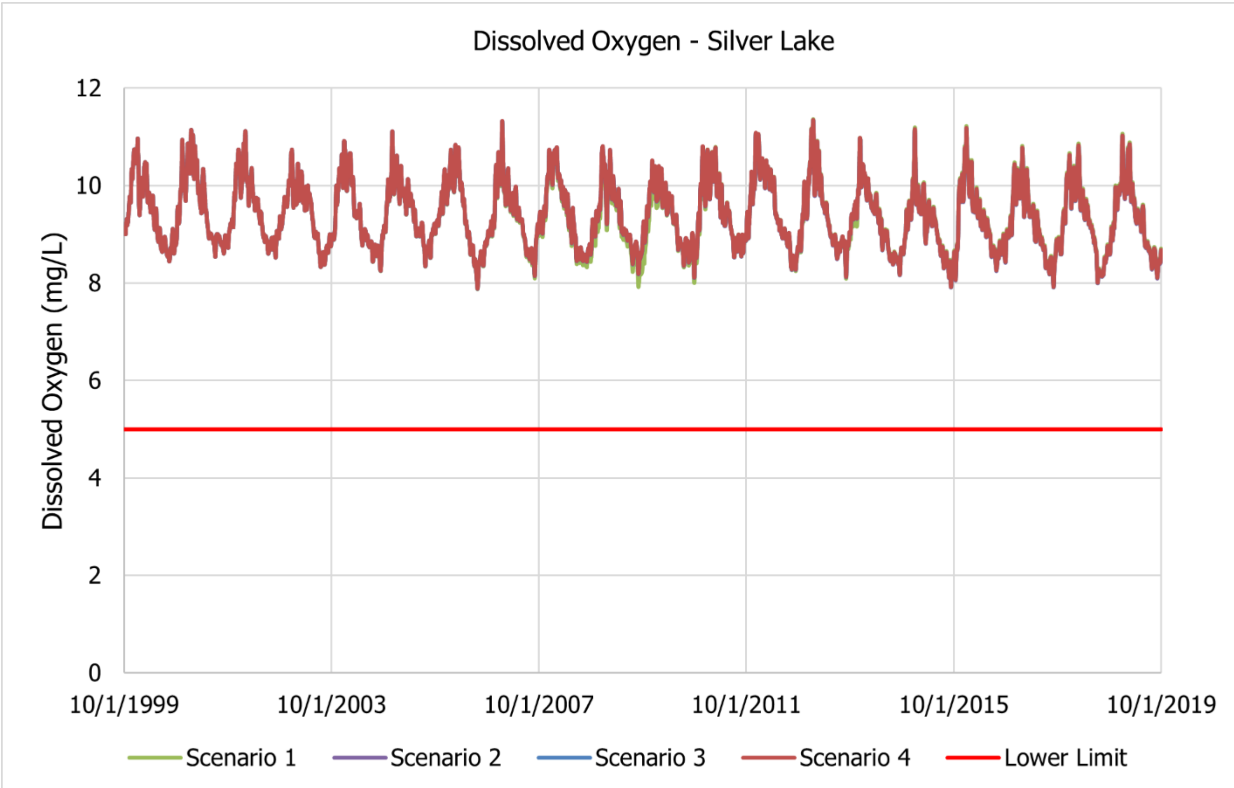

Figure 4-28 Dissolved Oxygen Concentration in Silver Lake Reservoir

5. Model Validation

The water quality model results have been compared to the water quality data collected at Ivanhoe and Silver Lake Reservoir from January 2018 to April 2019. Specific conductance, dissolved oxygen, pH, temperature, turbidity, and chlorophyll-a were measured approximately bi-weekly at or near the water surface at both Silver Lake and Ivanhoe Reservoirs. The data collection period most resembles the initial time period of Scenario 2, in which the inputs include precipitation, bird droppings, atmospheric deposition, and Pollock Well water. The measured values have been superimposed on the Scenario 2 model output from January 2000 to April 2001 as well as the corresponding time series from January 2018 to April 2019 for total dissolved solids, dissolved oxygen, and chlorophyll-a. The 2000 to 2001 time series more closely matches the conditions expected in the measured data due to the recent conversion from a drinking water reservoir and the start of Pollock Well water additions. The 2018-2019 model time series corresponds to the observed precipitation and temperature data for when the actual measurements were taken.

The specific conductance measurements were converted to total dissolved solid concentrations using a conversion factor of 0.7 (Gilmore and Luong, 2016). **Figure 5-1** shows the modeled and observed data for total dissolved solids in Ivanhoe Reservoir, and **Figure 5-2** shows the data for Silver Lake Reservoir. Measurements were taken prior to the first addition of Pollock Well water, which occurred in October 2018. This may explain why the modeled values were typically lower than the measured values prior to October 2018. This is more evident for Ivanhoe, which directly receives the Pollock Well water, compared to Silver Lake, which has a much larger volume for dilution.

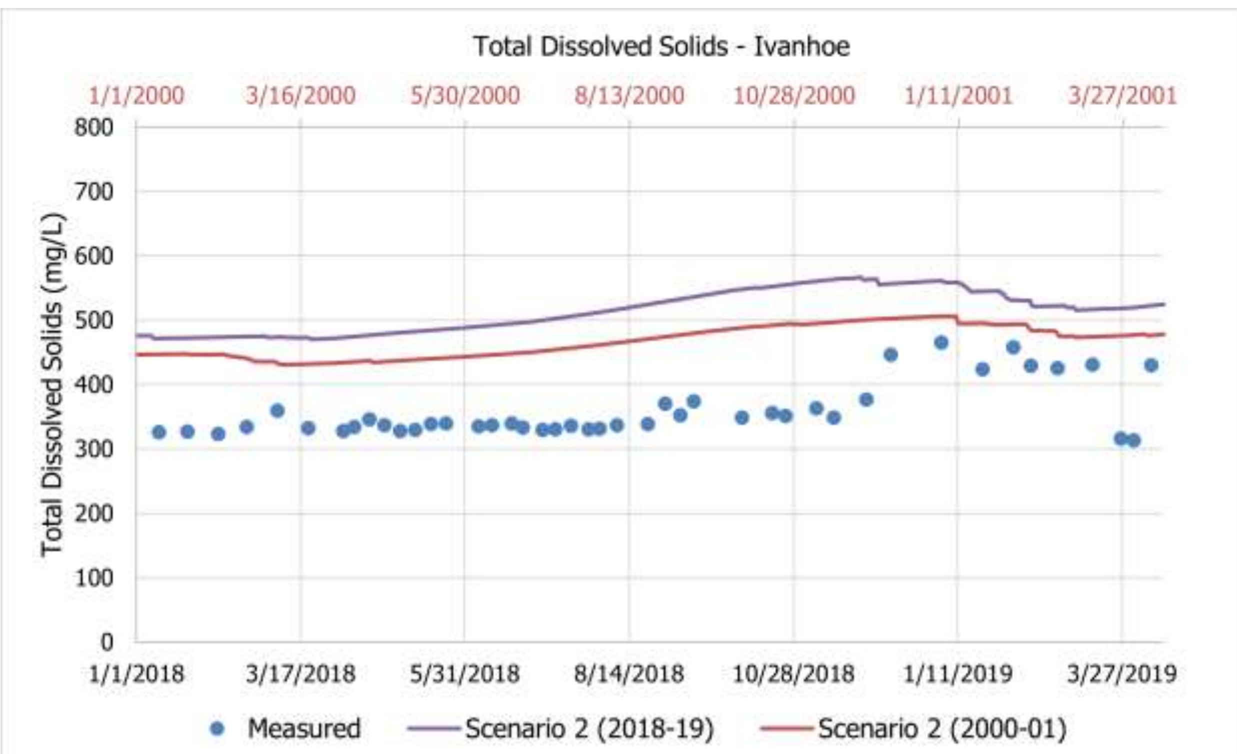

Figure 5-1 Dissolved Solids Concentration in Ivanhoe Reservoir

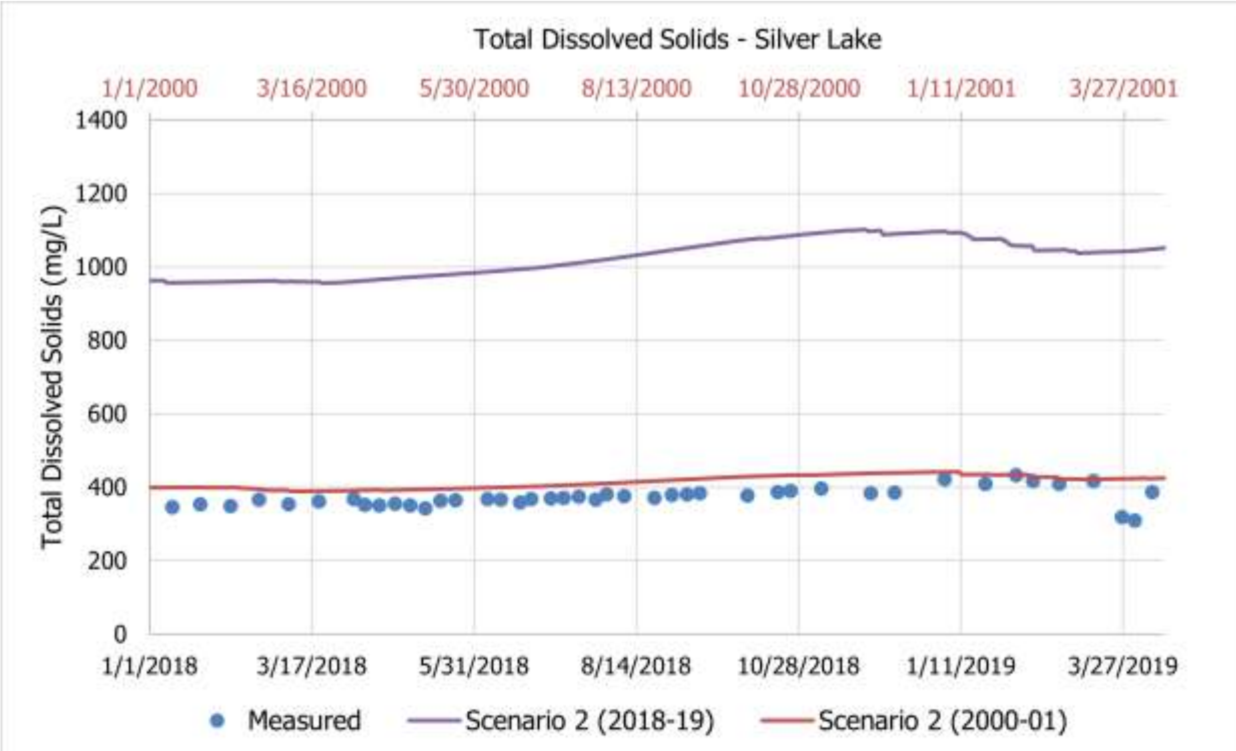

Figure 5-2 Dissolved Solids Concentration in Silver Lake Reservoir

Figure 5-3 shows the modeled and observed chlorophyll-a concentrations in Ivanhoe Reservoir, and **Figure 5-4** shows the data for Silver Lake Reservoir. The model does not capture the variability observed in the measured data after October 2018. This may be due to the model assumption of a phosphorus concentration of 0 mg/L for the Pollock Well water, as discussed in **Section 3.6.4**.

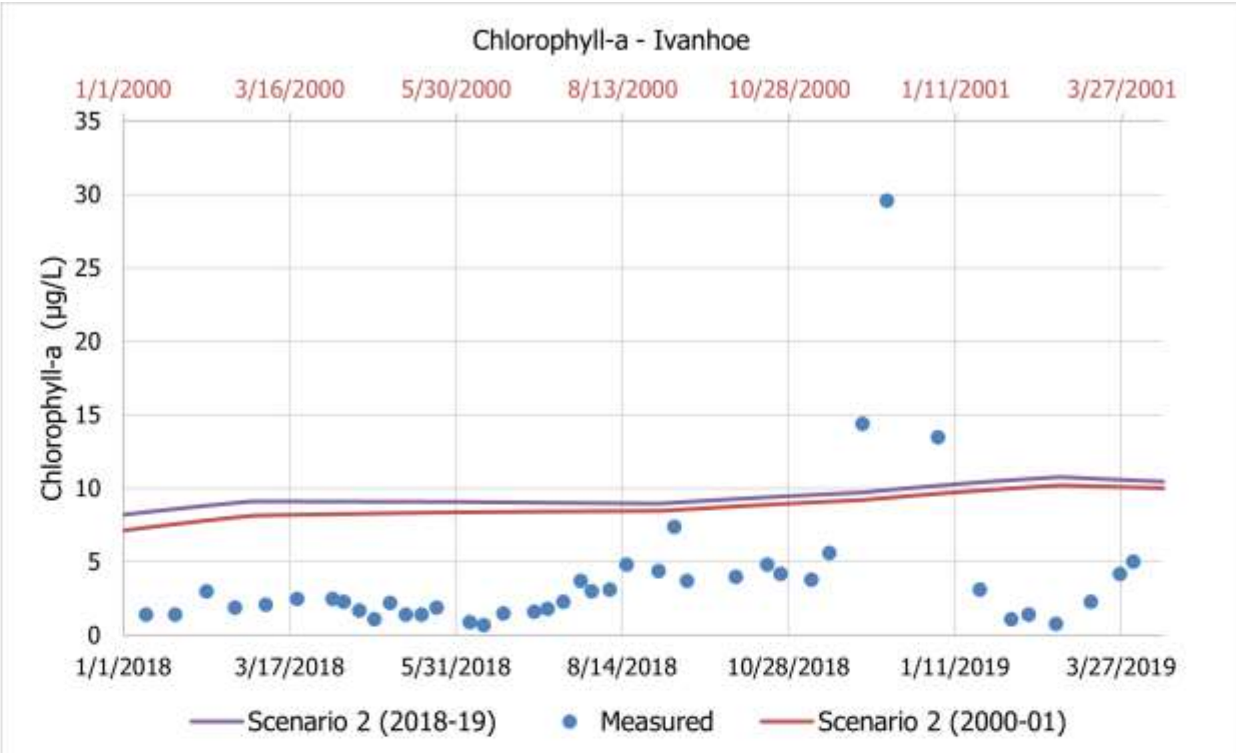

Figure 5-3 Chlorophyll-a Concentration in Ivanhoe Reservoir

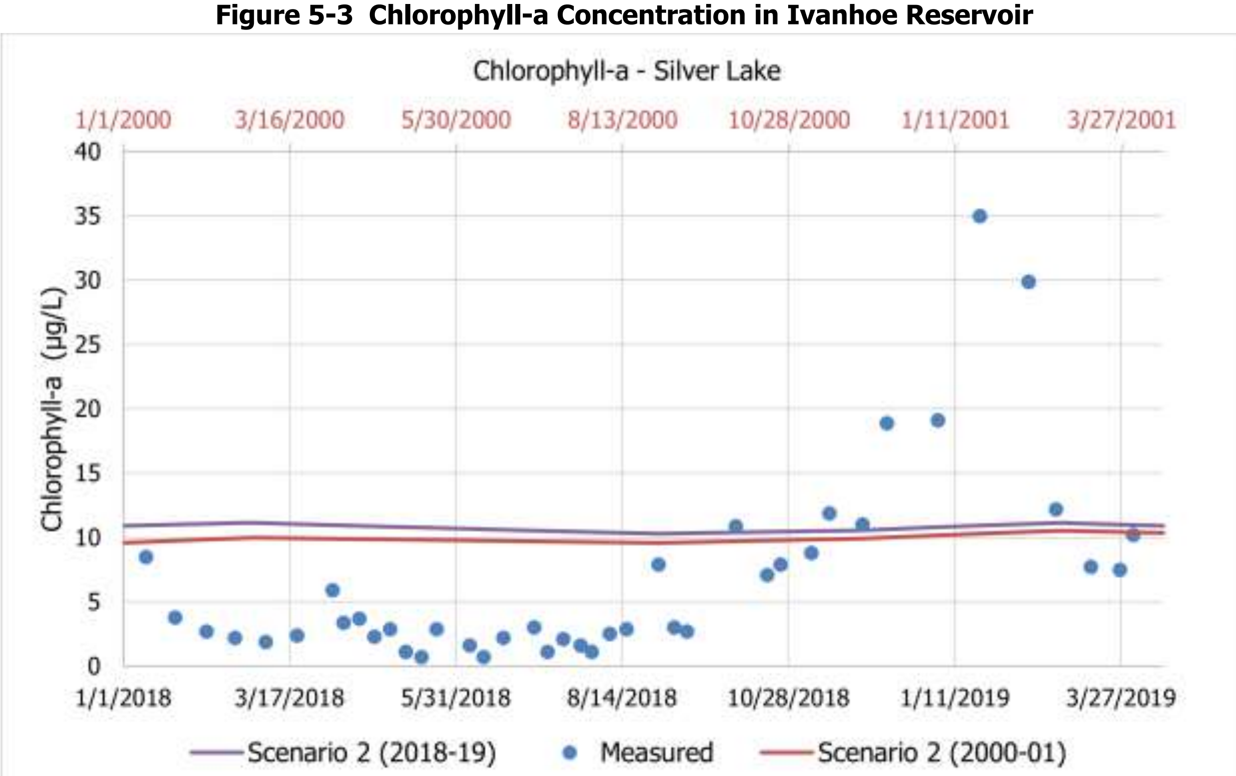

Figure 5-4 Chlorophyll-a Concentration in Silver Lake Reservoir

Figure 5-5 shows the modeled and observed dissolved oxygen concentrations in Ivanhoe Reservoir, and **Figure 5-6** shows the data for Silver Lake Reservoir.

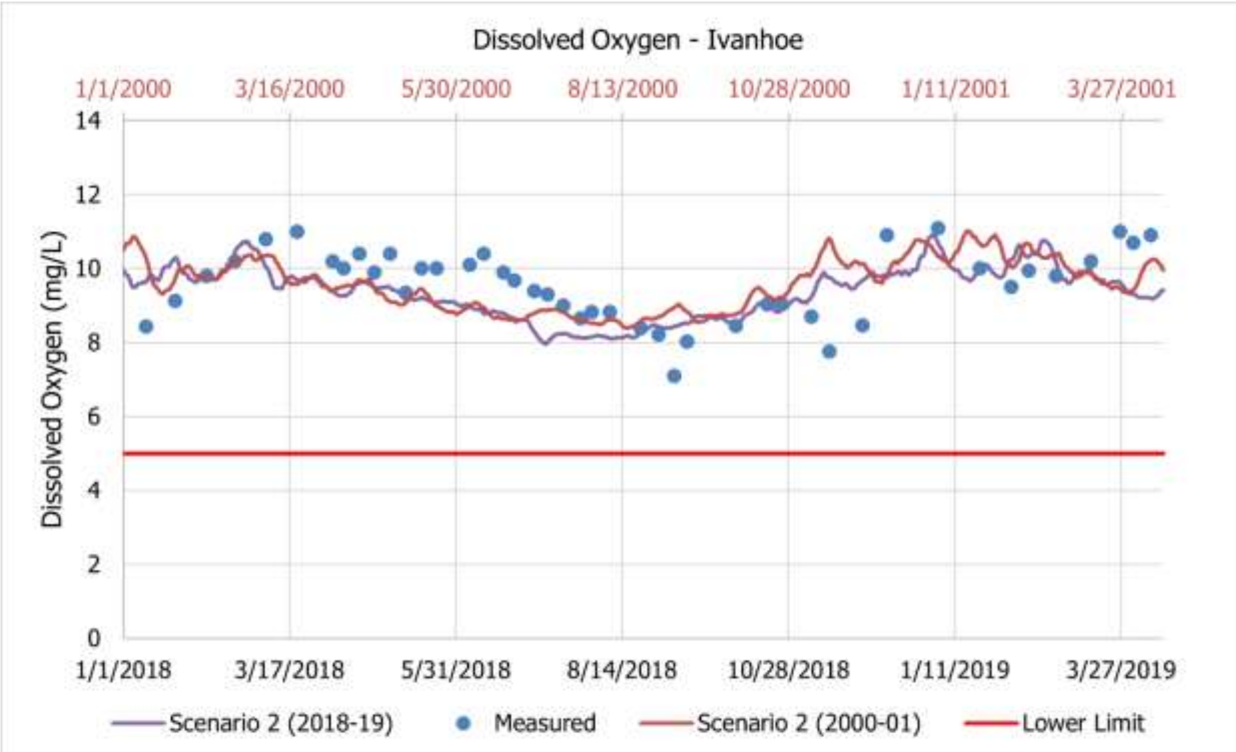

Figure 5-5 Dissolved Oxygen Concentration in Ivanhoe Reservoir

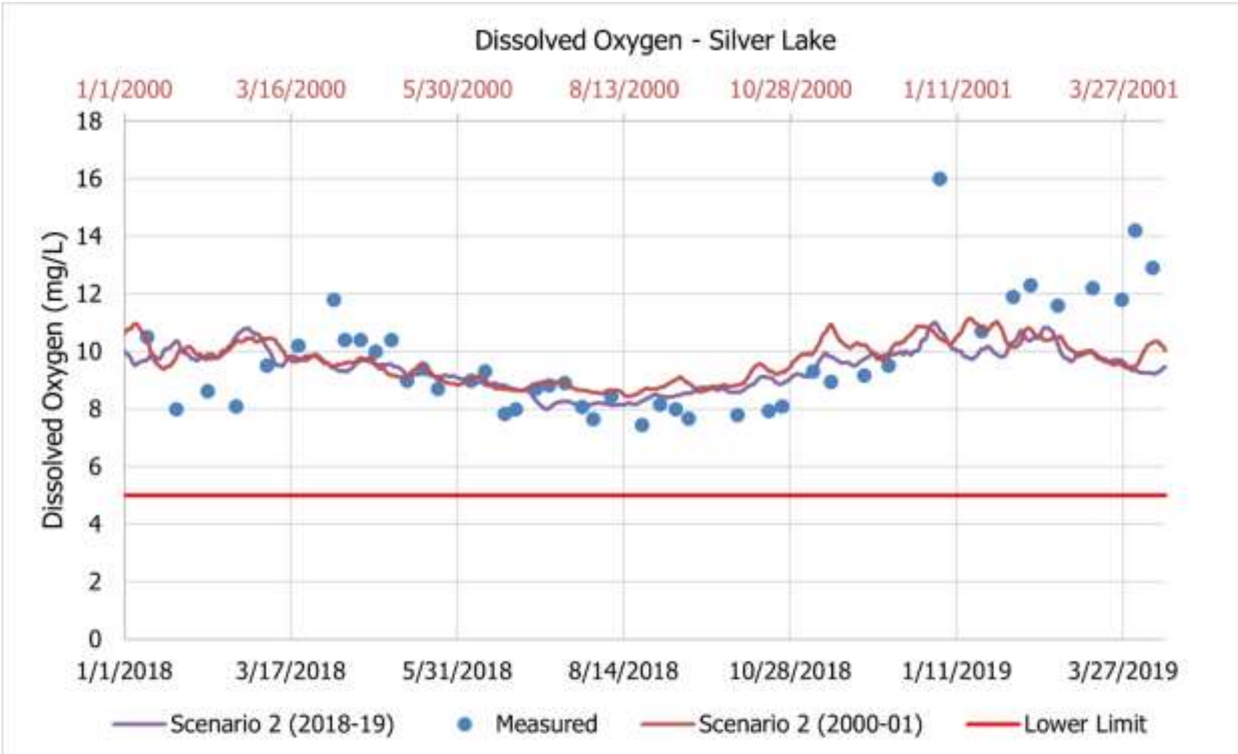

Figure 5-6 Dissolved Oxygen Concentration in Silver Lake Reservoir

6. Sensitivity Analysis

Sensitivity analysis was conducted to observe the effect on the results from changing various inputs and assumptions in the model. The predicted number of birds was doubled and increased ten-fold, which is possible when additional habitat is created at the SLRC. The nitrogen concentrations in each reservoir using both the low and high concentrations measured in the Pollock Well water inputs were modeled. The accumulation of sediment in each reservoir was modeled assuming no pre-treatment removal in the incoming stormwater runoff. The sensitivity to the areal size of the wetlands was investigated by decreasing the wetland footprint by half and doubling the footprint.

6.1 Bird Loadings

The number of birds at SLRC may increase in the future when fish are present and additional habitat has been provided as part of the Master Plan. The number of birds were doubled and increased by ten-fold to observe the effects on the total coliform, nitrogen, phosphorus concentrations. **Figure 6-1** shows the total coliform concentration for all four scenarios for doubling the loading from birds in Ivanhoe Reservoir, and **Figure 6-2** shows the total coliform concentration for Silver Lake Reservoir. **Figure 6-3** shows the total nitrogen concentrations for doubling the loading from birds for Ivanhoe Reservoir, and **Figure 6-4** shows the total nitrogen concentrations for Silver Lake Reservoir. **Figure 6-5** shows the total phosphorus concentrations for Ivanhoe Reservoir for doubling the bird loadings, and **Figure 6-6** shows the total phosphorus concentrations for Silver Lake Reservoir.

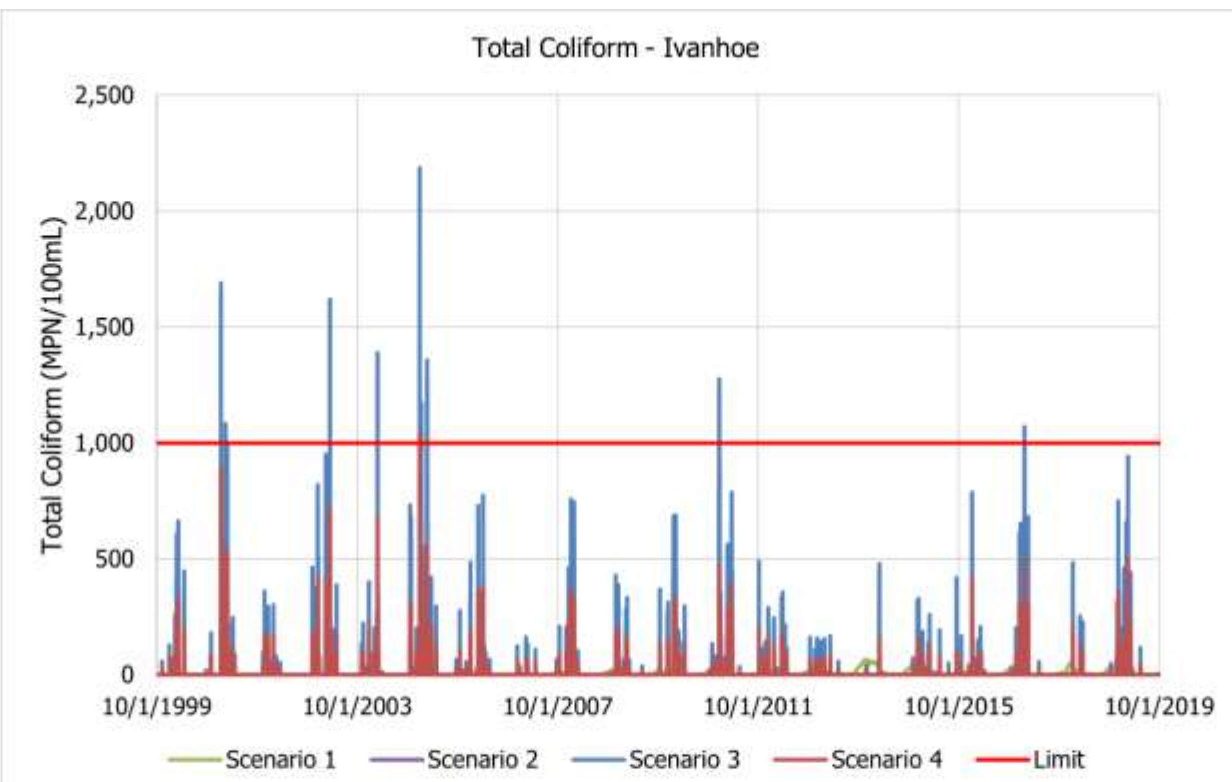

Figure 6-1 Total Coliform in Ivanhoe Reservoir from Doubled Bird Loadings

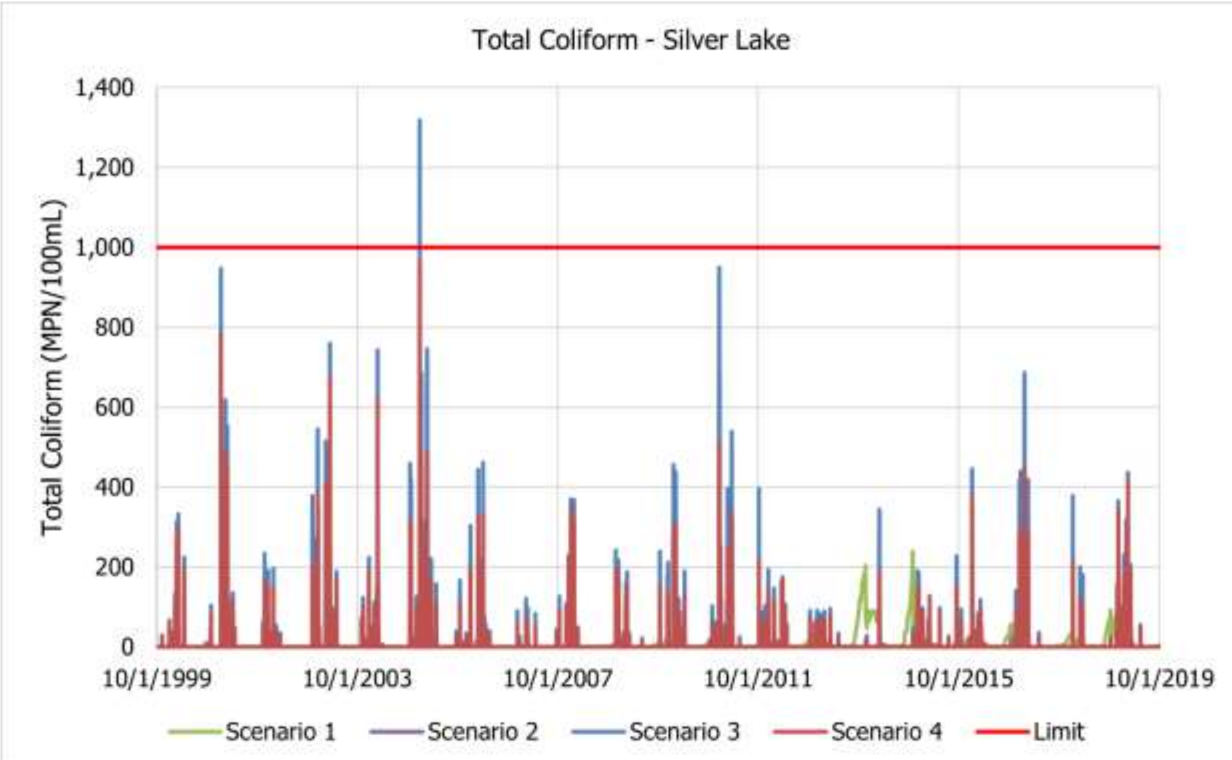

Figure 6-2 Total Coliform in Silver Lake Reservoir from Doubled Bird Loadings

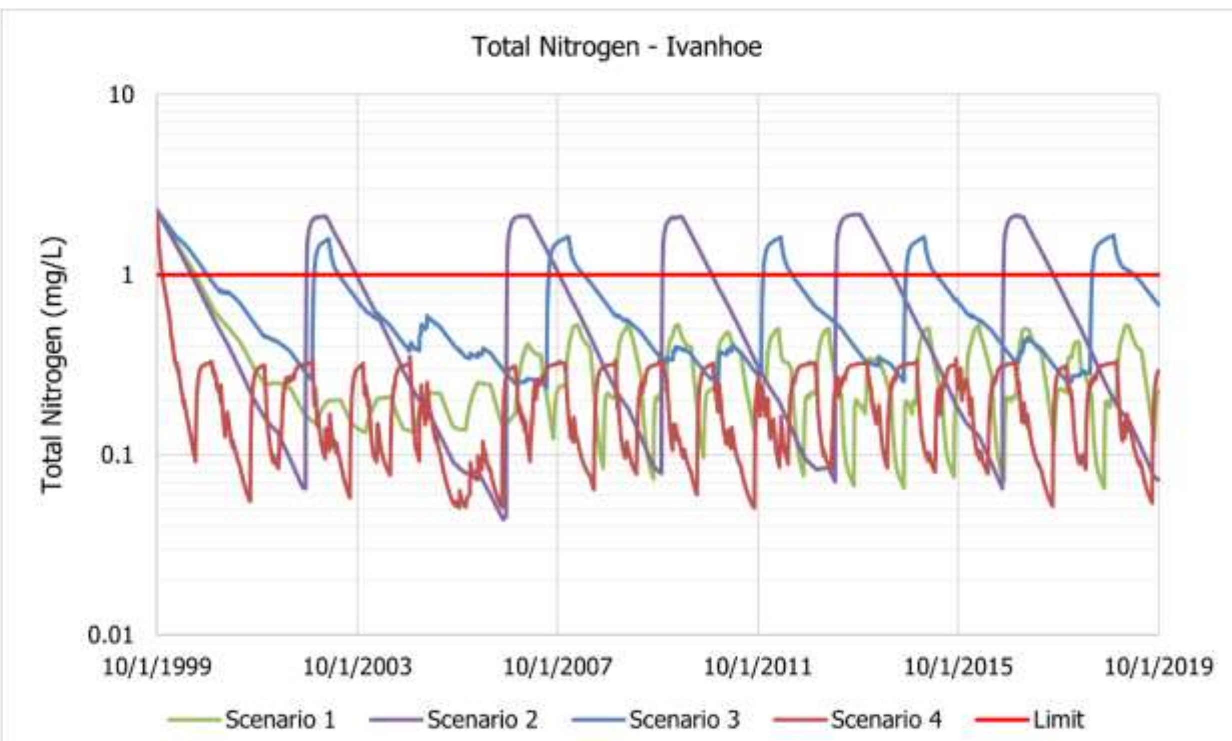

Figure 6-3 Total Nitrogen in Ivanhoe Reservoir from Doubled Bird Loadings

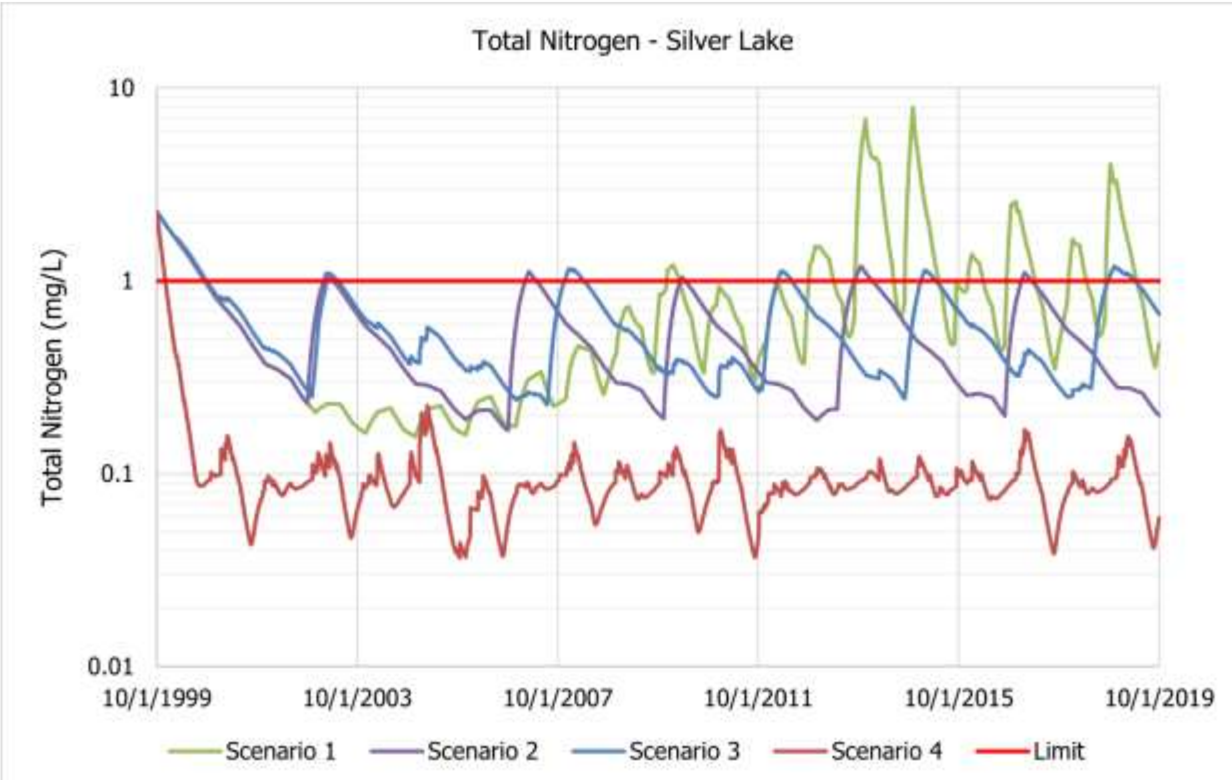

Figure 6-4 Total Nitrogen in Silver Lake Reservoir from Doubled Bird Loadings

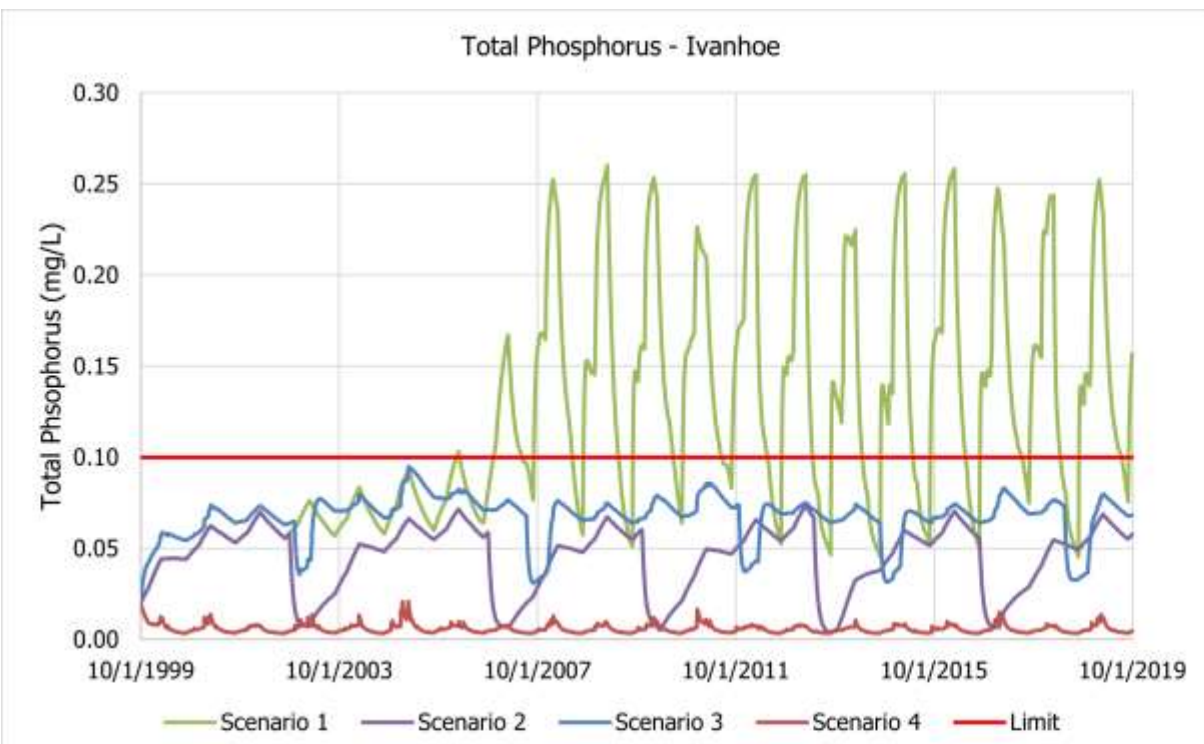

Figure 6-5 Total Phosphorus in Ivanhoe Reservoir from Doubled Bird Loadings

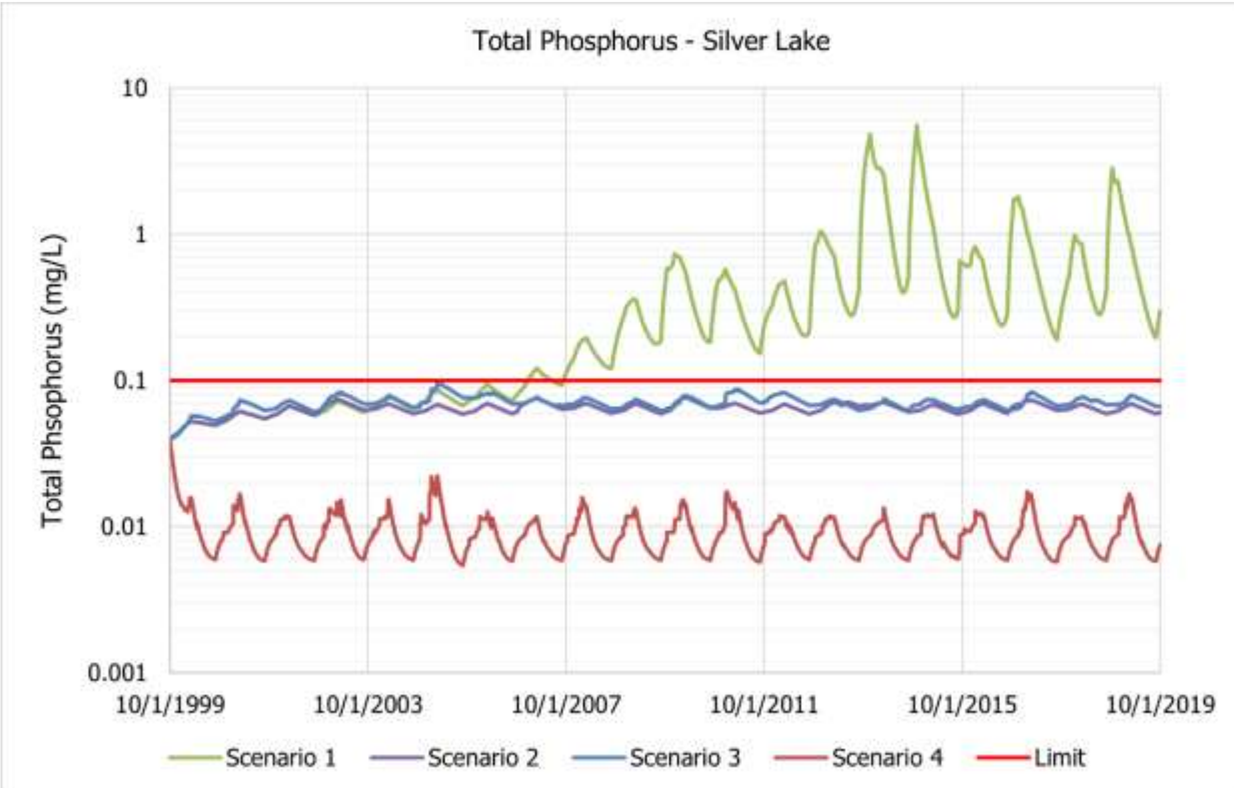

Figure 6-6 Total Phosphorus in Silver Lake Reservoir from Doubled Bird Loadings

Figure 6-7 shows the total coliform concentration for all four scenarios for increasing the loading from birds by ten times in Ivanhoe Reservoir, and **Figure 6-8** shows the total coliform concentration for Silver Lake Reservoir. **Figure 6-9** shows the total nitrogen concentrations for increasing the loading from birds by ten times for Ivanhoe Reservoir, and **Figure 6-10** shows the total nitrogen concentrations for Silver Lake Reservoir. **Figure 6-11** shows the total phosphorus concentrations for Ivanhoe Reservoir for ten times the bird loadings, and **Figure 6-12** shows the total phosphorus concentrations for Silver Lake Reservoir. Exceedances are shown for Scenario 1, but a ten-fold increase in birds will likely not be sustained as the water decreases in Scenario 1.

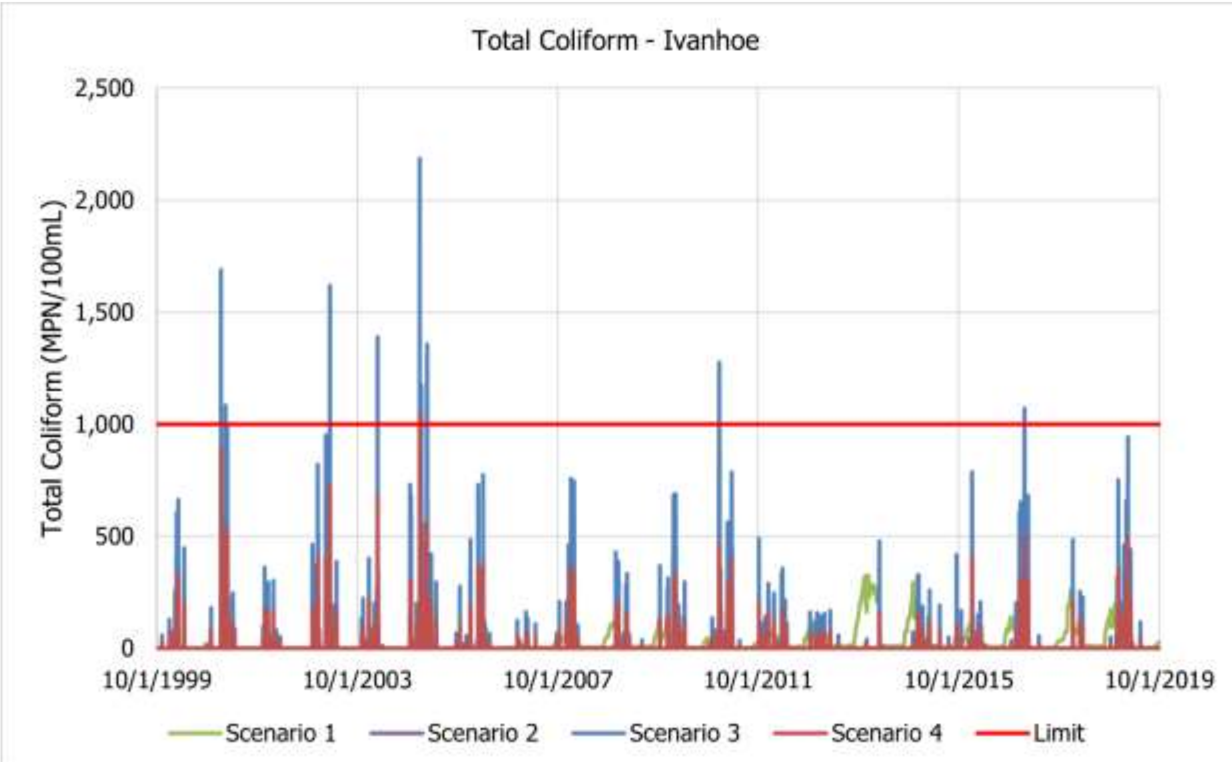

Figure 6-7 Total Coliform in Ivanhoe Reservoir from Ten-fold Bird Loadings

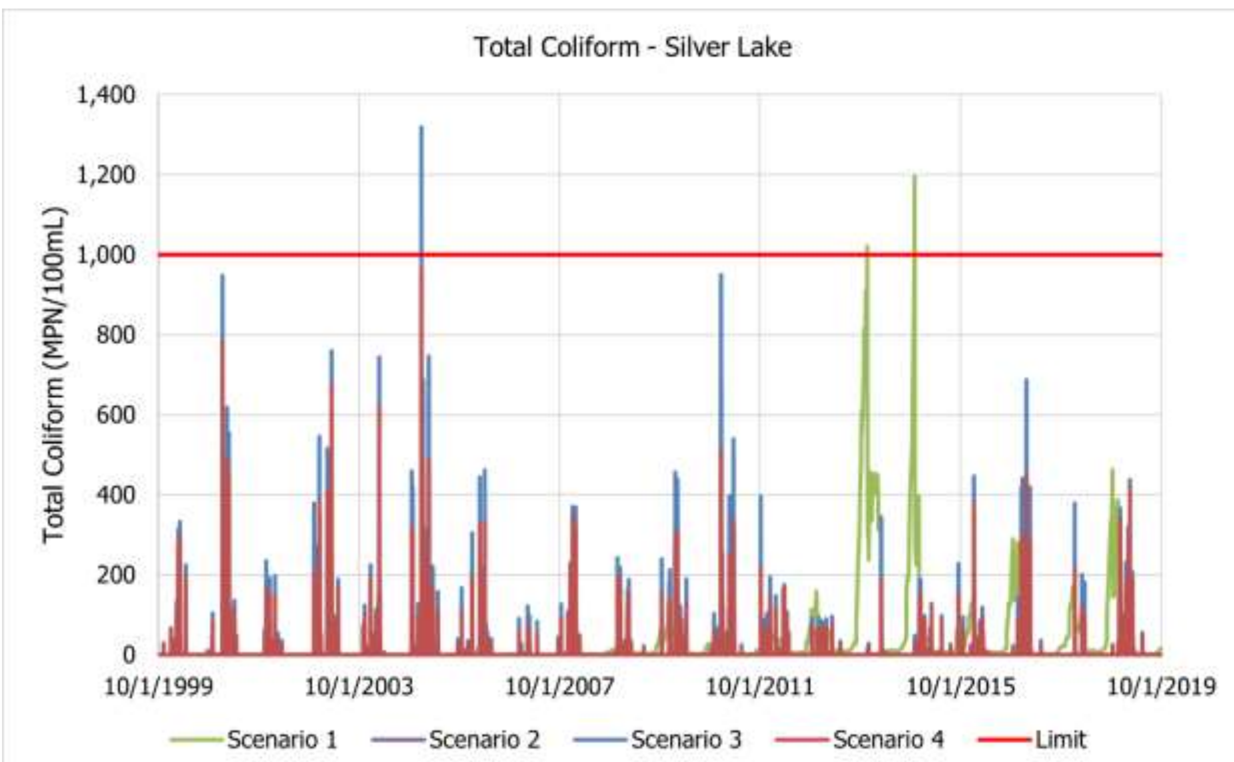

Figure 6-8 Total Coliform in Silver Lake Reservoir from Ten-fold Bird Loadings

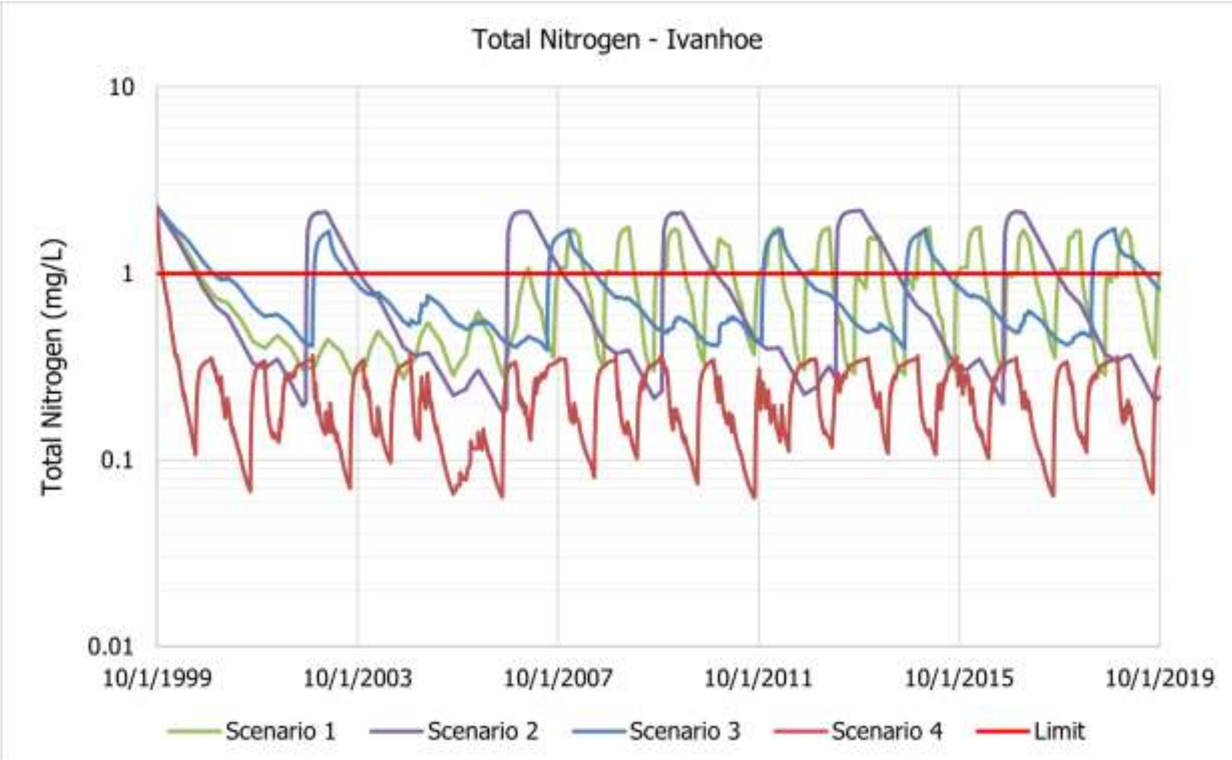

Figure 6-9 Total Nitrogen in Ivanhoe Reservoir from Ten-fold Bird Loadings

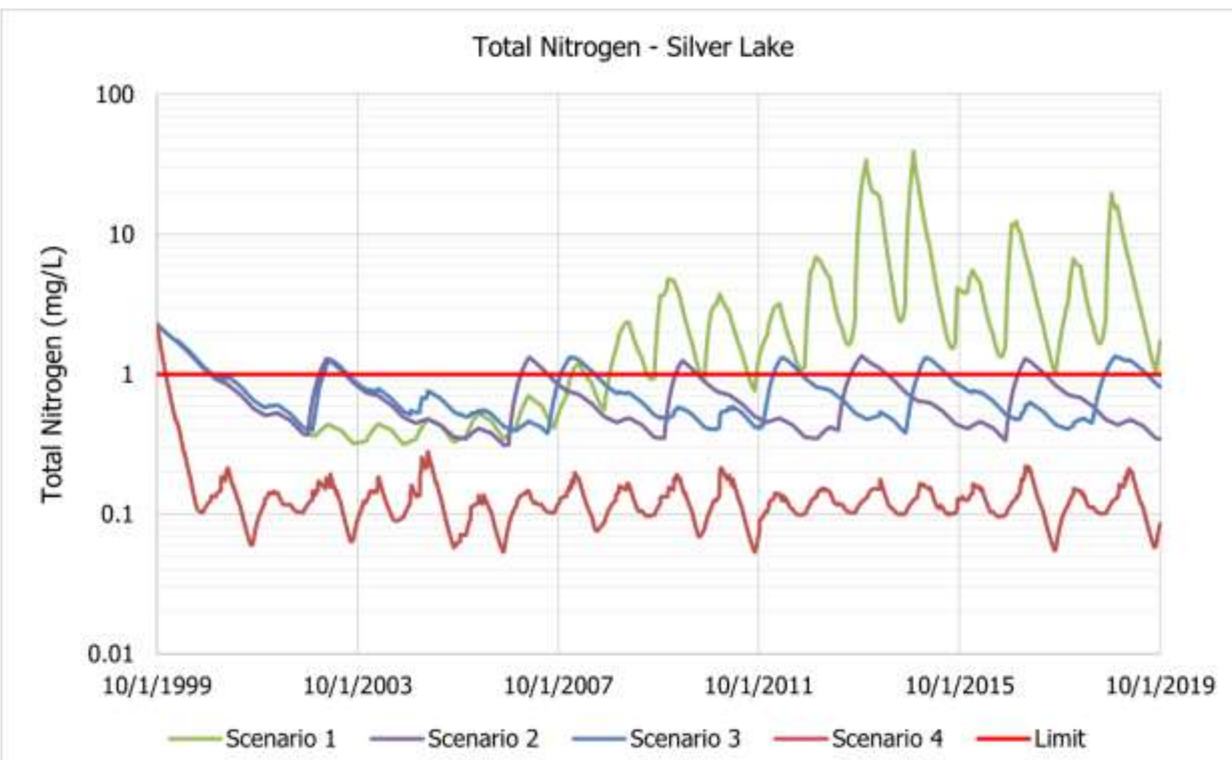

Figure 6-10 Total Nitrogen in Silver Lake Reservoir from Ten-fold Bird Loadings

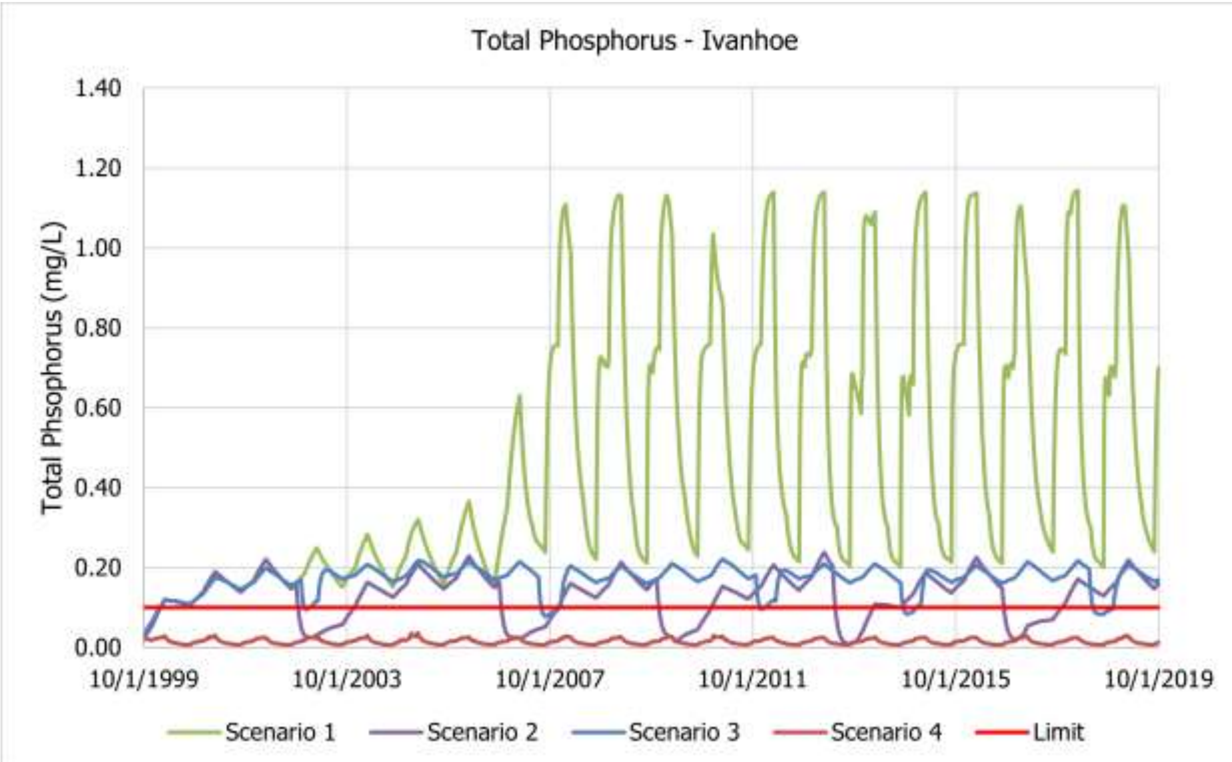

Figure 6-11 Total Phosphorus in Ivanhoe Reservoir from Ten-fold Bird Loadings

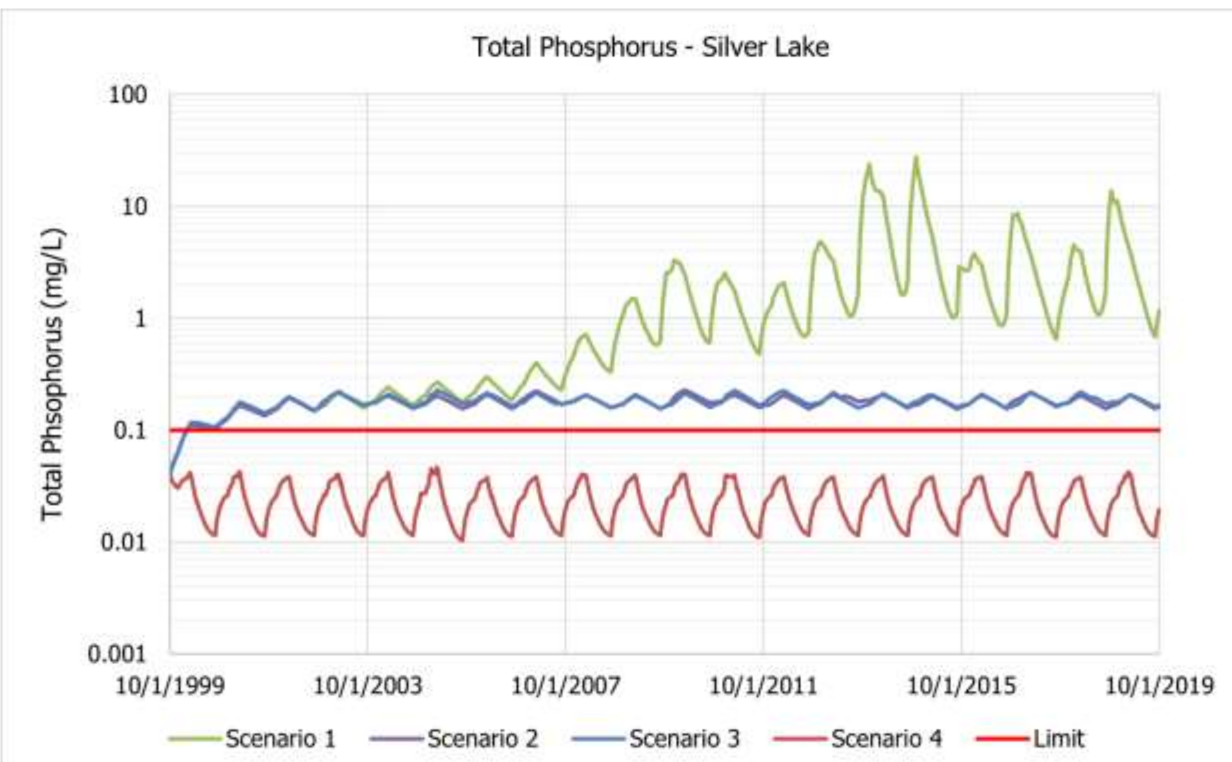

Figure 6-12 Total Phosphorus in Silver Lake Reservoir from Ten-fold Bird Loadings

6.2 Nitrogen Concentration of Pollock Well Water

The total nitrogen concentration of Pollock Well water ranged from 0.2 to 4.4 mg/L from the two days of measurements. The previous results used an average value of 2.3 mg/L for the Pollock Well water injections. The total nitrogen concentrations in each reservoir resulting the low end of the range (0.2 mg/L) are shown in **Figure 6-13** and **Figure 6-14** for Ivanhoe and Silver Lake Reservoirs, respectively. The total nitrogen concentrations in each reservoir using the high end of the range (4.4 mg/L) are shown in **Figure 6-15** and **Figure 6-16** for Ivanhoe and Silver Lake Reservoirs, respectively.

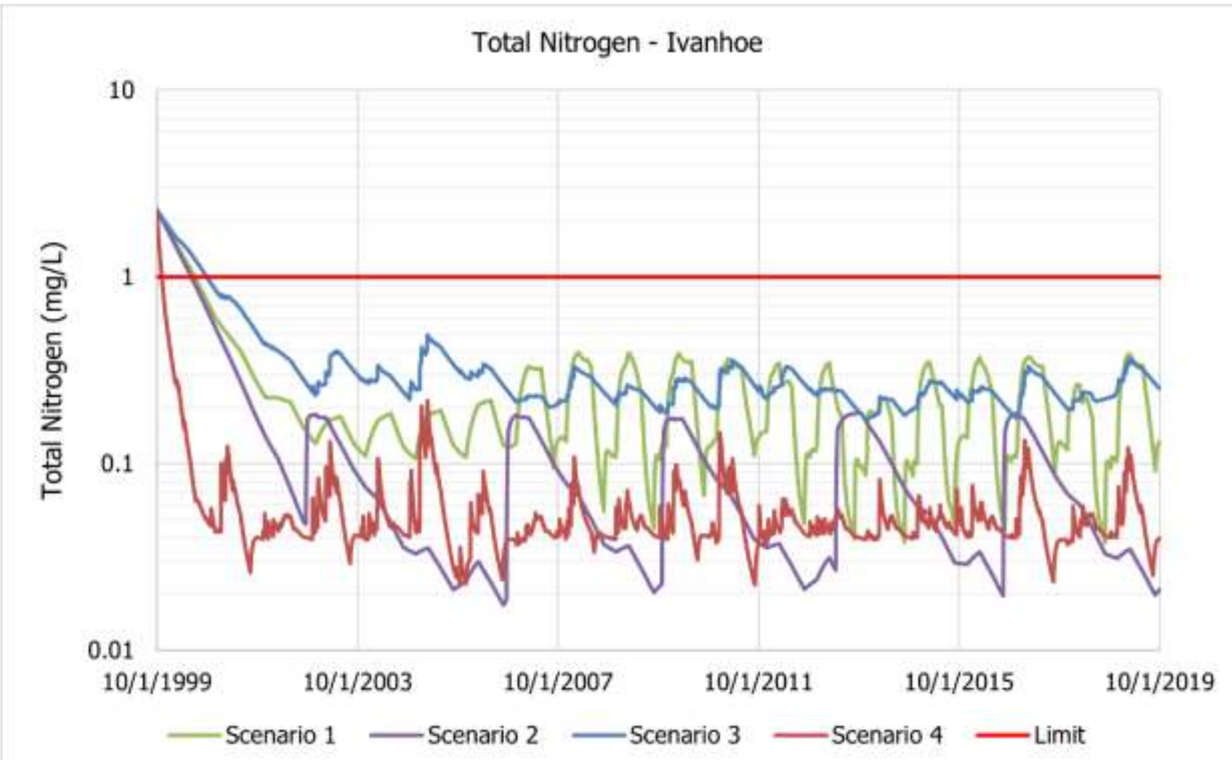

Figure 6-13 Total Nitrogen in Ivanhoe Reservoir from 0.2 mg/L Pollock Well Inputs

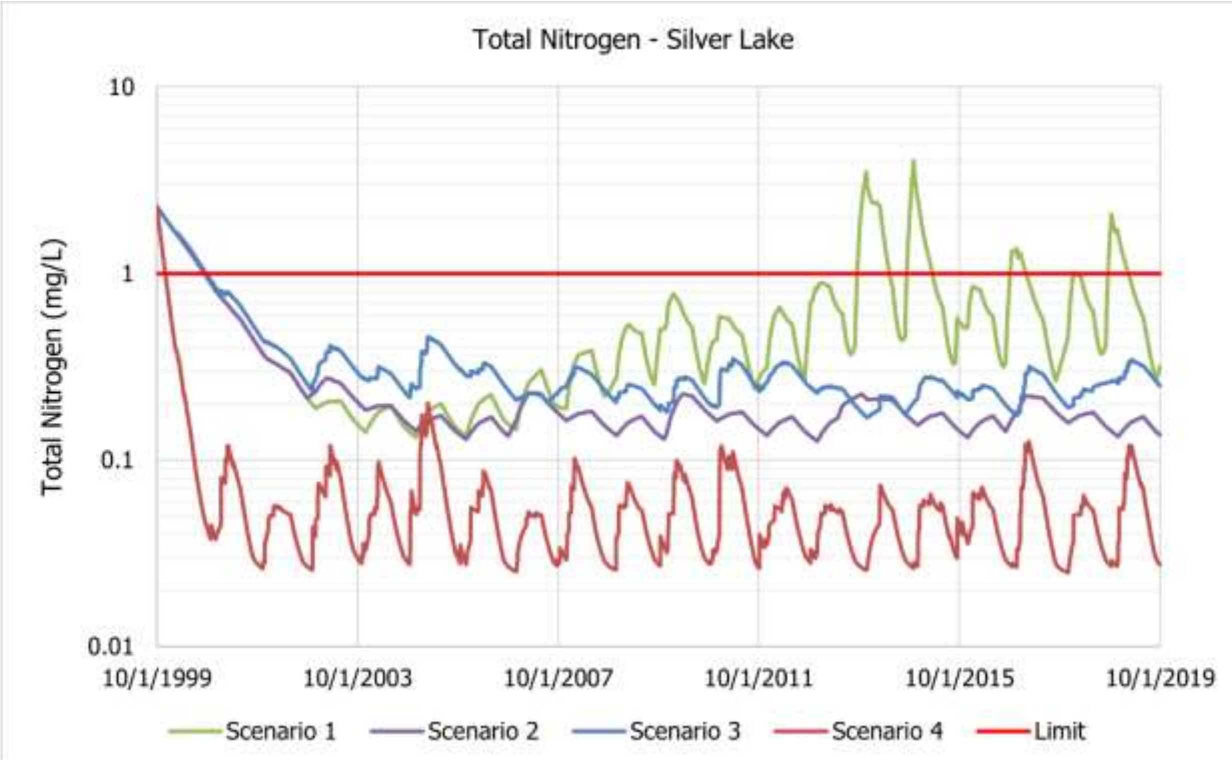

Figure 6-14 Total Nitrogen in Silver Lake Reservoir from 0.2 mg/L Pollock Well Inputs

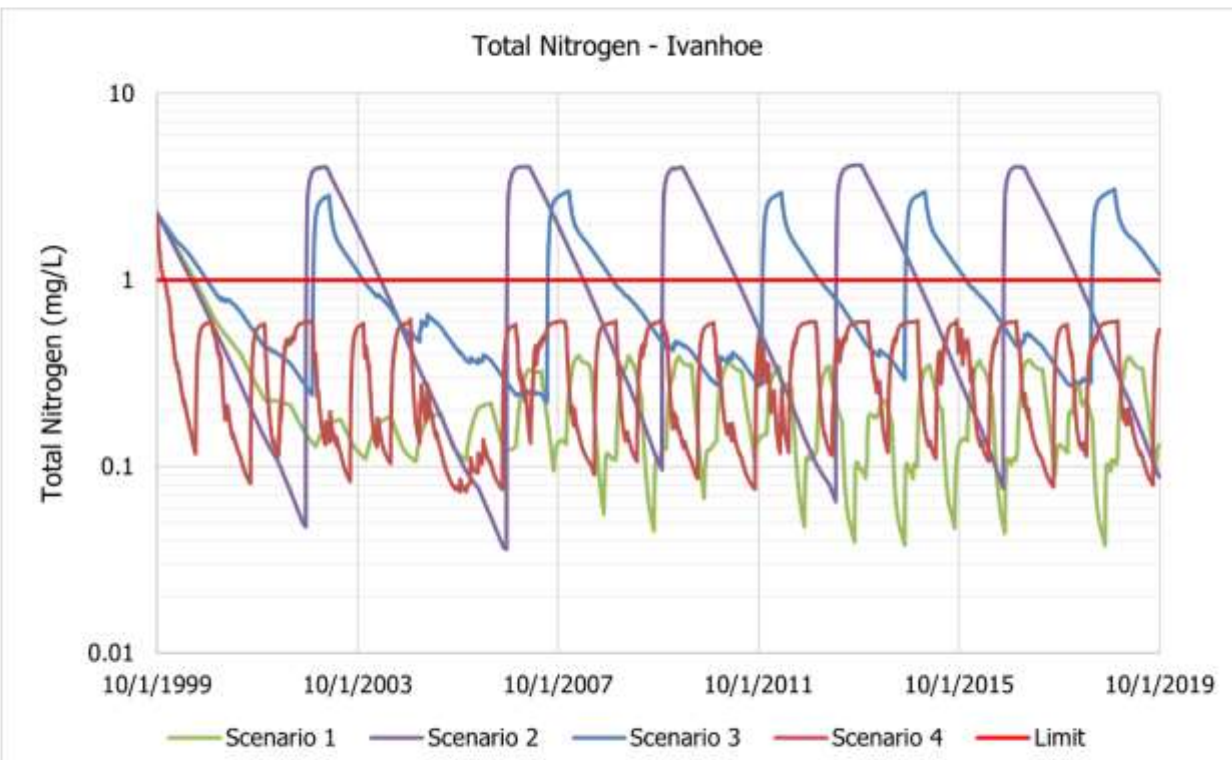

Figure 6-15 Total Nitrogen in Ivanhoe Reservoir from 4.4 mg/L Pollock Well Inputs

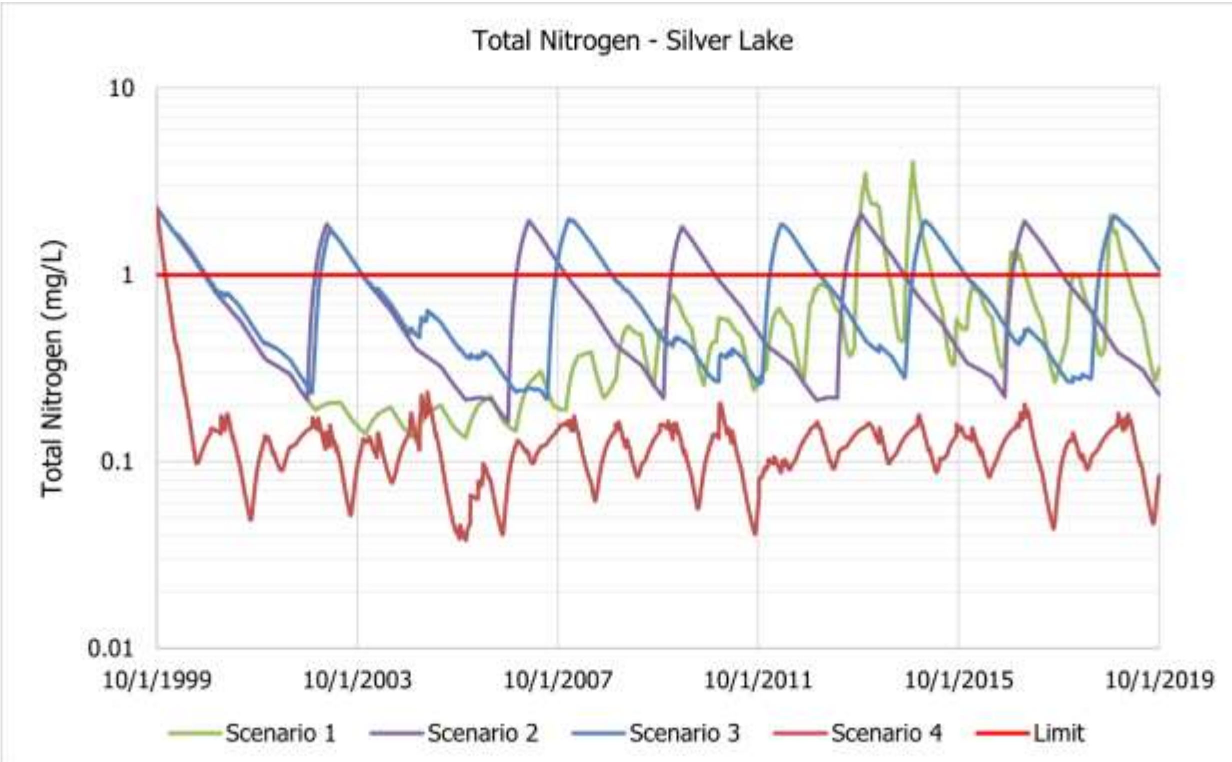

Figure 6-16 Total Nitrogen in Silver Lake Reservoir from 4.4 mg/L Pollock Well Inputs

6.3 Sediment Accumulation

The SLRC Water Quality Model assumes an efficiency based on flow rate for total suspended solids removal by the pre-treatment units. If these pretreatment units did not remove any suspended solids (not including trash), the average rate of accumulation is estimated to be 0.0003 acre-feet per year in Ivanhoe Reservoir and 0.002 acre-feet per year in Silver Lake Reservoir. Based on these rates, the sediment volume is predicted to reach 1% of the volume of Ivanhoe Reservoir after 7,000 years and 1% of the volume of Silver Lake after 12,000 years. The pretreatment removal of suspended solids may not be necessary for maintaining the design capacity of the reservoirs, but the proposed CDS units will remove trash and reduce the concentrations of pollutants entering the SLRC. **Figure 6-17** shows the volume of settled suspended solids in Ivanhoe Reservoir without capture, and **Figure 6-18** shows the volume of settled suspended solids in Silver Lake Reservoir without capture.

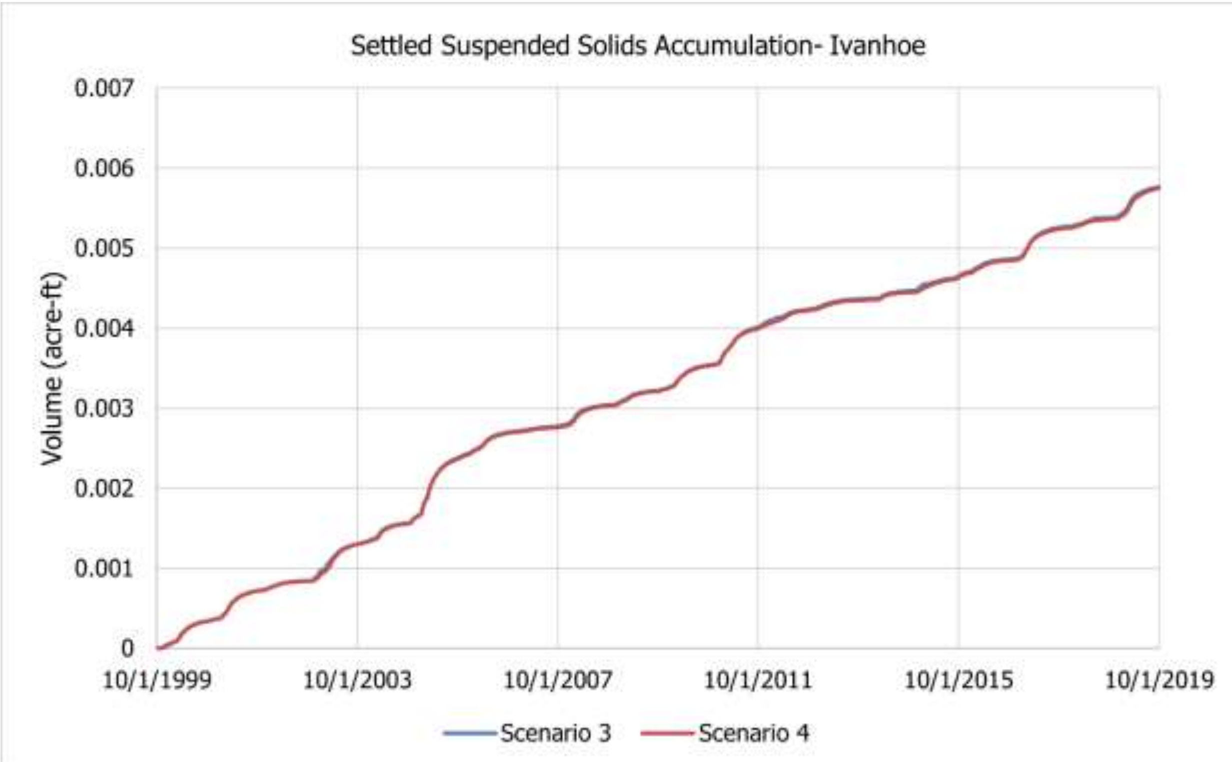

Figure 6-17 Accumulation of Sediment in Ivanhoe Reservoir with No Pretreatment

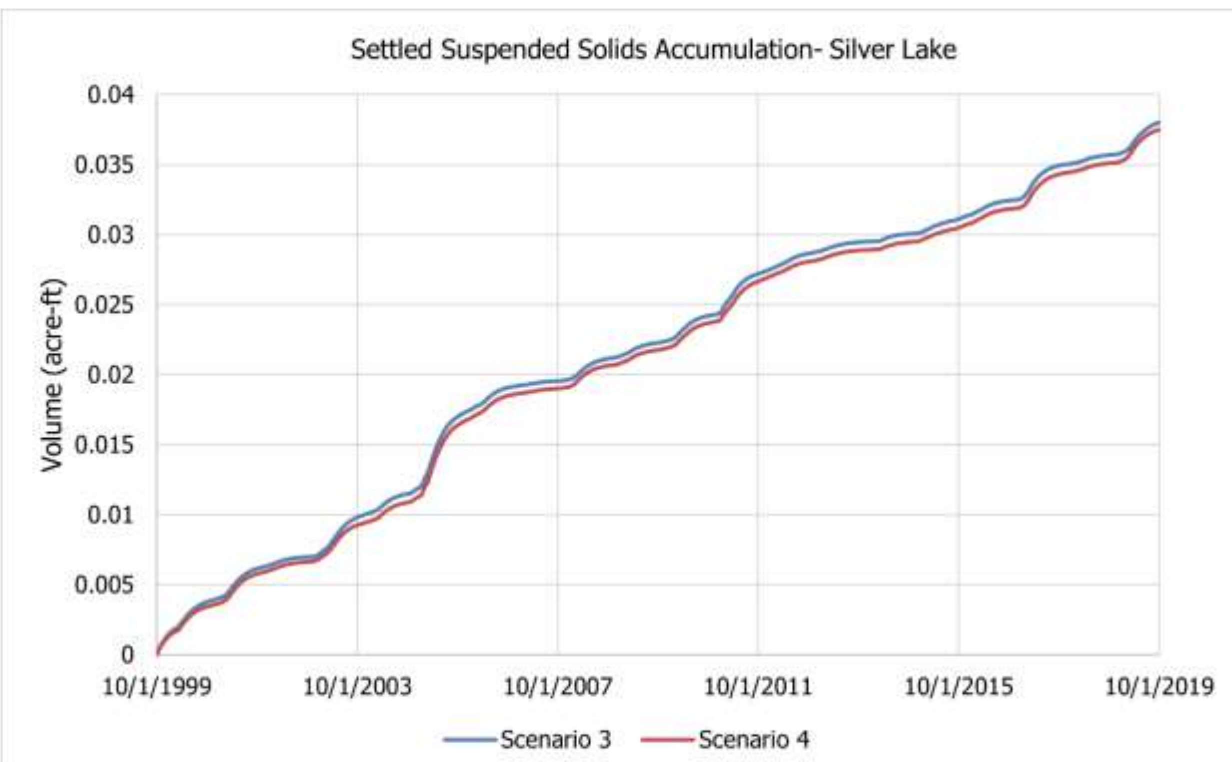

Figure 6-18 Accumulation of Sediment in Silver Lake Reservoir with No Pretreatment

6.4 Wetland Size

The wetlands size is proportional to the removal of bacteria, metals, and nutrients that will occur from wetland treatment. The wetland size was decreased by half and doubled to observe the effect on total coliform, copper, lead, nitrogen, and phosphorus concentrations. **Figure 6-19** shows the total coliform concentration for decreasing the wetland size by half in Ivanhoe Reservoir, and **Figure 6-20** shows the total coliform concentration for Silver Lake Reservoir. **Figure 6-21** shows the total copper concentrations for decreasing the wetland size for Ivanhoe Reservoir, and **Figure 6-22** shows the total copper concentrations for Silver Lake Reservoir. **Figure 6-23** shows the total lead concentrations for decreasing the wetland size for Ivanhoe Reservoir, and **Figure 6-24** shows the total lead concentrations for Silver Lake Reservoir. **Figure 6-25** shows the total nitrogen concentrations for decreasing the wetland size for Ivanhoe Reservoir, and **Figure 6-26** shows the total nitrogen concentrations for Silver Lake Reservoir. **Figure 6-27** shows the total phosphorus concentrations for Ivanhoe Reservoir for decreasing the wetlands, and **Figure 6-28** shows the total phosphorus concentrations for Silver Lake Reservoir. Exceedances were observed for total coliform for Scenario 4 with half the wetland size.

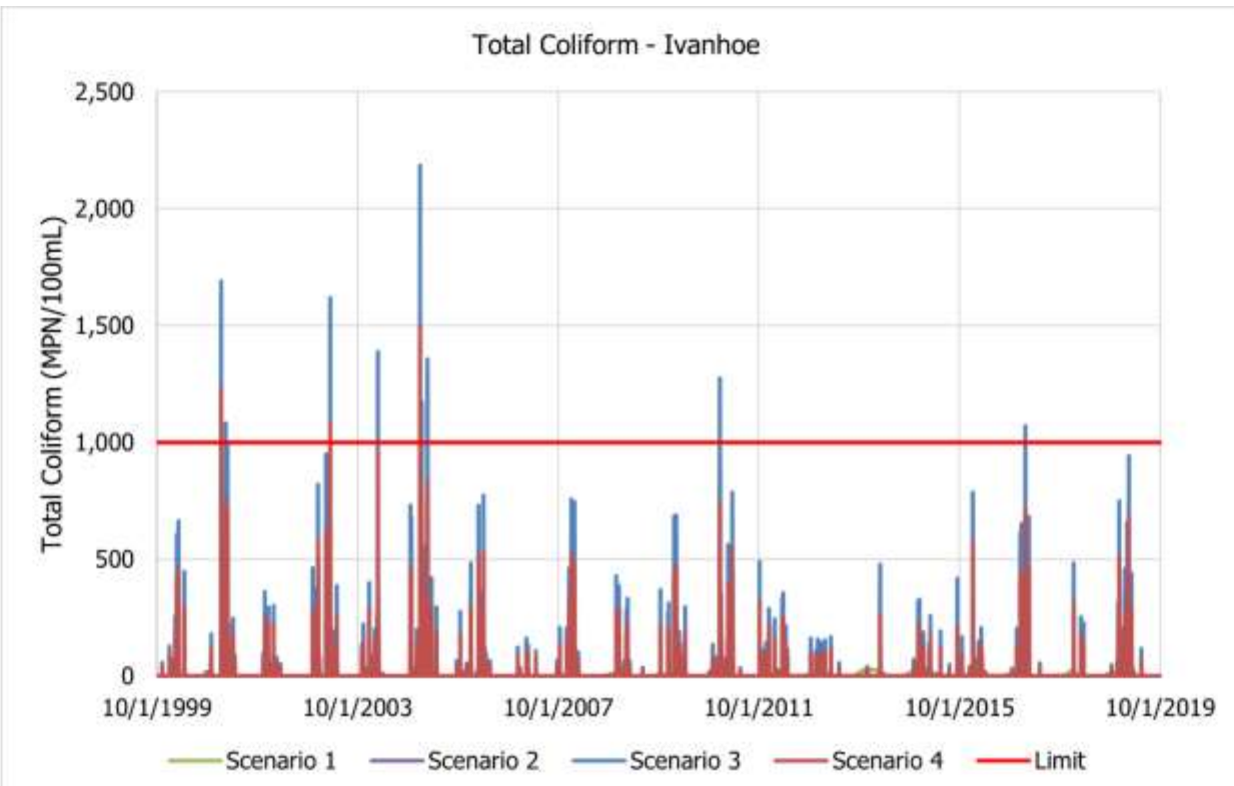

Figure 6-19 Total Coliform in Ivanhoe Reservoir from Half Wetland Size

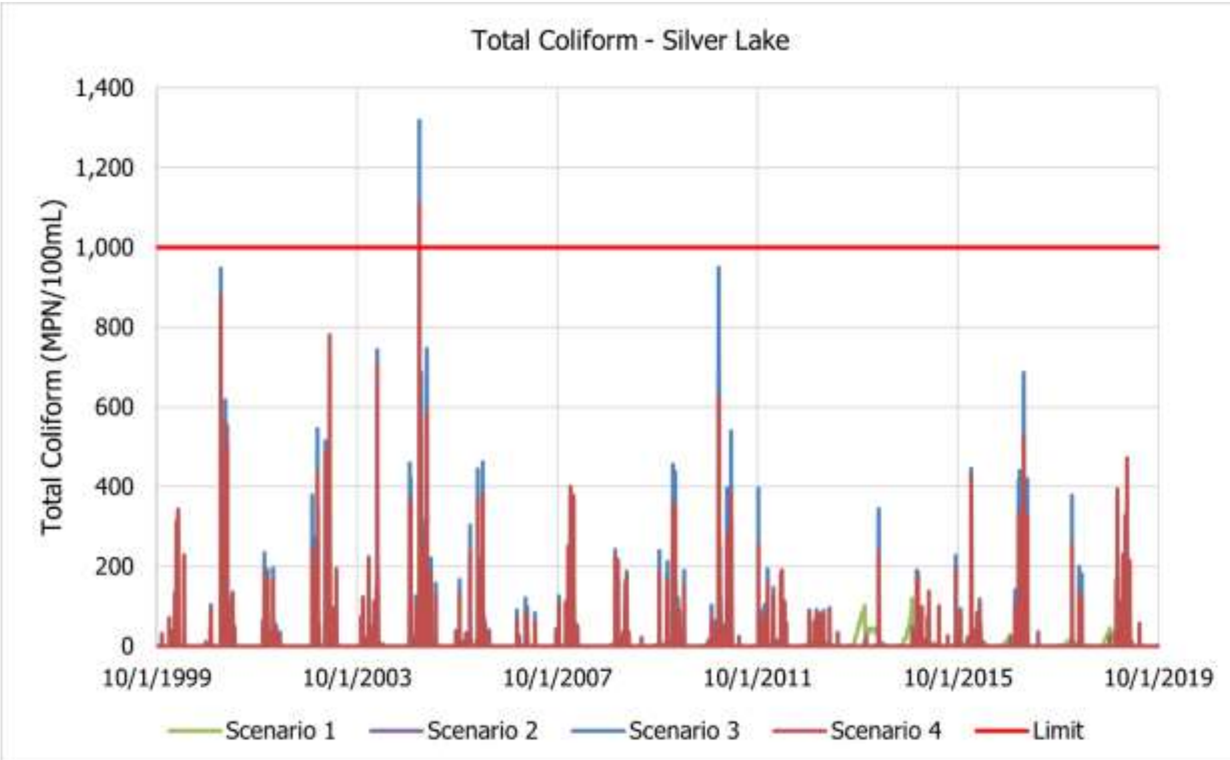

Figure 6-20 Total Coliform in Silver Lake Reservoir from Half Wetland Size

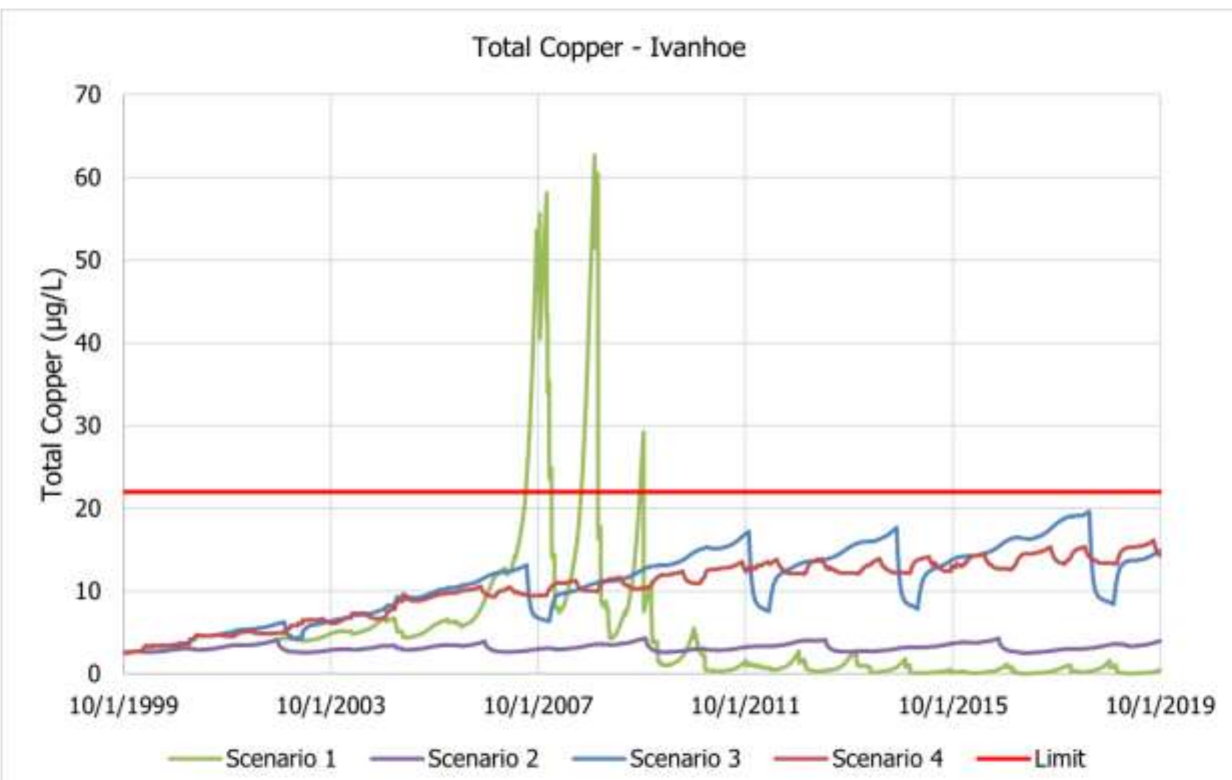

Figure 6-21 Total Copper in Ivanhoe Reservoir from Half Wetland Size

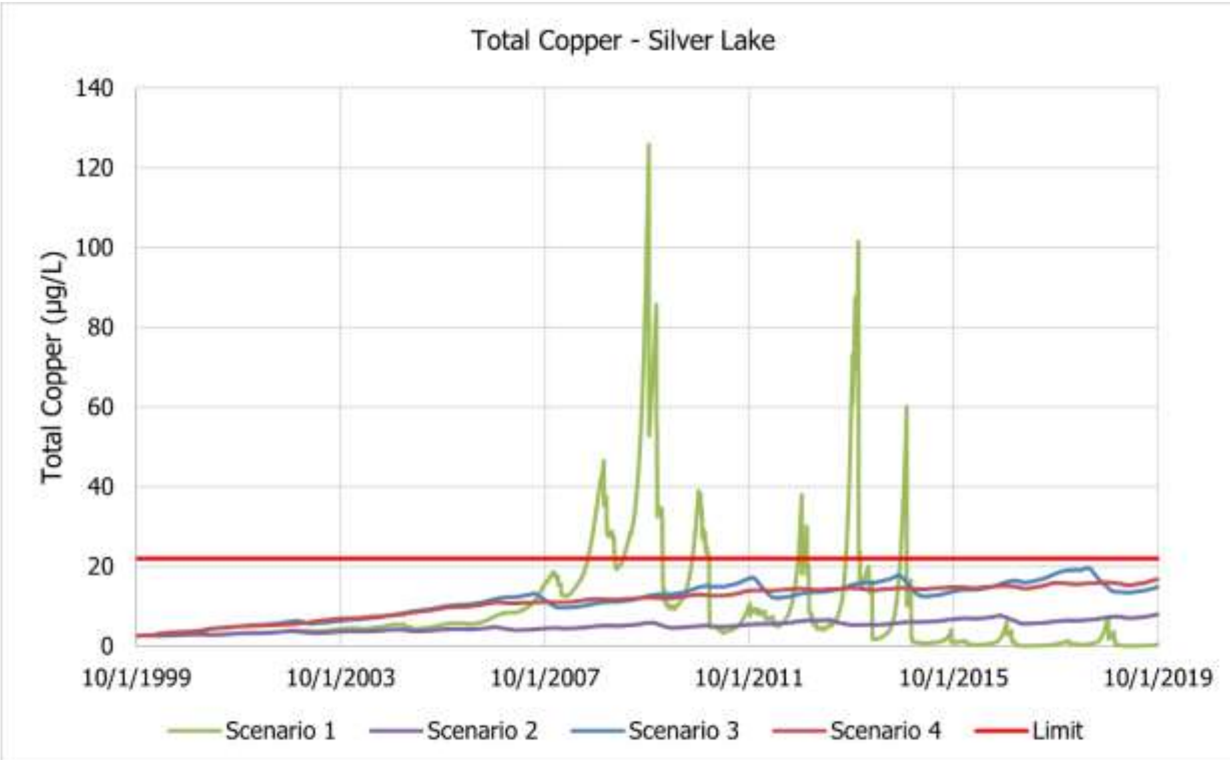

Figure 6-22 Total Copper in Silver Lake Reservoir from Half Wetland Size

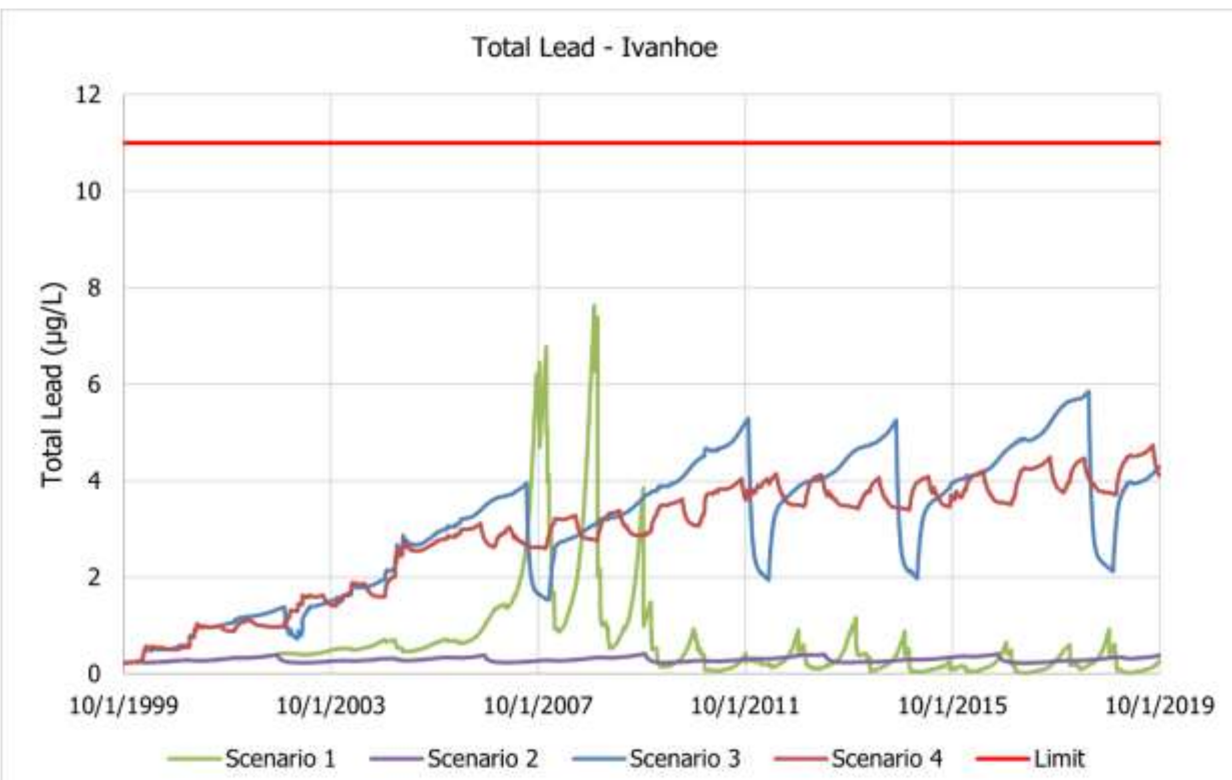

Figure 6-23 Total Lead in Ivanhoe Reservoir from Half Wetland Size

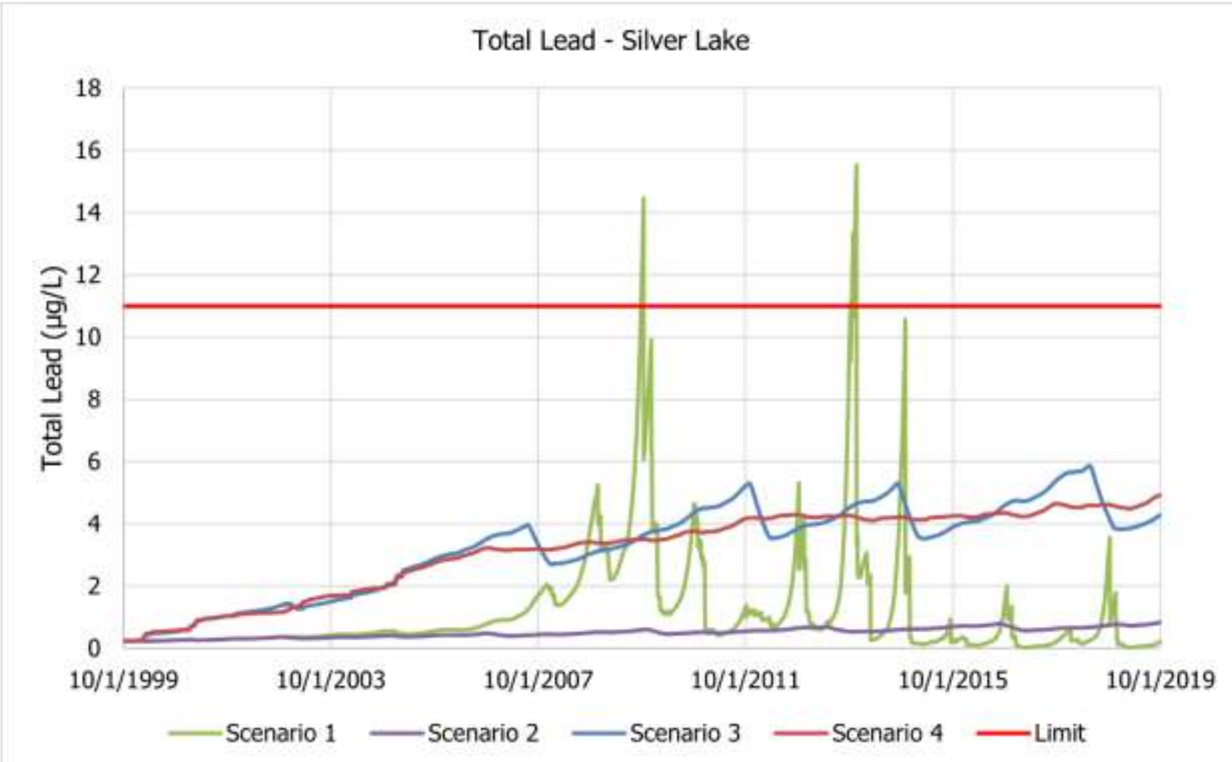

Figure 6-24 Total Lead in Silver Lake Reservoir from Half Wetland Size

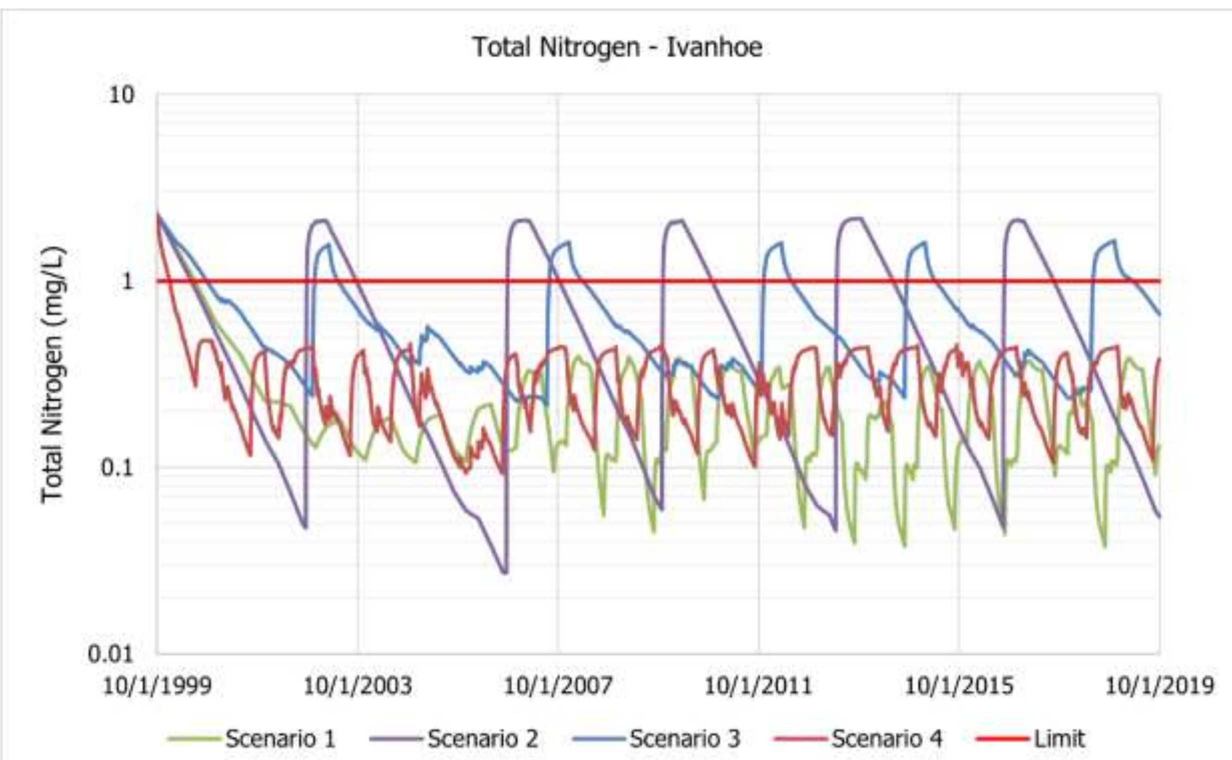

Figure 6-25 Total Nitrogen in Ivanhoe Reservoir from Half Wetland Size

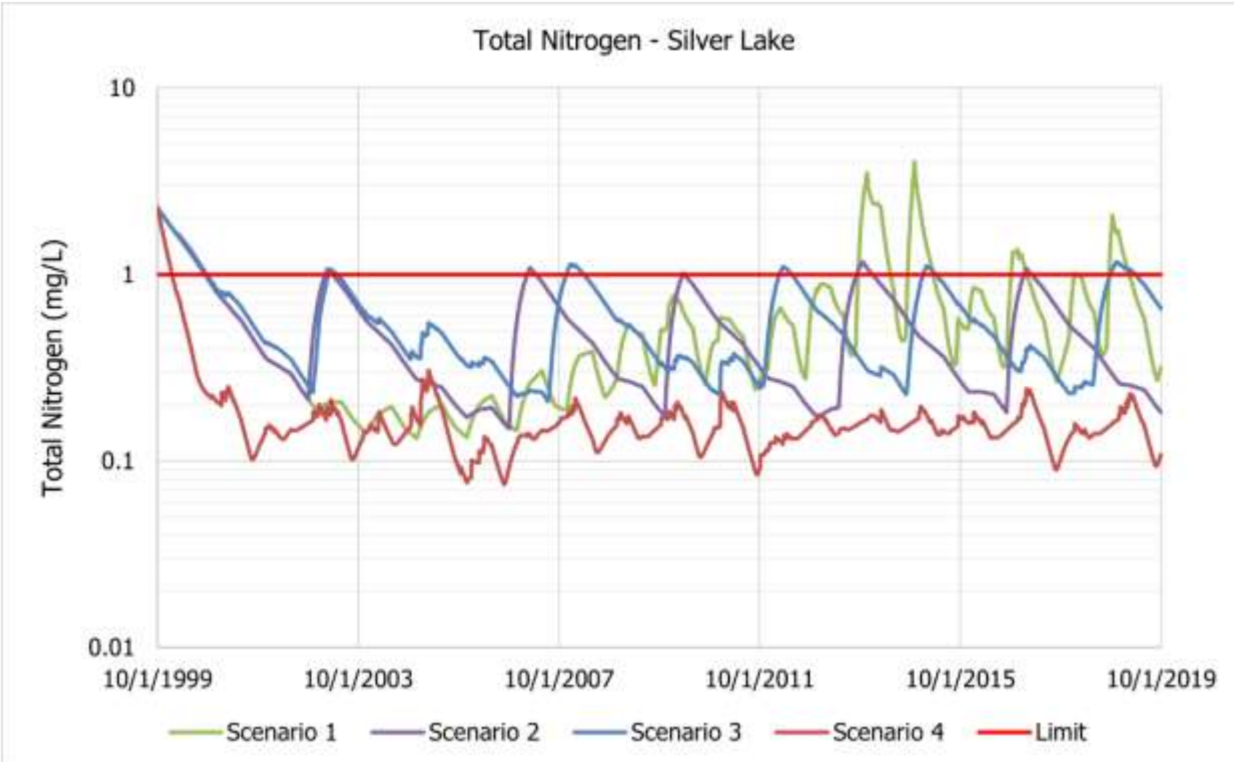

Figure 6-26 Total Nitrogen in Silver Lake Reservoir from Half Wetland Size

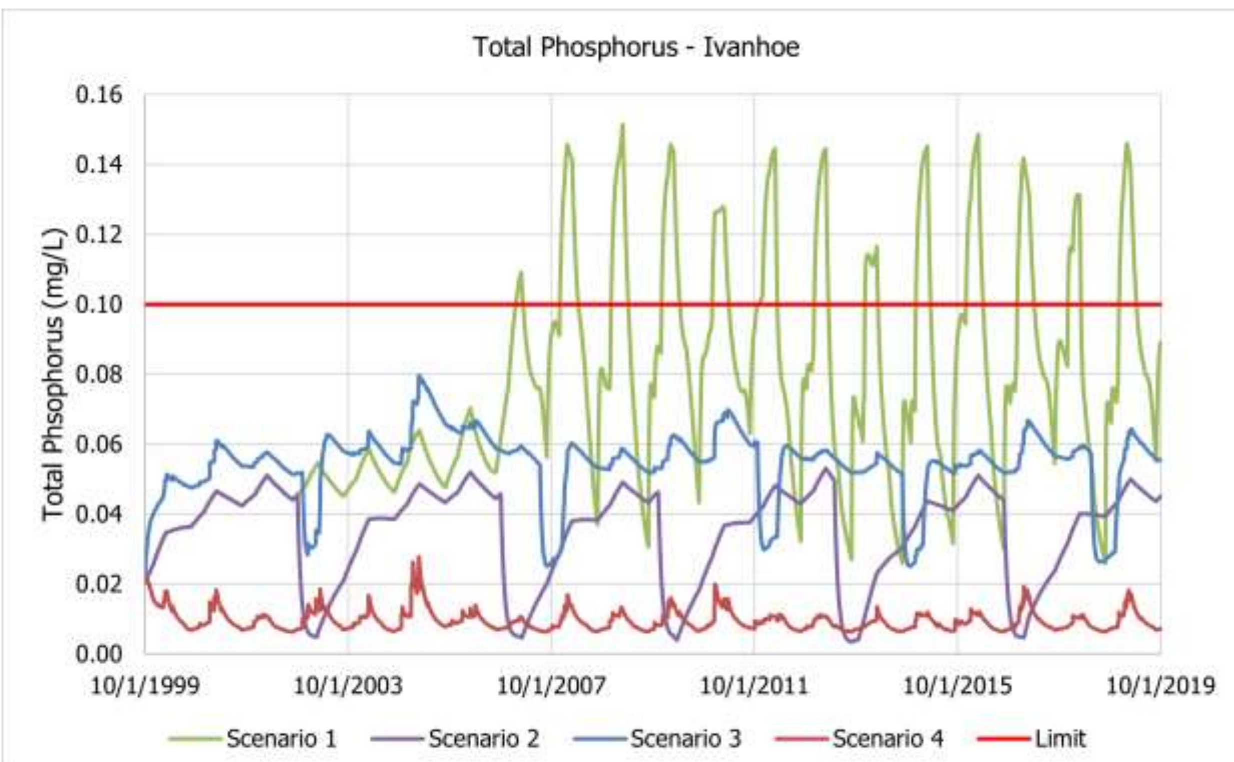

Figure 6-27 Total Phosphorus in Ivanhoe Reservoir from Half Wetland Size

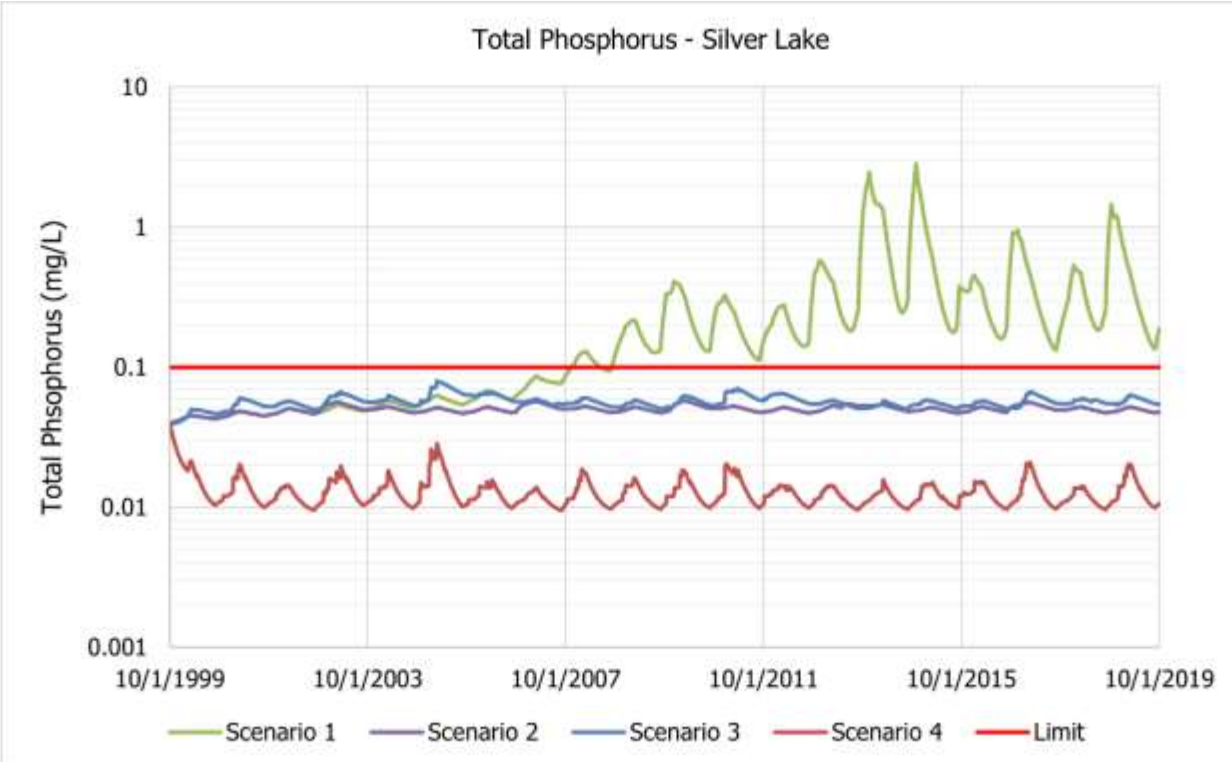

Figure 6-28 Total Phosphorus in Silver Lake Reservoir from Half Wetland Size

Figure 6-29 shows the total coliform concentration for doubling the wetland size in Ivanhoe Reservoir, and **Figure 6-30** shows the total coliform concentration for Silver Lake Reservoir. **Figure 6-31** shows the total copper concentrations for doubling the wetland size for Ivanhoe Reservoir, and **Figure 6-32** shows the total copper concentrations for Silver Lake Reservoir. **Figure 6-33** shows the total lead concentrations for doubling the wetland size for Ivanhoe Reservoir, and **Figure 6-34** shows the total lead concentrations for Silver Lake Reservoir. **Figure 6-35** shows the total nitrogen concentrations for doubling the wetland size for Ivanhoe Reservoir, and **Figure 6-36** shows the total nitrogen concentrations for Silver Lake Reservoir. **Figure 6-37** shows the total phosphorus concentrations for Ivanhoe Reservoir for doubling the wetlands, and **Figure 6-38** shows the total phosphorus concentrations for Silver Lake Reservoir.

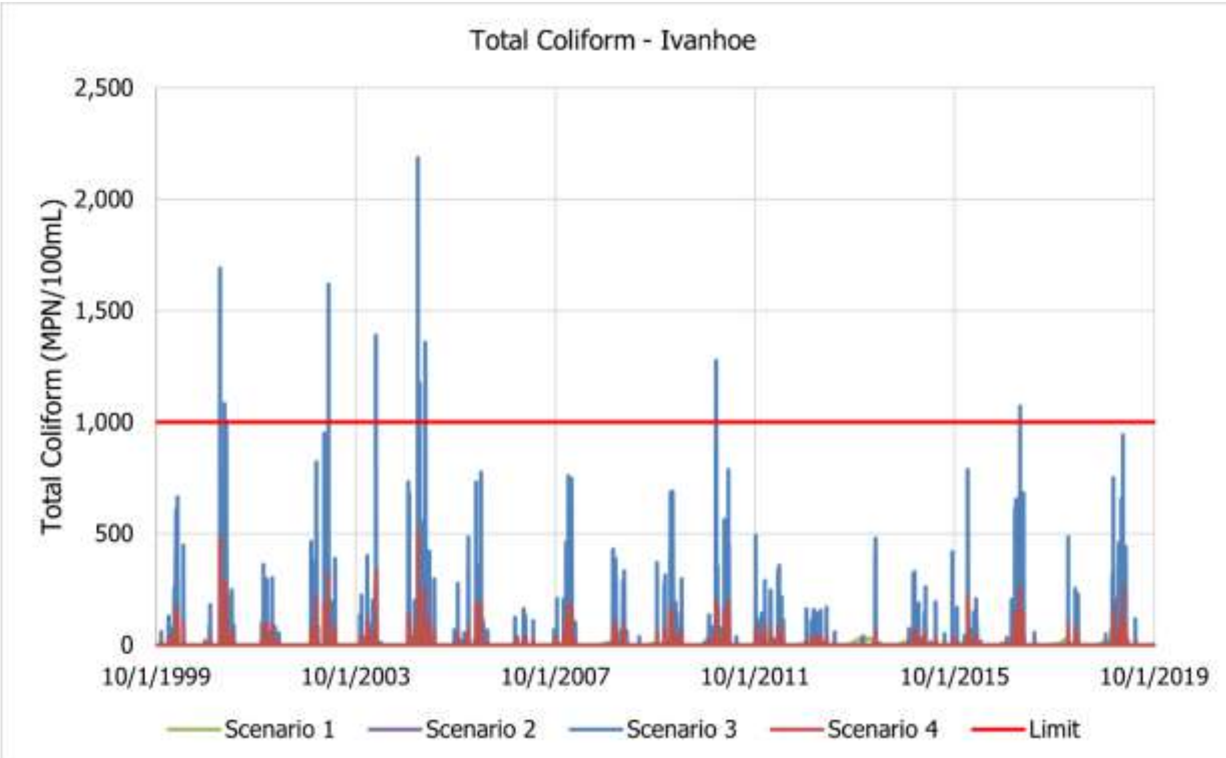

Figure 6-29 Total Coliform in Ivanhoe Reservoir from Double Wetland Size

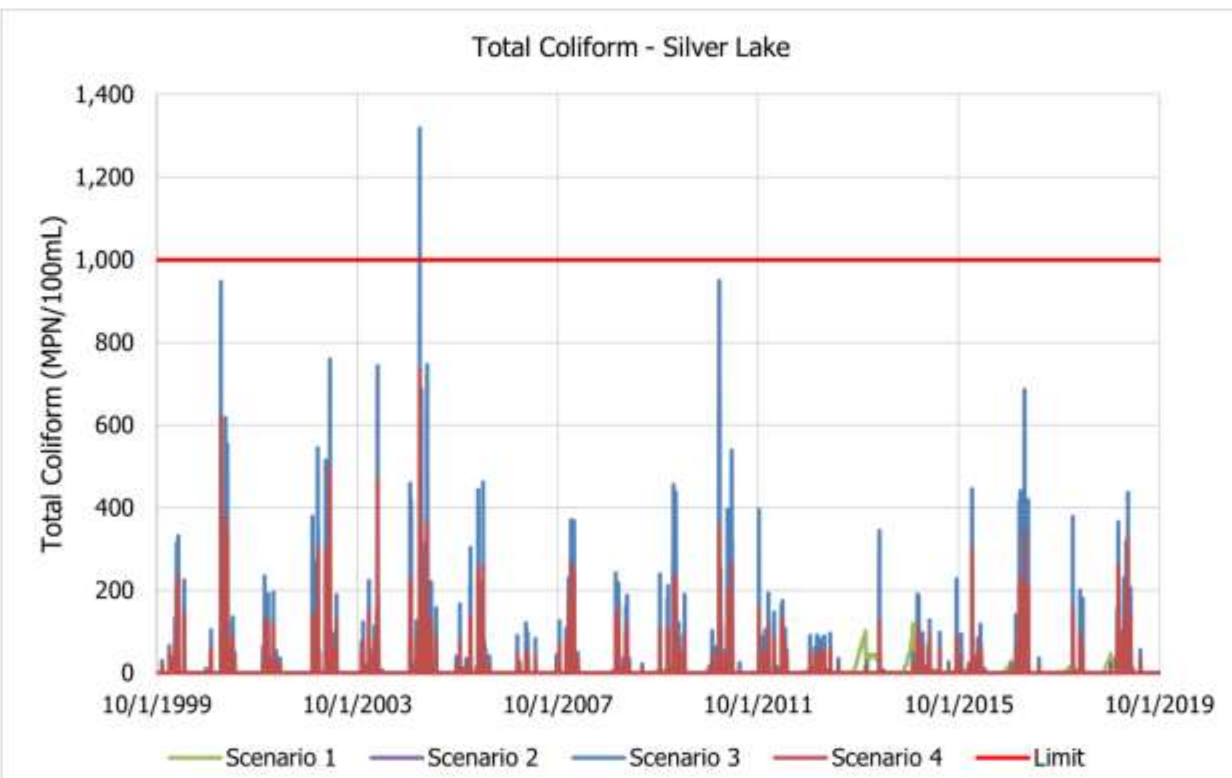

Figure 6-30 Total Coliform in Silver Lake Reservoir from Double Wetland Size

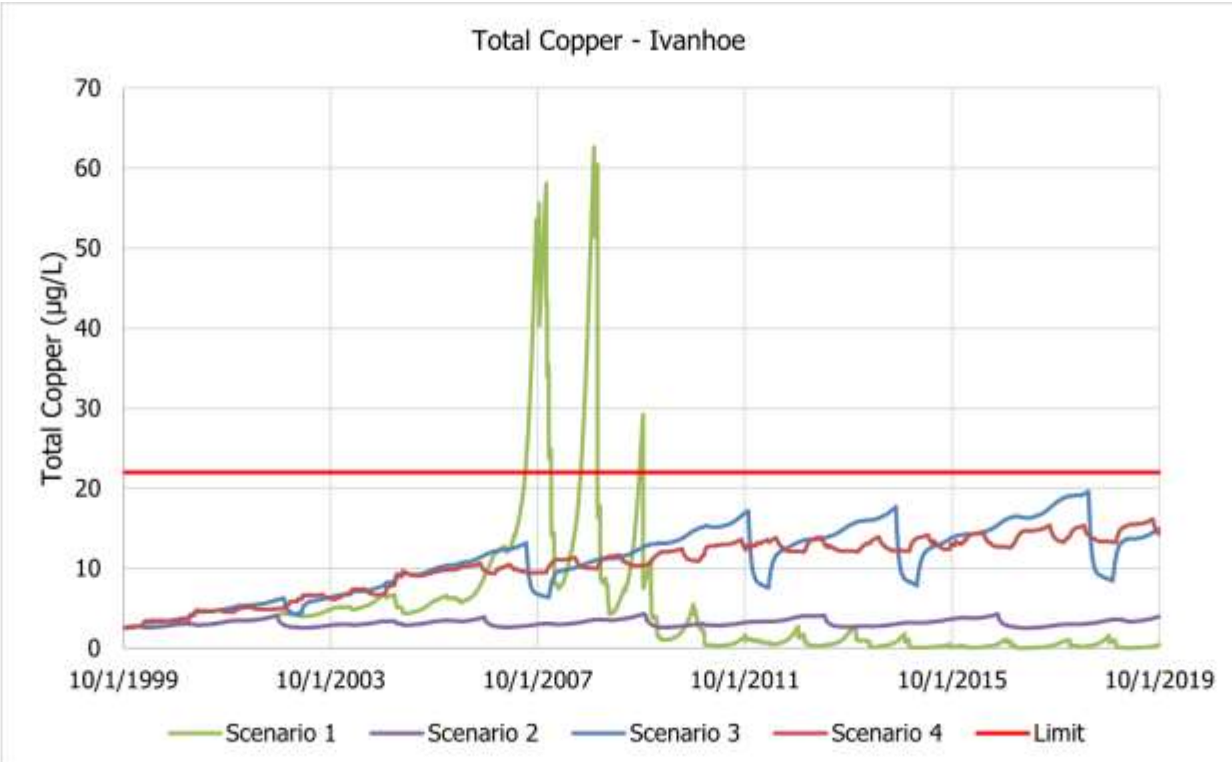

Figure 6-31 Total Copper in Ivanhoe Reservoir from Double Wetland Size

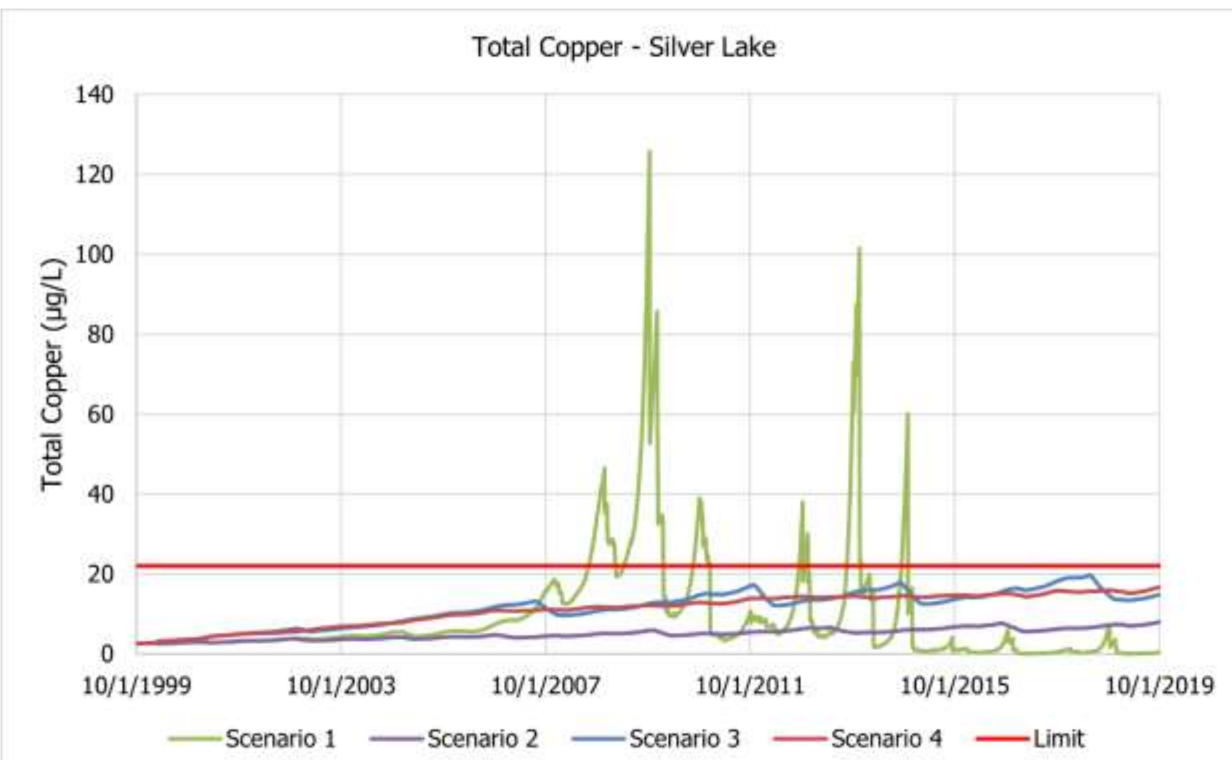

Figure 6-32 Total Copper in Silver Lake Reservoir from Double Wetland Size

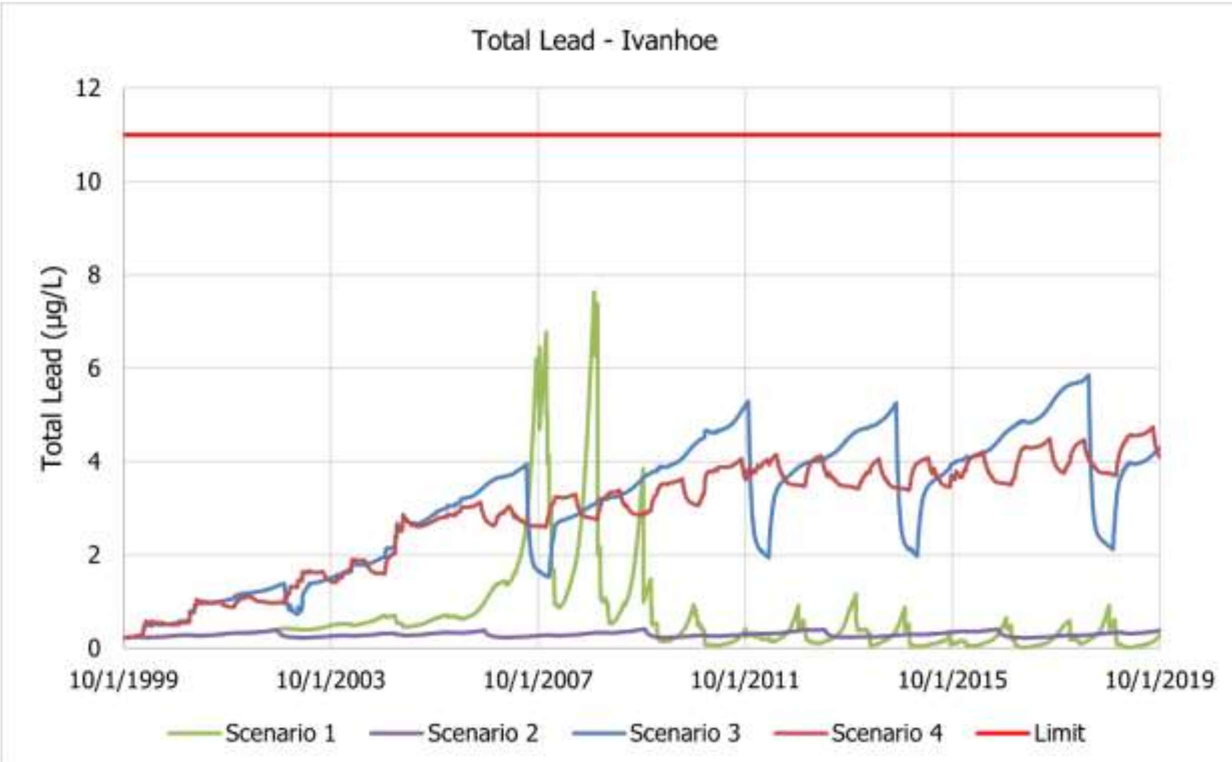

Figure 6-33 Total Lead in Ivanhoe Reservoir from Double Wetland Size

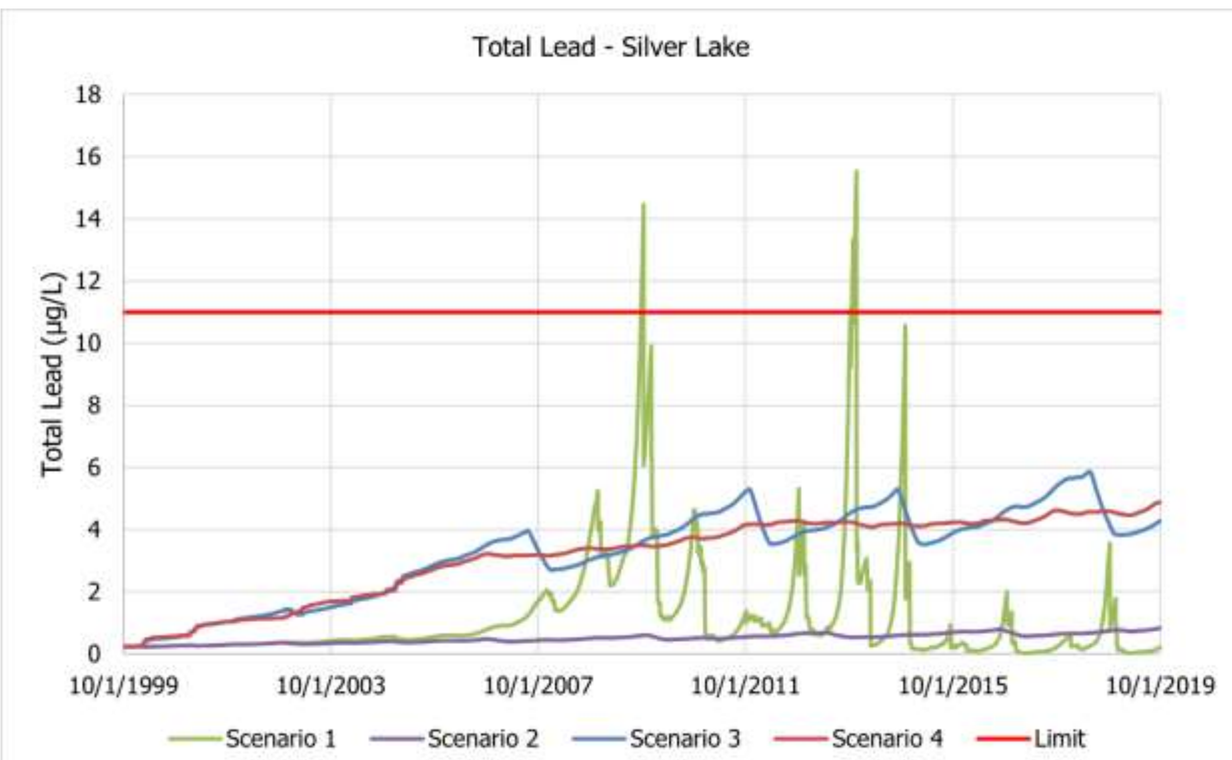

Figure 6-34 Total Lead in Silver Lake Reservoir from Double Wetland Size

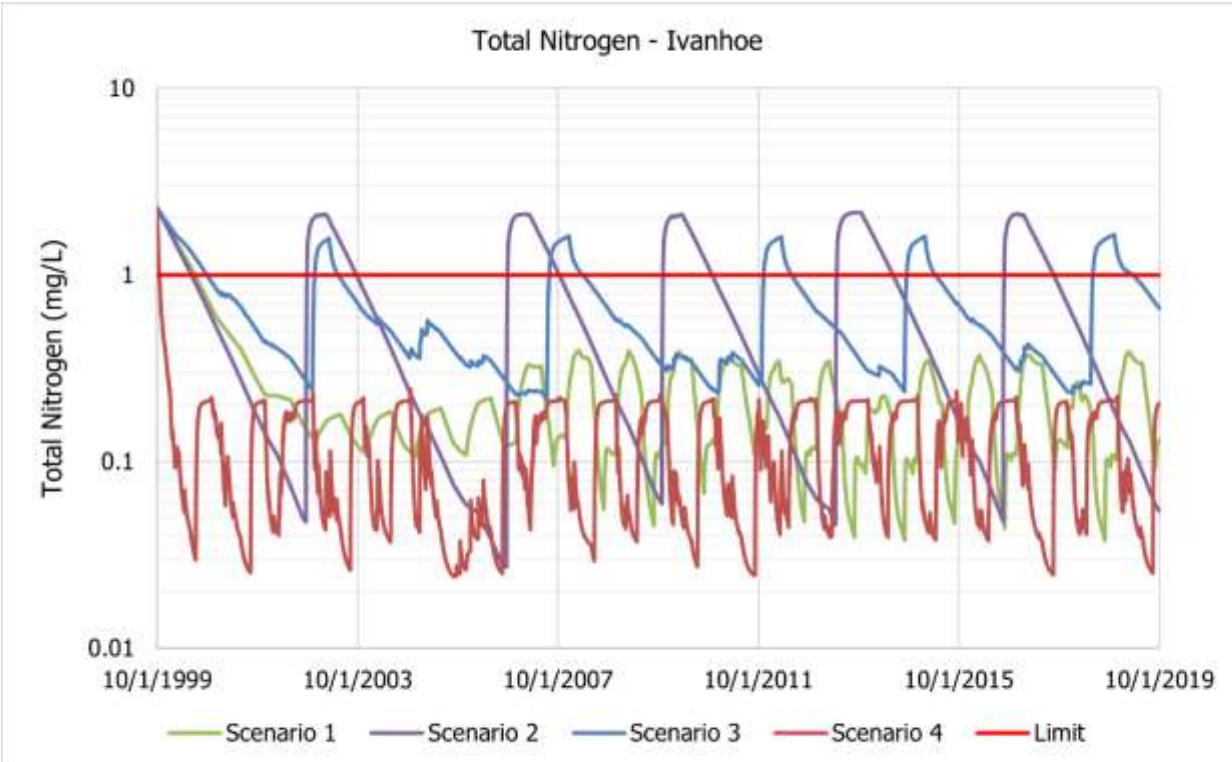

Figure 6-35 Total Nitrogen in Ivanhoe Reservoir from Double Wetland Size

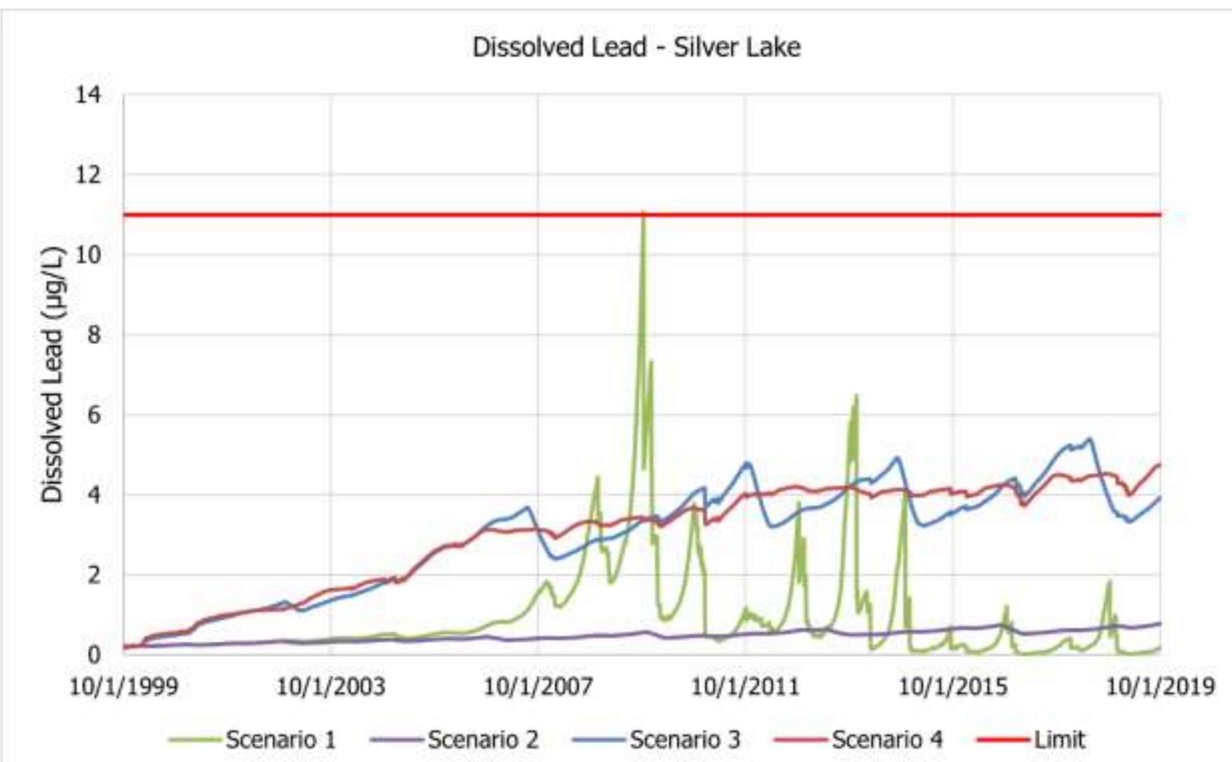

Figure 6-36 Total Nitrogen in Silver Lake Reservoir from Double Wetland Size

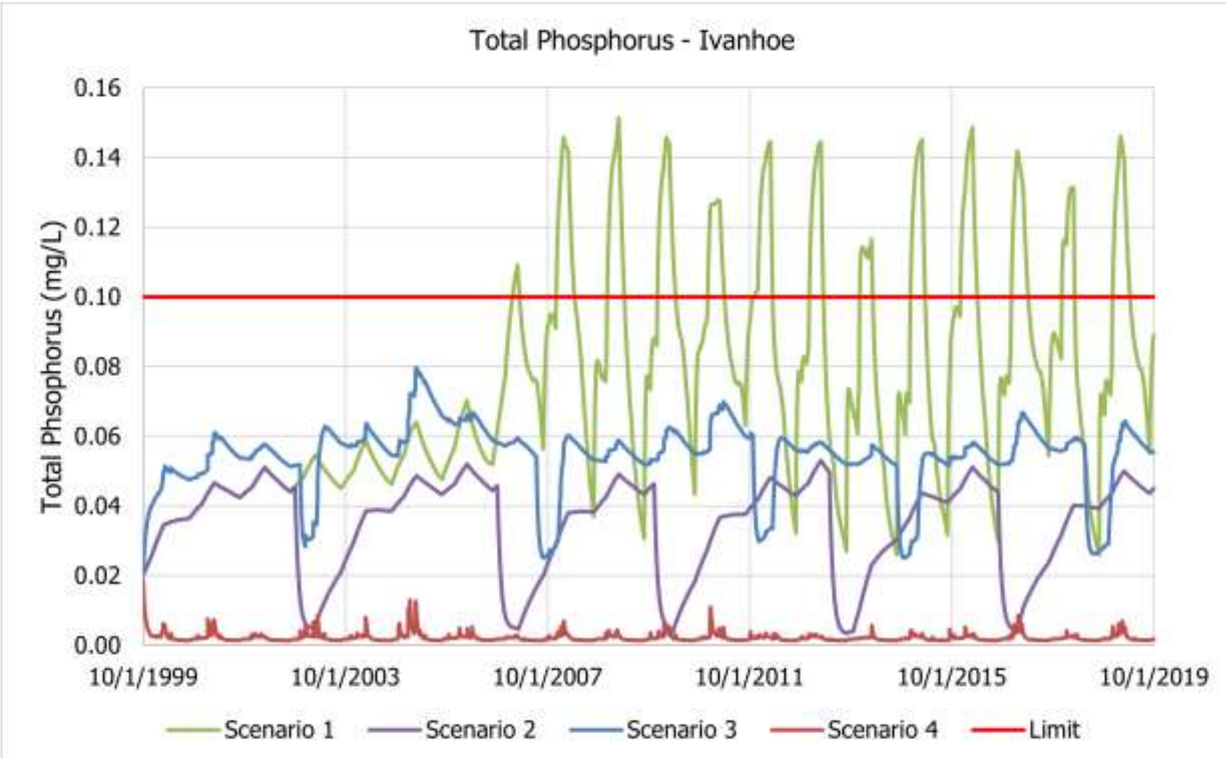

Figure 6-37 Total Phosphorus in Ivanhoe Reservoir from Double Wetland Size

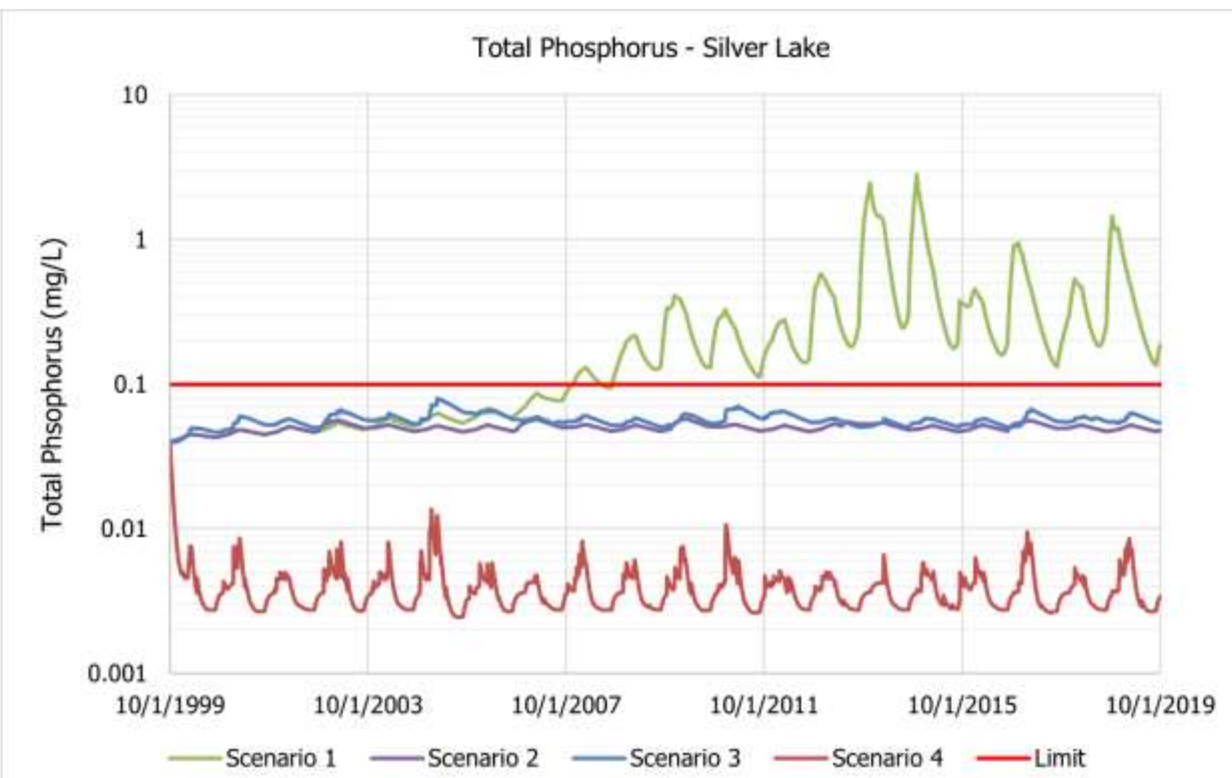

Figure 6-38 Total Phosphorus in Silver Lake Reservoir from Double Wetland Size

7. Operations and Maintenance

Following the completion of the SLRCMP, a Wetlands Maintenance Plan should be developed. The Wetlands Maintenance Plan should not only describe the maintenance requirements but also specify future funding to guarantee a sustaining source of financial support for wetlands maintenance. This section summarizes the operations and maintenance requirements that should be included in the Wetlands Maintenance Plan to ensure ongoing water quality benefits to the SLRC.

Even without wetlands, the SLRC will function as a wet pond, which is a class of waterbody that contains a permanent pool of water and retains stormwater. Pollutants will be removed through sedimentation and biological activity in each reservoir. Maintenance will be required to address issues related to standing water and vector breeding, trash accumulation, and the potential for algae growth. The ultimate condition of the SLRC as described in the SLRCMP will incorporate shoreline and floating wetlands that will require additional maintenance activities.

7.1 Wetlands Initiation

Adequate resources need to be committed to maintaining aquatic vegetation and control vector production. Mosquito and midge breeding may be a nuisance, and a proactive and routine preventative maintenance plan is needed to minimize vector habitat. Strategies identified in the SLRCMP will include the addition of mosquitofish that consume the larvae of mosquitos and midge flies. Preventing nutrients from entering the water column also will help reduce vector habitat.

Native plant species should be incorporated in the shoreline and floating wetlands. The floating treatment wetlands should not be planted with tall plants that could act as a sail in high wind conditions, which could cause drift or tipping. Plants with excessive biomass loss during senescence should also be avoided. When the floating treatment wetlands are initially planted, netting can be used to hinder bird access to the juvenile plants. After plants are established, the netting can be removed to provide habitat for birds.

The floating treatment wetlands should be anchored to keep them in the desired locations. Anchoring can be achieved using cinder blocks, boat anchors, or helical anchors screwed into the reservoir bottom. Tethers should be stainless steel cables and not galvanized metal cables that can leach heavy metals. The cables should be long enough to allow for changes in water elevation. The cables should be connected to the floating treatment wetland by swivel eye bolt snaps so that the floating treatment wetland can be easily removed from the anchor if needed for maintenance.

7.2 Inspections

Routine inspections and maintenance will be required under all four scenarios, but additional inspection and maintenance activities will be needed for the wetlands in Scenario 4. **Table 7-1** describes the inspection activities and frequency that will be required for the SLRC.

Table 7-1 Inspection Summary

Inspection Activities	Expected Frequency
➢ Look for invasive vegetation and note the need for removal. ➢ Check the condition and health of the wetland vegetation and identify areas that require special attention. Check the vigor and density of any grass turf on side slopes. Look for tree growth on dam or embankment. ➢ During initial plant establishment on the floating treatment wetlands, check the health and development of the plants and note any remedial actions needed. ➢ Inspect for trash and debris accumulation and clogging of inlet/outlet structures. ➢ Check for excessive erosion, cracking or settling of the dam, bank stability, differential settlement, slope failure, leakage, and subsidence. ➢ Inspect for damage to the emergency spillway, mechanical component conditions, and graffiti. ➢ Check for sediment buildup in basin or outlet. ➢ Inspect condition of inlet and outlet structures, pipes, pre-treatment units, and downstream channel conditions. ➢ Identify areas that may require immediate attention for corrective action. ➢ Check that floating treatments are properly anchored.	Semi-annual, after significant storms, or more frequently as needed
➢ Check for algal growth, signs of pollution such as oil sheens, discolored water, or unpleasant odors, and signs of flooding.	Annual Inspection

7.3 Maintenance

Table 7-2 describes the maintenance activities and frequency that will be required at the SLRC.

Table 7-2 Maintenance Summary

Maintenance Activities	Expected Frequency
➢ Work with Greater Los Angeles County Vector Control District and other regulatory agencies to implement a vector control program. ➢ Maintain emergent and shoreline vegetation to provide access for vector inspectors and facilitate vector control if needed. ➢ During initial plant establishment of the floating treatment wetlands, perform any necessary remedial actions, such as replanting bare spots.	Once or as needed
➢ Perform vector control, if necessary. ➢ Remove and dispose of sediment from outlet structure. ➢ Remove accumulated trash and debris from inlet/outlet structures, side slopes, and collection system. ➢ Repair undercut areas and erosion to banks.	Semi-annual, after significant storms, or more frequent as needed
➢ Maintain vegetation in and around basin to prevent any erosion or aesthetic problems. Minimize use of fertilizers, pesticides, and herbicides. ➢ Re-vegetate any slope areas that are bare. ➢ Manage and harvest wetland plants. Remove dead vegetation if it exceeds 10% of area coverage. Replace vegetation to maintain cover density and control erosion where soils are exposed. Remove and replace invasive vegetation with native vegetation. Remove tree growth on dam or embankment. ➢ Trim shoots and replant bare areas of floating treatment wetlands, if needed. ➢ Structural repairs and replacements, as needed. ➢ Remove sediment accumulation if needed.	Annual Maintenance

7.4 Contingent Strategies

In addition to the routine inspections and maintenance, a contingency plan should be developed to respond if water quality conditions deteriorate in the SLRC.

Water quality concerns, including cyanobacteria or algal blooms, are not anticipated due to the implementation of the recirculation and aeration projects and the limited concentrations of nutrients entering the SLRC. However, should chlorophyll-a concentrations increase, indicating the potential for an algal bloom, steps may need to be taken to mitigate nuisance or harmful conditions. Routine strategies implemented to minimize the effects of eutrophication include diverting excess nutrients, altering the nutrient ratios, physical mixing, shading with opaque liners or water-based stains, and applying algaecides and herbicides (Chislock et al., 2014). Some of these strategies may not be practical or effective at SLRC, but reducing the nutrients entering the system and implementing physical mixing with the recirculation and aeration projects should reduce the potential for algal blooms.

Significant sediment accumulation is not expected in the SLRC, but removing sediment that acts as a source for nutrients may be needed. Adding additional wetland plants to the SLRC and directing incoming stormwater through the wetland treatment areas may be needed to reduce the nutrient loading. Increasing the rate of recirculation and decreasing vertical stratification may reduce the potential for an algal bloom if chlorophyll-a concentrations are shown to be increasing during routine sampling. Applying algaecide may not be effective in the long-term control of algae in the SLRC and may also lead to the release of toxins from algal blooms. Instead, the nutrients responsible for eutrophication and algal blooms should be controlled. Nutrient loading can be controlled by treating the incoming stormwater, dredging sediment (if sediment is found to be a source of nutrients to the water column), and installing additional wetlands. In the short-term, increasing recirculation and aeration may be the best option for reducing the extent of an algal bloom in the SLRC.

8. Risk Assessment

Potential risks to the water quantity and quality in SLRC include fires, water security, and climate change. The SLRC Water Quality model does not include airborne fire debris or the potential water quality impacts as debris flows from fires within the watershed are not anticipated.

8.1 Fires

Deposition of fire debris on the SLRC and debris flows could cause temporary exceedances of water quality objectives. Deposition of cadmium, chromium, copper, iron, lead, manganese, nickel, silver, and zinc has been recorded in California due to fires (Young and Jan, 1977). The use and drawdown of water in the SLRC for firefighting was not included in the model, but the volume extracted is expected to be insignificant compared to the total reservoir volume under most conditions. Over-extraction would require refilling with Pollock Well water.

8.2 Water Security

Scenarios 2, 3, and 4 rely upon refill with groundwater from Pollock Well #3, which is located at the DWP Ripple Street Yard northwest of the SLRC. The well was rehabilitated with a new pump, motor, and water treatment system in 2017. DWP constructed a pipeline to connect the well to Ivanhoe Tunnel, which allows the SLRC to be refilled with local groundwater sources that do not impact the drinking water supply (DWP, 2017). Due to groundwater contamination in the Pollock Well field, extracted water is treated with GAC to remove chlorinated volatile organic compounds (VOCs) (ULARA Watermaster, 2016). In 2017, the Regional Board granted a Waste Discharge Permit that allowed groundwater from Pollock Well #3 to be discharged to the SLRC as long as it was first treated by a GAC system prior to discharge into the SLRC (Regional Board, 2017). The model scenarios assume that this supply of water will be available and sufficient to meet the refilling requirements.

8.3 Climate Change

The SLRC may experience increased daily temperatures in the decades to come due to climate change, but significant changes to annual precipitation totals are not currently expected (Berg, 2015). The SLRC Water Quality Model uses temperature and precipitation data from the past 20 years and does not adjust for any potential future conditions due to the uncertainty in the magnitude of the expected temperature change. Higher water temperatures can increase biological and algae growth, but higher temperatures will also increase the reaction and decay rates in the model. If annual precipitation volumes decrease, additional water from Pollock Well or other sources will be needed to supplement the decrease in stormwater runoff.

9. Conclusion

The SLRC Water Quality Model was built to forecast the future condition of water quality within the SLRC for four scenarios. These four scenarios included an isolation baseline scenario that does not include Pollock Well water additions, an existing baseline scenario that includes Pollock Well water additions, the DWP Project baseline scenario, and the Master Plan proposed scenario. Inflows, outflows, and the associated nutrient and contaminant concentrations were calculated for each daily time step. Additionally, transformations and removal of nutrients and contaminants within the SLRC were simulated based on rates from scientific and engineering literature. The model predicted concentrations of suspended solids, dissolved solids, total coliform bacteria, copper, lead, nitrogen, phosphorus, chlorophyll-a, algae, and dissolved oxygen.

Sediment accumulation during the modeled 20 years was approximately 0.0023 acre-feet of in Ivanhoe Reservoir and 0.018 acre-feet in Silver Lake Reservoir for Scenarios 3 and 4. These are approximately 0.001% and 0.0007% of the volume of Ivanhoe and Silver Lake Reservoirs, respectively. Sediment accumulation will not affect the capacity of the reservoirs.

The TDS concentration in Scenario 1 spikes to 7,500 mg/L in Ivanhoe and 12,000 mg/L in Silver Lake due to evaporation of water in the reservoirs, and then the concentrations decrease due to losses to exfiltration. The TDS concentration in Scenario 2 fluctuates with an average of approximately 500 mg/L in Ivanhoe and 740 mg/L in Silver Lake Reservoir. The TDS concentration in Scenario 3 fluctuates and increases with time, with a value of approximately 900 mg/L at the of the modeled timespan in both Ivanhoe and Silver Lake Reservoirs. The TDS concentration in Scenario 4 gradually increased with time to a final value of approximately 695 mg/L in Ivanhoe and 750 mg/L in Silver Lake Reservoir.

The total coliform loading from birds in Scenarios 1 and 2 did not exceed the limit of 1,000 MPN/100mL. The total coliform concentration due to both birds and Stormwater Capture Project flows in Scenario 3 occasionally exceeded the limit, but concentrations in Scenario 4 only exceeded the limit once. The attenuation is attributable to the wetland treatment system.

The two metals modeled were copper and lead, which have limits of 22 and 11 µg/L, respectively. The only exceedances observed for both metals were in Scenario 1 due to the decrease in reservoir volume, which causes an increase in concentration. Concentrations in Scenario 2 showed slight increases due to Pollock Well water additions, but the concentrations were well below those of Scenarios 3 and 4. Concentrations in Scenarios 3 and 4 gradually increased with time, with less fluctuations observed in Scenario 4 due to the wetland treatment systems. Neither metal concentration exceeded the limits in Scenarios 3 and 4.

Nutrients modeled included nitrogen and phosphorus. Chlorophyll-a and algae concentrations were also modeled and depended on phosphorus concentrations. Exceedances for nitrogen were observed in Silver Lake for Scenario 1 due to the decrease in reservoir volume. Exceedances were observed for Scenarios 2 and 3 for nitrogen due to Pollock Well water additions. Exceedances for nitrogen were not observed in Scenario 4 due to the wetland treatment system. The only scenario with exceedances for phosphorus and chlorophyll-a was Scenario 1 due to bird loadings into the reservoirs with decreased water volume.

The dissolved oxygen concentrations in all four scenarios remained above the lower limit of 5 mg/L. Seasonal fluctuations due to water temperature changes were observed. The dissolved oxygen concentration in Silver Lake Reservoir in Scenario 1 decreased below the other scenarios due to the increased dissolved solids concentration but did not dip below the 5 mg/L limit.

Overall, the SLRC Water Quality Model showed that Scenario 1, the isolation scenario, exceeded the limits set for copper, lead, nitrogen, phosphorus, and chlorophyll-a. Scenario 2, the existing baseline scenario, only exceeded the limits for nitrogen due to additions of Pollock Well water. Scenario 3, the DWP Project baseline scenario, exceeded the limits set for nitrogen and total coliform concentrations. Scenario 4, the Master Plan proposed scenario, exceeded the limit for nitrogen at the start of the model and once for total coliform in Ivanhoe Reservoir. Scenario 4 represents the most sustainable concept for the project.

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