REPORT

Back River Project

HYDRODYNAMIC AND WATER QUALITY MODELLING OF GOOSE LAKE

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1.0 INTRODUCTION

Sabina Gold & Silver Corp. (Sabina) owns the Back River Project (the Project), which is located in the West Kitikmeot Region of Nunavut. The Project design proposes an open pit and underground gold mine with an estimated 25-year life from Construction to the end of Closure (i.e., 3 years of Construction, 15 years of Operations, and 7 years of Closure).

The hydrodynamic and water quality model described in this report was used to assess the potential effects of the Project activities on the water balance and water quality of Goose Lake.

Sabina submitted a preliminary hydrodynamic modelling report of Goose Lake in February 2021 (Sabina 2021a) which presented predicted water quality at the Goose Lake outlet. The updated hydrodynamic model presented herein considers commitments made during the technical review of the Project, as well as final submission and issues raised during the Public Hearing process to secure the Type A Water Licence, 2AM-BRP1831 Amendment No.1, Part E, Item 15. The updated model and report include:

- an updated hydrodynamic and water quality model calibration (Section 4.0)
- results from the updated water and load balance model for the Project, which provides inputs to the hydrodynamic and water quality model and incorporates mitigation measures and modifications to the Water Management Plan (WSP Golder 2022)
- water quality predictions at various locations within Goose Lake, with particular focus on defining mixing zones for mine-affected discharge locations (Section 7.0)
- comparisons of water quality predictions within Goose Lake against background concentrations for constituents with chronic aquatic life guidelines or site-specific water quality objectives (SSWQOs) (Section 7.0)
- a sensitivity analysis examining the sensitivity of model results to variations in historical meteorological conditions (Appendix D)

This report has been prepared in accordance with the “Study Limitations”, Section 11, which are presented at the end of the report. The reader’s attention is specifically drawn to this information for reference during use of this report.

2.0 METHODS

2.1 Model Platform - Three-Dimensional (3D) MIKE3 Flexible Mesh (FM)

Several lake processes are of potential relevance to constituent behaviour and fate in Goose Lake, including the lake water balance, lake circulation, and chemical and temperature stratification. Accordingly, a 3D free-surface finite volume flow model platform, which can integrate these processes dynamically to enhance understanding of constituent behaviour and fate, was applied in this study.

The 3D hydrodynamic and water quality model of Goose Lake (hereafter referred to as “the Goose Lake Model”) was developed using MIKE3 Flexible Mesh (FM) software (2022 Version). MIKE is a hydrodynamic modelling platform, produced by the Danish Hydraulic Institute (DHI) that combines several computational components in either two-dimensional (2D) or 3D environments. The selected modelling platform provides 3D simulation of hydrodynamics and thermodynamics, as well as assimilation and dispersion-advection of constituents within Goose Lake. MIKE’s built-in capability to couple the hydrodynamic module with a thermodynamic module and a dispersion-advection module enables MIKE3 FM to provide an accurate and efficient way of tracking plumes and simulating lake circulation and mixing potential. The hydrodynamic module simulates unsteady 3D flows as a result of variable meteorology, density variations, bathymetric changes, currents, Coriolis forcing, and other hydrographic conditions (DHI 2017). The governing equations for MIKE3 correspond with the mass conservation equation and 3D Reynolds-averaged Navier-Stokes equations including a turbulence closure regime (i.e., hydrodynamic equations resolved in the hydrodynamic module) and the salinity and temperature conservation equations (i.e., advection-dispersion equations resolved in the transport module) (DHI 2017).

The FM component of MIKE3 was specifically designed for applications such as Goose Lake, allowing for increased mesh resolution in the vicinity of areas of interest (e.g., discharges and the near-shore areas), while limiting computational intensity in areas of less focus (e.g., middle of the lake). Water quality predictions were generated using MIKE's advection-dispersion (transport) module. Each modelled water quality constituent was individually represented using a generic conservative constituent (i.e., tracer) for each source (i.e., natural and mine-affected inflows) to Goose Lake. Water quality constituents were assumed to behave conservatively in the water column, which means that they were not modelled to undergo biological (e.g., consumption and release), chemical (e.g., precipitation), or physical (e.g., settling) processes.

2.2 Project Modelling Timelines

The time periods covered in the Goose Lake Model include the:

- **Calibration Period:** 2011 to 2021. The model was calibrated to reasonably match observed and predicted hydrodynamic, thermal, and transport behaviour in Goose Lake. During this period, all inflows to Goose Lake were not affected by mine activities (i.e., natural/baseline inflows).
- **Forecast Period:** Project Years -3 to 64 (WSP Golder 2022). This 67-year period was simulated to understand the potential effects of the Project on Goose Lake water quality and to evaluate long-term water quality in the lake after mine closure. This simulation period included natural and mine-affected inflows, which are not expected to begin until Year 16xxx. Specifically, this simulation covered the following mining phases:
  - Construction: 3 years from Year -3 to -1
  - Operations: 15 years from Year 1 to 15
  - Closure: 7 years from Year 16 to 22
  - Extended years beyond the proposed Closure Phase for the Project (referred to as the post-closure period for this study): 42 years, named Year 23 to 64 for consistency

2.3 Modelled Constituents and Screening Criteria

Total dissolved solids (TDS) and water temperature were included in the Goose Lake Model during the calibration period for the purposes of comparing model results to field measurements and iteratively optimizing model performance.

For future predictions, all constituents that have SSWQOs or aquatic life guidelines from the Canadian Council of Ministers of the Environment (CCME) were included in the model.

The following screening criteria were applied in the Goose Lake Model for future predictions (Table 1):

- Chronic aquatic life guidelines or the upper range of the oligotrophic range from CCME (1999, 2004), with the exception of aluminum, arsenic, copper, lead, and nitrate.
- Recently updated Federal Environmental Quality Guidelines for the protection of aquatic life for aluminum (ECCC 2021) and lead (ECCC 2020).
- SSWQOs for nitrate (Golder 2021a), copper (Sabina 2017), and arsenic (Golder 2017).

Calcium and magnesium were added to the list of modelled constituents to provide information required for the calculation of hardness-dependent benchmarks, and temperature and TDS were included to provide a generalized estimate of mixing throughout the lake.

Table 1: Modelled Constituents and Surface Water Quality Effects Benchmarks for the Protection of Aquatic Life

Parameter	Unit	Surface Water Quality Effects Benchmarks for the Protection of Aquatic Life	
		Aquatic Water Quality Guideline[(a)]	SSWQOs
Conventional Constituents			
Total dissolved solids	mg/L	-	-
Water temperature	°C	-	-
Major Ions			
Calcium	mg/L	-	-
Magnesium	mg/L	-	-
Chloride	mg/L	120	-
Fluoride	mg/L	0.12	-
Nutrients			
Nitrate as nitrogen	mg-N/L	2.93	2.93-10
Nitrite as nitrogen	mg-N/L	0.06	-
Ammonia[(b)]	mg-N/L	timeseries (2.3 - 12)	-
Phosphorus[(c)]	mg/L	0.01	-
Trace Elements			
Aluminum[(d)]	mg/L	timeseries (0.063 - 0.41)	-
Arsenic	mg/L	-	0.025
Boron	mg/L	1.5	-
Cadmium[(e)]	mg/L	timeseries (0.000036 - 0.00037)	-
Chromium[(f)]	mg/L	0.001	-
Copper	mg/L	-	0.0042
Iron	mg/L	0.3	-
Lead[(g)]	mg/L	timeseries (0.0028 - 0.0098)	-
Manganese[(h)]	mg/L	timeseries (0.19 - 0.76)	-
Mercury	mg/L	0.000026	-

Table 1: Modelled Constituents and Surface Water Quality Effects Benchmarks for the Protection of Aquatic Life

Parameter	Unit	Surface Water Quality Effects Benchmarks for the Protection of Aquatic Life	
		Aquatic Water Quality Guideline[(a)]	SSWQOs
Molybdenum	mg/L	0.073	-
Nickel [(e)]	mg/L	timeseries (0.025 - 0.15)	-
Selenium	mg/L	0.001	-
Silver	mg/L	0.00025	-
Thallium	mg/L	0.0008	-
Uranium	mg/L	0.015	-
Zinc [(i)]	mg/L	timeseries (0.0087 – 0.097)	-
Other			
Cyanide (free)	mg/L	0.005	-

a) Guidelines are based on chronic aquatic life water quality guidelines from CCME (1999), unless otherwise noted.
b) The guideline for ammonia is temperature and pH dependent. The range in the guideline is shown based on the range of predicted temperatures at the locations results are extracted (0 to 18°C) from the model and a pH 7.3, which was the maximum pH value at sampling depth in the baseline data for the Project at the time of the study.
c) This value is the upper limit of the oligotrophic range (CCME 2004) to maintain the current trophic status of Goose Lake (Golder 2019).
d) The guideline for aluminum is pH, DOC, and hardness-dependent, and based on the Federal Environmental Quality Guidelines for the protection of aquatic life for aluminum (ECCC 2021). The range in the guideline shown is based on a minimum pH of 5.9 at sampling depth and minimum DOC concentration (i.e., 3.5 mg/L) in the baseline data for the Project at the time of the study and the range in predicted hardness at the locations results are extracted (i.e., 0.82 to 300 mg/L, as $CaCO_3$).
e) The guidelines for cadmium and nickel are hardness dependent. The range in the guideline is shown based on a range in predicted hardness (i.e., 0.82 to 300 mg/L, as $CaCO_3$ at the mixing zone boundaries and calibration points).
f) Guideline is for chromium VI.
g) The guideline for lead is DOC and hardness-dependent and is based on Federal Environmental Quality Guidelines for the protection of aquatic life for lead (ECCC 2020). The range in the guideline shown is based on a minimum DOC concentration (i.e., 3.5 mg/L) in the baseline data for the Project at the time of the study and the range in predicted hardness at the locations results are extracted (i.e., 0.82 to 300 mg/L, as $CaCO_3$).
h) The guideline for manganese is pH and hardness dependent. The range in the guideline shown is the lowest chronic guidelines based on a minimum pH of 5.9 or maximum pH of 7.3 at sampling depth in the baseline data for the Project at the time of the study and the range in predicted hardness at the locations results are extracted (i.e., 0.82 to 300 mg/L, as $CaCO_3$ at the mixing zone boundaries and calibration points).
i) The guideline for zinc is pH, DOC, and hardness dependent. The range in the guideline shown is based on a maximum pH of 7.3 at sampling depth and minimum DOC concentration (i.e., 3.5 mg/L) in the baseline data for the Project at the time of the study and the range in predicted hardness at the locations results are extracted (i.e., 0.82 to 300 mg/L, as $CaCO_3$).

Notes:
Values of pH and DOC used to calculate pH and DOC-dependent guidelines were based on data collected in Goose Lake during open water conditions (Golder 2019, 2022).
Values of temperature and hardness used to calculate temperature and hardness dependent guidelines were based on the predicted value of temperature or hardness from the Goose Lake Model. Predicted hardness ranges, calculated from predicted calcium and magnesium concentrations, are: GLCB (8.8 – 166 mg/L), GLTL (8.6 – 223 mg/L), Goose Lake outflow (0.82 – 109 mg/L); and at the edge of mixing zones for PN04 (9.3 – 300 mg/L), PN05 (8.7 – 195 mg/L), and PN08 (8.7 – 195 mg/L).
$CaCO_3$ = calcium carbonate; - = guideline not available; DOC = dissolved organic carbon; mg-N/L = milligrams nitrogen per litre.

3.0 MODEL INPUTS

Inputs to the Goose Lake Model and their data sources are described in this section. Model inputs are categorized into bathymetric, meteorological, hydrological, and water quality data.

3.1 Bathymetric Data

A critical aspect of any hydrodynamic model involves achieving a reasonably accurate representation of the shape, depth, and volume of the modelled waterbody. Model segmentation is the process of discretizing the physical domain of a waterbody into small computational cells that can be used by the model to iteratively calculate variables at all locations within the lake, and to propagate momentum and mass among and between cells during each time step of the simulation. This discretized model domain is defined as the mesh (i.e., model grid).

A 3D flexible mesh of Goose Lake was developed using bathymetric data provided by Sabina (Sabina 2020a). The mesh used to represent lake bathymetry consisted of a combination of unstructured triangular and quadrangular cells ranging in size to provide sufficient resolution around points of interest (e.g., discharge points and the channels located at the neck on the west side of the lake) (Figure 1) to coarser resolution in areas of lower hydrothermal criticality for generating water quality projections (e.g., the middle of the lake). Cell sizes varied from approximately 20 m, close to mine-affected discharges, to approximately 150 m in the middle of the lake. Horizontally, the mesh is represented by 773 cells at the water surface, which covers the footprint of Goose Lake up to the land-water boundary (i.e., lake surface area of approximately 3.2 km^2). Vertically, the model domain includes 12 layers which covers the entire volume of Goose Lake (i.e., 11 Mm^3) and results in a total of 4,458 computational cells. Figure 1 presents the mesh and location of inflows to Goose Lake used for calibration and forecast periods, and the location of the lake outflow. The comparison of hypsographic curves developed for the Goose Lake Model from the bathymetric map are presented in Figure 2, which demonstrate reasonable representation of the lake surface area and volume.

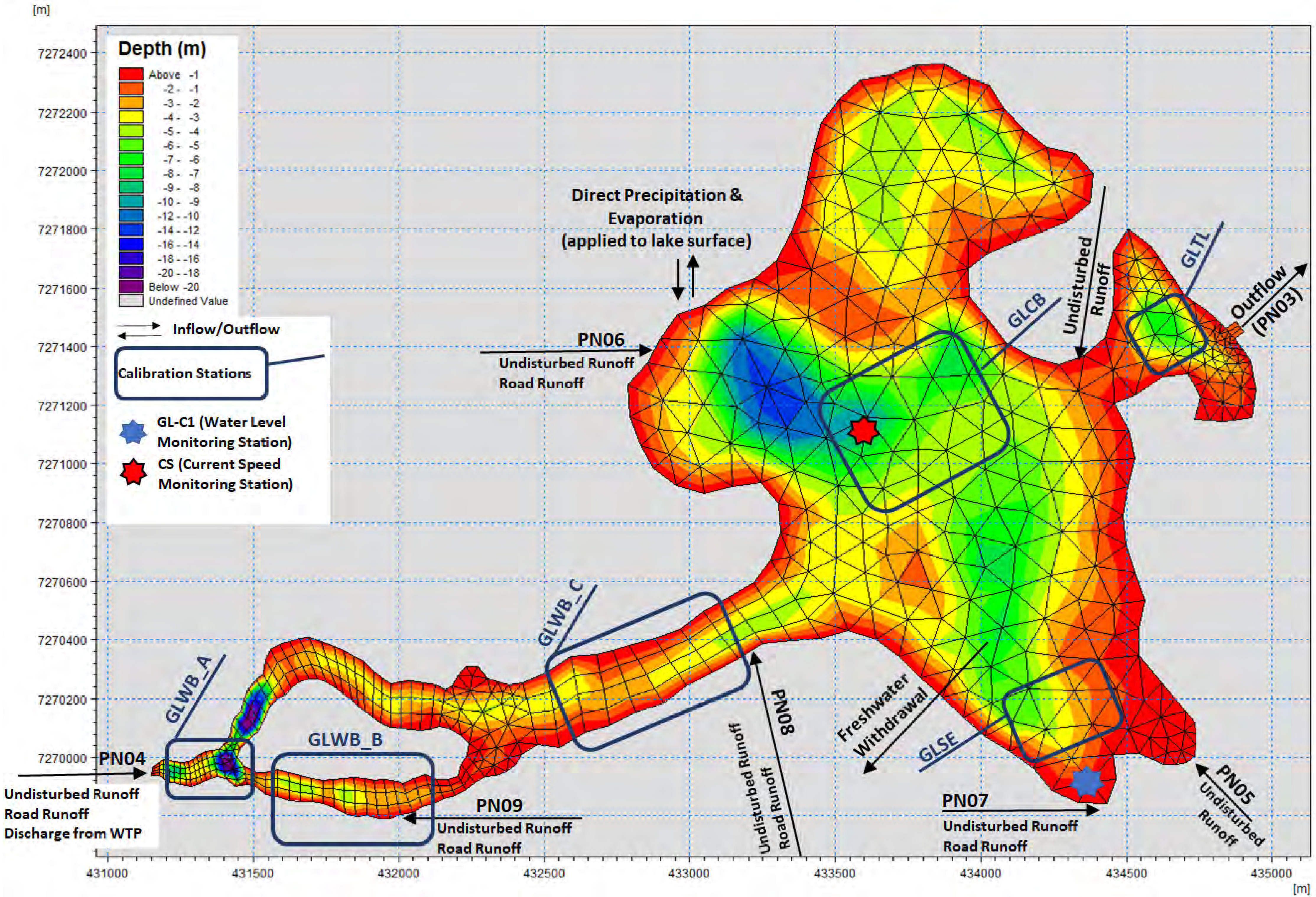
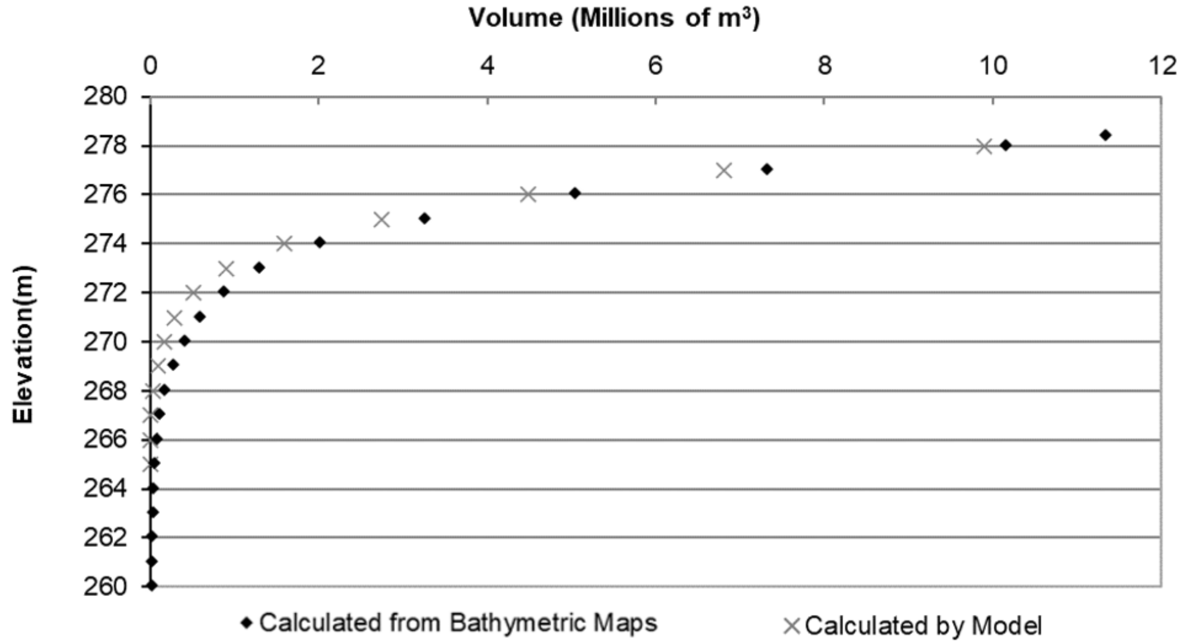


Figure 1: Goose Lake Model Mesh (Plan View) with Inflows and Outflows during Calibration and Forecast Periods and Calibration Stations

a) Elevation and Volume



b) Elevation and Surface Area

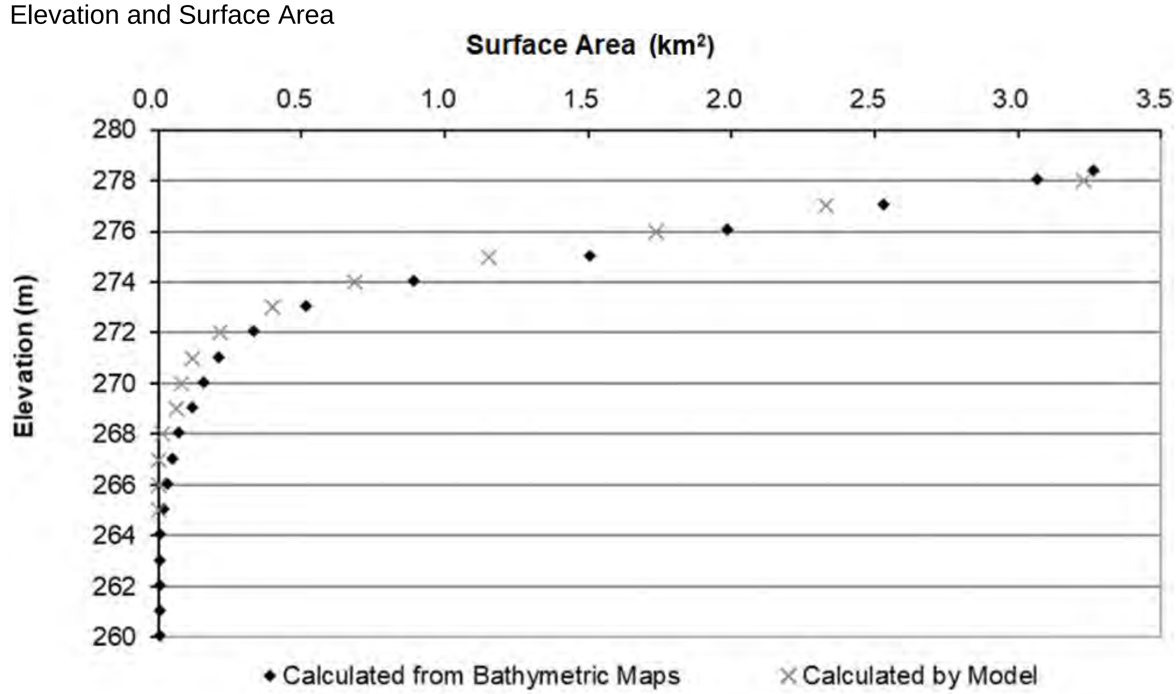


Figure 2: Hypsographic Curves for Goose Lake

3.2 Meteorological Data

Meteorological inputs are key drivers of lake circulation and thermal dynamics. The meteorological input data required for the Goose Lake Model were air temperature, wind speed and direction, relative humidity, short and long-wave radiation, clearness coefficient (i.e., cloud cover), and precipitation. Evaporation is calculated internally by the model. Details of each meteorological input and related assumptions applied to the model are provided below:

- Hourly timeseries were developed for each of the time-dependent variables based on observed data collected from the on-site meteorological station between 2010 and 2021 (Goose Lake Meteorological Station and Davis Weather Station; Sabina 2021b). These timeseries were developed for air temperature, wind speed and direction, relative humidity, and short-wave radiation. Data gaps were infilled using data from the Lupin meteorological station (ECCC 2021, Station ID: 230N002) and the Meteoblue database (Meteoblue 2021).
- Long-wave radiation was estimated by the model using an empirical formulation (Lind and Falkenmark 1972), which is a function of the Project's location, date and time, cloud cover, air temperature, vapour pressure of air, and relative humidity.
- Hourly cloud cover data were extracted from the Meteoblue database (Meteoblue 2021) and applied in the model in the form of a clearness coefficient.
- The precipitation data were extracted from Lupin station. An estimated under-catch factor was applied to the observed precipitation data based on the under-catch adjustment analysis completed by SRK (2015). For years with large gaps in precipitation data, monthly precipitation data for an average climate year were obtained from the Water and Load Balance (WLB) Model (WSP Golder 2022).
- For future simulations (i.e., forecast period), observed meteorological data collected on-site during the calibration period (i.e., 2010 to 2021), except for precipitation, were repeated to develop a 67-year timeseries. Monthly precipitation data from the WLB Model for an average climate year were used to provide consistency between water balance and hydrodynamic components.

3.3 Hydrologic Inputs

Hydrological inputs (i.e., inflows and outflows) for each modelling period are described below.

- Inflows to Goose Lake:
  - Calibration period (2011 to 2021): Inflows from regional watersheds / natural tributaries within the Goose Lake basin were obtained from the Hydrology Baseline Reports (Rescan 2011, 2012, and 2013; Golder 2021b). These inflows (i.e., daily timeseries) were based on observed data collected at the following monitoring stations: PL-H2, GL-H1, WR-H1, GI-H1, WL-H1, GL-H3, EL-H1. For years with no observed data (2014 to 2020), daily averages of data collected from 2011 to 2013 and 2021 were used.
  - Forecast period (Year -3 to Year 64): Inflows from local watersheds / natural tributaries and mine-affected discharges reporting to Goose Lake were obtained (i.e., daily basis) from the WLB Model (WSP Golder 2022).
- Outflows and evaporative losses from Goose Lake: For both modelling periods, the outflow from Goose Lake (i.e., through the outlet channel to Propeller Lake) was defined in terms of a stage-discharge relationship. Observed water levels at Goose Lake during the open water season in 2013 (Rescan 2013) and 2021 (Golder 2021b) and observed flows downstream of Goose Lake during the open water season

(Rescan 2013; Golder 2021b) were used to develop a relationship between outflows from Goose Lake and water levels in the lake. For both modelling periods, evaporation was calculated by the hydrodynamic model based on modelled water temperature, air temperature, relative humidity, and wind speed inputs (DHI 2017).

Figure 1 presents the location of inflows defined in the Goose Lake Model. Annual average flow rates for all hydrological inputs during calibration and forecast periods are summarized in Table 2.

Table 2: Annual Average Hydrological Inputs during Calibration and Forecast Periods

Inflow Name	Inflow Rates (Mm³/yr)					
	Calibration Period		Forecast Period			
	Rate	Year/Month of Available Data	Construction	Operations	Closure	Post-closure
PN04	1.6	2011 (Jun to Sep) 2012 (May to Sep) 2013 (May to Oct)	2.5	2.1	3.3	3.6
PN05	0.94	2011 (Jun to Sep) 2012 (May, Jun, Jul, Sep) 2013 (May to Oct)	5.6	5.5	3.1	5.3
PN06	3.8	2011 (Jun to Oct) 2012 (May to Sep) 2013 (May to Oct)	3.6	4.5	4.2	4.4
PN07	0.19	2011 (Jun to Sep) 2012 (May, Jun, Jul, Sep, Oct) 2013 (May to Oct)	4.0	4.5	Not active	
PN08	3.4	2011 (Jun to Sep) 2012 (May to Sep) 2013 (May to Oct)	0.99	1.1	1.5	1.5
PN09	0.7	2013 (May to Oct)	0.11	0.11	Not active	
Precipitation	1.7	2010 - 2021	1.4	1.4	1.4	1.4
Evaporation	-0.75	Calculated by the model	-0.75	-0.75	-0.76	-0.75
Discharge from Water Treatment Plant (WTP) (dewatering of Umwelt and Llama Lakes)	Not active		1.2	Not active		
Road Runoff			0.011	0.012	0.012	0.013
Undisturbed Runoff			1.4	1.6	1.7	1.7
Withdrawal			-0.22	-0.46	-0.17	Not active

3.4 Ice Formation and Melting

The simulation of ice formation and thawing processes was based on the following assumptions:

- Ice thickness, and the time of ice formation and thawing, were based on input timeseries developed using monitoring data collected as part of the baseline programs for the Project (Golder 2019, 2022).
- During ice formation, lake water was gradually drawn from the lake via evaporation to compensate for the rate of ice formation and to simulate salt rejection and the reduction in liquid lake volume. During ice thaw, lake water was gradually returned from ice to the lake during the melt period via direct precipitation to simulate ice-melt. Thus, salts were rejected from the water during ice formation (i.e., cryoconcentration), and pure water was added back as the ice melted.
- The volume of water removed to form ice and returned to the lake during melting was adjusted by a factor of 0.92 to account for the density difference between ice and fresh water.
- Ice formation occurred linearly over a 198-day period from 15 October to 30 April each year.
- Ice thawing occurred linearly over a 60-day period from 1 May to 30 June each year.
- Maximum ice thickness was set to 2 m.
- Ice covered the entire lake and ice thickness was assumed to be constant across the entire lake.
- Precipitation, represented as snow water equivalent, accumulated over the ice each winter and was added gradually as meltwater to the lake over the melting period.

3.5 Water Quality Inputs

The water quality data required to simulate loadings to the Goose Lake Model included chemistry (i.e., constituent concentrations) and temperature data for inflows to the lake. These inputs are summarized below:

- During the calibration period, monthly timeseries of inflow TDS concentrations from regional watersheds / natural tributaries were developed using observed, calculated TDS concentrations (Golder 2019 and 2022). The annual average TDS concentration for each inflow and range of available data are presented in Table 3. For inflows with no observed data, the monthly averages of data collected in other years were used to represent monthly inputs. Chemistry data were not available for the months of May and October; however, monitoring data show that there are some inflows to the lake during these months. It was assumed that the TDS concentrations of inflows during the months of May and October were equivalent to those in June and September, respectively. Continuous measurements of stream water temperature were not available for inflows from natural tributaries; thus, temperature timeseries were developed using data collected at streams draining into Snap Lake collected from 2009 and 2016 (De Beers 2017) and were applied to all tributary inflows to Goose Lake.
- During the forecast period, the water quality of inflows (Table 4) was based on outputs from the WLB Model (WSP Golder 2022). The water temperature of these inflows was assumed to be the same as for the calibration period. During the forecast period, water quality for inflows from PN04, PN05, and PN08 were characterized using mine-affected chemistry, while non-mine-affected inflows (e.g., undisturbed runoff) to the Goose Lake were represented using baseline (i.e., natural) concentrations.

- Initial conditions on the first day of the calibration period within Goose Lake were defined using observed data (Golder 2019). Temperature and TDS were spatially interpolated based on the locations of, and observed data collected at, monitoring stations.
- Initial conditions on the first day of forecast period within Goose Lake were also defined using observed data (Golder 2022).
- Salinity was estimated based on TDS concentrations (mg/L) and expressed in Practical Salinity Units (PSU). The applied conversion ratio assumed that 1 mg/L (TDS) equals 0.001 PSU (i.e., salinity).
- Constituent concentrations in rainfall, snowfall, and evaporation were assumed as zero. Accordingly, these variables affect the water balance and lake concentrations but not the mass balance.
- Concentrations of constituents that were below detection limits were assumed to be equal to half the detection limit.

Table 3: Annual Average Input TDS Concentration of Inflows – Calibration Period

Inflow	TDS Concentration (mg/L)	Year/Month of Available Data
PN-04	33	2017 (Aug), 2018 (Jun to Sep), 2021 (Jul, Sep)
PN-05	22	2013 (Jun, Aug), 2017 (Aug), 2018 (Jun to Sep), 2021 (Jul, Sep)
PN-06	14	2011 (Jun, Aug, Sep), 2012 (Jun, Sep), 2013 (Jun, Jul), 2021 (Jul, Sep)
PN-07	31	2011 (Jun, Sep), 2012 (Jun), 2018 (Aug, Sep), 2021 (Jul, Sep)
PN-08	12	2011 (Jun, Aug, Sep), 2012 (Jun & Aug), 2021 (Jul, Sep)
PN-09	18	2017 (Aug), 2021 (Jul, Sep)

Table 4: Model Input Chemistry (Average Concentrations) – Forecast Period (Part 1)

Constituent	Unit	PN04				PN05				PN06				PN08				PN09			
		Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure
Aluminum	mg/L	0.049	0.069	0.082	0.066	0.015	0.016	0.049	0.021	0.013	0.013	0.013	0.013	0.021	0.021	0.051	0.051	0.043	0.04	-	-
Ammonia as nitrogen	mg-N/L	0.0054	0.0048	1.1	0.041	0.0051	0.005	0.31	0.00062	0.0051	0.005	0.005	0.005	0.005	0.005	0.0043	0.0043	0.0066	0.0049	-	-
Arsenic	mg/L	0.0011	0.0016	0.0053	0.011	0.0003	0.00031	0.0018	0.0005	0.00024	0.00023	0.00024	0.00024	0.00043	0.00043	0.028	0.028	0.001	0.00092	-	-
Boron	mg/L	0.0049	0.0048	0.4	0.06	0.005	0.005	0.16	0.017	0.005	0.005	0.005	0.005	0.005	0.005	0.28	0.14	0.0049	0.0049	-	-
Cadmium	mg/L	0.0000098	0.0000097	0.000055	0.000015	0.000010	0.000010	0.000021	0.000011	0.000010	0.000010	0.000010	0.000010	0.000010	0.000010	0.000021	0.000021	0.0000098	0.0000099	-	-
Calcium	mg/L	2.4	2.6	35	6.0	2.2	2.2	36	4.8	2.2	2.2	2.2	2.2	2.2	2.2	8.7	8.7	2.4	2.4	-	-
Chloride	mg/L	0.98	0.97	31	3.6	1.0	1.0	88	7.8	1.0	1.0	1.0	1.0	0.99	0.99	2.9	2.9	0.98	0.98	-	-
Chromium	mg/L	0.00021	0.00025	0.00048	0.00027	0.00016	0.00016	0.00024	0.00017	0.00015	0.00015	0.00015	0.00015	0.00017	0.00017	0.00081	0.00047	0.0002	0.0002	-	-
Copper	mg/L	0.0014	0.0015	0.0024	0.0018	0.0014	0.0014	0.0015	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0027	0.0027	0.0014	0.0014	-	-
Cyanide (free)	mg/L	0.00023	0.00022	0.00023	0.00015	0.00023	0.00023	0.00011	0.000028	0.00023	0.00023	0.00023	0.00023	0.00023	0.00023	0.0002	0.0002	0.00023	0.00023	-	-
Fluoride	mg/L	0.02	0.02	0.044	0.022	0.02	0.02	0.026	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.024	0.024	0.02	0.02	-	-
Iron	mg/L	0.059	0.084	0.3	0.093	0.019	0.019	0.13	0.032	0.016	0.016	0.016	0.016	0.025	0.025	0.081	0.082	0.053	0.049	-	-
Lead	mg/L	0.000052	0.000052	0.0019	0.00028	0.00005	0.00005	0.00083	0.00011	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00061	0.00029	0.000051	0.000051	-	-
Magnesium	mg/L	1.3	1.4	6.3	1.9	1.3	1.3	4.0	1.5	1.3	1.3	1.3	1.3	1.3	1.3	2.6	2.6	1.3	1.3	-	-
Manganese	mg/L	0.0051	0.0068	0.11	0.02	0.0022	0.0023	0.038	0.0053	0.002	0.002	0.002	0.002	0.0027	0.0027	0.065	0.065	0.0046	0.0044	-	-
Mercury	mg/L	0.000010	0.0000099	0.000013	0.00001	0.000005	0.000005	0.0000057	0.000005	0.000005	0.000005	0.000005	0.000005	0.000010	0.000010	0.000012	0.000012	0.000005	0.000005	-	-
Molybdenum	mg/L	0.000067	0.000075	0.0025	0.0004	0.000052	0.000052	0.0007	0.0001	0.000051	0.000051	0.000051	0.000051	0.000054	0.000054	0.00072	0.00072	0.000064	0.000063	-	-
Nickel	mg/L	0.0045	0.0052	0.03	0.008	0.0035	0.0035	0.0098	0.004	0.0034	0.0034	0.0034	0.0034	0.0036	0.0036	0.011	0.011	0.0044	0.0043	-	-
Nitrate as nitrogen	mg-N/L	0.0072	0.0063	1.4	0.35	0.0067	0.0065	0.75	0.095	0.0067	0.0065	0.0065	0.0065	0.0068	0.0065	0.31	0.31	0.0091	0.0064	-	-
Nitrite as nitrogen	mg-N/L	0.001	0.00097	0.022	0.022	0.001	0.0010	0.0029	0.0011	0.001	0.0010	0.0010	0.0010	0.001	0.00099	0.076	0.076	0.0011	0.00098	-	-
Phosphorus	mg/L	0.0021	0.0022	0.0052	0.0069	0.0019	0.0019	0.0074	0.0023	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.032	0.032	0.0021	0.002	-	-
Selenium	mg/L	0.00011	0.00011	0.00082	0.00019	0.0001	0.0001	0.00031	0.00012	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00035	0.00035	0.0001	0.0001	-	-
Silver	mg/L	0.00001	0.00001	0.000032	0.000012	0.00001	0.00001	0.000017	0.00001	0.00001	0.000010	0.000010	0.00001	0.00001	0.00001	0.000014	0.000014	0.00001	0.00001	-	-
Thallium	mg/L	0.000049	0.000048	0.0001	0.000051	0.00005	0.00005	0.000074	0.000051	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.000086	0.000064	0.000049	0.000049	-	-
Total Dissolved Solids	mg/L	23	22	62	22	23	23	201	37	23	23	23	23	23	23	20	20	23	23	-	-
Uranium	mg/L	0.00001	0.00001	0.0035	0.00073	0.00001	0.00001	0.0004	0.000041	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.0074	0.0037	0.00001	0.00001	-	-
Zinc	mg/L	0.0033	0.0034	0.011	0.004	0.003	0.003	0.0053	0.0032	0.003	0.003	0.003	0.003	0.0031	0.0031	0.0047	0.0047	0.0032	0.0032	-	-

- = not active.

Table 4: Model Input Chemistry (Average Concentrations) – Forecast Period (Part 2)

Constituent	Unit	Undisturbed Runoff				Road Runoff			
		Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure
Aluminum	mg/L	0.011	0.011	0.011	0.011	1.7	1.7	1.7	1.7
Ammonia as nitrogen	mg-N/L	0.005	0.005	0.005	0.005	0.12	0.0088	0.000042	0.00000042
Arsenic	mg/L	0.0002	0.0002	0.0002	0.0002	0.044	0.044	0.044	0.044
Boron	mg/L	0.005	0.005	0.005	0.005	0.0003	0.0003	0.0003	0.0003
Cadmium	mg/L	0.00001	0.00001	0.00001	0.00001	0.0000013	0.0000013	0.0000013	0.0000013
Calcium	mg/L	2.1	2.1	2.1	2.1	16	16	16	16
Chloride	mg/L	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Chromium	mg/L	0.00015	0.00015	0.00015	0.00015	0.003	0.003	0.003	0.003
Copper	mg/L	0.0014	0.0014	0.0014	0.0014	0.0036	0.0036	0.0036	0.0036
Cyanide (free)	mg/L	0.00023	0.00023	0.00023	0.00023	0.00023	0.00023	0.00023	0.00023
Fluoride	mg/L	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Iron	mg/L	0.014	0.014	0.014	0.014	2.1	2.1	2.1	2.1
Lead	mg/L	0.00005	0.00005	0.00005	0.00005	0.00012	0.00012	0.00012	0.00012
Magnesium	mg/L	1.3	1.3	1.3	1.3	4.4	4.4	4.4	4.4
Manganese	mg/L	0.0019	0.0019	0.0019	0.0019	0.15	0.15	0.15	0.15
Mercury	mg/L	0.00001	0.00001	0.00001	0.00001	0.0000071	0.0000071	0.0000071	0.0000071
Molybdenum	mg/L	0.00005	0.00005	0.00005	0.00005	0.00081	0.00081	0.00081	0.00081
Nickel	mg/L	0.0033	0.0033	0.0033	0.0033	0.059	0.059	0.059	0.059
Nitrate as nitrogen	mg-N/L	0.0065	0.0065	0.0065	0.0065	0.2	0.014	0.000068	0.00000069
Nitrite as nitrogen	mg-N/L	0.001	0.001	0.001	0.001	0.0099	0.00071	0.0000034	0.000000034
Phosphorus	mg/L	0.0019	0.0019	0.0019	0.0019	0.01	0.01	0.01	0.01
Selenium	mg/L	0.0001	0.0001	0.0001	0.0001	0.00033	0.00033	0.00033	0.00033
Silver	mg/L	0.00001	0.00001	0.00001	0.00001	0.000015	0.000015	0.000015	0.000015
Thallium	mg/L	0.00005	0.00005	0.00005	0.00005	0.000004	0.000004	0.000004	0.000004
Total Dissolved Solids	mg/L	23	23	23	23	23	23	23	23
Uranium	mg/L	0.00001	0.00001	0.00001	0.00001	0.000025	0.000024	0.000024	0.000024
Zinc	mg/L	0.003	0.003	0.003	0.003	0.015	0.015	0.015	0.015

4.0 MODEL CALIBRATION

The calibration process for the Goose Lake Model involved selecting the appropriate mesh (i.e., grid) sizing, time step, vertical resolution, wind effects, and other driving forces, and adjusting input parameters to achieve a model that most closely approximated the behaviour of the system under study. Adjustment of model calibration parameters is standard practice during calibration (Cole and Wells 2008).

The Goose Lake Model was calibrated to closely match observed and predicted hydrodynamic, thermal, and transport behaviour in Goose Lake. The model was calibrated using observed data from 2010 to 2021 by comparing observed and predicted surface water levels, lake outflows, current speeds and directions, temperature, and TDS. Calibration parameters were adjusted to allow adequate representation of observed data. During calibration, default model parameters were used for all variables except those specified in Table 5.

For temperature and TDS, calibration considered the horizontal (i.e., spatial) and vertical distribution of temperature and TDS profiles in Goose Lake. For the horizontal transport calibration, timeseries plots of predicted surface temperature and TDS concentrations were compared against observed data. Vertical temperature and TDS plots were developed for each calibration station with available data. Observed TDS was not available for vertical profiles, thus observed specific conductivity (SC) was instead used to evaluate calibration performance for vertical TDS profiles. The calibration was considered adequate if the observed specific conductivity and predicted TDS followed the same pattern, while recognizing that the values would not be expected to match.

Table 5: Model Parameters Tested during the Calibration Period

Parameter	Tested Range	Selected Values
Hydrodynamic Module		
Roughness height	0.001 to 0.1 m	0.005 m
Wind friction coefficient	Constant (0.00001255 - 0.001255) or Variable with wind speed (0.001 - 0.01)	Variable (0.005 - 0.0097)
Ice coverage	constant and variable ice thickness over the lake; ice thickness range 1.6 - 2 m	2 m thickness
Temperature Module		
Vertical dispersion	Scaled eddy viscosity formulation, Constant: 0.0001 - 1	0.001
Heat exchange	Sensible heat – transfer coefficient for cooling: 0.0011 - 0.005	0.0018
	Ground heat – distance below surface: 0.01 to 1 m	0.1 m
	Ground temperature – tested constant (4°C to 5°C) and variable temperature spatially and temporally based on observed water temperature near lakebed	Spatially and temporally variable
Transport Module		
Vertical dispersion	Scaled eddy viscosity formulation, Constant: 0.0001 - 1	0.001

Calibration performance was evaluated using a graphical approach. Timeseries (i.e., surface water levels, lake outflows, current speed/direction, temperature, and TDS) and profile plots (i.e., temperature and TDS) were created to visually compare model results to observed data at several monitoring locations (see calibration stations, Figure 1) across the lake. Below is list of the calibration stations:

- For water level calibration: GL-C1.
- For outflow calibration: Goose Lake outlet.

- For current speed/direction calibration: CS.
- For temperature and TDS calibration, 6 locations were selected from the Aquatics Effects Monitoring Program (AEMP) water quality monitoring stations, based on the location and duration of available data, including:
  - GLWB_A, GLWB_B, GLWB_C, in the west basin
  - GLCB, in the central basin
  - GLSE, in the southern basin
  - GLTL, at the tail (or outlet) of Goose Lake

The following subsections present the qualitative evaluation of model performance based on a comparison of predicted and observed water levels, outflow rates, current speeds, water temperature, and TDS concentrations.

4.1 Water Levels and Outflow Rates

The first step in the calibration process was to achieve a suitable water balance within the model. For this purpose, modelled lake water levels and outflow rates were plotted against the observed data (Figure 3) to confirm the volume of the lake was seasonally balanced and model predictions match observed data (i.e., for the years with available data) or were within the observed historical range (i.e., for the years with no observed data). Observed water levels were collected at GL-C1 (Figure 1).

Overall, predicted water levels and outflow rates matched the observed data well, did not exhibit cumulative increasing or decreasing trends over multiple years, and reproduced the observed historical seasonal cycle (Figure 3).

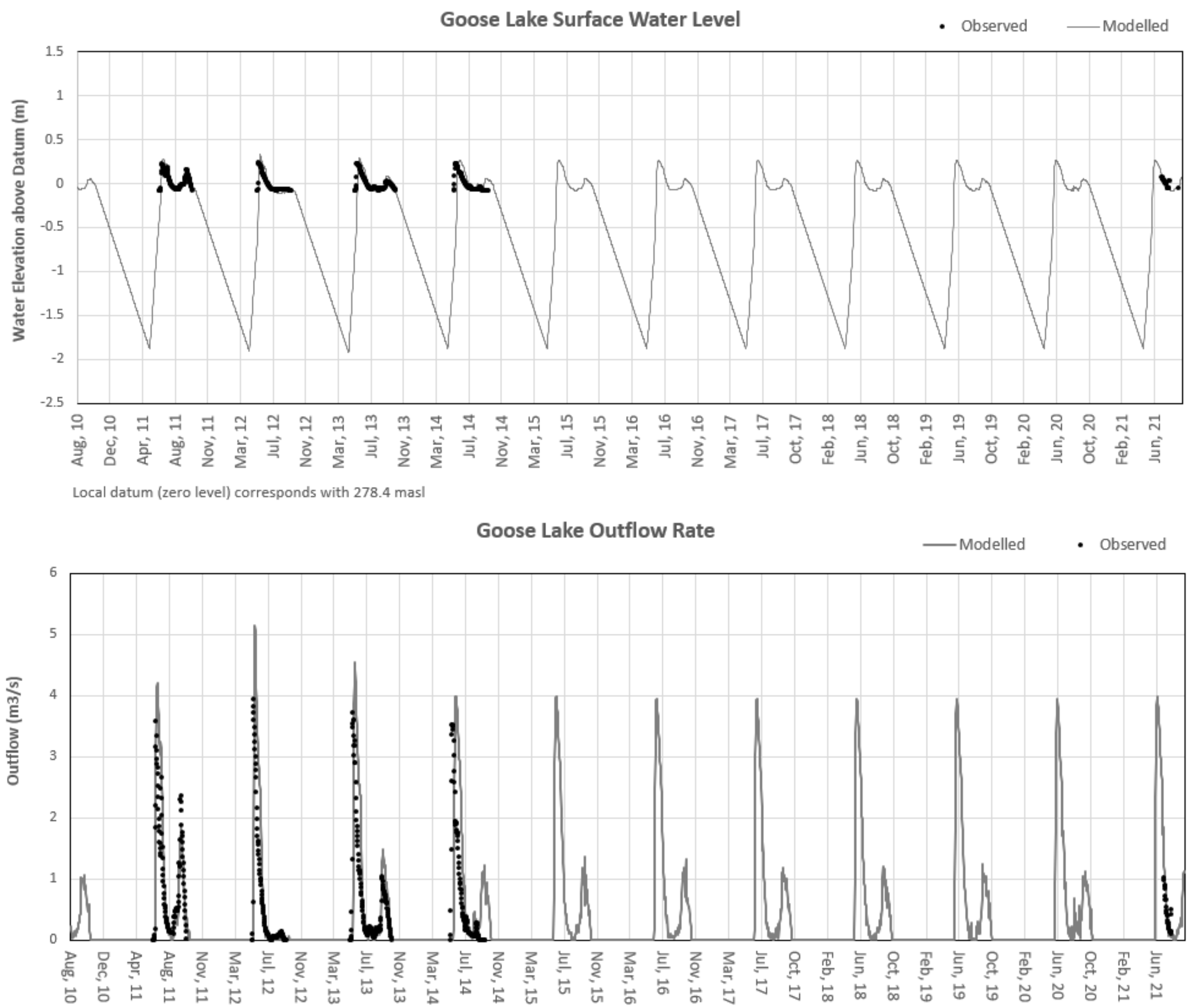


Figure 3: Modelled and Observed Goose Lake Water Level and Outflow Rates over the Calibration Period

4.2 Current Speeds and Direction

Timeseries plots of observed and modelled current speed were created to determine whether the model provides a reasonable representation of observed lake current behaviour in response to variable wind conditions.

Observed current data were collected in 2021 (Golder 2021c) during the open water season (i.e., 25 July to 2 October) using an Acoustic Doppler Current Profiler (ADCP) deployed on the lakebed at a relatively deep location (i.e., approximately 10 m) in the middle of the lake (location CS shown on Figure 1).

During the calibration process, the wind friction coefficient was iteratively adjusted (Table 5) to closely match the modelled current speeds with observed current speeds. Timeseries plots of depth-averaged observed and modelled current speeds, and current directions, are presented on Figure 4. Wind speed and direction used as an input to the model are also included in Figure 4. Modelled current speeds and directions reflect the general trend of observed data and wind speed/direction. Overall, the current calibration is sufficient to represent the movement of water and associated constituents throughout the lake in response to variable wind conditions.

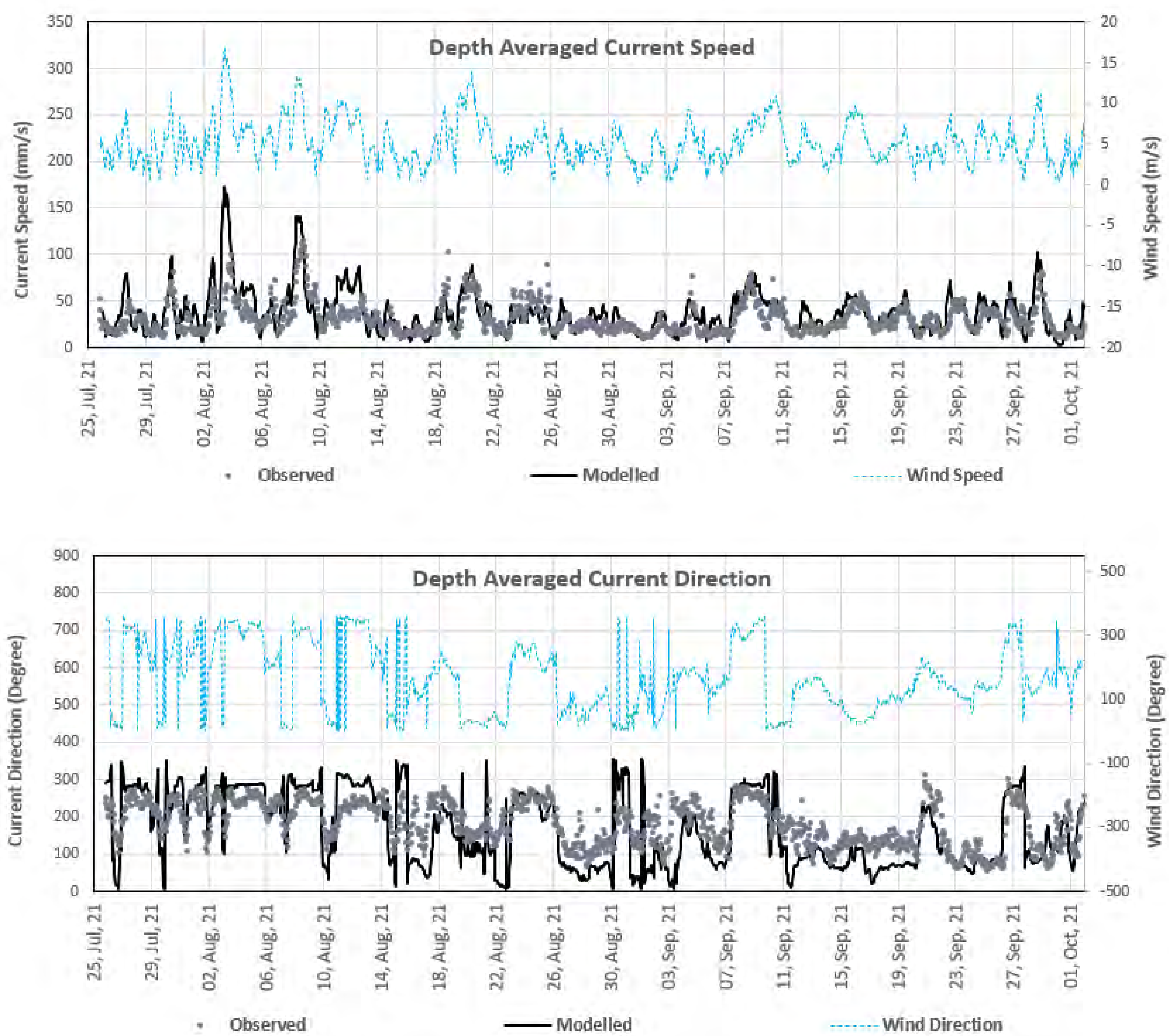


Figure 4: Modelled and Observed Depth-Averaged Current Speed and Direction over the Calibration Period

4.3 Water Temperature

Model performance for water temperature was evaluated qualitatively by comparing modelled and observed water temperatures using:

- timeseries graph of surface water temperature (Figure 5)
- profile plots of water column temperature (Appendix A)

The observed and modelled timeseries of surface water temperatures (Figure 5) show that the model matches the observed data during the open water and ice cover seasons reasonably well.

Default model parameters were used to simulate thermal processes, with the exception of the vertical dispersion coefficient, heat transfer coefficient for cooling, and ground heat temperature (Table 5). These parameters were adjusted to best capture the horizontal and vertical variability of water column temperatures in the observed dataset. To optimize thermal performance, a spatially and temporally variable ground heat input file was developed for the calibration period, 2011 to 2021. Ground heat temperature was set to:

- the monthly average of observed water temperature close to the lakebed during the open water season (AEMP data)
- 5°C during the ice cover season

Water column temperature profile plots for the dates that observed data were available are presented in Appendix A. Both observed and modelled profile data show that the lake is relatively well mixed vertically throughout the summer season. During the ice cover season, the model does not predict the small difference (approximately 2°C) between the surface and bottom layer temperatures as suggested by the observed data; this difference is not expected to have a material effect on water quality predictions from the model.

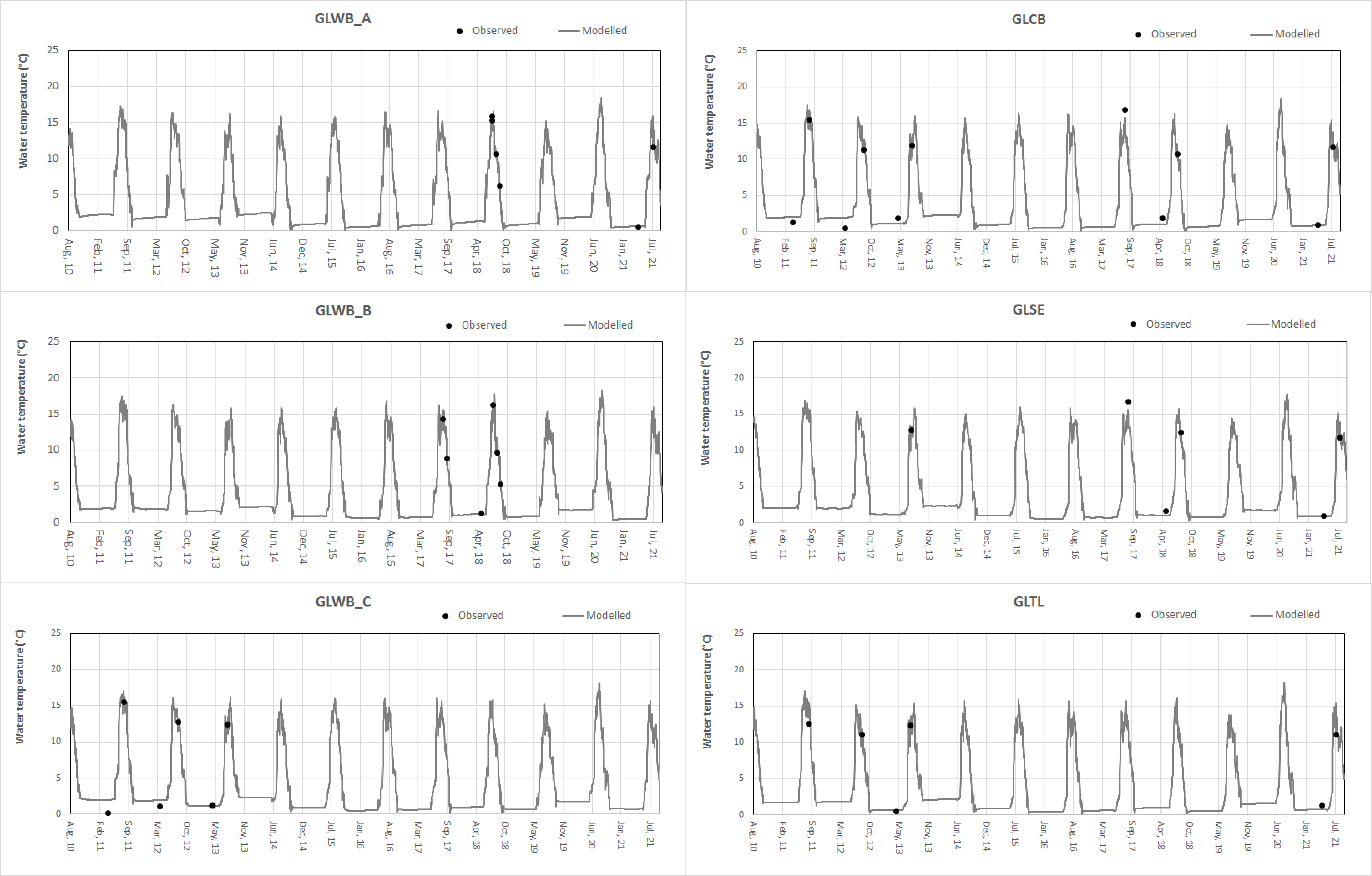


Figure 5:Modelled and Observed Goose Lake Water Temperature Timeseries over the Calibration Period

4.4 TDS Concentrations

The transport module of the Goose Lake Model was calibrated to closely match observed and predicted TDS behaviour in Goose Lake. Timeseries and profile plots of TDS concentrations were created to compare model results to observed data at calibration stations. Modelled and observed TDS concentrations are presented as:

- timeseries plots (Figure 6)
- profile plots (Appendix A)

The seasonal patterns and vertical variability of TDS were captured reasonably well by the model (Figure 6). The predicted TDS concentration timeseries replicate increasing TDS concentrations as ice forms in the lake (i.e., due to salt rejection; cryoconcentration) and then decreasing concentrations as the ice starts melting and during the freshet.

The peak in surface TDS concentrations occurring during ice cover is usually affected by the ice thickness, the time that ice reaches its maximum thickness, and inflow chemistry before ice forms on the lake (i.e., there are no inflows to Goose Lake during ice cover months). The lowest TDS concentrations usually occur during the freshet, and are affected by the time of ice melting, ice thickness, and inflow rates/chemistries to the lake.

Water column TDS profile plots for the dates that observed data were available are presented in Appendix A. During both open water and ice cover seasons, the predicted TDS profile follows the observed specific conductivity profile pattern well and shows an overall lack of chemical stratification (i.e., the lake is vertically mixed). As described in Section 4.0, observed TDS concentrations were not available for vertical profiles and observed specific conductivity was used to evaluate calibration performance for vertical TDS profiles. Thus, calibration was considered adequate if the observed specific conductivity and predicted TDS followed the same pattern, while recognizing that the values would not be expected to perfectly match.

Overall, the transport calibration indicates that the model is tracking the movement of water and dissolved constituents (represented by TDS) reasonably well throughout the vertical and lateral extents of the lake.

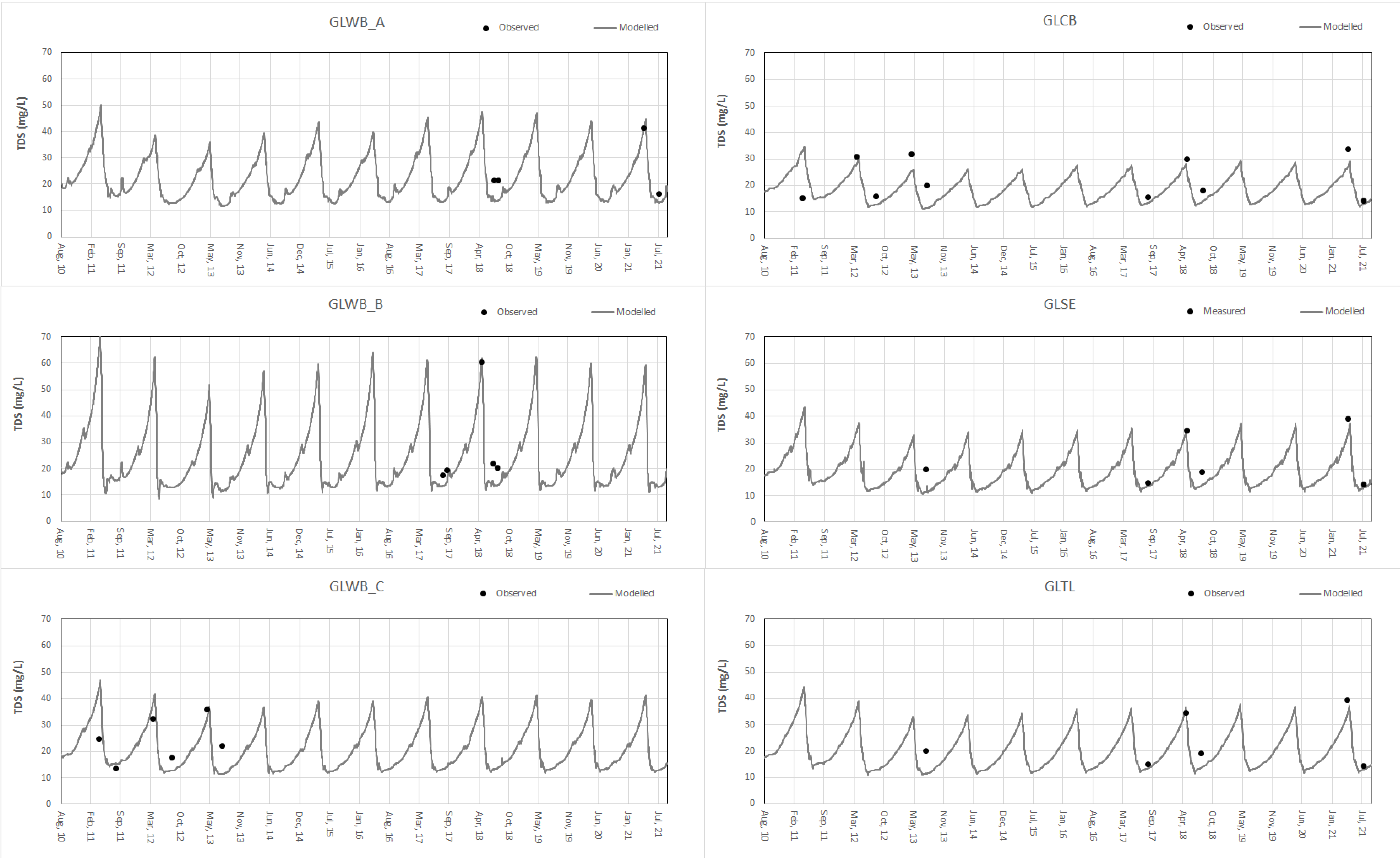


Figure 6: Modelled and Observed Goose Lake Surface TDS Concentration Timeseries over the Calibration Period

4.5 Calibration Results Summary

Overall, the model calibration demonstrates adequate model performance as a predictive tool for water quality forecasts in Goose Lake. The model captures the range in water levels, outflow rates, current speeds, temperature, and TDS concentrations from monitoring data sufficiently well. In addition, the model was able to reasonably match the seasonal patterns observed in the monitoring data and spatial distributions of temperature and TDS concentrations across Goose Lake.

5.0 MODEL ASSUMPTIONS AND UNCERTAINTIES

Modelling requires the use of simplified assumptions related to the physical and chemical characteristics of a system. Predictions are based on several inputs, all of which have inherent uncertainty. Given these inherent uncertainties, models should be relied upon as tools in project planning and to outline potential risks, rather than for the purposes of producing forecasts with extreme accuracy. Used appropriately, models can be developed with conservative assumptions that tend to overestimate concentrations, and thereby avoid underestimating the overall risk; this approach was applied to the Goose Lake Model.

Key assumptions and sources of model uncertainty in the Goose Lake Model are discussed below:

- It is assumed that inflow rates and chemistry inputs to the Goose Lake Model are representative of their respective sources and will continue to be so in the future.
- Water quality constituents are modelled as conservative constituents in the water column, meaning that they do not undergo chemical or biological reactions or physical processes that would remove mass from the system. This approach adds conservatism to the modelling and could lead to an over-estimate of in-lake concentrations for some constituents. Examples of constituents for which concentrations could be overestimated in the model are nitrite and ammonia, which are known to be oxidized in aerobic environments (Bowie et al. 1985, Snow and Vandenberg 2016).
- Concentrations of constituents that were below detection limits were assumed to be equal to half the detection limit.
- MIKE3 FM does not include a comprehensive ice module. The ice thickness and timing of ice-on/ice-off were manually applied to the Goose Lake Model based on the monitored data. The model assumes that ice forms on the lake at the same rate and at the same maximum thickness each year during the simulation period. Assumptions related to ice coverage are listed in Section 3.4.
- The Goose Lake Model does not account for the ice-water heat exchange; this assumption is not expected to materially affect water quality predictions.
- Free cyanide was assumed to be 10% of the total cyanide concentration (Mudder et al. 2001).
- The inputs to the model during the forecast period are based on average climate conditions (WSP Golder 2022).
- No groundwater inflows/outflows to/from Goose Lake were included in the Goose Lake Model.
- Iterative improvements to the Water and Load Balance Model resulted in the inputs used in this study to differ slightly from results presented in WSP Golder (2022); however, this is not expected to change the conclusions made in this study. Updates to both Water and Load Balance Model and Hydrodynamic Model

are expected as the Project proceeds to subsequent phases and additional site monitoring data are collected.

6.0 MODEL SIMULATIONS (FORECAST PERIOD)

Once the model calibration was complete, the Goose Lake Model was used to simulate water quality conditions over the forecast period (i.e., Construction, Operations, Closure, and post-closure).

7.0 MODEL RESULTS

Results of the Goose Lake Model over the forecast period are presented for:

- Timeseries of predicted constituent concentrations at the edges of mixing zones for the mine-affected inflows to Goose Lake (i.e., PN04, PN05, and PN08) (Appendix B).
- Timeseries of predicted daily in-lake constituent concentrations at the assessment locations (i.e., AEMP stations) (Appendix C).
- 50th (median) and 95th percentile of daily constituent concentrations based on the predicted timeseries for the edges of mixing zones and assessment locations (Table 6 to Table 9).

The 50th percentile and the more conservative 95th percentile concentrations were selected for comparisons to water quality benchmarks for the protection of aquatic life. Results are discussed further in the following subsections.

7.1 Predicted Concentrations at the Edge of Mixing Zones

The Goose Lake Model predictions at the edge of mixing zones for each mine-affected inflow (i.e., PN04, PN05, and PN08) are presented in Table 6 and Table 7, and Appendix B (timeseries plots). For PN04 and PN08 mine-affected inflows, the model results were extracted along an arc located at a radius of approximately 180 to 220 m from the discharge point to Goose Lake. For PN05, model results were extracted along the arc located at a radius of approximately 390 to 440 m, because the mesh cells located within the approximately 200 m radius from the PN05 discharge point did not contain water for the full duration of each year (i.e., the lake is frozen to bottom during winter at these locations) and thus the closest cell with unfrozen water for the entire year was selected to extract results.

The arcs encompass several adjacent grid cells to fully capture the concentration of each inflow plume across a range of current conditions. Model results (i.e., daily timeseries of concentrations) were extracted at several locations along the arc (i.e., extraction points, which contained water the entire year); then, daily concentrations were calculated for each arc by averaging the daily timeseries extracted from all extraction points.

As shown in Table 6, the 50th percentile of all constituent concentrations at the edge of mixing zones were predicted to remain below water quality benchmarks (Table 1) at all times. The 95th percentile of constituent concentrations at the edge of mixing zones (Table 7) were predicted to remain below the corresponding water quality benchmarks with the exception of phosphorus. Phosphorus concentrations were predicted to be slightly above the water quality benchmark at the edge of PN04, PN05, and PN08 mixing zones during the ice cover season over the Closure period. As presented in Table 7, the predicted 95th percentile of daily phosphorus concentrations during the open water season, when the effects from nutrient enrichment are more likely to occur, were below the water quality effect benchmark at the edge of the mixing zones. In addition, the predicted phosphorus concentrations are expected to be overestimated because the model treats phosphorus conservatively, and it does not consider biological uptake (e.g., uptake by algae during the open water season) which would result in reduction of phosphorus concentrations in the lake.

Daily timeseries of depth-averaged concentrations of TDS and other modelled water quality constituents at the edge of mixing zones over the forecast period are presented in Appendix B. On these figures, the timeseries are separately plotted with and without surface water quality benchmarks because many constituent concentrations are so far below the corresponding benchmark that changes, or lack of changes, in concentrations are not detectable at coarser scales if the benchmark is co-presented.

Overall, constituent concentrations were predicted to follow one of the two following patterns during the forecast period:

- **Peaking during Closure**, due to overflow from Llama, Umwelt, and Goose Main Pit lakes, **and decreasing into post-closure**: The concentrations of these constituents are predicted to stabilize about four to eight years into post-closure. Constituents included in this category are aluminum, ammonia, antimony, barium, boron, cadmium, calcium, chloride, chromium, copper, cyanide, fluoride, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, nitrate, phosphorus, selenium, silver, strontium, thallium, TDS, uranium, and zinc.
- **Increasing during Closure, peaking at the beginning of post-closure, and then decreasing or stabilizing into post-closure**: Constituents included in this category are arsenic and nitrite. The concentrations of these two constituents are predicted to increase slightly at the beginning of post-closure because treatment of mine-affected inflows stops at the end of Closure (i.e., concentrations in PN04 inflow at the start of post-closure are higher than at the end of Closure).

Table 6: Predicted 50th Percentile Daily Depth-Averaged Concentrations at the Edge of Mixing Zones in Goose Lake over the Forecast Period

Constituent	Units	Surface Water Quality Benchmark	Observed Background Concentrations in Goose Lake(a) 50th% (5th% - 95th%)	Edge of Mixing Zone for PN04				Edge of Mixing Zone for PN05				Edge of Mixing Zone for PN08			
				Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure
Aluminum	mg/L	0.063 - 0.41	0.0092 (0.0042 – 0.029)	0.02	0.026	0.046	0.038	0.02	0.023	0.039	0.034	0.021	0.025	0.042	0.038
Ammonia as nitrogen	mg-N/L	2.3 - 9.5	0.0074 (0.0025 – 0.036)	0.0049	0.005	0.54	0.0039	0.0048	0.0052	0.48	0.005	0.0047	0.0052	0.49	0.005
Arsenic	mg/L	0.025	0.00025 (0.00017 – 0.00045)	0.00041	0.00057	0.0048	0.0067	0.0004	0.00049	0.0048	0.0062	0.00042	0.00054	0.0051	0.0069
Boron	mg/L	1.5	0.0019 (0.0012 – 0.0062)	0.0045	0.005	0.24	0.036	0.0045	0.0051	0.22	0.036	0.0045	0.0052	0.22	0.04
Cadmium	mg/L	0.000036 - 0.00037	0.0000063 (0.0000025 – 0.000022)	0.0000095	0.000010	0.000033	0.000013	0.0000095	0.00001	0.000031	0.000013	0.0000095	0.00001	0.000031	0.000014
Calcium	mg/L	-	3.8 (2.3 – 7.2)	2.5	2.3	24	4.3	2.7	2.3	24	4.4	2.8	2.4	24	4.7
Chloride	mg/L	120	4 (1.6 – 10)	1.5	1.0	27	2.2	1.7	1.0	35	2.4	1.8	1.0	34	2.4
Chromium	mg/L	0.001	0.000083 (0.00003 – 0.00025)	0.00016	0.00018	0.00034	0.00023	0.00015	0.00017	0.00032	0.00023	0.00015	0.00018	0.00034	0.00024
Copper	mg/L	0.0042	0.0017 (0.0012 – 0.0033)	0.0015	0.0014	0.0019	0.0016	0.0015	0.0014	0.0018	0.0017	0.0016	0.0015	0.0019	0.0017
Cyanide (free)	mg/L	0.005	0.0025 (0.0005 – 0.0025)	0.00025	0.00023	0.00022	0.00015	0.00025	0.00024	0.00022	0.00015	0.00026	0.00024	0.00022	0.00016
Fluoride	mg/L	0.12	0.02 (0.01 – 0.034)	0.019	0.02	0.032	0.021	0.019	0.021	0.03	0.022	0.019	0.021	0.031	0.022
Iron	mg/L	0.3	0.009 (0.0024 – 0.029)	0.031	0.032	0.16	0.054	0.028	0.028	0.15	0.05	0.031	0.031	0.15	0.054
Lead	mg/L	0.0046 - 0.0098	0.000014 (0.000005 – 0.000071)	0.000046	0.000052	0.0011	0.00015	0.000045	0.000052	0.00098	0.00014	0.000045	0.000053	0.00099	0.00016
Magnesium	mg/L	-	2.1 (1.4 – 4.2)	1.5	1.3	4.2	1.7	1.5	1.3	3.9	1.7	1.6	1.4	3.9	1.8
Manganese	mg/L	0.19 - 0.71	0.0028 (0.00012 – 0.0091)	0.0033	0.0033	0.063	0.014	0.0031	0.003	0.058	0.014	0.0033	0.0032	0.06	0.016
Mercury	mg/L	0.000026	0.00025 (0.00000025 – 0.00082)	0.0000069	0.000008	0.0000093	0.0000082	0.0000067	0.000008	0.0000087	0.0000078	0.0000067	0.000008	0.0000092	0.0000084
Molybdenum	mg/L	0.073	0.000025 (0.000015 – 0.00032)	0.000052	0.000059	0.0013	0.00023	0.00005	0.000057	0.0012	0.00023	0.00005	0.000058	0.0012	0.00026
Nickel	mg/L	0.025 - 0.15	0.004 (0.0027 – 0.01)	0.0038	0.0039	0.016	0.006	0.0038	0.0038	0.015	0.0059	0.0039	0.0039	0.016	0.0063
Nitrate as nitrogen	mg-N/L	2.9 - 10	0.0096 (0.0025 – 0.13)	0.0063	0.0065	0.79	0.15	0.0062	0.0067	0.74	0.14	0.0062	0.0068	0.75	0.15
Nitrite as nitrogen	mg-N/L	0.06	0.0005 (0.0005 – 0.0013)	0.00095	0.0010	0.016	0.015	0.00094	0.001	0.015	0.015	0.00093	0.001	0.016	0.016
Phosphorus	mg/L	0.01	0.0037 (0.0023 – 0.007)	0.0024	0.002	0.0068	0.0065	0.0025	0.002	0.0078	0.0066	0.0026	0.0021	0.008	0.0071
Phosphorus (open water) (b)	mg/L	0.01	0.0038 (0.0018 – 0.0071)	0.002	0.0018	0.0061	0.0056	0.0019	0.0018	0.0069	0.0054	0.0019	0.0018	0.0069	0.0055
Selenium	mg/L	0.001	0.00002 (0.00002 – 0.00005)	0.000092	0.0001	0.00048	0.00016	0.00009	0.00011	0.00045	0.00016	0.00009	0.00011	0.00046	0.00017
Silver	mg/L	0.00025	0.0000025 (0.000001 – 0.000005)	0.0000091	0.00001	0.000021	0.000011	0.000009	0.00001	0.00002	0.000012	0.000009	0.000011	0.00002	0.000012
Thallium	mg/L	0.0008	0.0000025 (0.0000021 – 0.000025)	0.000044	0.00005	0.00008	0.000052	0.000044	0.000051	0.000078	0.000054	0.000044	0.000052	0.00008	0.000056
Total Dissolved Solids	mg/L	-	22 (14 – 43)	22	23	65	24	22	24	85	26	22	24	83	27
Uranium	mg/L	0.015	0.000005 (0.000005 – 0.000016)	0.0000095	0.00001	0.0022	0.00059	0.0000093	0.00001	0.002	0.00059	0.0000093	0.000011	0.0021	0.00066
Zinc	mg/L	0.0087 - 0.097	0.0015 (0.0004 – 0.0042)	0.0028	0.0032	0.0068	0.0036	0.0028	0.0032	0.0064	0.0037	0.0028	0.0032	0.0065	0.0038

a) The 50th percentile, 5th percentile and 95th percentile concentrations presented for Goose Lake are based on data from monitoring stations located in GLWB, GLCB, GLSE, and GLTL (2011-2013, 2017-2018, 2021) (Figure 1).
b) Open water time period is from 1 July to 15 October each year.
- = no guideline; mg-N/L = milligrams nitrogen per litre.

Table 7: Predicted 95th Percentile Daily Depth-Averaged Concentrations at the Edge of Mixing Zones in Goose Lake over the Forecast Period

Constituent	Units	Surface Water Quality Benchmark	Observed Background Concentrations in Goose Lake[a] 50th% (5th% - 95th%)	Edge of Mixing Zone for PN04				Edge of Mixing Zone for PN05				Edge of Mixing Zone for PN08			
				Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure
Aluminum	mg/L	0.063 - 0.41	0.0092 (0.0042 – 0.029)	0.038	0.054	0.073	0.056	0.034	0.042	0.07	0.06	0.035	0.042	0.071	0.061
Ammonia as nitrogen	mg-N/L	2.3 - 9.5	0.0074 (0.0025 – 0.036)	0.0062	0.0064	1.0	0.11	0.0085	0.0093	0.94	0.086	0.0089	0.0095	0.97	0.097
Arsenic	mg/L	0.025	0.00025 (0.00017 – 0.00045)	0.00088	0.0013	0.0068	0.012	0.00068	0.00089	0.0084	0.011	0.00073	0.00091	0.0087	0.011
Boron	mg/L	1.5	0.0019 (0.0012 – 0.0062)	0.0058	0.0064	0.38	0.099	0.0077	0.0093	0.39	0.1	0.008	0.0095	0.4	0.11
Cadmium	mg/L	0.000036 - 0.00037	0.0000063 (0.0000025 – 0.000022)	0.000012	0.000013	0.000052	0.000018	0.000016	0.000019	0.000055	0.000023	0.000017	0.000019	0.000057	0.000023
Calcium	mg/L	-	3.8 (2.3 – 7.2)	4.5	2.9	45	13	5.7	4.2	46	14	6.0	4.3	48	14
Chloride	mg/L	120	4 (1.6 – 10)	4.7	1.3	82	19	5.9	1.9	91	24	6.2	1.9	91	24
Chromium	mg/L	0.001	0.000083 (0.00003 – 0.00025)	0.00021	0.00022	0.0005	0.00029	0.00026	0.00032	0.00057	0.0004	0.00028	0.00032	0.00058	0.0004
Copper	mg/L	0.0042	0.0017 (0.0012 – 0.0033)	0.002	0.0018	0.0026	0.0021	0.0028	0.0026	0.0031	0.0029	0.0028	0.0027	0.0031	0.0029
Cyanide (free)	mg/L	0.005	0.0025 (0.0005 – 0.0025)	0.00032	0.0003	0.00032	0.00019	0.00046	0.00043	0.0004	0.00027	0.00046	0.00044	0.00042	0.00027
Fluoride	mg/L	0.12	0.02 (0.01 – 0.034)	0.024	0.026	0.046	0.027	0.032	0.038	0.053	0.038	0.034	0.038	0.054	0.038
Iron	mg/L	0.3	0.009 (0.0024 – 0.029)	0.048	0.066	0.27	0.087	0.054	0.051	0.26	0.091	0.054	0.052	0.27	0.092
Lead	mg/L	0.0046 - 0.0098	0.000014 (0.000005 – 0.000071)	0.000059	0.000065	0.0018	0.00047	0.000078	0.000095	0.0018	0.00049	0.000081	0.000096	0.0018	0.0005
Magnesium	mg/L	-	2.1 (1.4 – 4.2)	2.5	1.7	6.7	2.4	3.1	2.4	7.1	3.0	3.3	2.5	7.2	3.0
Manganese	mg/L	0.19 - 0.71	0.0028 (0.00012 – 0.0091)	0.0048	0.0055	0.1	0.028	0.0058	0.0053	0.1	0.029	0.0058	0.0054	0.11	0.03
Mercury	mg/L	0.000026	0.00025 (0.00000025 – 0.00082)	0.0000094	0.0000098	0.000012	0.00001	0.000011	0.000014	0.000015	0.000014	0.000012	0.000014	0.000015	0.000014
Molybdenum	mg/L	0.073	0.000025 (0.000015 – 0.00032)	0.000067	0.000071	0.0023	0.00051	0.000086	0.0001	0.0022	0.00051	0.00009	0.0001	0.0023	0.00052
Nickel	mg/L	0.025 - 0.15	0.004 (0.0027 – 0.01)	0.0047	0.0048	0.028	0.0085	0.0068	0.0069	0.028	0.01	0.0069	0.007	0.029	0.01
Nitrate as nitrogen	mg-N/L	2.9 - 10	0.0096 (0.0025 – 0.13)	0.0083	0.0084	1.6	0.57	0.011	0.012	1.3	0.59	0.012	0.012	1.3	0.59
Nitrite as nitrogen	mg-N/L	0.06	0.0005 (0.0005 – 0.0013)	0.0012	0.0013	0.025	0.023	0.0016	0.0019	0.027	0.025	0.0017	0.0019	0.027	0.026
Phosphorus	mg/L	0.01	0.0037 (0.0023 – 0.007)	0.0048	0.0025	**0.012**	0.0081	0.0061	0.0037	**0.014**	**0.011**	0.0064	0.0037	**0.014**	**0.011**
Phosphorus (open water)[b]	mg/L	0.01	0.0038 (0.0018 – 0.0071)	0.0024	0.0019	0.0077	0.0065	0.0026	0.0018	0.0083	0.0065	0.0026	0.0018	0.0084	0.0066
Selenium	mg/L	0.001	0.00002 (0.00002 – 0.00005)	0.00012	0.00013	0.00078	0.00024	0.00015	0.00019	0.0008	0.00028	0.00016	0.00019	0.00083	0.00028
Silver	mg/L	0.00025	0.0000025 (0.000001 – 0.000005)	0.000012	0.000013	0.000032	0.000015	0.000015	0.000019	0.000035	0.00002	0.000016	0.000019	0.000036	0.00002
Thallium	mg/L	0.0008	0.0000025 (0.0000021 – 0.000025)	0.000057	0.000064	0.00012	0.000067	0.000073	0.000093	0.00014	0.000094	0.000078	0.000095	0.00014	0.000096
Total Dissolved Solids	mg/L	-	22 (14 – 43)	28	29	182	56	38	43	206	69	40	44	208	67
Uranium	mg/L	0.015	0.000005 (0.000005 – 0.000016)	0.000012	0.000013	0.0039	0.00097	0.000016	0.000019	0.0037	0.001	0.000017	0.000019	0.0039	0.0011
Zinc	mg/L	0.0087 - 0.097	0.0015 (0.0004 – 0.0042)	0.0036	0.004	0.01	0.0046	0.0048	0.0058	0.011	0.0063	0.005	0.0059	0.012	0.0064

a) The 50th percentile, 5th percentile and 95th percentile concentrations presented for Goose Lake are based on data from monitoring stations located in GLWB, GLCB, GLSE, and GLTL (2011-2013, 2017-2018, 2021) (Figure 1).
b) Open water time period is from 1 July to 15 October each year.
Bold indicates concentration is above a chronic water quality benchmark.
- = no guideline; mg-N/L = milligrams nitrogen per litre.

7.2 Predicted In-Lake Concentrations over the Forecast Period

The Goose Lake Model predictions for in-lake concentrations over the forecast period are presented in tabular format in Table 8 and Table 9 as 50th and 95th percentile daily depth-averaged concentrations, respectively. Results are presented for three assessment locations (Figure 1):

- GLCB, in the central basin of Goose Lake
- GLTL, in the tail of Goose Lake (i.e., upstream of the outlet channel)
- Outflow, at the outlet of Goose Lake (i.e., PN03)

Daily timeseries of depth-averaged concentrations of modelled water quality constituents over the forecast period are presented in Appendix C. For the lake outlet, timeseries plots present predicted concentrations for the open water season only because the outflow channel is frozen during the ice cover season and no discharges from Goose Lake are anticipated during this season. Similar to the figures in Appendix B, the timeseries are separately plotted with and without surface water quality benchmarks because many constituent concentrations are so far below the corresponding benchmark that changes, or lack of changes, in concentrations are not detectable at coarser scales if the benchmark is co-presented. Results for the west and south basins of Goose Lake (i.e., GLWB and GLSE) are similar to those presented in Section 7.1 for PN04 and PN05.

As shown in Table 8 and Table 9, the 50th and 95th percentile of all daily-depth-averaged constituent concentrations at the assessment locations (i.e., central basin, the tail, and lake outflow) are predicted to remain below benchmarks, except for occasional benchmark exceedances of the 95th percentile concentrations of iron and phosphorus for one or more mining phases, as described below:

- At the GLTL (i.e., Goose Lake's tail), the 95th percentile of daily iron concentrations is predicted to be slightly above the applicable water quality benchmark during the Closure period (Table 9). During the Closure period, timeseries plots at GLTL (Appendix C) show that daily iron concentrations are predicted to be slightly above the water quality benchmark for several days during each ice cover season over a 4-year period (i.e., approximately 18 days/year). Cryoconcentration effects are more pronounced in the tail of Goose Lake because the channel connecting the lake's tail to the main basin of the lake freezes to the bottom, which results in the tail, which is relatively a small area of the lake, to be annually disconnected from the lake. The outlet channel of the lake also freezes to the bottom during ice cover season; therefore, no outflow from Goose Lake occurs during the ice cover season.
- The 95th percentile of daily phosphorus concentrations is predicted to be slightly above the water quality benchmark during Closure (i.e., at GLTL and GLCB) and post-closure (i.e., at GLTL) under ice cover conditions (Table 9 and Appendix C). The predicted 95th percentile daily phosphorus concentrations during the open water season, when the effects from nutrient enrichment are more likely to occur, were below the water quality effect benchmark at all assessment locations.

As described in Section 5.0, water quality constituents are modelled as conservative constituents in the water column, meaning that they do not undergo chemical or biological reactions or physical processes that would remove mass from the system, besides through advective outflow. This assumption adds conservatism to the modelling because it can result in an overestimation of some in-lake constituent concentrations.

Table 8: Predicted 50th Percentile Daily (Depth-Averaged) Concentrations in Goose Lake at the Assessment Locations over the Forecast Period

Constituent	Units	Surface Water Quality Benchmark	Observed Background Concentrations in Goose Lake[a] 50th% (5th% - 95th%)	Goose Lake Central Basin (GLCB)				Goose Lake's Tail (GLTL)				Goose Lake Outflow				
				Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure	Observed Background Concentrations in Goose Lake Outflow 50th% (5th% - 95th%)	Construction	Operations	Closure	Post-closure
Aluminum	mg/L	0.063 - 0.35	0.0082 (0.0042 – 0.021)	0.02	0.023	0.039	0.034	0.02	0.025	0.041	0.036	0.012 (0.0027 - 0.029)	0.018	0.02	0.036	0.029
Ammonia as nitrogen	mg-N/L	2.9 - 12	0.017 (0.0025 – 0.04)	0.0047	0.0052	0.47	0.0044	0.0048	0.0055	0.5	0.0052	0.0052 (0.0025 - 0.025)	0.0044	0.0045	0.42	0.003
Arsenic	mg/L	0.025	0.00023 (0.00015 – 0.0005)	0.0004	0.00049	0.0047	0.0061	0.00041	0.00053	0.0048	0.0063	0.00019 (0.00014 - 0.00023)	0.00037	0.00043	0.0043	0.0052
Boron	mg/L	1.5	0.0025 (0.0014 – 0.0076)	0.0044	0.0052	0.22	0.035	0.0045	0.0055	0.22	0.038	0.003 (0.0005 - 0.0079)	0.0041	0.0045	0.2	0.027
Cadmium	mg/L	0.000036 - 0.00031	0.000005 (0.0000025 – 0.000011)	0.0000095	0.00001	0.00003	0.000013	0.0000097	0.000011	0.000031	0.000014	0.0000055 (0.0000025 - 0.000012)	0.0000085	0.000009	0.000026	0.000011
Calcium	mg/L	-	3.7 (2.2 – 6.4)	2.7	2.3	23	4.2	2.9	2.5	24	4.7	2.6 (1.8 - 4)	2.2	2.0	19	3.3
Chloride	mg/L	120	3.9 (1.4 – 9.7)	1.7	1.0	34	2.2	1.9	1.1	35	2.5	2.9 (1.4 - 7)	1.1	0.9	35	1.6
Chromium	mg/L	0.001	0.00011 (0.00003 – 0.00025)	0.00015	0.00018	0.00032	0.00023	0.00016	0.00019	0.00033	0.00024	0.000086 (0.00003 - 0.00015)	0.00014	0.00015	0.00029	0.00019
Copper	mg/L	0.0042	0.0017 (0.0012 – 0.0032)	0.0015	0.0015	0.0018	0.0017	0.0016	0.0015	0.0019	0.0017	0.0014 (0.0011 - 0.0017)	0.0013	0.0013	0.0016	0.0014
Cyanide (free)	mg/L	0.005	0.0025 (0.0005 – 0.0025)	0.00025	0.00024	0.00022	0.00016	0.00027	0.00025	0.00023	0.00016	0.0016 (0.0005 - 0.0025)	0.00022	0.00021	0.00016	0.00013
Fluoride	mg/L	0.12	0.023 (0.01 – 0.031)	0.018	0.021	0.03	0.022	0.019	0.022	0.031	0.023	0.012 (0.01 - 0.031)	0.017	0.018	0.027	0.018
Iron	mg/L	0.3	0.005 (0.0018 – 0.024)	0.029	0.029	0.15	0.049	0.031	0.03	0.15	0.053	0.017 (0.0041 - 0.06)	0.024	0.025	0.13	0.04
Lead	mg/L	0.0028 - 0.0092	0.000025 (0.0000025 – 0.00013)	0.000045	0.000053	0.00097	0.00014	0.000045	0.000056	0.00099	0.00015	0.000017 (0.000005 - 0.000025)	0.000042	0.000046	0.00086	0.00011
Magnesium	mg/L	-	1.9 (1.3 – 3.5)	1.6	1.4	3.9	1.7	1.7	1.4	3.9	1.8	1.5 (0.95 - 2.2)	1.2	1.2	3.6	1.4
Manganese	mg/L	0.2 - 0.76	0.0016 (0.000059 – 0.0057)	0.0031	0.003	0.057	0.014	0.0033	0.0032	0.059	0.015	0.0042 (0.0011 - 0.01)	0.0026	0.0026	0.05	0.011
Mercury	mg/L	0.000026	0.000005 (0.00000025 – 0.00068)	0.0000066	0.0000078	0.0000087	0.0000078	0.0000067	0.0000083	0.0000093	0.0000082	0.00023 (0.00000051 - 0.0012)	0.0000061	0.0000068	0.0000075	0.0000066
Molybdenum	mg/L	0.073	0.000025 (0.000015 – 0.000031)	0.00005	0.000057	0.0012	0.00022	0.00005	0.000061	0.0012	0.00024	0.000035 (0.000025 - 0.00015)	0.000046	0.000049	0.00099	0.00018
Nickel	mg/L	0.025 - 0.15	0.0049 (0.0027 – 0.0085)	0.0038	0.0039	0.015	0.0058	0.004	0.0041	0.015	0.0062	0.0034 (0.0021 - 0.0055)	0.0033	0.0033	0.013	0.0047
Nitrate as nitrogen	mg-N/L	2.9 - 10	0.0076 (0.0025 – 0.056)	0.0062	0.0068	0.73	0.13	0.0062	0.0072	0.74	0.14	0.0058 (0.0025 - 0.027)	0.0057	0.0058	0.69	0.11
Nitrite as nitrogen	mg-N/L	0.06	0.0005 (0.0005 – 0.0005)	0.00092	0.001	0.015	0.014	0.00095	0.0011	0.015	0.015	0.0005 (0.0005 - 0.0005)	0.00086	0.0009	0.014	0.012
Phosphorus	mg/L	0.01	0.0034 (0.0025 – 0.0074)	0.0026	0.002	0.0076	0.0065	0.0027	0.0022	0.008	0.0067	0.0045 (0.0005 - 0.007)	0.0019	0.0018	0.0069	0.0054
Phosphorus (open water) [b]	mg/L	0.01	0.0038 (0.0028 – 0.008)	0.0019	0.0018	0.0069	0.0054	0.0019	0.0018	0.0069	0.0053	0.0034 (0.0005 - 0.0047)	0.0019	0.0018	0.0069	0.0053
Selenium	mg/L	0.001	0.000031 (0.00002 – 0.00005)	0.00009	0.00011	0.00044	0.00016	0.00009	0.00011	0.00045	0.00017	0.000038 (0.00002 - 0.00005)	0.000084	0.000092	0.00038	0.00013
Silver	mg/L	0.00025	0.0000025 (0.000001 – 0.000005)	0.0000089	0.00001	0.00002	0.000012	0.000009	0.000011	0.00002	0.000012	0.000004 (0.0000025 - 0.000005)	0.0000083	0.0000091	0.000018	0.0000097
Thallium	mg/L	0.0008	0.0000025 (0.000002 – 0.000029)	0.000043	0.000052	0.000077	0.000054	0.000044	0.000055	0.00008	0.000057	0.00002 (0.0000025 - 0.00005)	0.00004	0.000045	0.00007	0.000046
Total Dissolved Solids	mg/L	-	20 (14 – 36)	22	24	84	26	23	25	87	28	16 (12 - 28)	20	21	84	20
Uranium	mg/L	0.015	0.000005 (0.000005 – 0.000013)	0.0000092	0.000011	0.002	0.00058	0.0000094	0.000011	0.0021	0.00062	0.000005 (0.000005 - 0.000005)	0.0000085	0.0000091	0.0018	0.00047
Zinc	mg/L	0.0094 - 0.079	0.0015 (0.0004 – 0.0022)	0.0028	0.0032	0.0064	0.0036	0.0028	0.0034	0.0064	0.0038	0.0012 (0.0004 - 0.0015)	0.0026	0.0028	0.0056	0.003

a) The 50th percentile, 5th percentile and 95th percentile concentrations presented for Goose Lake are based on data from monitoring stations located in GLCB and GLTL (2011-2013, 2017-2018, 2021) (Figure 1).

b) Open water time period is from 1 July to 15 October each year.

- = no guideline; mg-N/L = milligrams nitrogen per litre.

Table 9: Predicted 95th Percentile Daily (Depth-Averaged) Concentrations in Goose Lake at the Assessment Locations over the Forecast Period

Constituent	Units	Surface Water Quality Benchmark	Observed Background Concentrations in Goose Lake[(a)] 50th% (5th% - 95th%)	Goose Lake Central Basin (GLCB)				Goose Lake's Tail (GLTL)				Goose Lake Outflow				
				Construction	Operations	Closure	Post-closure	Construction	Operations	Closure	Post-closure	Observed Background Concentrations in Goose Lake Outflow 50th% (5th% - 95th%)	Construction	Operations	Closure	Post-closure
Aluminum	mg/L	0.063 - 0.35	0.0082 (0.0042 – 0.021)	0.03	0.034	0.061	0.05	0.037	0.044	0.08	0.065	0.012 (0.0027 - 0.029)	0.02	0.021	0.038	0.032
Ammonia as nitrogen	mg-N/L	2.9 - 12	0.017 (0.0025 – 0.04)	0.0073	0.0076	0.86	0.085	0.0094	0.0099	1.1	0.096	0.0052 (0.0025 - 0.025)	0.0048	0.0048	0.64	0.064
Arsenic	mg/L	0.025	0.00023 (0.00015 – 0.0005)	0.00062	0.00072	0.0074	0.0088	0.00077	0.00094	0.0097	0.011	0.00019 (0.00014 - 0.00023)	0.00044	0.00044	0.0049	0.0057
Boron	mg/L	1.5	0.0025 (0.0014 – 0.0076)	0.0067	0.0076	0.35	0.099	0.0084	0.0099	0.45	0.11	0.003 (0.0005 - 0.0079)	0.0047	0.0048	0.24	0.083
Cadmium	mg/L	0.000036 - 0.00031	0.000005 (0.0000025 – 0.000011)	0.000014	0.000015	0.00005	0.00002	0.000018	0.00002	0.000064	0.000025	0.0000055 (0.0000025 - 0.000012)	0.0000094	0.0000097	0.000034	0.000015
Calcium	mg/L	-	3.7 (2.2 – 6.4)	5.2	3.4	44	14	6.5	4.4	55	15	2.6 (1.8 - 4)	2.8	2.1	31	11
Chloride	mg/L	120	3.9 (1.4 – 9.7)	5.4	1.5	85	23	6.7	2.0	107	26	2.9 (1.4 - 7)	2.3	0.97	59	20
Chromium	mg/L	0.001	0.00011 (0.00003 – 0.00025)	0.00023	0.00026	0.0005	0.00033	0.00029	0.00033	0.00066	0.00043	0.000086 (0.00003 - 0.00015)	0.00016	0.00016	0.00032	0.00022
Copper	mg/L	0.0042	0.0017 (0.0012 – 0.0032)	0.0023	0.0021	0.0027	0.0024	0.003	0.0028	0.0036	0.0031	0.0014 (0.0011 - 0.0017)	0.0014	0.0013	0.0017	0.0016
Cyanide (free)	mg/L	0.005	0.0025 (0.0005 – 0.0025)	0.00038	0.00035	0.00035	0.00022	0.00049	0.00045	0.00045	0.00029	0.0016 (0.0005 - 0.0025)	0.00024	0.00022	0.00024	0.00014
Fluoride	mg/L	0.12	0.023 (0.01 – 0.031)	0.028	0.031	0.047	0.032	0.036	0.04	0.061	0.041	0.012 (0.01 - 0.031)	0.019	0.019	0.03	0.021
Iron	mg/L	0.3	0.005 (0.0018 – 0.024)	0.047	0.042	0.24	0.083	0.059	0.054	**0.30**	0.098	0.017 (0.0041 - 0.06)	0.026	0.026	0.16	0.068
Lead	mg/L	0.0028 - 0.0092	0.000025 (0.0000025 – 0.00013)	0.000068	0.000077	0.0016	0.00047	0.000085	0.0001	0.002	0.00051	0.000017 (0.000005 - 0.000025)	0.000048	0.000049	0.0011	0.00039
Magnesium	mg/L	-	1.9 (1.3 – 3.5)	2.9	2.0	6.3	2.6	3.6	2.6	8.2	3.2	1.5 (0.95 - 2.2)	1.6	1.3	4.3	2.1
Manganese	mg/L	0.2 - 0.76	0.0016 (0.000059 – 0.0057)	0.0051	0.0043	0.096	0.028	0.0063	0.0056	0.12	0.031	0.0042 (0.0011 - 0.01)	0.0028	0.0027	0.064	0.023
Mercury	mg/L	0.000026	0.000005 (0.00000025 – 0.00068)	0.00001	0.000012	0.000013	0.000011	0.000012	0.000015	0.000017	0.000015	0.00023 (0.00000051 - 0.0012)	0.0000076	0.0000072	0.0000082	0.0000072
Molybdenum	mg/L	0.073	0.000025 (0.000015 – 0.000031)	0.000074	0.000084	0.002	0.0005	0.000095	0.00011	0.0025	0.00053	0.000035 (0.000025 - 0.00015)	0.000051	0.000052	0.0013	0.00041
Nickel	mg/L	0.025 - 0.15	0.0049 (0.0027 – 0.0085)	0.0056	0.0056	0.026	0.0087	0.0073	0.0073	0.033	0.011	0.0034 (0.0021 - 0.0055)	0.0035	0.0035	0.017	0.0068
Nitrate as nitrogen	mg-N/L	2.9 - 10	0.0076 (0.0025 – 0.056)	0.0094	0.0099	1.2	0.56	0.012	0.013	1.5	0.6	0.0058 (0.0025 - 0.027)	0.0062	0.0063	0.78	0.48
Nitrite as nitrogen	mg-N/L	0.06	0.0005 (0.0005 – 0.0005)	0.0014	0.0015	0.023	0.021	0.0018	0.002	0.031	0.027	0.0005 (0.0005 - 0.0005)	0.00095	0.00096	0.015	0.015
Phosphorus	mg/L	0.01	0.0034 (0.0025 – 0.0074)	0.0056	0.003	**0.013**	0.0093	0.007	0.0039	**0.016**	**0.012**	0.0045 (0.0005 - 0.007)	0.0028	0.0019	0.0084	0.0066
Phosphorus (open water)[(b)]	mg/L	0.01	0.0038 (0.0028 – 0.008)	0.0026	0.0018	0.0083	0.0065	0.0026	0.0018	0.0083	0.0065	0.0034 (0.0005 - 0.0047)	0.0026	0.0018	0.0083	0.0065
Selenium	mg/L	0.001	0.000031 (0.00002 – 0.00005)	0.00014	0.00015	0.00073	0.00025	0.00017	0.0002	0.00093	0.0003	0.000038 (0.00002 - 0.00005)	0.000096	0.000098	0.00048	0.0002
Silver	mg/L	0.00025	0.0000025 (0.000001 – 0.000005)	0.000013	0.000015	0.000032	0.000017	0.000017	0.00002	0.000041	0.000022	0.000004 (0.0000025 - 0.000005)	0.0000095	0.0000097	0.000021	0.000012
Thallium	mg/L	0.0008	0.0000025 (0.000002 – 0.000029)	0.000066	0.000076	0.00012	0.000079	0.000082	0.000099	0.00016	0.0001	0.00002 (0.0000025 - 0.00005)	0.000047	0.000048	0.000079	0.000054
Total Dissolved Solids	mg/L	-	20 (14 – 36)	33	35	194	67	42	45	242	72	16 (12 - 28)	22	22	132	55
Uranium	mg/L	0.015	0.000005 (0.000005 – 0.000013)	0.000014	0.000015	0.0034	0.00097	0.000018	0.00002	0.0043	0.0011	0.000005 (0.000005 - 0.000005)	0.0000095	0.0000097	0.0023	0.00075
Zinc	mg/L	0.0094 - 0.079	0.0015 (0.0004 – 0.0022)	0.0042	0.0047	0.01	0.0053	0.0053	0.0061	0.013	0.0069	0.0012 (0.0004 - 0.0015)	0.0029	0.003	0.0067	0.0037

a) The 50th percentile, 5th percentile and 95th percentile concentrations presented for Goose Lake are based on data from monitoring stations located in GLCB and GLTL (2011-2013, 2017-2018, 2021) (Figure 1).

b) Open water time period is from 1 July to 15 October each year.

Bold indicates concentration is above a chronic water quality benchmark. Comparisons to benchmarks were completed prior to rounding.

- = no guideline; mg-N/L = milligrams nitrogen per litre.

8.0 SENSITIVITY ANALYSIS

Sensitivity analysis of the Goose Lake Model was completed to better understand the potential implications of model uncertainty and to estimate whether reasonable adjustments to inputs or assumptions would change the overall conclusions of this study (i.e., whether constituent concentrations would exceed benchmarks).

Six sensitivity scenarios were completed to evaluate the model's sensitivity to input meteorological conditions, ice cover period, and quantity and quality of inflows to Goose Lake. For ease of interpretation, the details for each scenario are provided, along with the summary of results, in Appendix D, Table D1.

In this section and Appendix D, the forecast period model setup and results (presented in Sections 6.0 and 7.0) is referred to as the Base Case scenario. The simulation period for the sensitivity scenarios was set from Year 17 to 27 (i.e., last 6 years of Closure Phase and first 5 years of post-closure period). This 10—year period was selected because the constituent concentrations were predicted to peak during this period under the Base Case conditions. The sensitivity scenarios were run for a limited constituent list, including TDS (to provide an overall understanding of mixing conditions), several metals (i.e., aluminum, arsenic, copper, iron, and selenium) and two of nutrients (i.e., nitrite and phosphorus). Initial conditions for the sensitivity runs were set using the Base Case model results.

The results of sensitivity scenarios are presented for:

- Timeseries of predicted in-lake daily depth-averaged constituent concentrations at Goose Lake central basin (i.e., GLCB) and Lake Outlet (Appendix D, Figures D1 to D6).
- 50^{th} and 95^{th} percentile of daily depth-averaged constituent concentrations based on the predicted timeseries for Goose Lake central basin (i.e., GLCB) and Lake Outlet (Appendix D, Tables D2 to D7).

In Appendix D, the figures and tables include results for sensitivity scenarios alongside the Base Case (Section 7.2). On these figures, the timeseries are plotted with and without the surface water quality benchmark. Figures D2, D4, and D6 present predicted timeseries concentrations at the Lake Outlet timeseries during the open water season since there is no outflow from the lake during the ice cover season.

Results (Appendix D) indicate that reasonable adjustments to the key model inputs did not result in significant changes to predicted concentrations. Relative to the Base Case, none of the sensitivity runs resulted in the predicted 95^{th} percentile concentration exceeding benchmarks for additional constituents.

9.0 SUMMARY AND CONCLUSIONS

The Goose Lake hydrodynamic and water quality model was developed using MIKE3 FM to predict water quality concentrations in Goose Lake during the Construction, Operations, Closure, and post-closure periods of the Project.

The model was calibrated using observed data and reproduced seasonal fluctuations in water levels, outflow rates, current speeds, water temperatures, and TDS concentrations across the lake. Overall, the model calibration indicates that the model is tracking the movement of water and dissolved constituents reasonably well throughout the lake.

During the 67-year forecast period of the model (i.e., Construction, Operations, Closure, and post-closure), 95th percentile concentrations of constituents are predicted to remain below water quality benchmarks (Table 1) at the edge of mixing zones, with the exception of phosphorus. The predicted 95th percentile concentration of phosphorus at two other assessment locations (i.e., central basin and tail of Goose Lake) also were above the benchmark. The conservative model approach adopted (e.g., exclusion of biological uptake during open-water conditions) likely contributed to the exceedances of the phosphorus benchmark. The predicted 95th percentile concentrations of phosphorus during the open water season, when nutrient enrichment effects are more likely to occur, were below the benchmark at all locations in Goose Lake.

During Closure, the predicted 95th percentile concentration of iron was slightly above the water quality benchmark in the tail of Goose Lake. During this time period, daily iron concentrations are predicted to exceed the benchmark for a short period during the ice cover season at Goose Lake's tail, which is a small area of the lake that gets disconnected from rest of the lake annually. However, as noted above, the lake outflow is frozen during the ice cover season and no discharges from Goose Lake are anticipated during this period.

Mine-affected discharges to Goose Lake are not planned to occur until Year 16 (WSP Golder 2022), which provides a period of time during Operations to better understand the system. During this time, Sabina will continue monitoring site water quality, inflows to the lake, water quality in the lake, and can improve and refine the assumptions and approaches used in the WLB and Goose Lake models, such as incorporating updates to source terms, water quality input assumptions, water management approach, revaluating site-specific water quality objectives, as needed, based on literature values or by performing site-specific toxicity testing. If necessary, the identification of mitigation measures (e.g., treatment options), and testing their effectiveness with the Goose Lake model, can be completed in advance of initiating discharges to Goose Lake.

10.0 SIGNATURE PAGE

We trust that the content of this technical report meets your expectations. Please do not hesitate to contact the undersigned should you have any questions or comments.

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https://golderassociates.sharepoint.com/sites/136792/project files/5 technical work/2400_hydrodynamic/reporting/final_submitted_aug 2022_rev. 0/21505757-118-r-rev0-15000-goose lake hydrodynamic report 26aug_22.docx

11.0 STUDY LIMITATIONS

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APPENDIX A

Goose Lake Model - Calibration Results - Profile Plots

Figures below present profile plots of modelled and observed temperature (Figures A1 to A4), and modelled TDS concentrations and observed specific conductivity (SC) (Figures A5 to A8) at the calibration stations (i.e., GLWB, GLCB, GLSE, and GLTL).

As discussed in Section 4.0, observed TDS was not available for vertical profiles, thus observed specific conductivity (SC) was instead used to evaluate calibration performance for vertical TDS profiles. The calibration was considered adequate if the observed specific conductivity and predicted TDS followed the same pattern, while recognizing that the values would not be expected to match.

Figure A1: Modelled and Observed Temperature Profiles in Goose Lake at GLWB during the Calibration Period

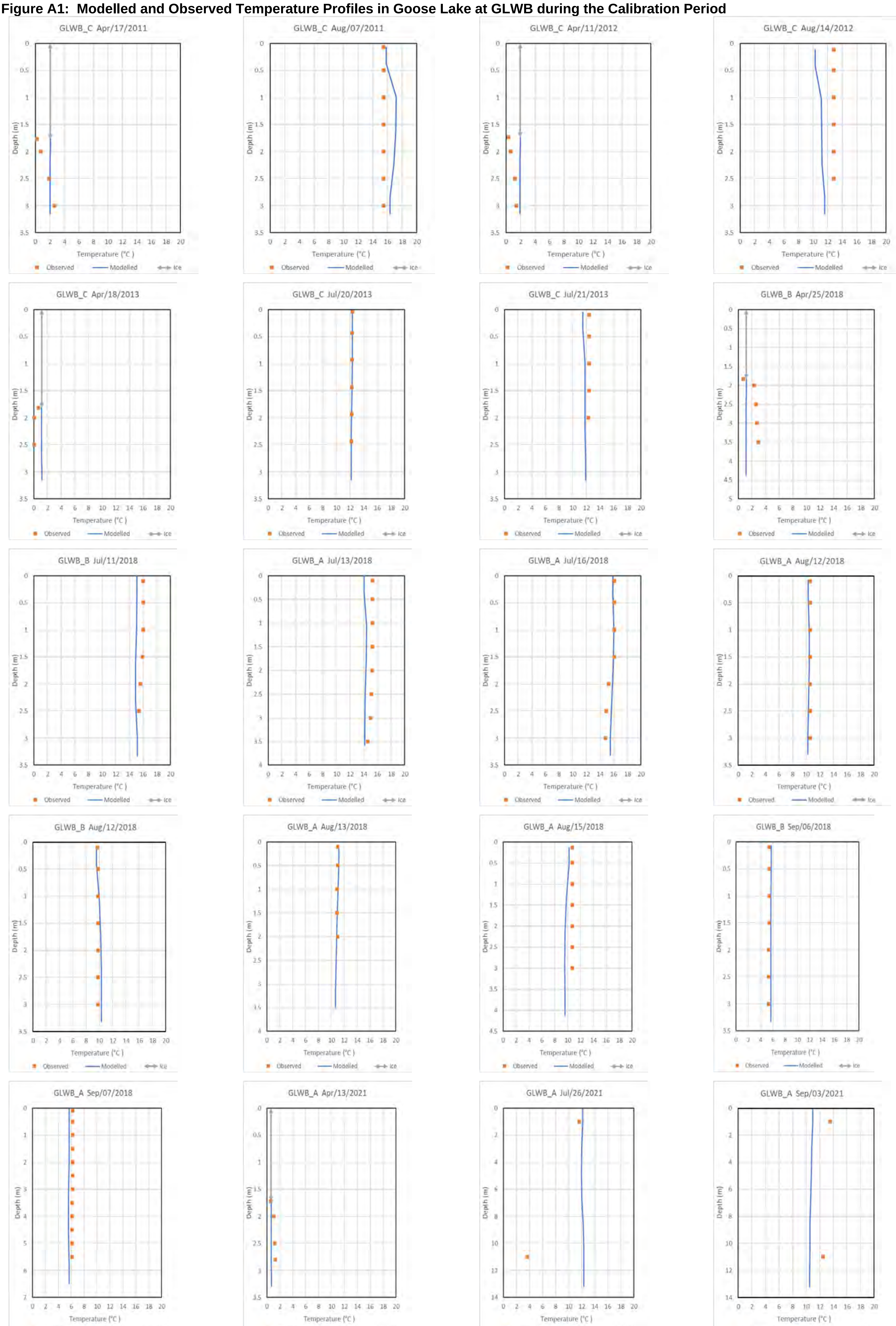


Figure A2: Modelled and Observed Temperature Profiles in Goose Lake at GLCB during the Calibration Period

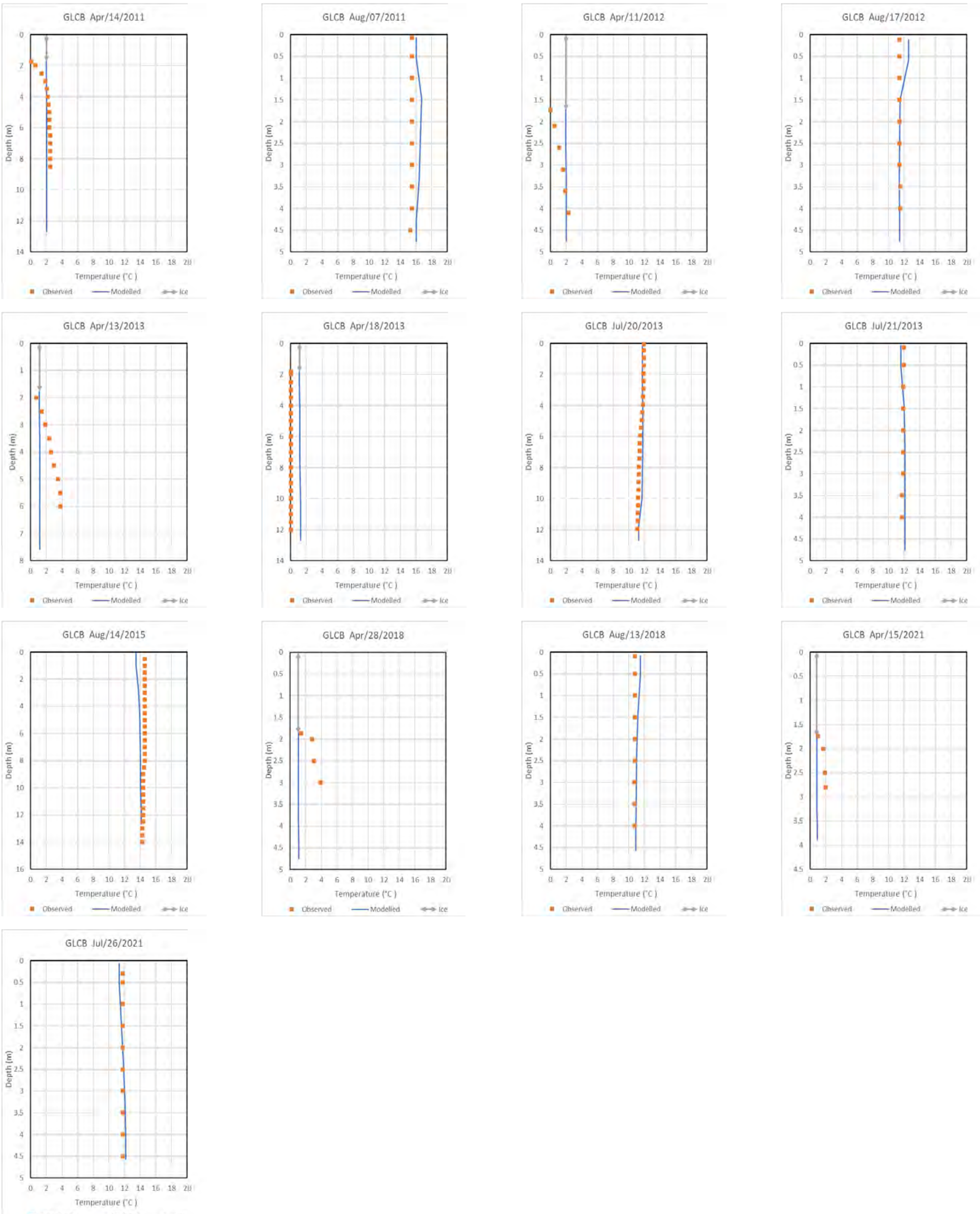


Figure A3: Modelled and Observed Temperature Profiles in Goose Lake at GLSE during the Calibration Period

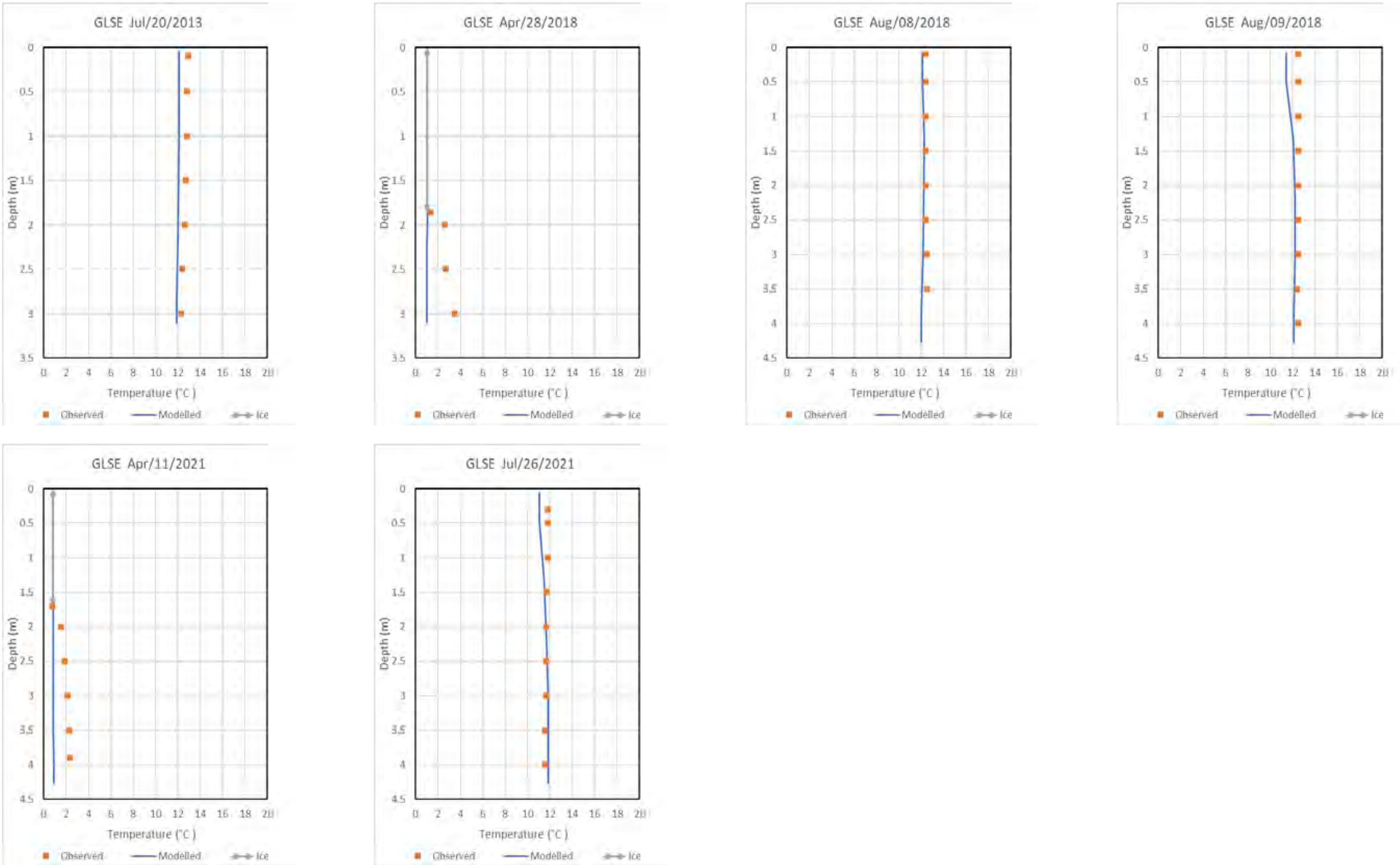


Figure A4: Modelled and Observed Temperature Profiles in Goose Lake at GLTL during the Calibration Period

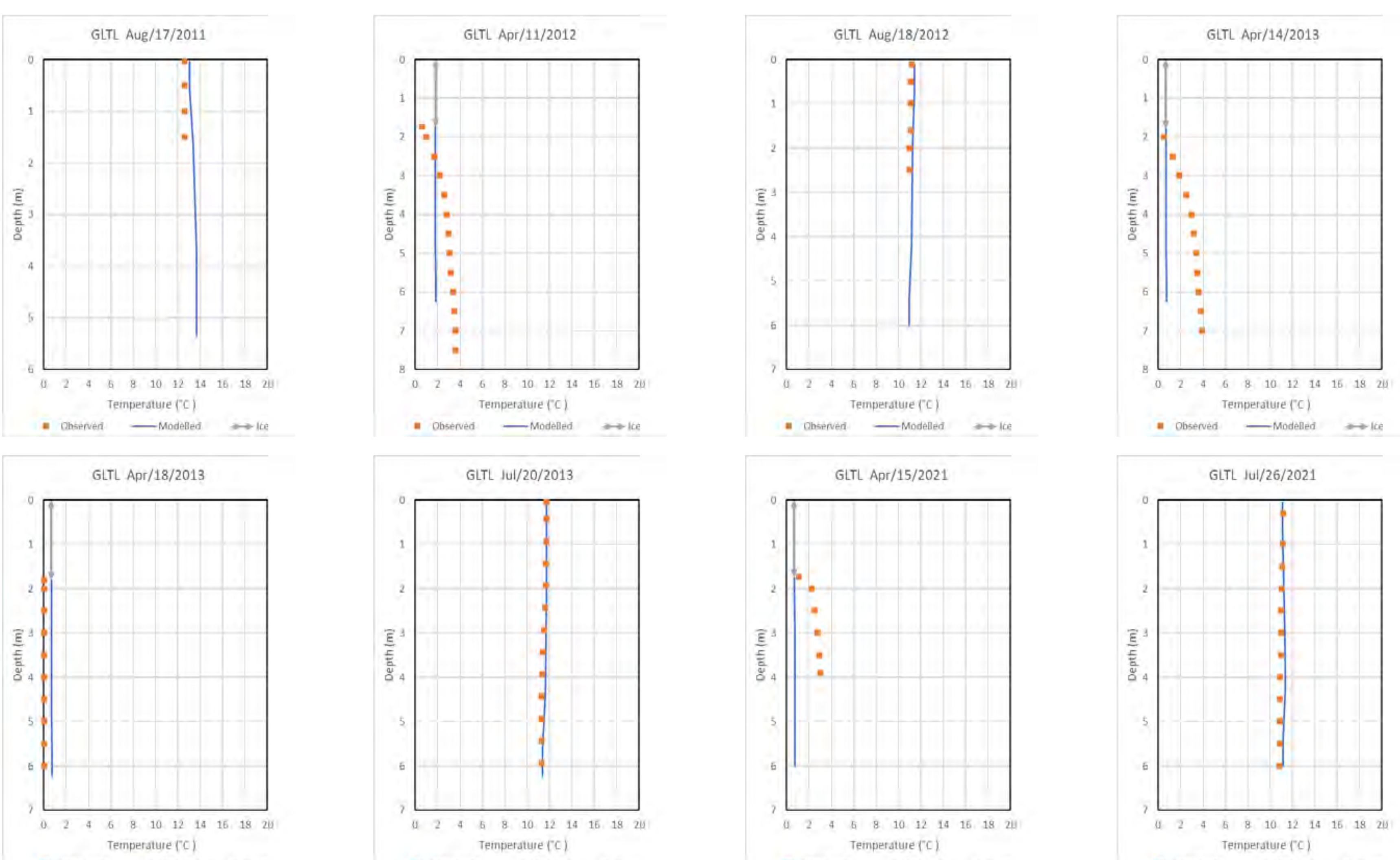


Figure A5: Modelled TDS and Observed Specific Conductivity (SC) Profiles in Goose Lake at GLWB during the Calibration Period

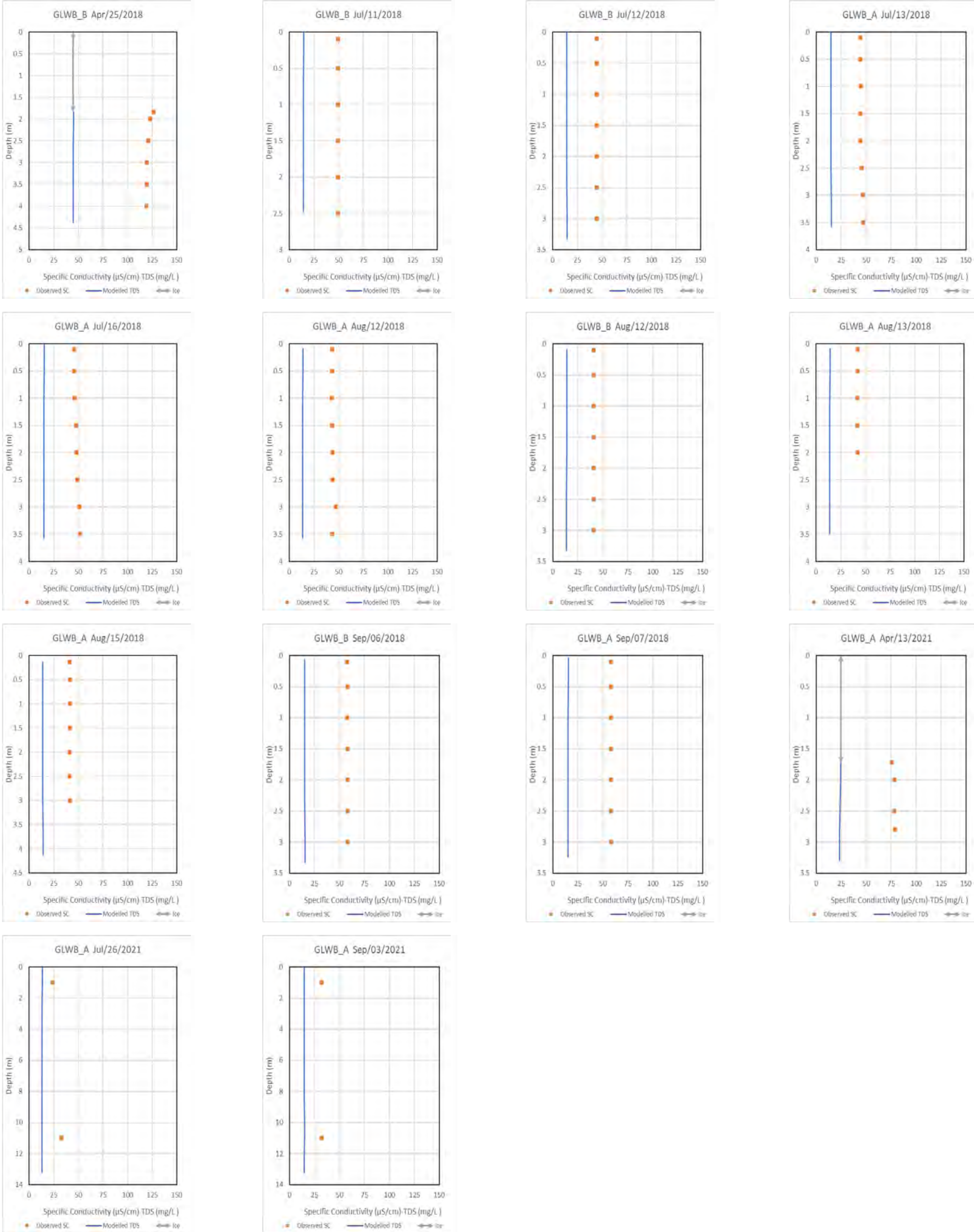


Figure A6: Modelled TDS and Observed Specific Conductivity (SC) Profiles in Goose Lake at GLCB during the Calibration Period

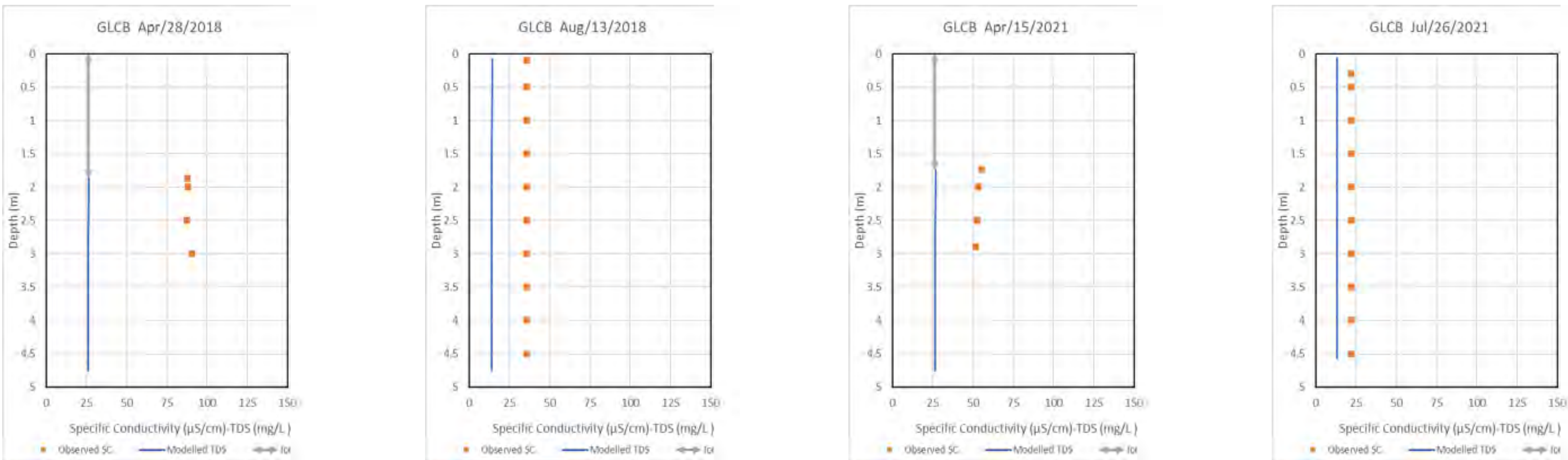


Figure A7: Modelled TDS and Observed Specific Conductivity (SC) Profiles in Goose Lake at GLSE during the Calibration Period

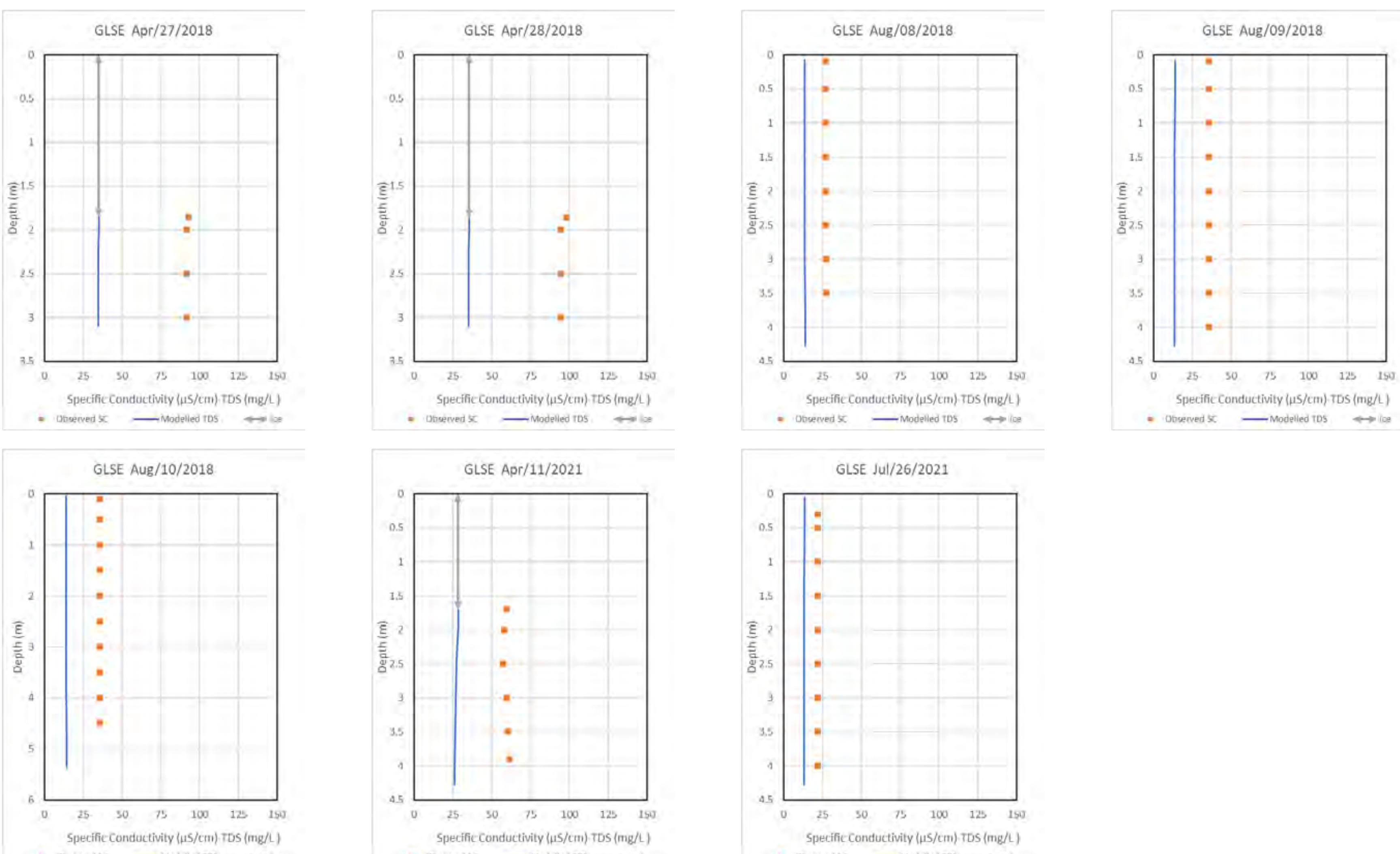
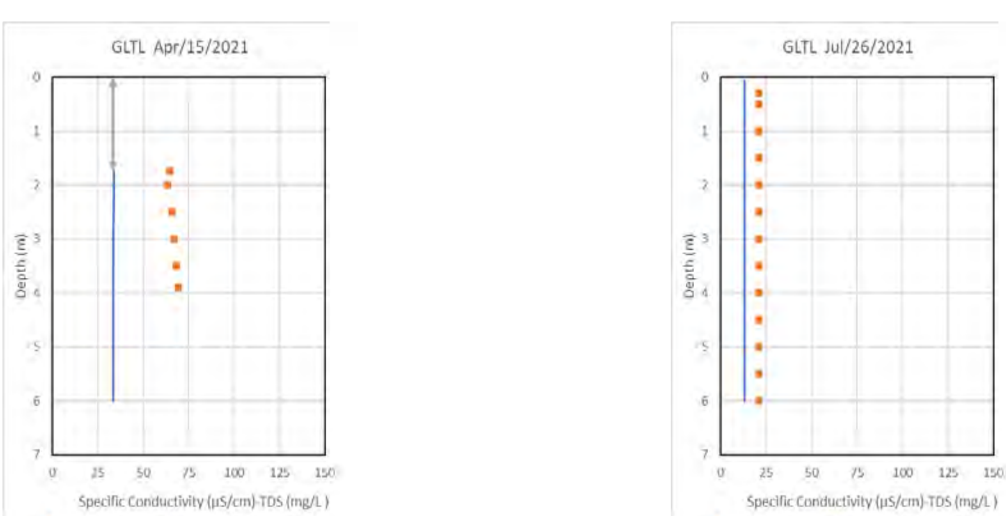


Figure A8: Modelled TDS and Observed Specific Conductivity (SC) Profiles in Goose Lake at GLTL during the Calibration Period

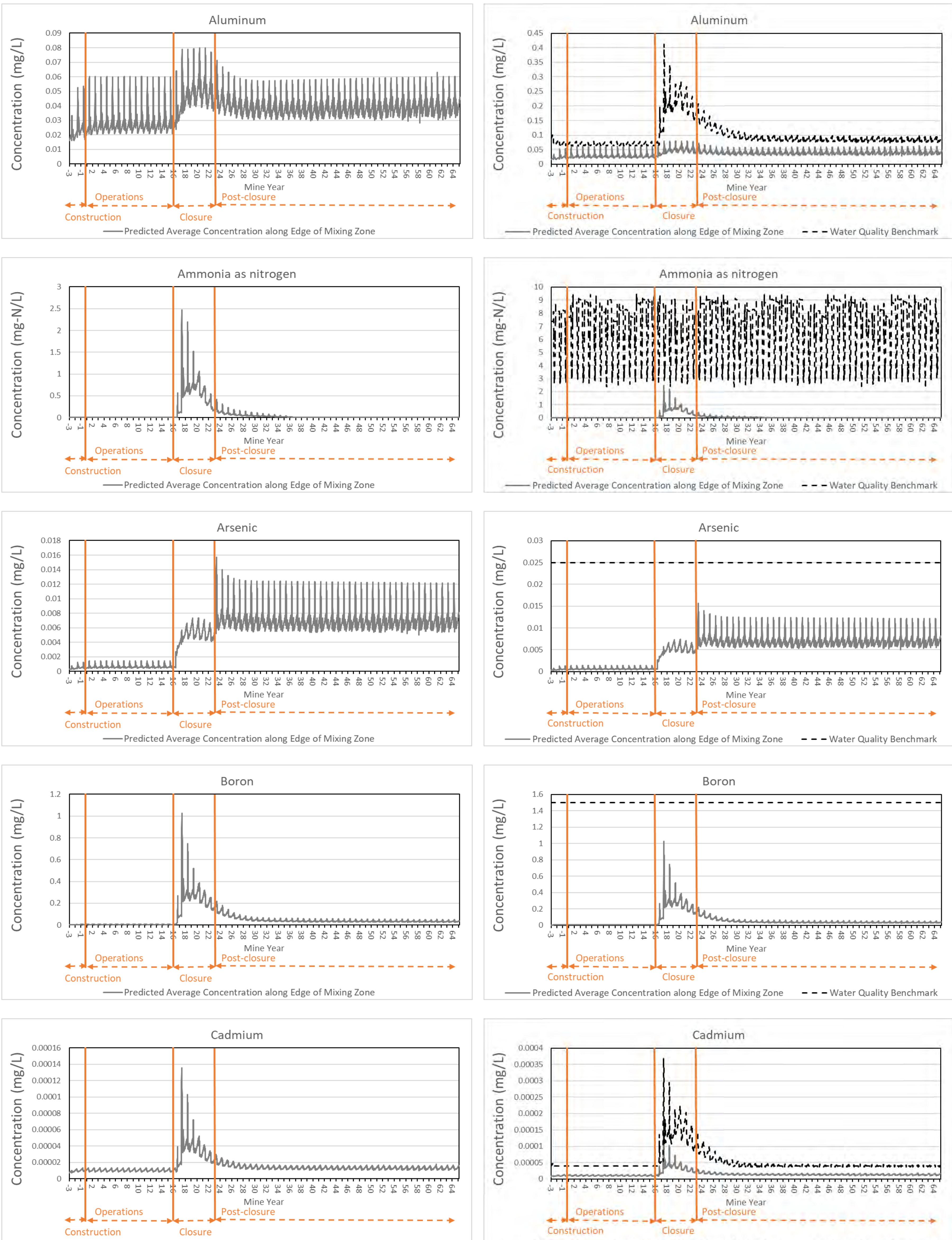


APPENDIX B

Goose Lake Model - Timeseries of Predicted Constituent Concentrations at the Edges of Mixing Zones during the Forecast Period

Please note the timeseries are separately plotted with and without surface water quality benchmarks (except for calcium, magnesium and TDS which don’t have benchmarks, see Table 1) because many constituent concentrations are so far below the corresponding benchmark that changes, or lack of changes, in concentrations are not detectable at coarser scales if the benchmark is co-presented.

Figure B1: Predicted Timeseries Concentration of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN04 over the Construction, Operations, Closure and Post-closure Periods



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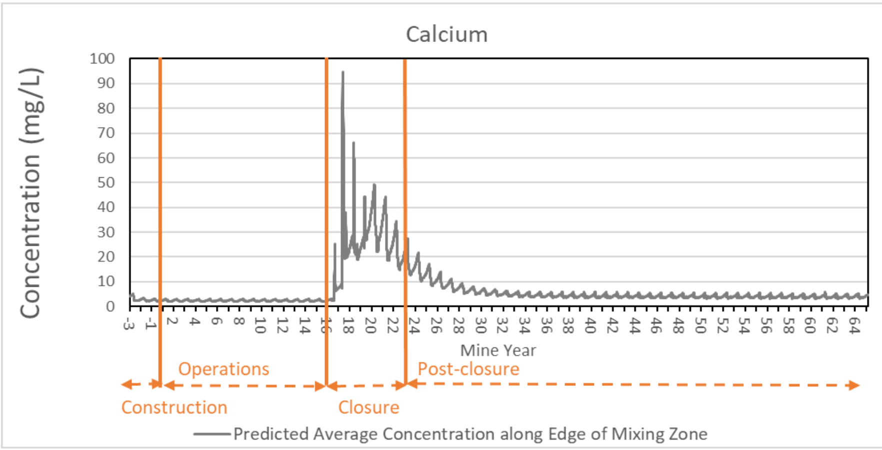
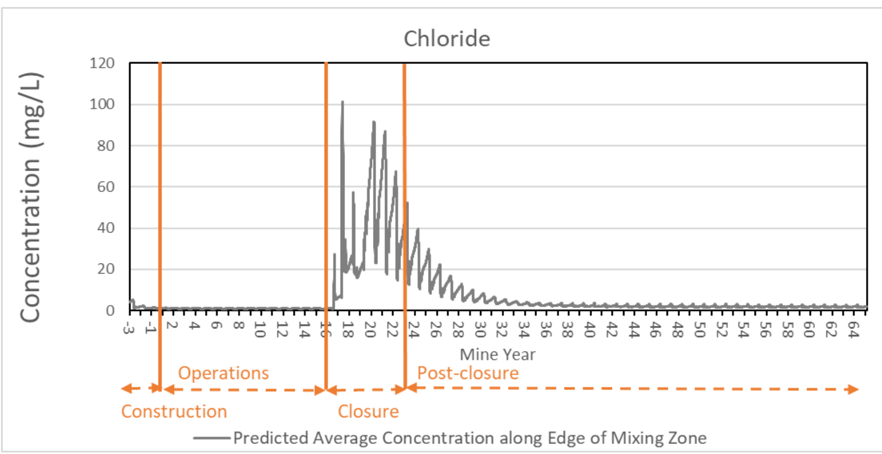
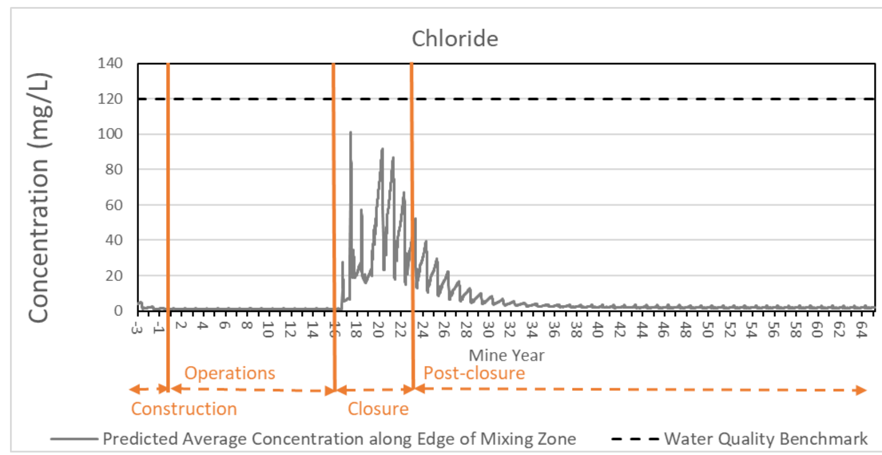
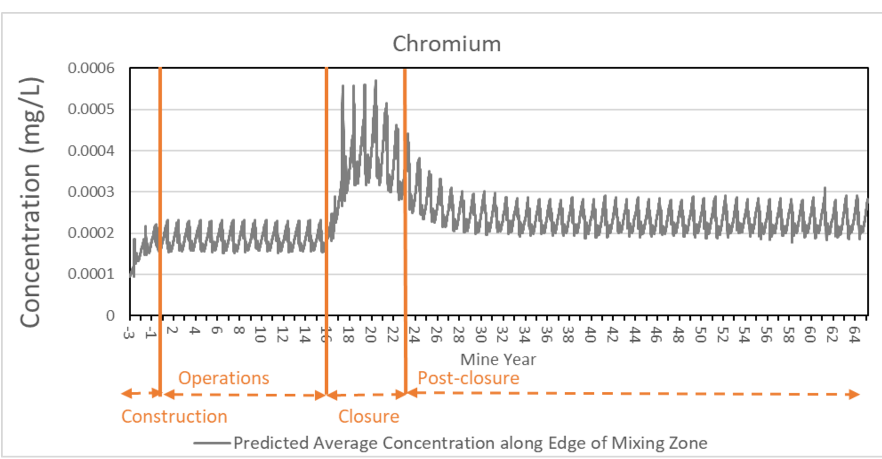
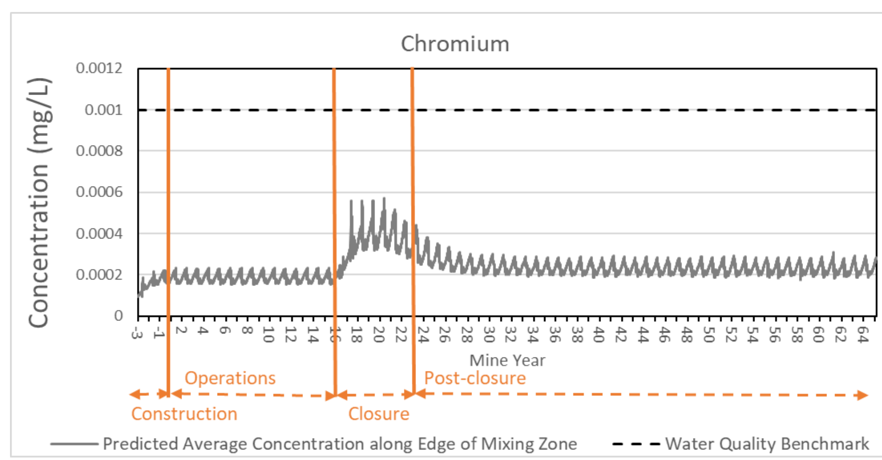
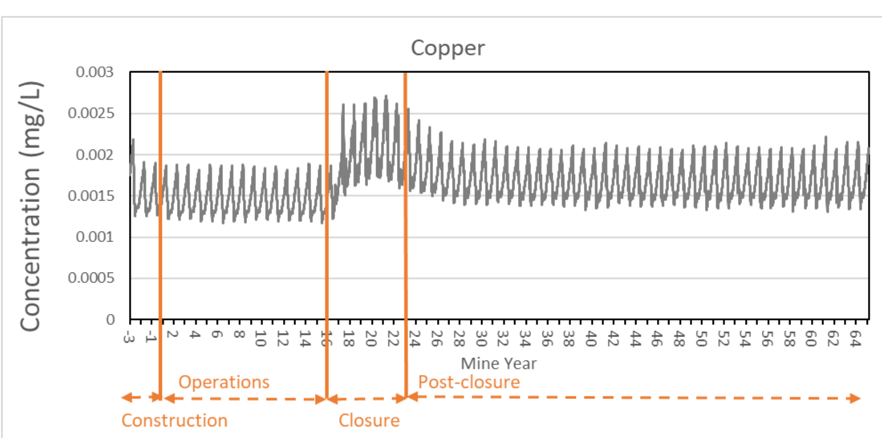


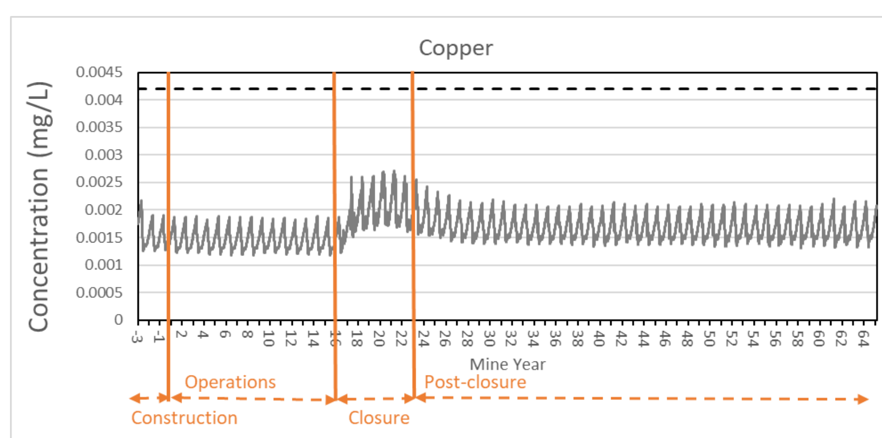


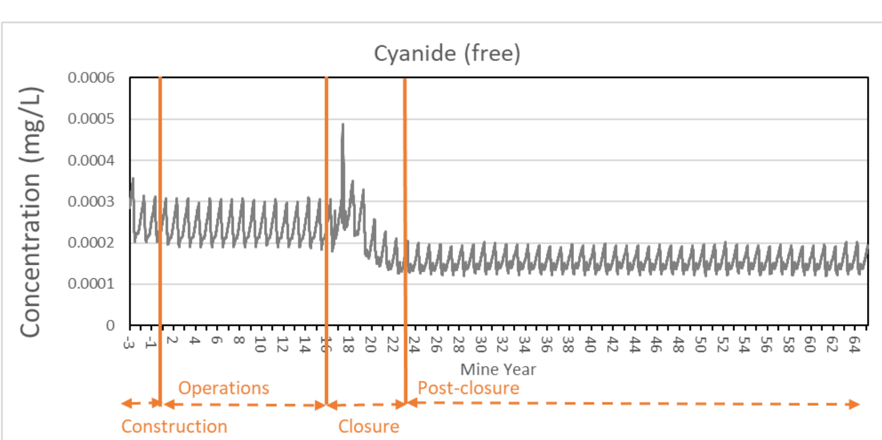












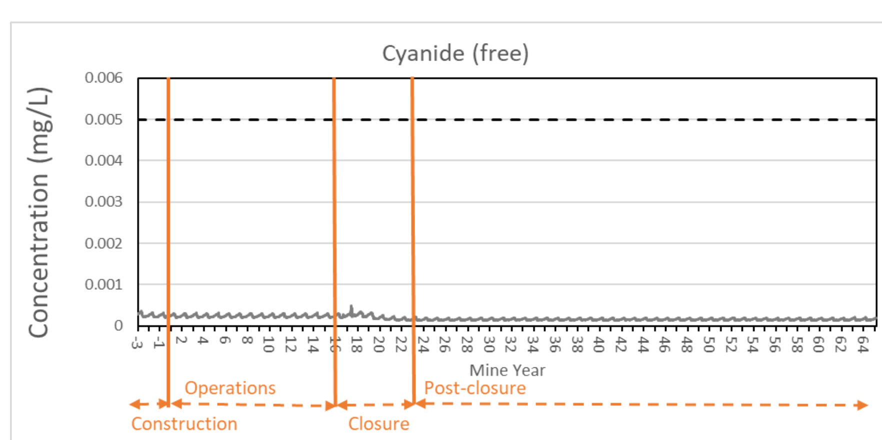
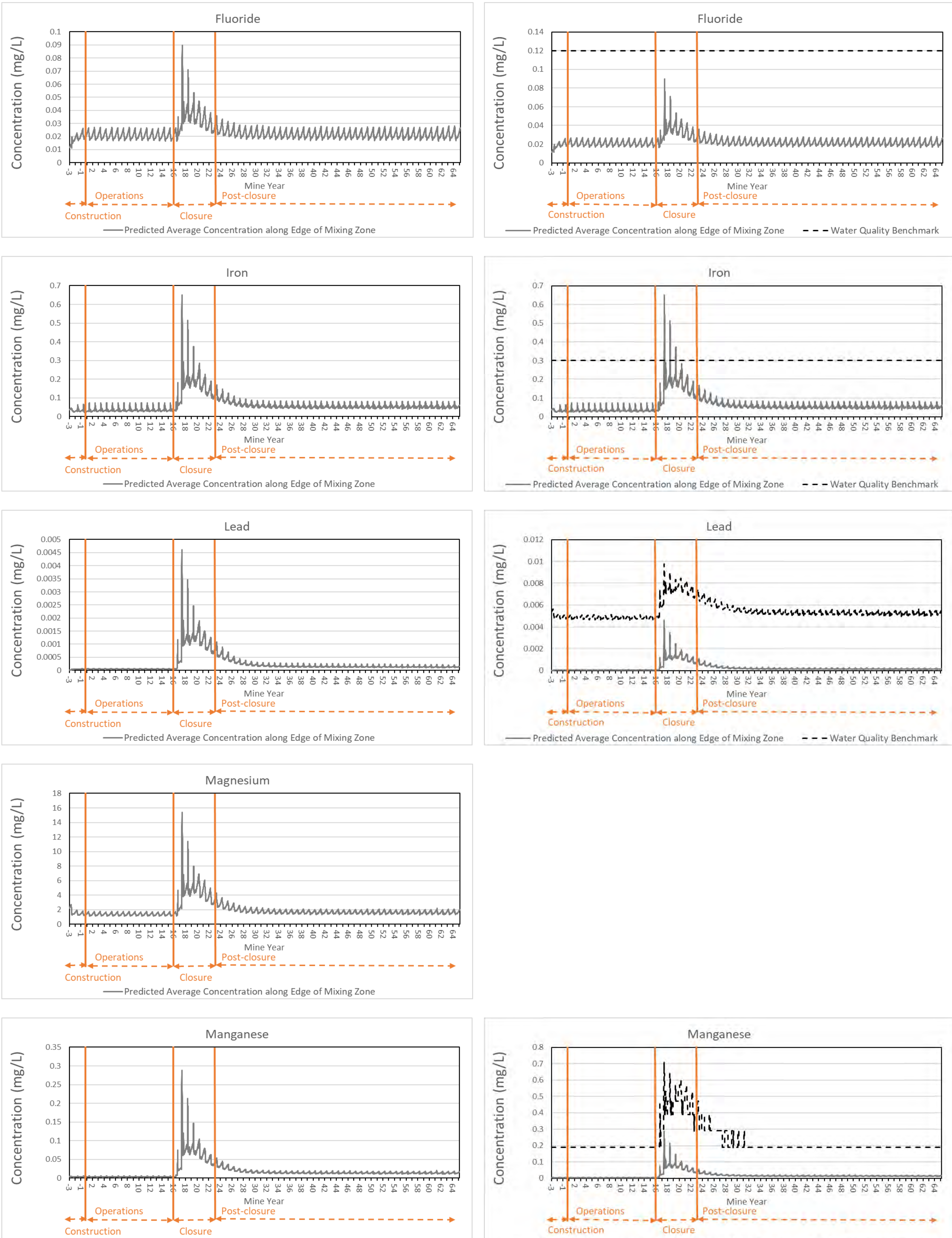


Figure B1: Predicted Timeseries Concentration of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN04 over the Construction, Operations, Closure and Post-closure Periods



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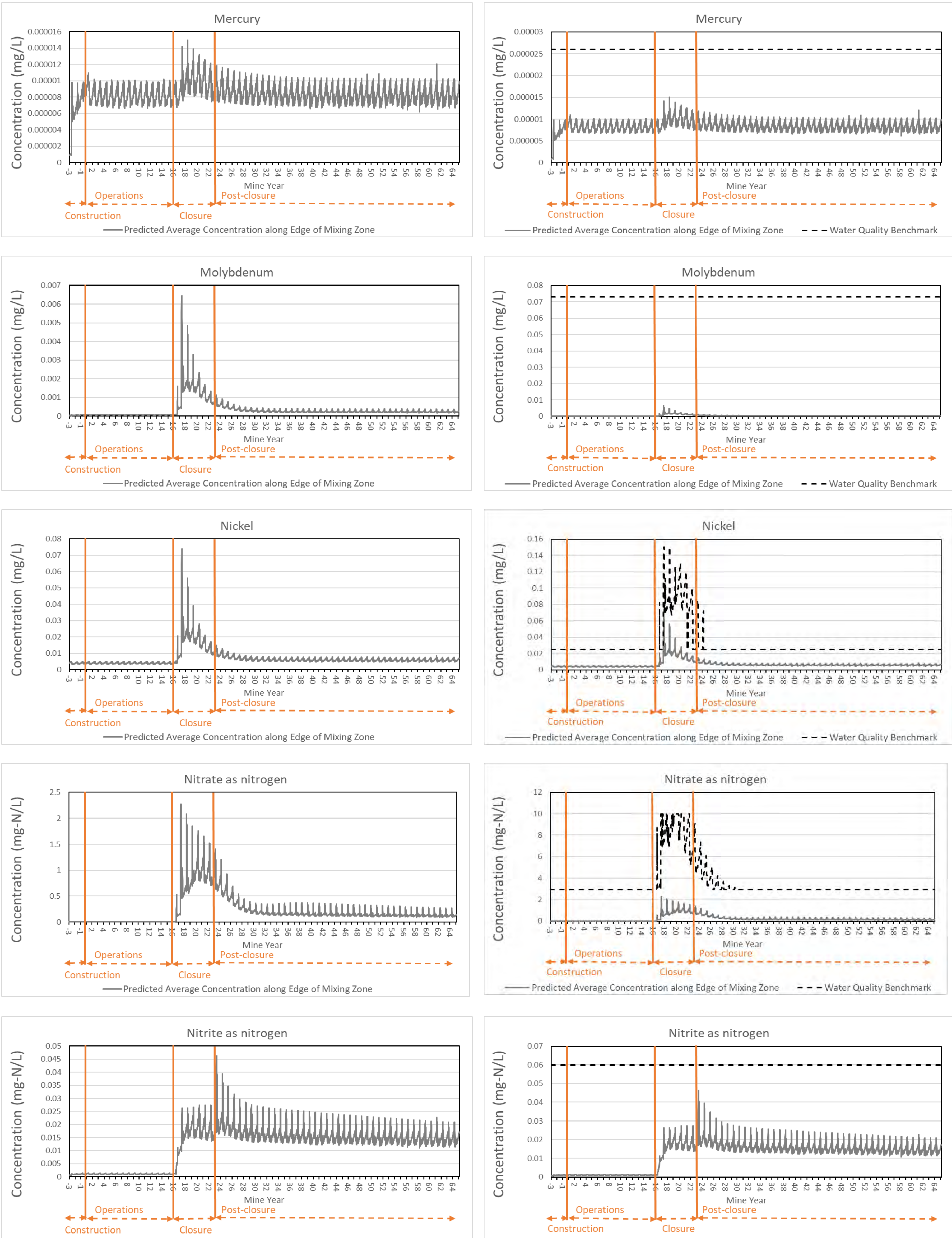

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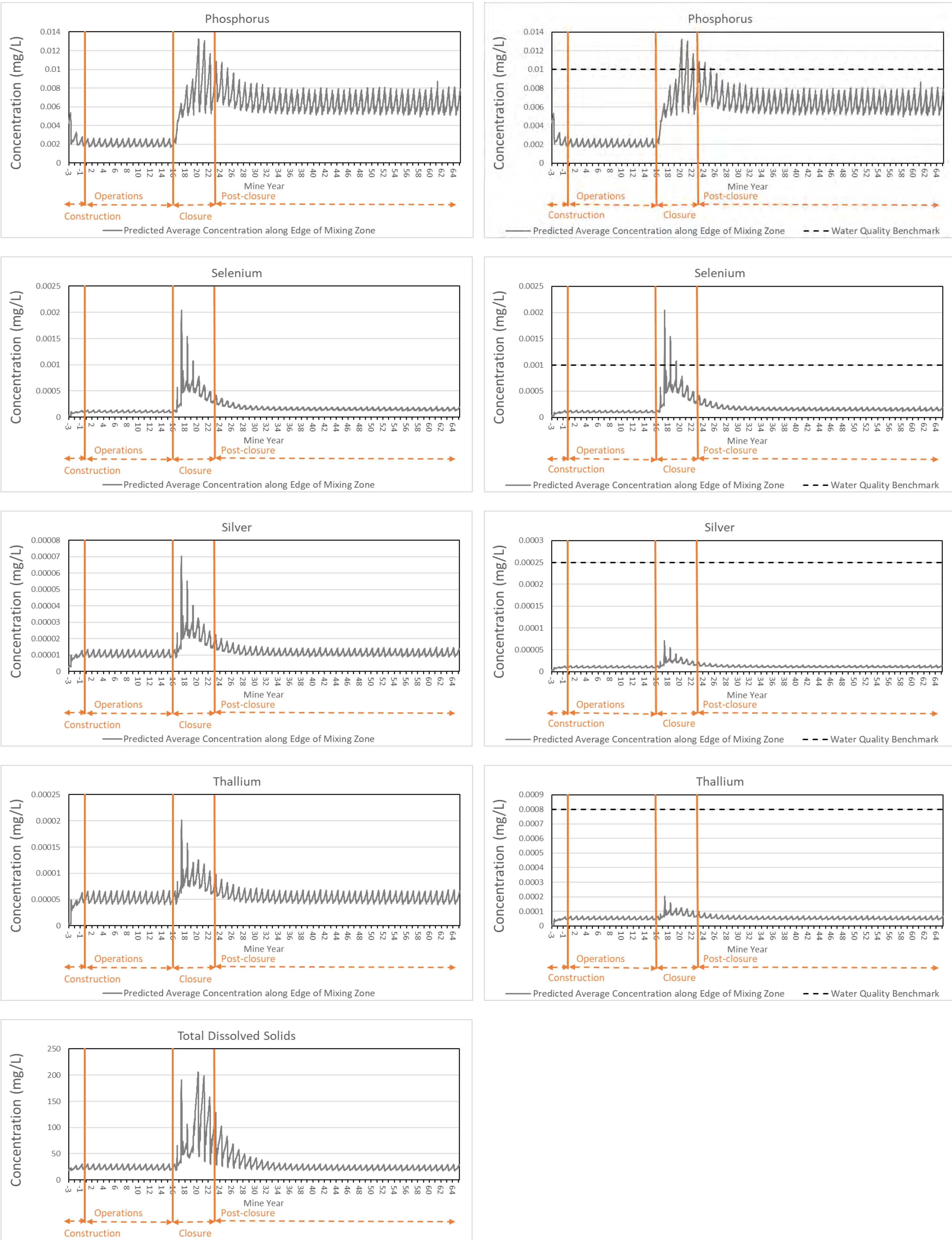


Figure B1: Predicted Timeseries Concentration of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN04 over the Construction, Operations, Closure and Post-closure Periods

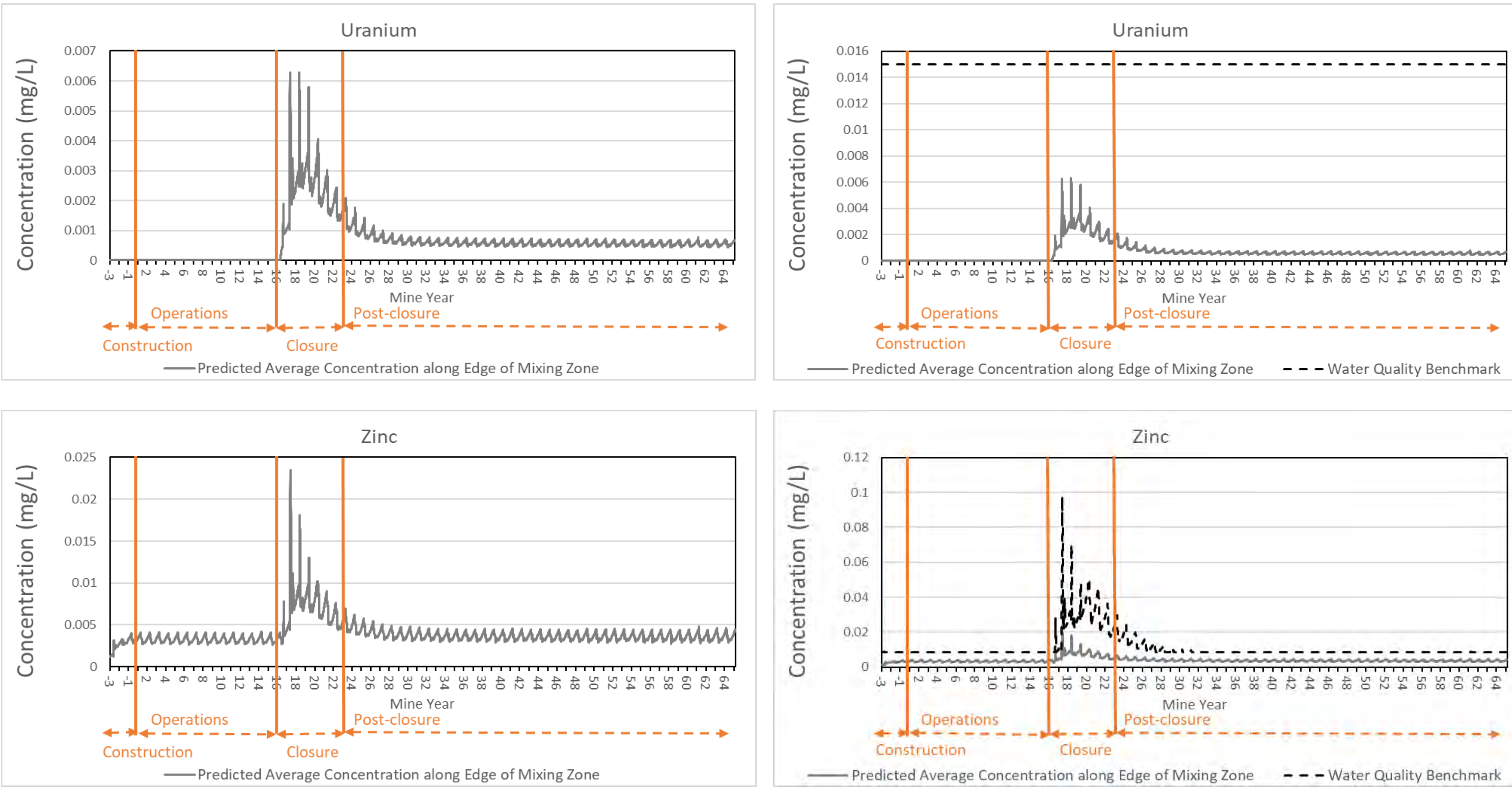


Figure B2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN05 over the Construction, Operations, Closure and Post-closure Periods

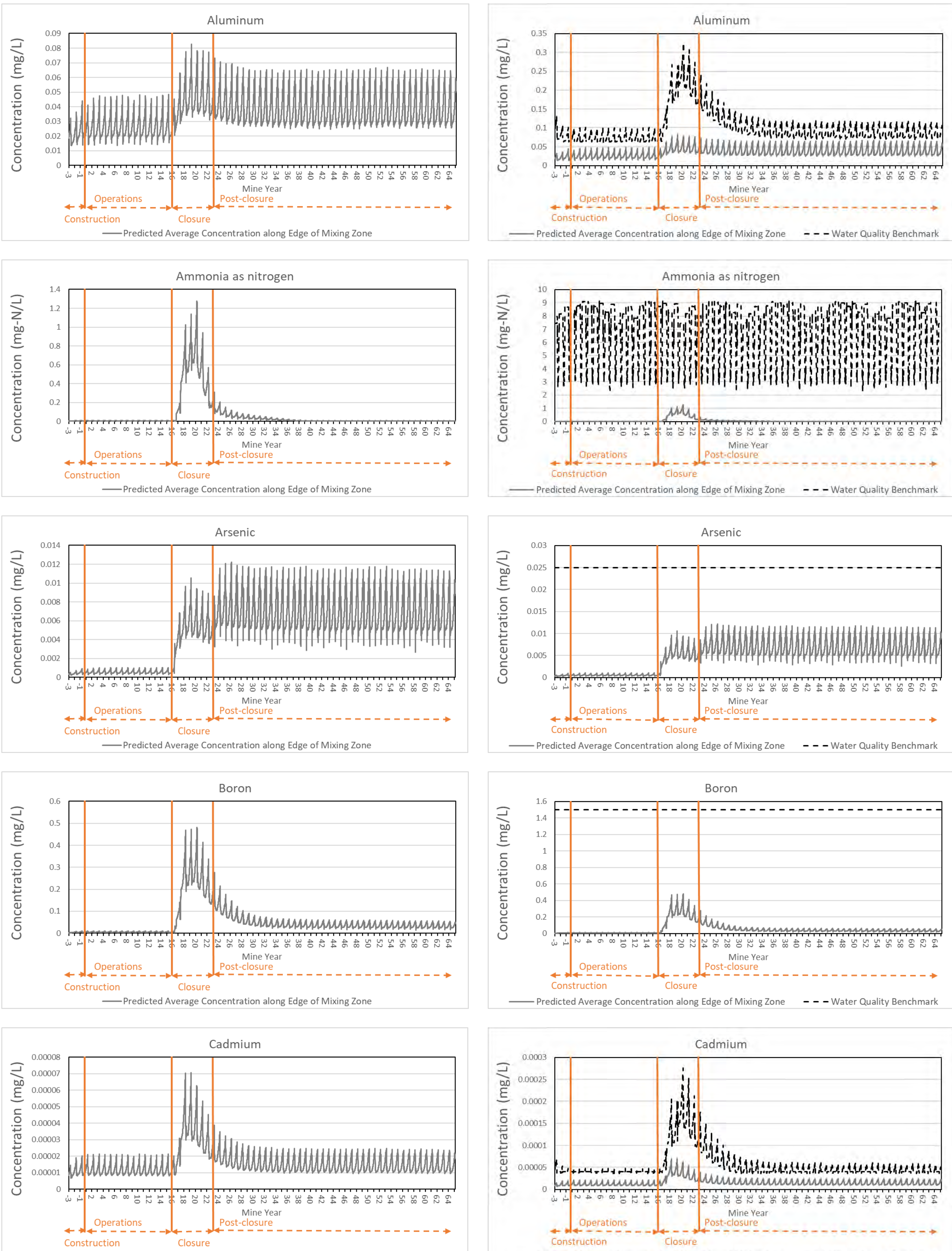


Figure B2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN05 over the Construction, Operations, Closure and Post-closure Periods

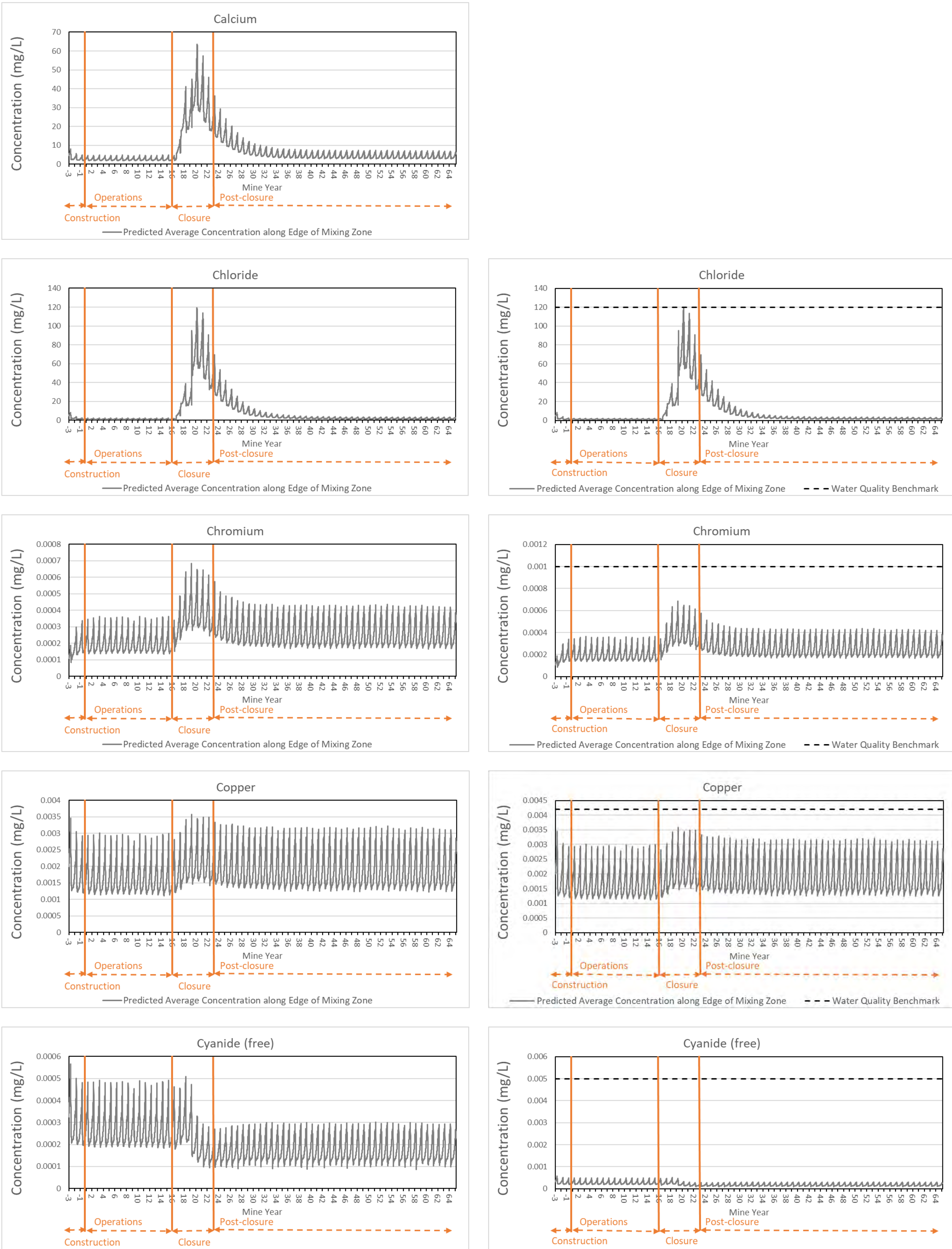


Figure B2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN05 over the Construction, Operations, Closure and Post-closure Periods

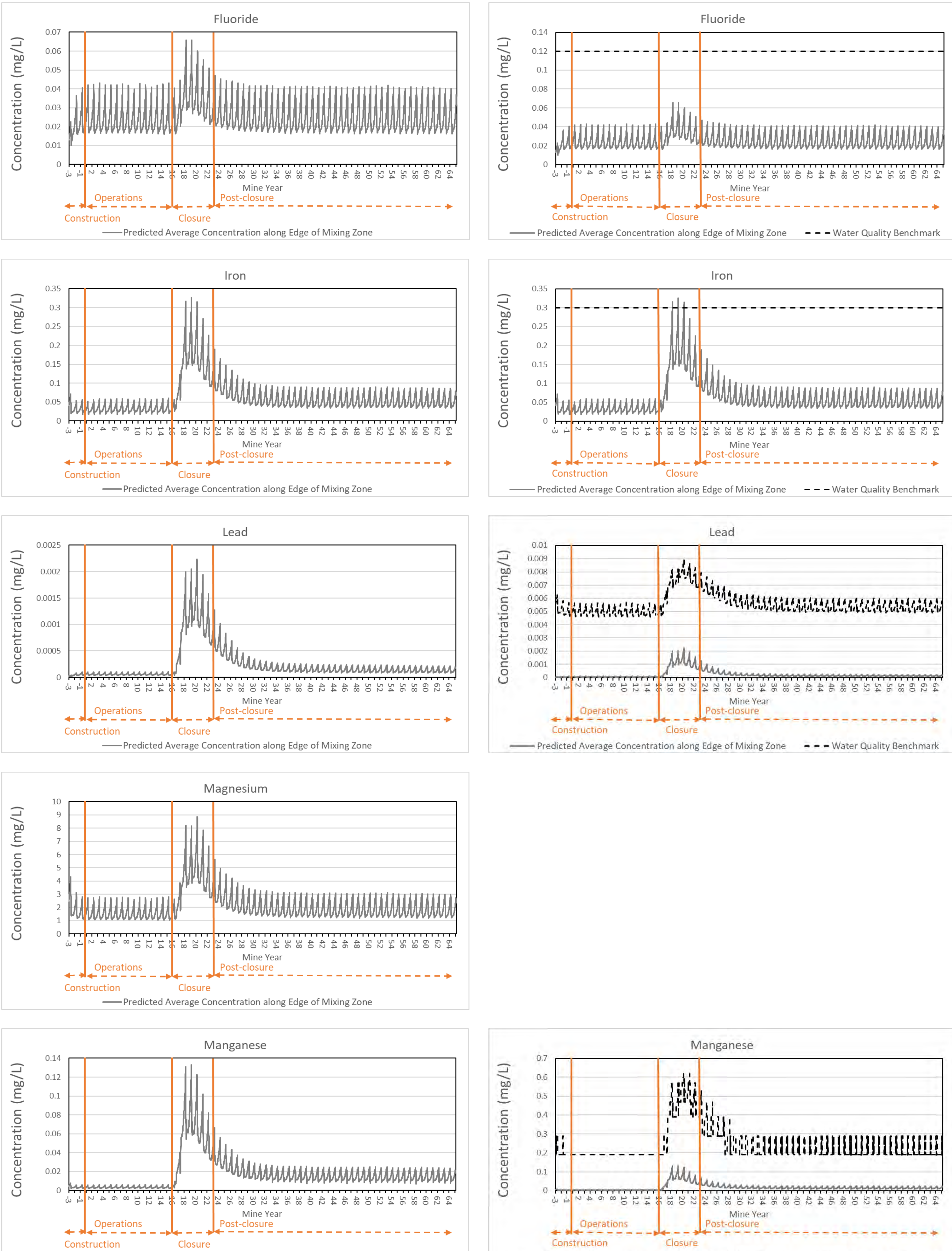


Figure B2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN05 over the Construction, Operations, Closure and Post-closure Periods

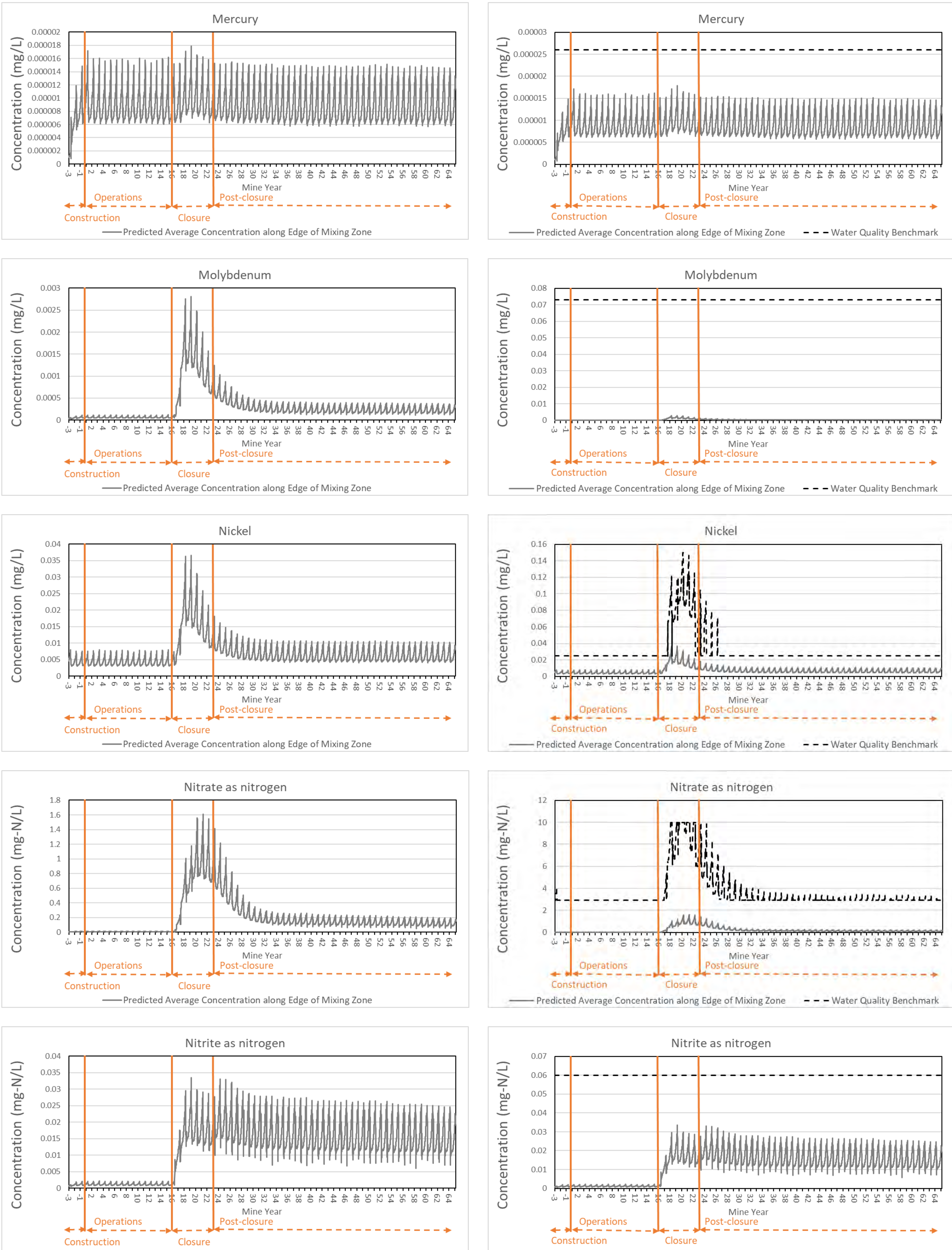


Figure B2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN05 over the Construction, Operations, Closure and Post-closure Periods

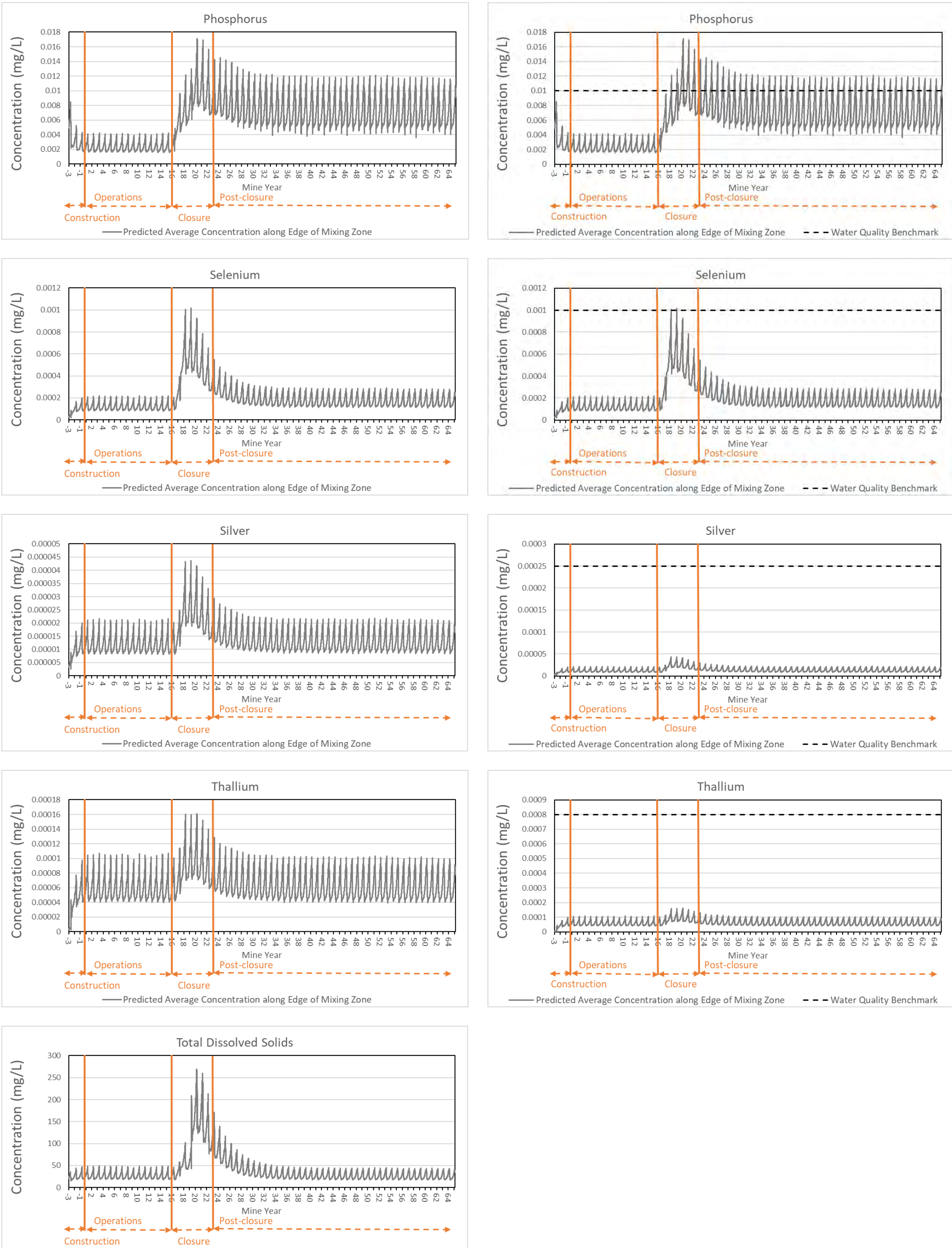


Figure B2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN05 over the Construction, Operations, Closure and Post-closure Periods

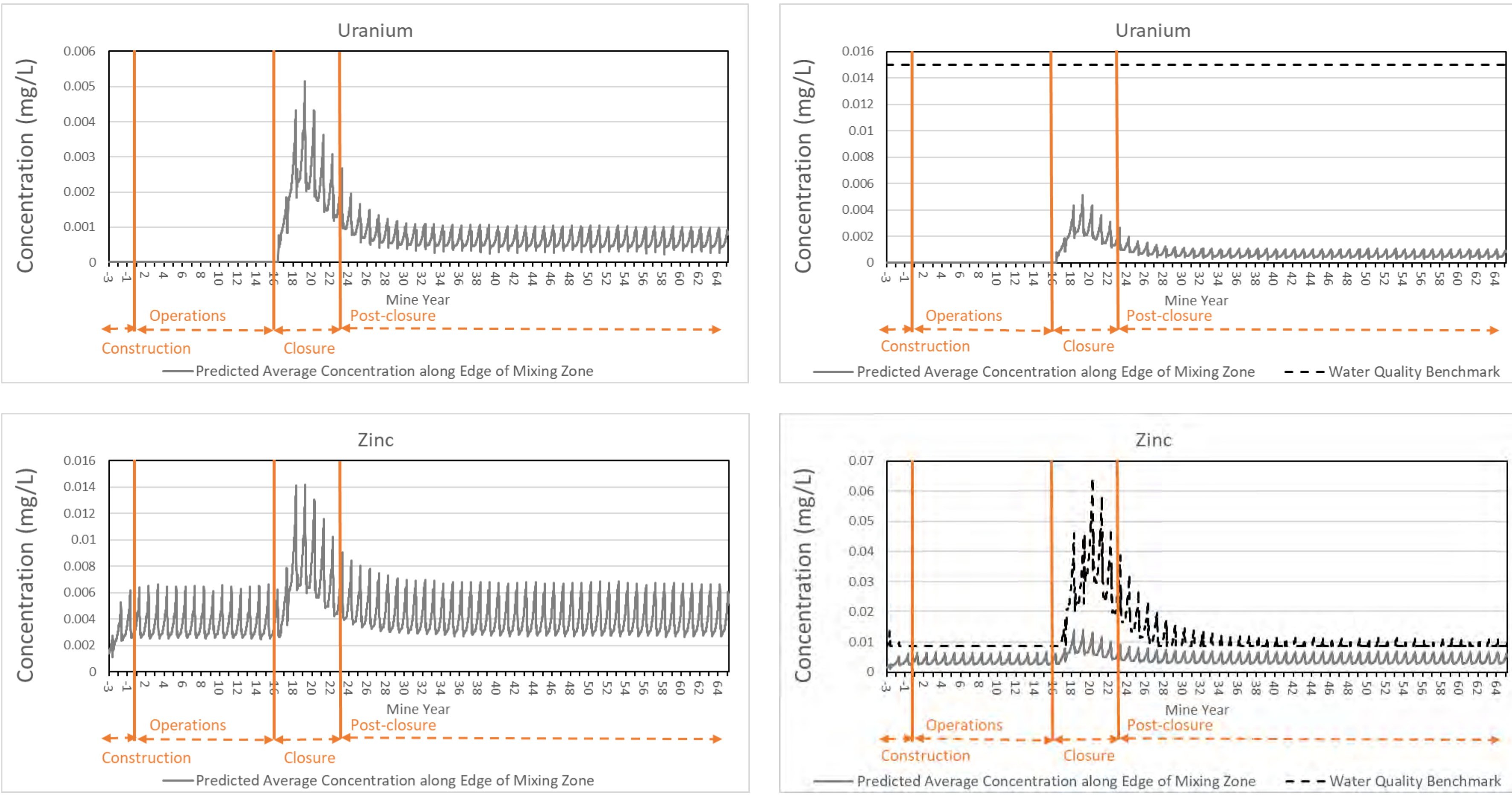


Figure B3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN08 over the Construction, Operations, Closure and Post-closure Periods

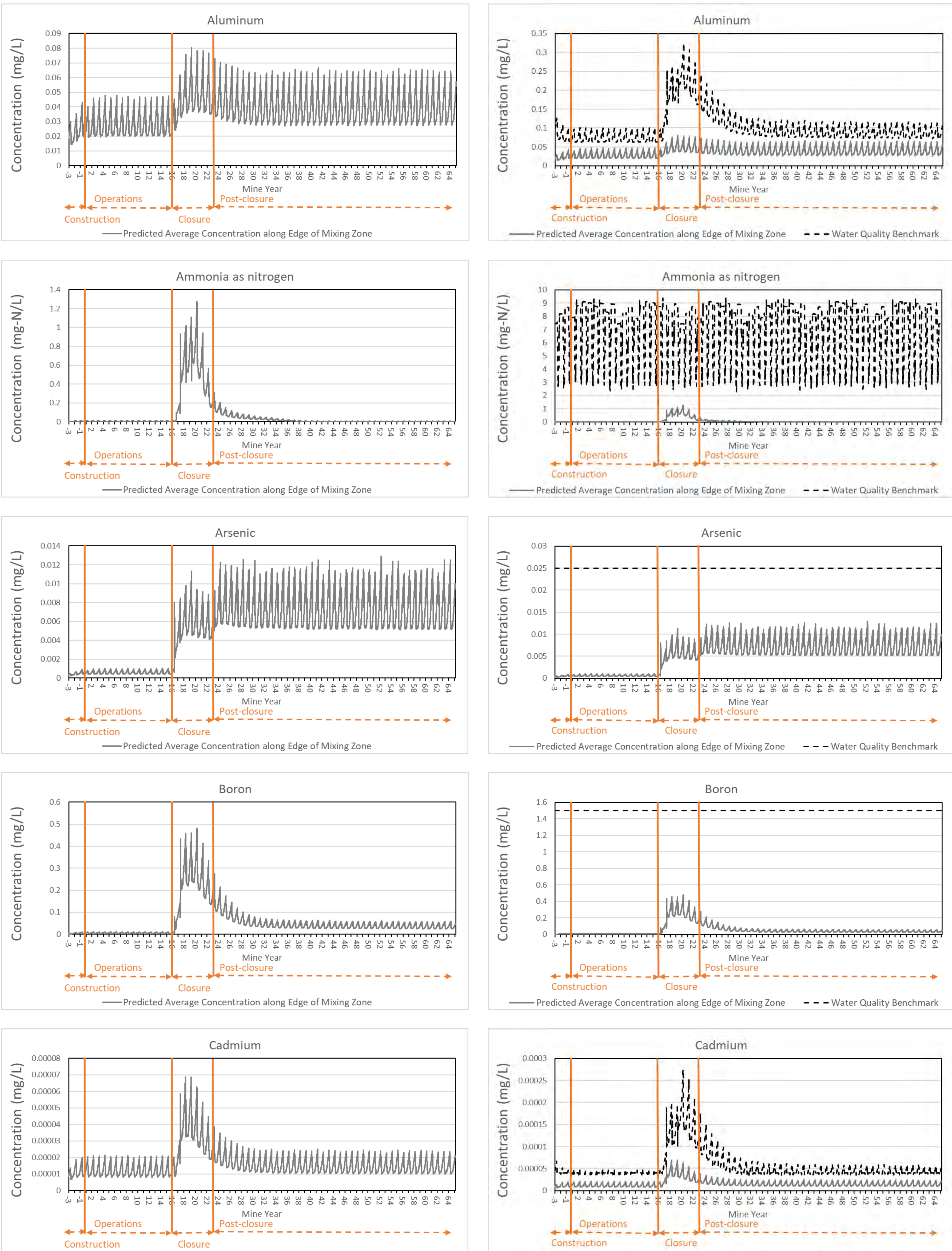


Figure B3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN08 over the Construction, Operations, Closure and Post-closure Periods

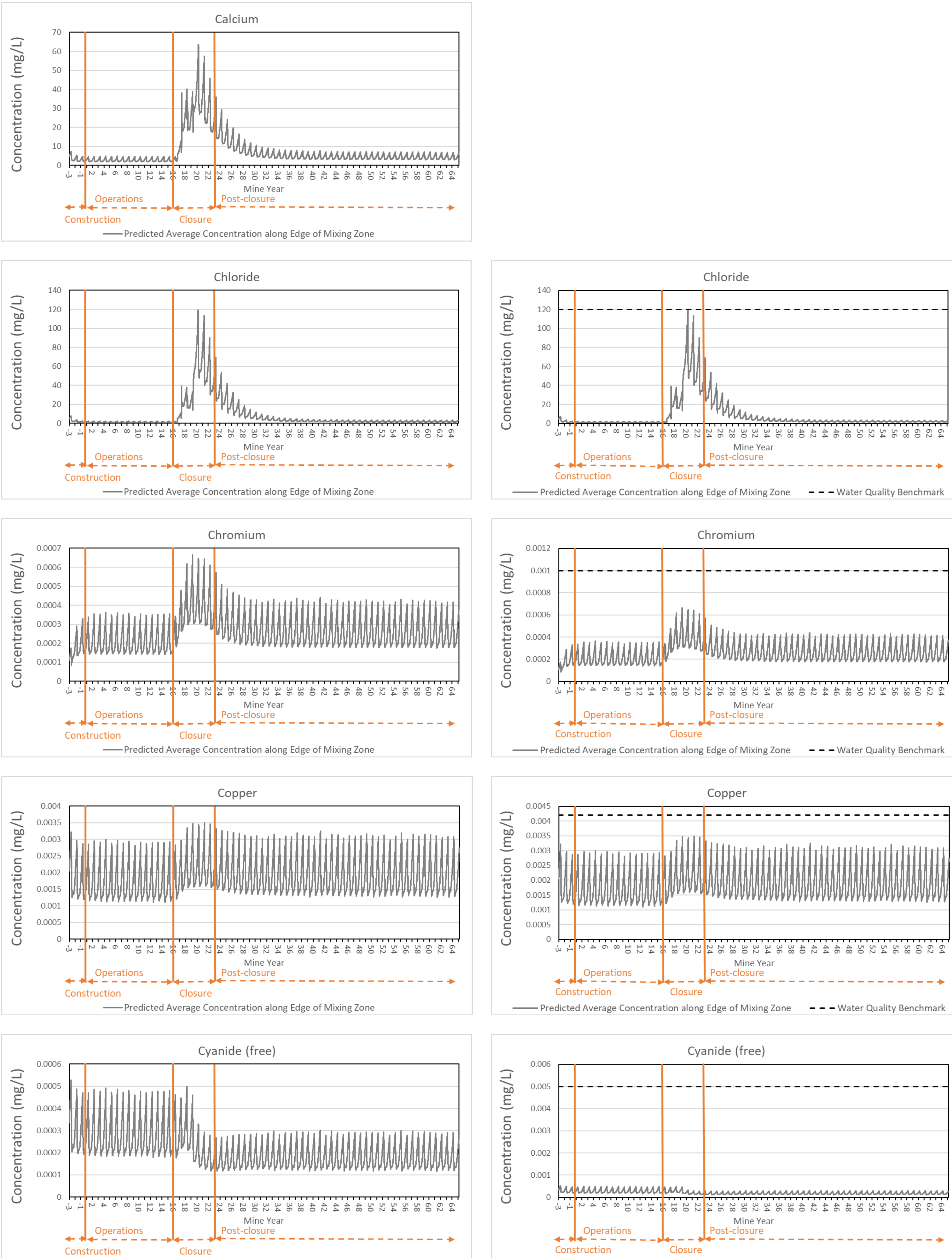


Figure B3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN08 over the Construction, Operations, Closure and Post-closure Periods

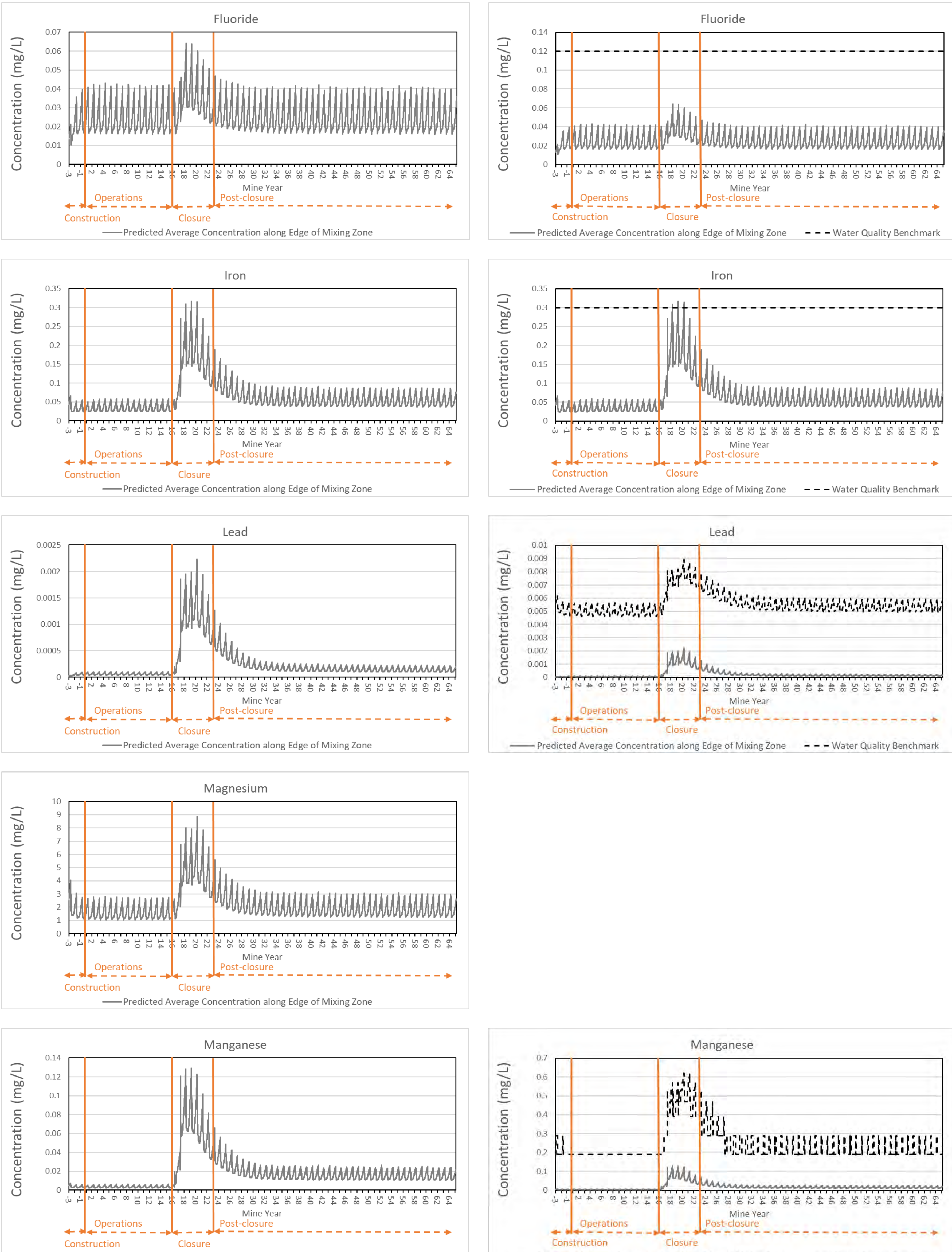


Figure B3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN08 over the Construction, Operations, Closure and Post-closure Periods

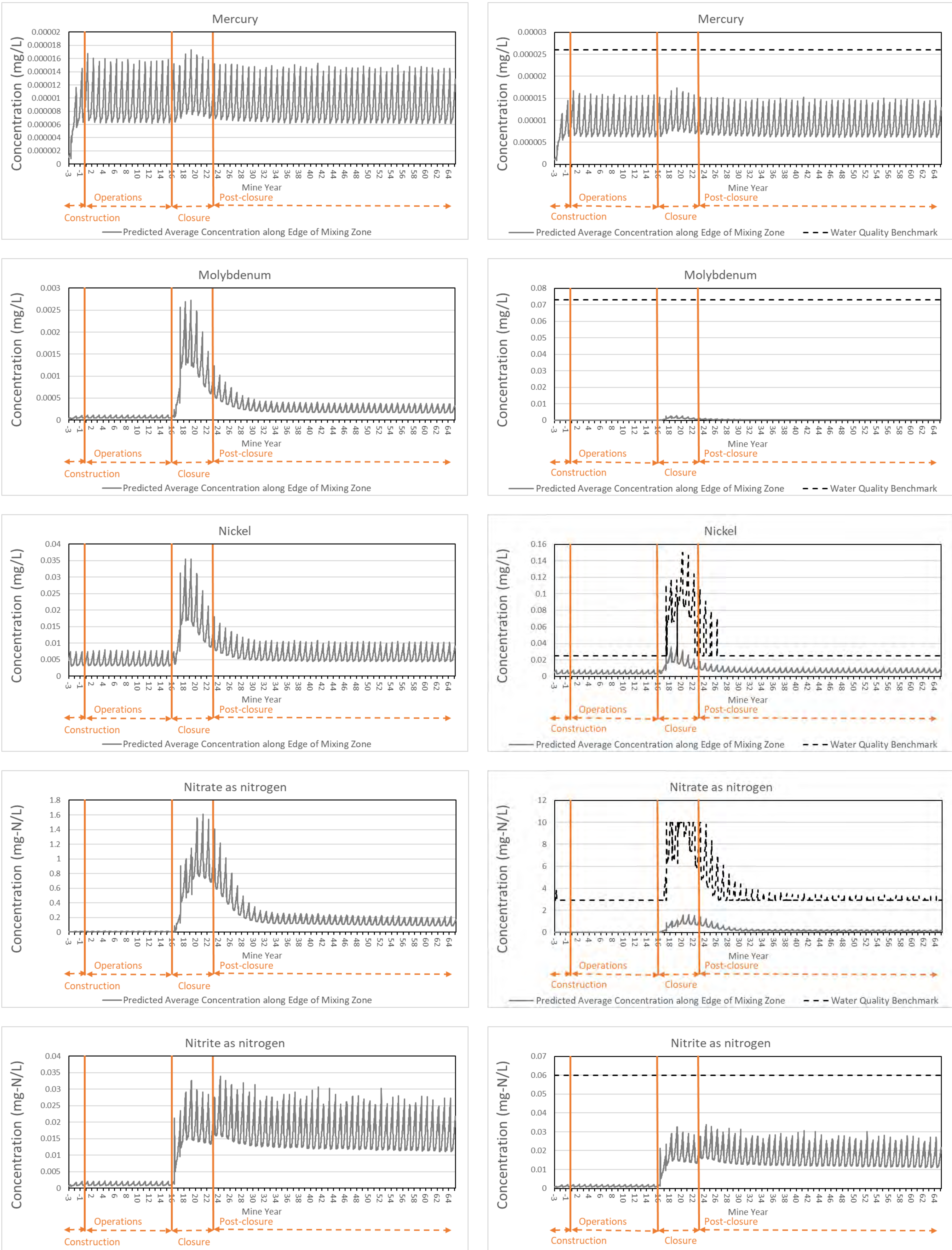


Figure B3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN08 over the Construction, Operations, Closure and Post-closure Periods

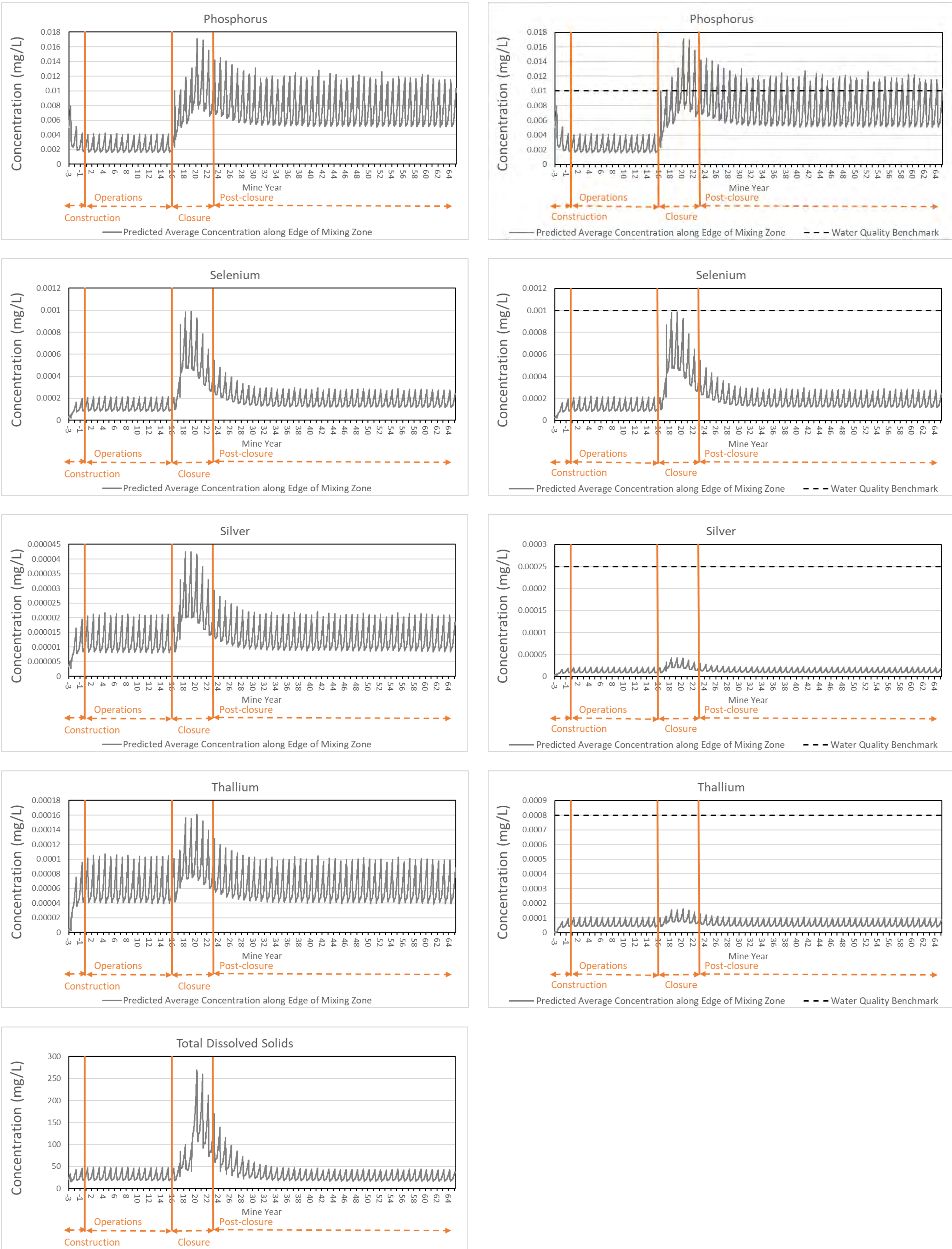
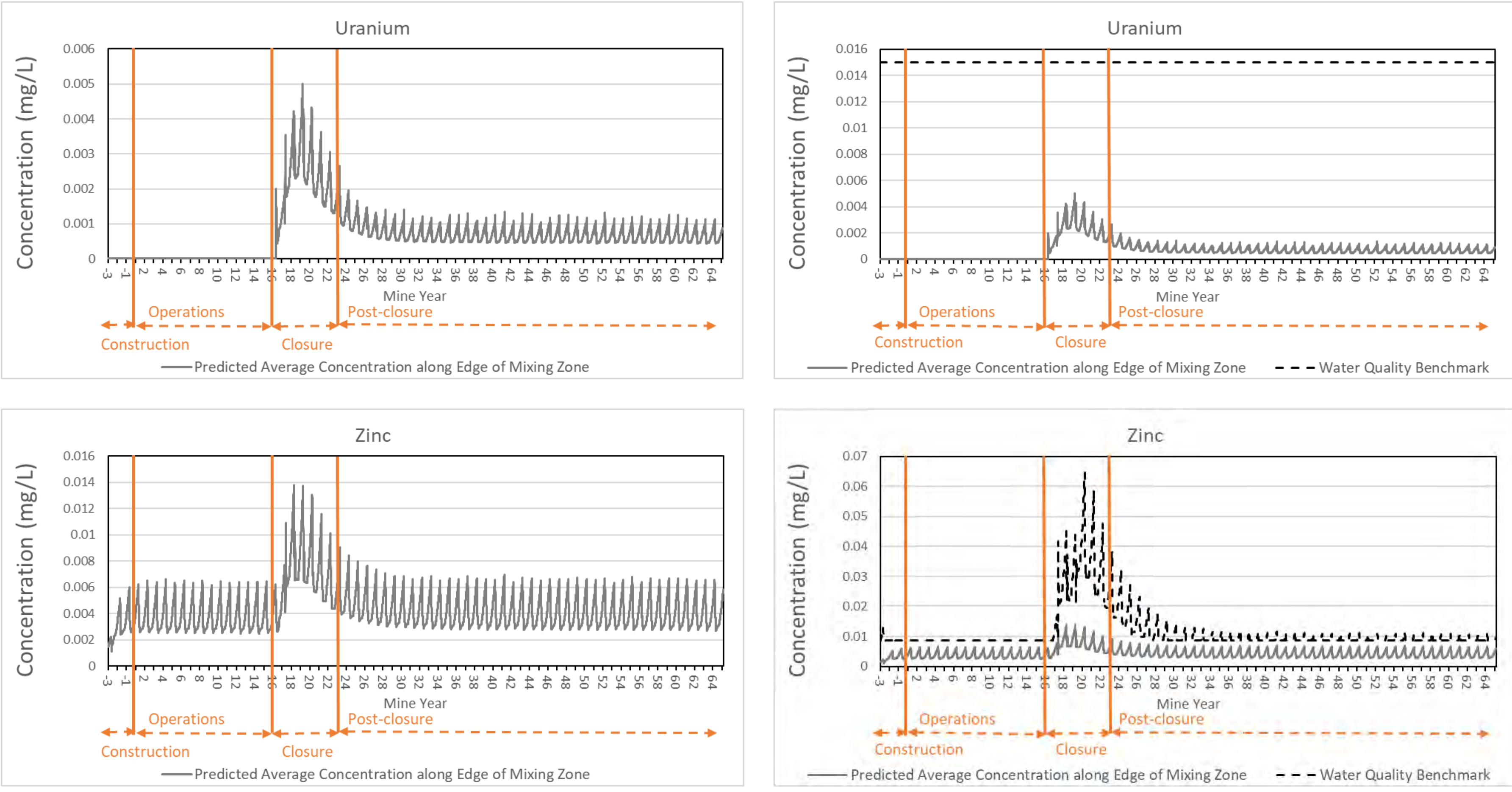


Figure B3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at the Edge of Mixing Zone for PN08 over the Construction, Operations, Closure and Post-closure Periods



APPENDIX C

Goose Lake Model - Timeseries of Predicted Constituent Concentrations at the Assessment Stations during the Forecast Period

Please note the timeseries are separately plotted with and without surface water quality benchmarks (except for calcium, magnesium and TDS which don’t have benchmarks, see Table 1) because many constituent concentrations are so far below the corresponding benchmark that changes, or lack of changes, in concentrations are not detectable at coarser scales if the benchmark is co-presented.

Figure C1: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLCB over the Construction, Operations, Closure and Post-closure Periods

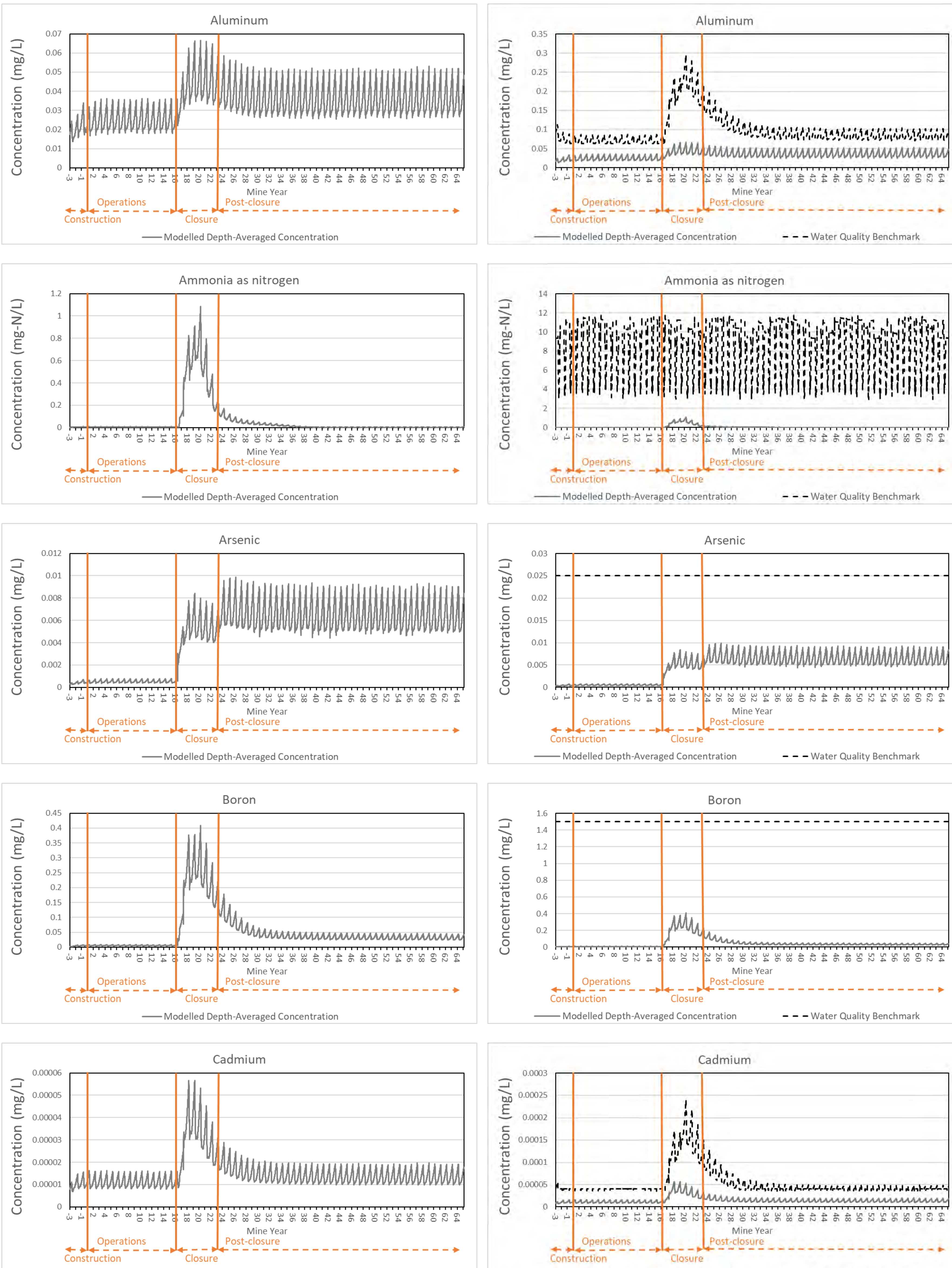


Figure C1: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLCB over the Construction, Operations, Closure and Post-closure Periods

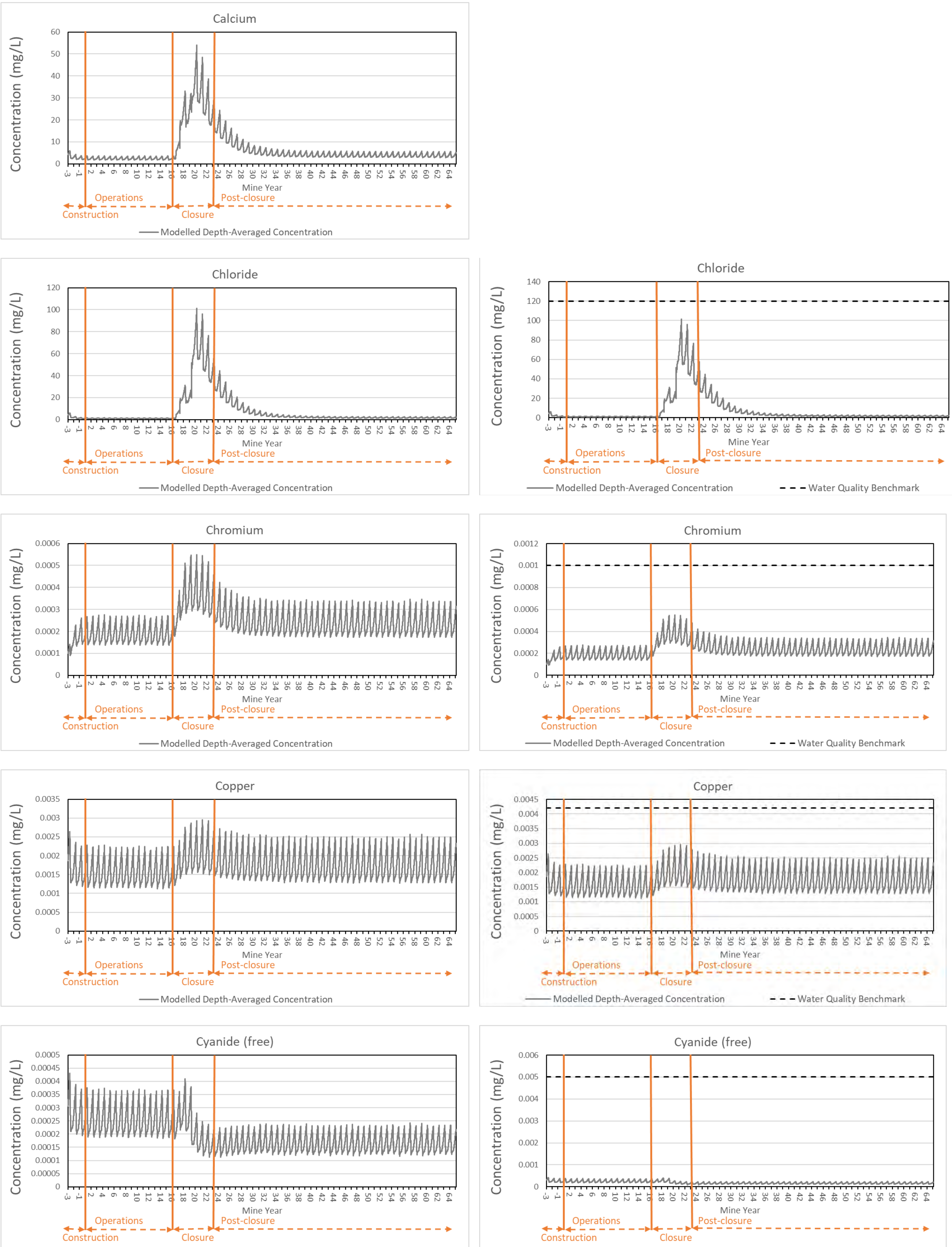


Figure C1: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLCB over the Construction, Operations, Closure and Post-closure Periods

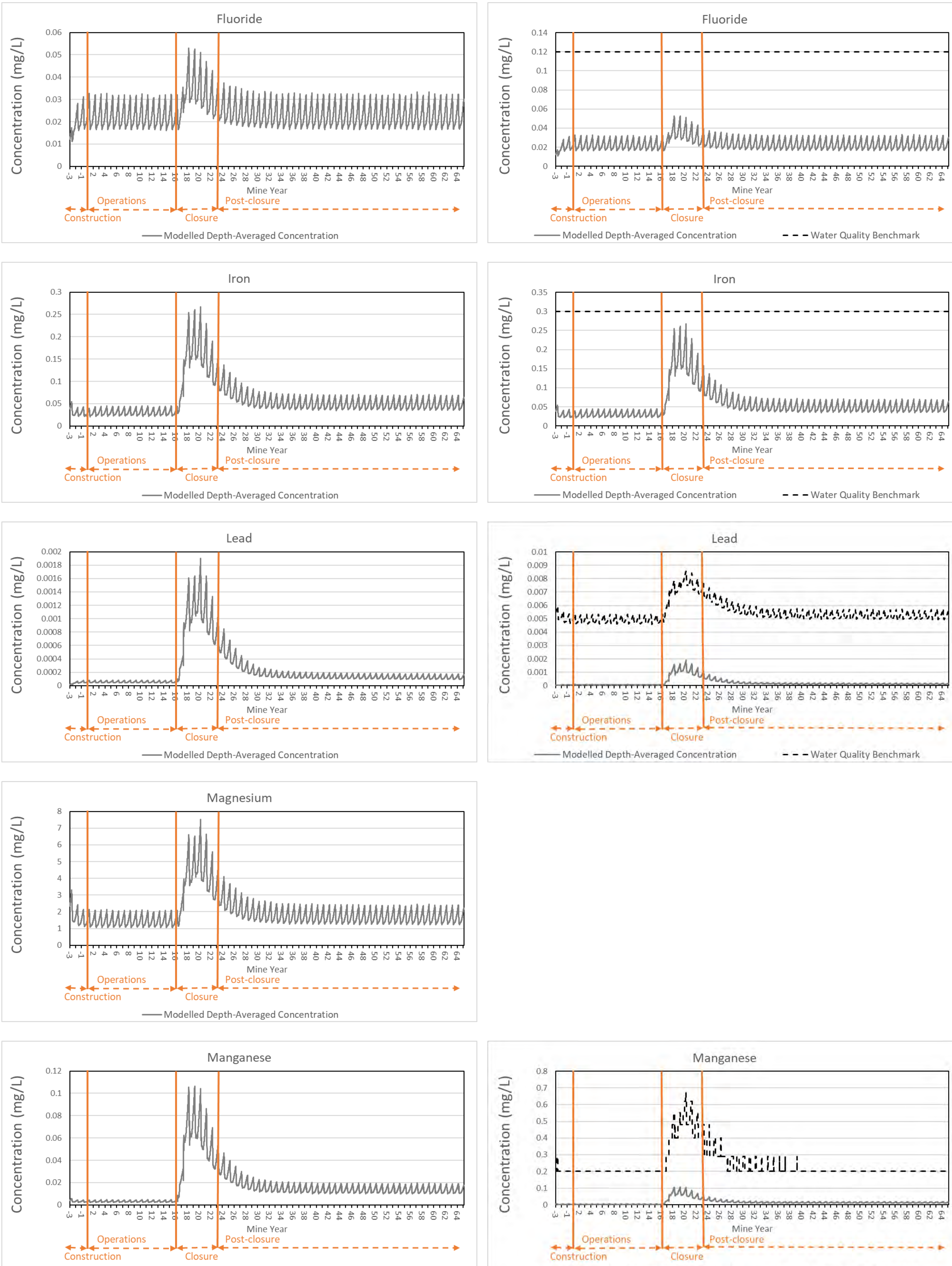


Figure C1: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLCB over the Construction, Operations, Closure and Post-closure Periods

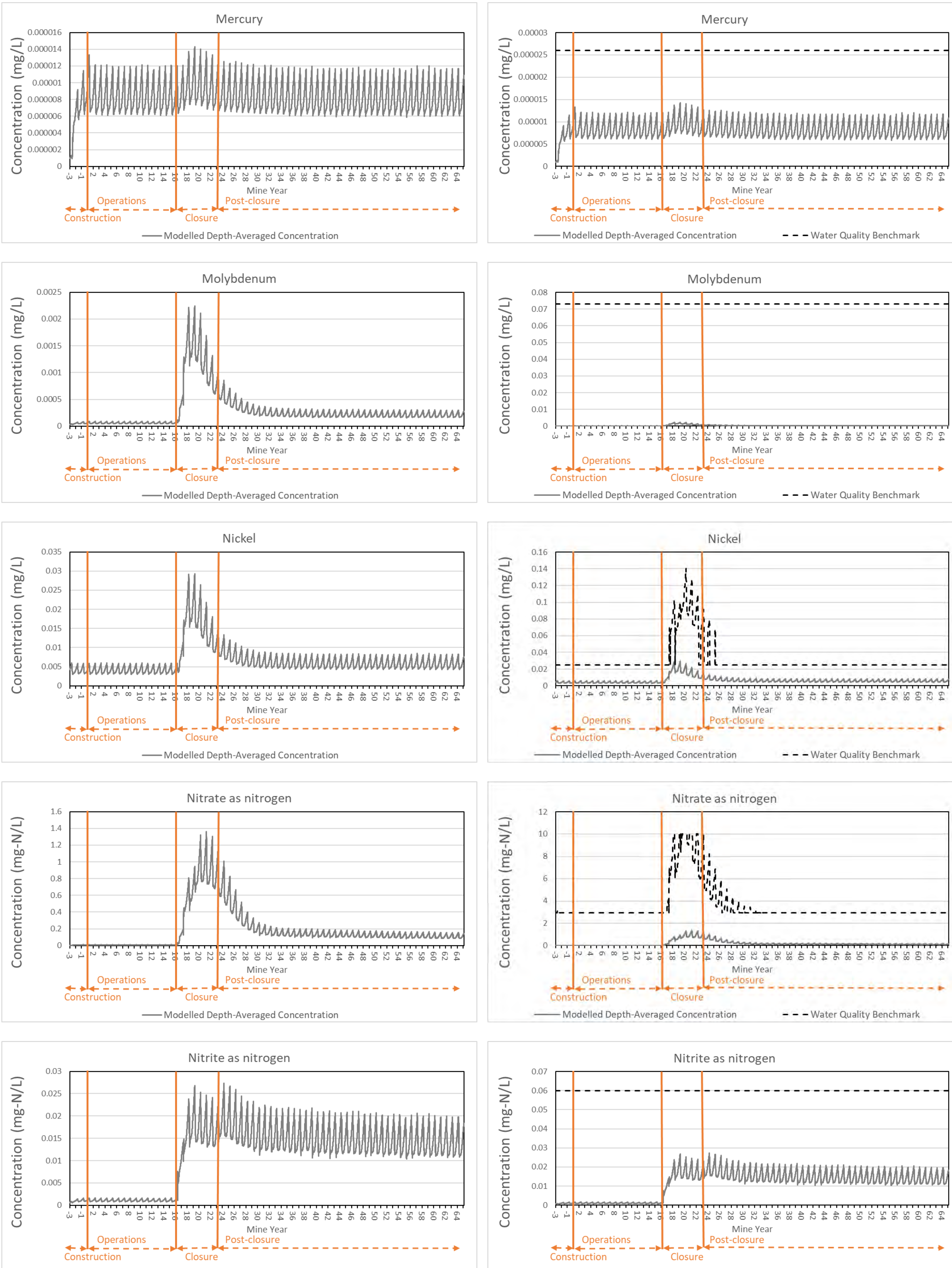


Figure C1: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLCB over the Construction, Operations, Closure and Post-closure Periods

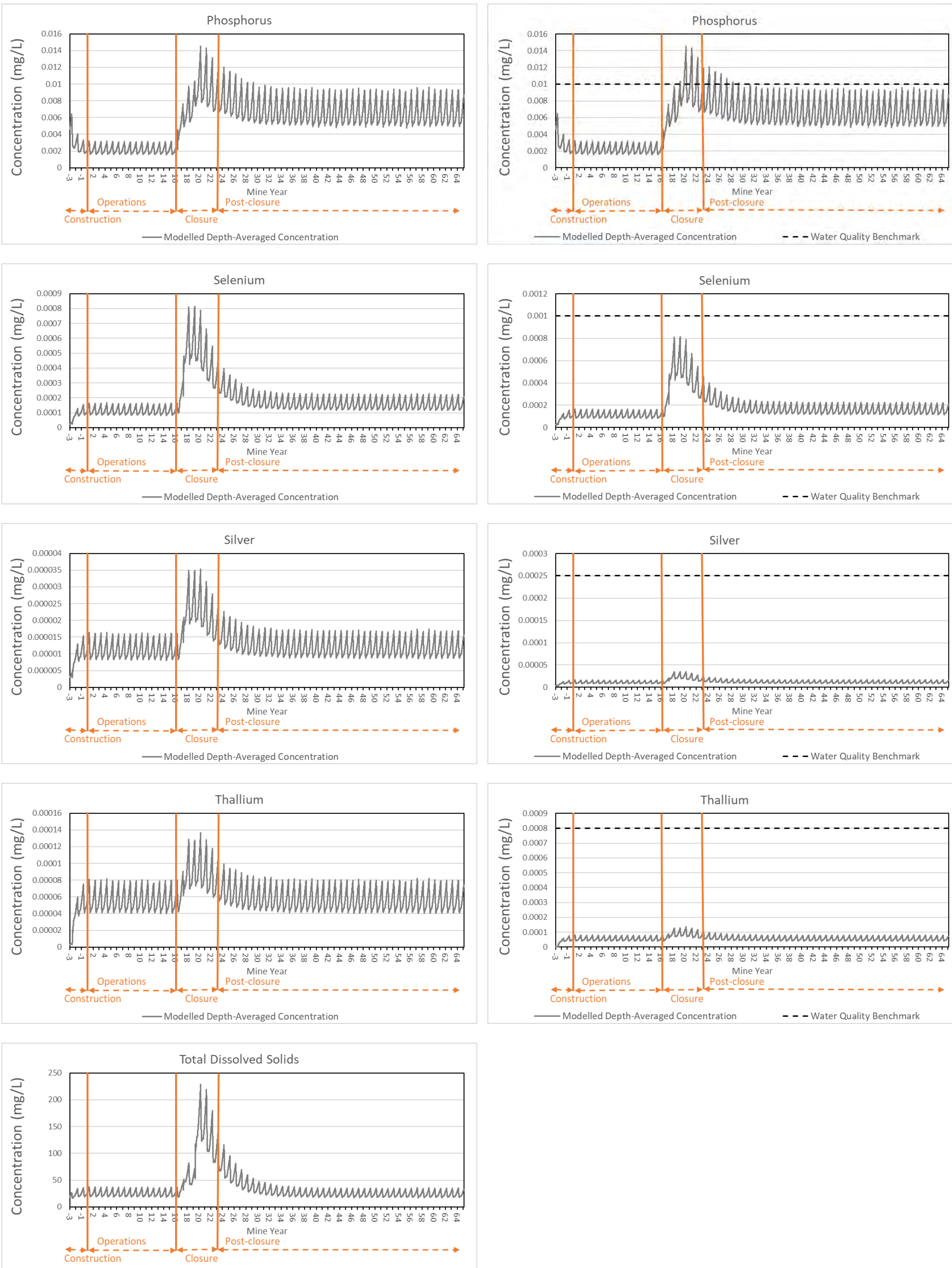


Figure C1: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLCB over the Construction, Operations, Closure and Post-closure Periods

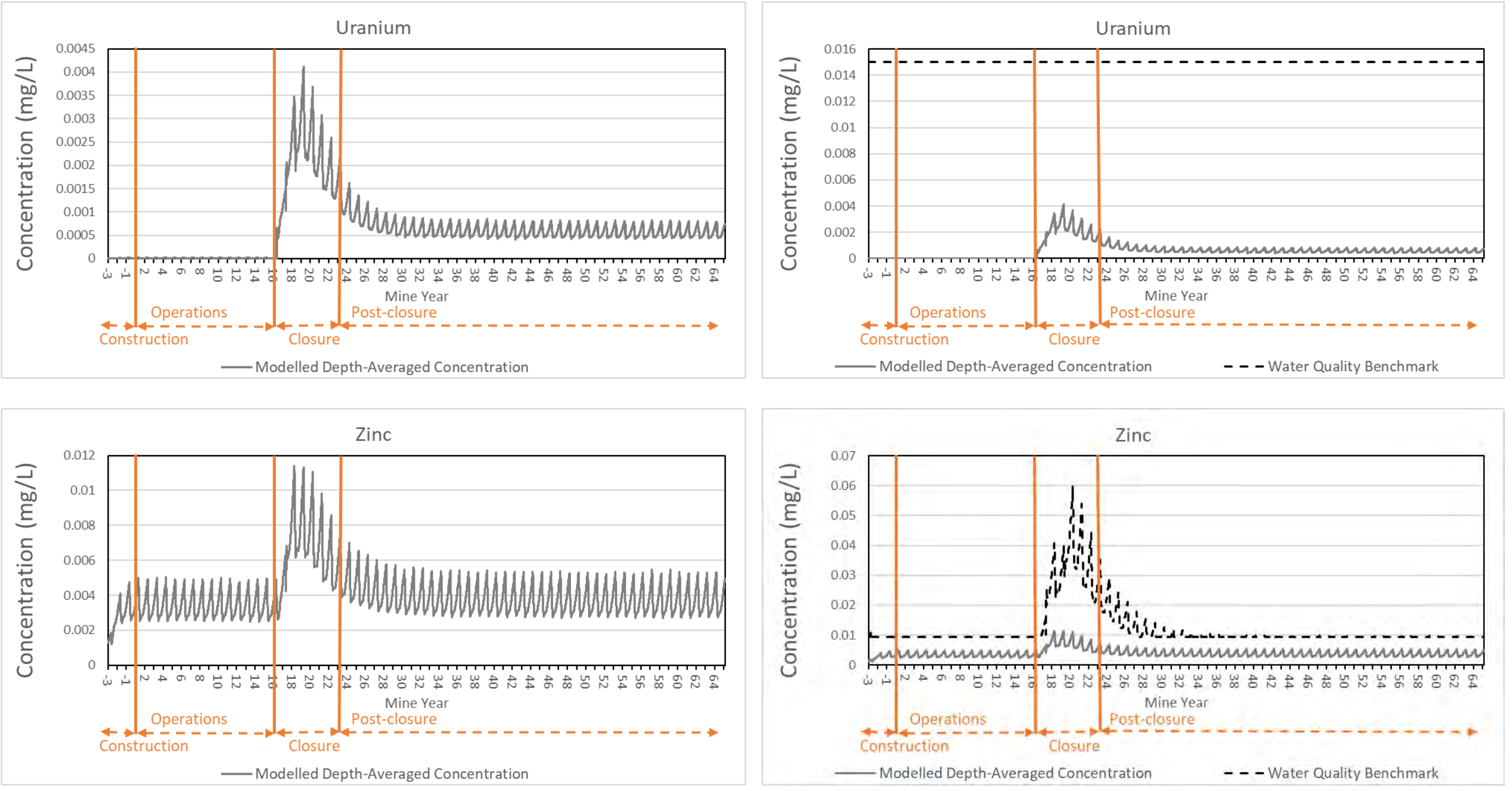


Figure C2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLTL over the Construction, Operations, Closure and Post-closure Periods

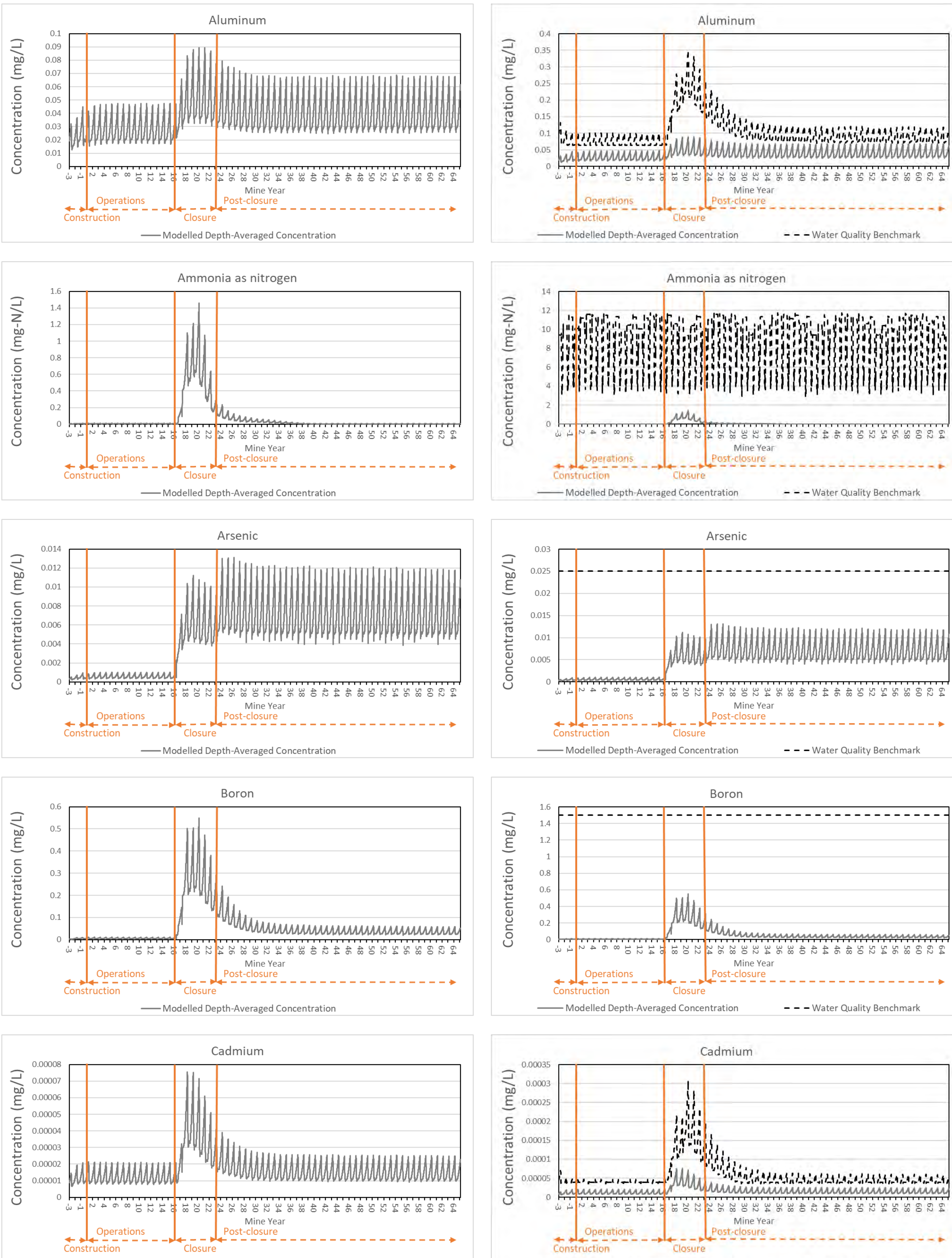


Figure C2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLTL over the Construction, Operations, Closure and Post-closure Periods

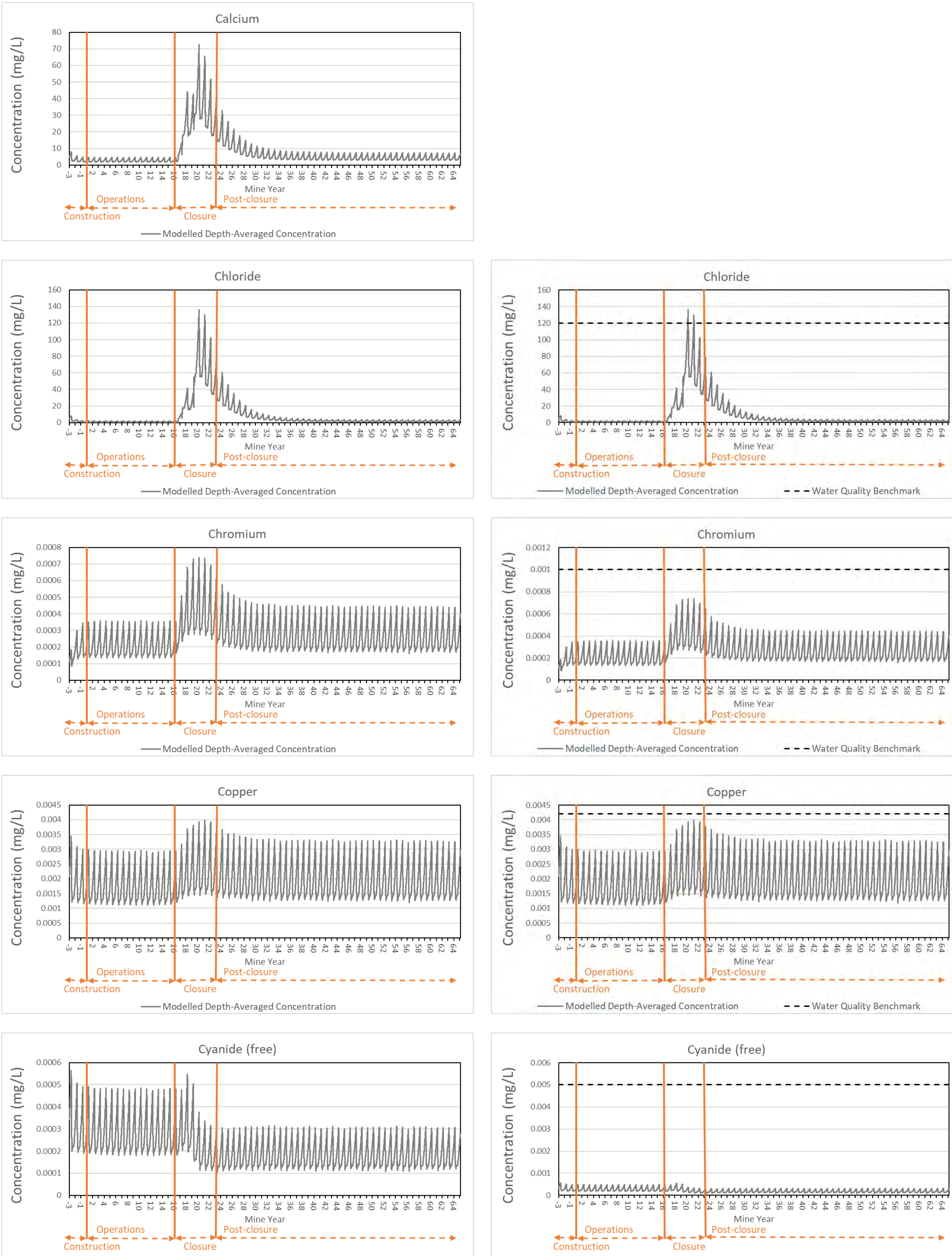


Figure C2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLTL over the Construction, Operations, Closure and Post-closure Periods

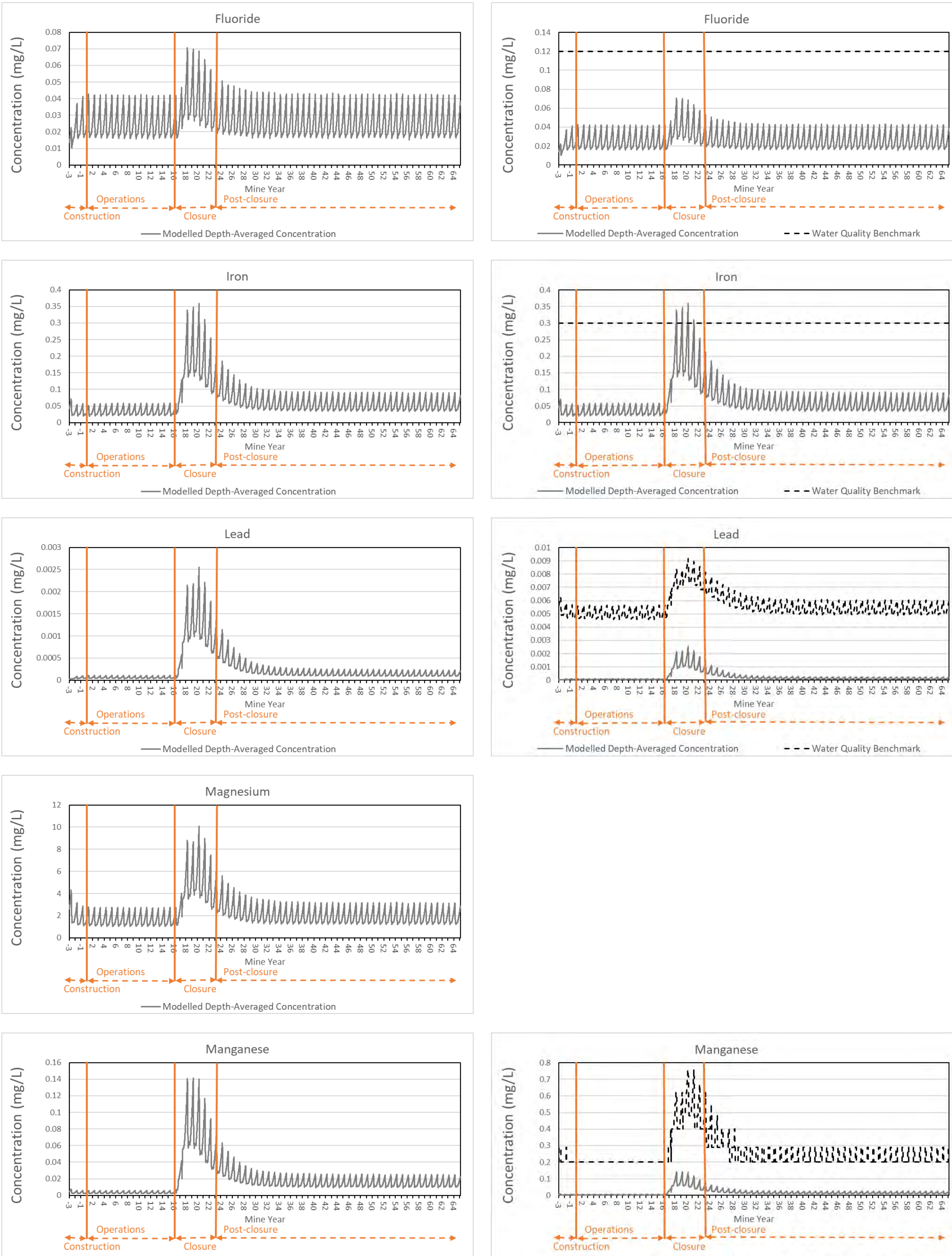


Figure C2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLTL over the Construction, Operations, Closure and Post-closure Periods

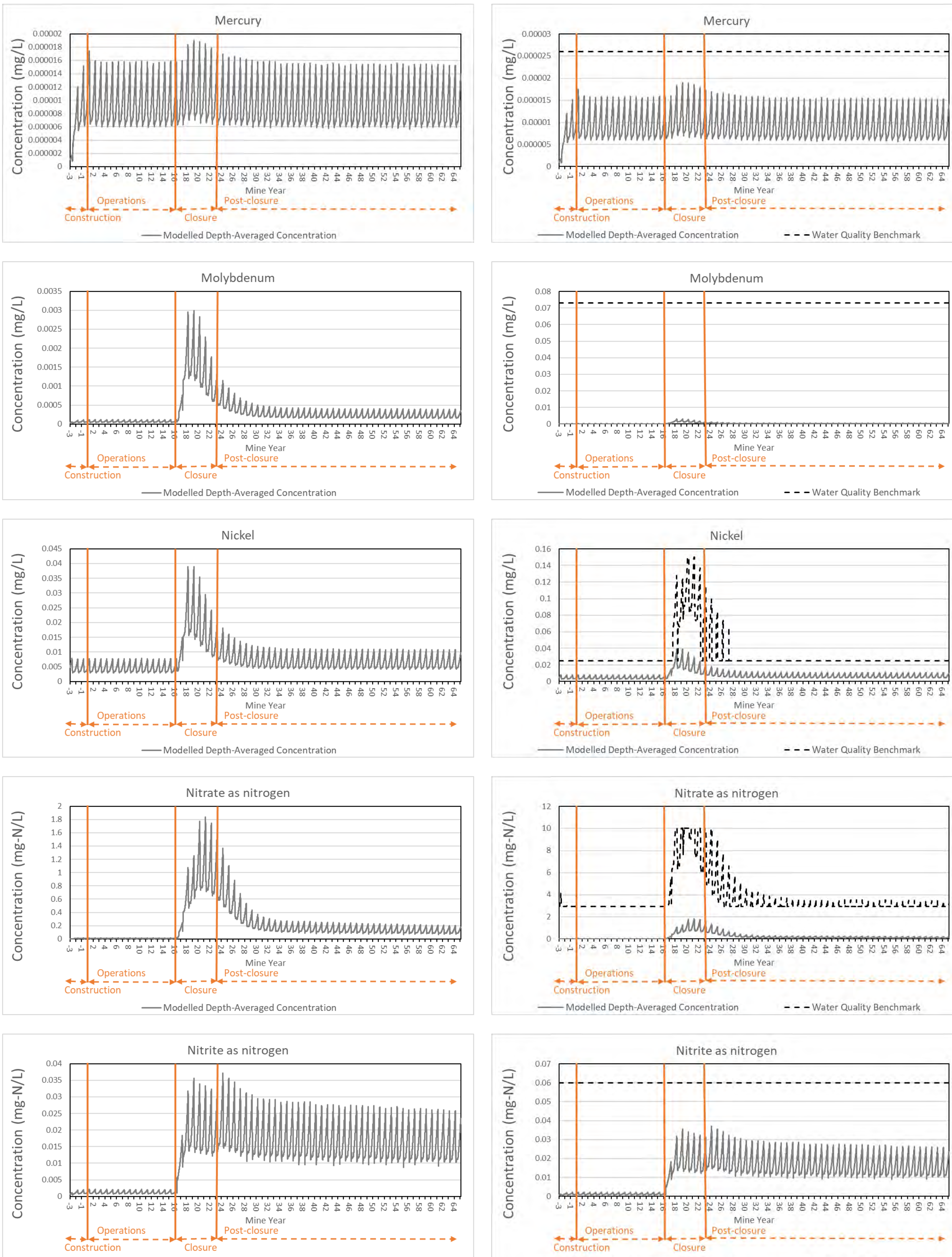


Figure C2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLTL over the Construction, Operations, Closure and Post-closure Periods

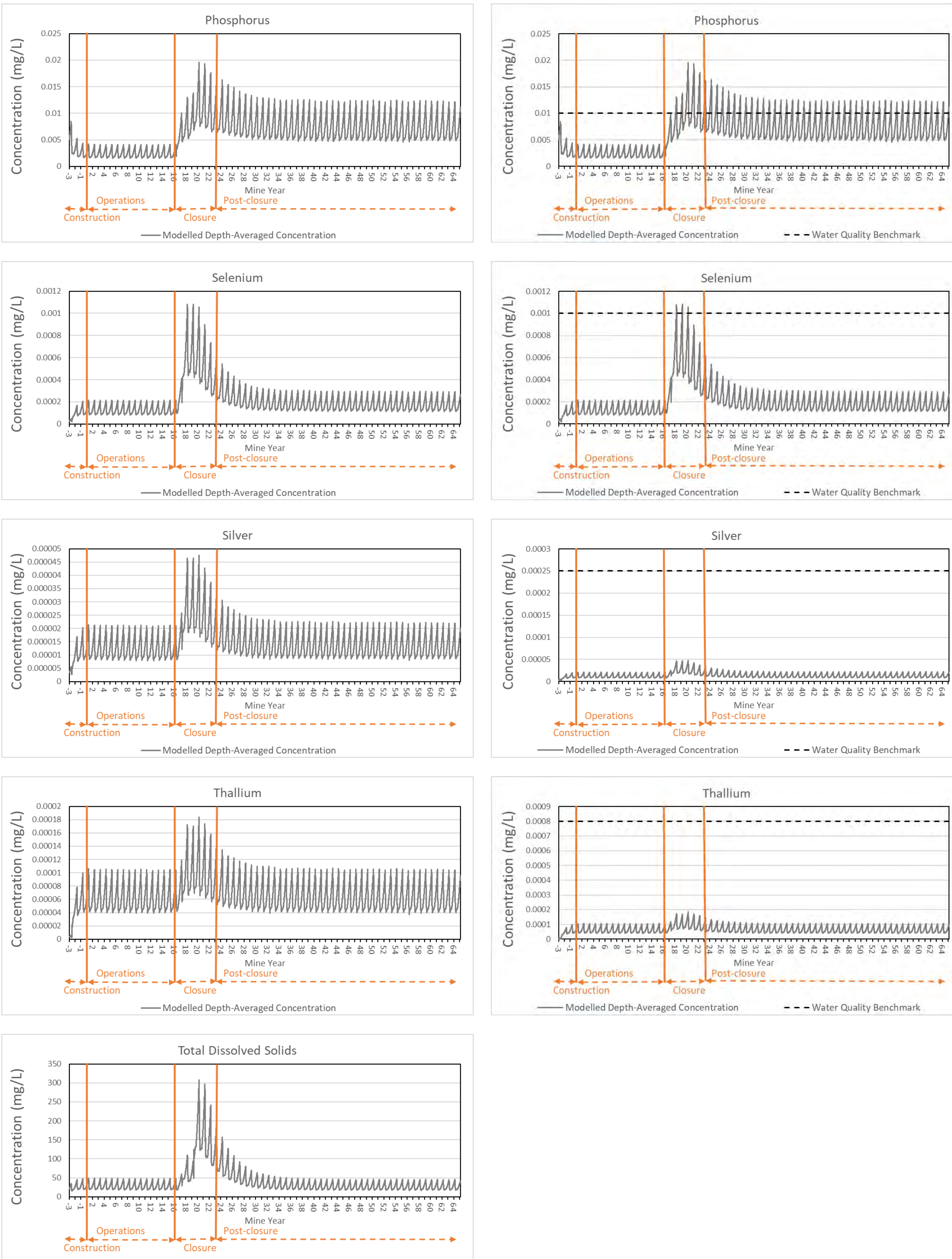


Figure C2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake at GLTL over the Construction, Operations, Closure and Post-closure Periods

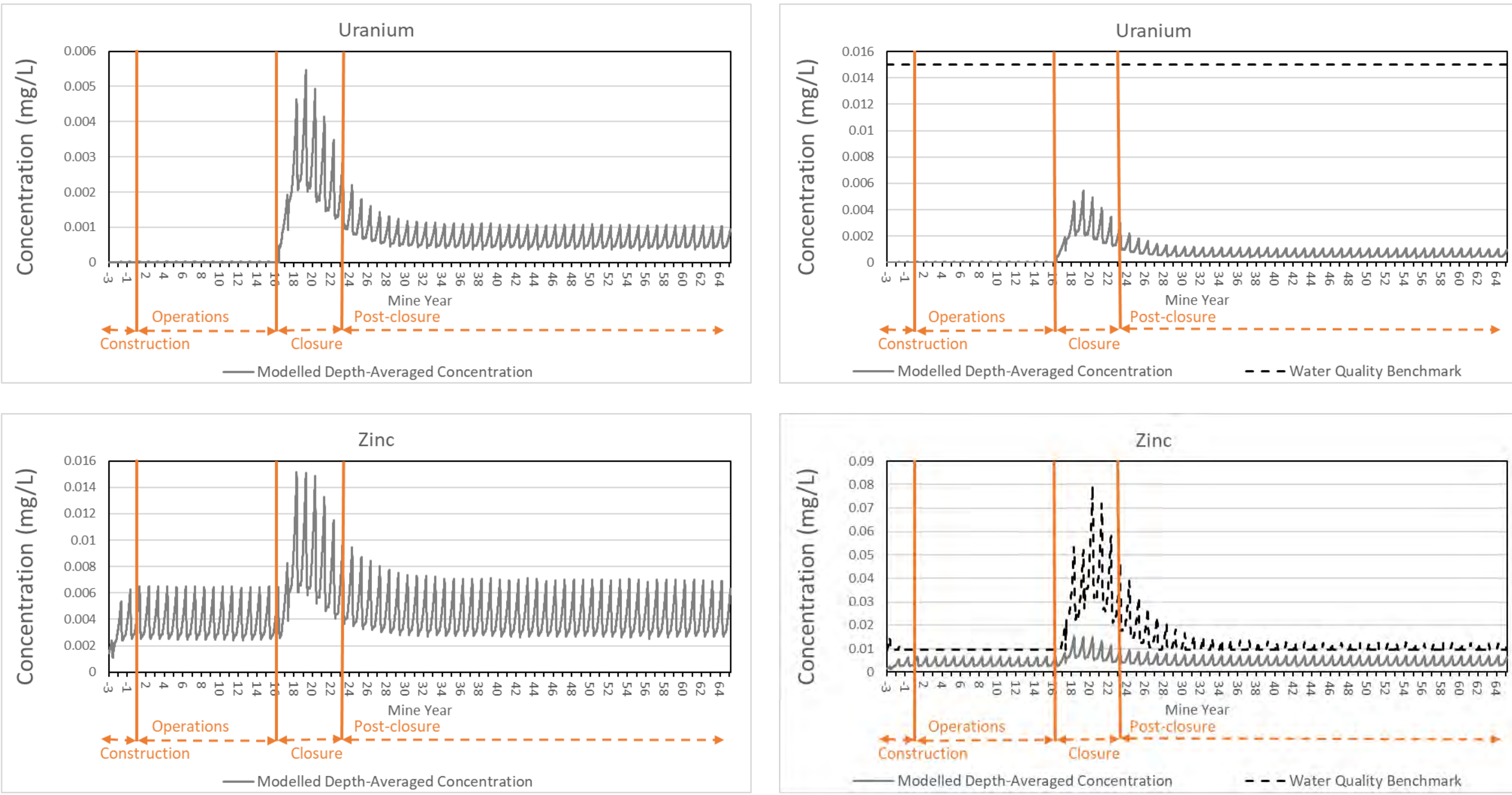


Figure C3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake Outflow over the Construction, Operations, Closure and Post-closure Periods

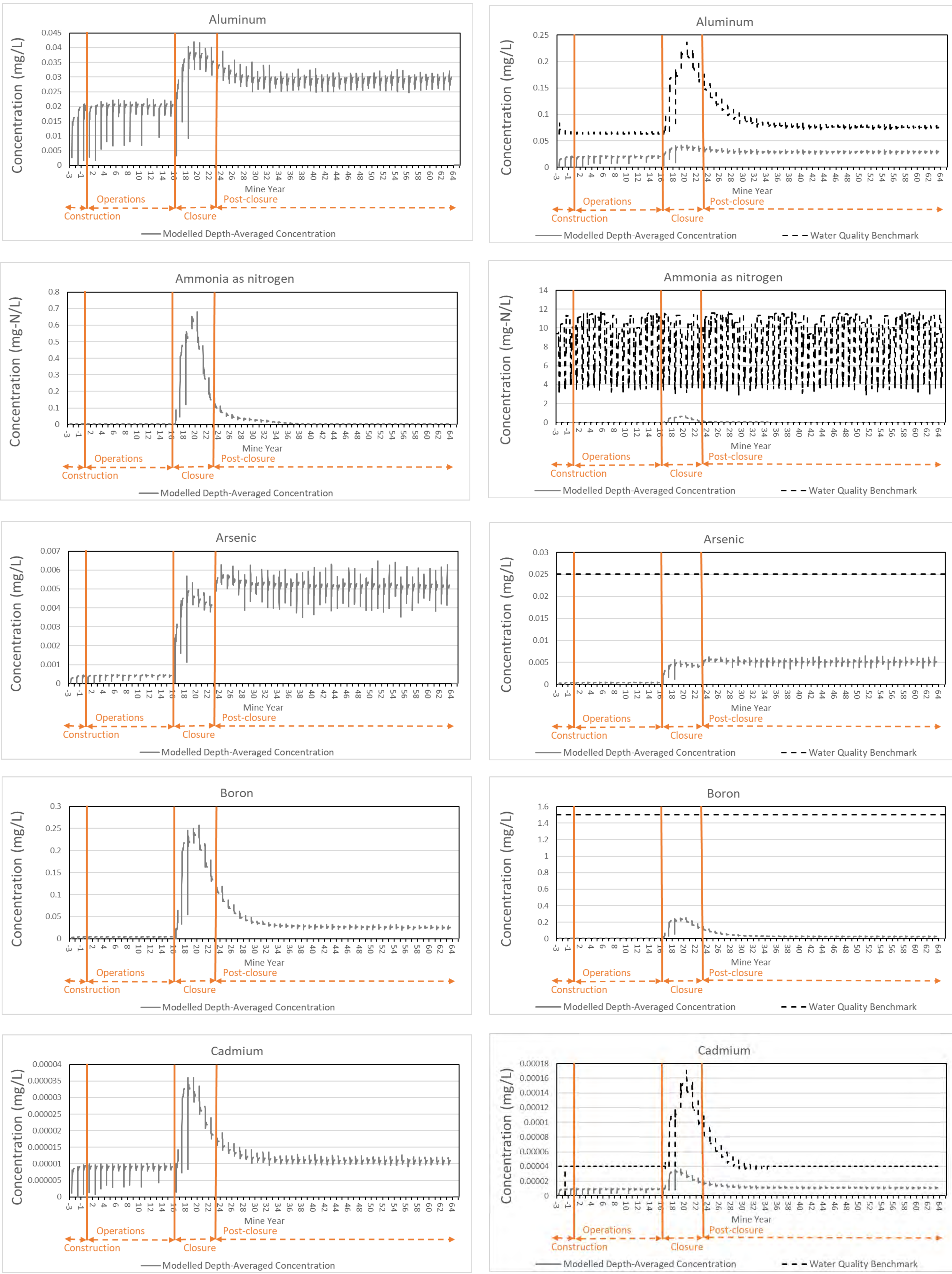


Figure C3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake Outflow over the Construction, Operations, Closure and Post-closure Periods

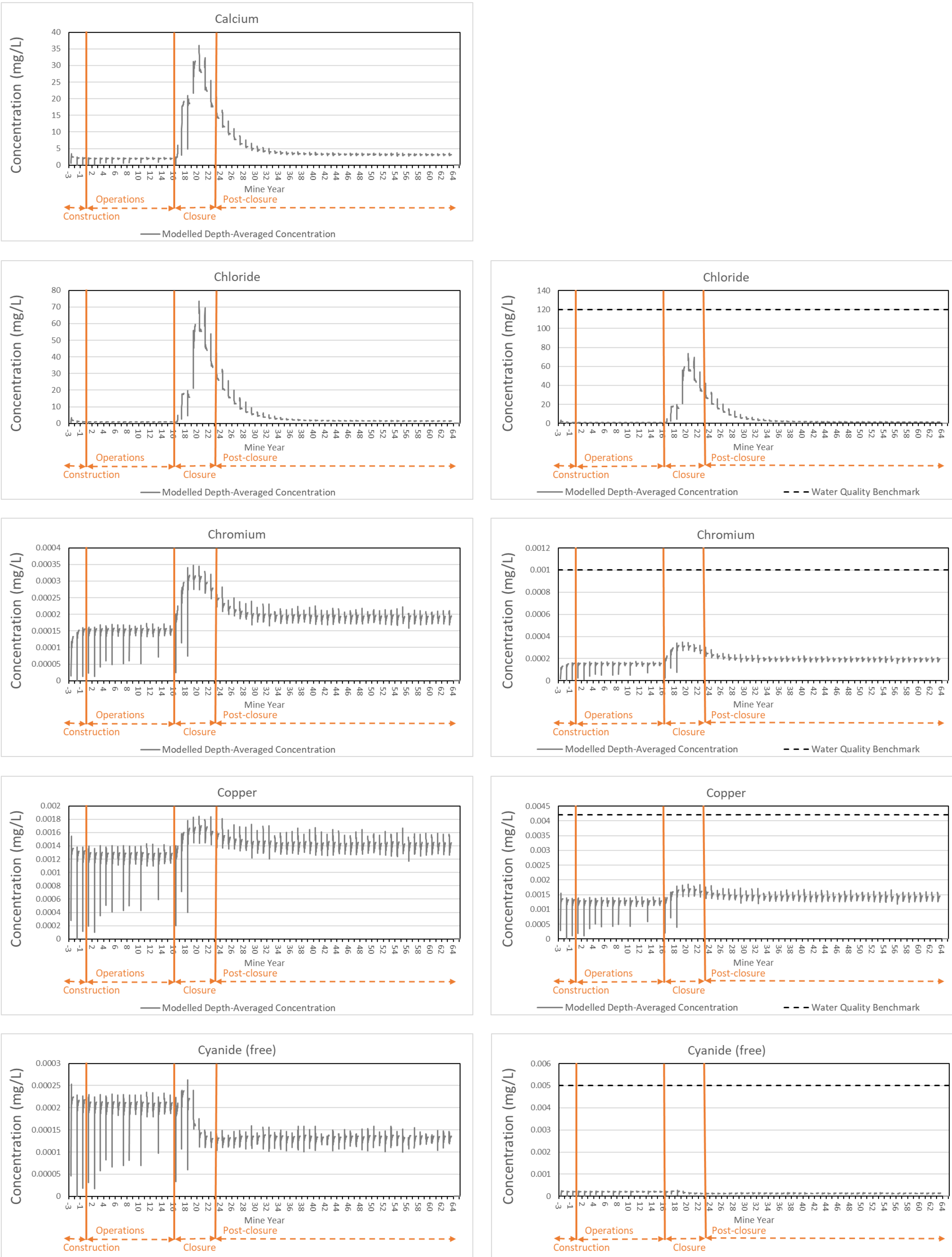


Figure C3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake Outflow over the Construction, Operations, Closure and Post-closure Periods

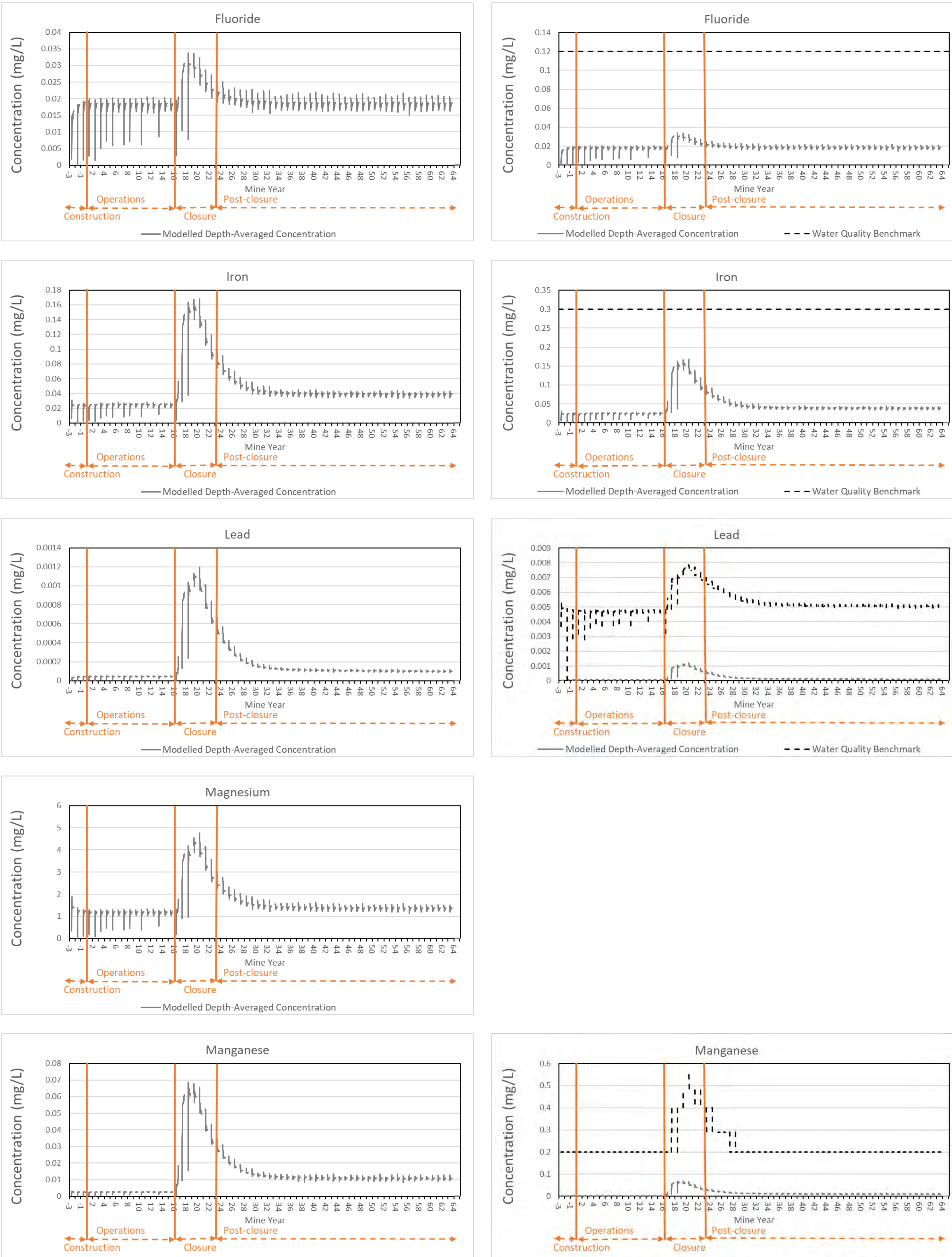


Figure C3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake Outflow over the Construction, Operations, Closure and Post-closure Periods

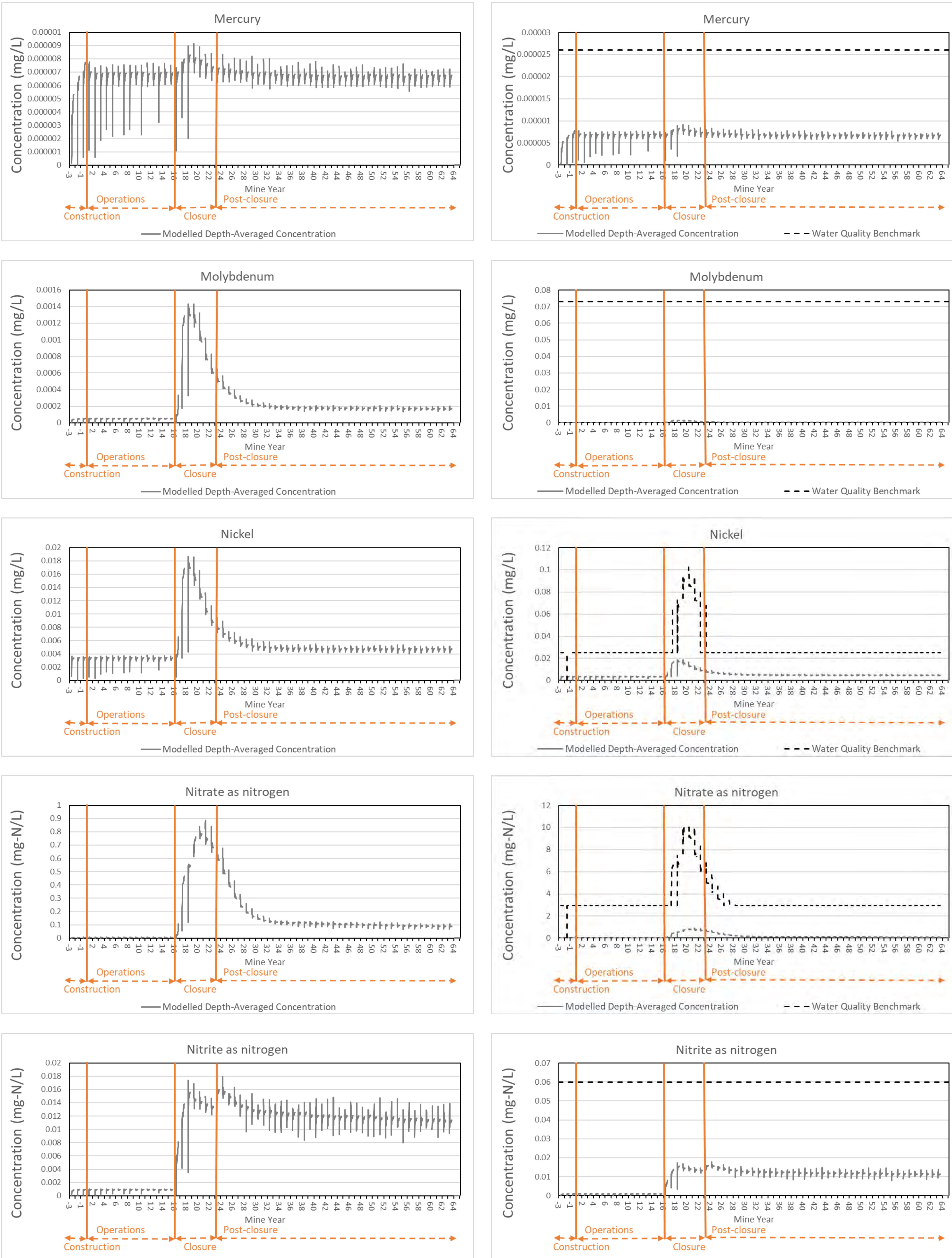


Figure C3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake Outflow over the Construction, Operations, Closure and Post-closure Periods

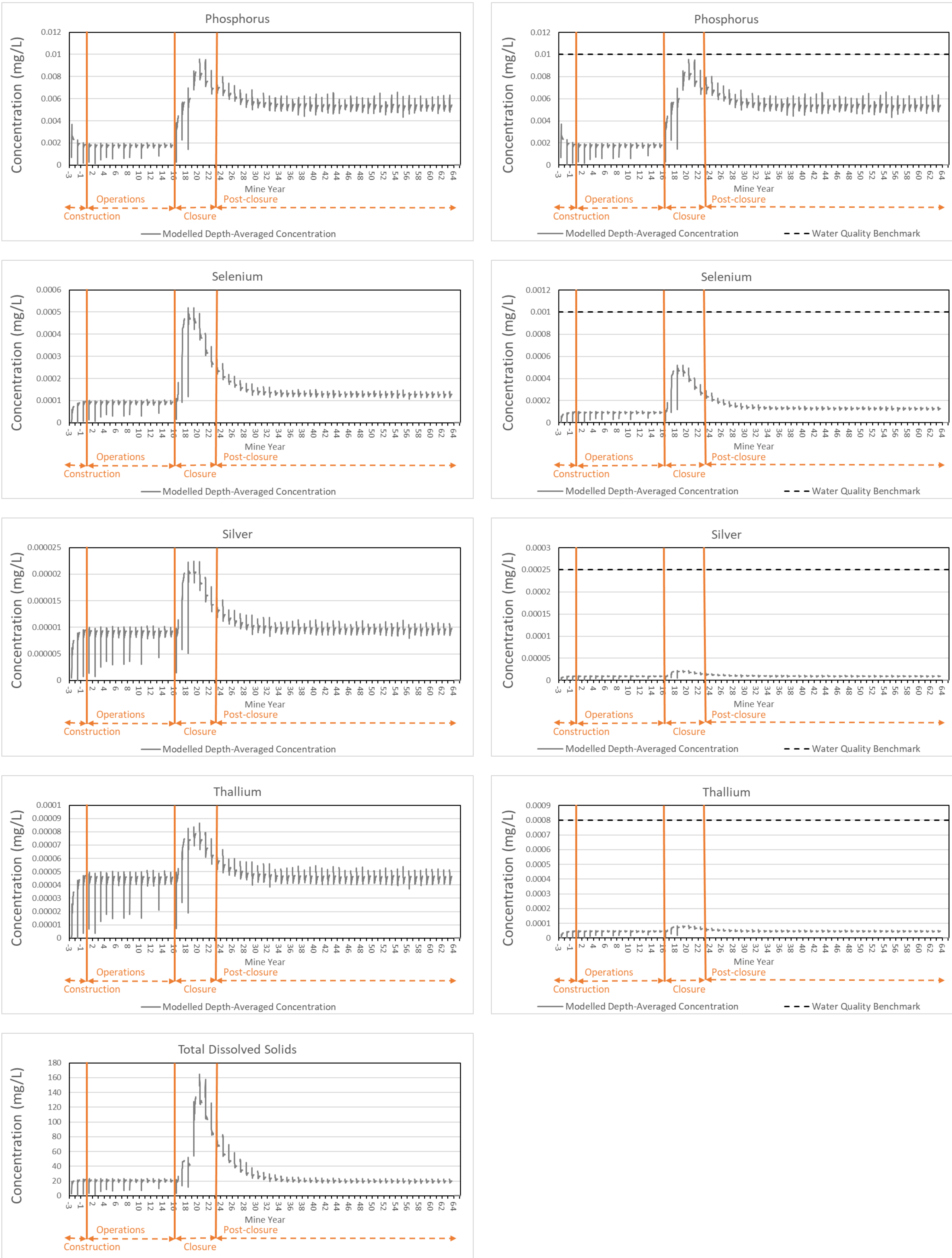
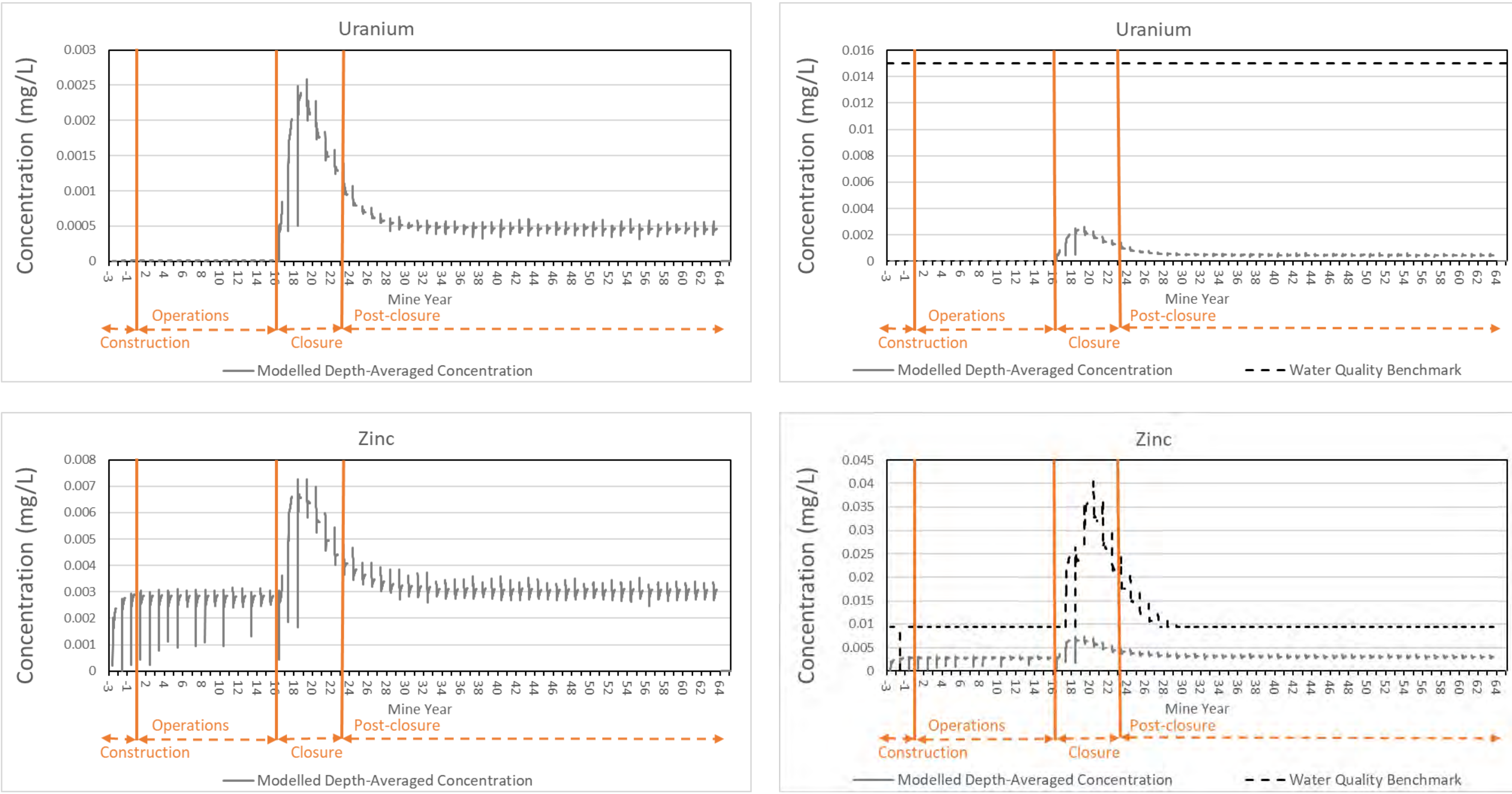


Figure C3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake Outflow over the Construction, Operations, Closure and Post-closure Periods



APPENDIX D

Goose Lake Model - Sensitivity Analysis Results

Table D1: Sensitivity Scenarios Completed on the Goose Lake Model

Sensitivity Run Number	To Evaluate Sensitivity of Model Predictions to	Assumptions	Results
Sensitivity A	Different meteorological conditions	Updated the annual historical precipitation rate, and quantity and quality of inflows to Goose Lake based on results of the stochastic WLB model (WSP Golder 2022; Section 5.1.2) for the realization that was representative of the 96th percentile of historical precipitation conditions (the Base Case model annual precipitation rates were based on the average historical meteorological conditions). Simulation period was from Year 17 to Year 27.	Some variations in predicted concentrations in the lake from year to year depending on annual load to the lake which changes from year to year under these two sensitivities (based on annual precipitation and runoff rates). No extra benchmark exceedances of the 95th percentile of predicted daily concentrations.
Sensitivity B		Updated the annual historical precipitation rate, and quantity and quality of inflows to Goose Lake based on results of the stochastic WLB model (WSP Golder 2022; Section 5.1.2) for the realization that was representative of the 4th percentile of historical precipitation conditions (the Base Case model annual precipitation rates were based on the average historical meteorological conditions). Simulation period for this scenario was from Year 17 to Year 27.	
Sensitivity C	Longer ice cover period (cryoconcentration effects)	Longer ice cover period for Goose Lake. The ice cover period was set to 1 October to 14 July (212 days) while the ice cover period in the Base Case model was from 15 October to 30 June (198 days). Simulation period was from Year 19 to Year 21; with Year 19 having longer ice cover season (i.e., 1 October Year 19 to 14 July Year 20).	Negligible changes in predicted constituent concentrations in the lake
Sensitivity D	Changes in predicted inflow rates	Inflow rates to Goose Lake were increased by 15%. Simulation period was from Year 17 to Year 27.	
Sensitivity E		Inflow rates to Goose Lake were decreased by 15%. Simulation period was from Year 17 to Year 27.	
Sensitivity F	Changes in predicted mine-affected inflow chemistries	Constituent concentrations in mine-affected inflows (i.e., PN04, PN05, and PN08) were increased by 15%. Simulation period was from Year 17 to Year 27.	Higher concentrations of constituents in the lake relative to Base Case because of increased inflow concentrations (i.e., larger load to the lake). No extra benchmark exceedances of the 95th percentile of predicted daily concentrations.

Table D2: Predicted 50th Percentile Daily Depth-Averaged Concentrations in Goose Lake in Central Basin (i.e., GLCB) and Lake Outlet (Sensitivities A and B)

Constituent	Units	Surface Water Quality Benchmark[(a)]	GLCB						Lake Outlet					
			Closure (Year 17 to 22)			Post-Closure (Year 23 to Year 27)			Closure (Year 17 to 22)			Post-Closure (Year 23 to Year 27)		
			Scenario A	Scenario B	Base Case	Scenario A	Scenario B	Base Case	Scenario A	Scenario B	Base Case	Scenario A	Scenario B	Base Case
Aluminum	mg/L	0.063 – 0.35	0.04	0.039	0.039	0.036	0.036	0.036	0.035	0.035	0.036	0.031	0.031	0.031
Arsenic	mg/L	0.025	0.0048	0.0048	0.0047	0.0062	0.0063	0.0061	0.0043	0.0043	0.0043	0.0055	0.0056	0.0055
Copper	mg/L	0.0042	0.0018	0.0018	0.0018	0.0017	0.0017	0.0017	0.0016	0.0016	0.0016	0.0015	0.0015	0.0015
Iron	mg/L	0.3	0.12	0.11	0.15	0.066	0.081	0.08	0.098	0.10	0.13	0.054	0.065	0.062
Nitrite as nitrogen	mg-N/L	0.06	0.015	0.015	0.015	0.017	0.018	0.017	0.014	0.014	0.014	0.015	0.016	0.015
Phosphorus	mg/L	0.01	0.0079	0.0076	0.0076	0.0072	0.0078	0.0074	0.007	0.0064	0.0069	0.0062	0.0068	0.0064
Phosphorus (open water) [(b)]	mg/L	0.01	0.0069	0.0062	0.0069	0.0062	0.0067	0.0064	0.0069	0.0062	0.0069	0.0062	0.0066	0.0064
Selenium	mg/L	0.001	0.00032	0.0003	0.00044	0.00018	0.00022	0.00023	0.00026	0.00027	0.00038	0.00016	0.00018	0.00019
Total Dissolved Solids	mg/L	-	97	74	84	53	75	61	89	58	84	41	59	47

a) For surface water quality benchmarks please see Table 1.

b) Open water time period is from 1 July to 15 October each year.

- = no guideline; mg-N/L = milligrams nitrogen per litre.

Table D3: Predicted 95th Percentile Daily Depth-Averaged Concentrations in Goose Lake in Central Basin (i.e., GLCB) and Lake Outlet (Sensitivities A and B)

Constituent	Units	Surface Water Quality Benchmark[(a)]	GLCB						Lake Outlet					
			Closure (Year 17 to 22)			Post-Closure (Year 23 to Year 27)			Closure (Year 17 to 22)			Post-Closure (Year 23 to Year 27)		
			Scenario A	Scenario B	Base Case	Scenario A	Scenario B	Base Case	Scenario A	Scenario B	Base Case	Scenario A	Scenario B	Base Case
Aluminum	mg/L	0.063 – 0.35	0.061	0.06	0.061	0.054	0.055	0.055	0.038	0.037	0.038	0.033	0.034	0.034
Arsenic	mg/L	0.025	0.0074	0.0074	0.0074	0.0093	0.0094	0.0092	0.0047	0.0047	0.0049	0.0058	0.0058	0.0057
Copper	mg/L	0.0042	0.0028	0.0027	0.0027	0.0026	0.0026	0.0026	0.0017	0.0017	0.0017	0.0016	0.0016	0.0016
Iron	mg/L	0.3	0.20	0.18	0.24	0.11	0.14	0.13	0.12	0.12	0.16	0.066	0.081	0.081
Nitrite as nitrogen	mg-N/L	0.06	0.024	0.023	0.023	0.026	0.027	0.025	0.015	0.015	0.015	0.016	0.017	0.016
Phosphorus	mg/L	0.01	**0.012**	**0.012**	**0.013**	**0.011**	**0.012**	**0.011**	0.0084	0.0082	0.0084	0.0069	0.0074	0.0072
Phosphorus (open water) [(b)]	mg/L	0.01	0.0083	0.0082	0.0083	0.0067	0.0074	0.007	0.0084	0.0081	0.0083	0.0067	0.0073	0.007
Selenium	mg/L	0.001	0.00055	0.00048	0.00073	0.00029	0.00036	0.00038	0.00035	0.00031	0.00048	0.00018	0.00022	0.00024
Total Dissolved Solids	mg/L	-	184	190	194	100	136	116	133	129	132	61	82	70

a) For surface water quality benchmarks please see Table 1.

b) Open water time period is from 1 July to 15 October each year.

- = no guideline; mg-N/L = milligrams nitrogen per litre.

Bold indicates the predicted concentration is above the chronic water quality benchmark.

Table D4: Predicted 50th Percentile Daily Depth-Averaged Concentrations in Goose Lake in Central Basin (i.e., GLCB) and Lake Outlet (Sensitivity C)

Constituent	Units	Surface Water Quality Benchmark[(a)]	GLCB		Lake Outlet	
			Closure (Year 19 to Year 21)			
			Scenario C	Base Case	Scenario C	Base Case
Aluminum	mg/L	0.063 – 0.35	0.042	0.042	0.036	0.037
Arsenic	mg/L	0.025	0.005	0.005	0.0043	0.0043
Copper	mg/L	0.0042	0.0019	0.0019	0.0016	0.0017
Iron	mg/L	0.3	0.15	0.15	0.13	0.13
Nitrite as nitrogen	mg-N/L	0.06	0.016	0.016	0.014	0.014
Phosphorus	mg/L	0.01	0.0089	0.0091	0.0077	0.008
Phosphorus (open water) [(b)]	mg/L	0.01	0.0077	0.0079	0.0077	0.0079
Selenium	mg/L	0.001	0.00045	0.00045	0.00038	0.00038
Total Dissolved Solids	mg/L	-	135	139	118	126

a) For surface water quality benchmarks please see Table 1.

b) Open water time period is from 1 July to 15 October for Base Case and 15 July to 30 September for Sensitivity C.

- = no guideline; mg-N/L = milligrams nitrogen per litre.

Table D5: Predicted 95th Percentile Daily Depth-Averaged Concentrations in Goose Lake in Central Basin (i.e., GLCB) and Lake Outlet (Sensitivity C)

Constituent	Units	Surface Water Quality Benchmark[(a)]	GLCB		Lake Outlet	
			Closure (Year 19 to Year 21)			
			Scenario C	Base Case	Scenario C	Base Case
Aluminum	mg/L	0.063 – 0.35	0.062	0.062	0.038	0.038
Arsenic	mg/L	0.025	0.0074	0.0074	0.0047	0.0047
Copper	mg/L	0.0042	0.0028	0.0028	0.0017	0.0018
Iron	mg/L	0.3	0.25	0.24	0.15	0.15
Nitrite as nitrogen	mg-N/L	0.06	0.023	0.024	0.015	0.015
Phosphorus	mg/L	0.01	**0.013**	**0.014**	0.009	0.0092
Phosphorus (open water) [(a)]	mg/L	0.01	0.0085	0.0084	0.0084	0.0084
Selenium	mg/L	0.001	0.00072	0.00072	0.00045	0.00045
Total Dissolved Solids	mg/L	-	207	212	144	148

a) For surface water quality benchmarks please see Table 1.

b) Open water time period is from 1 July to 15 October for Base Case and 15 July to 30 September for Sensitivity C.

- = no guideline; mg-N/L = milligrams nitrogen per litre.

Bold indicates the predicted concentration is above the chronic water quality benchmark.

Table D6: Predicted 50th Percentile Daily Depth-Averaged Concentrations in Goose Lake in Central Basin (i.e., GLCB) and Lake Outlet (Sensitivities D, E, and F)

Constituent	Units	Surface Water Quality Benchmark[a]	GLCB								Lake Outflow							
			Closure (Year 17 to Year 22)				Post-Closure (Year 23 to Year 27)				Closure (Year 17 to Year 22)				Post-Closure (Year 23 to Year 27)			
			Scenario D	Scenario E	Scenario F	Base Case	Scenario D	Scenario E	Scenario F	Base Case	Scenario D	Scenario E	Scenario F	Base Case	Scenario D	Scenario E	Scenario F	Base Case
Aluminum	mg/L	0.063 – 0.35	0.04	0.039	0.044	0.039	0.036	0.036	0.041	0.036	0.036	0.035	0.04	0.036	0.031	0.031	0.035	0.031
Arsenic	mg/L	0.025	0.0049	0.0047	0.0054	0.0047	0.0062	0.006	0.007	0.0061	0.0043	0.0042	0.0049	0.0043	0.0055	0.0054	0.0063	0.0055
Copper	mg/L	0.0042	0.0018	0.0018	0.002	0.0018	0.0017	0.0017	0.0019	0.0017	0.0016	0.0016	0.0018	0.0016	0.0015	0.0015	0.0016	0.0015
Iron	mg/L	0.3	0.15	0.14	0.17	0.15	0.079	0.079	0.09	0.08	0.14	0.13	0.15	0.13	0.062	0.062	0.07	0.062
Nitrite as nitrogen	mg-N/L	0.06	0.015	0.015	0.017	0.015	0.017	0.017	0.019	0.017	0.014	0.013	0.016	0.014	0.015	0.015	0.017	0.015
Phosphorus	mg/L	0.01	0.008	0.0077	0.0089	0.0076	0.0074	0.0073	0.0083	0.0074	0.0072	0.0069	0.008	0.0069	0.0064	0.0063	0.0073	0.0064
Phosphorus (open water)[b]	mg/L	0.01	0.0069	0.0069	0.0079	0.0069	0.0064	0.0063	0.0072	0.0064	0.0069	0.0069	0.0079	0.0069	0.0063	0.0063	0.0072	0.0064
Selenium	mg/L	0.001	0.00046	0.00044	0.00051	0.00044	0.00023	0.00023	0.00026	0.00023	0.0004	0.00039	0.00045	0.00038	0.00019	0.00019	0.00021	0.00019
Total Dissolved Solids	mg/L	-	91	91	104	84	60	60	68	61	90	89	103	84	46	47	53	47

a) For surface water quality benchmarks please see Table 1.
b) Open water time period is from 1 July to 15 October each year.
- = no guideline; mg-N/L = milligrams nitrogen per litre.

Table D7: Predicted 95th Percentile Daily Depth-Averaged Concentrations in Goose Lake in Central Basin (i.e., GLCB) and Lake Outlet (Sensitivities D, E, and F)

Constituent	Units	Surface Water Quality Benchmark[a]	GLCB								Lake Outflow							
			Closure (Year 17 to Year 22)				Post-Closure (Year 23 to Year 27)				Closure (Year 17 to Year 22)				Post-Closure (Year 23 to Year 27)			
			Scenario D	Scenario E	Scenario F	Base Case	Scenario D	Scenario E	Scenario F	Base Case	Scenario D	Scenario E	Scenario F	Base Case	Scenario D	Scenario E	Scenario F	Base Case
Aluminum	mg/L	0.063 – 0.35	0.062	0.06	0.068	0.061	0.056	0.054	0.062	0.055	0.038	0.037	0.042	0.038	0.034	0.033	0.038	0.034
Arsenic	mg/L	0.025	0.0075	0.0072	0.0084	0.0074	0.0093	0.009	0.011	0.0092	0.0048	0.0046	0.0054	0.0049	0.0058	0.0056	0.0065	0.0057
Copper	mg/L	0.0042	0.0028	0.0027	0.003	0.0027	0.0026	0.0025	0.0028	0.0026	0.0017	0.0017	0.0019	0.0017	0.0016	0.0016	0.0018	0.0016
Iron	mg/L	0.3	0.24	0.23	0.27	0.24	0.13	0.13	0.15	0.13	0.16	0.15	0.18	0.16	0.081	0.081	0.092	0.081
Nitrite as nitrogen	mg-N/L	0.06	0.024	0.023	0.027	0.023	0.025	0.025	0.029	0.025	0.015	0.014	0.017	0.015	0.016	0.016	0.018	0.016
Phosphorus	mg/L	0.01	0.013	0.013	0.014	0.013	0.011	0.011	0.013	0.011	0.0086	0.0081	0.0095	0.0084	0.0071	0.0069	0.008	0.0072
Phosphorus (open water)[b]	mg/L	0.01	0.0085	0.0081	0.0094	0.0083	0.007	0.0069	0.0079	0.007	0.0085	0.0081	0.0094	0.0083	0.007	0.0069	0.0079	0.007
Selenium	mg/L	0.001	0.00075	0.0007	0.00083	0.00073	0.00038	0.00039	0.00043	0.00038	0.00049	0.00045	0.00054	0.00048	0.00023	0.00024	0.00027	0.00024
Total Dissolved Solids	mg/L	-	201	188	223	194	115	116	132	116	138	125	152	132	69	69	78	70

a) For surface water quality benchmarks please see Table 1.
b) Open water time period is from 1 July to 15 October each year.
- = no guideline; mg-N/L = milligrams nitrogen per litre.
Bold indicates the predicted concentration is above the chronic water quality benchmark.

Please note the timeseries below are separately plotted with and without surface water quality benchmarks (except for TDS which does not have a benchmark, see Table 1).

Figure D1: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake in Central Basin (i.e., GLCB) (Sensitivities A and B)

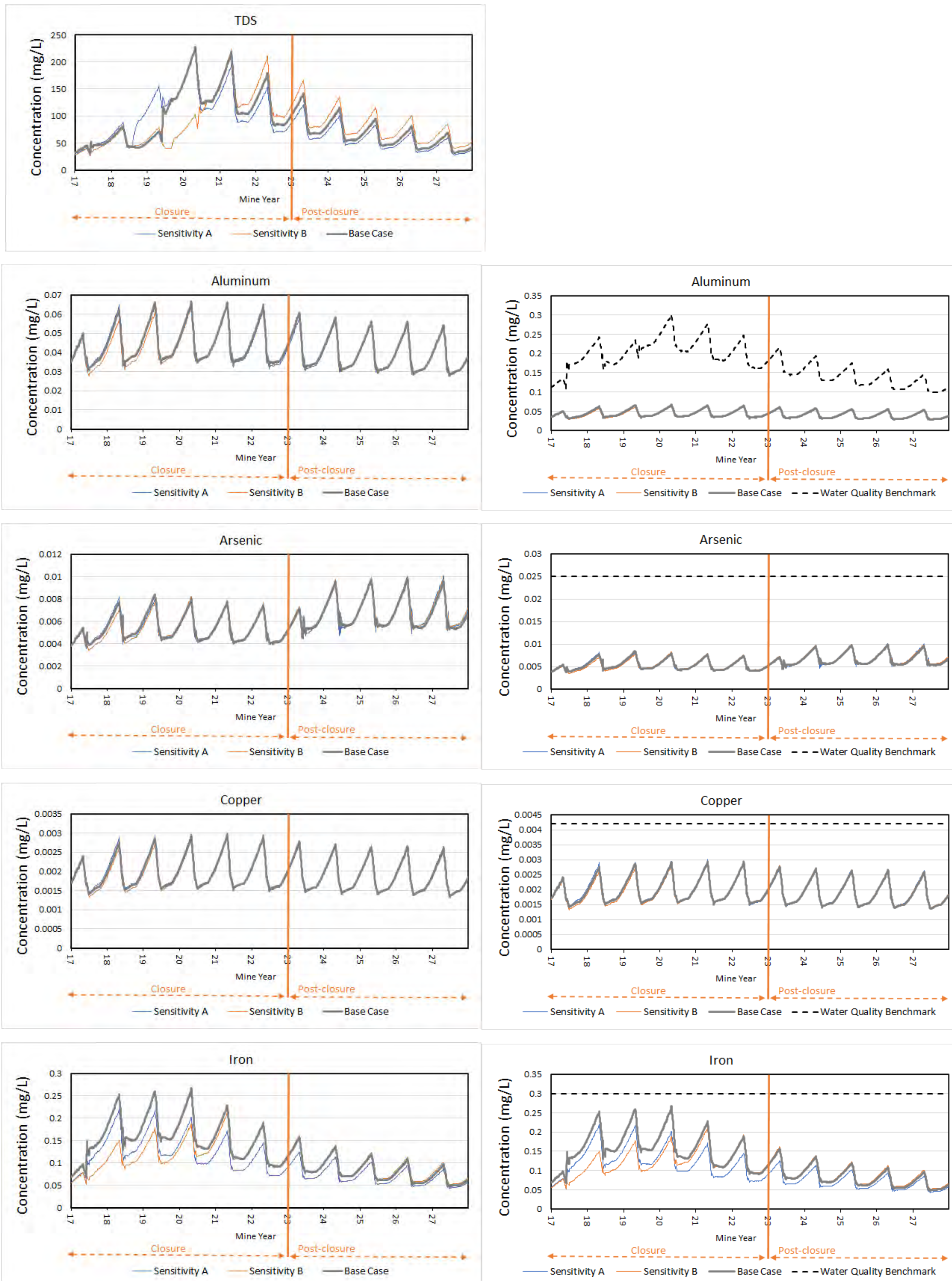


Figure D1: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake in Central Basin (i.e., GLCB) (Sensitivities A and B)

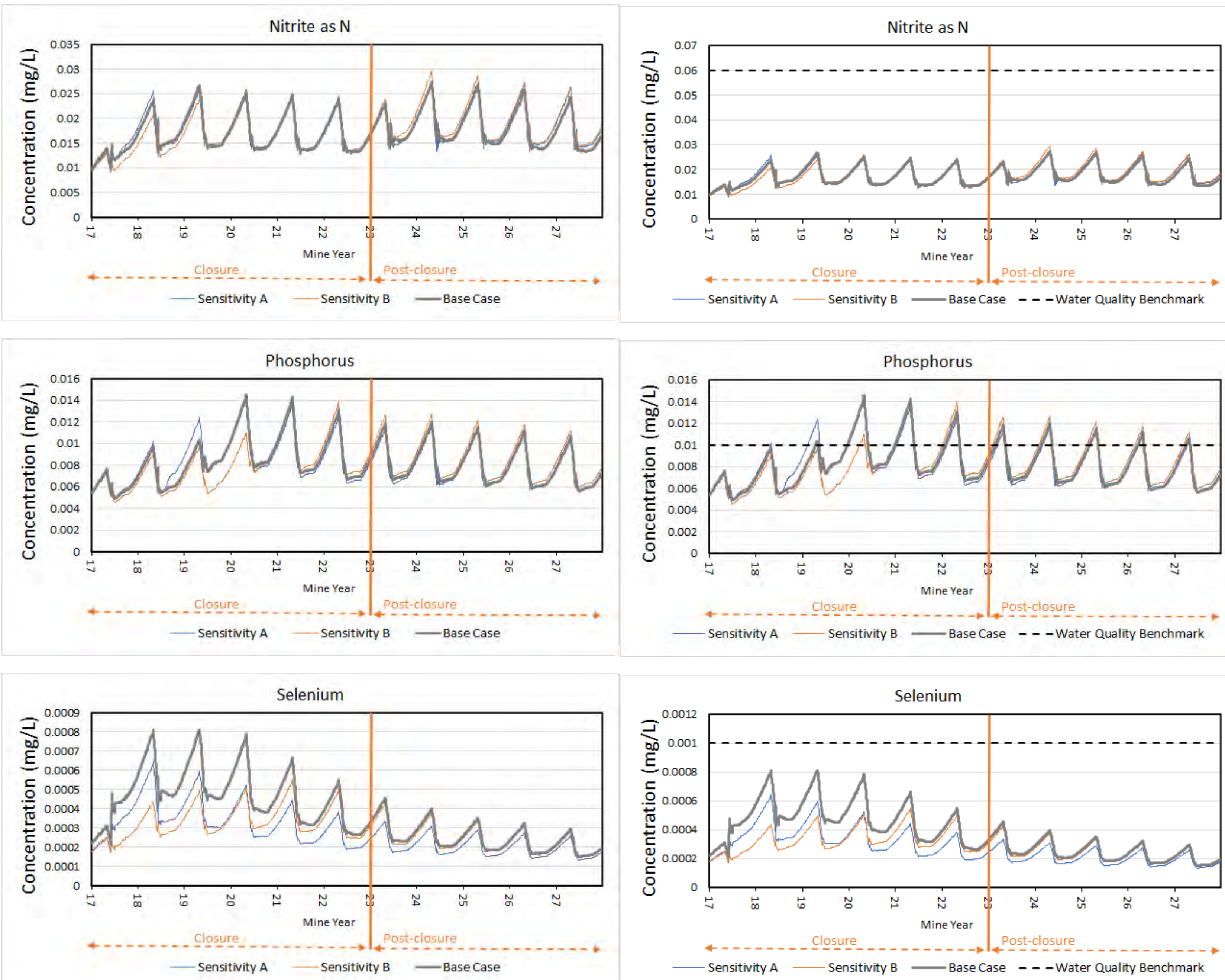


Figure D2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for the Lake Outlet (Sensitivities A and B)

Figure D2: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for the Lake Outlet (Sensitivities A and B)

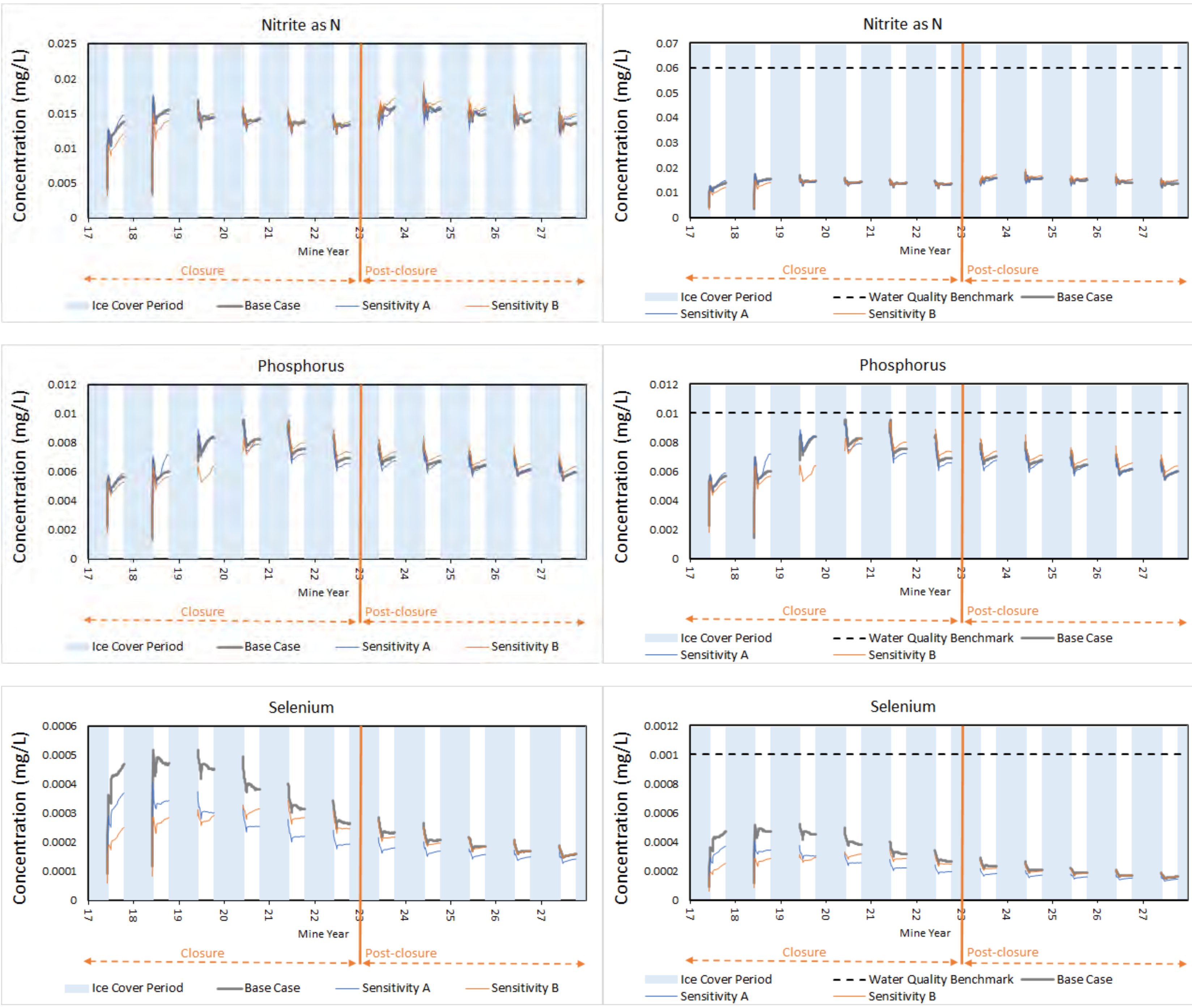


Figure D3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for GLCB (Sensitivity C)

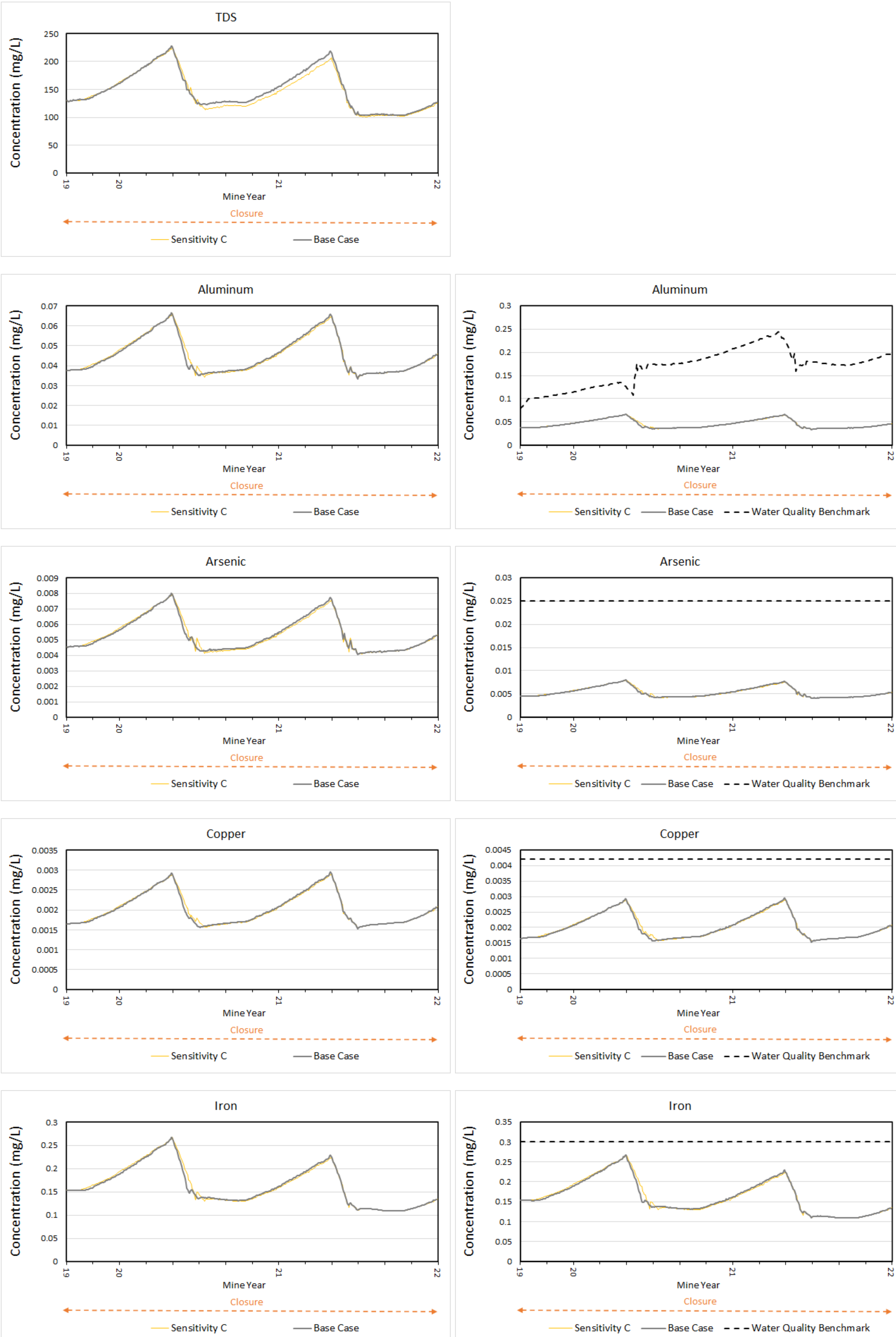


Figure D3: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for GLCB (Sensitivity C)

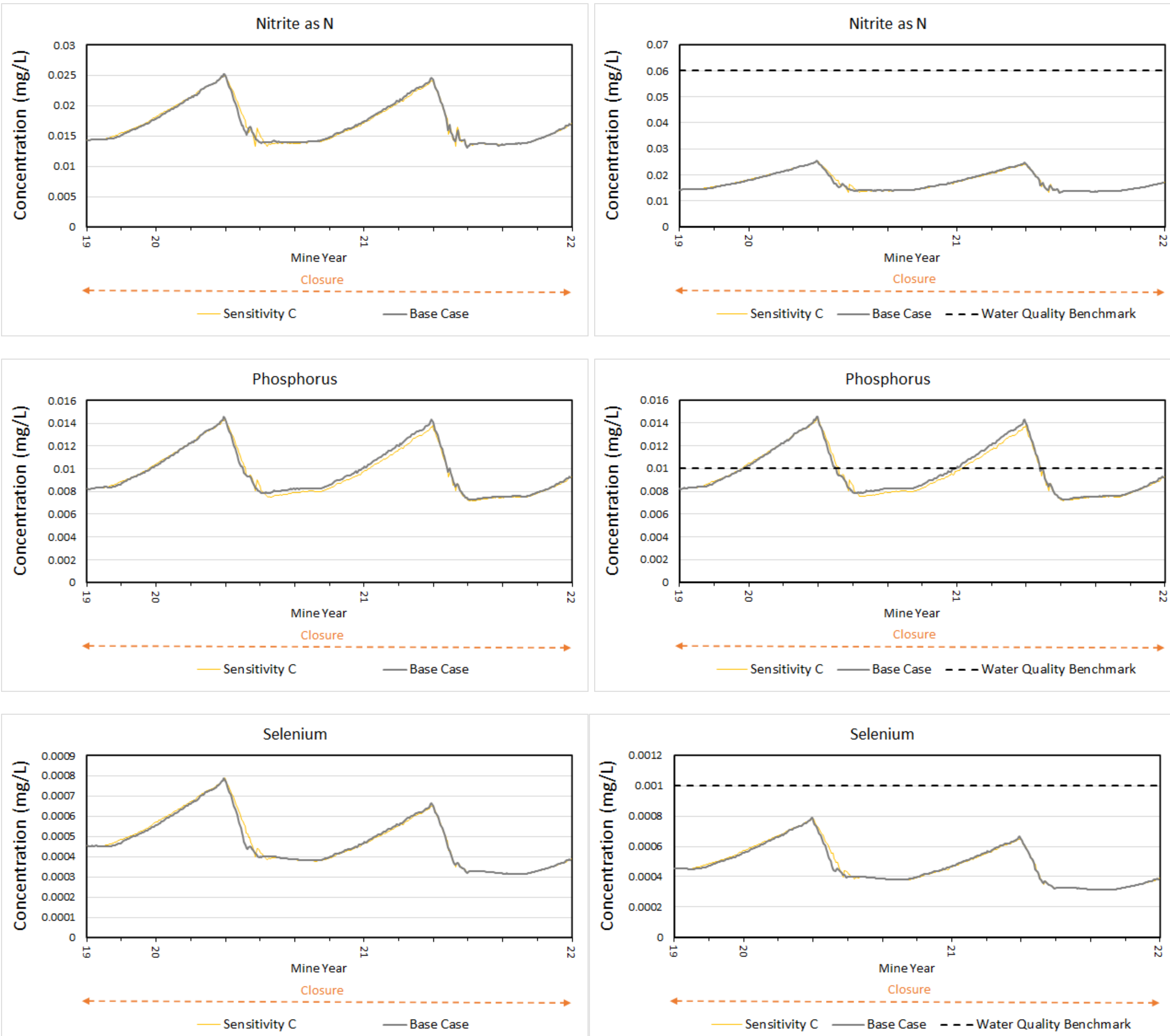


Figure D4: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for the Lake Outlet (Sensitivity C)

Figure D4: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for the Lake Outlet (Sensitivity C)

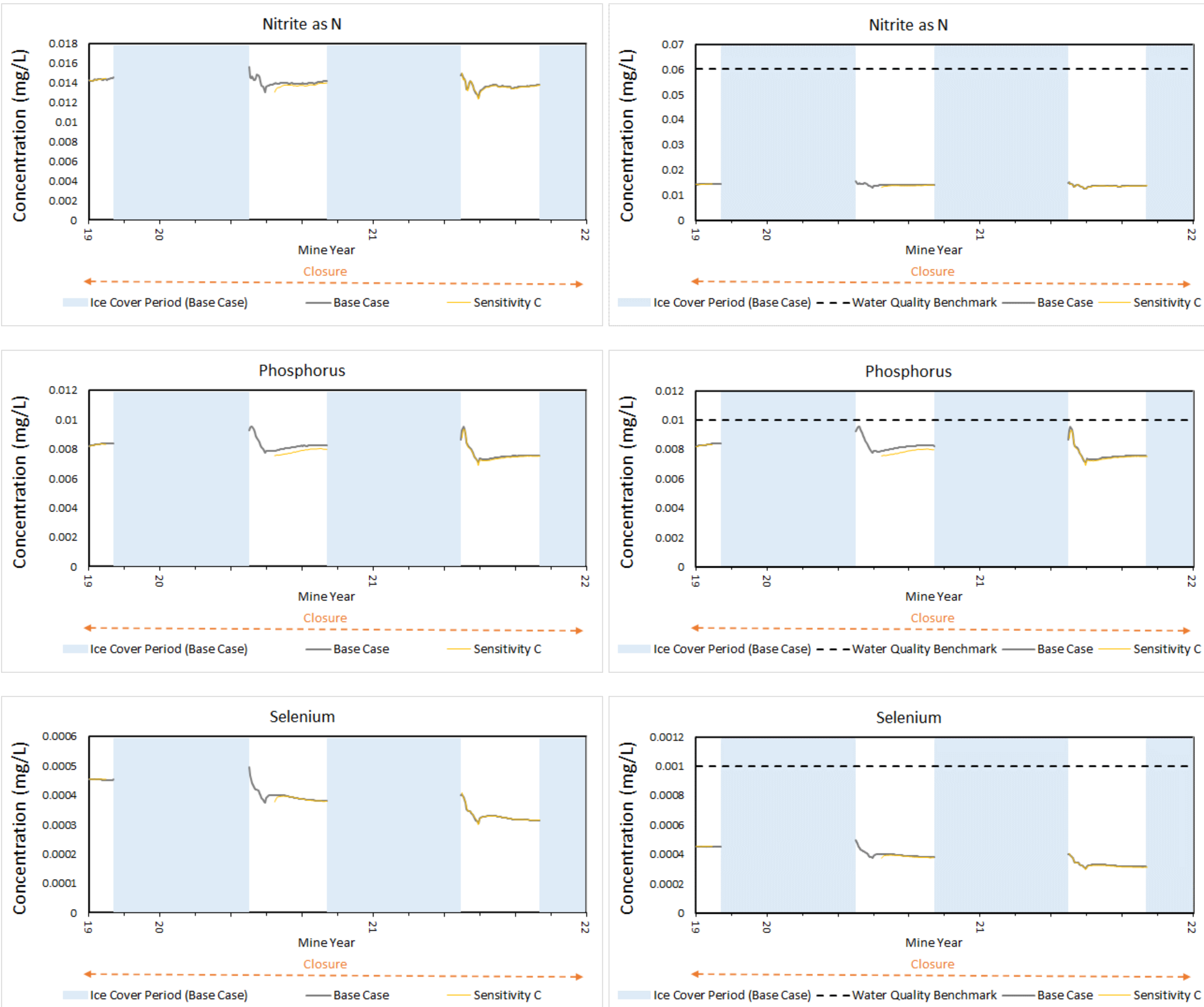


Figure D5: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for GLCB (Sensitivities D, E and F)

Figure D5: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for GLCB (Sensitivities D, E and F)

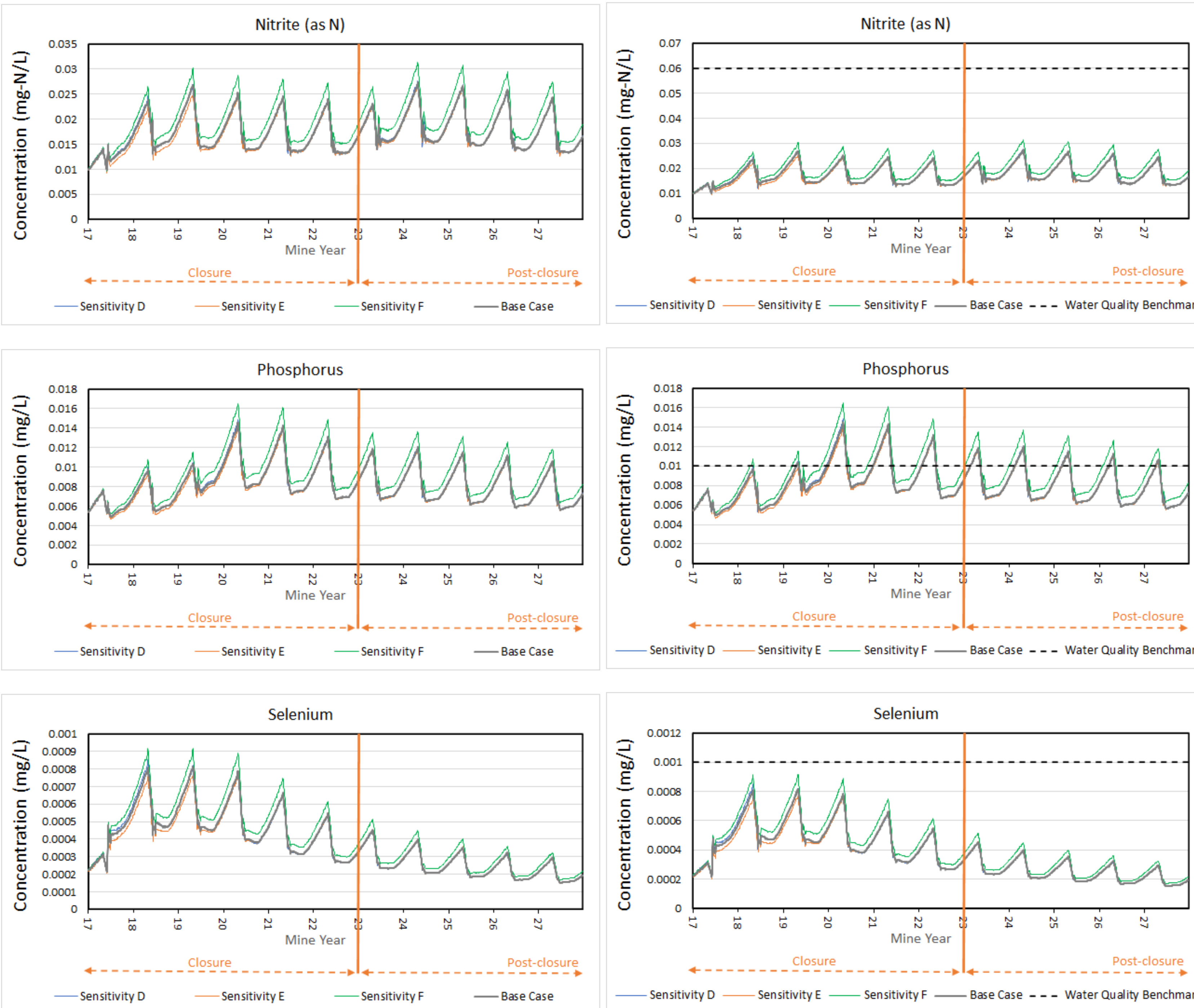
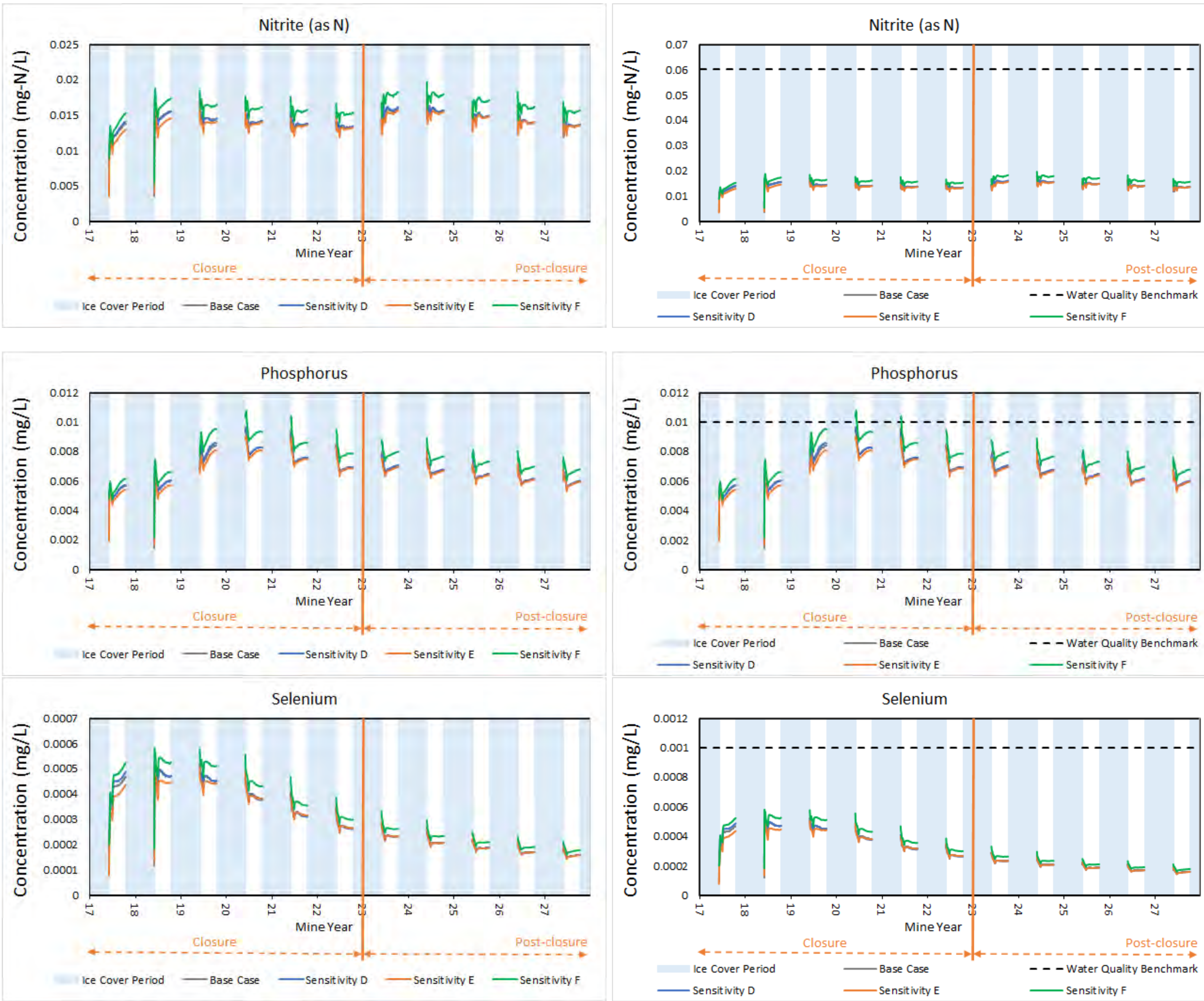


Figure D6: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for the Lake Outlet (Sensitivities D, E and F)

Figure D6: Predicted Timeseries Concentrations of Water Quality Constituents in Goose Lake for the Lake Outlet (Sensitivities D, E and F)



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