Appendix H. Capitol Lake Water Quality Model Calibration and Verification

The original Budd Inlet model (Aura Nova Consultants et al., 1998) included Capitol Lake as a boundary condition to Budd Inlet. The present project required a simulation of conditions within Capitol Lake and a linked Budd Inlet-Capitol Lake model. The Department of Ecology (Ecology) contracted with ERM Inc. (ERM) to extend the computational grid into Capitol Lake and to add a water quality module necessary to simulate the combined population of macrophytes, epiphytes, and attached bottom algae (hereafter referred to as "macrophytes"). Ecology hypothesized that understanding both macrophytes and phytoplankton would be necessary to simulate water quality in Capitol Lake.

The original Budd Inlet model was previously developed by J.E. Edinger Associates Inc. for Lacey, Olympia, Tumwater, Thurston County Partnership (LOTT). For the 2008 draft of the present report, Ecology contracted with ERM to develop and calibrate the combined Capitol Lake and Budd Inlet hydrodynamic and water quality model (Prakash and Kolluru, 2008). The scope of work for ERM for the 2008 draft report included:

- Initial calibration of the combined Capitol Lake/Budd Inlet GEMSS® model application to recent data collected during 2003-04 by Ecology and Thurston County.
- Initial verification of the calibration of the combined Capitol Lake/Budd Inlet model application with recent data collected during 2000-01 by the Miller Brewing Company and Thurston County.

Following the 2008 draft report, Ecology discovered and corrected numerous errors in the model source code. Following the 2008 draft report, Ecology revised the calibration and verification after the errors were fixed. This appendix documents the most recent re-calibration and verification of the Capitol Lake model that was linked to the Budd Inlet model.

Grid Layering of the Model Domain

The Capitol Lake grid was developed by ERM (Prakash and Kolluru, 2008) from bathymetry data collected by USGS and Ecology in 2004. Bottom elevations were relative to MLLW at Boston Harbor. The lake is deepest near the outlet (near station CL4 in Figure H1) with a depth of approximately 4 meters and shallowest (1.7 meters) in Percival Cove (station PC in Figure H1).

GEMSS Modules Used

The following GEMSS water quality modules were used to simulate water quality in Capitol Lake:

- **WQADD** - The macrophyte module WQADD was used to simulate the growth and decay of the macrophyte variable including simulating the herbicide application in 2004 with the use of time-varying rates (TVR) for kinetics.
- **GAM** - The Generalized Algae Module (GAM) was used to simulate two algal groups to help simulate seasonal variation in chlorophyll *a*.

- **WQCBM -** The WQCBM module was used to predict dissolved oxygen (DO), nitrogen, and phosphorus concentrations (both organic and inorganic fractions) and organic carbon (both particulate and dissolved) in response to autotroph (phytoplankton and macrophyte) growth, respiration and die-off, and biochemical transformations by heterotrophic bacteria.

The kinetic rates for heterotrophs, as well as rates for physical processes (like settling of particulate organic matter), are included in the WQCBM module. The kinetic rates for the autotrophs (phytoplankton and macrophytes) are included in the respective modules of GAM and WQADD. The final rates and constants used in model calibration are presented at the end of this appendix in Tables H3 through H12.

Calibration Period (2004)

Ecology collected a dataset for model calibration during 2004 (Roberts et al, 2004). The calibration period adopted was 05/18/2004 to 09/30/2004, based on availability of boundary condition and calibration data. Data collected by Ecology were also supplemented by data collected by Thurston County during 2004.

Field stations used for Calibration

During the calibration period, several field measurements were available that were used to calibrate the model. These field measurement locations and the corresponding grid cells are shown in Figure H1. Stations CL1, CL2, CL3, and CL4 were monitored by Ecology while stations PC (Percival Cove), MB (Middle Basin) and NB (North Basin) were monitored by Thurston County. Field monitoring included temperature, salinity, DO, total and ortho phosphate, nitrate, ammonia, organic nitrogen, organic phosphorus, total organic carbon, particulate organic carbon, and chlorophyll. Not all the parameters were monitored for all stations.

Figure H1. Field measurement locations for the calibration period (2004).

Tributaries

The two inflows to Capitol Lake are from Deschutes River and Percival Creek. There were no continuous monitoring data available for nutrients for these inflows. The only continuous data available were for temperature. A synthetic time series of continuous DO values for tributaries were calculated from temperature by assuming that DO was at 100% saturation conditions. The available nutrient data were intermittent and thus do not capture any short-term variations in the stream conditions. Figures H2 and H3 show the boundary condition data for the calibration period. Figure H4 shows the temperature and calculated DO values for these inflows.

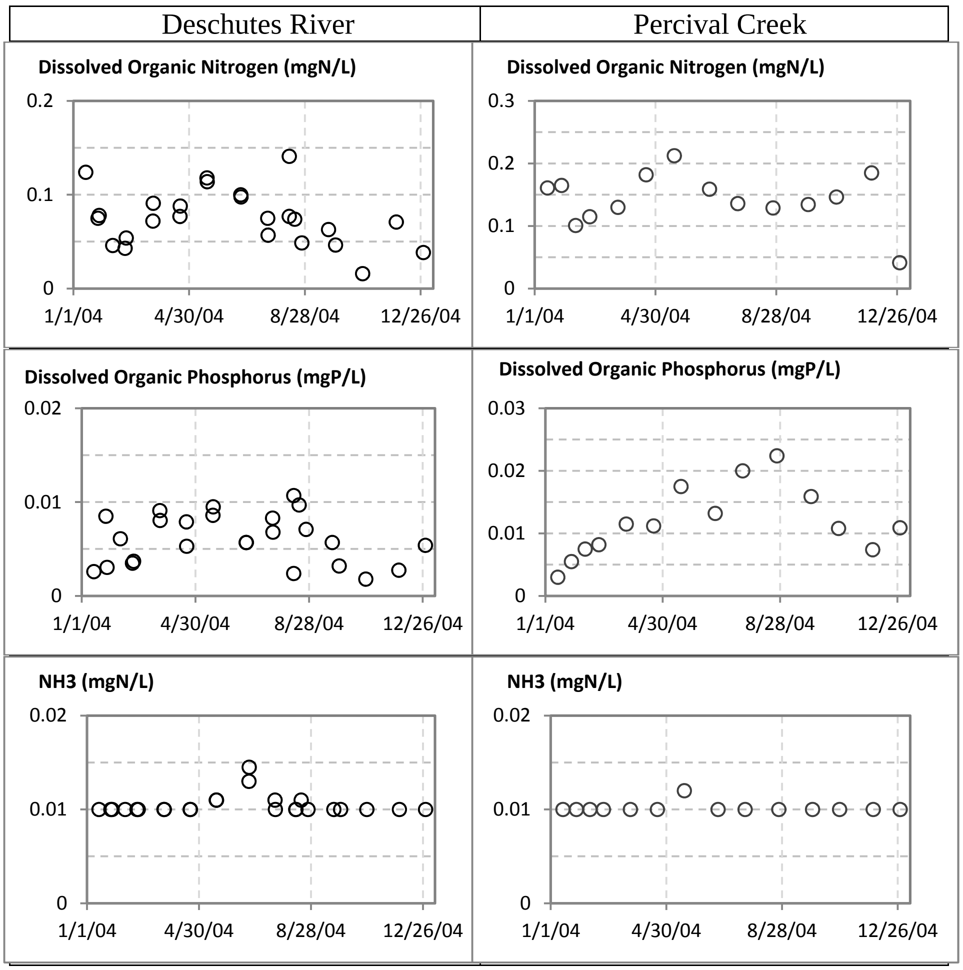


Figure H2. Boundary condition values for Deschutes River and Percival Creek during calibration, 2004.

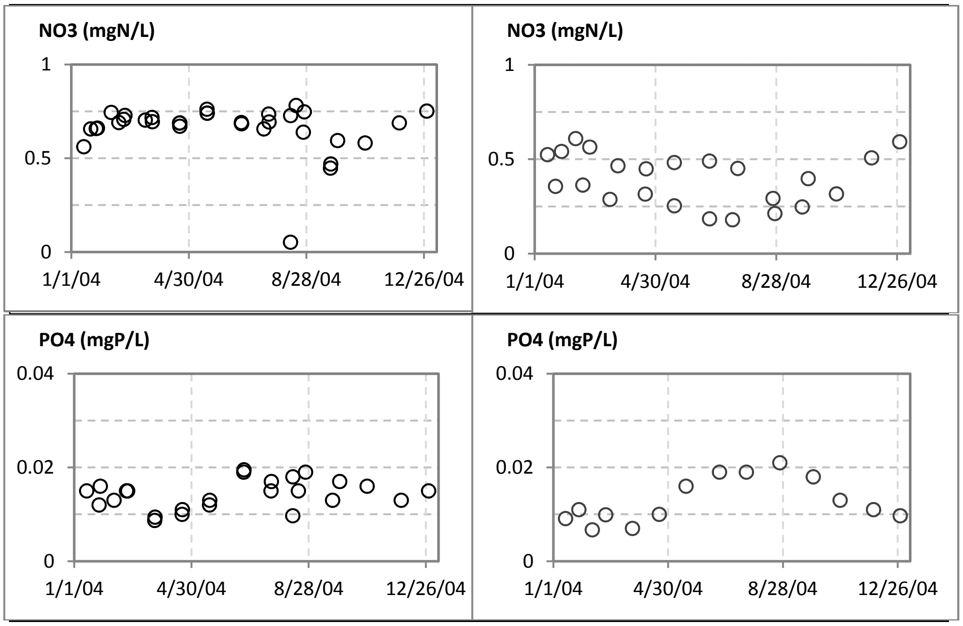


Figure H3. Boundary condition values for Deschutes River and Percival Creek during calibration, 2004 (continued).

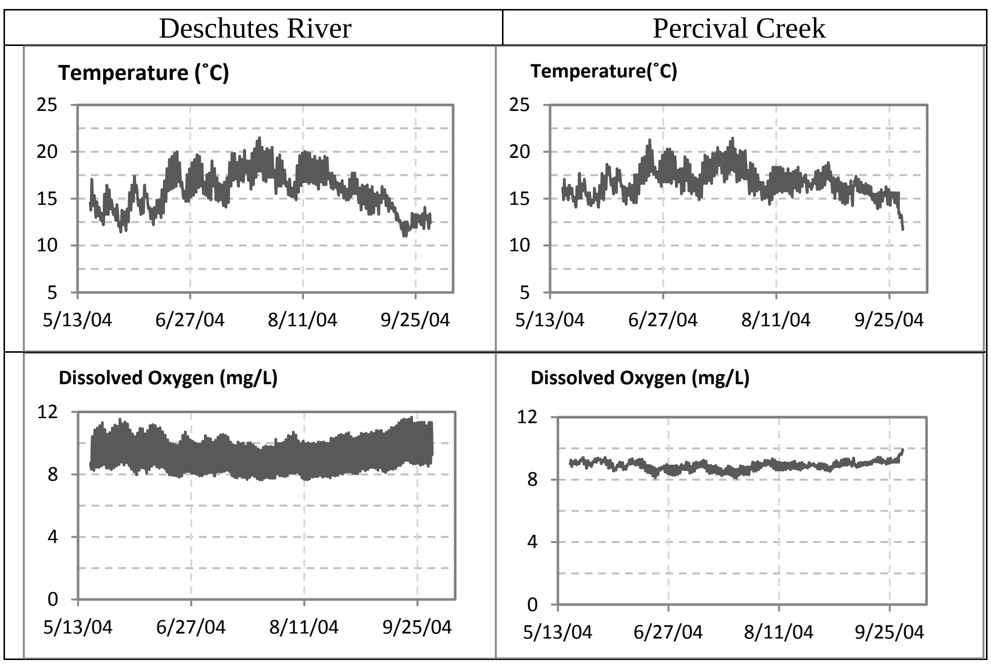


Figure H4. Inflow temperatures and DO for Deschutes River and Percival Creek.

Sediment Fluxes

Sediment fluxes of DO, nitrate, ammonia, and phosphate were quantified at four different locations within Capitol Lake once in 2004. These sediment flux values and the regions over which they were applied are shown in Figure H5.

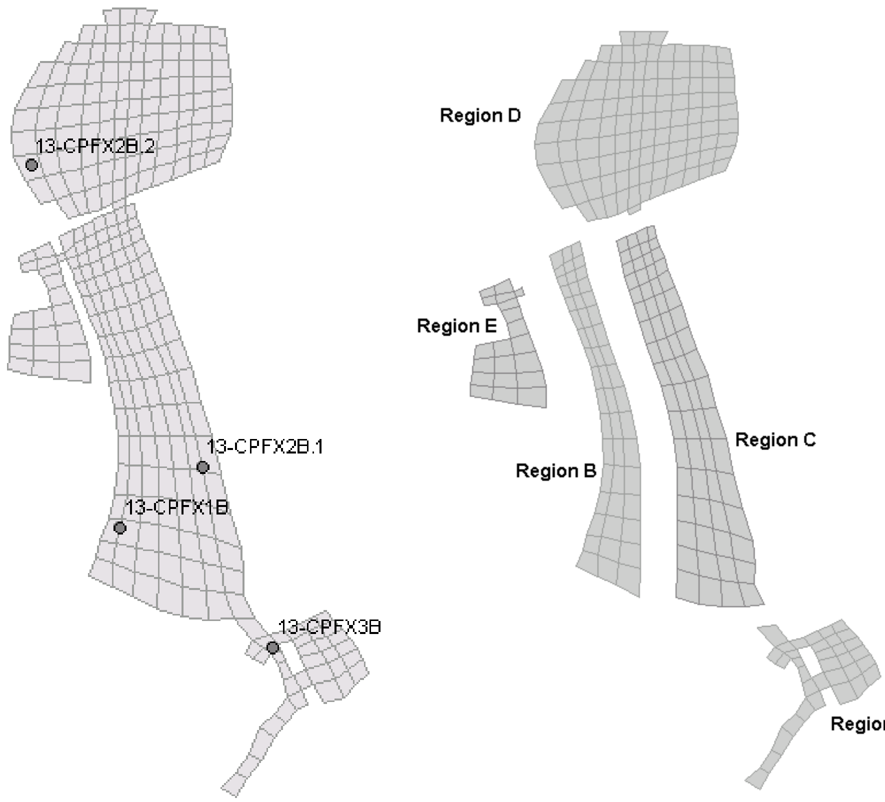


Figure H5. Stations where sediment fluxes were measured and sediment regions used in the model.

Sediment fluxes for Region E were assumed to be the same as for Region A (station 13-CPFX3B), as these two regions are influenced by mouths of tributaries. The middle basin is divided into two regions (Region B and Region C) based on data at two respective stations, 13-CPFX1B and 13-CPFX2B.1. Region D sediment fluxes were based upon the northern station 13-CPFX2B.2. Constant sediment fluxes were assumed throughout the model simulation period. Scalars were used to vary sediment fluxes within a narrow margin, where necessary to calibrate the model. Figure H6 shows the final sediment fluxes used in Capitol Lake.

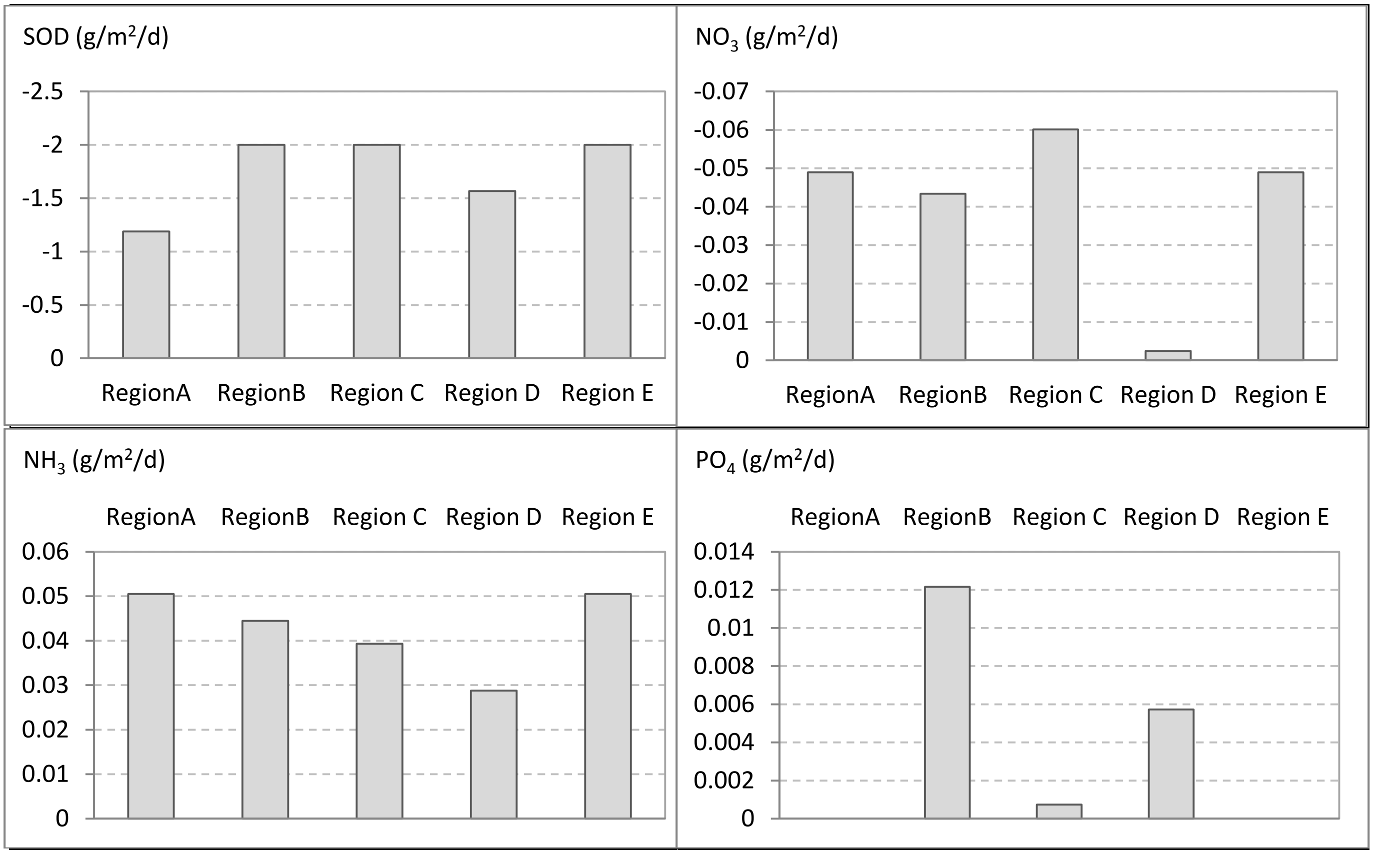


Figure H6. Sediment fluxes used in Capitol Lake.

Macrophytes

During the calibration period, herbicide was introduced into Capitol Lake to remove macrophytes. Due to this, there was a sudden release of nutrients into the lake from decaying macrophyte biomass. This sudden rise in nutrients resulted in excessive algal growth. The application of herbicide was carried out in two steps. Herbicide was first introduced in the Middle and South basins on July 19, 2004 and then in the north basin on July 29, 2004. To replicate this behavior, two sets of kinetic rates were adopted. One set represented the pre-herbicide period and the second set represented the post-herbicide period. The herbicide used was triclopyr (brand name Renovate®) and was specific to the invasive non-native macrophyte Eurasian watermilfoil (*Myriophyllum spicatum*). Other macrophyte species remained viable following the application of herbicides.

The average concentration of macrophytes in Capitol Lake prior to application of herbicide (July 11-12, 2004) was 65.3 g/m^2 out of which 54.8 g/m^2 was Eurasian watermilfoil. So, approximately 10 g/m^2 of non-invasive macrophytes were viable following the application of the plant specific herbicide. The average concentration of macrophytes on September 13-16, 2004 was approximately 63 g/m^2 with almost no Eurasian watermilfoil present (Parsons, 2004). Biomass measurements within Percival Cove indicated that there were no Myriophyllum spicatum (Eurasian watermilfoil) so there was no impact of the herbicide application in this cove.

Although the lake could be divided up into two distinct regions with different dates for herbicide application, it was deemed appropriate to create four regions where different macrophyte kinetic rates could be applied as shown in Figure H7. An evaluation of macrophyte data (see Appendix C) in North, Middle and South basins suggest that the macrophyte speciation were distinctly different in North basin compared with Middle and South basins (Figure H8). Therefore North basin was regionalized. South and Middle basins were also regionalized separately since they are distinctly different, the South basin being at the mouth of the Deschutes River while Middle basin being a wide shallow channel. This regionalization provided an avenue for utilizing separate kinetic rates for these regions to facilitate calibration as necessary.

The GEMSS module WQADD was used to enter the kinetic rates. The final kinetic rates in the different regions are described in Tables H6 and H7 at the end of this appendix. Time-varying kinetic rates were used for North, Middle and South basins to facilitate simulation of herbicide application (see Table H8) while time-varying kinetic rates were not necessary for Percival Cove since no die-off of macrophytes from herbicide application was present.

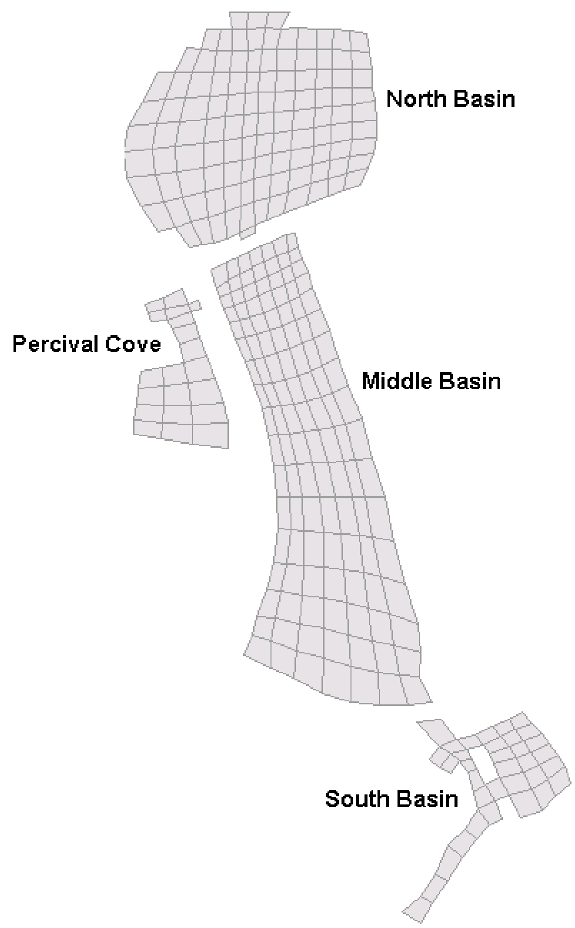
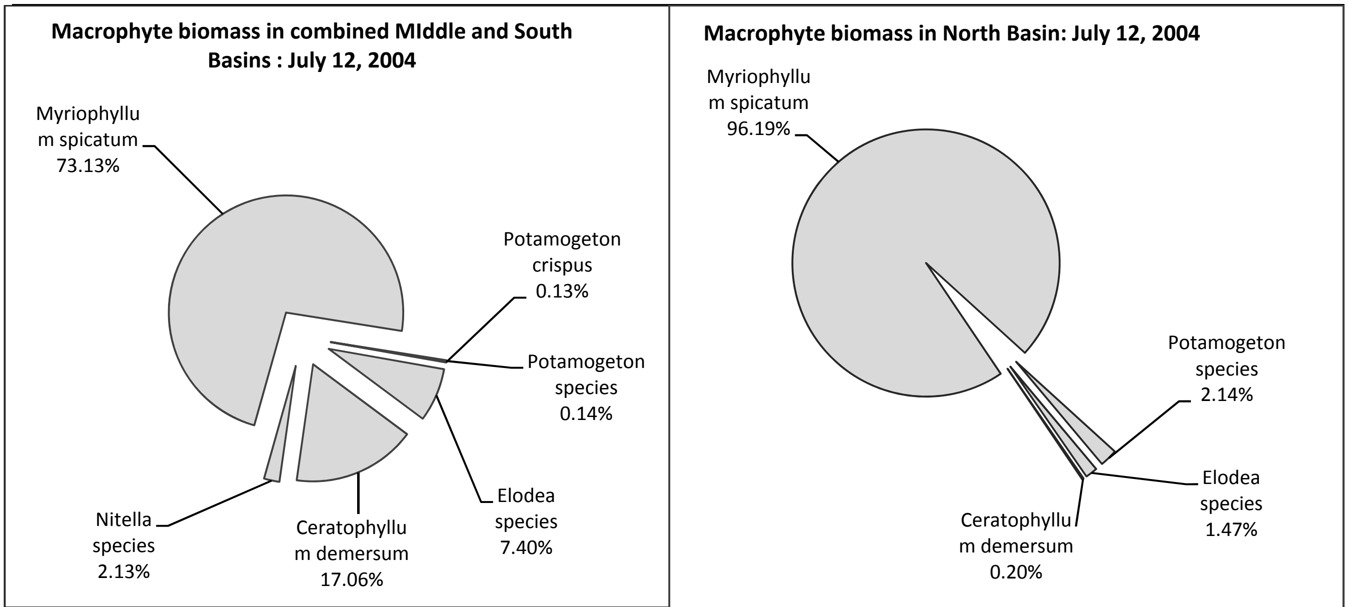


Figure H7. Macrophyte regions used in calibration.



Elodea species = waterweed;	*Ceratophyllum demersum = coontail, hornwort)*
Nitella species = Stonewort;	*Myriophyllum spicatum = Eurasian water-milfoil*
Potamogeton species = thin leaved ponweed;	*Potamogeton crispus = curly leaved ponweed*

Figure H8. Comparison of population diversity in North and Middle-South basins.

Phytoplankton

As described in the main report (see Figure 27), the algal biomass and speciation varied significantly between South and North basins. This variation was also seasonal. It was therefore deemed appropriate to use two phytoplankton groups during calibration. These were labeled GAM1 and GAM2, referring to the generalized algae module (GAM) in GEMSS. Four regions were created similar to the macrophyte regions (Figure H7) to facilitate calibration using region specific kinetic rates. The final kinetic rates for algae in the different regions are described at the end of this appendix in Tables H9 and H10.

Light extinction

The GEMSS model calculates the light extinction coefficient (Ke, m^-1) based on the following formula:

Ke = 0.336 + 0.0365 * Chla ^ 0.64

Where Chla is the phytoplankton chlorophyll a concentration (ug/L) in the water column. The parameters 0.336, 0.0365, and 0.64 were estimated based on regression of observed extinction and phytoplankton data from South Puget Sound.

For typical chlorophyll a concentrations in the range of 10 to 50 ug/L, the resulting light extinction is about 0.5 to 0.8 m^{-1} from the equation used in the GEMSS model. This is very similar to the observed interquartile range of light extinction in Capitol Lake measured during 2003-2004 of 0.5 to 0.8 m^{-1}.

Meteorology and precipitation

Source of meteorological data were same as those for the Budd Inlet region as discussed in Appendix G except for year 2004 (year 2001 for model verification). Similarly, solar radiation was entered as cloud corrected values (cloud correction for solar radiation was turned OFF in the model). The temperature for rainfall was estimated as average of air and dew point temperatures with negative temperatures assumed as zero. This temperature was then used to calculate the saturation DO concentration for the rainfall. Meteorological constants used in the model are presented in Table H11.

Calibration Results

As mentioned above, the input data for boundary conditions are not continuous, and thus it is expected that the model results would not be able to capture short-term responses like storms. The model should still be able to capture the system trend. The following sections compare model predictions with available discrete or continuous data using the root mean square error (RMSE) statistic. The RMSE is defined as follows:

$$RMSE = \sqrt{\frac{\sum (Xm - Xd)^2}{N}}$$

Where Xm = model predicted value
Xd = Field data
N = number of observations

The overall goal of the calibration exercise was to minimize RMSE. The calibration process included varying the rates and constants in the three GEMSS modules (WQCBM, WQADD and GAM) in successive batches with RMSE calculated for each run within a batch. The run with the lowest RMSE was considered for further improvement in the next batch of runs. Similarly, for temperature calibration, the following variables were varied during the calibration process, Chezy friction coefficient, wind sheltering coefficient, wind speed function, transport scheme, and dispersion functions. The final hydrodynamic and transport constants used in the model are presented in Table H12.

<u>Calibration to discrete and continuous temperature measurements</u>

Figure H9 shows predicted and observed temperature plots at stations CL1, CL2, CL3, CL4, MB, NB, and PC, along with the RMSE values. The model does a reasonably good job in defining the temperature trends at the various stations. The July measurement at stations NB and MB were overestimated. However, the July measurements at other stations suggests much warmer temperatures compared with those at stations MB and NB. It is not clear why temperature reading at these two stations were so low for July. Stations MB, NB, and PC were monitored by Thurston County. Figure H9 also shows continuous model predictions versus continuous observed temperatures at station CL4 in the month of August. The model is able to predict the general trend of the observed continuous temperature measurements.

Bottom temperature time series were available at two stations CL3 in the North basin and MB in the Middle basin. These plots are shown in Figure H10. Station MB again shows a low measurement in July which was overestimated by the model. Bottom temperatures are also over estimated in late August. However, the model is able to predict the general trend of the bottom temperatures.

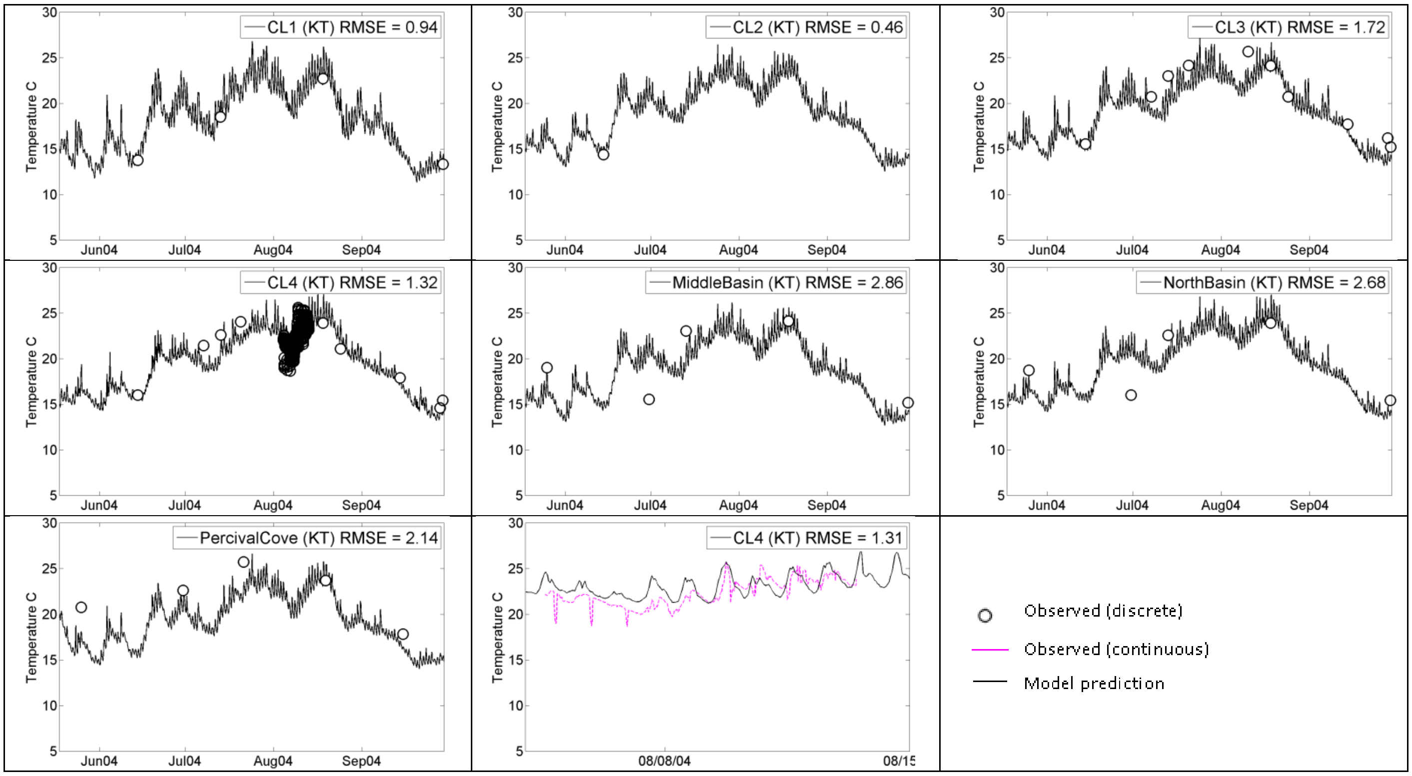


Figure H9. Predicted and observed temperatures at the various stations, including continuous temperatures at CL4.

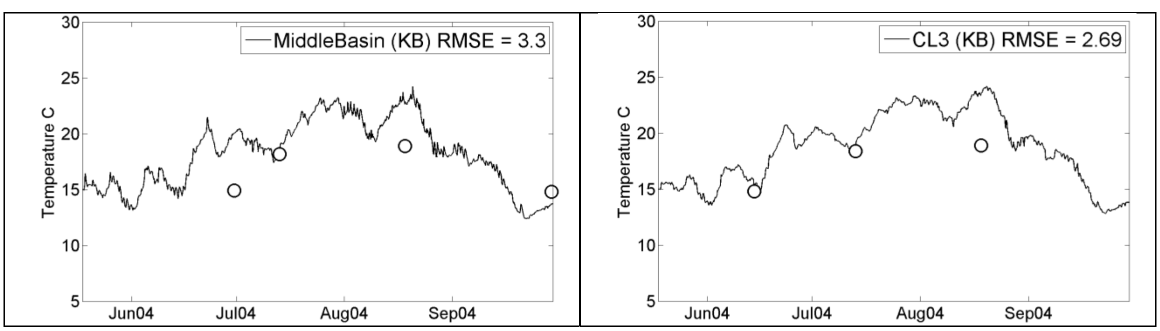


Figure H10. Predicted and observed temperatures in the bottom layer (KB) at stations CL3 and MB.

Calibration to basin-wide average macrophyte measurements

Figure H11 shows plots of observed (average basin-wide macrophyte concentrations) versus model predictions. The model does a reasonably good job of predicting observed macrophyte concentrations both before during and after herbicide applications. Station CL4 is deep and the lower macrophyte predictions at this station are likely due to light limitation. The observed concentration is not a representation of the specific station but rather a basin-wide average measurement. As indicated earlier, Percival Cove (PC) did not have any milfoil and therefore the herbicide did not reduce any macrophyte as shown in Figure H11. Station CL4 is the deepest station near the lake outlet and the macrophyte growth is likely suppressed due to insufficient light at the bottom.

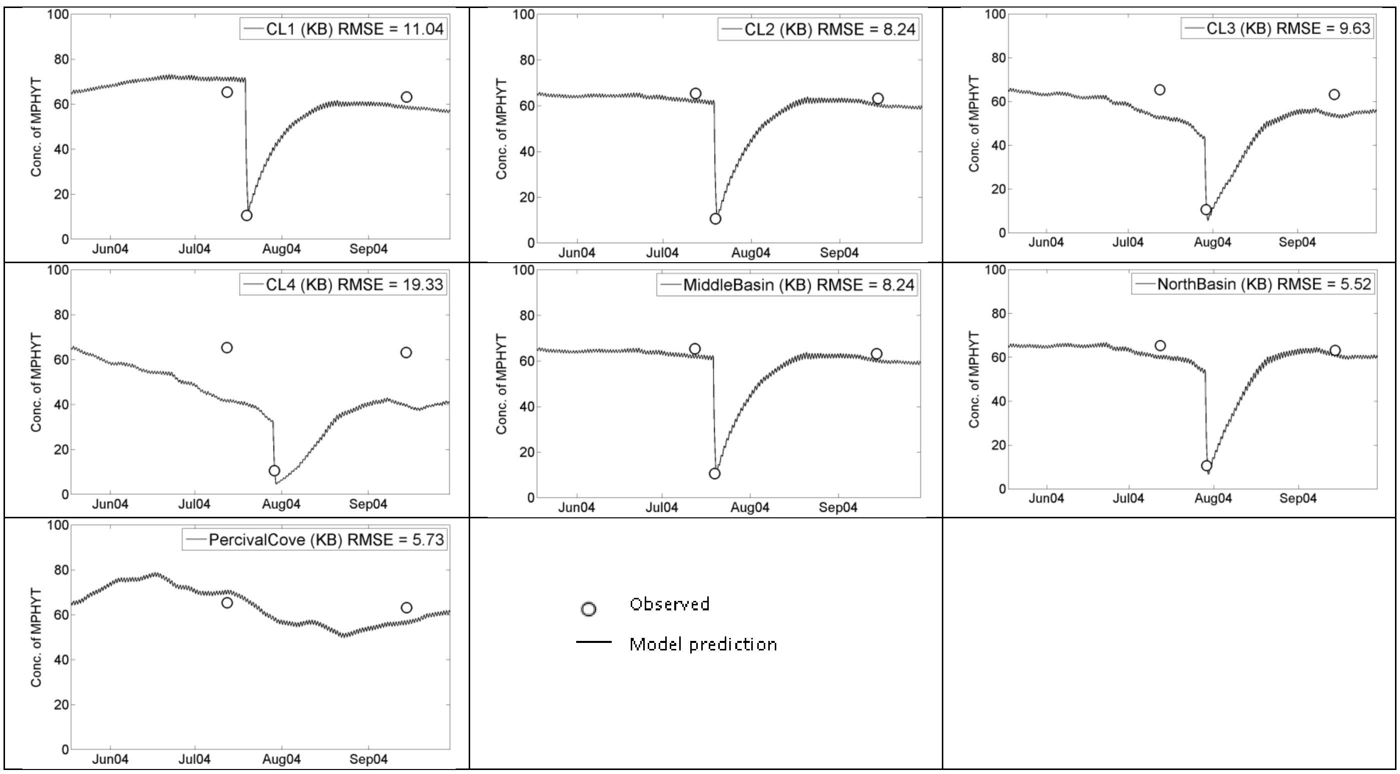


Figure H11. Predicted and observed macrophyte concentrations (g dry weight /m^2) at various stations.

Calibration to water quality measurements

Figures H12 through H15 show the model results compared with discrete water quality measurements at stations CL1, CL3, CL4, MB, NB, and PC. Data were not available for station CL2. Stations MB, NB, and PC only had DO data. Station CL1 represents the South basin, while stations MB and PC represent the Middle basin and Percival Cove, respectively. Stations CL3, CL4, and NB are all in North basin. The model successfully captures the long-term system trend for DO and nutrients. The total chlorophyll is over estimated initially; however, DO predictions during this period match the observed data reasonably well. The continuous DO predictions at station CL4 capture the average trend. The continuous DO monitoring (station CL4) was conducted within a week of herbicide application in the north basin. The data suggests supersaturated oxygen levels. The model underestimates the elevated oxygen levels observed during this period. Dissolved inorganic nitrogen (DIN), organic nitrogen (ON) and particulate organic carbon (POC) predictions match the observed data reasonably well.

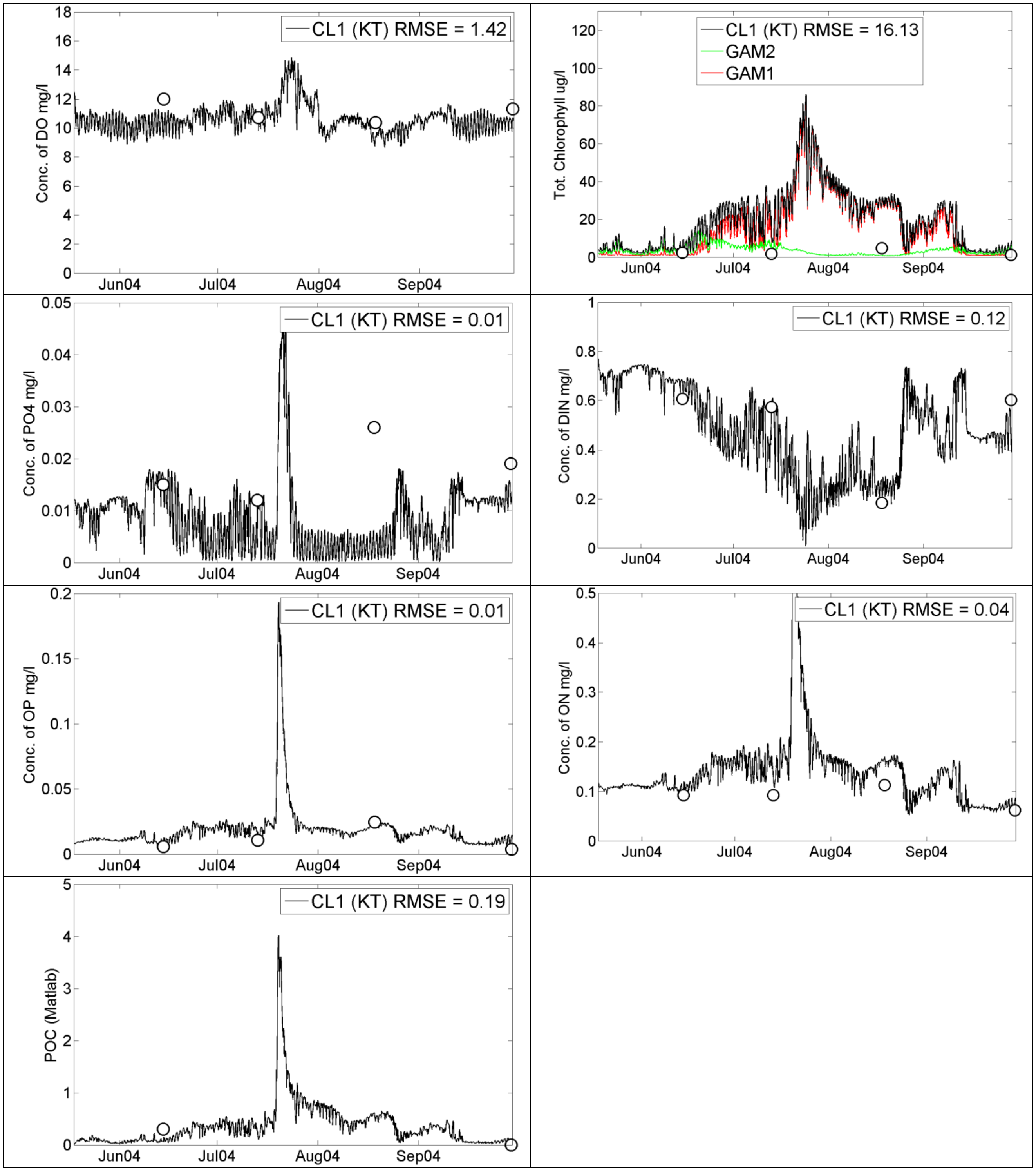


Figure H12. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, orthophosphate (PO4), dissolved inorganic nitrogen (DIN), organic phosphorus (OP), organic nitrogen (ON), particulate organic carbon (POC) and ultimate BOD at stations CL1 (top layer, KT).

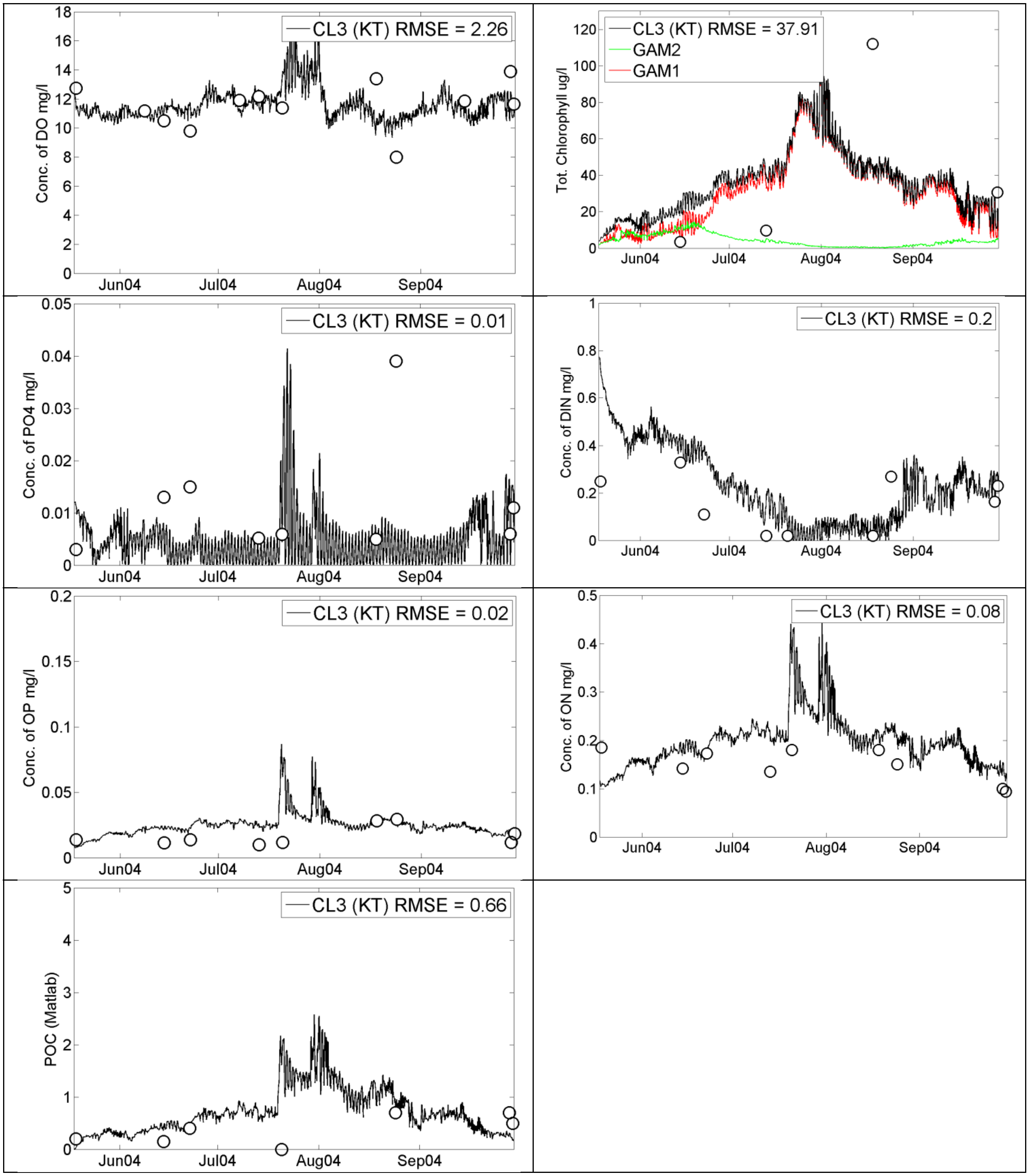


Figure H13. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, orthophosphate (PO4), dissolved inorganic nitrogen (DIN), organic phosphorus (OP), organic nitrogen (ON), particulate organic carbon (POC) and ultimate BOD at stations CL3 (top layer, KT).

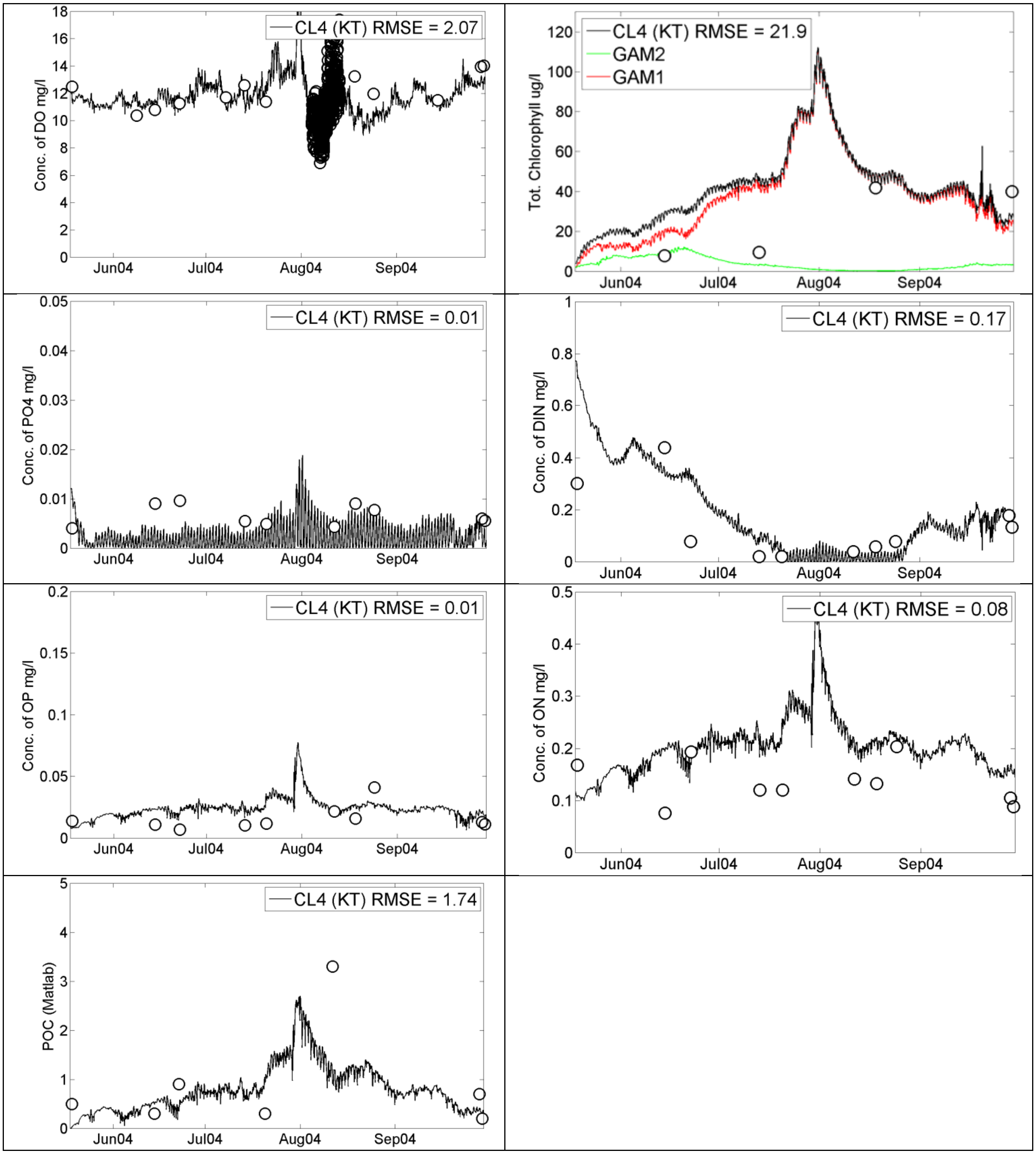


Figure H14. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, orthophosphate (PO4), dissolved inorganic nitrogen (DIN), organic phosphorus (OP), organic nitrogen (ON), particulate organic carbon (POC) and ultimate BOD at stations CL4 (top layer, KT).

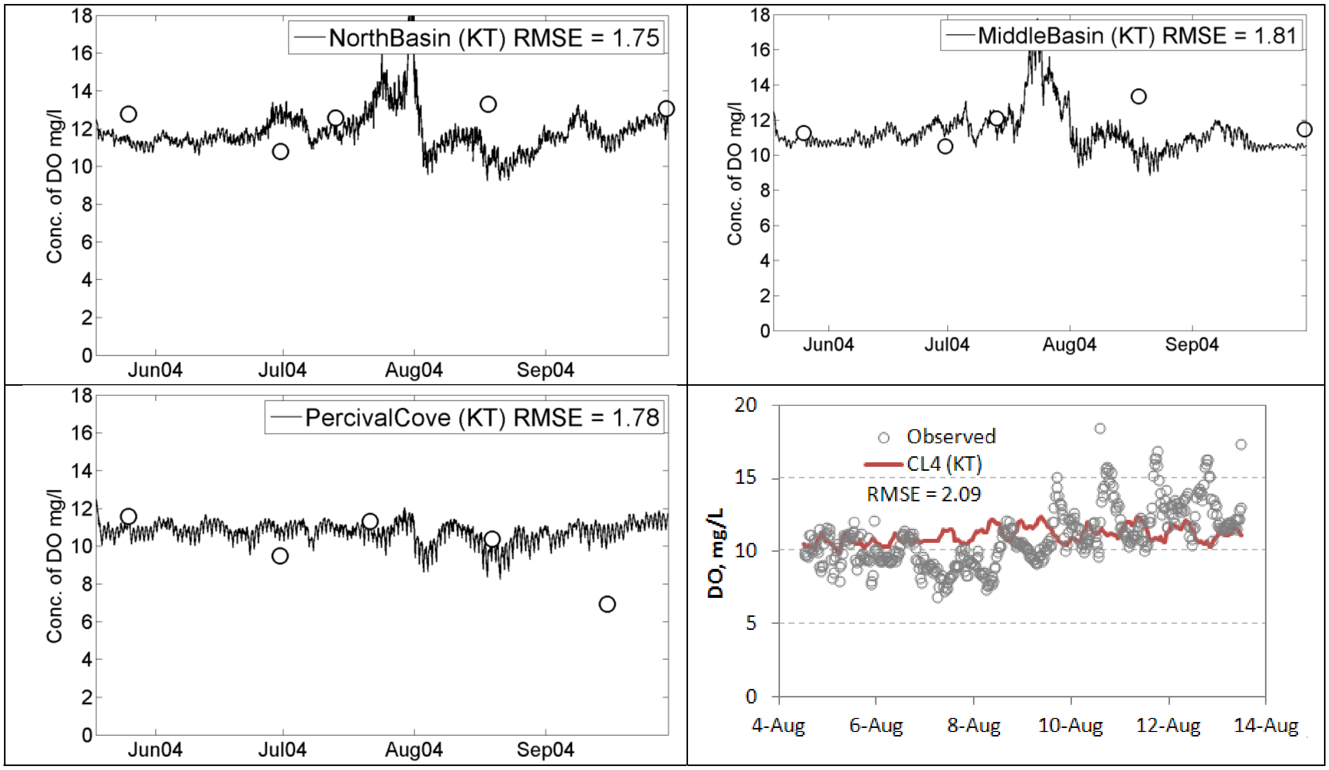


Figure H15. Predicted and observed dissolved oxygen (DO) at stations North Basin (NB), Middle Basin (MB) and Percival Cove (PC) and continuous DO at station CL4 (North Basin station).

<u>Profile Measurements</u>

Temperature and DO profiles are available at Ecology stations (CL1, CL2, CL3 and CL4) as well as at Thurston County stations (MB, NB, and PC). Figures H16 through H21, show the model predicted and observed profiles in North, Middle and South basins, respectively. The South basin plot also includes temperature profiles in Percival Cove. The model performs well in most instances where it accurately reproduces the observed profiles. However, the bottom temperatures are over-predicted in August. This is true for all stations from the mouth of Deschutes River (station CL1) to the lake outlet at station CL4. The predicted temperature profiles in other months are reasonably good. The DO profiles indicate that the model predictions overestimate the DO below the surface layers in deeper parts of the lake (North basin). This is probably due to the inherent model assumption that macrophyte biomass is contained within the bottom layer.

The predicted DO throughout the water column as a whole is reasonably accurate. In Middle and South basins and in Percival Cove the model is able to predict the DO profiles fairly well. It should be noted that the calibration to macrophyte concentration was done on a basin-wide basis. Actual macrophyte concentrations at individual stations likely vary and result in different DO profiles.

Considering that Capitol Lake is very shallow where macrophytes are abundant and stratification is often not very strong, the most important consideration is the accurate simulation of DO conditions in the water column as a whole in the areas of high macrophyte biomass. Accurate simulation of stratification in the shallow macrophyte beds is considered to be secondary in importance compared with typical water column conditions.

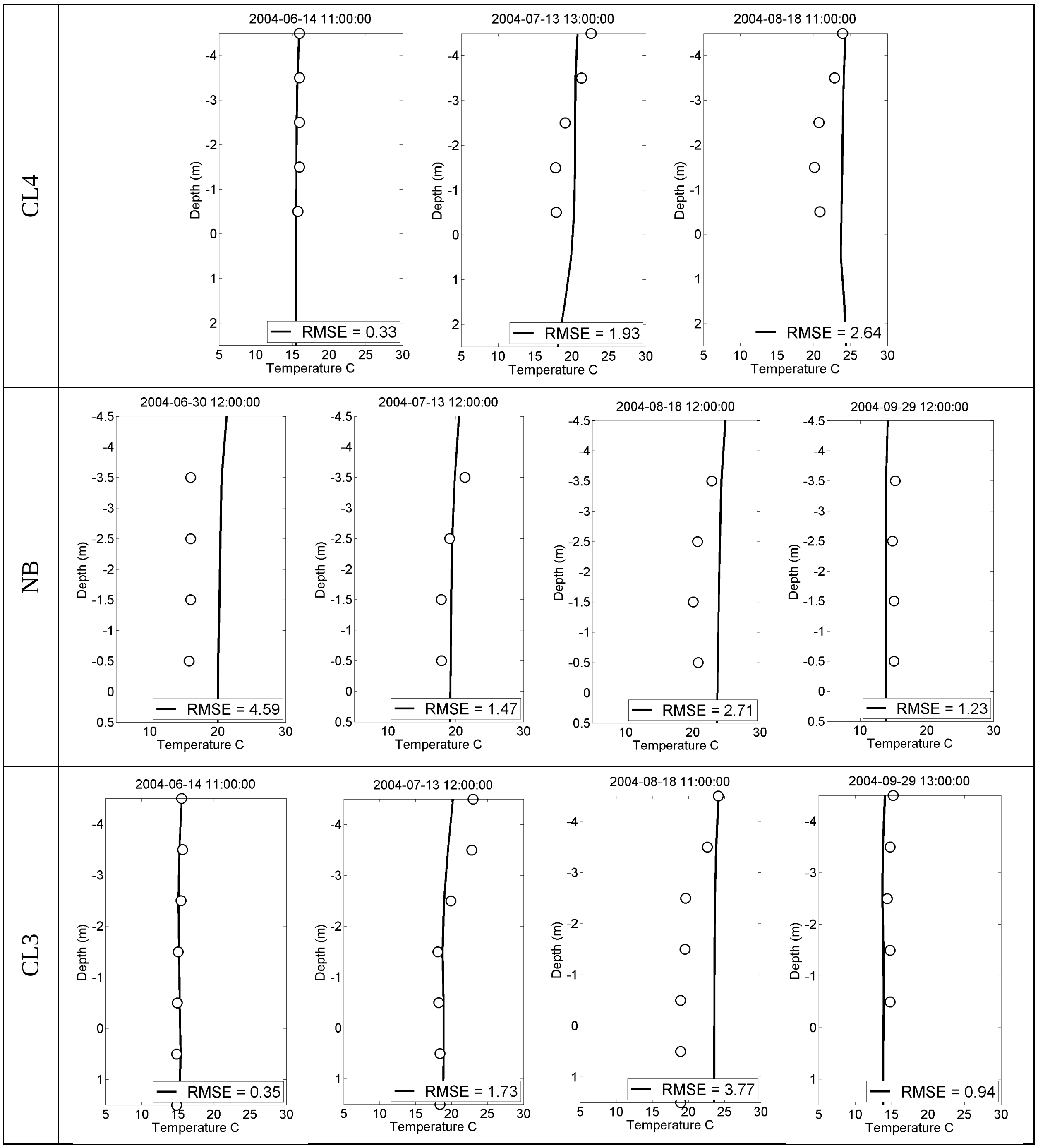


Figure H16. Temperature profiles in the North Basin (Stations Cl4, NB, and CL3).

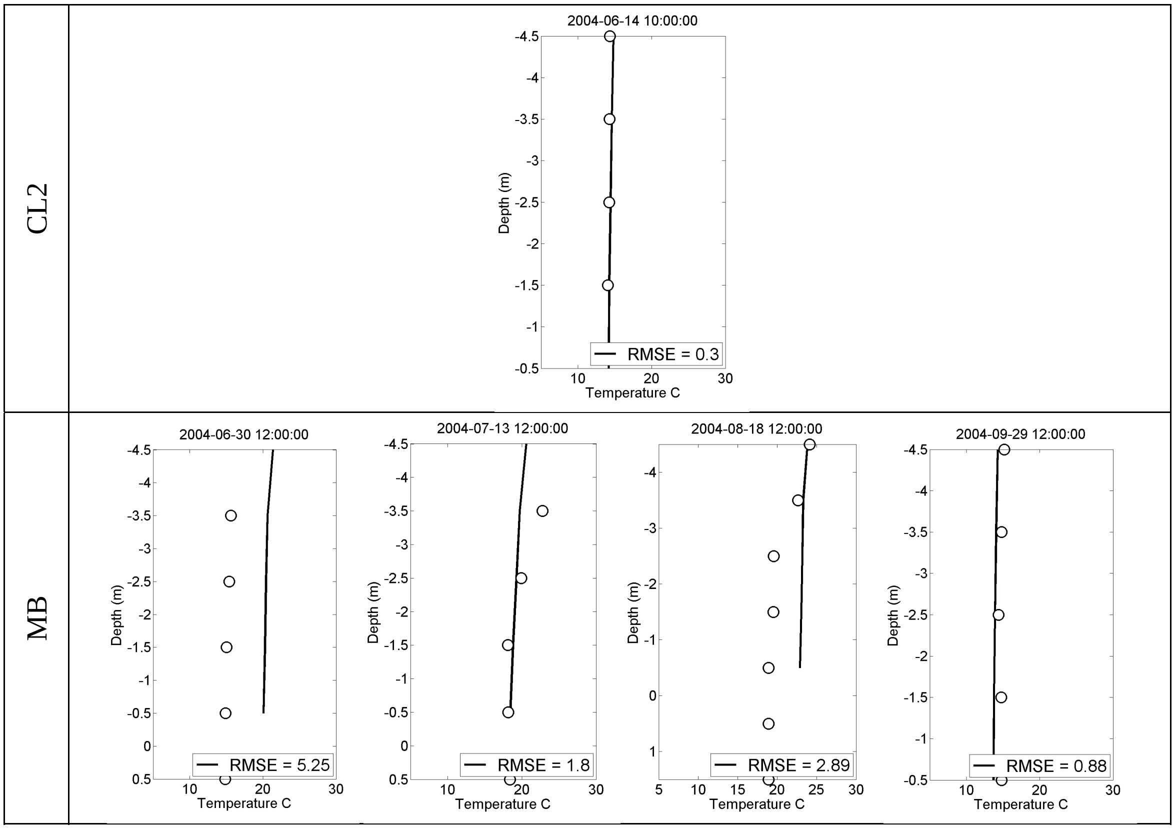


Figure H17. Temperature profiles in the Middle Basin (Stations CL2 and MB).

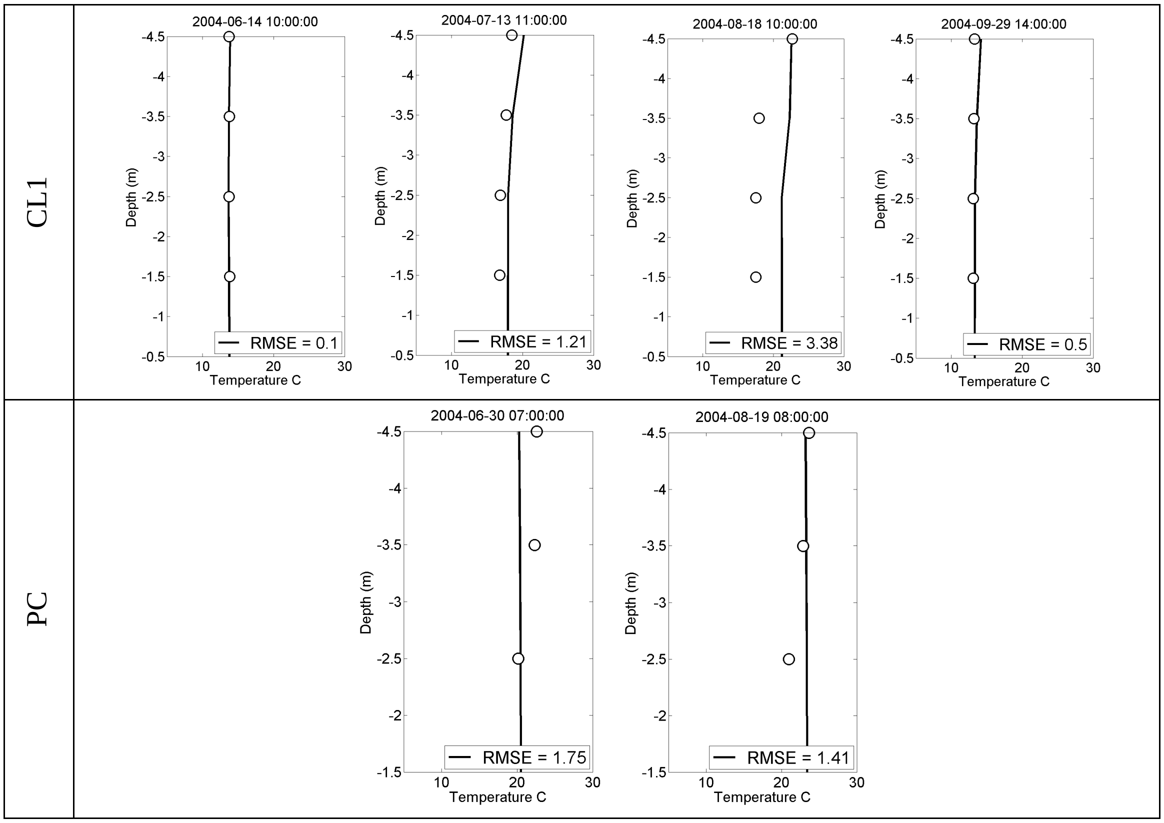


Figure H18. Temperature profiles in the South Basin (station CL1) and in Percival Cove (PC).

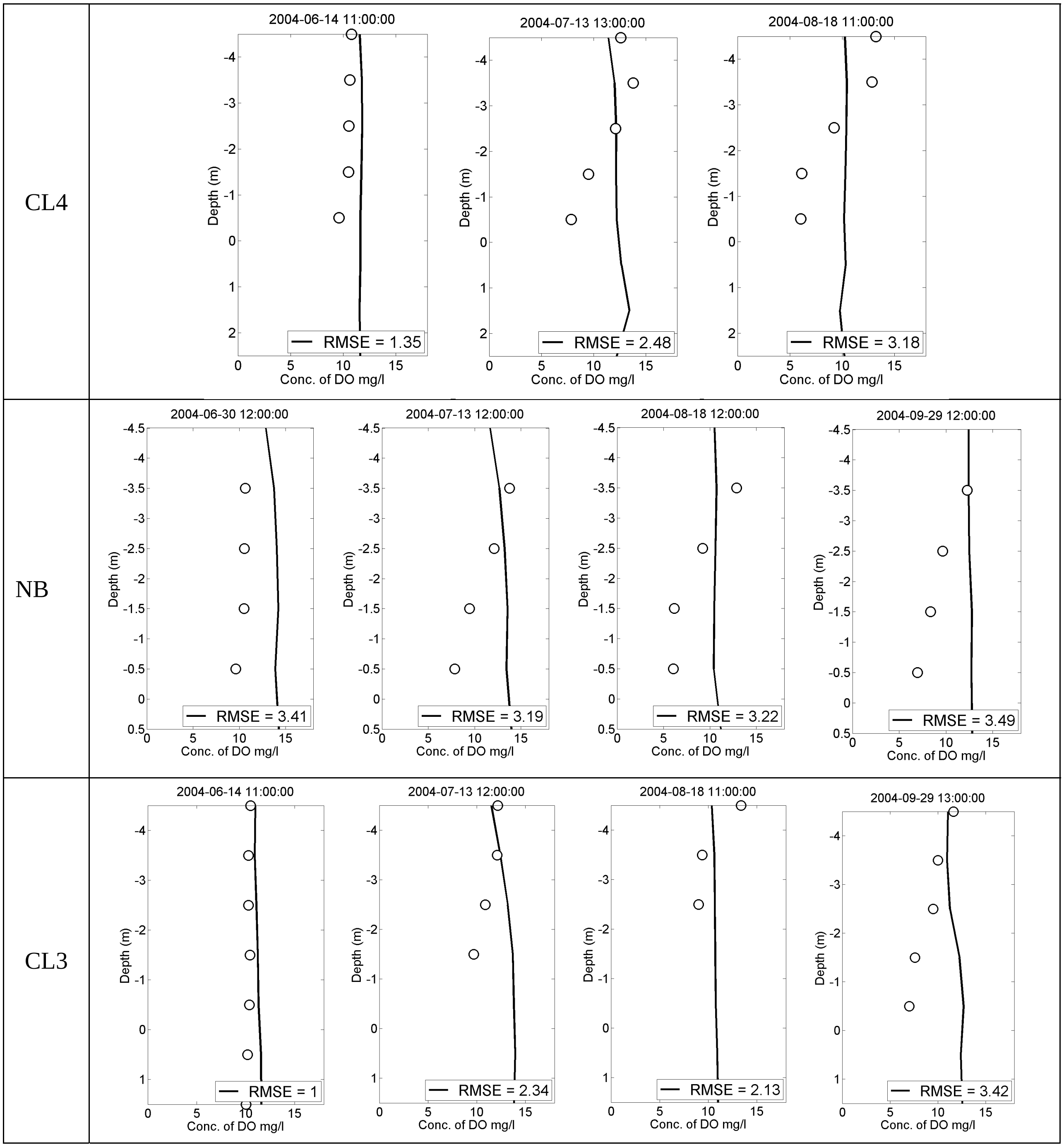


Figure H19. Dissolved Oxygen profiles in the North Basin (Stations Cl4, NB, and CL3).

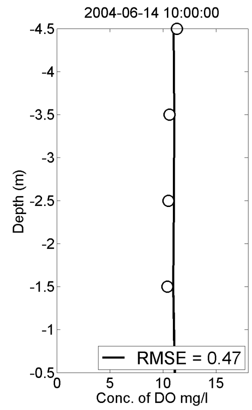
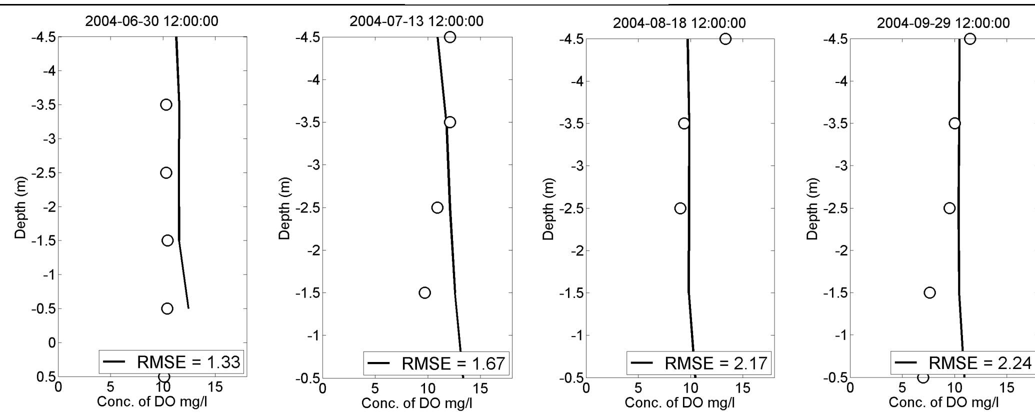
CL2	
MB	

Figure H20. Dissolved Oxygen profiles in the Middle Basin (Stations CL2 and MB).

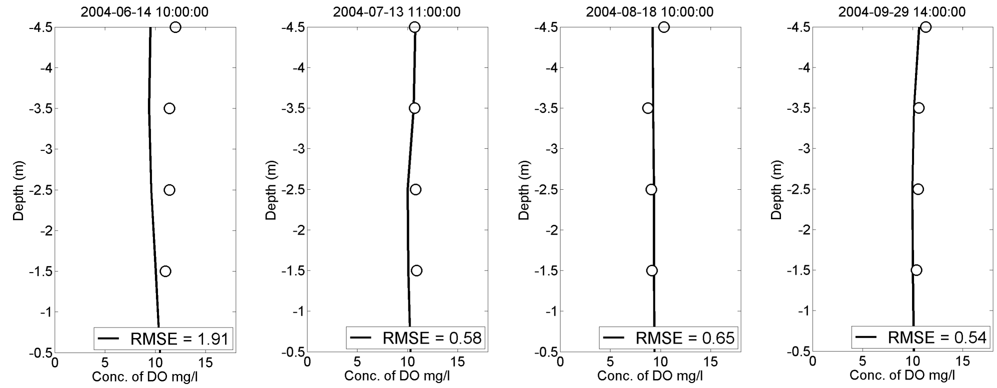
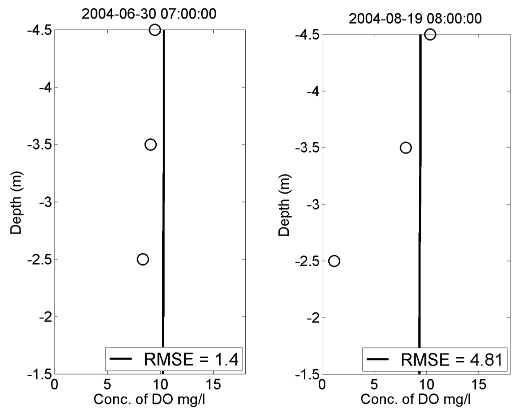
CL1	
PC	

Figure H21. Dissolved Oxygen profiles in the South Basin (station CL1) and in Percival Cove (PC).

Overall error statistics

Table H1 shows the overall error statistics when all field data are compared with associated model predictions for each variable. The RMSE has been defined earlier. The mean and the standard deviation of the residuals are other statistics that give an estimate of bias. The standard deviation of the residuals is similar to the RMSE, in that it gives an indication of the “spread” of the variation around the mean. However, the RMSE is an unbiased statistic that presumes that the mean residual is zero.

The mean of the residuals indicates the bias of the model predictions, and together with the standard deviation of the residuals, is an indication of whether the bias is significant. If the confidence interval around the mean of the residuals overlaps zero, then this would indicate that the bias is not significant (e.g. of the mean residual +/- 2 standard deviations of the residual overlaps with zero). In Table H1, temperature, DO, DIN, and total chlorophyll has a positive bias (i.e. the model overpredicts), whereas for PO4 the bias is negative (i.e. the model underpredicts). The magnitude of the mean gives an indication of how far off the error is from zero (i.e. accurate predictions). Because the mean +/- 2 standard deviations of the residuals overlap with zero, the statistics in Table H1 indicate that the bias is not significantly different from zero (i.e. the model is not biased).

Table H1. Overall error statistics.

Variable	n	RMSE	Mean residual	Standard deviation of residuals
Dissolved Oxygen (DO)	567	2.2	0.29	2.17
Orthophosphate (PO4)	23	0.011	-0.007	0.009
Dissolved Inorganic Nitrogen (DIN)	23	0.17	0.054	0.17
Temperature	571	1.6	0.66	1.4
Total Chlorophyll	12	27	5.56	27.5

Verification Period (2001)

Miller Brewing Company collected data from Capitol Lake in 2001 (CH2M Hill, 2001). The 2001 data used as the verification period adopted for the present study was 04/25/2001 to 06/13/2001. During this period, the pre-herbicide set of kinetic rates from the calibration period was used to model DO, nutrients, macrophytes, and phytoplankton in the lake. During the verification period, several field measurements in different forms were available that were used to verify the model (CH2M Hill, 2001). These field measurement locations are shown in Figure H22.

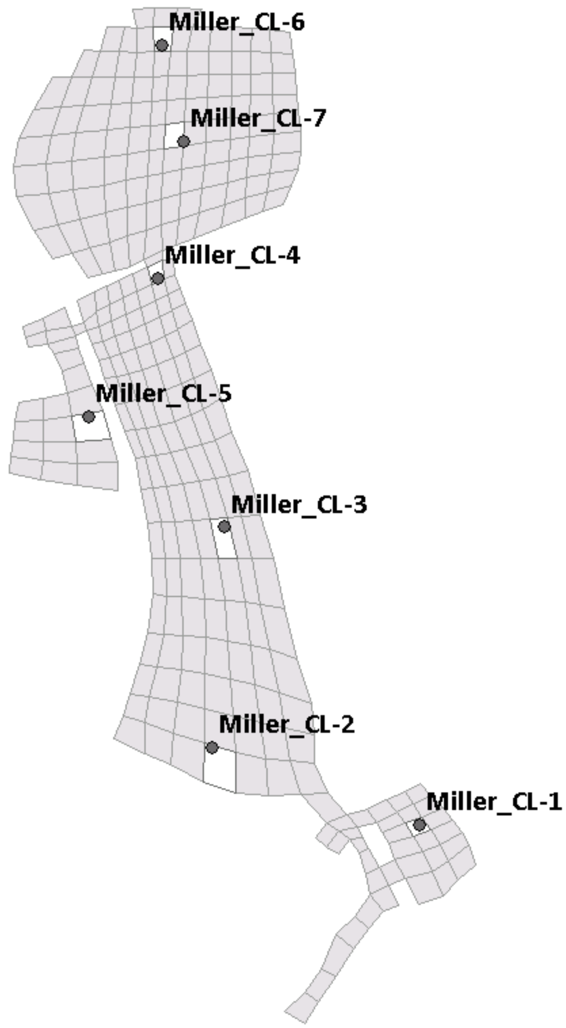


Figure H22. Field measurement locations for the verification period (2001).

Boundary Condition Data

As discussed in the calibration section the two inflows to Capitol Lake are from Deschutes River and Percival Creek. There was no continuous monitoring of nutrient data available for these inflows. The available data are monthly and do not capture any short-term variations in the stream conditions. Figures H23 and H24 show the boundary condition data for the verification period. The same sediment flux data used for calibration run (Figure H6) were used for the verification run.

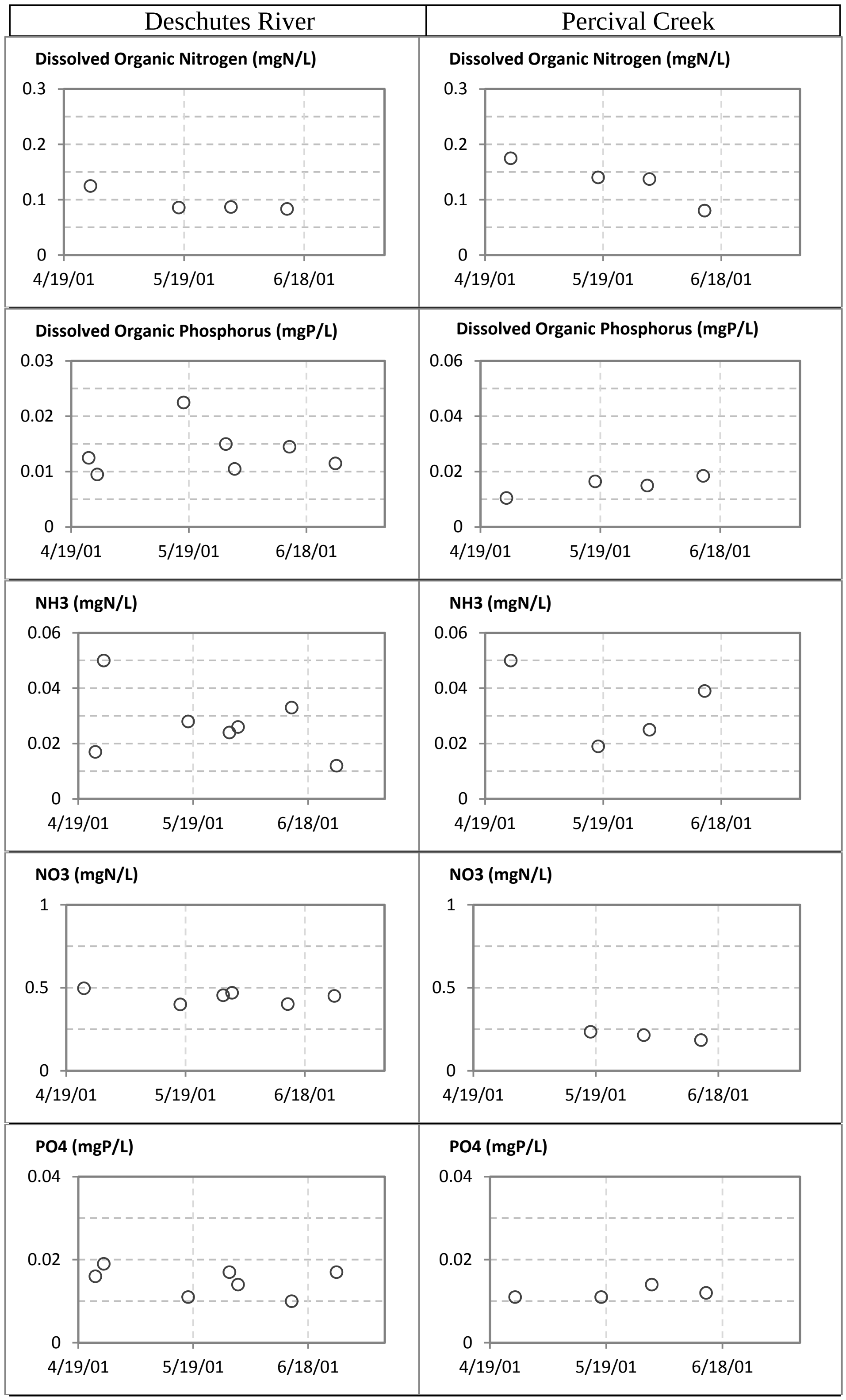


Figure H23. Boundary condition values for Deschutes River and Percival Creek during verification, 2001.

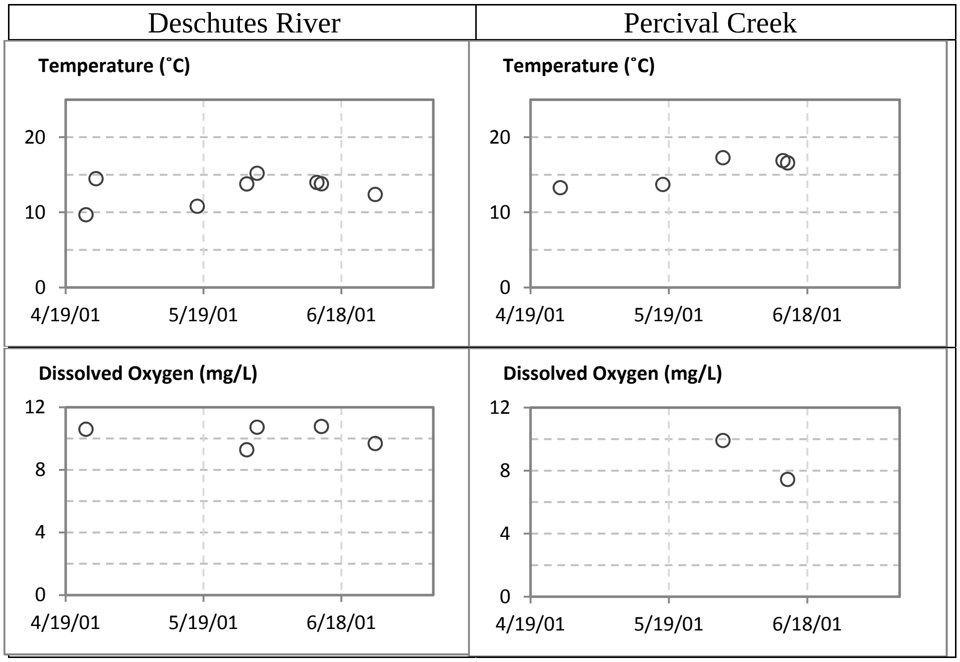


Figure H24. Inflow temperatures and dissolved oxygen (DO) for Deschutes River and Percival Creek, 2001.

Verification Results

As mentioned earlier, the input data for boundary conditions are not continuous. Thus it is expected that the model results would not be able to capture short-term responses like storms. The model should still be able to capture the system trend.

Discrete measurements

Figures H25 to H38 show the model results compared with discrete measurements at Miller stations CL1, CL2, CL3, CL4, CL5, CL6, and CL7. The model also successfully captures the long-term system trend for nutrients and other water quality variables.

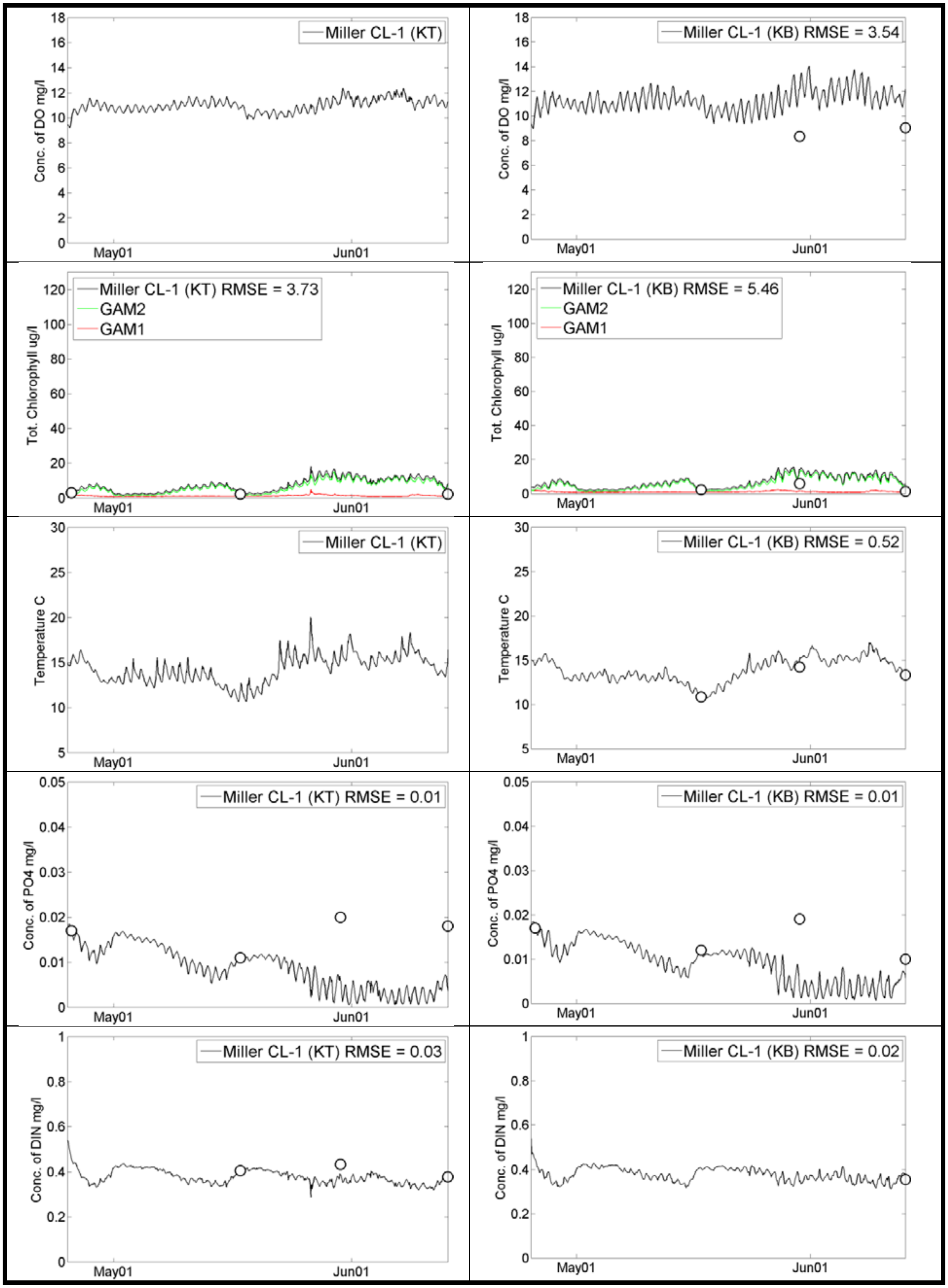


Figure H25. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, temperature, PO4, and DIN at station Miller_CL1 (layer KT and KB).

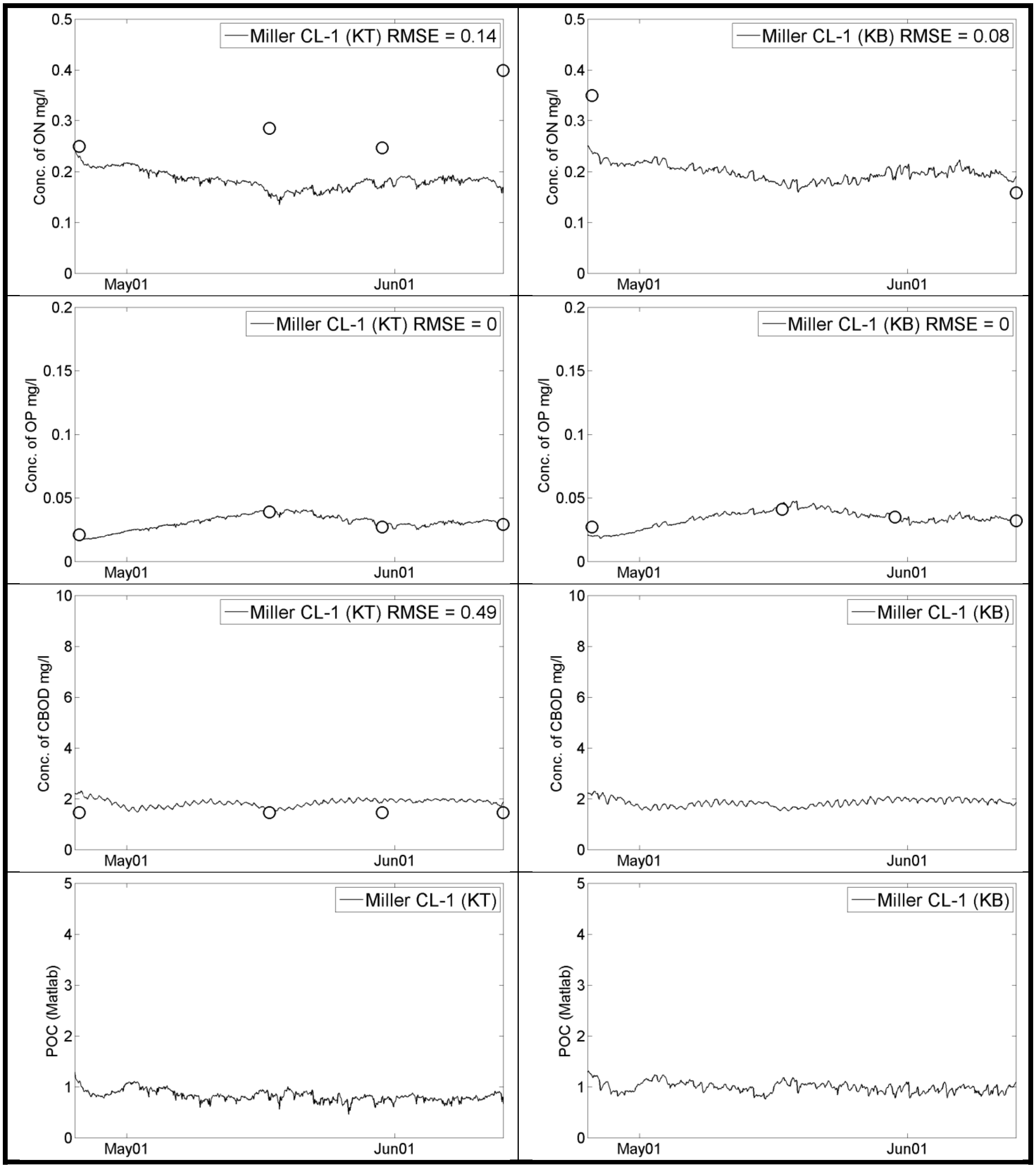


Figure H26. Predicted and observed ON, OP, CBOD, and POC at station Miller_CL1 (layer KT and KB).

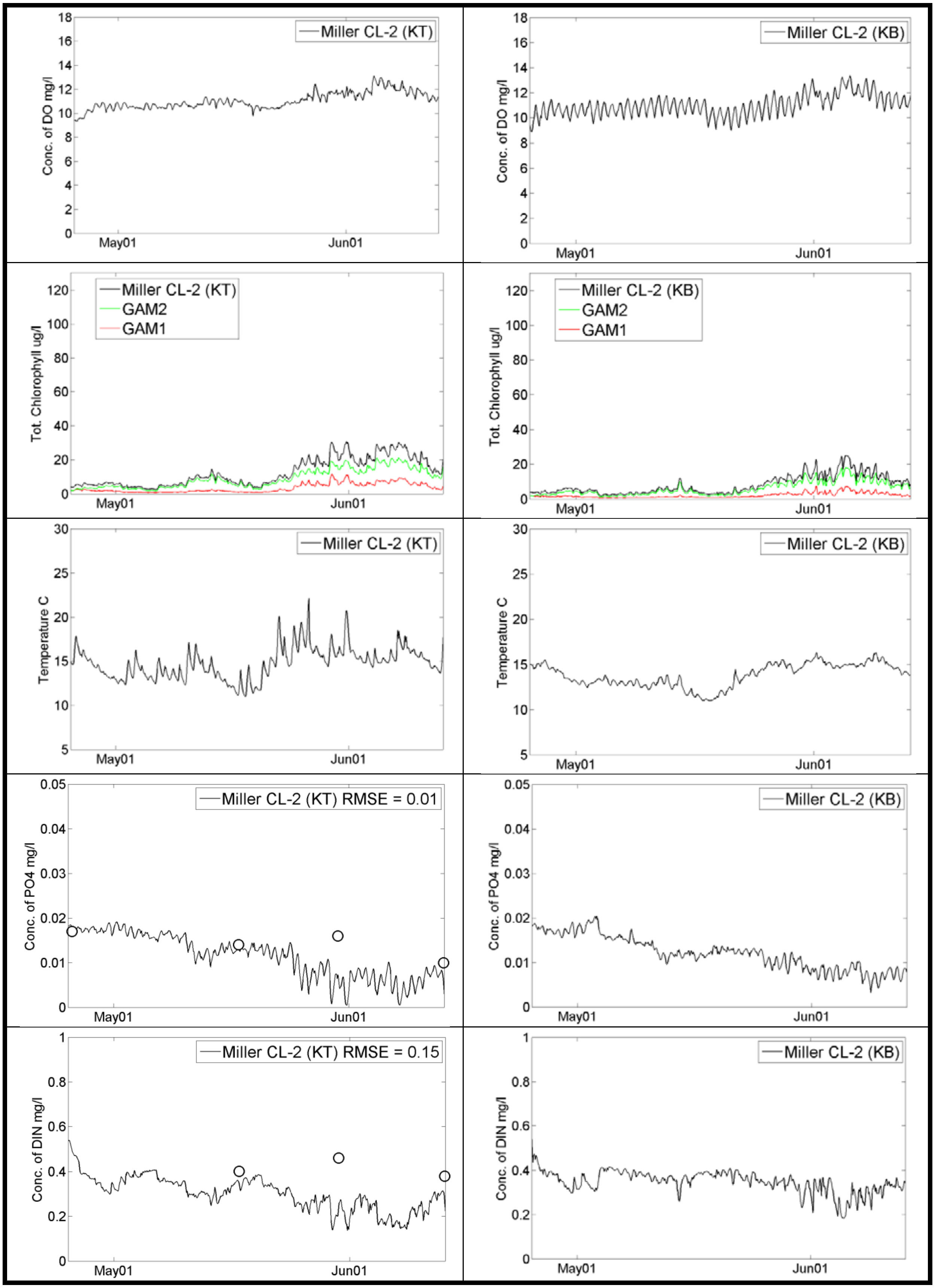


Figure H27. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, temperature, PO4, and DIN at station Miller_CL2 (layer KT and KB).

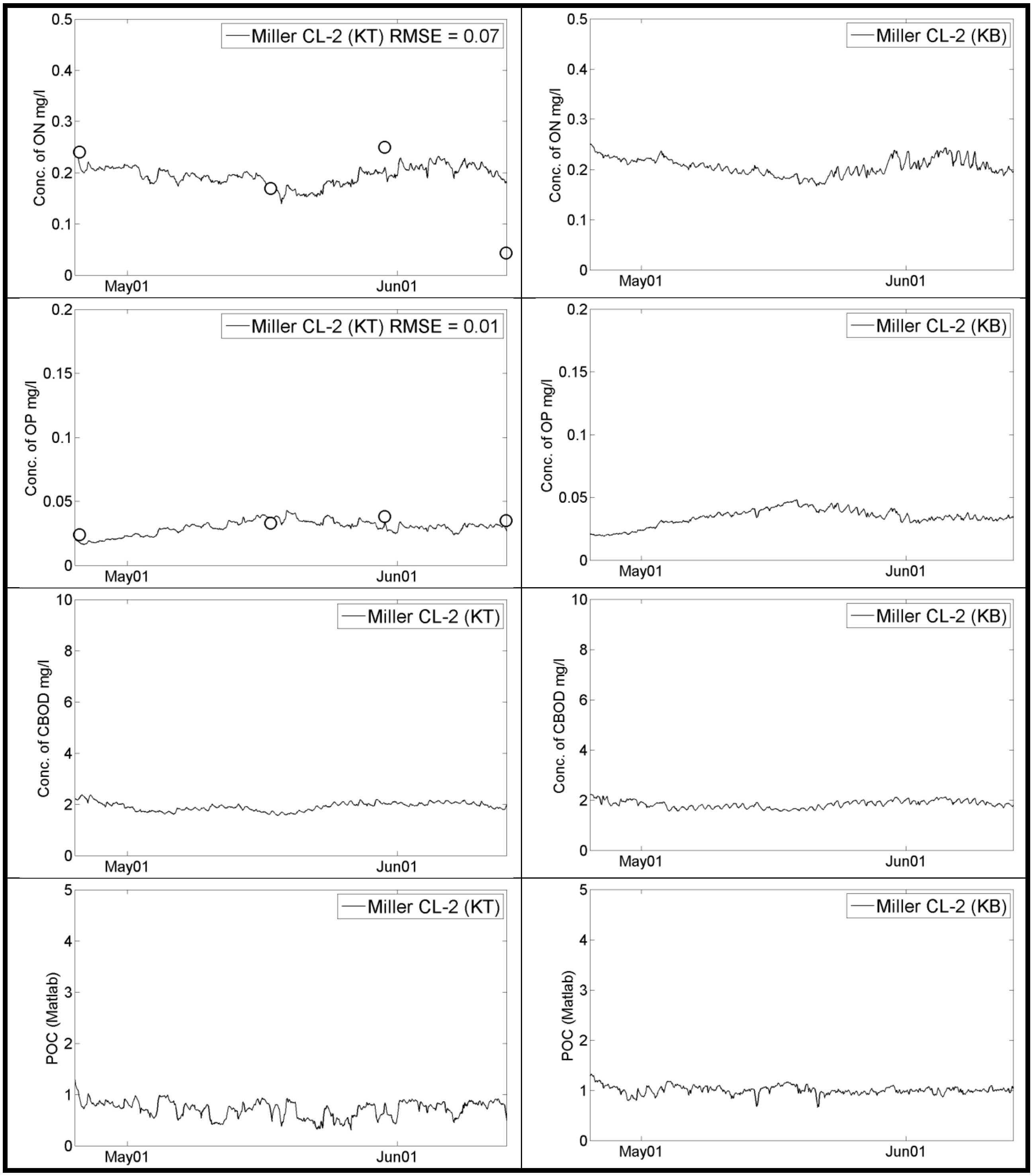


Figure H28. Predicted and observed ON, OP, CBOD, and POC at station Miller_CL2 (layer KT and KB).

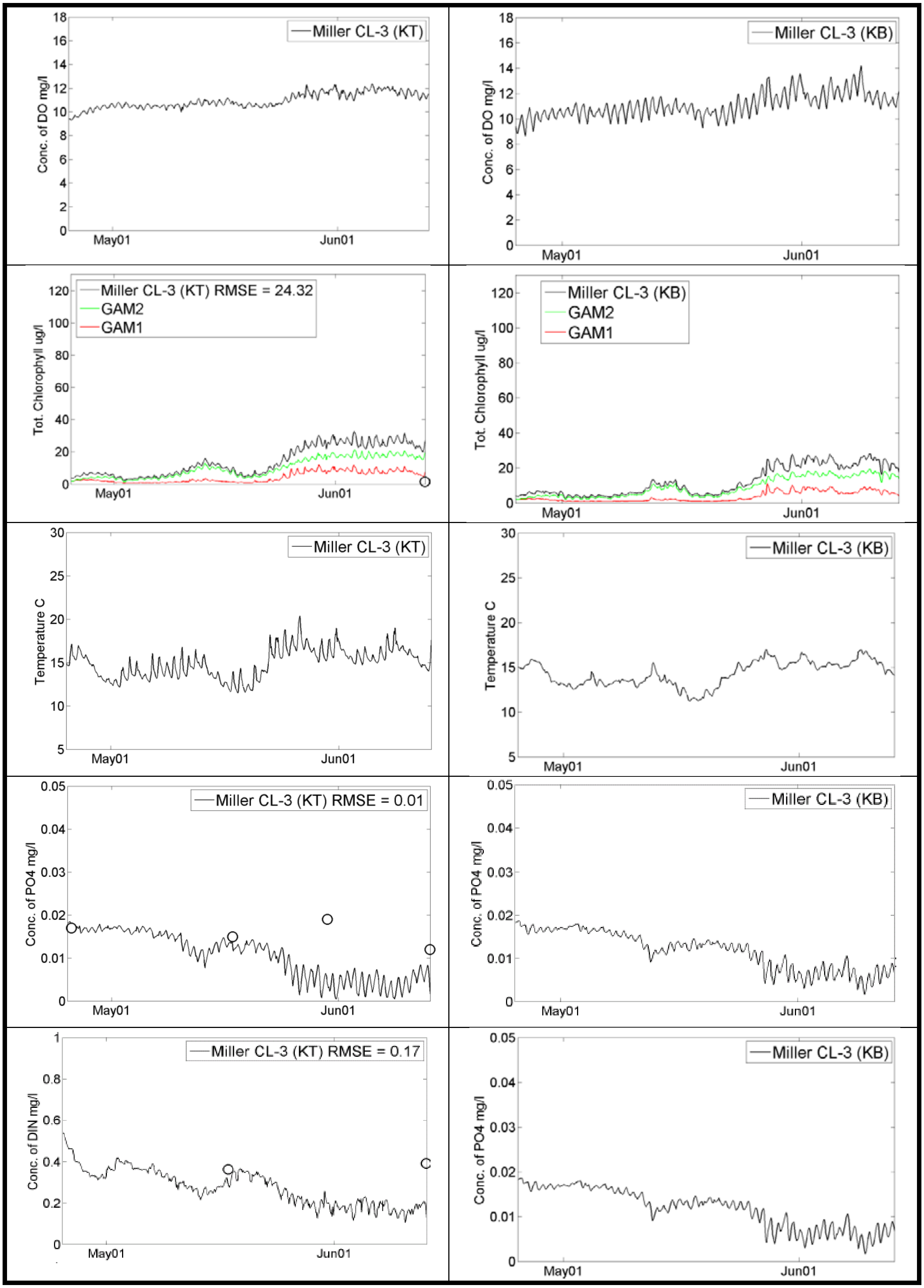


Figure H29. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, temperature, PO4, and DIN at station Miller_CL3 (layer KT and KB).

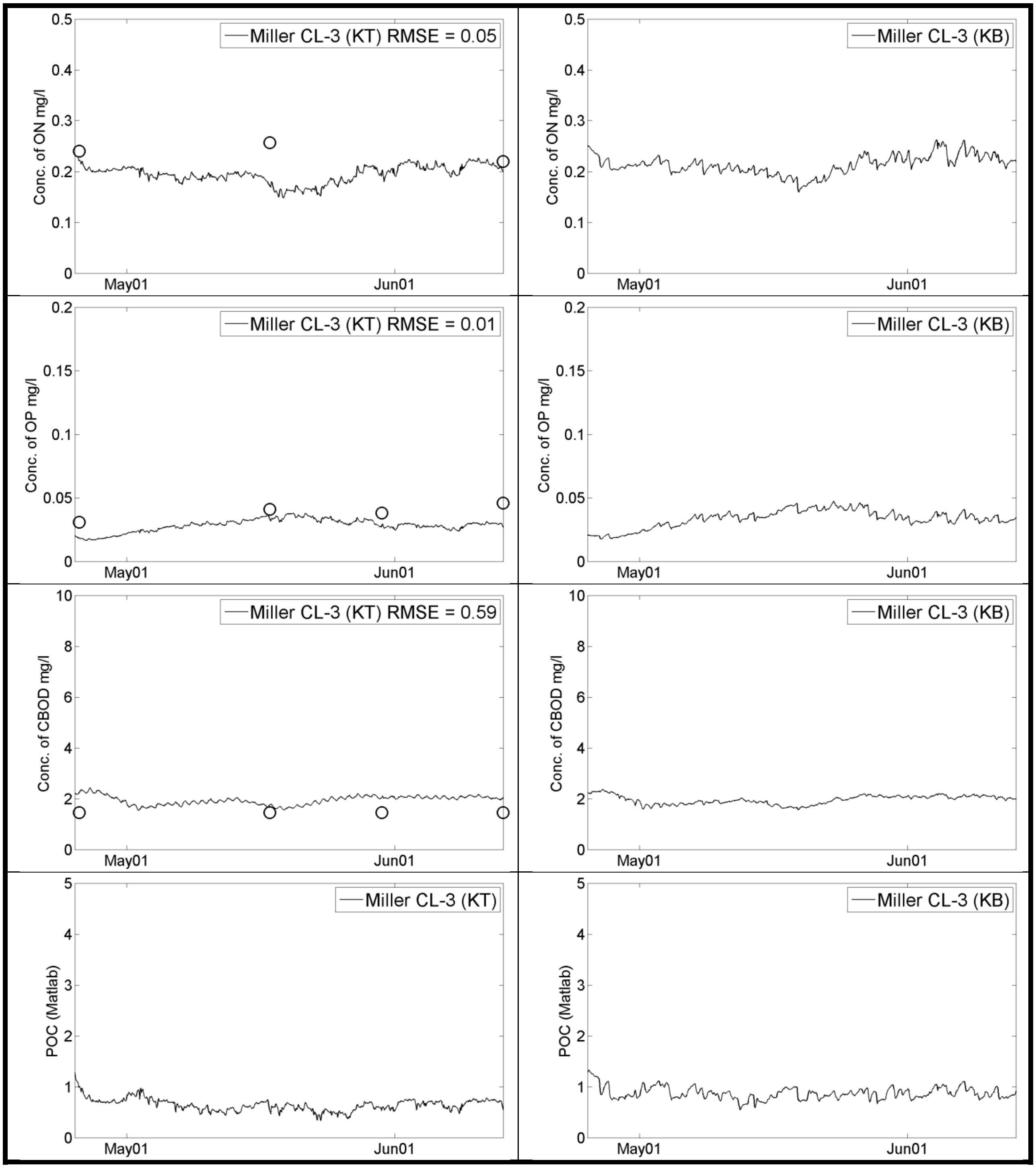


Figure H30. Predicted and observed ON, OP, CBOD, and POC at station Miller_CL3 (layer KT and KB).

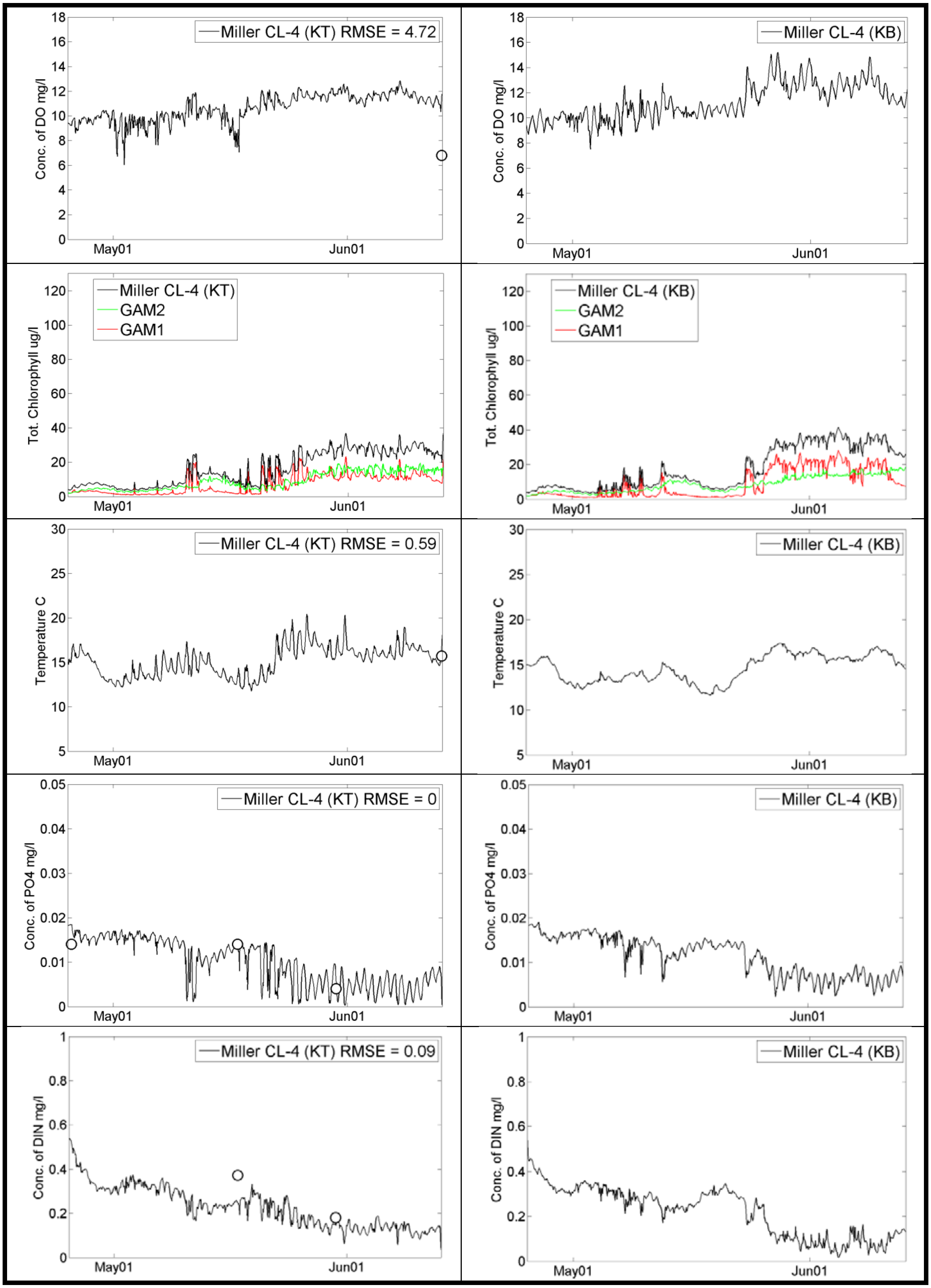


Figure H31. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, temperature, PO4, and DIN at station Miller_CL4 (layer KT and KB).

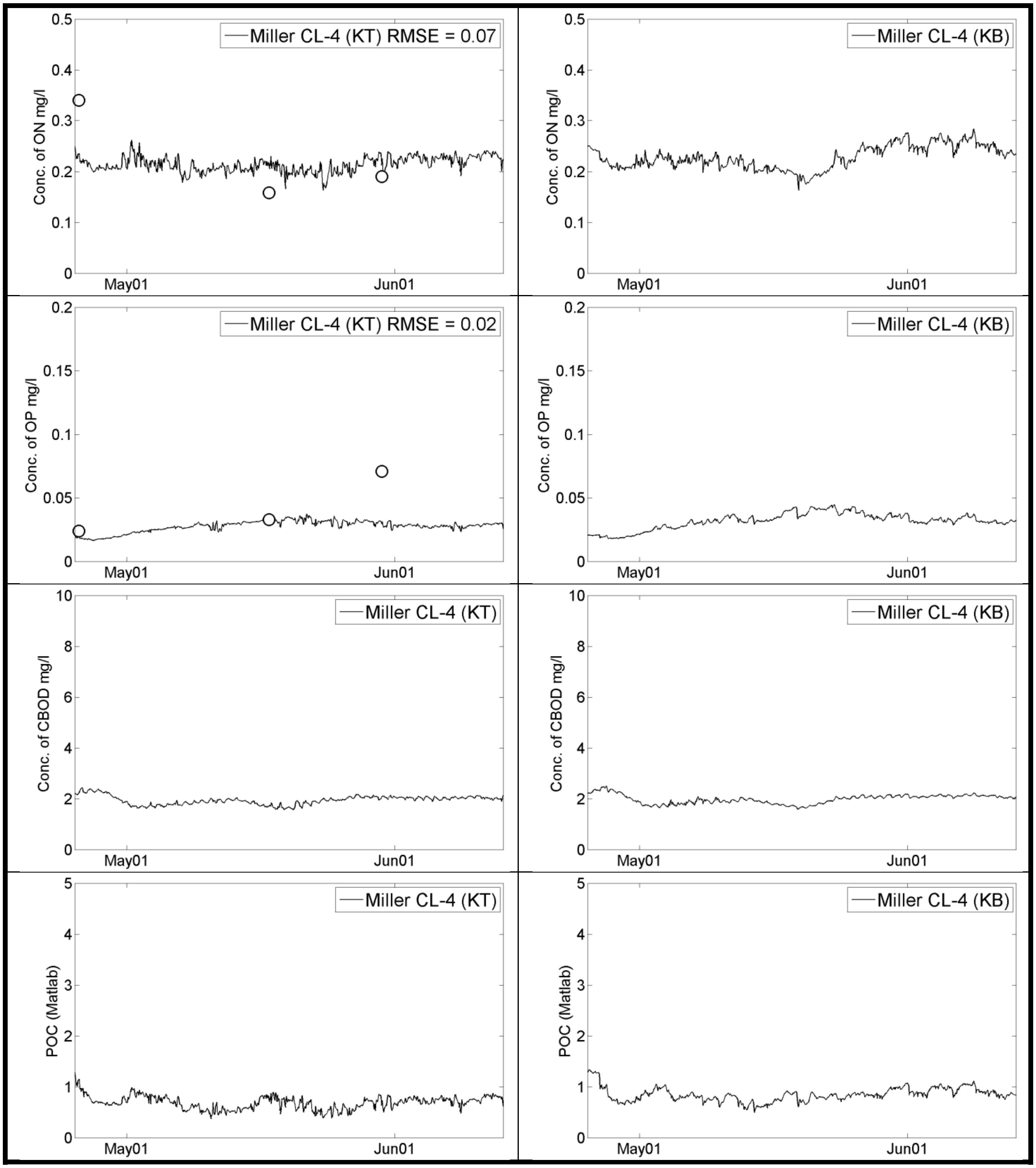


Figure H32. Predicted and observed ON, OP, CBOD, and POC at station Miller_CL4 (layer KT and KB).

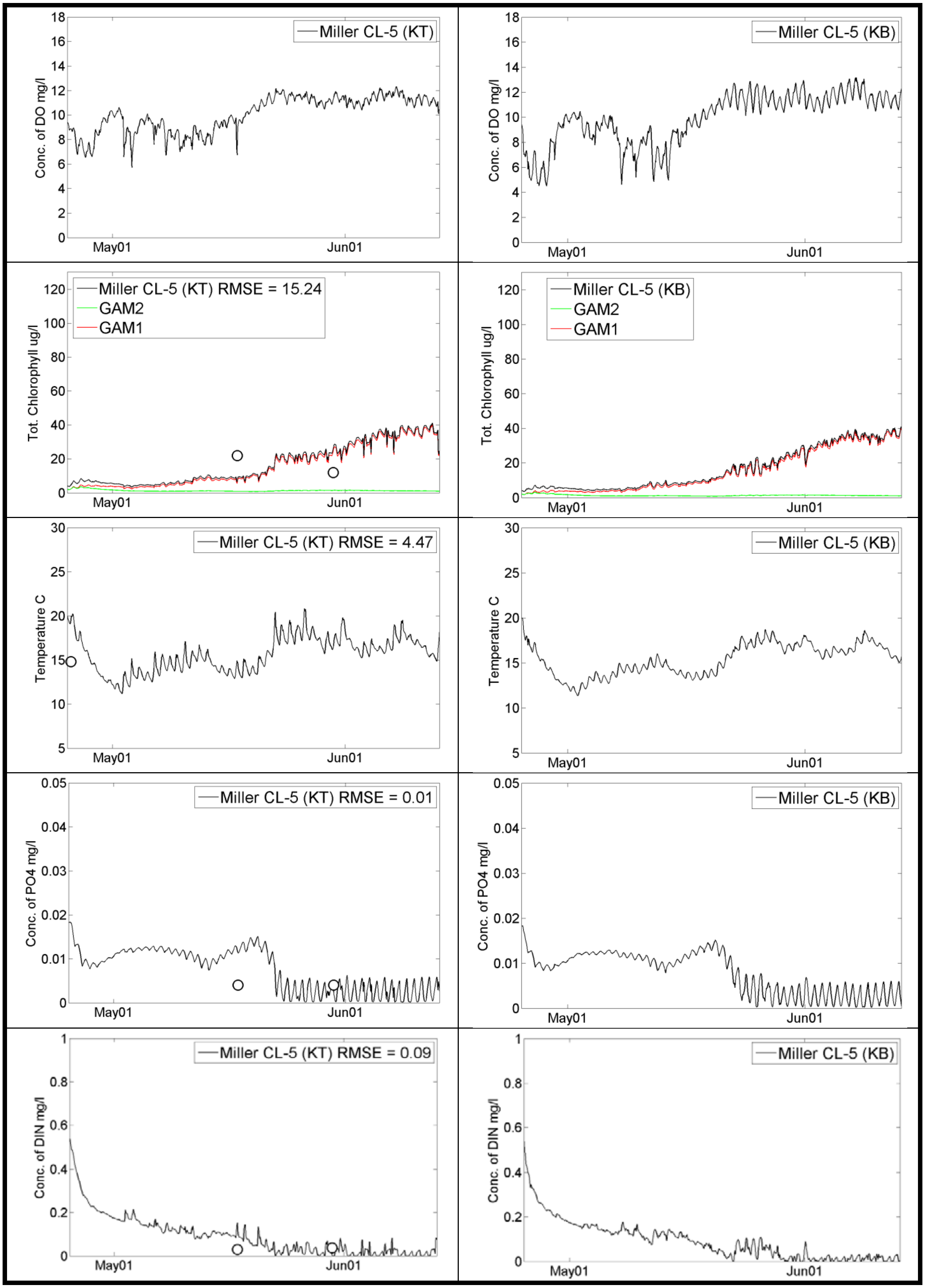


Figure H33. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, temperature, PO4, and DIN at station Miller_CL5 (layer KT and KB).

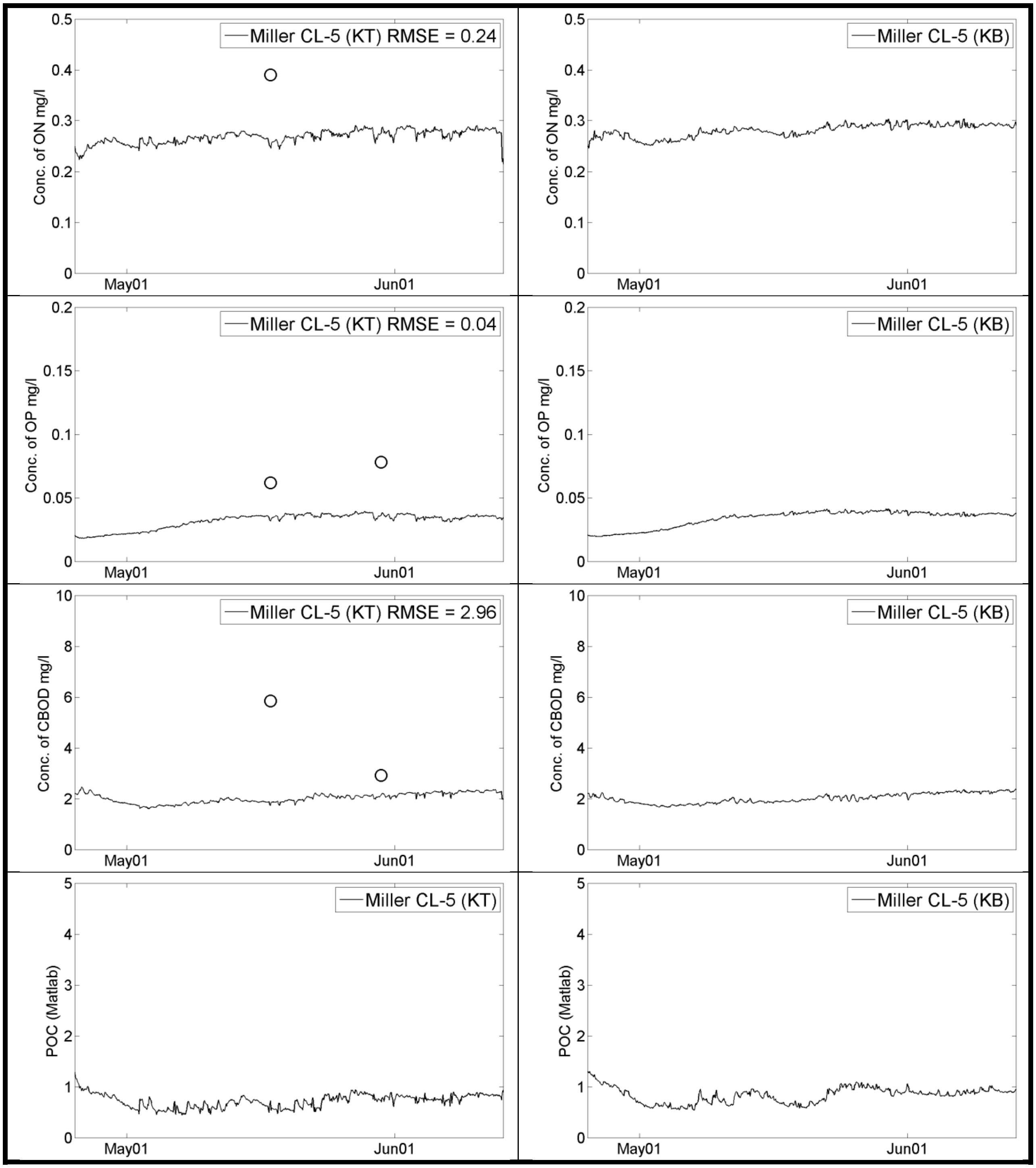


Figure H34. Predicted and observed ON, OP, CBOD, and POC at station Miller_CL5 (layer KT and KB).

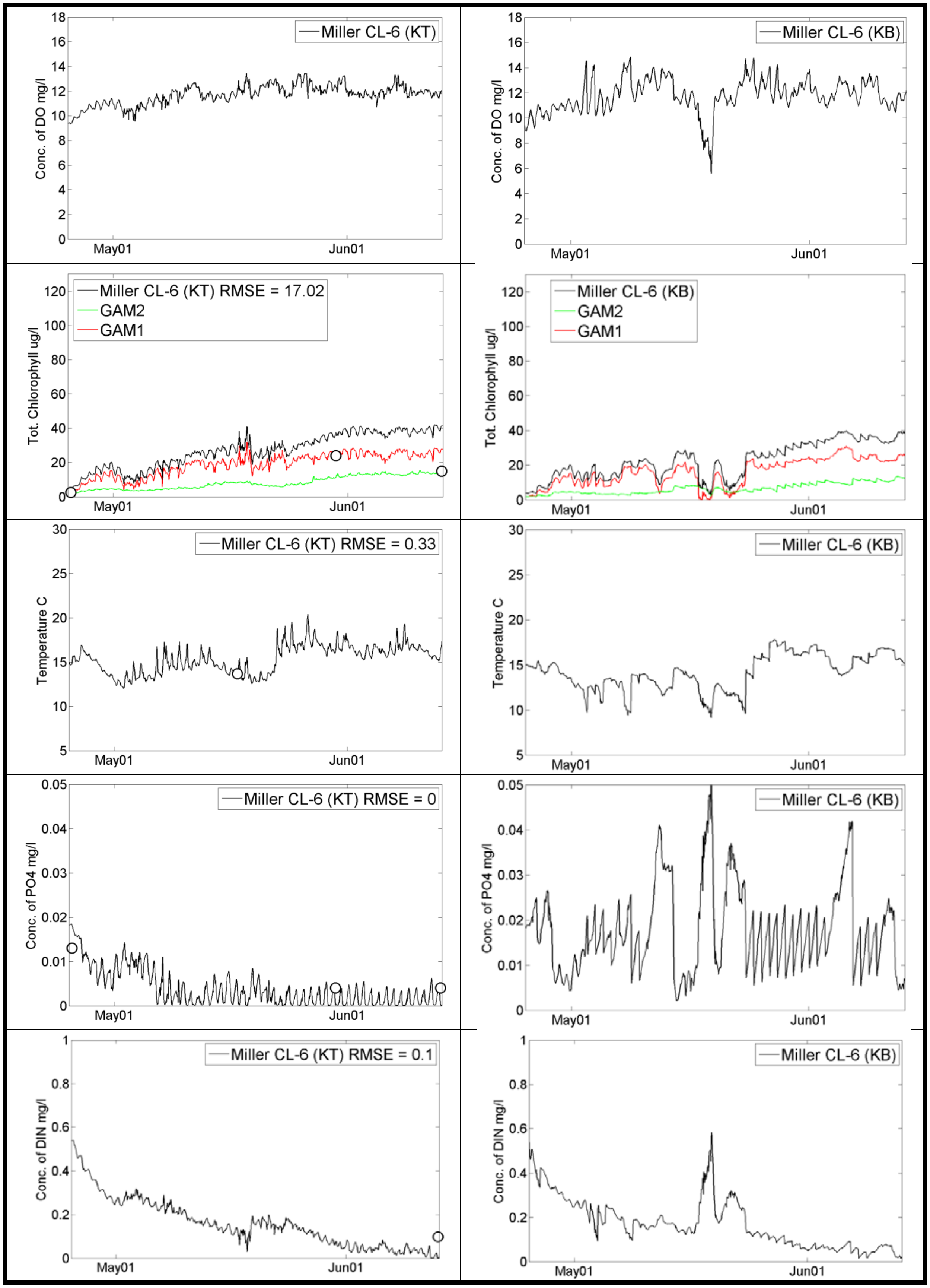


Figure H35. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, temperature, PO4, and DIN at station Miller_CL6 (layer KT and KB).

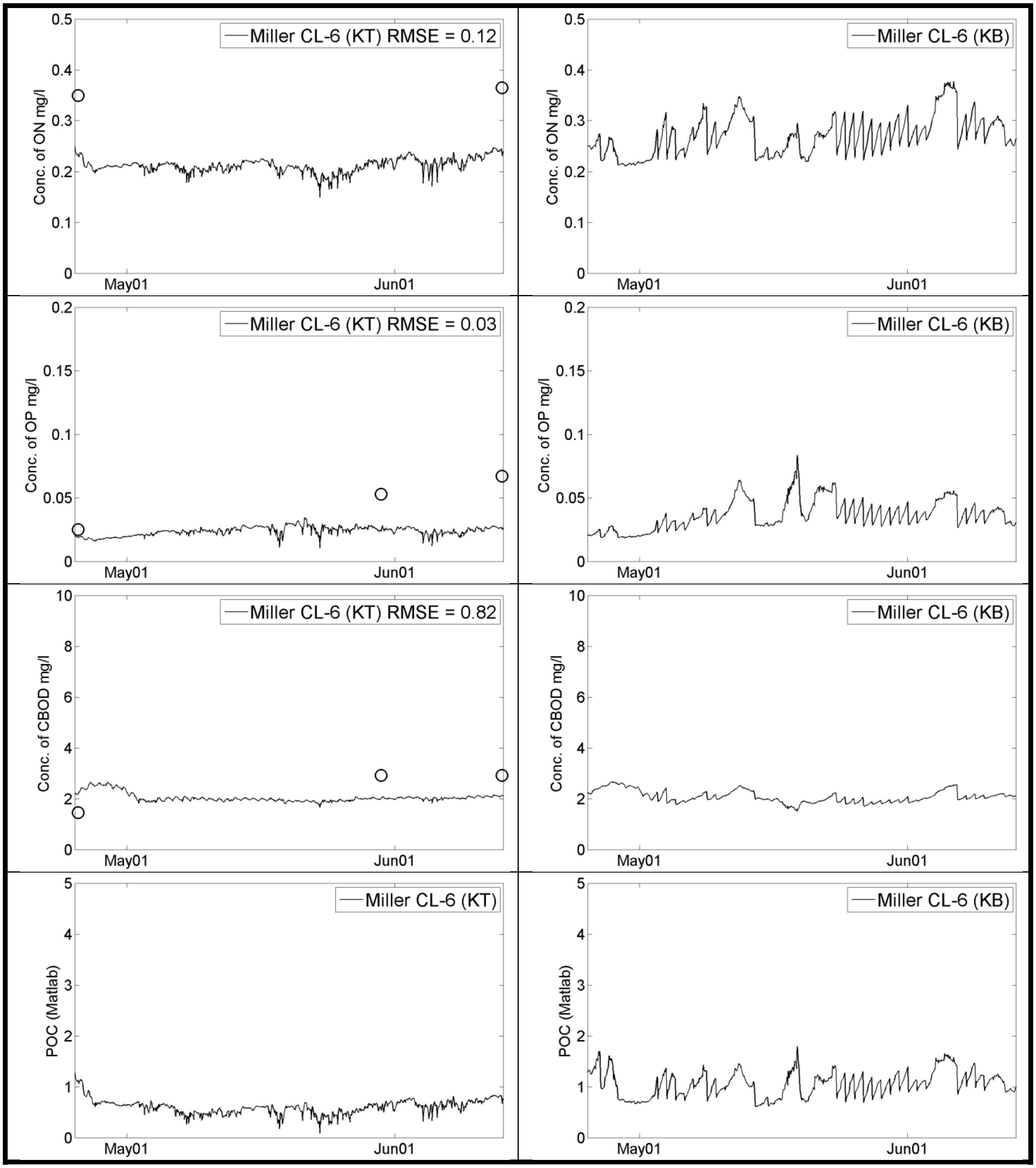


Figure H36. Predicted and observed ON, OP, CBOD, and POC at station Miller_CL6 (layer KT and KB).

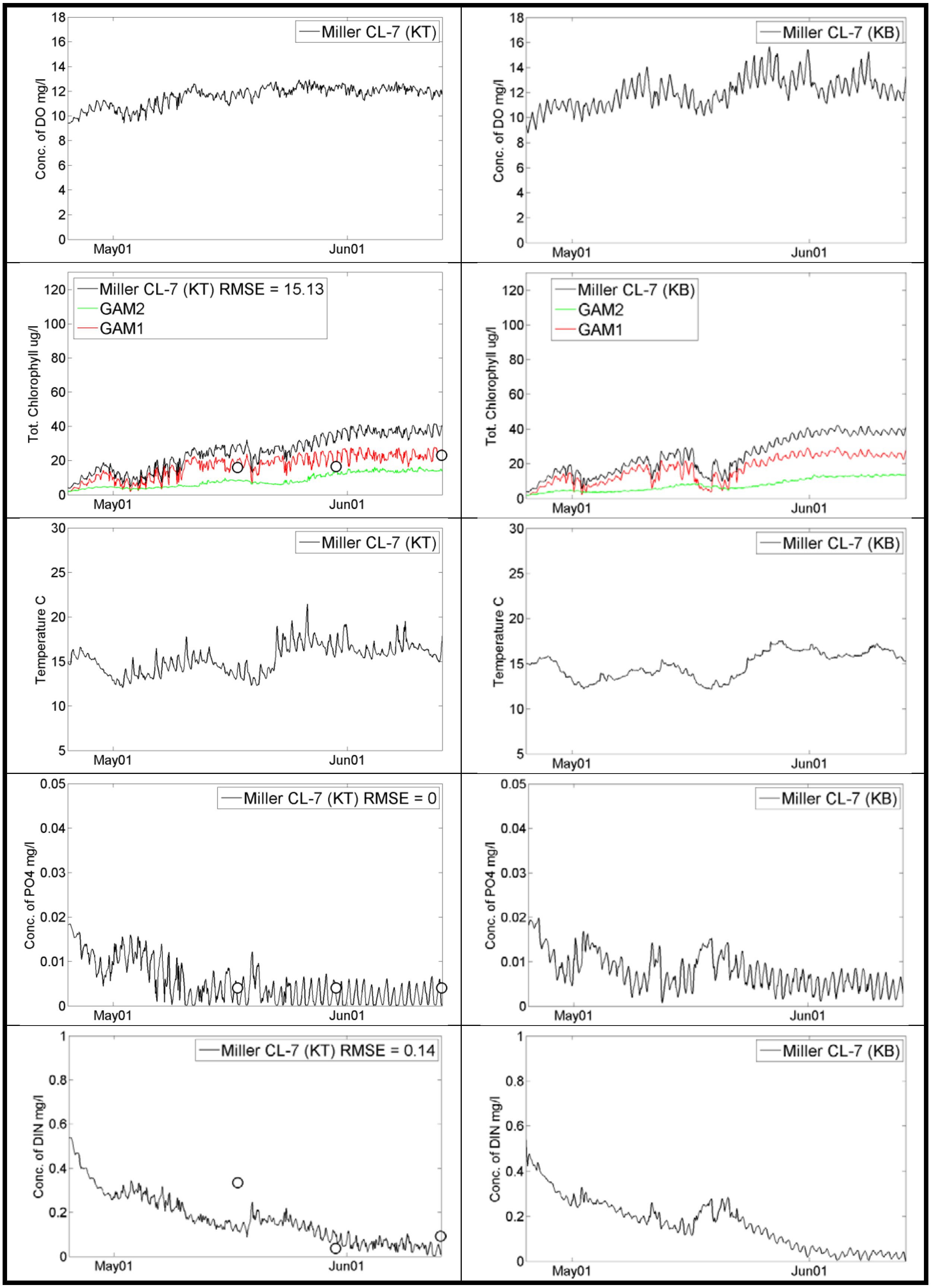


Figure H37. Predicted and observed dissolved oxygen (DO), total chlorophyll-a, temperature, PO4, and DIN at station Miller_CL7 (layer KT and KB).

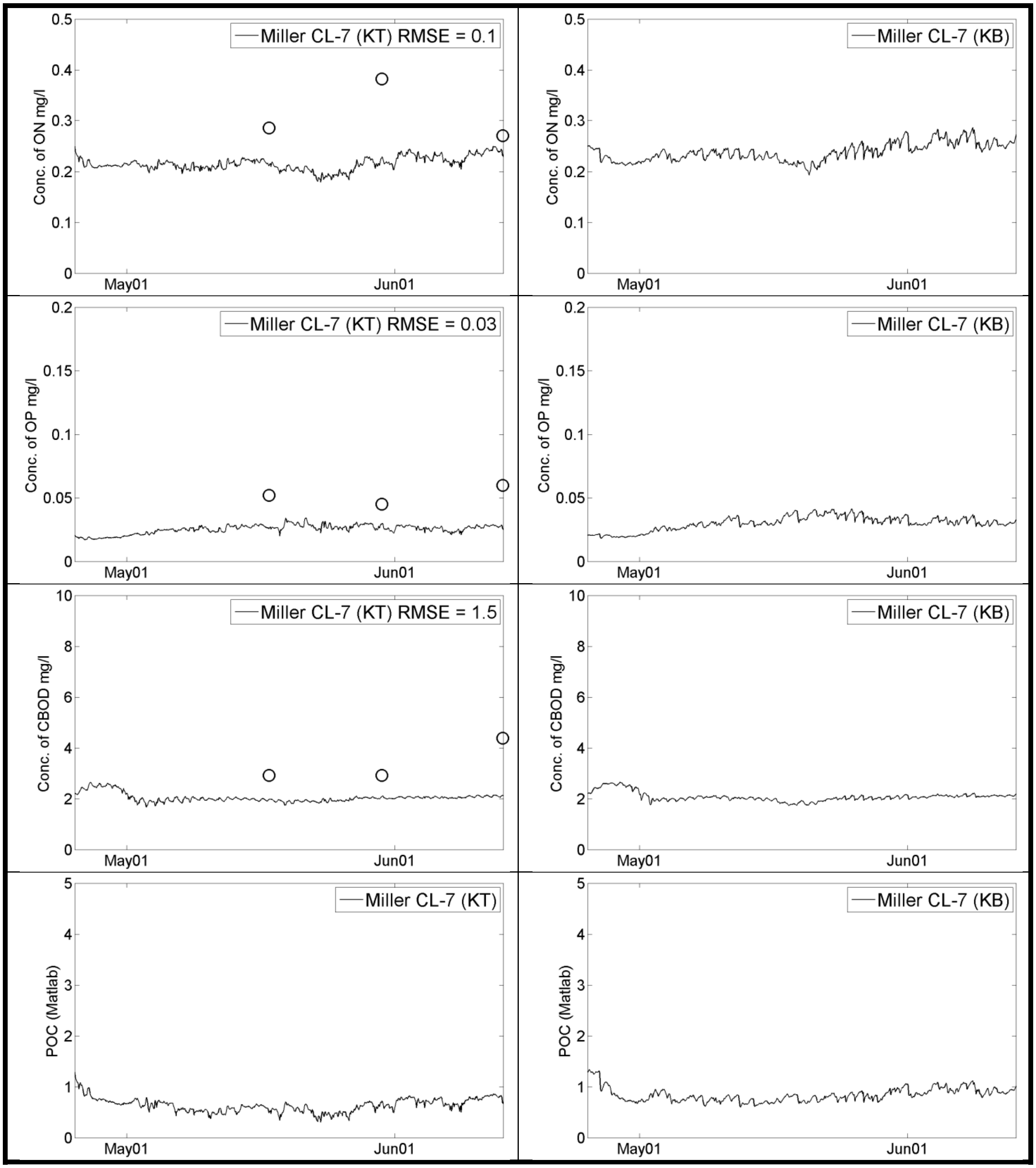


Figure H38. Predicted and observed ON, OP, CBOD, and POC at station Miller_CL7 (layer KT and KB).

Profile measurements

Temperature and DO profiles are available at six locations (Miller stations CL1, CL3, CL4, CL5, CL6, and CL7) during the verification period. Figures H39 through H41 show the model predicted profiles at these locations compared with the measured profiles. The model performs reasonably well in predicting the temperature profiles during the verification period. However, the model over-estimates the DO profiles.

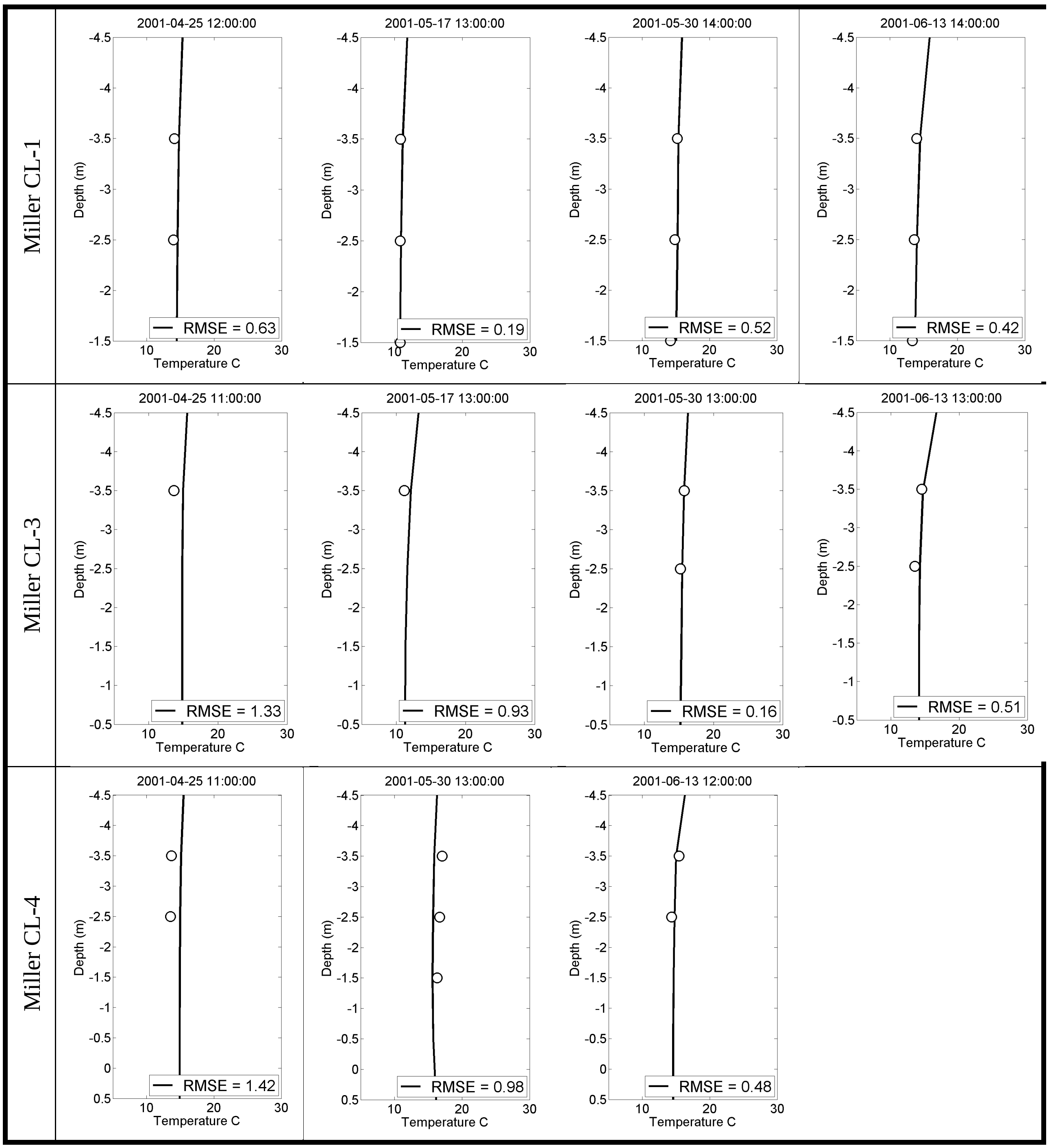


Figure H39. Temperature profile comparisons at Miller stations CL1, CL3, and CL4.

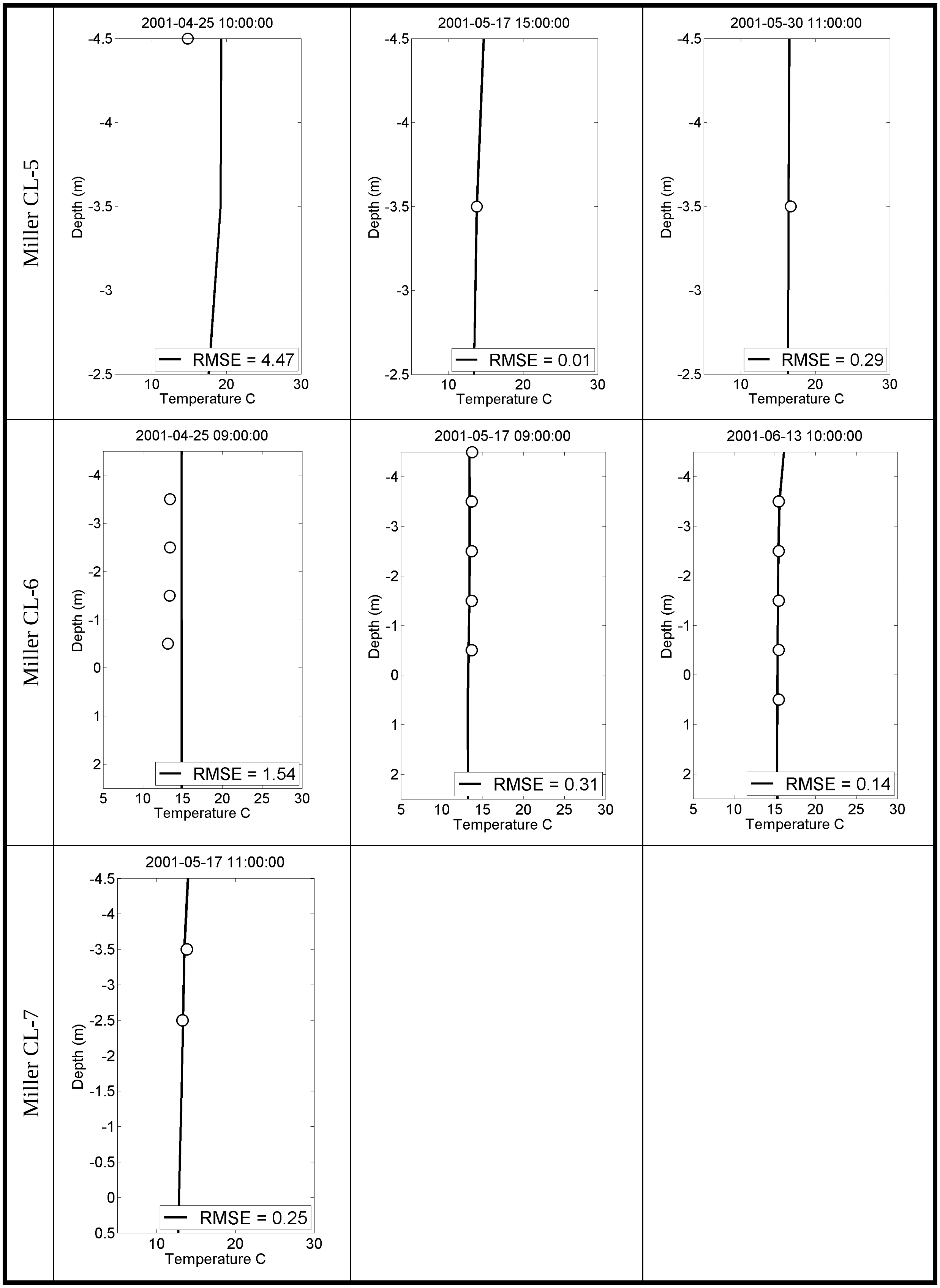
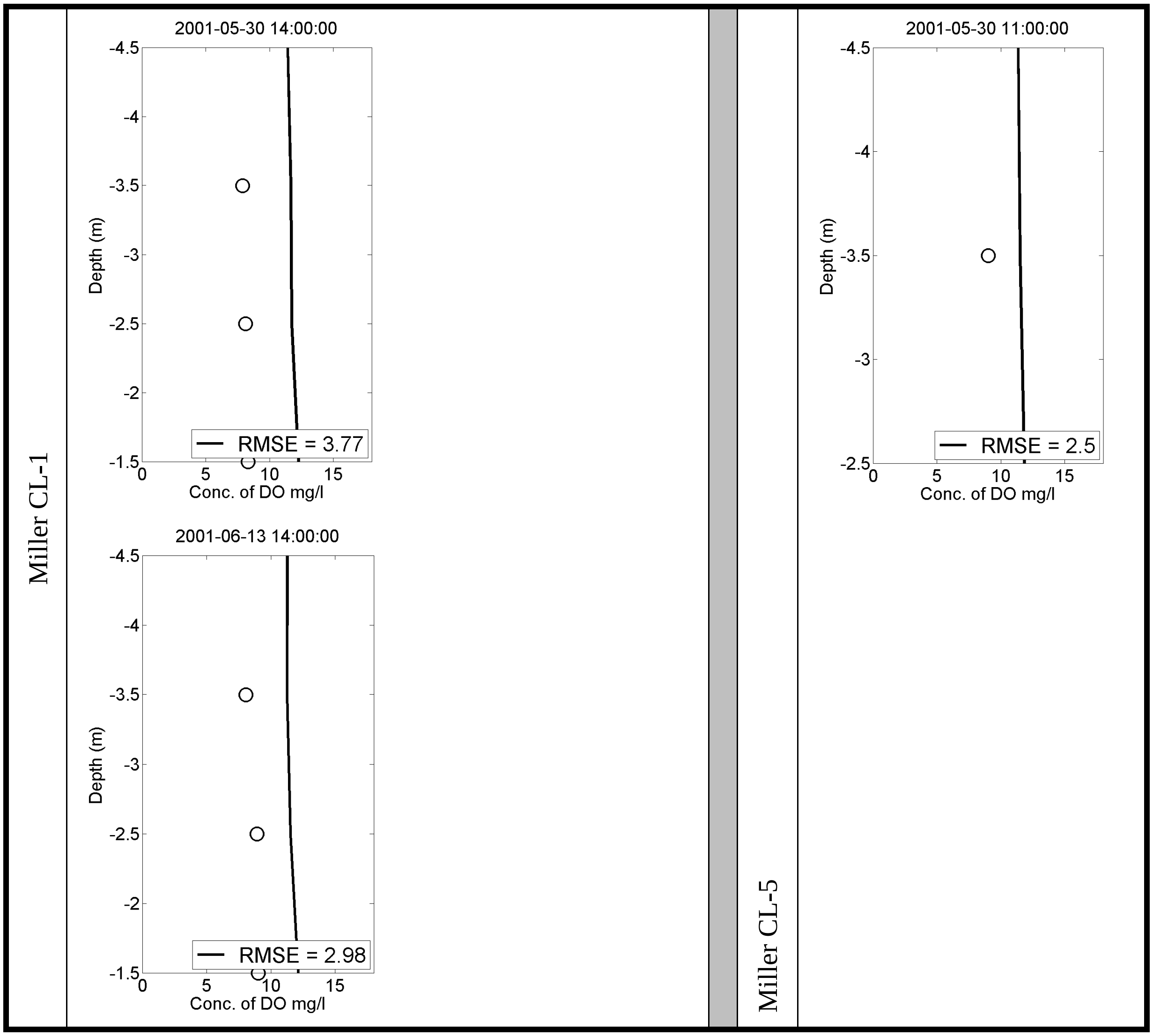
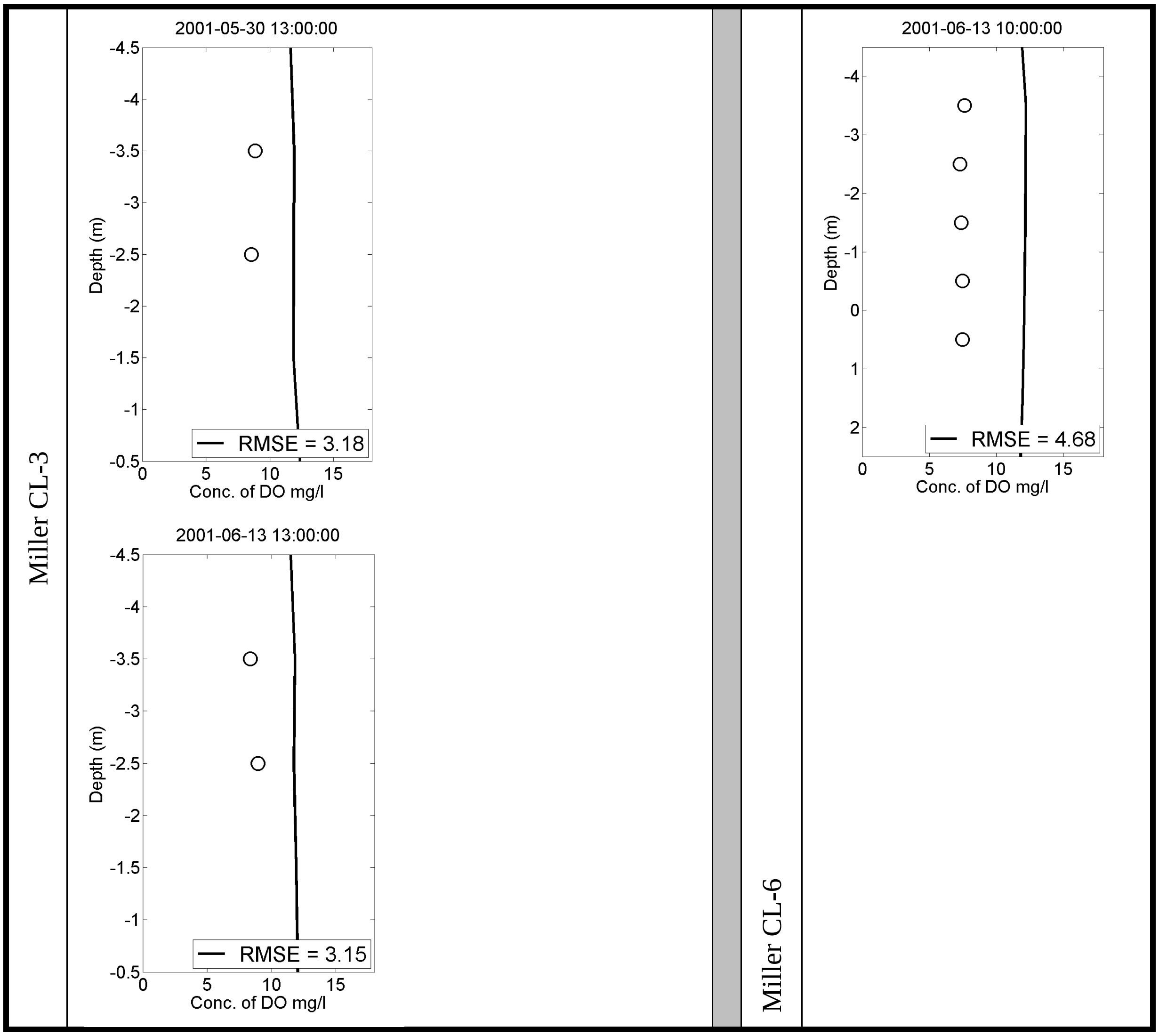


Figure H40. Temperature profile comparisons at Miller stations CL5, CL6, and CL7.


Miller CL-1
2001-05-30 14:00:00
Depth (m)
Conc. of DO mg/l
RMSE = 3.77
2001-06-13 14:00:00
Depth (m)
Conc. of DO mg/l
RMSE = 2.98
Miller CL-5
2001-05-30 11:00:00
Depth (m)
Conc. of DO mg/l
RMSE = 2.5


Miller CL-3
2001-05-30 13:00:00
Depth (m)
Conc. of DO mg/l
RMSE = 3.18
2001-06-13 13:00:00
Depth (m)
Conc. of DO mg/l
RMSE = 3.15
Miller CL-6
2001-06-13 10:00:00
Depth (m)
Conc. of DO mg/l
RMSE = 4.68

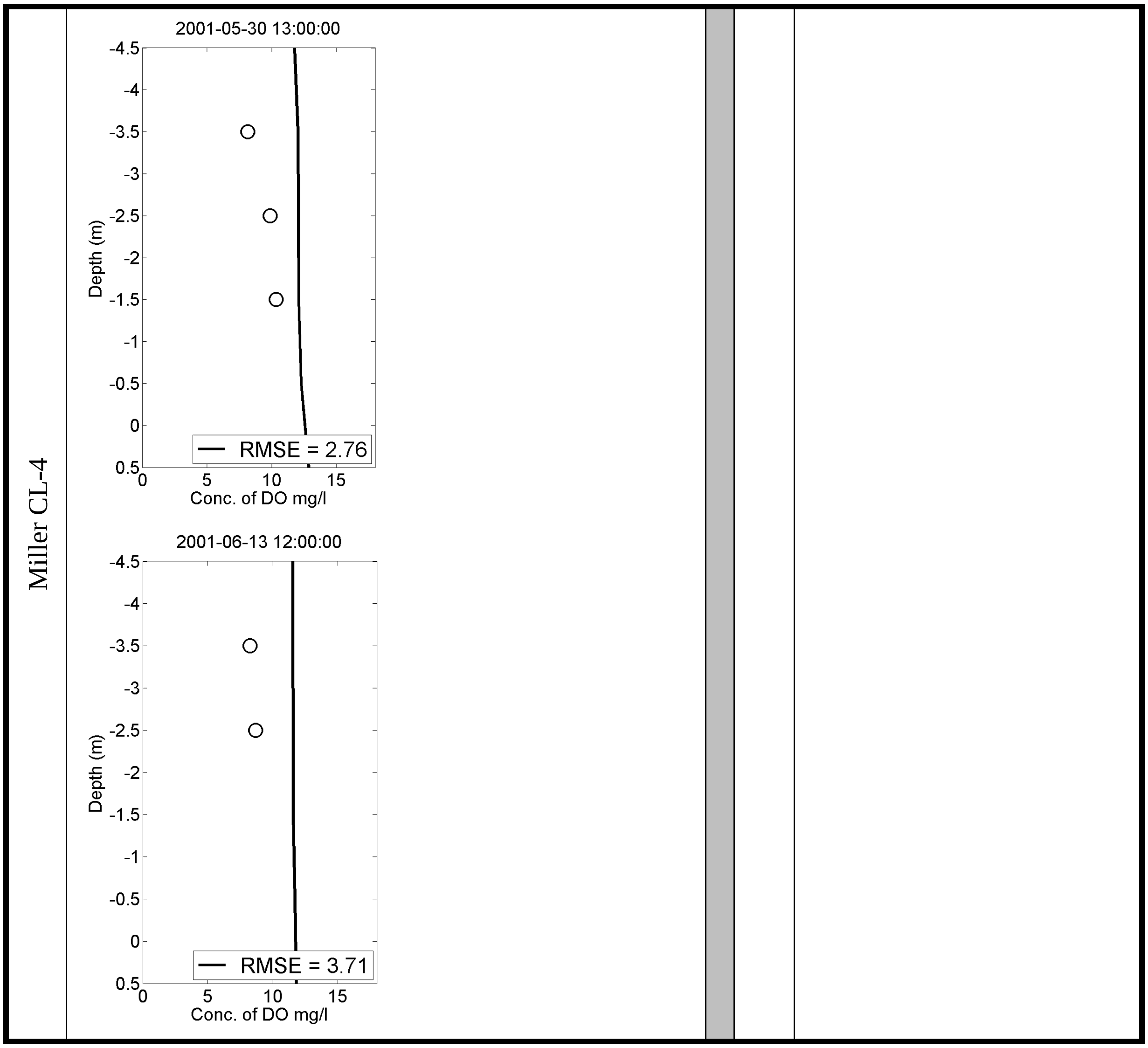


Figure H41. DO profiles at Miller stations CL1, CL3, CL4, CL5, and CL6.

Overall error statistics

Table H2 shows the overall error statistics when all field data are compared with associated model predictions for each variable during the verification period. In Table H2 the DO has a significant positive bias (i.e. the model overpredicts). Temperature and total chlorophyll have a non-significant positive bias whereas for PO4 and DIN the bias is non-significant and negative (i.e. the model underpredicts). In the calibration period (2004) the DO predictions were not significantly biased and the RMSE was lower compared with the verification period.

Figure H42 shows box-and-whisker plot for DO in the month of June 2001 and 2004 for all field data collected in Capitol Lake. The June 2004 DO concentrations are significantly higher (>2.5 mg/L) than those in June 2001. The 2001 data were not collected under a "quality assurance project plan" or QAPP, so the quality assurance (QA) procedures for the collected data are not known. River flows and air temperatures were higher in the beginning of June 2004 for a few days but moving forward in the month, the flows and air temperatures were comparable to those in 2001. The median lake chlorophyll_and DO saturation concentrations were similar for June 2001 and June 2004.

Table H2. Overall error statistics during the verification period (2001)

Variable	n	RMSE	Mean	Standard deviation
Dissolved Oxygen (DO)	32	3.5	3.3	1
Orthophosphate (PO4)	39	0.007	-0.003	0.006
Dissolved Inorganic Nitrogen (DIN)	24	0.13	-0.087	0.096
Temperature	57	0.99	0.14	0.986
Total Chlorophyll	24	13.8	9.8	9.9

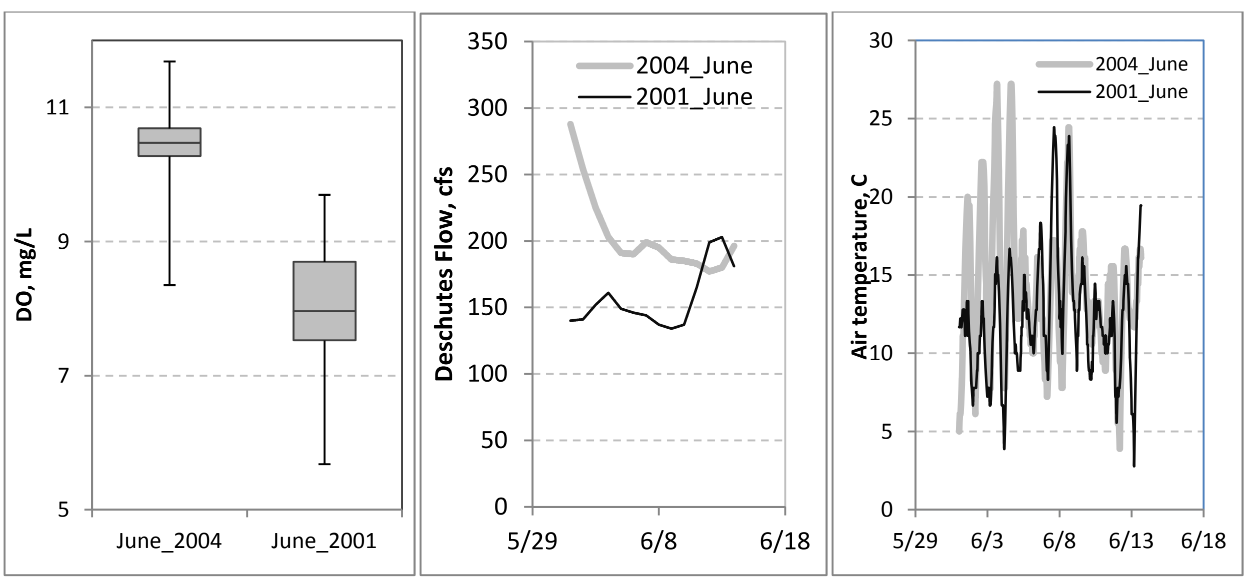


Figure H42. DO concentrations in Capitol Lake, flow in Deschutes River, and local air temperatures in June 2004 and 2001.

Conclusion

The model performed well against the observed conditions based on the data available for boundary conditions. The calibration period focused on two sets of conditions, pre-herbicide and post-herbicide. Both of these periods were successfully calibrated and the pre-herbicide settings were used for verification period. The existing calibrated model is capable of reproducing the system response under different loadings and forcings.

References

Prakash S. and V.S. Kolluru. 2008. Capitol Lake Water Quality calibration and verification. Memorandum to Greg Pelletier, Washington State Department of Ecology from ERM. Feb 28, 2008.

CH2M Hill. 2001. Technical Evaluation Report for the Discharge of Treated Wastewater from the Tumwater Brewery. Prepared for Miller Brewing Company.

Table H3. Kinetic rates and constants for WQCBM.

General Variables	Variable description	NB	MB	SB	PC	Unit	Min	Max
Ke_a	Background non-algal light extinction	0.336	0.336	0.336	0.336	0 : 1/m	0	4
Ke_b	Coefficient for chlorophyll for light extinction	0.0365	0.0365	0.0365	0.0365	0 : 1/m/(ugA/L)^Ke_c)	0	0.054
Ke_c	Exponent for chlorophyll for light extinction	0.64	0.64	0.64	0.64	0 : No Units	0	1
NH3	Ammonia							
anc	Nitrogen to carbon ratio	0.14	0.14	0.14	0.14	0 : g N/g C	0	0.25
k71	Organic nitrogen mineralization rate	0.75	0.75	0.75	0.75	0 : 1/day	0.01	0.15
th71	Temperature coefficient	1.07	1.07	1.07	1.07	No Units	0	1.08
k12	Nitrification rate	0.09	0.09	0.09	0.09	0 : 1/day	0.09	0.13
th12	Temperature coefficient	1.08	1.08	1.08	1.08	No Units	0	1.08
knit	Half saturation constant for oxygen limitation of nitrification	1	1	1	1	0 : g O2/m^3	0	2
kmnc	Half saturation constant for nitrogen mineralization	0.9	0.9	0.9	0.9	0 : g C/m^3	0	1
NO3	Nitrate							
k2d	Denitrification rate @ 20 °C	0.15	0.15	0.15	0.15	0 : 1/day	0.09	0.16
th2d	Temperature coefficient	1.05	1.05	1.05	1.05	No Units	0	2
kno3	Michaelis constant for denitrification	0.1	0.1	0.1	0.1	0 : g O2/m^3	0.1	0.1
PO4	Inorganic Phosphorous							
apc	Phosphorus to carbon ratio	0.02	0.02	0.02	0.02	0 : g P/g C	0.025	0.025
k83	Dissolved organic phosphorus mineralization @ 20 °C	1.05	1.05	1.05	1.05	0 : 1/day	0.1	0.3
th83	Temperature coefficient	1.02	1.02	1.02	1.02	No Units	0	1.08
kmpc	Half saturation constant for phosphorus mineralization	0.5	0.5	0.5	0.5	0 : g C/m^3	1	10
plc	Phosphorus limiting switch	0	0	0	0	No Units		
DAP	Diatoms - Phytoplankton	1	1	1	1			
c2chla_d	Ratio of carbon to chlorophyll a	70	70	70	70	No Units	10	100
rins_d	Saturating light intensity	215	215	215	215	0 : cal/m^2-day	110	200
kmn_d	Half saturation constant for nitrogen	0.005	0.005	0.005	0.005	0 : g N/m^3	0.001	0.025
ZPGMode_d	Zooplankton grazing mode	1 : LinearGrazing	1 : LinearGrazing	1 : LinearGrazing	1 : LinearGrazing	No units	0	2
kgmicro_d	Grazing rate due to microzooplankton	0.11	0.11	0.11	0.11	0 : 1/day	0	0.08
kgmacro_d	Grazing rate due to macrozooplankton	0.1	0.1	0.1	0.1	0 : 1/day	0	0.101
thkt_d	Temperature coefficient	1.04	1.04	1.04	1.04	No Units	1.045	1.045
k1d_d	Death rate	0.02	0.02	0.02	0.02	0 : 1/day	0.015	0.2
k1c_d	Maximum growth rate	0	0	0	0	0 : 1/day	0.01	4
th1c_d	Temperature coefficient	1.07	1.07	1.07	1.07	No Units	0	1.08
kmp_d	Half saturation constant for phosphorus	0.001	0.001	0.001	0.001	0 : g P/m^3	0.001	0.002
k1r_d	Endogenous respiration rate @ 20 °C	0.05	0.05	0.05	0.05	0 : 1/day	0.05	0.2
th1r_d	Temperature coefficient	1.05	1.05	1.05	1.05	No Units	1.045	1.045
vs4_d	Settling velocity	0.05	0.05	0.05	0.05	5 : m/day	0.05	0.5
fe_d	Excretion fraction of phytoplankton	0.05	0.05	0.05	0.05	No Units	0.1	0.8
as_d	Assimilation efficiency of zooplankton grazing	0.5	0.5	0.5	0.5	No Units	0.5	0.8

Table H4. Kinetic rates and constants for WQCBM (continued).

General Variables	Variable description	NB	MB	SB	PC	Unit	Min	Max
DFP	Dynoflagellates - Phytoplankton	1	1	1	1			
c2chla_f	Ratio of carbon to chlorophyll a	70	70	70	70	No Units	10	100
rins_f	Saturating light intensity	45	45	45	45	0 : cal/m^2-day	110	200
kmn_f	Half saturation constant for nitrogen	0.01	0.01	0.01	0.01	0 : g N/m^3	0.001	0.025
ZPGMode_f	Zooplankton grazing mode	1 : LinearGrazing	1 : LinearGrazing	1 : LinearGrazing	1 : LinearGrazing	No Units	0	2
kgmicro_f	Grazing rate due to microzooplankton	0.11	0.11	0.11	0.11	0 : 1/day	0	0.08
kgmacro_f	Grazing rate due to macrozooplankton	0.100224	0.100224	0.100224	0.100224	0 : 1/day	0	0.101
thkt_f	Temperature coefficient	1.04	1.04	1.04	1.04	No Units	1.045	1.045
k1d_f	Death rate	0.02	0.02	0.02	0.02	0 : 1/day	0.015	0.2
k1c_f	Maximum growth rate	0	0	0	0	0 : 1/day	0.01	4
th1c_f	Temperature coefficient	1.07	1.07	1.07	1.07	No Units	0	1.08
kmp_f	Half saturation constant for phosphorus	0.001	0.001	0.001	0.001	0 : g P/m^3	0.001	0.002
k1r_f	Endogenous respiration rate @ 20 °C	0.35	0.35	0.35	0.35	0 : 1/day	0.05	0.2
th1r_f	Temperature coefficient	1.05	1.05	1.05	1.05	No Units	1.045	1.045
vs4_f	Settling velocity	0.1	0.1	0.1	0.1	5 : m/day	0.05	0.5
fe_f	Excretion fraction of phytoplankton	0.15	0.15	0.15	0.15	No Units	0.1	0.8
as_f	Assimilation efficiency of zooplankton grazing	0.5	0.5	0.5	0.5	No Units	0.5	0.8
UseVtemp	Use temperature dependent velocity	1	1	1	1	View Equation		
Vtmax	Maximum temperature dependent velocity	0.000145	0.000145	0.000145	0.000145	0 : m/sec	0	0.0002
b	Empirical Constant	0.632	0.632	0.632	0.632	No Units	0	2
c	Empirical Constant	2	2	2	2	No Units	0	5
tL	Lower temperature constant °C	11.68	11.68	11.68	11.68	0 : C	0	20
tH	Higher temperature constant °C	33	33	33	33	0 : C	10	50
Voff	Swim speed enhancement due to light during experiments	3.50E-05	3.50E-05	3.50E-05	3.50E-05	No Units	0	0.0002
UseVlight	Use light dependent velocity	1	1	1	1	View Equation		
Vlmax	Maximum light dependent velocity	3.50E-05	3.50E-05	3.50E-05	3.50E-05	0 : m/sec	0	0.0002
Alpha	Empirical Constant	10	10	10	10	0 : um m^2/uEinst	0	20
DO	Dissolved Oxygen							
SDOEMethod	Surface DO reaeration formulation	2 : Chen & Kanwisher	2 : Chen & Kanwisher	2 : Chen & Kanwisher	2 : Chen & Kanwisher	View Equation		
kdf	deoxygenation rate @ 20°C for fast CBOD	0.2	0.2	0.2	0.2	0 : 1/day	0.16	0.21
kds	deoxygenation rate @ 20°C for slow CBOD	0.02	0.02	0.02	0.02	0 : 1/day	0.16	0.21
ReaerationFactor	Factor to increase the reaeration rate	0.6	0.6	0.6	0.6	No Units	1	10
Thtk2	Temperature correction for reaeration	1.024	1.024	1.024	1.024	No Units	1	1.07
CBOD_F	Fast Reacting Dissolved Carbonaceous BOD							
aoc	Oxygen to carbon ratio	2.67	2.67	2.67	2.67	0 : g O2/g C	2.67	2.67
thd	Temperature coefficient	1.05	1.05	1.05	1.05	No Units	1.047	1.047
kbod	Half saturation constant for oxygen limitation	0.5	0.5	0.5	0.5	0 : g O2/m^3	0.5	0.5
foc	Oxygen from dead algae	0.25	0.25	0.25	0.25	No Units	0.5	0.5
r_CBODP	Stoichiometric equivalent between CBOD and phosphorous	0.004	0.004	0.004	0.004	No Units	0.004	0.004
r_CBODN	Stoichiometric equivalent between CBOD and nitrogen	0.006	0.006	0.006	0.006	No Units	0.006	0.006
r_CBODC	Stoichiometric equivalent between CBOD and carbon	0.32	0.32	0.32	0.32	No Units	0.32	0.32
CBOD_S	Slow Reacting Dissolved Carbonaceous BOD							
fd5	Fraction of dead phyto recycled to fast reacting CBOD	0.5	0.5	0.5	0.5	No Units	0.5	

Table H5. Kinetic rates and constants for WQCBM (continued).

General Variables	Variable description	NB	MB	SB	PC	Unit	Min	Max
ON_D and ON_P	Dissolved and Particulate Organic Nitrogen							
kh7p	Hydrolysis rate for particulate organic nitrogen	0.2	0.2	0.2	0.2	0 : 1/day	0.075	0.1
thh7p	Temperature coefficient	1.07	1.07	1.07	1.07	No Units		
fon	Organic nitrogen from dead algae	0.1	0.1	0.1	0.1	No Units	0	0.5
vs7	Organic matter settling velocity	1.2	1.2	1.2	1.2	5 : m/day	0.05	0.5
ancp	Particulate organic nitrogen to carbon ratio	0.07	0.07	0.07	0.07	No Units	0.25	0.8
OP_D and OP_P	Dissolved and Particulate Organic Phosphorus							
kh8p	Hydrolysis rate for particulate organic phosphorus	0.2	0.2	0.2	0.2	0 : 1/day	0.075	0.1
thh8p	Temperature coefficient	1.07	1.07	1.07	1.07	No Units	0	1.08
fop	Organic P from dead algae; Fraction to dissolved component	0.55	0.55	0.55	0.55	No Units	0.5	0.5
vs8	Organic matter settling velocity	1.2	1.2	1.2	1.2	5 : m/day	0.05	0.2
apcp	Particulate organic phosphorus to carbon ratio	0.75	0.75	0.75	0.75	No Units	0.7	0.8
OC_P_F	Fast Reacting Particulate Organic Carbon							
fd9f	Fraction of dead phyto recycled to fast reacting POC	0.65	0.65	0.65	0.65	No Units	0	1
fg9f	Fraction of micro-Grazing to fast reacting POC	0.55	0.55	0.55	0.55	No Units	0	1
kpd9f	Hydrolysis rate for fast reacting POC	0.02	0.02	0.02	0.02	0 : 1/day	0.075	0.08
thpd9p	Temperature coefficient for the hydrolysis rate	1.04	1.04	1.04	1.04	No Units	0	1.08
vs9	Settling velocity of particulate organic carbon	1.2	1.2	1.2	1.2	5 : m/day	0.05	0.2
OC_P_S	Slow Reacting Particulate Organic Carbon							
fd9s	fraction of dead phyto recycled to slow reacting POC	0.25	0.25	0.25	0.25	No Units	0	1
fg9s	fraction of micro-grazing to slow reacting POC	0.32	0.32	0.32	0.32	No Units	0	1
kpd9s	Hydrolysis rate for slow reacting POC	0.01	0.01	0.01	0.01	0 : 1/day	0.005	0.02
thpd9s	Temperature coefficient for the hydrolysis rate	1.04	1.04	1.04	1.04	No Units	0	1.07
OC_P_R	Refractory Particulate Organic Carbon							
fd9r	fraction of dead phytoplankton to recycled to refractory POC	0.1	0.1	0.1	0.1	No Units	0	1
fg9r	fraction of micro-grazing to refractory POC	0.13	0.13	0.13	0.13	No Units	0	1
TVRC File Settings								
UseTVRCData	Use time varying rates and constants data	0	0	0	0			
TVRCFileName	Time varying rates and constants file name	No_Data_File	No_Data_File	No_Data_File	No_Data_File			

Table H6. Kinetic rates and constants for WQADD.

Variable	Description	NB	MB	SB	PC	Unit	Min	Max
Stoichiometry	Stoichiometry for Bottom Algae							
mgC	Carbon	35	40	40	35	0 : gC	30	50
mgN	Nitrogen	7.2	7.2	7.2	7.2	0 : gN	3	9
mgP	Phosphorous	1	1	1	1	0 : gP	0.4	2
mgD	Dry weight	100	100	100	100	0 : gD	100	100
mgA	Chlorophyll	1	1	1	1	0 : gA	0.4	2
MPHYT	Bottom Algae/Macrophyte	1	1	1	1			
BotAlgGrowthModel	Growth model	1 : Zero Order	1 : Zero Order	1 : Zero Order	1 : Zero Order			
Cgb20	Growth rate	0.3	0.3	0.3	90	0 : mgA/m^2-day	0	500
ThtCgb20	Temperature correction	1.07	1.07	1.07	1.01	No Units	1	1.07
abMax	First order model carrying capacity	1000	1000	1000	1000	0 : mgA/m^2	1000	1000
krb	Respiration rate	0.05	0.05	0.05	0.05	0 : 1/day	0	0.5
Thtkrb	Temperature correction	1.07	1.07	1.07	1.07	No Units	1	1.07
keb	Excretion rate	0.005	0.005	0.005	0.005	0 : 1/day	0	5
Thtkeb	Temperature correction	1.07	1.07	1.07	1.07	No Units	1	1.07
kdb	Death rate	0.05	0.05	0.05	0.03	0 : 1/day	0	0.5
Thtkdb	Temperature correction	1.07	1.07	1.07	1.07	No Units	1	1.07
ksNb	External nitrogen half saturation constant	0	0	0	0	0 : ugN/l	0	300
ksPb	External phosphorous half saturation constant	0	0	0	0	0 : ugP/l	0	100
ksCb	Inorganic carbon half saturation constant	0.0001	0.0001	0.0001	0.0001	0 : moles/l	0.0000013	0.00013
HCO3useF	Use HCO3 as substrate	0	0	0	0			
BotAlgLightModel	Light model	1 : Half Saturation	1 : Half Saturation	1 : Half Saturation	1 : Half Saturation	No Units		
PAR	Photosynthetically available radiation	0.45	0.45	0.45	0.45	No Units		
KLb	Light constant	1.72	1.72	1.72	0.5	0 : langleys/day	1	100
khnxb	Ammonia preference	100	100	100	100	0 : ugN/l	1	100
q0N	Subsistence quota for nitrogen	0.63189468	0.63189468	0.63189468	0.01	0 : mgN/mgA	0.0072	7.2
q0P	Subsistence quota for phosphorous	0.3389707	0.3389707	0.3389707	0.005	0 : mgP/mgA-day	0.001	1
rmN	Maximum uptake for nitrogen	49	49	49	49	0 : mgN/mgA-day	1	500
rmP	Maximum uptake for phosphorous	7	7	7	7	0 : mgP/mgA-day	1	500
KqN	Internal nitrogen half saturation ratio	1.5	1.5	1.5	1.5	No Units	1.05	5
KqP	Internal phosphorous half saturation ratio	1.5	1.5	1.5	1.5	No Units	1.05	5
NUpWCFactor	Nitrogen uptake water column factor	0.4	0.4	0.4	0.4	No Units	0	1
PUpWCFactor	Phosphorous uptake water column factor	0	0	0	0	No Units	0	1
Ikoxb	Oxygen enhance model for respiration	1 : Exponential	1 : Exponential	1 : Exponential	1 : Exponential			
ksob	Oxygen enhance parameter for respiration	0.6	0.6	0.6	0.6	0 : l/mg O2	0.6	0.6
Modeling Method	Modeling approach	1 : QUAL2KW	1 : QUAL2KW	1 : QUAL2KW	1 : QUAL2KW	No Units		
pH	pH	0	0	0	0			
pHMethod	Method fo pH only	1 : Newtow-Raphson	1 : Newtow-Raphson	1 : Newtow-Raphson	1 : Newtow-Raphson	No Units		
ALKL	Alkalinity	0	0	0	0			
NoVariable	No user specified input variable for the constituent ALKL	Not Applicable	Not Applicable	Not Applicable	Not Applicable			

Table H7. Kinetic rates and constants for WQADD.

Variable	Description	NB	MB	SB	PC	Unit	Min	Max
TIOC	Total Inorganic Carbon	0	0	0	0			
pCO2SetMethod	Set up method for partial pressure of carbon dioxide	1 : Compute	1 : Compute	1 : Compute	1 : Comput e	No Units		
pCO2	Partial pressure of carbon dioxide	347	347	347	347	1 : ppm		
COND	Conductivity	0	0	0	0			
NoVariable	No user specified input variable for the constituent COND	Not Applicab le	Not Applicab le	Not Applicab le	Not Applica ble			
LDOM	Labile Dissolved Organic Matter	0	0	0	0			
K_LDOM	Labile DOM decay rate	0.1	0.1	0.1	0.1	0 : 1/day	0.1	0.65
Tht_K_LDOM	Temperature correction factor for labile DOM	1.005	1.005	1.005	1.005	No Units	1	1.07
K_L2RDOMTR	Labile to refractory DOM transfer rate	0.01	0.01	0.01	0.01	0 : 1/day	0.05	0.05
RDOM	Refractory Dissolved Organic Matter	0	0	0	0			
K_RDOM	Refractory DOM decay rate	0.001	0.001	0.001	0.001	0 : 1/day	0.0001	0.005
Tht_K_RDOM	Temp. correction factor for refractory DOM decay rate	1.005	1.005	1.005	1.005	No Units	1	1.07
LPOM	Labile particulate organic matter	0	0	0	0			
K_LPOM	Labile POM decay rate	0.08	0.08	0.08	0.08	0 : 1/day	0.01	1
Tht_K_LPOM	Temperature correction factor for labile POM decay rate	1.005	1.005	1.005	1.005	No Units		
K_L2RPOMTR	Labile to refractory POM transfer rate	0.01	0.01	0.01	0.01	0 : 1/day	0.01	0.1
vs_LPOM	Settling velocity of labile POM	0.1	0.1	0.1	0.1	5 : m/day	0.01	10
kds_LPOM	Dissolution rate of labile POM	2.5661	2.5661	2.5661	2.5661	0 : 1/day	0	5
Tht_kds_LPOM	Temp. correction factor for labile POM dissolution rate	1.005	1.005	1.005	1.005	No Units		
Pam	Fraction of algal biomass that is converted into POM	0.8	0.8	0.8	0.8	No Units	0	1
RPOM	Refractory particulate organic matter	0	0	0	0			
K_RPOM	Refractory DOM decay rate	0.001	0.001	0.001	0.001	0 : 1/day	0.0005	0.002
Tht_K_RPOM	Temp. correction factor for refractory DOM decay rate	1.005	1.005	1.005	1.005	No Units		
vs_RPOM	Settling velocity of refractory POM	0.1	0.1	0.1	0.1	5 : m/day	0.01	10
kds_RPOM	Dissolution rate of refractory POM	2.5661	2.5661	2.5661	2.5661	0 : 1/day	0	5
Tht_kds_RPOM	Temp. correction factor for refractory POM dissolution rate	1.005	1.005	1.005	1.005	No Units		
Stoichiometry	Stoichiometry for Organic Matter							
r_OMN	Stoichiometric equivalent between organic matter and N	0.08	0.08	0.08	0.08	No Units		
r_OMP	Stoichiometric equivalent between organic matter and P	0.005	0.005	0.005	0.005	No Units		
r_OMC	Stoichiometric equivalent between organic matter and C	0.45	0.45	0.45	0.45	No Units		
TDS	Total Dissolved Solids	0	0	0	0			
NoVariable	No user specified input variable for the constituent TDS	Not Applicab le	Not Applicab le	Not Applicab le	Not Applica ble			
SSS	Total Suspended Solids	0	0	0	0			
SSSVelType	Total suspended solids velocity type	0 : User Supplied Velocity	0 : User Supplied Velocity	0 : User Supplied Velocity	0 : User Supplie d Velocit y	No Units		
SSSVel	Total suspended solids velocity	0	0	0	0	5 : m/day		
SSSSize	Total suspended solids size	50	50	50	50	0 : microns		
SSSDensity	Total suspended solids density	1.5	1.5	1.5	1.5	0 : gm/cc	1	5
TVRC File Settings								
UseTVRCData	Use time varying rates and constants data	1	1	1	0			
TVRCFileName	Time varying rates and constants file name	TVR file	TVR file	TVR file	No_Dat a_File	Browse	View	

Table H8. Time varying rate file for WQADD.

Region	TVR File Name	Year	Month	Day	Hour	Minute	q0N	q0P	kdb	Cgb20	Nup WC Factor	Klb	Kr	mgC
NB	CL_NBWQADD_ZeroOrder_half_Cg100_130_Kd03_Klb05_Nup0_mgC35_40_qn01.kdg	2004	5	15	0	0	0.01	0.005	0.03	100	0	0.5		35
		2004	7	29	0	0	0.01	0.005	1.83	100	0	0.5		35
		2004	7	30	0	0	0.01	0.005	0.03	130	0	0.5		40
		2004	8	13	0	0	0.01	0.005	0.03	130	0	0.5		40
		2004	10	1	0	0	0.01	0.005	0.03	130	0	0.5		40
SB	CL_SBWQADD_ZeroOrder_half_Cg100_Kd03_Klb05_Nup0_qn01.kdg	2004	5	15	0	0	0.01	0.005	0.03	100	0	0.5		
		2004	7	19	0	0	0.01	0.005	1.83	100	0	0.5		
		2004	7	20	0	0	0.01	0.005	0.03	100	0	0.5		
		2004	8	13	0	0	0.01	0.005	0.03	100	0	0.5		
		2004	10	1	0	0	0.01	0.005	0.03	100	0	0.5		
MB	CL_MBWQADD_ZeroOrder_half_Cg90_100_Kd03_025_krb05_mgC40_qn01.kdg	2004	5	15	0	0	0.01	0.005	0.03	90	0	0.5	0.05	40
		2004	7	19	0	0	0.01	0.005	1.83	90	0	0.5	0.05	40
		2004	7	20	0	0	0.01	0.005	0.025	100	0	0.5	0.05	40
		2004	8	13	0	0	0.01	0.005	0.025	100	0	0.5	0.05	40
		2004	10	1	0	0	0.01	0.005	0.025	100	0	0.5	0.05	40

Table H9. Kinetic rates and constants for GAM.

Parameter	Description	NB	MB	SB	PC	Unit	Min	Max
GAM1	I_GAM1							
UseNutrientLimit	Use nutrient limit function in growth computations	1	1	1	1	No Units		
UseTempLimit	Use temperature limit function in growth computations	1	1	1	1	No Units		
UseSalineToxicLimit	Use saline toxicity limit function in growth computations	1	1	1	1	No Units		
UseLightLimit	Use light limit function in growth computations	1	1	1	1	No Units		
k1r	Respiration rate @t 20 °C	0.08	0.08	0.08	0.08	0 : 1/day	0.05	0.2
Tht_k1r	Temperature Coefficient	1.045	1.045	1.045	1.045	No Units	1	1.08
k1c	Growth rate @ 20 °C	3	2.2	2.5	2.5	0 : 1/day	0.05	4
Tht_k1c	Temperature Coefficient	1	1	1	1	No Units	1	1.08
k1d	Death rate @ 20 °C	0.02	0.02	0.02	0.02	0 : 1/day	0.015	0.2
fe	Excretion fraction	0.1	0.1	0.1	0.1	No Units	0.1	0.8
as	Assimilation efficiency of zooplankton grazing	0.5	0.5	0.5	0.5	No Units	0.5	0.8
ws	Settling velocity	0.05	0.05	0.05	0.05	5 : m/day	0.5	0.8
ZPGMode	Zooplankton grazing mode	1 : Linear Grazing	1 : Linear Grazing	1 : Linear Grazing	1 : Linear Grazing	No Units	0	2
kgmicro	Grazing rate due to micro zooplankton	0.02	0.02	0.02	0.02	0 : 1/day	0	0.08
Tht_kgmicro	Temperature Coefficient	1.045	1.045	1.045	1.045	No Units	1	1.08
kgmacro	Grazing rate due to macro zooplankton	0.05	0.05	0.05	0.05	0 : 1/day	0	0.101
Tht_kgmacro	Temperature Coefficient	1.045	1.045	1.045	1.045	No Units	1	1.08
cchl	Carbon to chlorophyll ratio	60	60	60	60	0 : gC/gChl-a	30	150
LightModel	Light model	1 : Half Saturation	1 : Half Saturation	1 : Half Saturation	1 : Half Saturation	No Units		
kke	Light extinction coefficient	1	1	1	1	No Units	0	1
kechl	Light attenuation coefficient	17	17	17	17	0 : m^2/mg	0	20
lsat	Light constant	50	80	100	40	0 : langleys/day	28.8	115.2
khn	Constant for algae nitrogen uptake	0.00000001	0.00000001	0.00000001	0.00000001	0 : gm N/m^3		
khp	Constant for algae phosphorous uptake	0.001	0.001	0.002	0.001	0 : gm P/m^3		
stMethod	Salinity toxicity method	1 : Equation_1	1 : Equation_1	1 : Equation_1	1 : Equation_1	View Equation		
stf	Maximum mortality due to salinity toxicity	0.05	0.05	0.05	0.05	0 : 1/day	0.01	0.05
khst	Salinity at which toxicity is half the maximum value	9	9	9	9	0 : ppt	0	1
tm	Optimum temperature for algae growth	16	20	20	20	0 : C	0	30
ktg1	Suboptimal temperature effect for algae growth	0.024	0.024	0.024	0.024	No Units	0	0.005
ktg2	Superoptimal temperature effect for algae growth	0	0.024	0.024	0.024	No Units	0	0.1
fd5	Fraction of dead phytoplankton recycled to fast CBOD	0.5	0.5	0.5	0.5	No Units		
fon	Organic nitrogen from dead algae	0.5	0.5	0.5	0.5	No Units	0	0.5
fop	Organic phosphorous from dead algae	0.55	0.55	0.55	0.55	No Units	0	0.5
foc	Organic carbon from dead algae	0.25	0.25	0.25	0.25	No Units	0	0.5

Table H10. Kinetic rates and constants for GAM (Continued).

Parameter	Description	NB	MB	SB	PC	Unit	Min	Max
GAM2	I_GAM2							
UseNutrientLimit	Use nutrient limit function in growth computations	1	1	1	1	No Units		
UseTempLimit	Use temperature limit function in growth computations	1	1	1	1	No Units		
UseSalineToxicLimit	Use saline toxicity limit function in growth computations	1	1	1	1	No Units		
UseLightLimit	Use light limit function in growth computations	1	1	1	1	No Units		
k1r	Respiration rate @t 20 °C	0.08	0.08	0.08	0.08	0 : 1/day	0.05	0.2
Tht_k1r	Temperature Coefficient	1.045	1.045	1.045	1.045	No Units	1	1.08
k1c	Growth rate @ 20 °C	1.5	2.2	3	2.5	0 : 1/day	0.05	4
Tht_k1c	Temperature Coefficient	1	1	1	1	No Units	1	1.08
k1d	Death rate @ 20 °C	0.02	0.02	0.04	0.02	0 : 1/day	0.015	0.2
fe	Excretion fraction	0.1	0.1	0.1	0.1	No Units	0.1	0.8
as	Assimilation efficiency of zooplankton grazing	0.5	0.5	0.5	0.5	No Units	0.5	0.8
ws	Settling velocity	0.05	0.05	0.05	0.05	5 : m/day	0.5	0.8
ZPGMode	Zooplankton grazing mode	1 : Linear Grazing	1 : Linear Grazing	1 : Linear Grazing	1 : Linear Grazing	No Units	0	2
kgmicro	Grazing rate due to micro zooplankton	0.02	0.02	0.02	0.02	0 : 1/day	0	0.08
Tht_kgmicro	Temperature Coefficient	1.045	1.045	1.045	1.045	No Units	1	1.08
kgmacro	Grazing rate due to macro zooplankton	0.05	0.05	0.05	0.05	0 : 1/day	0	0.101
Tht_kgmacro	Temperature Coefficient	1.045	1.045	1.045	1.045	No Units	1	1.08
cchl	Carbon to chlorophyll ratio	60	60	60	60	0 : gC/gChl-a	30	150
LightModel	Light model	1 : Half Saturation	1 : Half Saturation	1 : Half Saturation	1 : Half Saturation	No Units		
kke	Light extinction coefficient	1	1	1	1	No Units	0	1
kechl	Light attenuation coefficient	17	17	17	17	0 : m^2/mg	0	20
lsat	Light constant	40	100	20	40	langleys/day	28.8	115.2
khn	Constant for algae nitrogen uptake	0.00000001	0.000001	0.00000001	0.00000001	0 : gm N/m^3		
khp	Constant for algae phosphorous uptake	0.002	0.002	0.002	0.002	0 : gm P/m^3		
stMethod	Salinity toxicity method	1 : Equation_1	1 : Equation_1	1 : Equation_1	1 : Equation_1	View Equation		
stf	Maximum mortality due to salinity toxicity	0.05	0.05	0.05	0.05	0 : 1/day	0.01	0.05
khst	Salinity at which toxicity is half the maximum value	9	9	9	9	0 : ppt	0	1
tm	Optimum temperature for algae growth	18	15	16	20	0 : C	0	30
ktg1	Suboptimal temperature effect for algae growth	0.024	0.024	0.024	0.05	No Units	0	0.005
ktg2	Superoptimal temperature effect for algae growth	0.024	0.02	0.024	0.024	No Units	0	0.1
fd5	Fraction of dead phytoplankton recycled to fast CBOD	0.5	0.5	0.5	0.5	No Units		
fon	Organic nitrogen from dead algae	0.5	0.55	0.5	0.5	No Units	0	0.5
fop	Organic phosphorous from dead algae	0.55	0.55	0.55	0.55	No Units	0	0.5
foc	Organic carbon from dead algae	0.25	0.25	0.25	0.25	No Units	0	0.5
TVRC File								
UseTVRCData	Use time varying rates and constants data	0	0	0	0			
TVRCFileName	Time varying rates and constants file name	No_Data_File	No_Data_File	No_Data_File	No_Data_File	Browse	View	

Table H11. Meteorological constants.

Meteorological variables		Value
ta	Air Temperature ta Unit / Status	0 : C
ta_v	Air Temperature	0 : From TVD File
td	Dew Point Temperature td Unit / Status	0 : C
td_v	Dew Point Temperature	0 : From TVD File
twb	Wet Bulb Temperature teb Unit / Status	0 : C
twb_v	Wet Bulb Temperature teb Value	0 : From TVD File
rt	Response Temperature rt Unit / Status	0 : C
rt_v	Response Temperature rt Value	0 : From TVD File
cc	Cloud Coverage cc Unit / Status	0 : tenths
cc_v	Cloud Coverage cc Value	0 : From TVD File
sp	Atmospheric Pressure sp Unit / Status	0 : mm of Hg
sp_v	Atmospheric Pressure sp Value	0 : From TVD File
phi	Wind Direction phi Unit / Status	0 : degrees
phi_v	Wind Direction phi Value	0 : From TVD File
wa	Wind Speed wa Unit / Status	0 : m/sec
wa_v	Wind Speed wa Value	0 : From TVD File
rs	Solar Radiation rs Unit / Status	0 : w/m^2
rs_v	Solar Radiation rs Value	0 : From TVD File
wsc	Wind Sheltering Coefficient wsc Status	0 : No Units
wsc_v	Wind Sheltering Coefficient wsc Value	0.80
sd	Secchi Depth sd Unit / Status	0 : m
sd_v	Secchi Depth sd Value	1.00
rh	Relative Humidity rh Unit / Status	-99 : Not Applicable
rh_v	Relative Humidity rh Value	0.00
rscc	Compute Solar Radiation Using Cloud Cover	0
rsts	Vegetative and Topographic Shading Factor rsts Unit / Status	0 : No Units
rsts_v	Vegetative and Topographic Shading Factor rsts Value	0.00
ishe	Surface Heat Exchange Method	2 : Term by Term
KEMethod	Compute K & E in the Model	0
cshe	Surface Heat Exchange Coefficient Unit	0 : w/m2/C
cshe_v	Surface Heat Exchange Coefficient	30.00
te	Equilibrium Temperature Unit	0 : C
te_v	Equilibrium Temperature Value	21.00
PAR	Fraction of Solar Radiation in the Range of 400 to 700 nm	0.43
Albedo	Fraction of Solar Radiation Reflected from the Water Surface	0.07
iwsf	Wind Speed Function	3 : Ryan and Harkeman
BetaMethod	Method to Compute Fraction of Solar Energy Absorbed at Sfc	1 : Linear Relation
Beta	Fraction of Solar Energy Absorbed at the Surface	0.43
Gamma_A	Light Attenuation Parameter a	1.20
Gamma_B	Light Attenuation Parameter b	0.60

Table H12. Hydrodynamics constants.

Hydrodynamic and Transport variables		values
Forcing Terms		
	Use Vertical Acceleration Terms	0
	Use Coriolis Force Terms	1
	Specify (degrees)	47.5
Wind Stress Coefficient		
	Method	Wu (1983)
	A =	Not Applicable
	B =	Not Applicable
Bottom Friction		
	Method	Chezy
	Mannings Factor	Not Applicable
	Chezy Coefficient	Constant
	Limiting Chezy Selector	0
	Czo = (units m^1/2/sec)	40
	do =	Not Applicable
	n =	Not Applicable
Transport Modeling Scheme		
	Scheme	Upwind First Order
	Advection Theta in Z-Direction	0
	Diffusion Theta in Z-Direction	0
	HOTS Initiation Time Period (days)	Not Applicable
Wetting and Drying of Layers		
	Use Wetting and Drying of Layers	1
	Wetting Limiting Thickness Factor	0.85
	Drying Limiting Thickness Factor	0.8
Density		
	Density Function	Gill (1982)
Dispersion		
Vertical Momentum Dispersion		
	Scheme	0-Equation
	Sub Model	Not Applicable
	Mixing Length	Von Karman
Momentum Dispersion Coef. (m^2/sec)		
	X-Direction	Okubo
	Axo =	0.00584
	n(x) =	1.1
	Y-Direction	Okubo
	Ayo =	0.0054
	n(y) =	1.1
Transport Diffusion Coef. (m^2/sec)		
	X-Direction	Prandtl
	Dxo =	Not Applicable
	n(x) =	Not Applicable
	Y-Direction	Prandtl
	Dyo =	Not Applicable
	n(y) =	Not Applicable
Prandtl Number		10