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SECTION 1

BACKGROUND

As part of the San Joaquin River Deep Water Ship Channel (DWSC) dissolved oxygen (DO) TMDL HydroQual Inc., has developed models for both the San Joaquin River (SJR) from Stevinson to Vernalis and from Vernalis through the Deep Water Ship Channel. (DWSC). The upstream SJR water quality model calibration above Vernalis used the California Department of Water Resource (DWR) DSM2 hydrodynamic and water quality modules and was calibrated to data for years 2000 and 2001. This portion of the SJR is essentially non-tidal and since the DSM2 water quality module was developed for this region (Rajbhindari, 1998) this model framework was used. Figure 1 shows the upstream SJR study area. A detailed description of the upstream SJR DSM2 model inputs and calibration has been presented in HydroQual, 2005.

From Vernalis and through the DWSC, the SJR is tidal so that it becomes important to apply a model that can capture tidal influences. HydroQual's Estuarine and Coastal Ocean Model (ECOM) provides a 3 dimensional time-dependent hydrodynamic model that calculates water surface elevation, water velocity (in three-dimensions), temperature, salinity and water turbulence in response to weather conditions (wind and solar radiation), freshwater flows, and tides, temperature and salinity. Hydrodynamic model outputs are linked to HydroQual's 3-D water quality model, RCA. The 3D SJR DWSC model was also calibrated for the same upstream SJR 2000 to 2001 calibration period and this work is presented in HydroQual, 2006. Figure 2 shows the SJR DWSC study area.

Both the upstream and DWSC calibrations provide a means to compute the processes that impact water quality in the SJR and can be used as management tools. For example, unit response model runs were made using the DSM2 model calibration showing the impacts of the major inflows, the smaller drains, and instream algal growth on algal, carbon and dissolved oxygen levels along the upstream SJR from Stevinson to Vernalis (HydroQual, 2006). The 3-D DWSC model can be used similarly to provide information on the contribution of the upstream carbon load or the effects of ammonia load from the Stockton RWCF in the DWSC on the dissolved oxygen balance. The following report summarizes these types of unit responses in the DWSC using the 3D hydrodynamic and water quality model as well as model projections of water quality in the SJR DWSC under variable flow conditions as determined by changing flow diversions to the Old River, the impact of reducing ammonia levels in the Stockton RWCF effluent, and impacts of reducing Mud Slough flow to the upstream SJR.

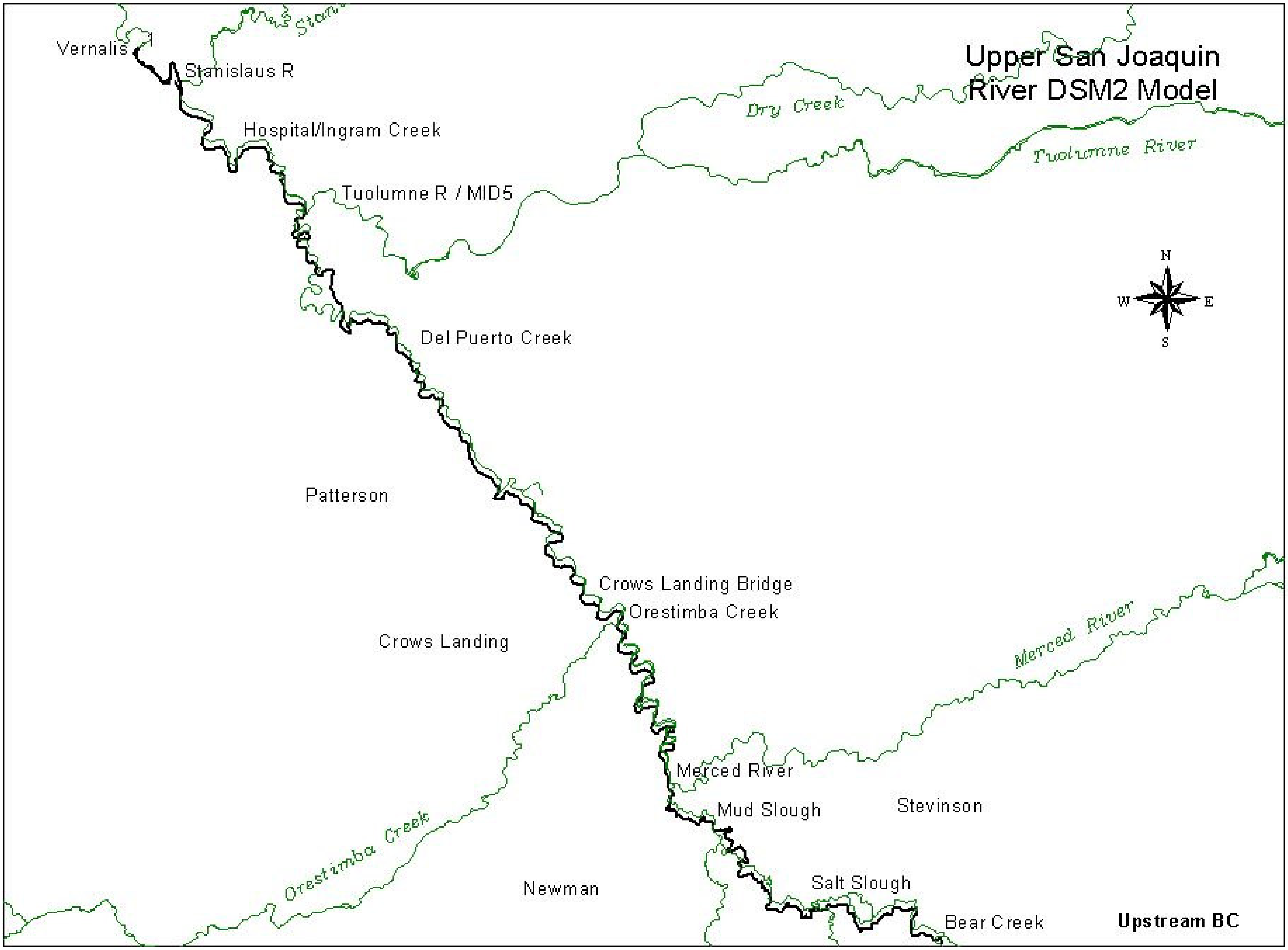


Figure 1. Upper San Joaquin River DSM2 Model

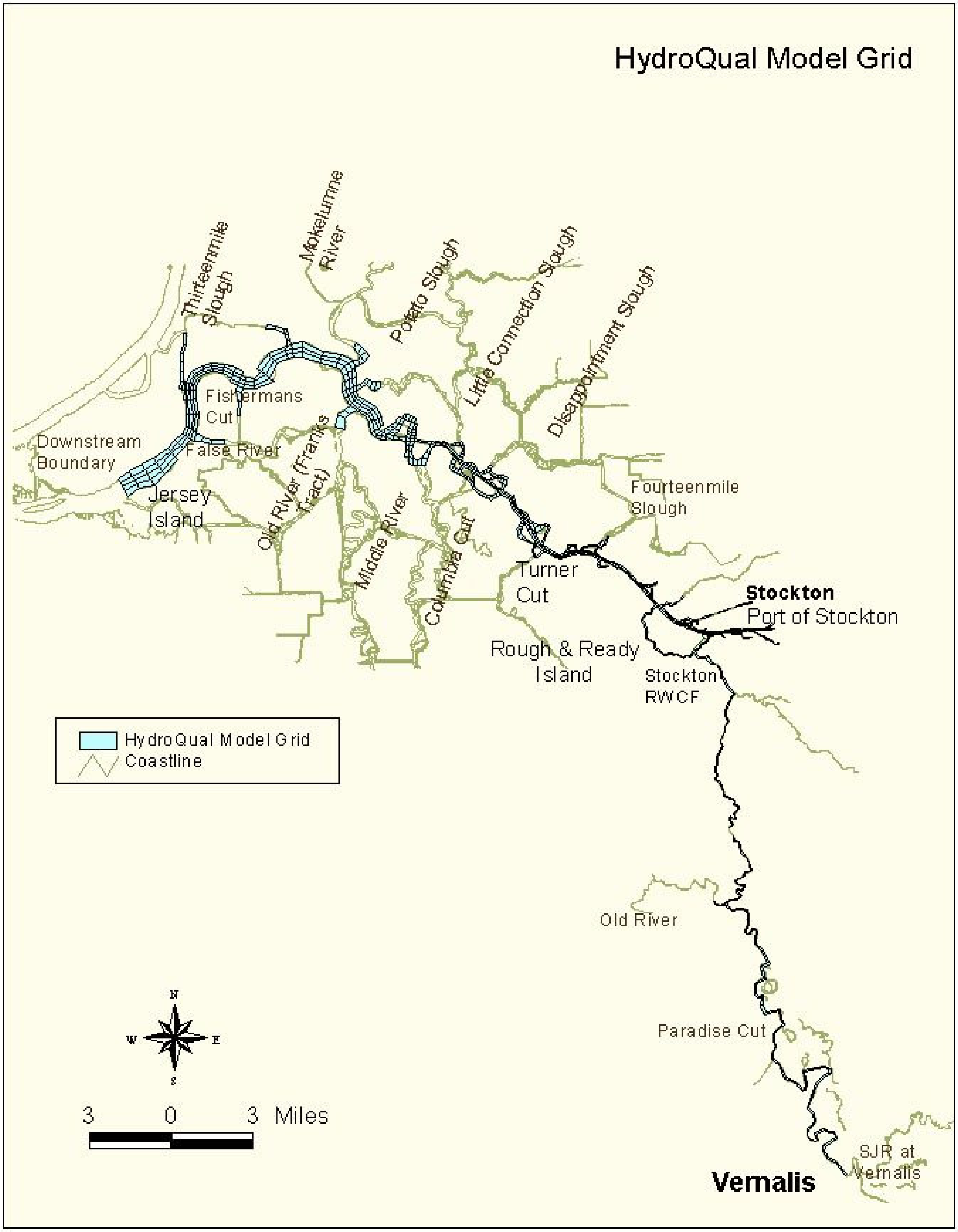


Figure 2. HydroQual 3D Hydrodynamic and Water Quality Model Grid

SECTION 2

PURPOSE

The rational for model calibrations and projections is first to construct a model that is able to define processes that occur in the study area that describe ambient hydrodynamic and water quality conditions and then to apply the model to project conditions under various scenarios of interest. For this project the SJR study area can be viewed as three areas with distinct characteristics to be captured in the applicable models. These areas are the USJR from Stevinson to Vernalis, the USJR from Vernalis to the confluence with the DWSC, and the SJR DWSC. The purpose of this task is to apply the calibrated 1 dimensional upstream SJR and 3 dimensional SJR DWSC models that define transport, loads and instream processes to scenarios that will quantify unit impacts on dissolved oxygen and to predict dissolved oxygen under various flow regimes.

The USJR above Vernalis is a nontidal river that receives inputs from several major inflows as well as many smaller agricultural drains. Also, this part of the upstream SJR is a source for agricultural diversions. Data indicated that Mud Slough can contribute chlorophyll-a concentrations ranging from 80 to 400 ug/L and summer nitrate concentrations above 12 mg/L. As such consideration is being given to reduce flow to the upstream SJR from Mud Slough. Therefore a model projection showing impacts in the SJR above Vernalis as a result of a 50% reduction in Mud Slough flows to the SJR will be presented.

Since the SJR is tidal to the vicinity of Mossdale and a set of applicable data to formulate boundary conditions exists at Vernalis, the 3-D model upstream boundary was selected at Vernalis (Dahlgren, 2004, Kratzer, 2004, HydroQual, 2006). Oxygen demand in the DWSC is generally thought to result from a combination of factors including changes in river velocity with changing geometry in the DWSC, flow conditions effecting instream processes and therefore oxygen usage, and ammonia inputs from the Stockton RWCF. It is recognized that carbon loading from the upstream SJR contributes to the DO deficit that can occur in the DWSC in the summer and early fall months. To project impacts on dissolved oxygen in the DWSC two types of model scenarios were simulated. First, unit responses were performed to quantify contributions of oxygen demand from upstream carbon loads, instream chlorophyll-a growth and decay, from the Stockton RWCF ammonia load,a nd from sediment oxygen demand (SOD). A second type of projection was done to simulate dissolved oxygen conditions that would result under various flow scenarios. The Stockton RWCF plans to reduce it's ammonia discharge in the summer of 2006 to 2.0 mg/L so that varying flow projections have been done for existing Stockton RWCF ammonia discharges as well as reduced ammonia discharge concentrations. Lastly, DWR is installing an aeration device to inject up to 10,000 lb/d of oxygen into the DWSC in the vicinity of Rough and Ready Island. Model projections were performed to simulate dissolved oxygen in the DWSC under operation of the aeration device.

The following sections presents each of the model projections and discusses implications for adaptive management strategies. First dissolved oxygen unit responses to net chlorophyll-a growth in the DWSC, Stockton RWCF ammonia loads, upstream carbon loadings and sediment oxygen demand (SOD) will be shown. Responses to varying the SJR flow in the DWSC by adjusting flow to the Old River both with and without Stockton RWCF nitrification will be presented. Lastly, model simulations of USJR impacts from reducing Mud Slough flows to the USJR and of oxygen injection into the DWSC will then be shown.

SECTION 3

MODEL PROJECTIONS

3.1 UNIT RESPONSES

Unit response simulations to quantify contributions of upstream boundary carbon, the Stockton RWCF ammonia load, instream chlorophyll-a processes, and SOD to the DO deficit were performed. To simulate the DO demand from the Stockton RWCF, the ammonia load was set to zero with all remaining boundary, load, and kinetic processes remaining the same. Figure 3 compares the 2 year temporal ammonia base model (light blue lines) and the simulation (light green lines) at Mossdale, R1, R2, R3, R4, R5, R6, R7, and R8. Figure 3 shows that ammonia levels are reduced, especially in the winter when the Stockton RWCF ammonia concentrations are greater, starting at R2 and through to R8. Figure 4 presents 2 year temporal DO for the base model and unit response simulation. Due to boundary nitrogen as well as Stockton RWCF nitrite and nitrate load, it is not expected that the reduced discharged ammonia would effect chlorophyll-a levels. Therefore the change in instream SJR DO is expected to result only from reduced Stockton RWCF ammonia load. Figure 4 shows that as expected, winter DO is generally unaffected by the STP ammonia due to both lower nitrification during the winter months as well as greater upstream SJR flows that dilute and push the nitrogen through the DWSC at a greater rate. Summer, 2000 DO shows little change from the base model as the ammonia discharge had little impact on the instream SJR ammonia levels. Summer 2001 DO changes between R3 and R6 average less than 1 mg/L.

The dissolved oxygen unit response from chlorophyll-a processes in the SJR was simulated by turning off growth, decay, and settling in the model. In this way the simulated net dissolved oxygen can be compared to the base run to quantify the contribution from algal processes. Figure 5 compares the base model and the simulated DO. Chlorophyll-a growth, death and settling contribute an overall positive oxygen change. This change is generally also less than 1 mg/L.

The oxygen demand from upstream nonalgal carbon can be estimated by comparing the base model oxygen with a simulation run where upstream dissolved and particulate nonalgal carbon boundary concentrations were set to zero. Figure 6 presents this comparison. The summer upstream carbon is comprised of approximately 3 mg/L DOC and 0.4 mg/L nonalgal POC (2 mg/L POC – 40 ug Chl-a/L X 40C/Chl-a). The DOC model decay rate based on studies by Litton, 2004, of 0.11/d and an 2.67 mgO_2/L carbon decay and retention time of about 2.5 days (Jones & Stokes, 2006) at 500 cfs can result in about 2.2 mg/L oxygen demand. This along with the nonalgal POC decay and settling contribute approximately 2 to 2.5 mg/L DO deficit in the DWSC.

Lastly, a model run was performed to quantify the SOD contribution to the DO deficit. To do this the base model was run with the SOD flux simply turned off. In this all processes are

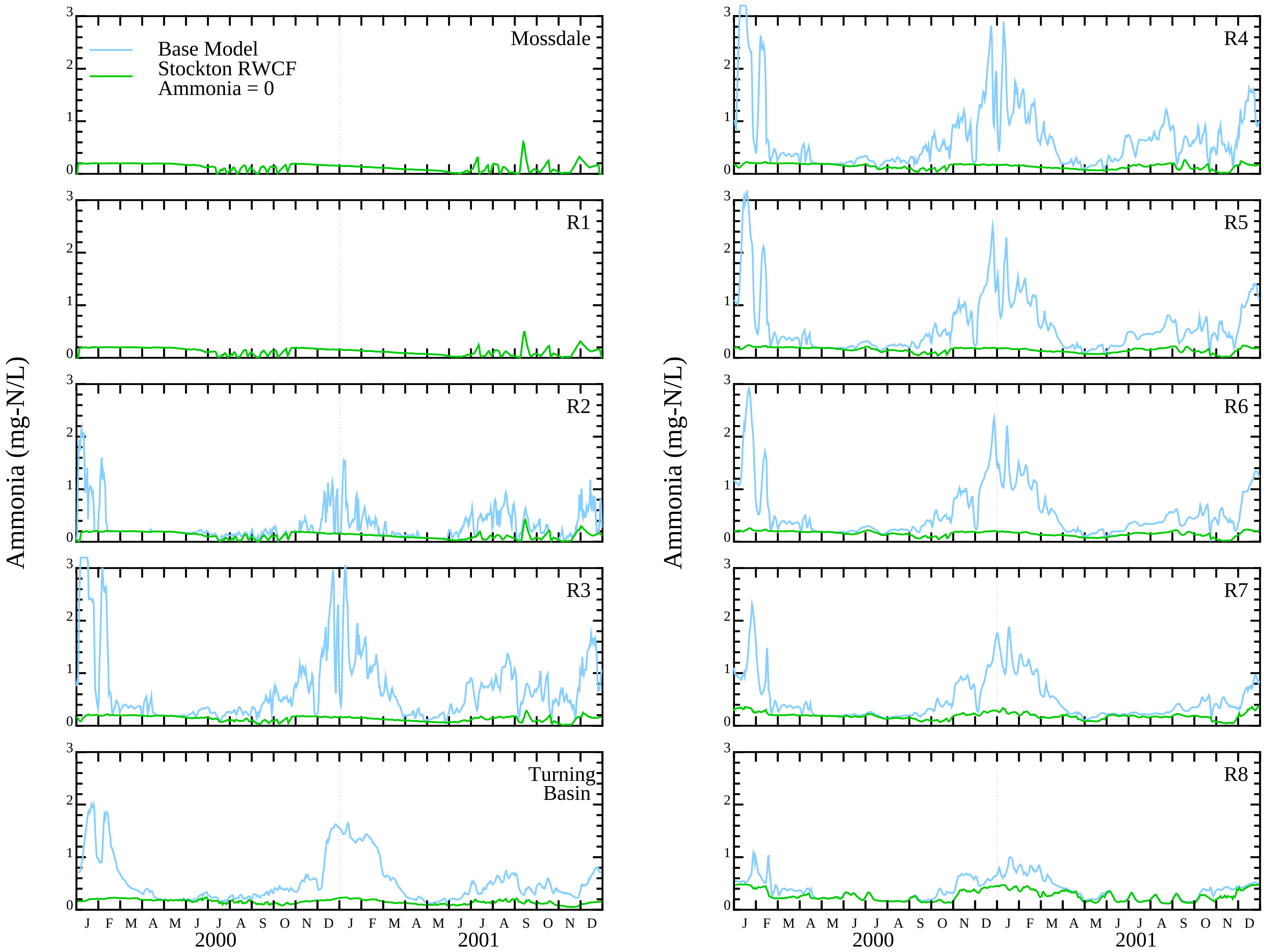


Figure 3. Unit Response Comparison of Ammonia Base Model and Stockton RWCF Ammonia=0

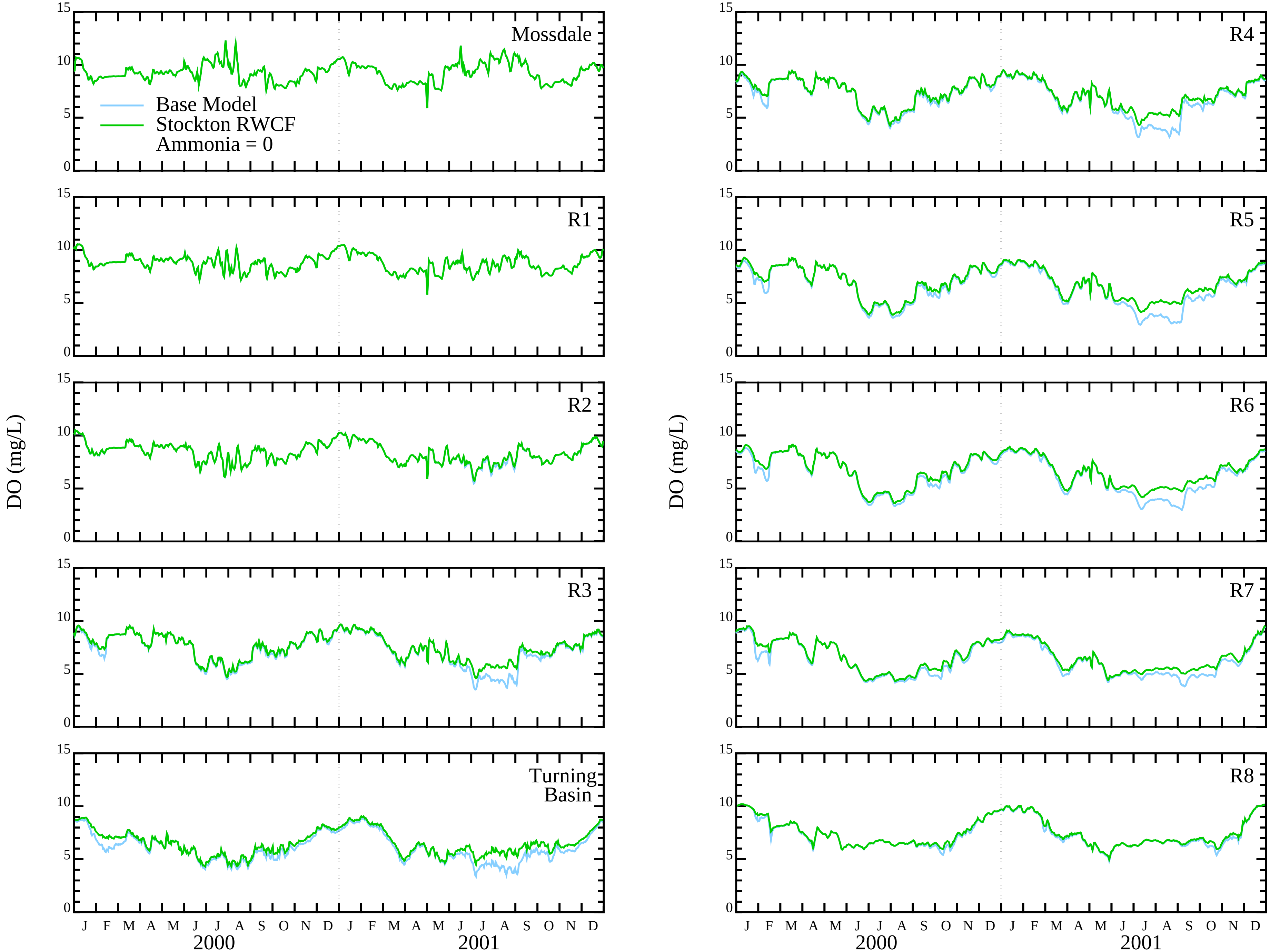


Figure 4. Unit Response Comparison of DO Base Model and Stockton RWCF Ammonia=0

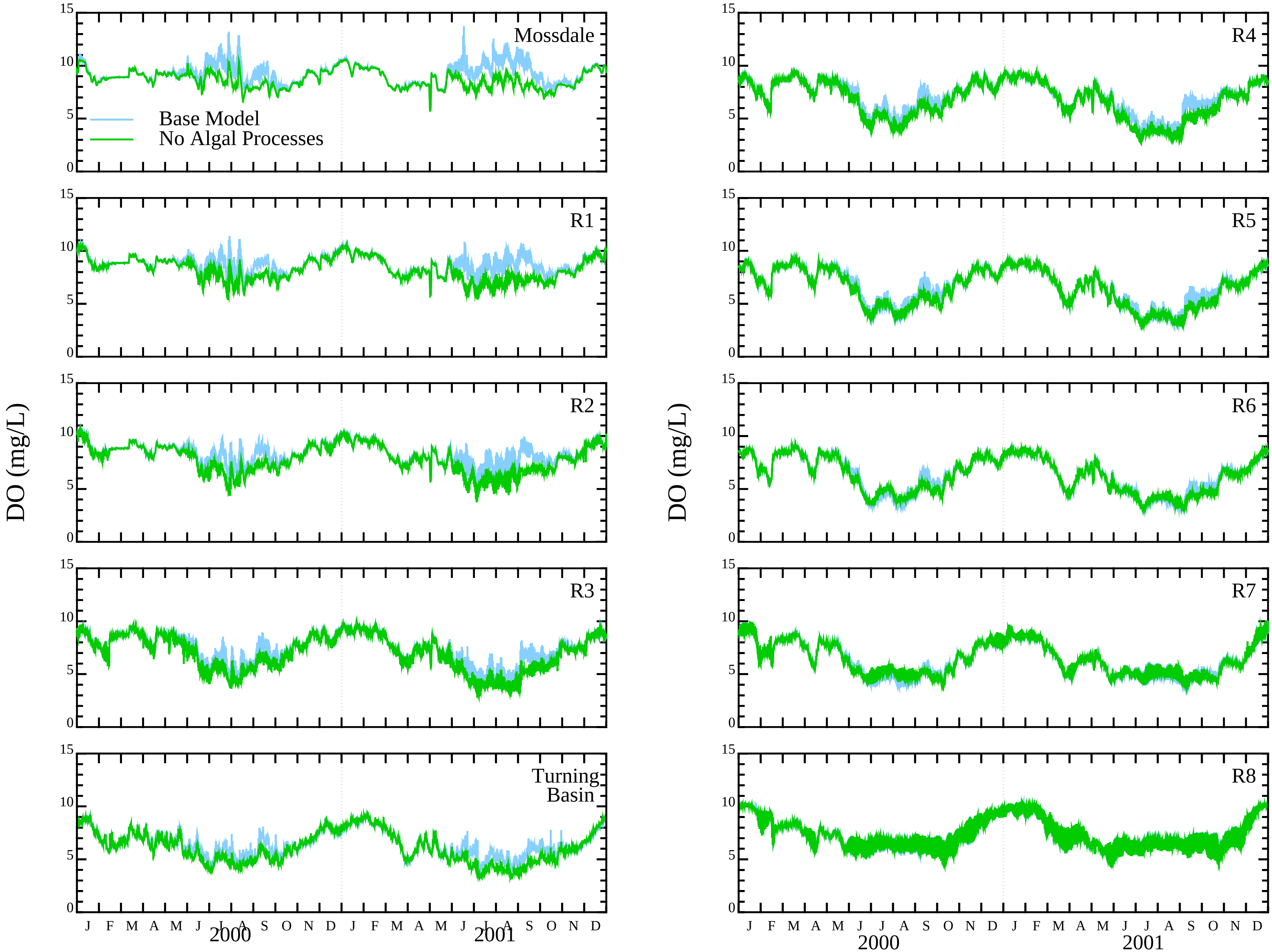


Figure 5. Unit Response Comparison of DO Base Model and No Algal Processes

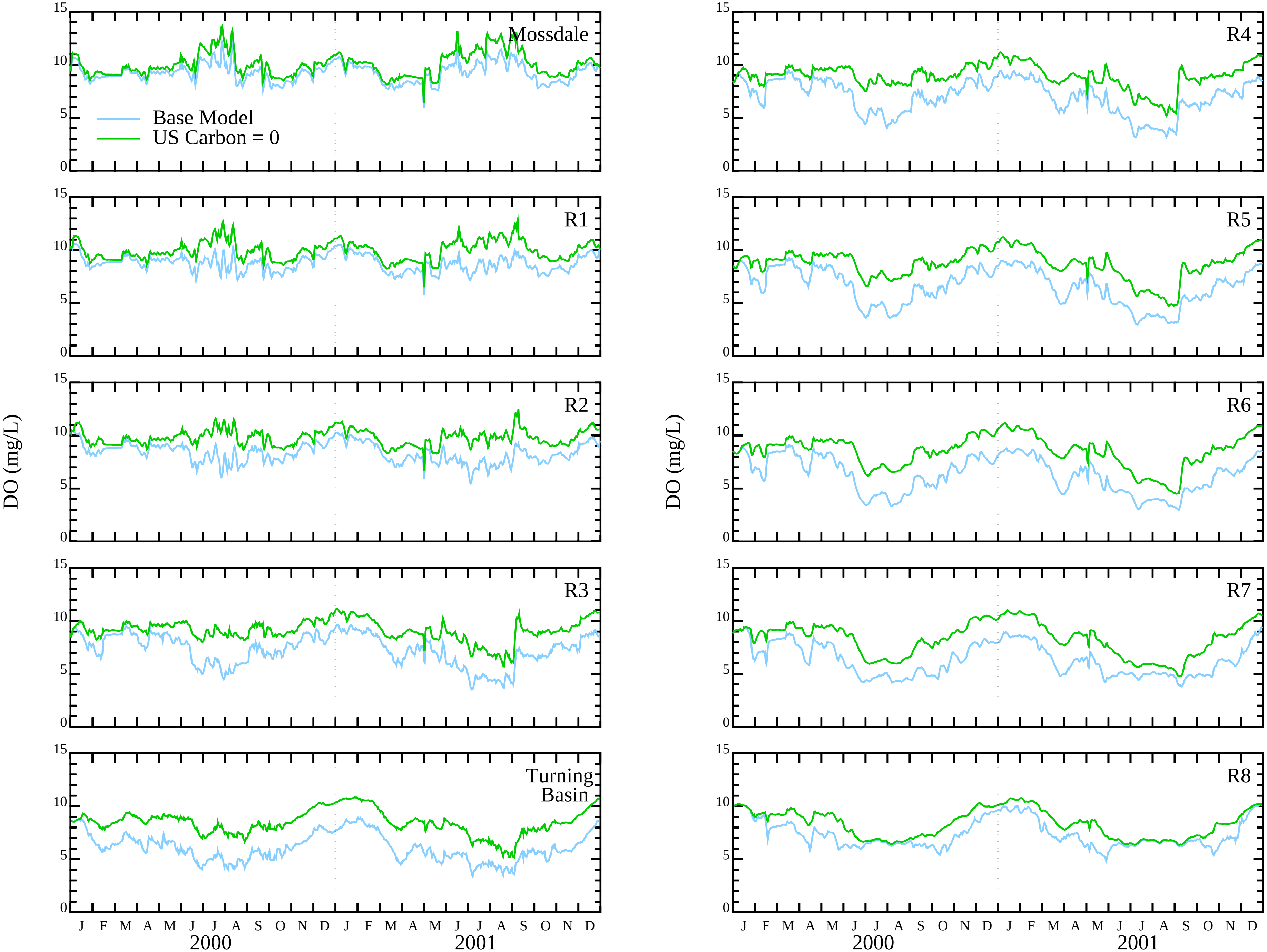


Figure 6. Unit Response Comparison of DO Base Model and No Upstream Carbon Load

continued. The average SOD for the 2000 and 2001 summer periods are 0.5 mg/L and 0.7 mg/L respectively.

Figure 7 summarizes contributions of the Stockton RWCF ammonia load, algal processes, upstream carbon loads, and the SOD to the overall DO deficit for the summer of 2000 and 2001 model calibrations. The overall deficits of 2-3 mg/L at R3 and 3-4 mg/L at R6 are impacted mostly from the upstream nonalgal carbon. Net chlorophyll-a growth contributes less than -1 mg/L oxygen deficit. The Stockton STP contributes less than 1 mg/L deficit and SOD contributes about 0.5 mg/L deficit. The upstream carbon load contributes the greatest deficit of about 2.5 mg/L. Differences between 2000 and 2001 reflect flow differences with the summer (June 1 – Oct 31) flow average of 600 cfs in 2001 and the flow average of 980 cfs in 2000.

3.2 VARIABLE USJR FLOW IMPACTS IN THE DWSC

The combination of low flow conditions and temperatures that trigger algal growth and oxygen demanding decay processes in the SJR during the summer months along with river geometry, has resulted in exceedences of the DO criteria in the summer and early fall. The DO criteria in the SJR DWSC is 5.0 mg/L in December to August and 6.0 mg/L in September to November to protect migrating fall-run Chinook salmon. Data has been presented that suggests that SJR DWSC tidally averaged fresh water flows in excess of 1,500 cfs at the Stockton UVM (near the Stockton RWCF) may be sufficient to prevent DO violations (Lee, 2005). Model projections to examine the potential impacts on DO in the DWSC under variable flow conditions have been completed. Hydrodynamic model simulations were done to produce flows in the DWSC at R3 of 250 cfs, 750 cfs, 1,250 cfs, 1,500 cfs, and 1,750 cfs. These flows were selected to encompass a range of low flows and flows where DWSC DO concentrations are above the criteria.

Simulations were completed using the summer 2001 calibration as this represented a low flow year where greater algal and carbon loadings upstream of Vernalis would occur. Summer average flow at Vernalis was 1,400 cfs from June to September, 2001 and begin to increase in mid October. Therefore simulations were done for the June1 to September 30 period. Since a barrier may be installed at the Head of Old River (HOR), flow variability in the DWSC at Stockton was accomplished by diverting SJR flow from Vernalis into the Old River for the projections at or below 1,250 cfs. In this way, nutrient, chlorophyll-a, DO, and carbon concentrations at Vernalis based on 2001 data could be used to compute upstream loads. The development of boundary input concentrations were presented in HydroQual, 2006. Model calibrations indicated that about 15% of the SJR flow is diverted to the left side of Rough and Ready Island below the Stockton RWCF so that about 85% of the flow above the Rough & Ready Island split enters the DWSC. To produce 1,500 cfs and 1,750 cfs in the DWSC the Vernalis flow was increased to 2,100 cfs. The 4 month summer tidally averaged model base flow in the DWSC at Stockton is 425 cfs. Figure 8 compares the model base flow and the model projection flows for the five variable flow scenarios.

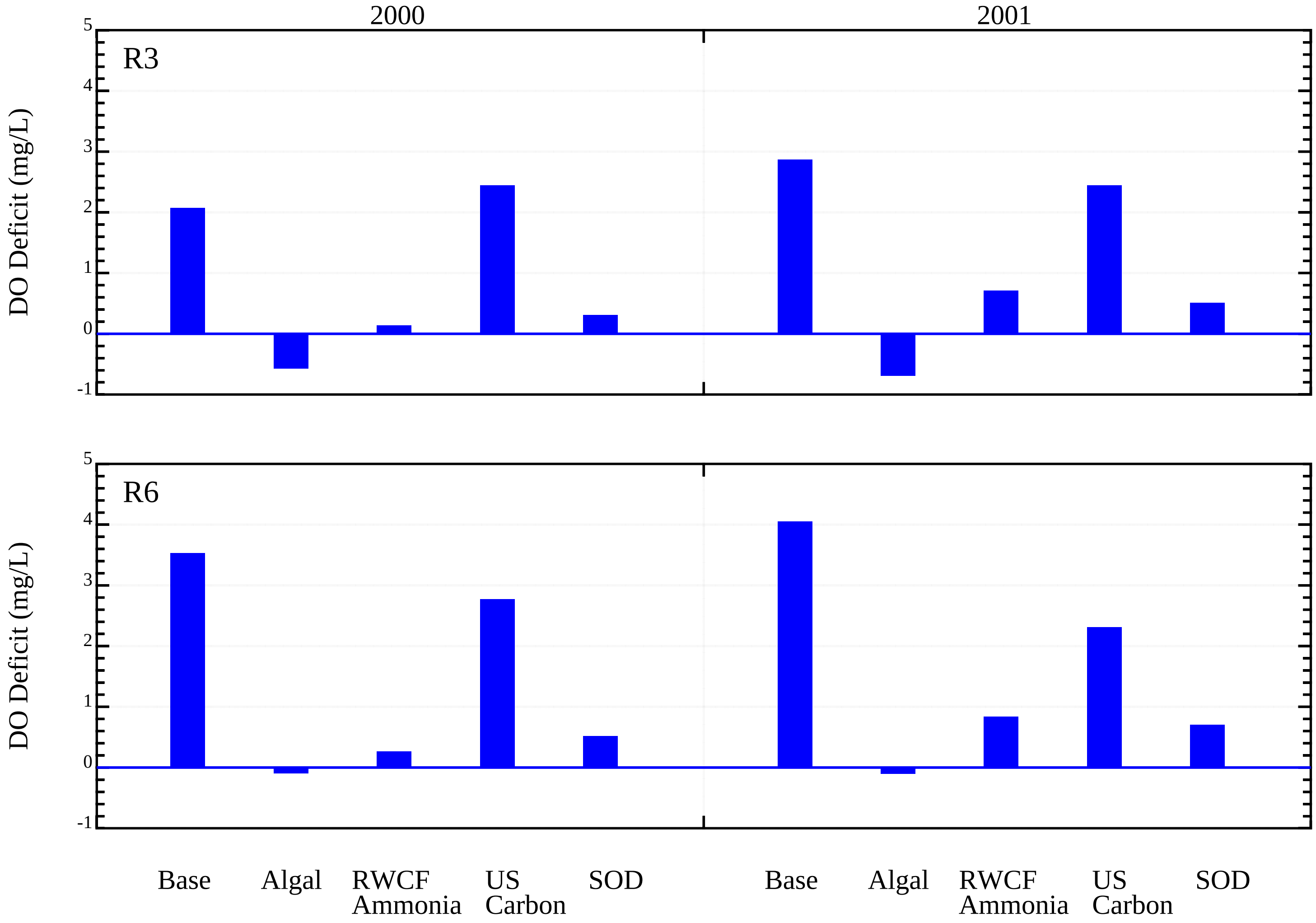


Figure 7. Average Summer (June 1-Oct 30) DO Deficit Unit Response Contributions

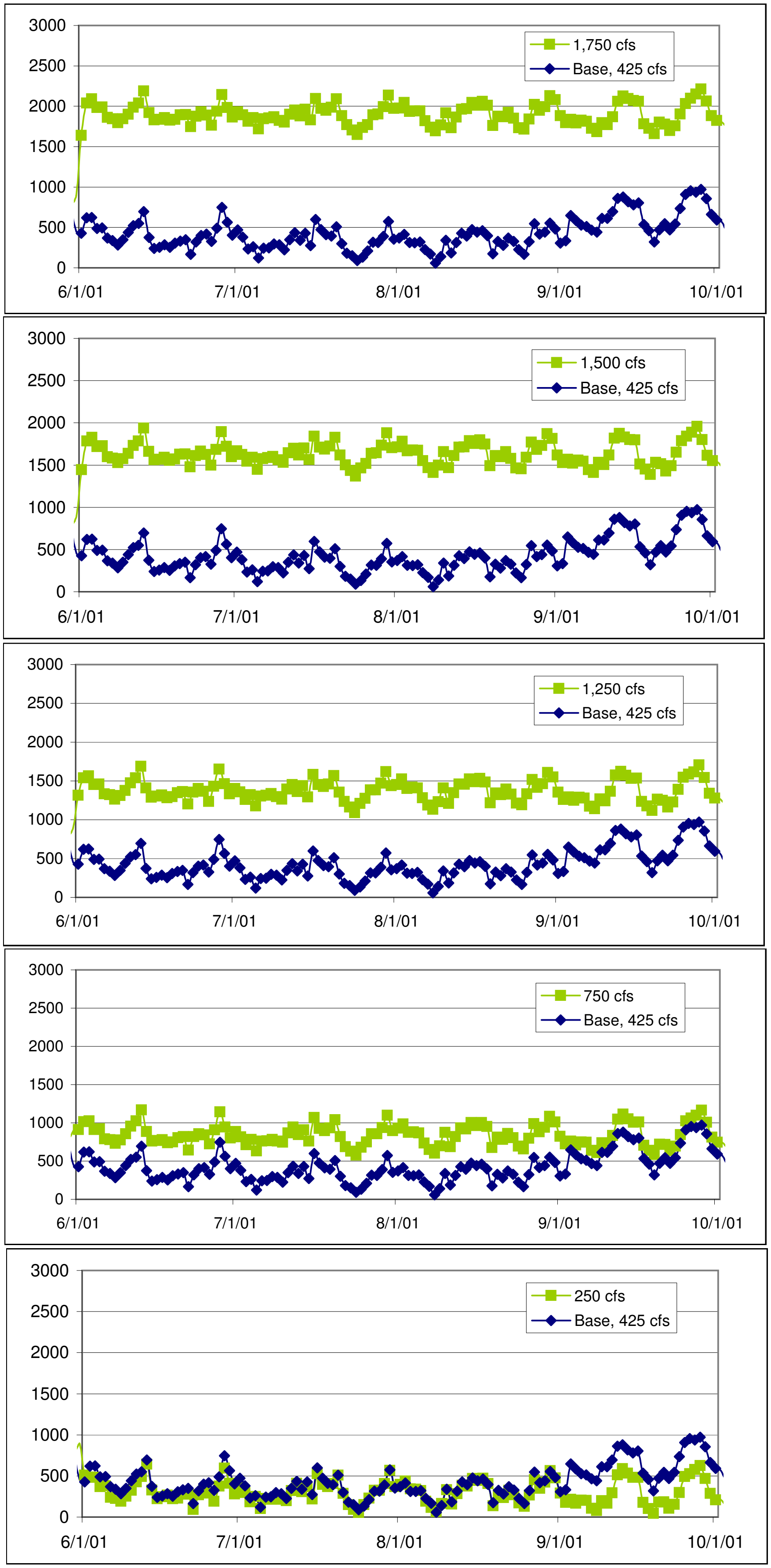


Figure 8. Base Model 2001 Summer Flow and Variable Projection Flows

Data indicate that summer upstream boundary concentrations at Vernalis exhibit changes at flows greater than approximately 1,500 cfs. This may be expected since increases in flows would likely reflect greater dilution from the larger inflows (Tuolumne, Stanislaus, Merced Rivers) and the potential for less algal growth with faster travel time. Therefore the 1,500 and 1,750 cfs projection scenarios where Vernalis flow was increased from a summer average of 1,400 cfs to 2,100 cfs requires some changes to the upstream boundary concentrations. Though data is limited, changes in concentrations to flow are evident for dissolved and particulate organic carbon (DOC, POC), organic nitrogen, organic phosphorus, and chlorophyll-a. Concentration flow relationships are less clear for ammonia, nitrate, and TSS. Chlorophyll-a, DOC, POC and TSS summer data for years 2000, 2001, 2002, & 2003 from the Jones & Stokes Data Atlas are plotted versus flow in Figure 9. Chlorophyll-a boundary concentrations were adjusted assuming proportionate increases in respective concentrations based on each of the incoming flows represented in Table 1. These inflows were discussed in detail in the 1D upstream SJR model calibration report (HydroQual, 2005). Since much of the increase results from incoming flow from the larger river sources, instream processes were not accounted for. Based on Figure 9 DOC and POC were set to 3.0 mg/L and 0.5 mg/L respectively. Though the TSS data represents about a 70 mg/L spread there does appear to be an approximately 20% increase in TSS at 2,100 cfs so that 20% increase was made to the base model TSS boundary concentrations.

Table 1. Upstream San Joaquin River Inflows

Location	**Average Flow 2000-2001 cfs**	**Percent of Final Flow %**
SJR at Stevinson	142	4
Salt Slough	187	5
Mud Slough*	130	4
Merced River	523	15
Orestimba Creek	42	1
"add-water" near Patterson	200	6
Tuolumne River	930	27
Stanislaus River	701	20
groundwater	18	1
"add-water" near Vernalis	150	4
small inflows	422	12
Final Flow at Vernalis	3445	100

*At 50% reduction to 64 cfs Mud Slough would contribute 2% of final flow

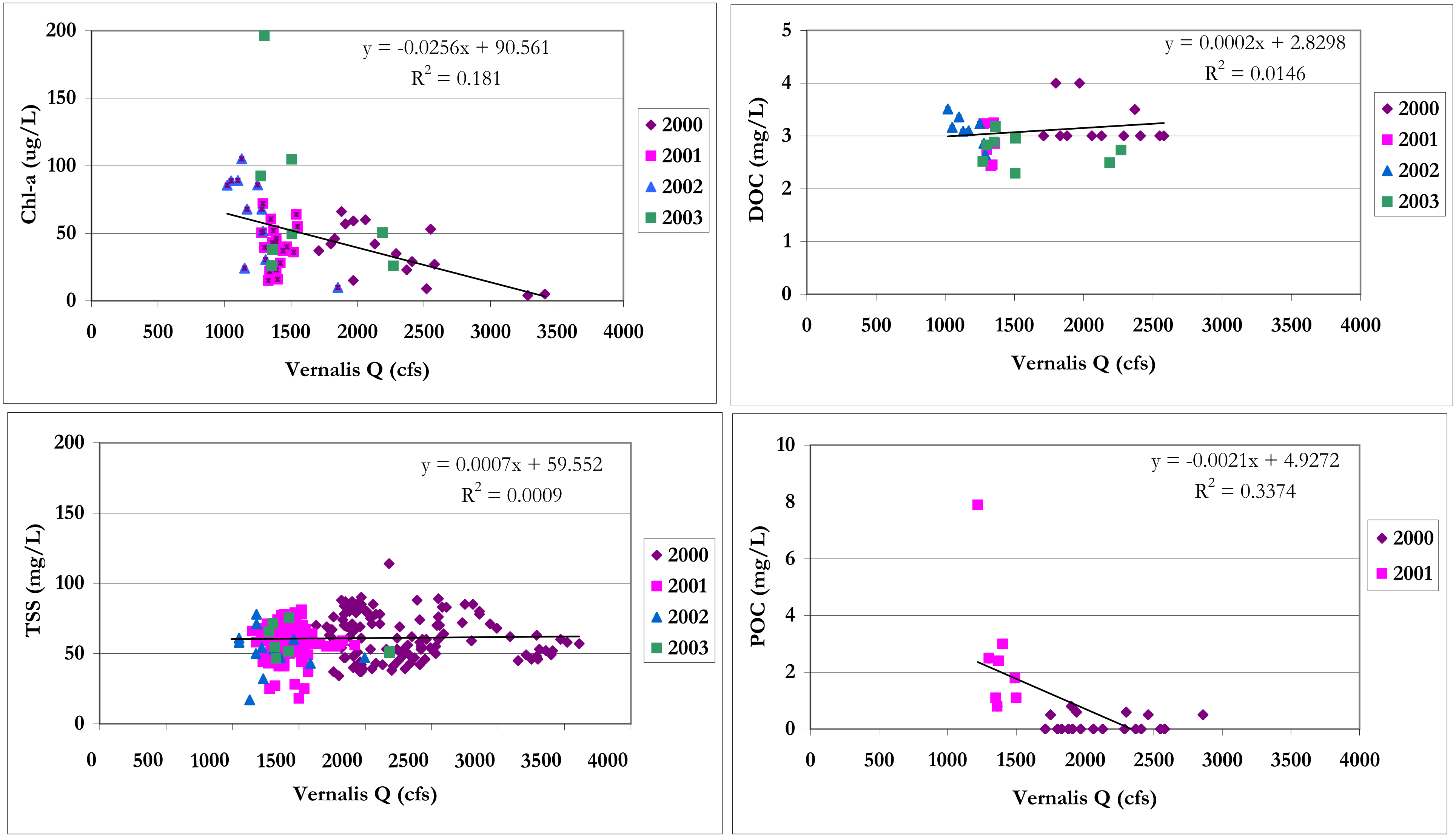


Figure 9. Relationships of Chlorophyll-a, Dissolved and Particulate Organic Carbon, and TSS to Flow at Vernalis, June 1 - September 30, 2000-2003

Figure 10 shows summer ammonia, nitrite + nitrate, and dissolved organic nitrogen (DON). Figure 11 shows orthophosphate and organic phosphorus (OP) data. There does not appear to be a relationship of ammonia to flow so base model ammonia boundary was used. At 2,100 cfs NO_2+NO_3 appears to decrease from an average of about 2.5 mg/L to 1.7 mg/L so that 1.7 mg/L was used for the higher Vernalis flow simulations. There is no PON data so that ON was set at 0.5 mg/L based on doubling the DON at higher flow of 0.25 mg/L. OP data also show some decrease at higher flows so 0.01 mg/L OP concentration was used for the higher Vernalis flow simulations. A PO4 concentration of 0.10 mg/L was used for the higher flow scenarios based on Figure 11.

Temporal comparisons of base model and projections for the five flow scenarios at sample locations Mossdale, R1, R2, R3, R4, R5, R6, R7, R8 and the Turning Basin have been generated for the one year simulation period and are included in the Appendix A of this report. The figures show temporal profiles of surface and bottom chlorophyll-a and DO, dissolved inorganic nitrogen, DIN, (average ammonia plus NO2+NO3), dissolved inorganic phosphorus, DIP, (PO4), total organic carbon (TOC) and TSS at the above sample locations. Except for the Turning Basin, these figures show that surface and bottom projected chlorophyll-a and DO are similar for the flow scenarios as in the base model results indicating little stratification. In general these figures show improvements in DO for the increasing flow scenarios with greater improvements at R3, R4 and R5 and less of an impact below R5. For ease of further discussion depth averaged spatial comparisons of model base and projection results from June 1 to September 30 are presented.

Figures 12 and 13 compare spatial TSS and TOC base model and projection concentrations in the SJR. Changes in both TOC and TSS largely reflect effects of varying transport on the upstream boundary concentrations. Variations in flows entering the DWSC results in changes in loads to the DWSC. To quantify concentration changes in the DWSC due to varying upstream load the following dilution calculation was done based on incremetnal changes in flow of 500 cfs. For each 500 cfs change in flow, there is a 1,223 kg/d change in load for each 1 mg/L concentration.

Load Change = 1mg/L * 500cfs * 28.32L/ft3 * 86400s/d * 1E-6kg/mg = 1223 kg/d. (1)

Tracer model runs performed by HydroQual to track oxygen injection at Rough and Ready Island indicated that at the 2001 flow conditions there is an approximate 1.0 mile longitudinal spread. At DWSC depths of 30 ft and width of 650ft the receiving volume is 2.92 million cubic meters (MCM).

DWSC Receiving Volume = 1.5mi*5280ft/mi*650ft*30ft*0.02832 = 4.37 MCM. (2)

Therefore the change in DWSC concentration for each 500 cfs increment is load/volume yielding 0.28 mg/L-d change per 1 mg/L of upstream concentration.

Concentration change per 1 mg/L = 1224kg/d * 4.37 MCM = 0.28 mg/L-d (3)

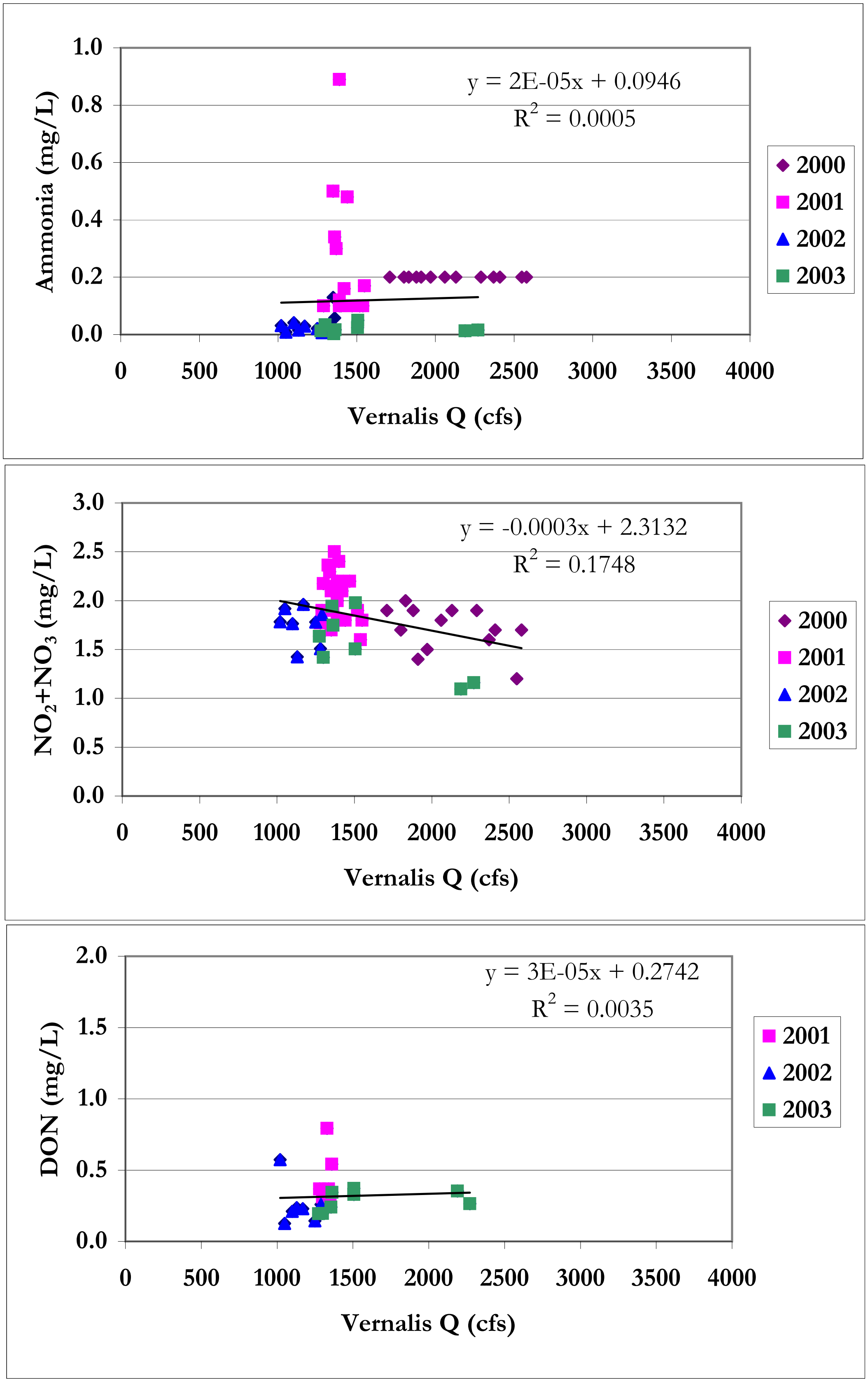
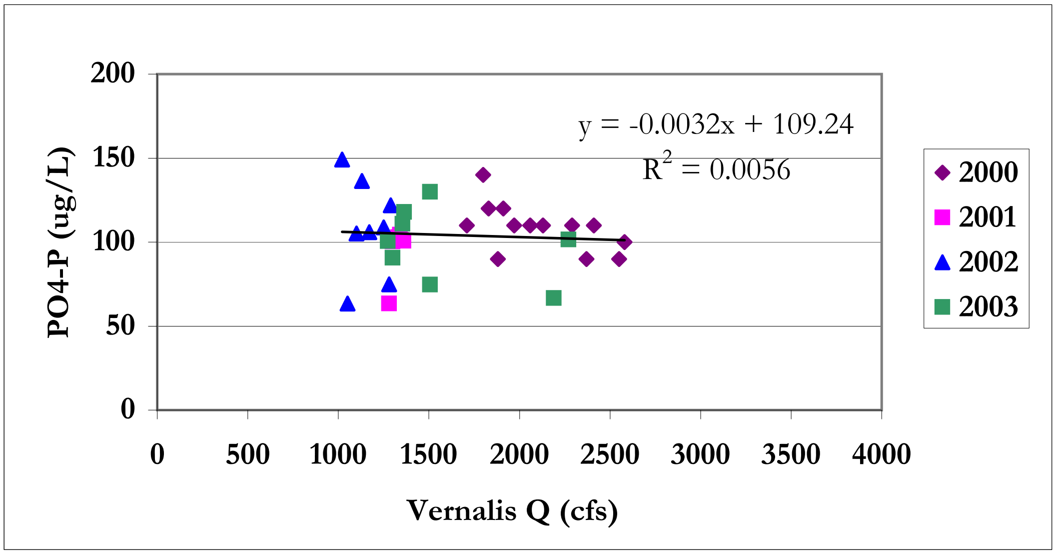


Figure 10. Relationships of Ammonia, Nitrite+Nitrate, and Dissolved Organic Nitrogen to Flow at Vernalis, June 1 - September 30, 2000-2003



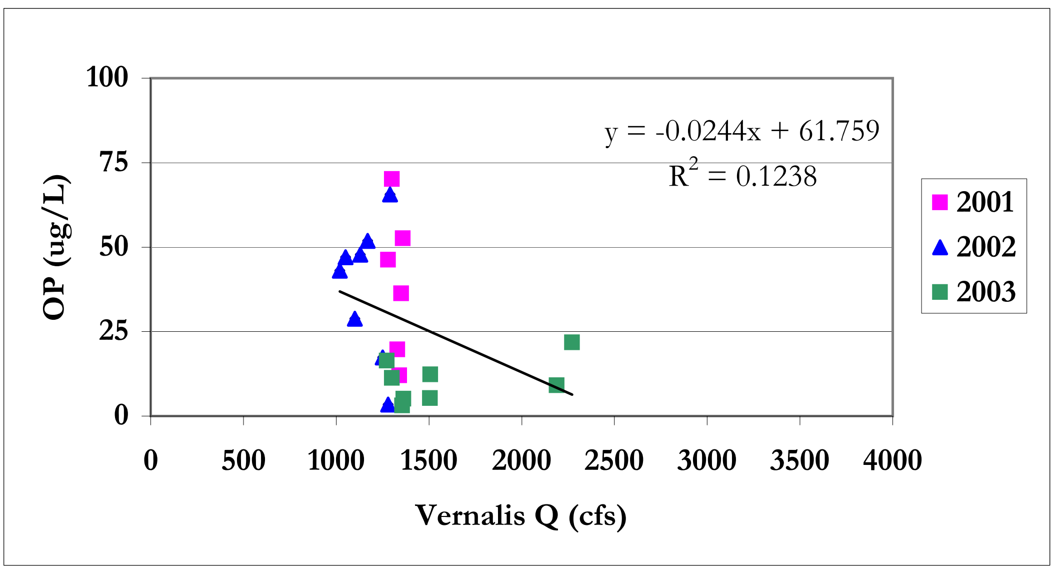


Figure 11. Relationships of Dissolved Inorganic Phosphorus (PO_4) and Organic Phosphorus to Flow at Vernalis, June 1 - September 30, 2000-2003

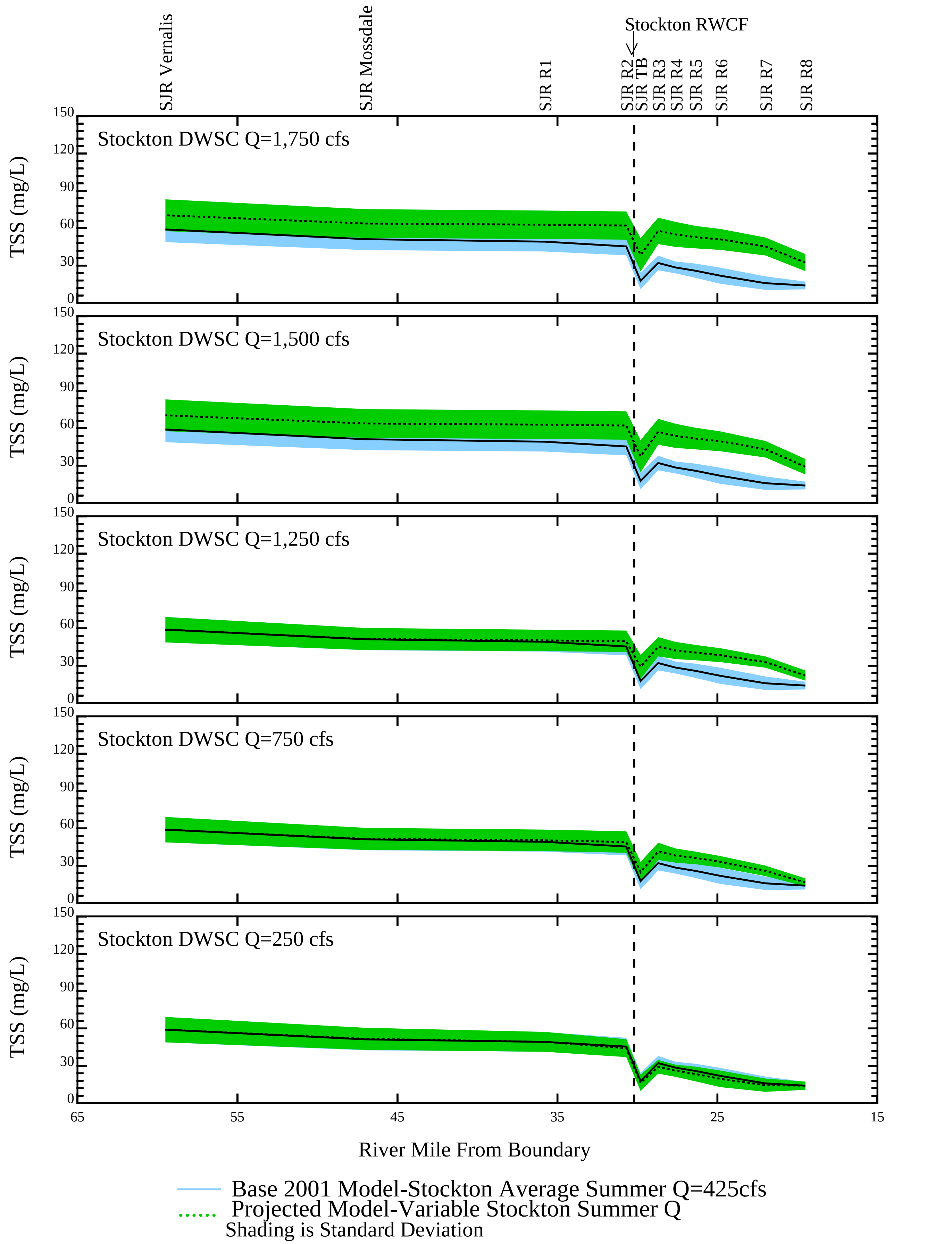


Figure 12. Spatial Comparisons of Summer Water Quality Model Base and Projection

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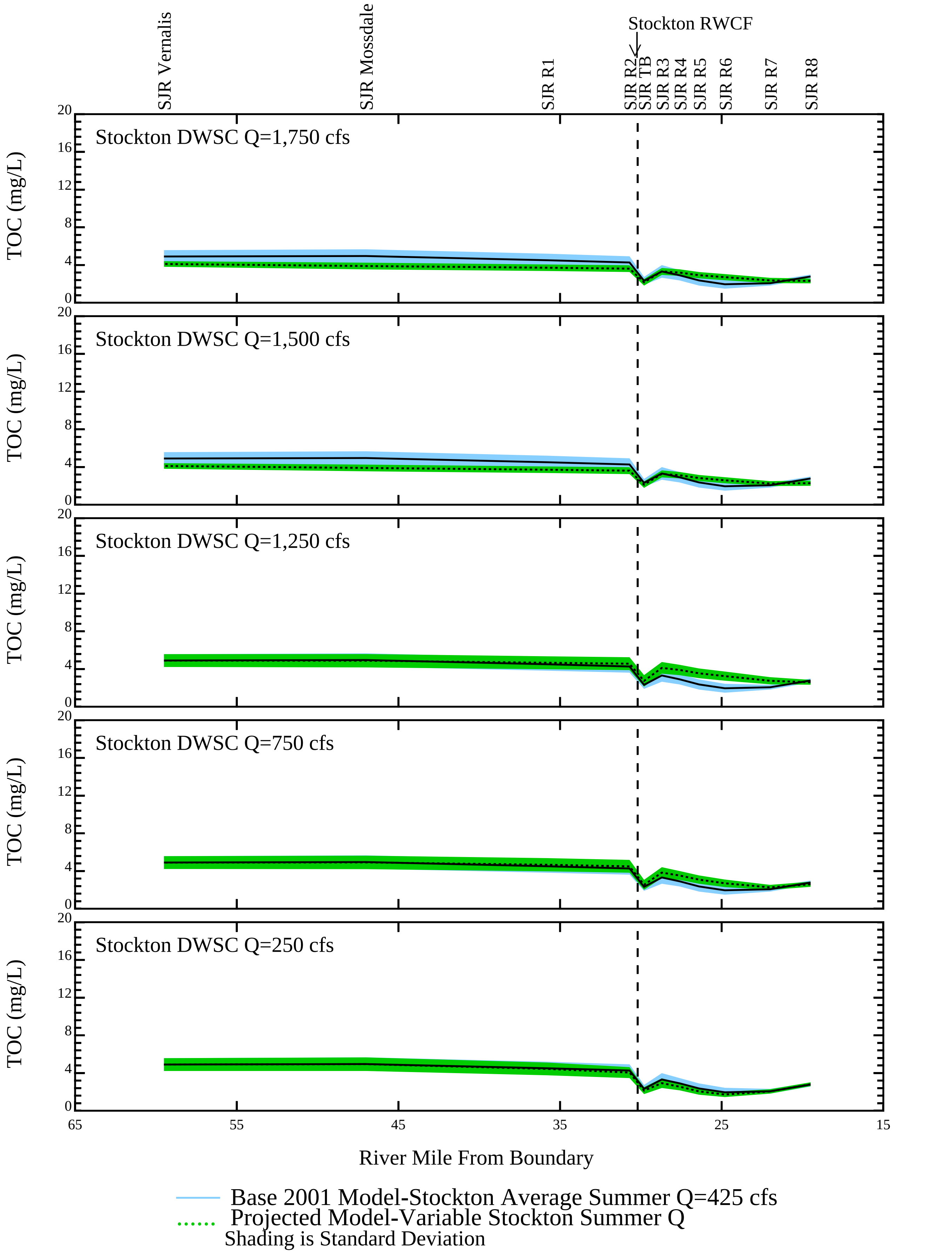

Figure 13. Spatial Comparisons of Summer Water Quality Model Base and Projection

These calculations are for conservative substance and are somewhat approximate as the DWSC effective dilution volume will change at varying flows. In addition there is settling in the DWSC that is not accounted for. However the calculation can serve as a guide to discuss the following projection scenarios. In summary approximately 0.28 mg/L-d increase in concentration from the base model results can be expected upon entering the DWSC for each 500 cfs increase or decrease in flow due to dilution for each 1 mg/L upstream concentration. For example, for the 750 cfs projection, the upstream TSS concentration is 50 mg/L. So a flow change of 325 cfs (750 cfs – 425 cfs) and a concentration of 50 mg/L should result in an approximate change in concentration of 10 mg/L ((325/500)*0.28*50) in the DWSC from the base model. At 1,750 cfs the approximate change from the base model would be 37 mg/L. Comparisons of base model and projections also show this approximate 28% change in concentration per 500 cfs change.

Figure 14 shows spatial summer chlorophyll-a concentrations for the base and projection scenarios. The pattern of increasing then decreasing chlorophyll-a from Vernalis to Mossdale then to the confluence with the DWSC is similar to flows at the 250, 750 and 1,250 cfs scenarios. At 1,500 and 1,750 cfs Vernalis boundary chlorophyll-a is reduced reflecting upstream dilution and with less growth at faster travel times so that the DWSC experiences a lower algal load. Also there is less time for growth in the DWSC.

Figures 15 and 16 compare spatial summer DIN and DIP. As flows increase from 250 cfs to 1,750 cfs nitrogen and phosphorus concentrations, which largely reflect the Stockton RWCF discharge experience greater dilution. The peak DIP concentration at 250 cfs occurs near R5, whereas the peak concentrations for the 750, and 1,250 cfs projections occur near and below R7 respectively also indicating that, in addition to dilution, upstream loads will move downstream more quickly with higher flows.

Figure 17 compares spatial summer depth averaged DO. Though at 750 cfs, average DO at R3 shows improvement from 5 mg/L to about 6.5 mg/L, the minimum average DO of near 4.5 mg/L shifts downstream from near R5 to R7. This trend continues with increasing flow indicating that the upstream loads contribute a significant source of the oxygen demand that is carried further downstream at higher flows.

The number of DO violations for the base model summer 2001 calibration and each of the five flow scenarios along the SJR DWSC are shown in Figure 18. A DO violation of less than 5.0 mg/L from June to August and 6.0 mg/L for September can occur at any depth during the day to be counted as a day with a violation. The bottom panel plots both the base model with summer average flow of 425 cfs and the 250 cfs scenario. The total number of model days from June 1 to September 30 is 122 days. The base and 250 cfs scenario maintain DO violations almost all days in the DWSC. At higher flow scenarios, the number of violations increases downstream showing that at higher flows the maximum oxygen deficit or sag is pushed downstream.

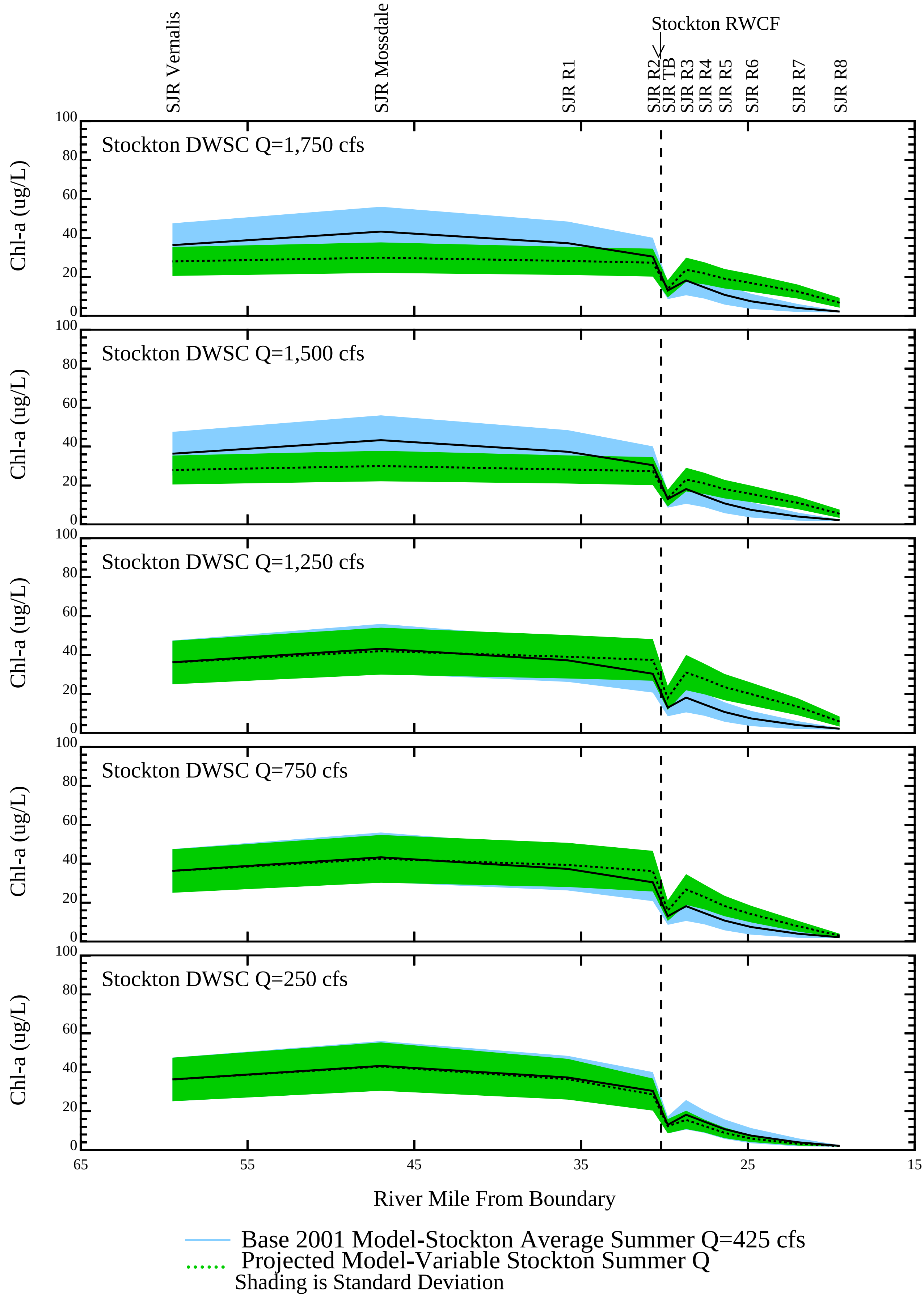

Figure 14. Spatial Comparisons of Summer Water Quality Model Base and Projection

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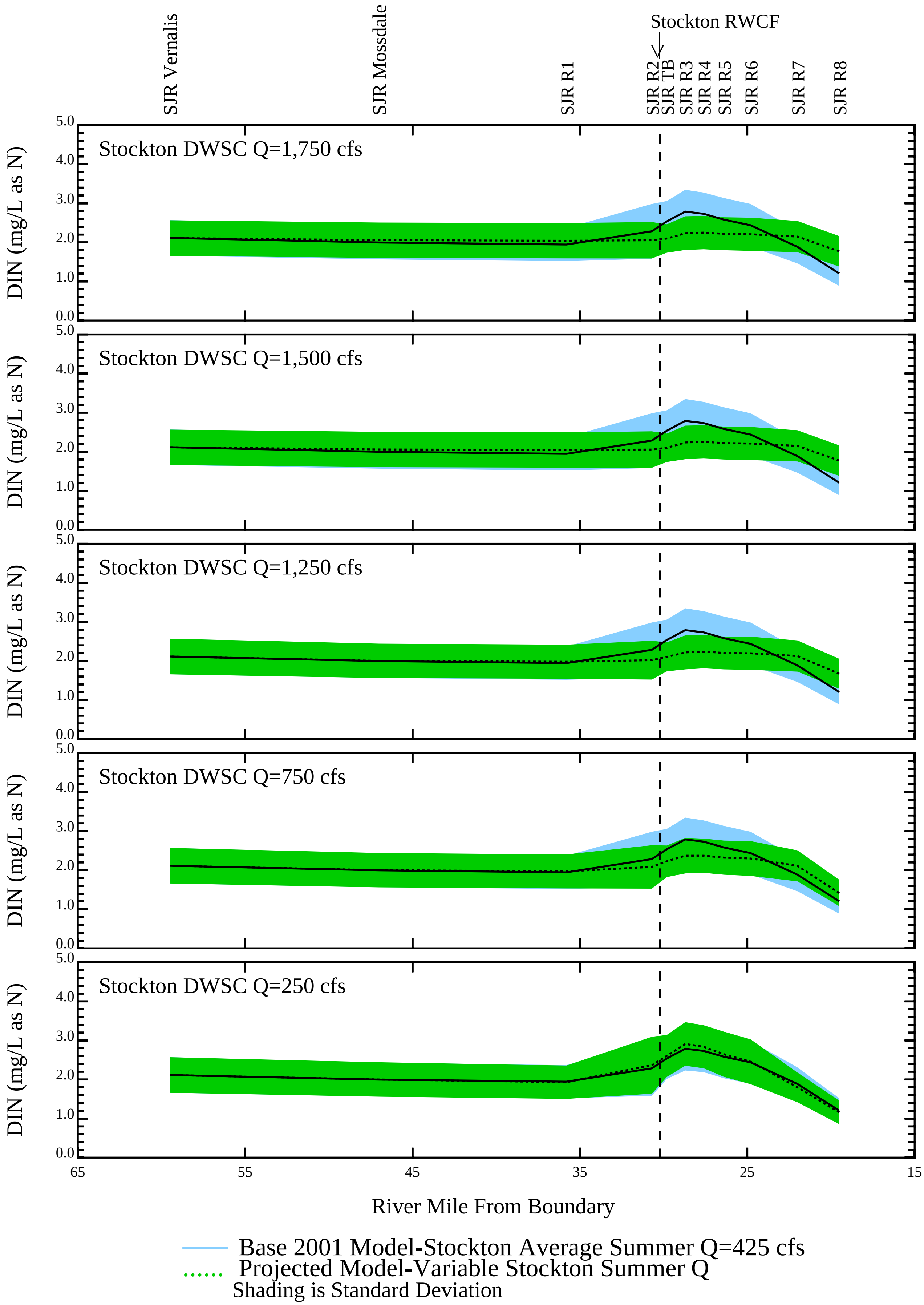

Figure 15. Spatial Comparisons of Summer Water Quality Model Base and Projection

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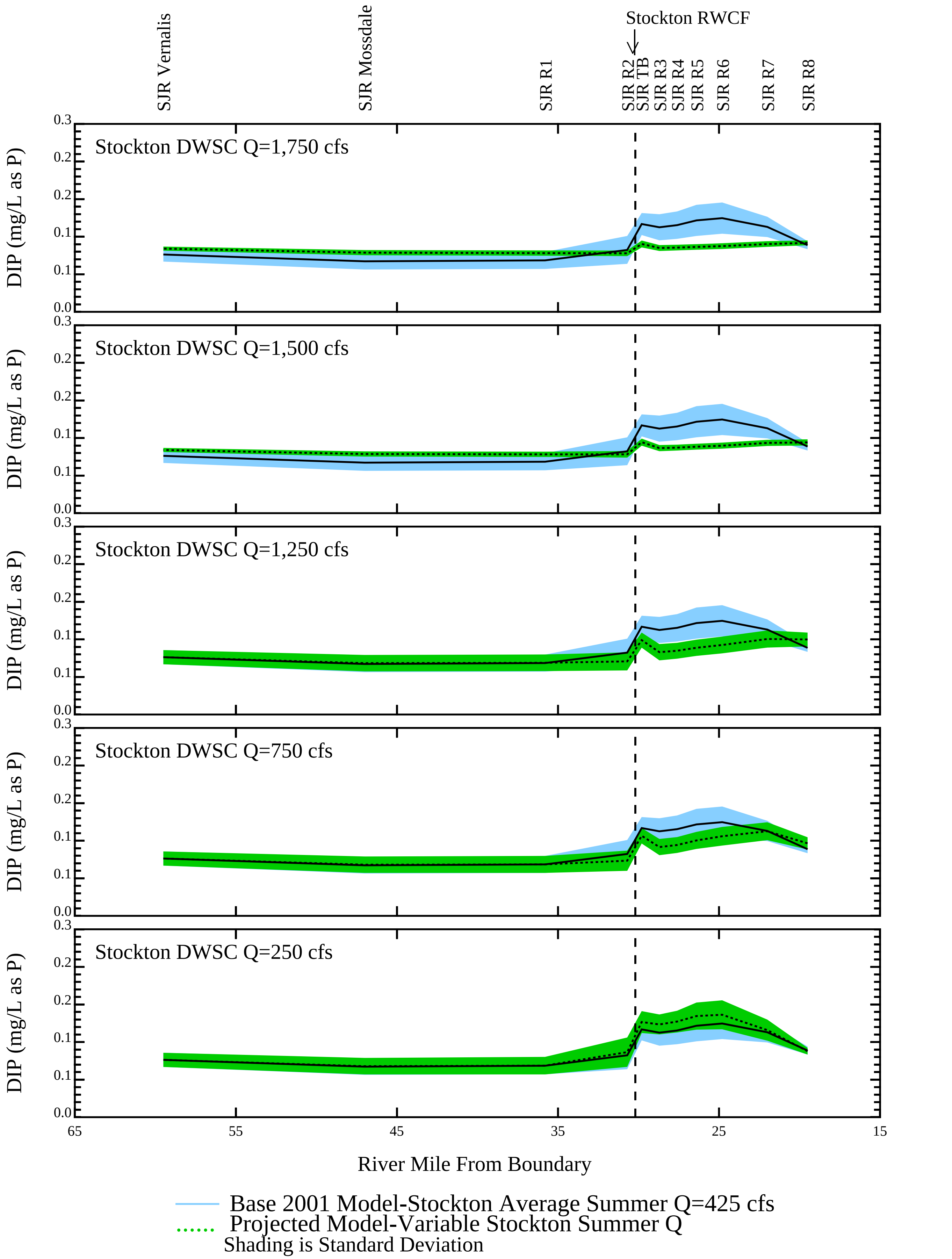

Figure 16. Spatial Comparisons of Summer Water Quality Model Base and Projection

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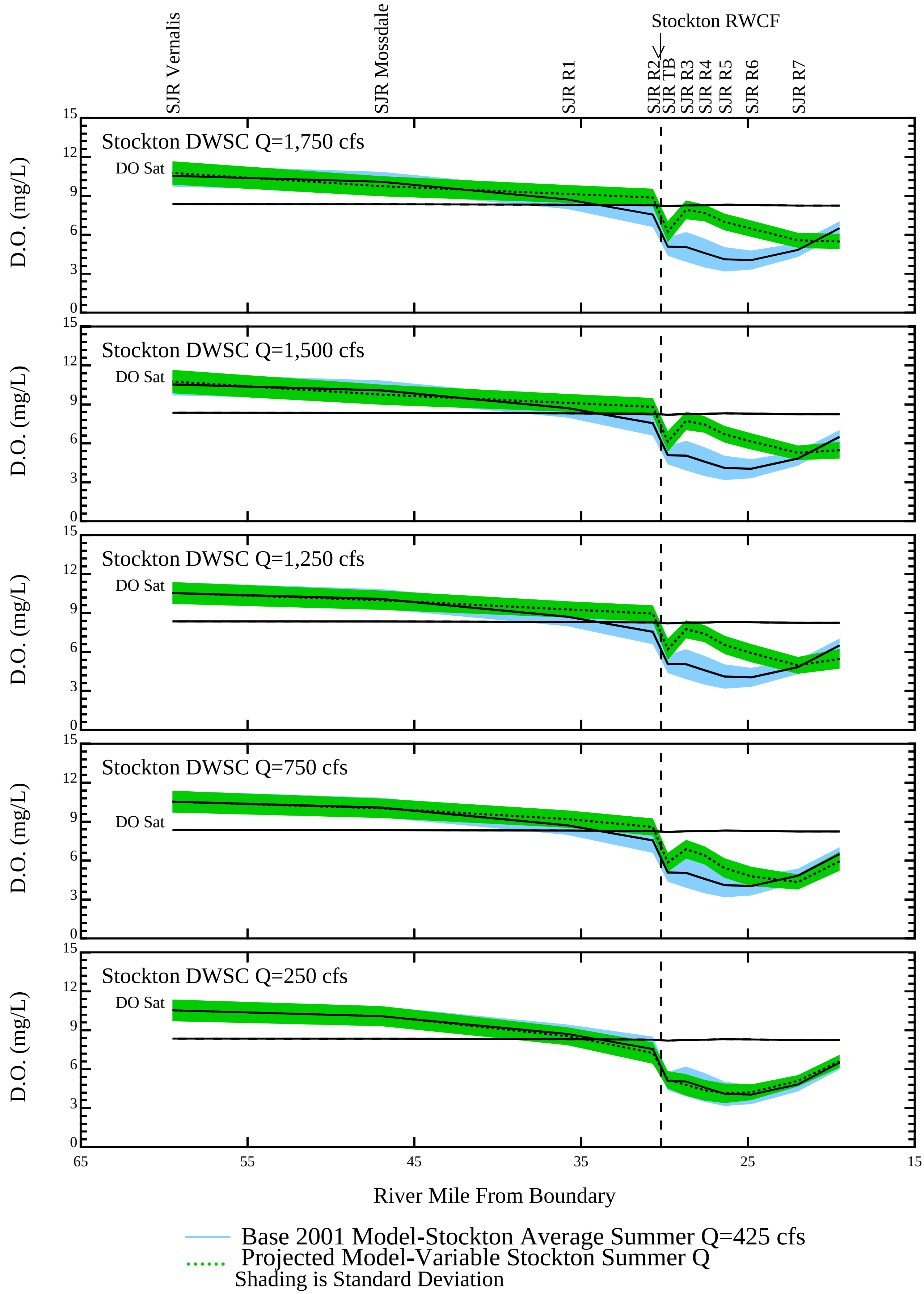

Figure 17. Spatial Comparisons of Summer Water Quality Model Base and Projection

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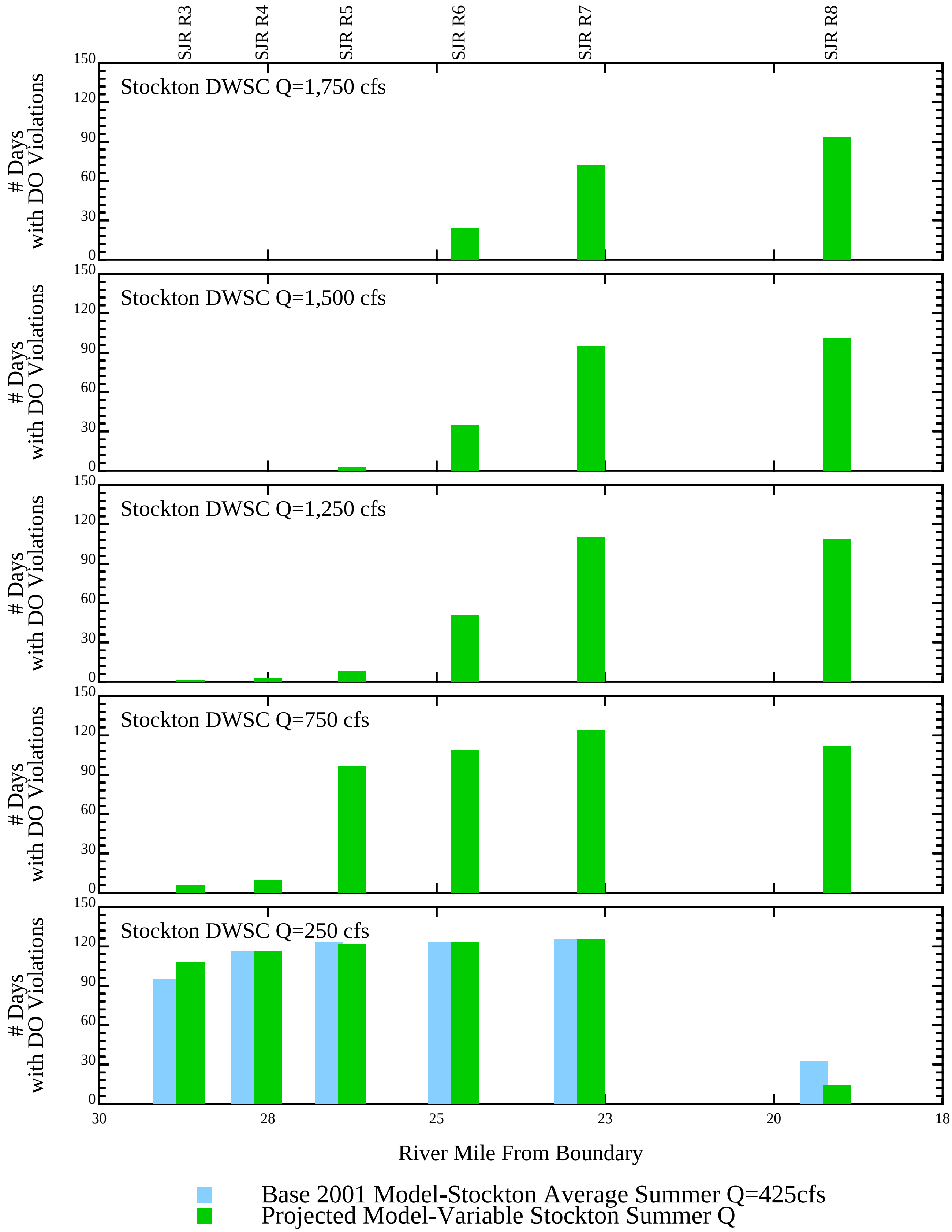

Figure 18. Comparisons of Water Quality Model Base and Projections Summer (June 1-Sept 30, 2001)

DO violations show the greatest reductions at flows above 1,250 cfs. This is in agreement with other observations (Lee, 2005) that indicate no DO violations occurred at SJR flows of 1,500 cfs, measured at the USGS UVM meter above the Stockton RWCF. Approximately 15% of the measured UVM flow is diverted to Burns Cutoff resulting in a flow of 1,275 cfs on the DWSC. At 1,500 and 1,750cfs the upstream boundary concentrations are adjusted as discussed above. Therefore these scenarios reflect both transport and upstream boundary effects. Though still counted as violations, at higher flows DO concentrations are closer to 5.0 or 6.0 mg/L. These results show that at these flows DO violations while reduced are still occurring at locations R7 and R8.

3.3 STOCKTON RWCF AMMONIA REDUCTION

The Stockton RWCF plans to reduce ammonia effluent concentrations to 2.0 mg/L in the summer of 2006. Model projections were done at the five flow scenarios with RWCF ammonia concentrations set to 2.0 mg/L to project water quality improvements in the DWSC.

Temporal comparisons of base model and projections for the five flow scenarios with reduced RWCF ammonia at Mossdale, R1, R2, R3, R4, R5, R6, R7, R8 and the Turning Basin have been generated for the one year simulation period and are included in the Appendix B of this report. Spatial figures of ammonia and nitrite+nitrate are shown in Figures 19, and 20, respectively. The base model average summer ammonia at R3 is 0.4 mg/L. SJR DWSC ammonia for all the five flow scenarios generally reflects the upstream boundary of approximately 0.1 mg/L resulting in an approximate 0.3 mg/L reduction in instream ammonia levels. Nitrite+nitrate also shows reductions of about 0.5 mg/L. These small reductions will not impact chlorophyll-a levels so that the only effect should be from reduced oxygen consumption during nitrification. Figure 21 compares DO for the five flow scenarios with and without Stockton STP ammonia reduction. It appears that reducing the STP ammonia will provide an average of less than 1 mg/L oxygen benefit under the 250 cfs scenario with less benefit as flow increases. This is likely due to faster flow rates and less time for nitrification along with greater dilution.

As in Figure 18, the number of DO violations for the base model summer 2001 calibration and each of the five flow scenarios along the SJR DWSC with Stockton RWCF ammonia reduction are shown in Figure 22. The numbered DO violations are reduced from 90 to 60 at R3 with RWCF nitrification

3.4 FIFTY PERCENT REDUCTION IN MUD SLOUGH FLOW TO USJR

Modeling work under Task 5 indicated that the major and minor inflows can provide sources of nutrients and chlorophyll-a and the major inflows such as the Tuolumne and Stanislaus Rivers can act as sources for dilution. For example, The Tuolumne and Stanislaus Rivers add flow with very low chlorophyll-a so that chlorophyll-a concentrations resulting from either growth between Stevinson and Vernalis or from inputs are reduced at Vernalis. The DSM2 modeling work has also

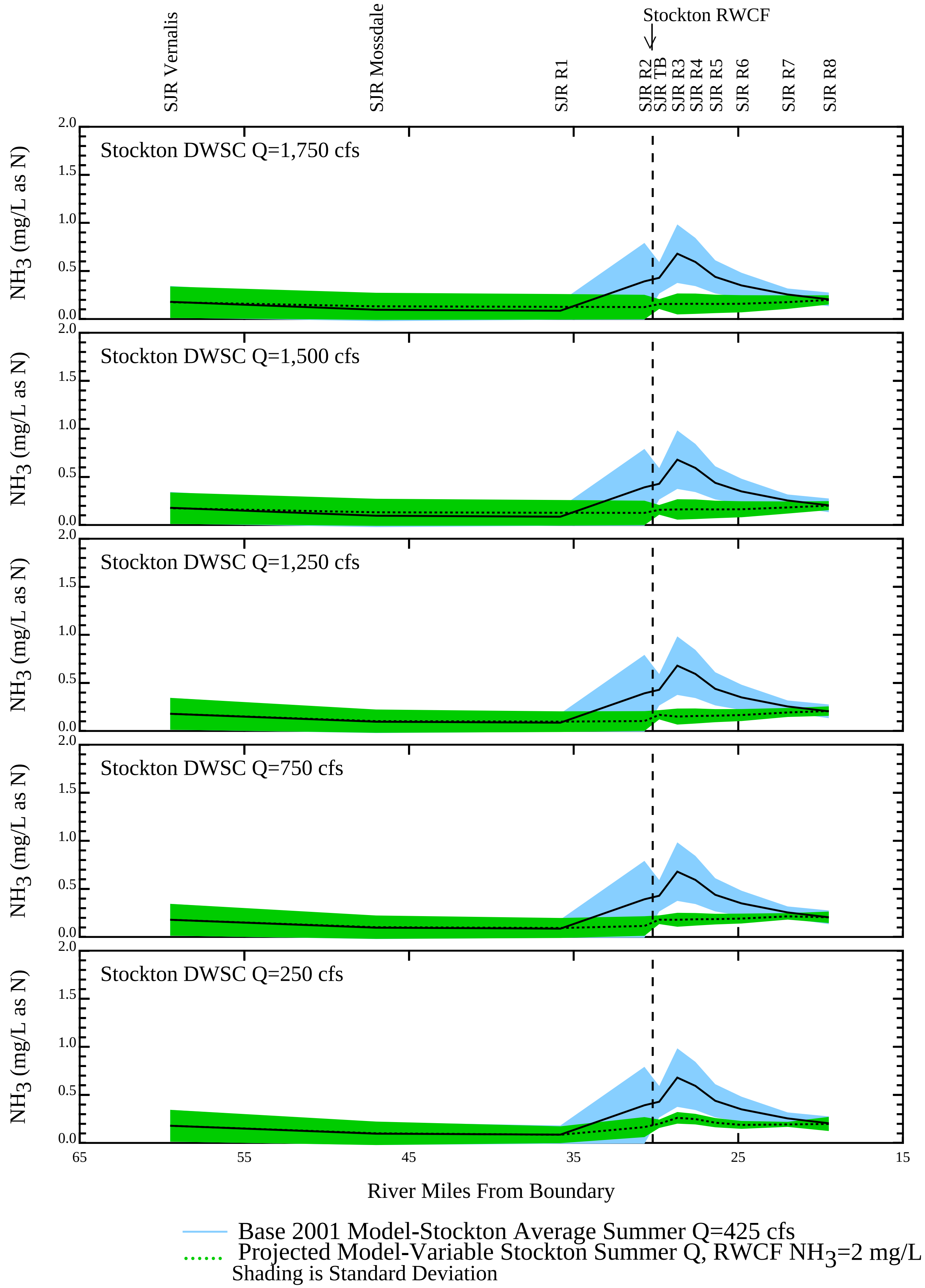

Figure 19. Spatial Comparisons of Summer Water Quality Model Base and Projection

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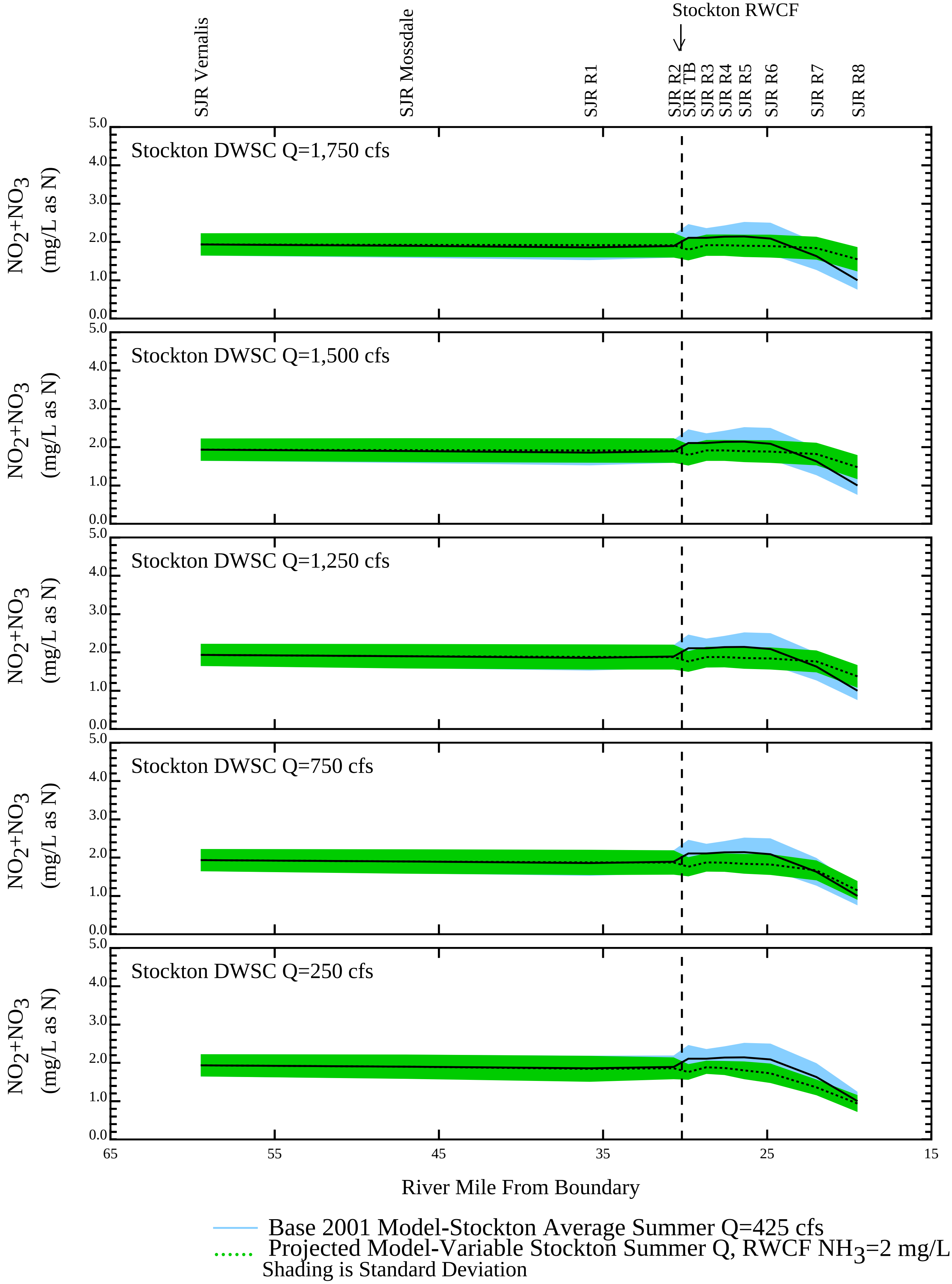

Figure 20. Spatial Comparisons of Summer Water Quality Model Base and Projection

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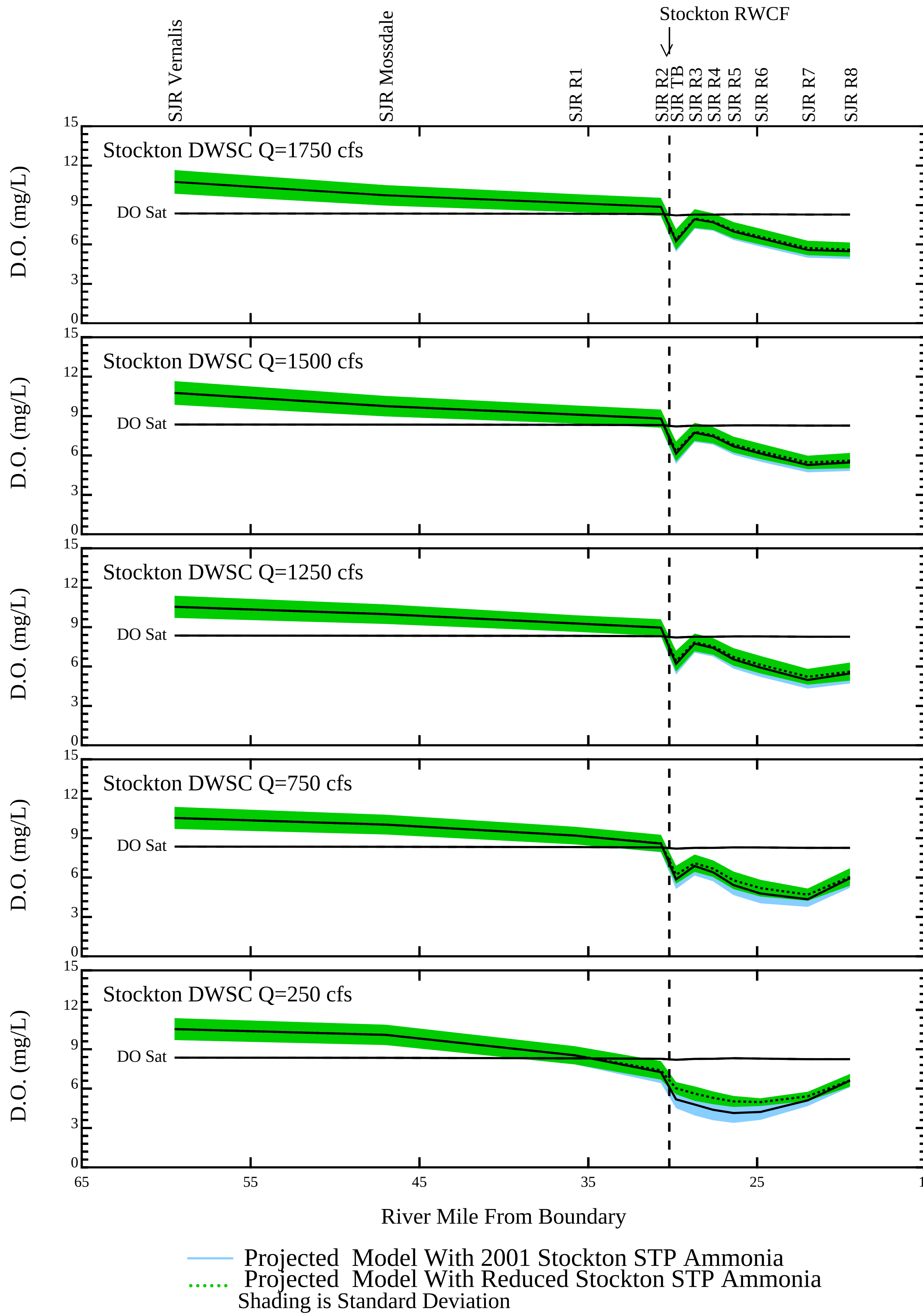

Figure 21. Spatial Comparisons of Summer Water Quality Model Base and Projection

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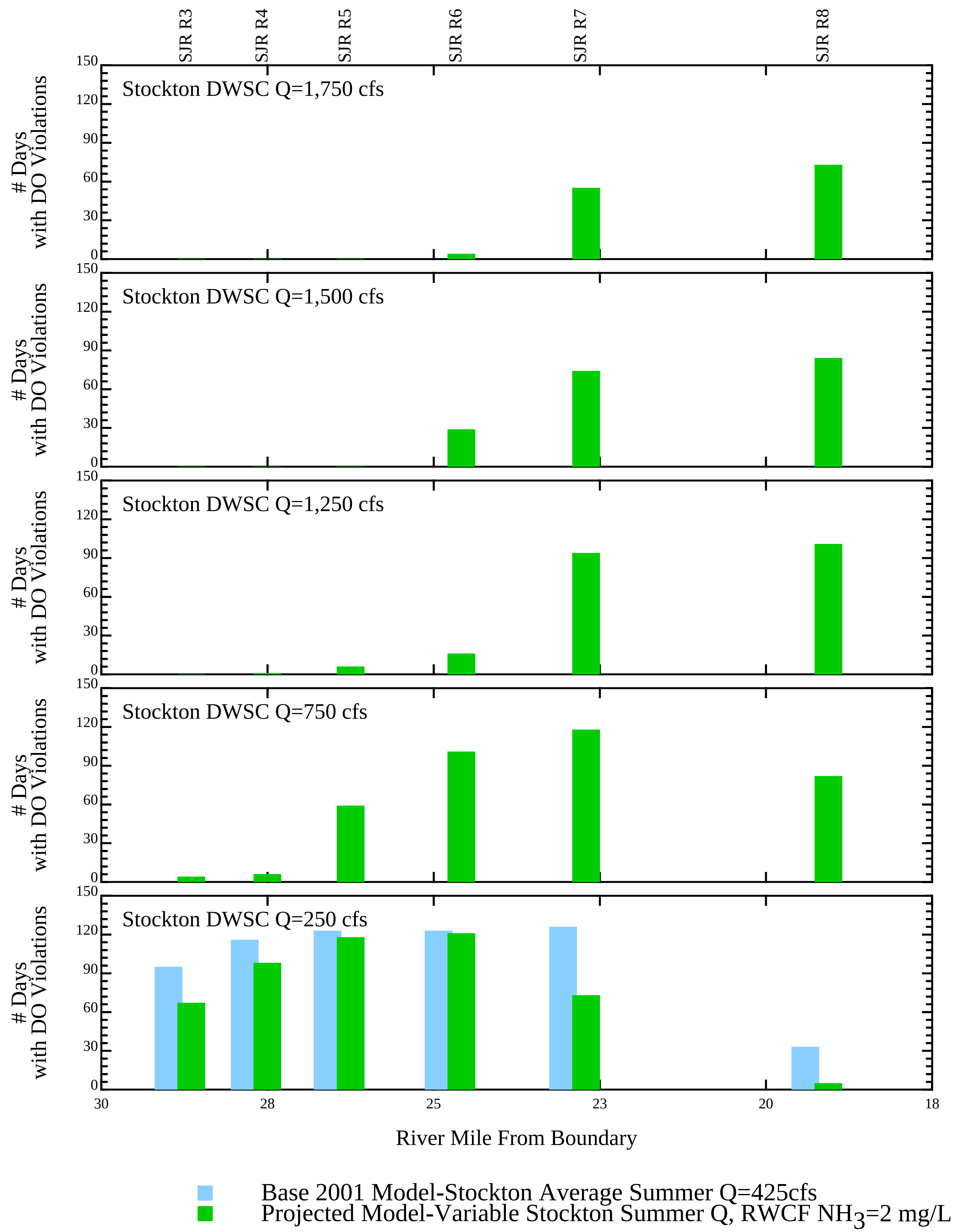

Figure 22. Comparisons of Water Quality Model Base and Projections Summer (June 1-Sept 30, 2001)

indicated that the smaller agricultural inflows act as sources of nutrients and chlorophyll-a to the USJR. Though it would be difficult to change loadings from the larger inflows (Merced, Tuolumne, Stanislaus, Creeks), it has been suggested that flows from Mud Slough may be reduced by half if used for irrigation purposes (R Brown, personal communication). As a result a DSM2 hydrodynamic and water quality model simulation was performed to simulate a 50% reduction in flow from Mud Slough into the USJR. Mud Slough enters the USJR above the Merced River (Figure 1).

Comparison of base and projected model outputs upstream of Merced River indicate an approximate 1 mg/L reduction in nitrate in the USJR with reduced Mud Slough flow (Figure 23). However changes in instream ammonia, orthophosphorus, chlorophyll-a, DO, BOD, temperature and flow indicate negligible changes resulting from this flow reduction. This can be expected as Table 1 presents average flow for the 2000-2001 period and % of final flow at Vernalis for each of the model flow inputs. Mud Slough with an average 2 year flow of 130 cfs contributes 4% of the overall flow. Although there is a reduction in nitrate, there is still enough nitrogen to allow algal growth. As the Merced River enters the USJR contributing 15% of the overall flow and with average nitrate levels of about 2.0 mg/L effects of the reduction of Mud Slough begin to dissipate. This trend continues to Vernalis as other flows enter the USJR. Figure 24 indicates that there is virtually no change in nutrients, algae, DO or BOD at Vernalis as a result of a 50% reduction in Mud Slough inflows.

It should be noted that although the model does not simulate solids, a mass balance calculation using average TSS concentrations at Stevinson, Mud Slough, Salt Slough and the Merced River of 48 mg/L, 55 mg/L, 110 mg/L and 12 mg/L respectively (Kratzer, 2004) and average flows from Table 1 with a 50% reduction in Mud Slough flows would result in a 1 mg/L decrease in TSS below the Merced River. Therefore changes in the light regime to effect chlorophyll-a growth would not occur.

3.5 SIMULATIONS FOR DISSOLVED OXYGEN INJECTION

An oxygen injection device is scheduled to be installed beneath the Rough & Ready Island (RRI) Dock in the summer of 2006. The device will inject 10,000 lb/d of oxygen from a 1,000 foot diffuser at a 15-foot depth and1,000 feet upstream of the RRI dock intake. A simulation of oxygen injection was done to quantify the improvements in DO that can be expected from oxygen injection. For the projection, 10,000 lb/d was input to the DWSC 1,000 feet upstream of the RRI Dock from June 1 to September 30. Oxygen was added as a load into a mid depth segment (750ft long X 225 ft wide) on the "west" side of the model grid. Average daily tidal flows during this summer period were about 425 cfs, with average upstream or down stream gross flows of about 3,400 cfs so that the 50 cfs from the injection discharge would not have an effect.

The model outputs average DO every 2 hours so that the diurnal variations in DO are represented and maximums and minimums are captured. Average DO over the period from June 1 to September 30 is shown in Figure 25 with +- one standard deviation for surface and bottom DO. The DO is improved from about sample location R4 to R7. The added oxygen does not appear to increase DO at R3. Figure 26 shows number of days with DO violations for the June 1 to September 30 period for the base model calibration (top panel) and the oxygen injection simulation (bottom panel). There is a marked improvement in number of days with DO less than 5 or 6 mg/L at R5, R6 and R7. There is some improvement at R3 and R4 indicating the zone of influence for the oxygen injection is greatest below R4 and to R7. This simulation is done under the summer 2001 low flow condition with an average flow of 425 cfs. The above simulations for varying flows showed that the maximum DO deficit will move downstream as flows increase so it can be expected that the oxygen injection device will yield greater improvements at summer flows at and above 750 cfs.

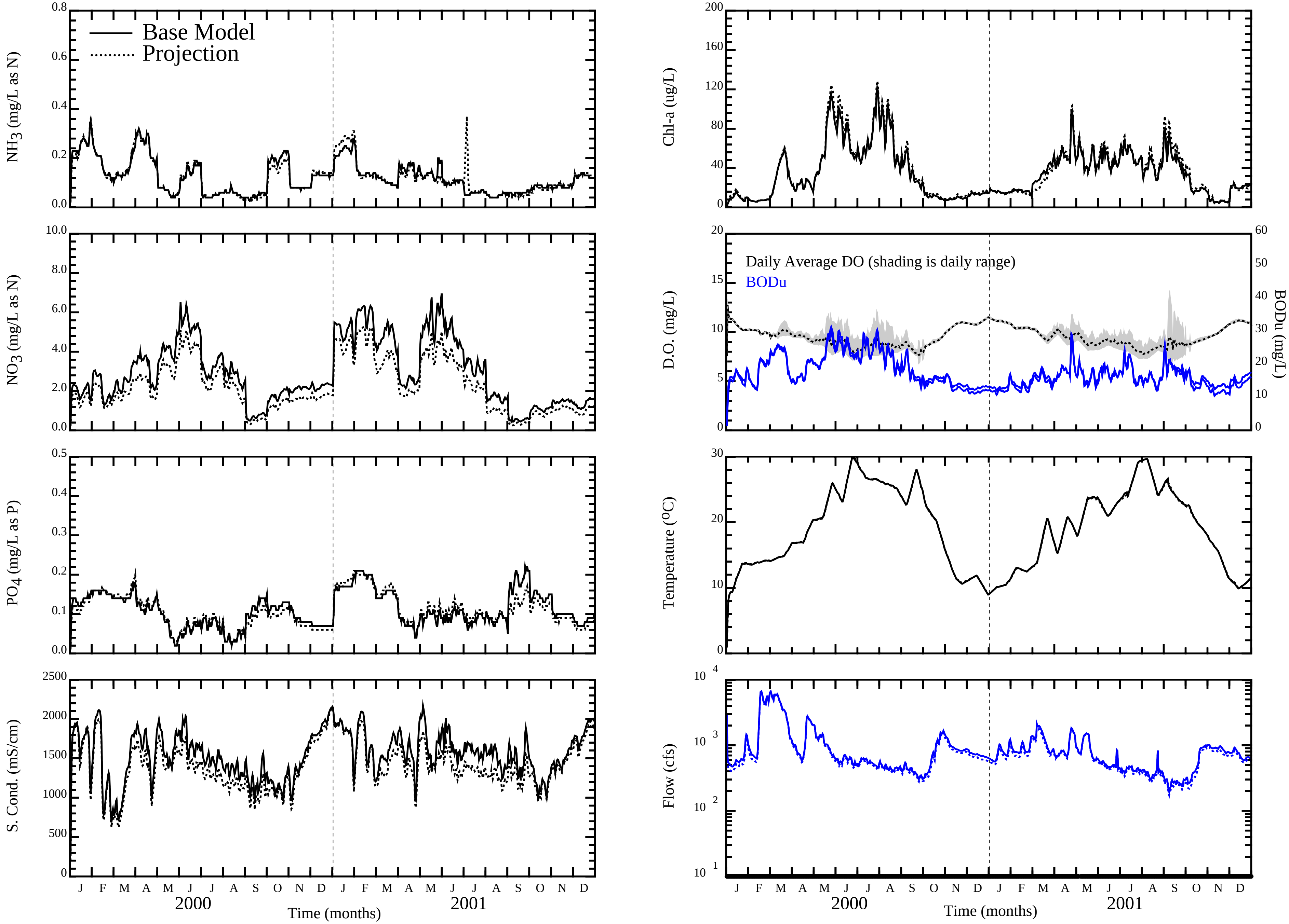

Figure 23. Upper SJR Comparison of Model Base Calibration to 50% Reduction of Mud Slough Flow: Upstream of Merced R.

DATE: 4/19/2006 TIME: 16:32: 9

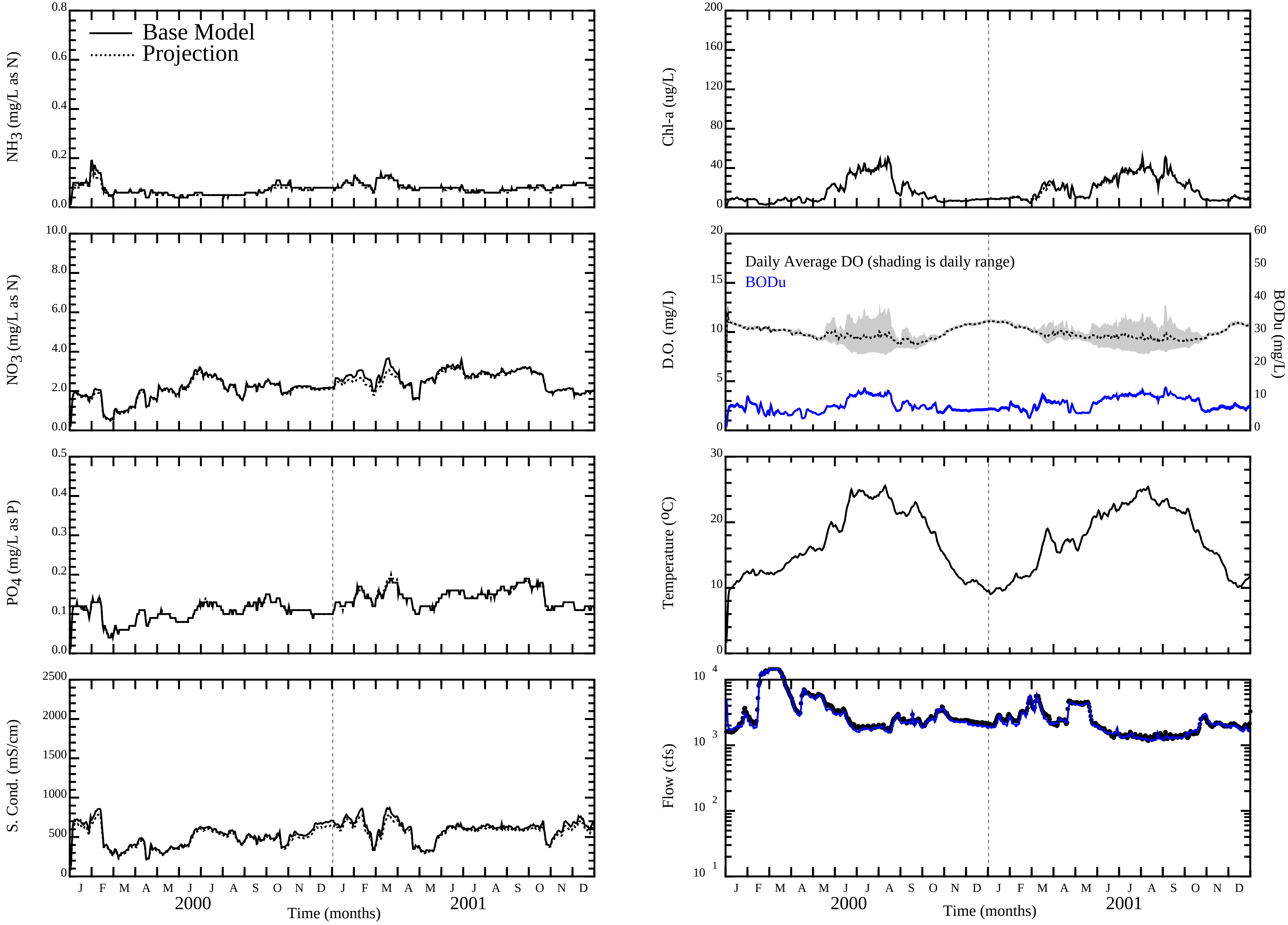

Figure 24. Upper SJR Comparison of Model Base Calibration to 50% Reduction of Mud Slough Flow: near Vernalis

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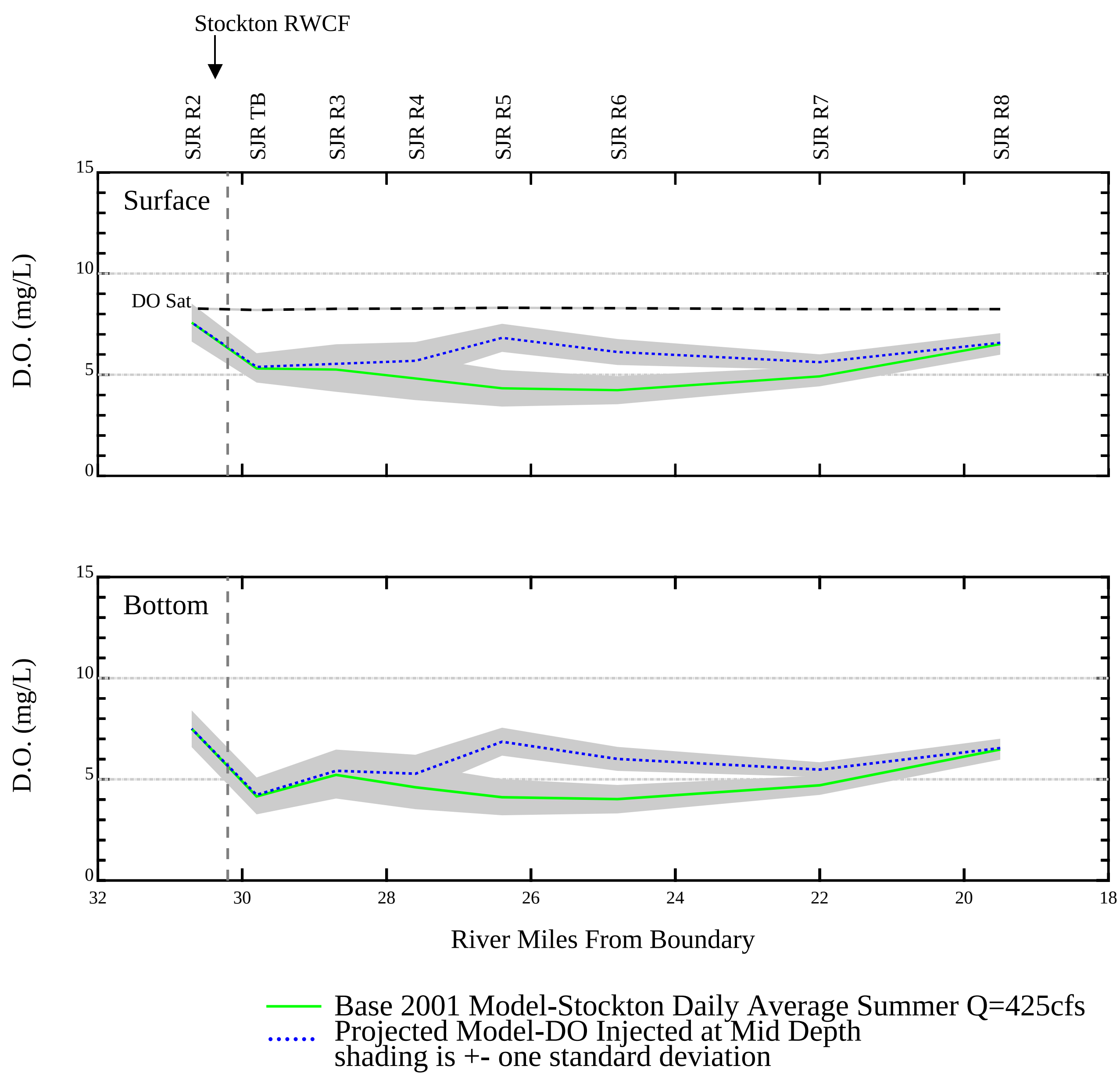

Figure 25. Spatial Comparisons of Summer Water Quality Model Base and Projection

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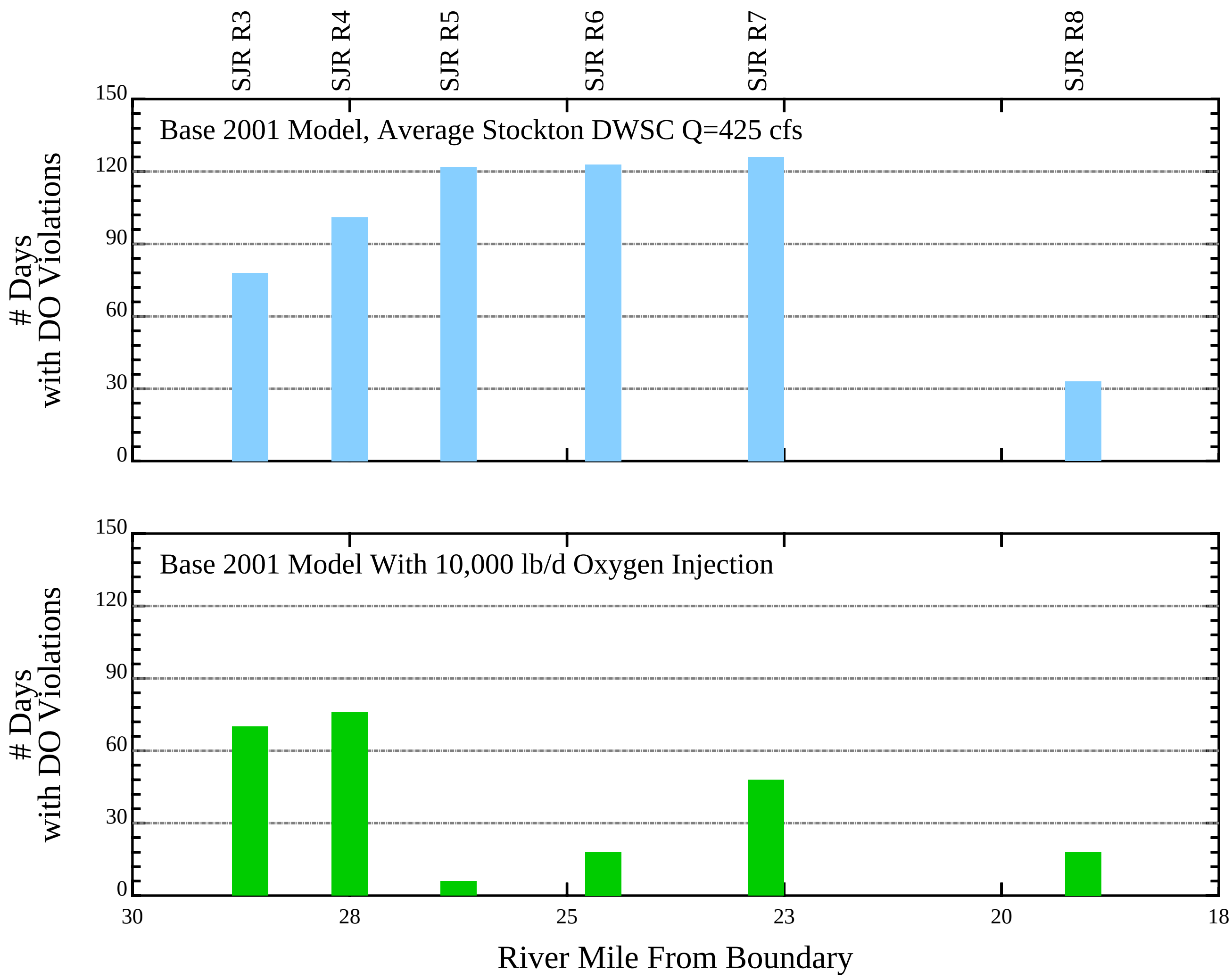

Figure 26. Comparisons of Summer (June 1 - Sept 30, 2001) Dissolved Oxygen Model Base and 10,000 lb/d O_2 Injection

SECTION 4

SUMMARY AND CONCLUSIONS

The 3D SJR DWSC hydrodynamic and water quality model has been calibrated for the 2000 and 2001 period. The model has been calibrated based on data, studies and experience to support many of the required inputs and appears to adequately reproduce the major processes that affect water quality and eutrophication in the river. The model simulates transport, dissolved oxygen, algal and sediment processes. A full development and discussion of the model calibration has been presented (HydroQual, 2006). With the calibration completed, the model can now be used as an aid to evaluate alternative management scenarios to improve water quality in the SJR DWSC. Therefore, 16 projection scenarios were made:

1) 4 Simulations to quantify DO demand from each of the major oxygen demand sources (algal processes, Stockton RWCF ammonia nitrification, upstream carbon load, SOD),
2) 5 simulations to compare base model with varying flows in the DWSC (250, 750, 1,250, 1,500, and 1,750 cfs) to simulate diversions to the Old River,
3) 5 simulations to compare base model with varying flows in the DWSC along with Stockton RWCF ammonia reduction to 2.0 mg/L (250, 750, 1,250, 1,500, and 1,750 cfs),
4) 1 simulation of reducing Mud Slough flow and hence load to the USJR,
5) 1 simulation of dissolved oxygen injection in the DWSC.

Four unit response scenarios were made that essentially quantify the unit contributions to the DO deficit in the River for algal processes, Stockton RWCF ammonia, upstream carbon and SOD. Results indicated that chlorophyll-a growth and loss processes added 0.1 to 0.75 mg/L oxygen to the DWSC for the 2000 and 2001 summer periods. Summer oxygen demand from nitrification of Stockton RWCF ammonia load contributed 0.1 to 0.75 mg/L to the DO deficit. Summer SOD processes contribute approximately 0.5 mg/L to the DO deficit. Unit response model simulations indicated that the largest contributor to the DO deficit in the DWSC for the 2000 and 2001 summer periods is the upstream nonalgal carbon load with an approximate 2.5 mg/L summer average oxygen demand. The addition of all of these oxygen demanding sources results in a summer average DO deficit of 2-3 mg/L at R3 and 3-4 mg/L at R6 under the summer average flows of 980 cfs in 2000 and 600 cfs in 2001.

Simulations for five flow conditions (250, 750, 1,250, 1,500, 1,750 cfs) indicated that as flow increases the DO deficit is improved and also moves downstream. DO violations occur often at 250 cfs and the base model summer flow of 425 cfs from R3 to R7. As flows increase DO violations are less likely at R3 and R4 as greater dilution and less retention time for oxygen demand from nitrification and carbon decay processes can occur. DO violations show the greatest reductions at flows above 1,250 cfs in agreement with data observations. However, a significant number of violations still occur at R7 and R8.

Simulations for the five flow conditions (250, 750, 1,250, 1,500, and 1,750 cfs) and with Stockton RWCF ammonia discharge = 2.0 mg/L show similar trends in reducing DO violations as without the RWCF ammonia reduction. In addition, occurrences of DO violations are also reduced in comparison to the base model at all flow scenarios.

Model simulations to reduce Mud Slough flows by 50% show no benefit to the DO deficit in the DWSC. This is the result of Mud Slough flows contributing only a small percentage (2-4%) of the final flow at Vernalis. Model simulations for dissolved oxygen injection near Rough & Ready Island at 10,000 lb/d for the summer period indicate improvements between R4 and R8 with greatest improvements between R5 and R7. This simulation was done at the summer low flow of 425 cfs. At higher flows the DO deficit sag will move downstream of R3 and R4 so a greater benefit would be achieved between R4 and R8.

Nutrient, carbon, and solids concentrations at Vernalis show reductions at flows greater than about 1,500 cfs during the summer months. There is, however, only a small amount of data between 2000 and 2003 to formulate relationships. Since upstream carbon appears to be a significant source contributing to the DO deficit in the DWSC, it would be beneficial to have a more complete set of data to formulate better concentration-flow relationships.

SECTION 5

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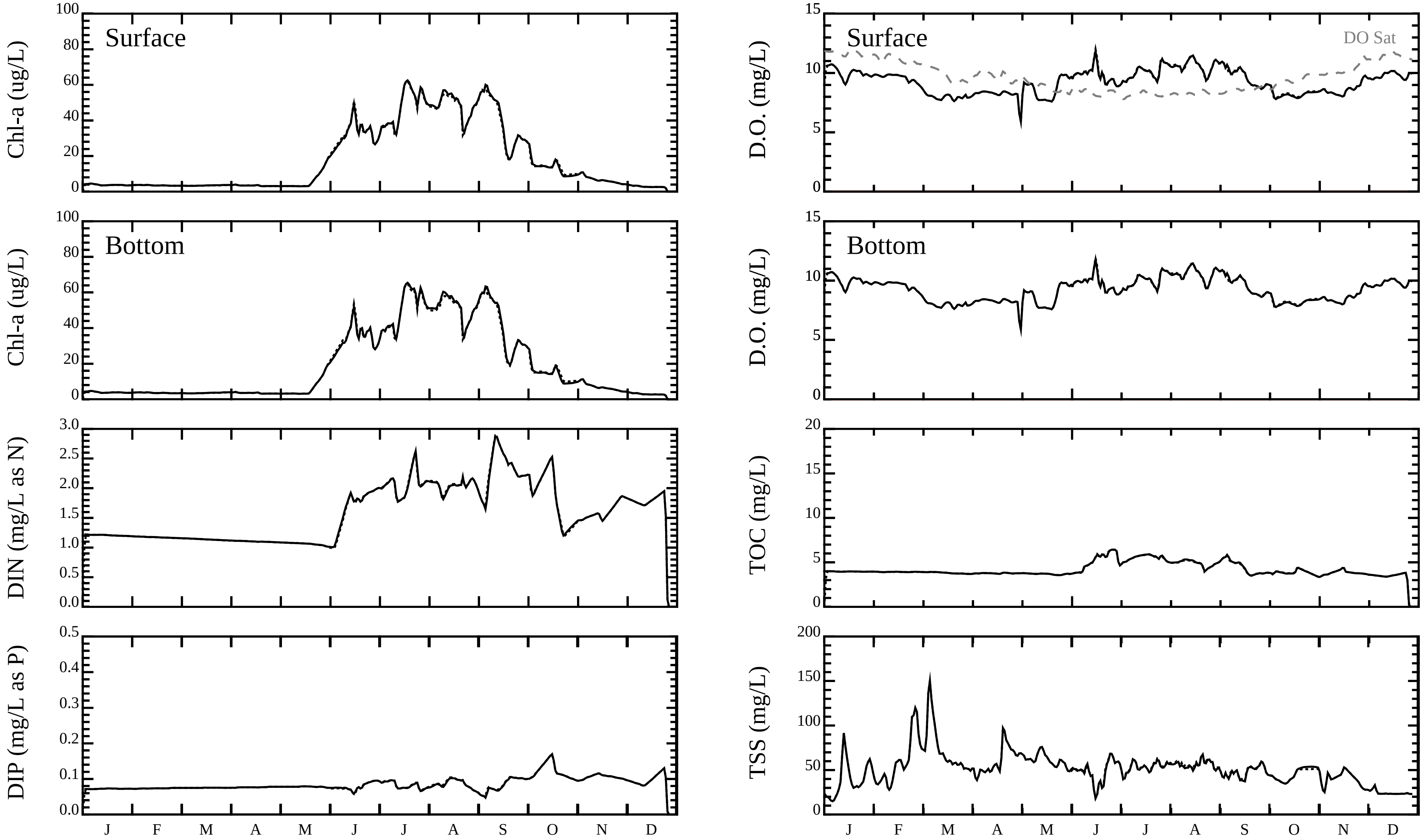
Rajbhandari, H.L. (1998). "Chapter 3: DSM2 Quality". *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 21st Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.

APPENDIX A

TEMPORAL PROFILE
COMPARISONS OF BASE MODEL AND PROJECTIONS
AT 250, 750, 1,250, 1,500 AND 1,750 CFS



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Comparison of Water Quality Model Base and Projection: SJR at Mossdale

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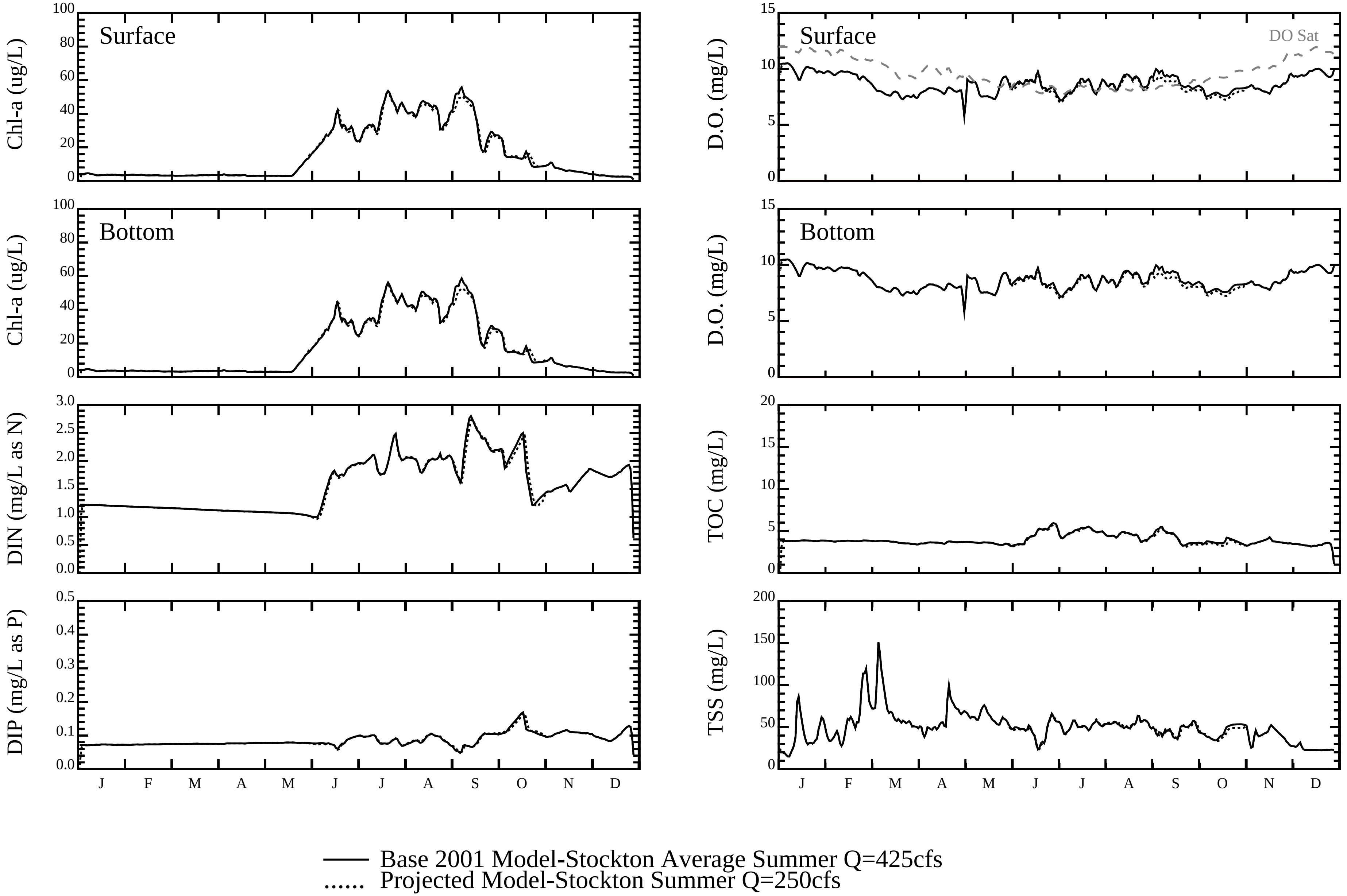

Comparison of Water Quality Model Base and Projection: SJR at R1

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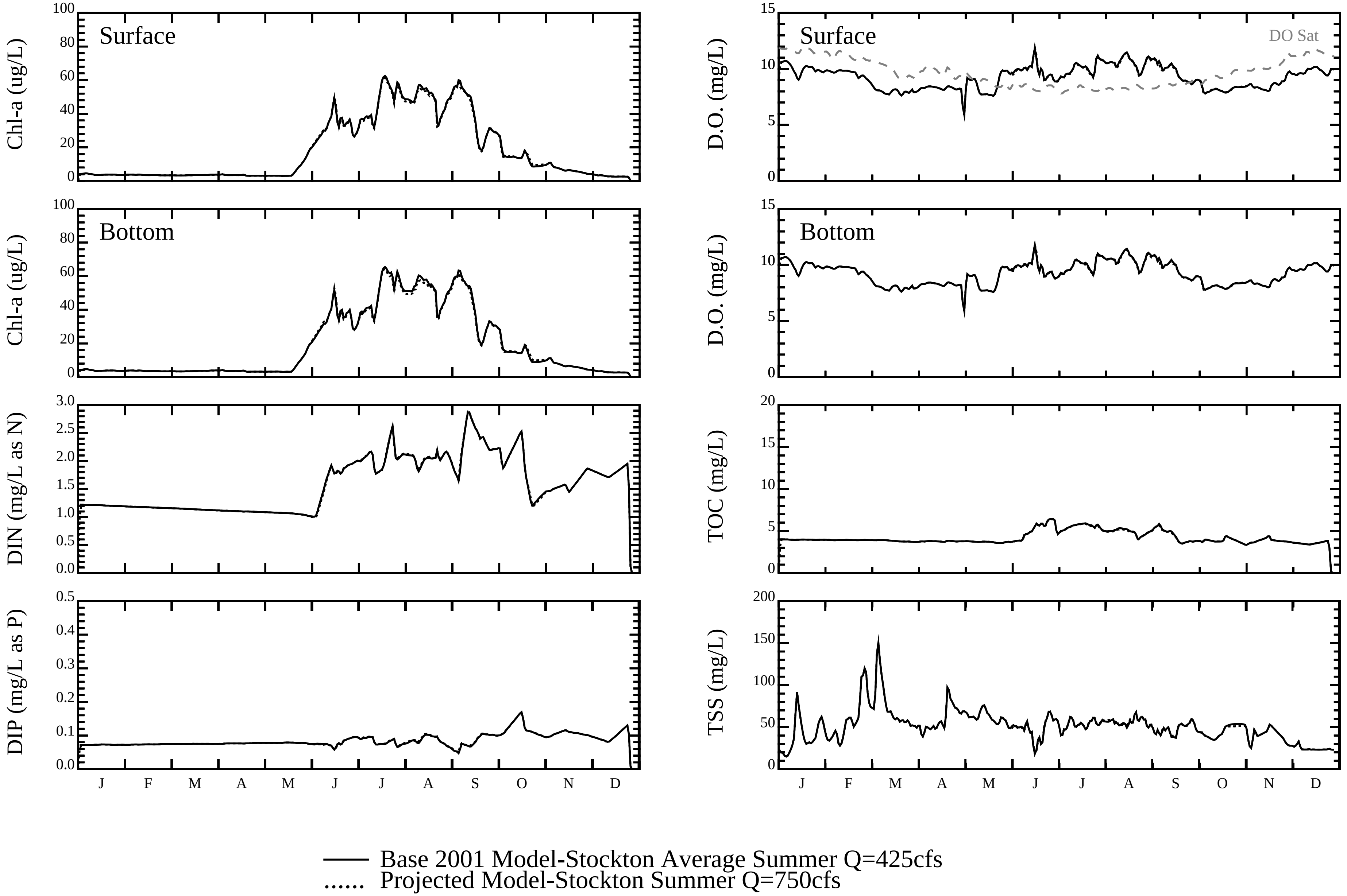

Comparison of Water Quality Model Base and Projection: SJR at Mossdale

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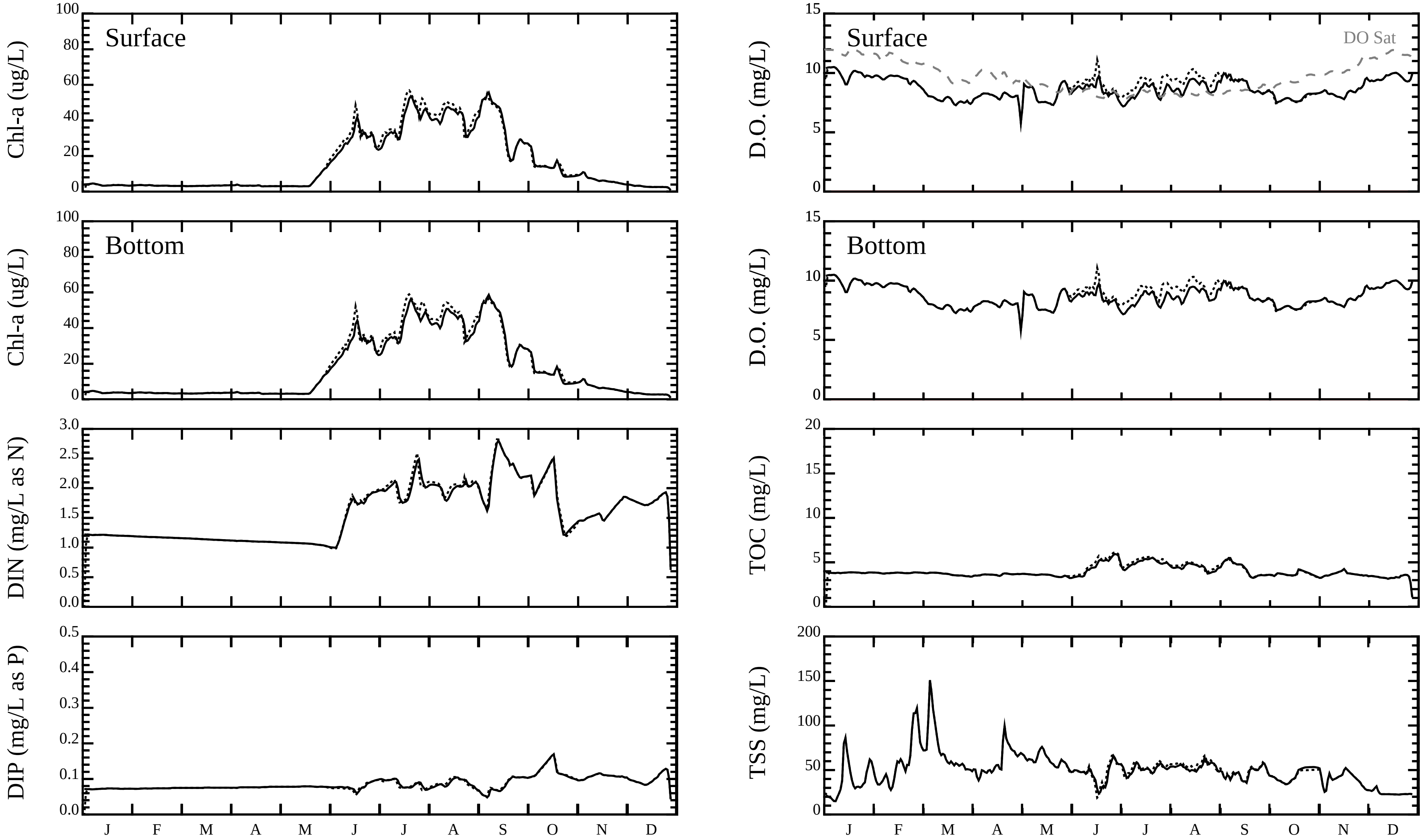

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Comparison of Water Quality Model Base and Projection: SJR at R1

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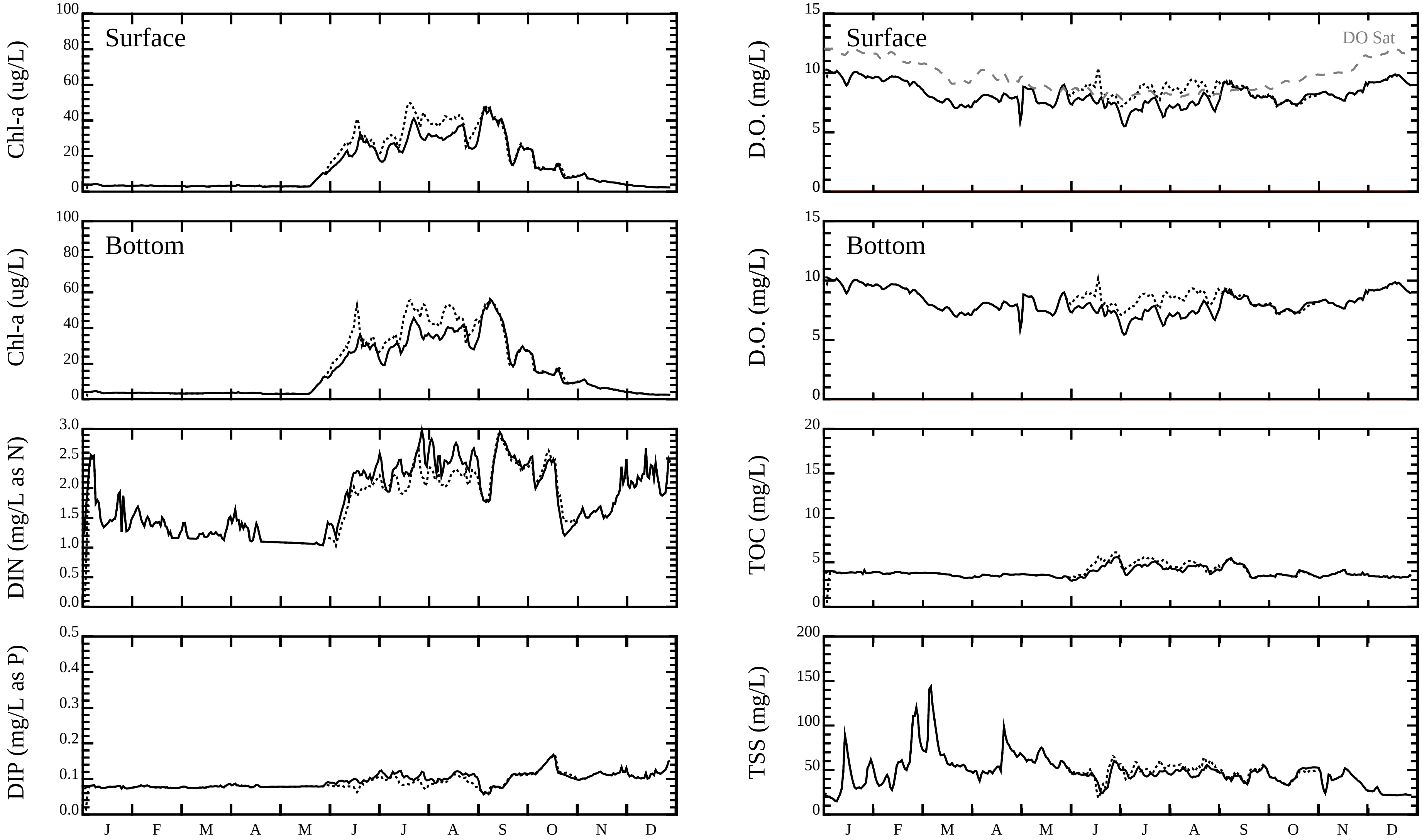

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Comparison of Water Quality Model Base and Projection: SJR at R2

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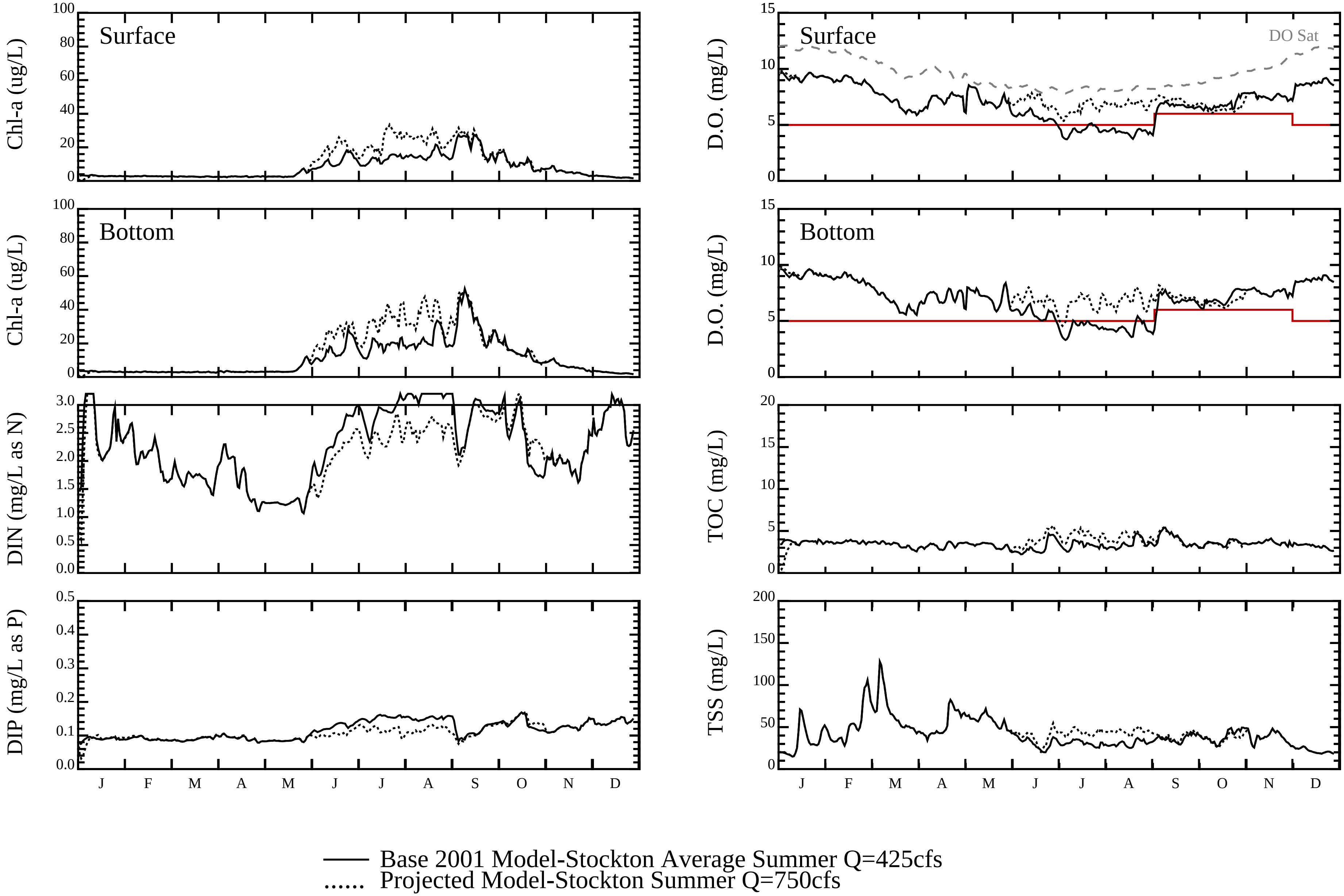

Comparison of Water Quality Model Base and Projection: SJR at R3

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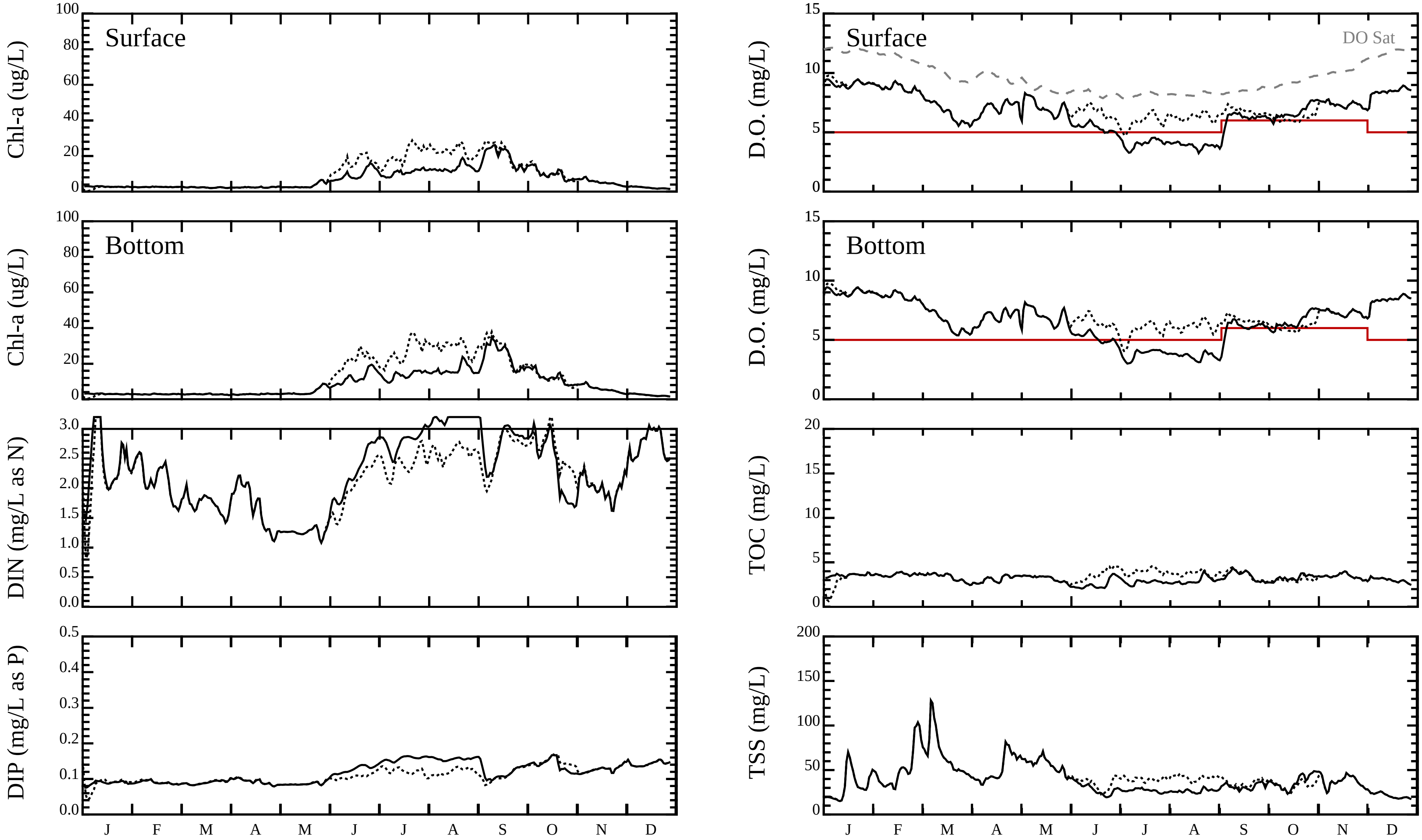

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Comparison of Water Quality Model Base and Projection: SJR at R4

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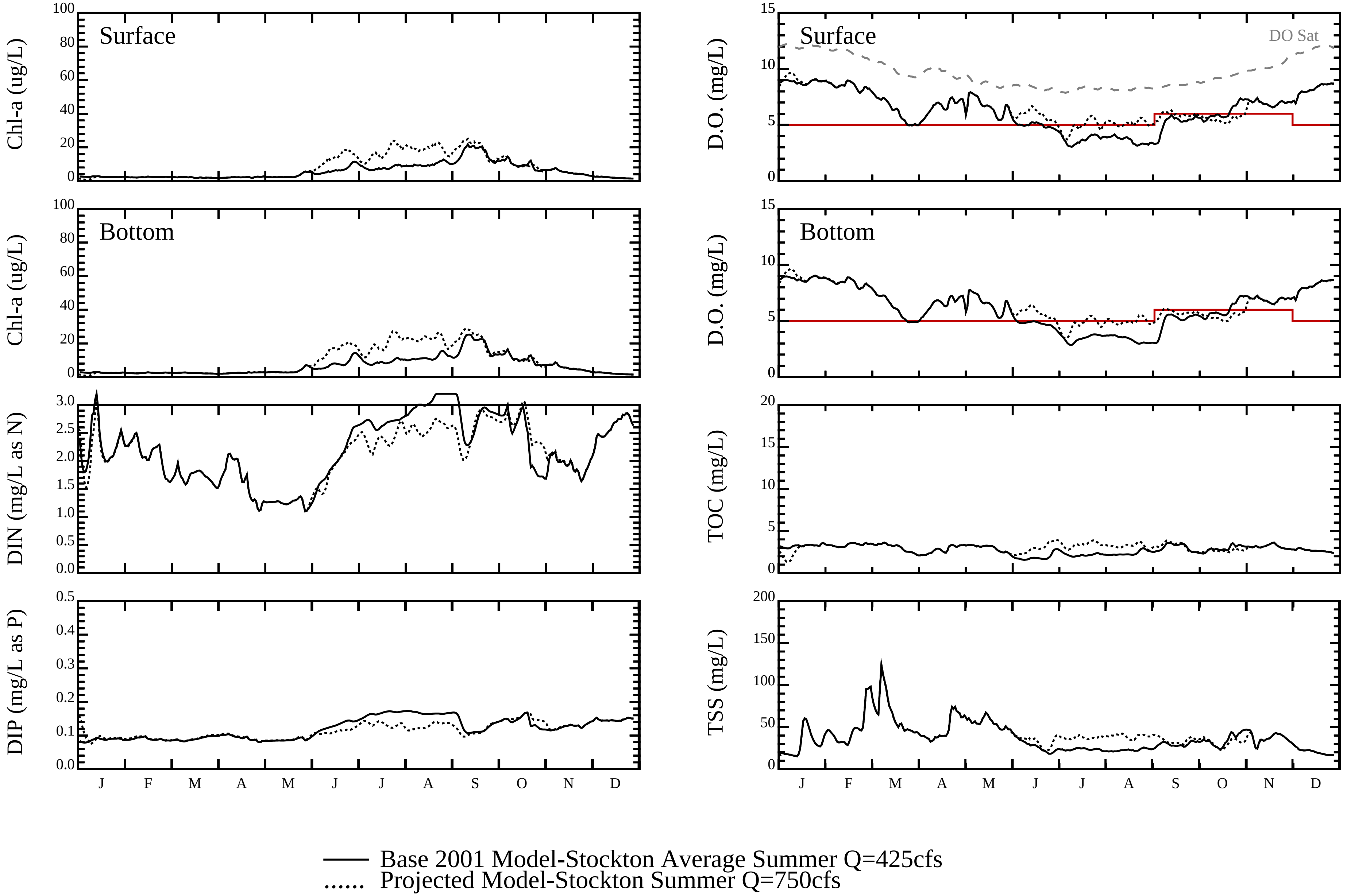

Comparison of Water Quality Model Base and Projection: SJR at R5

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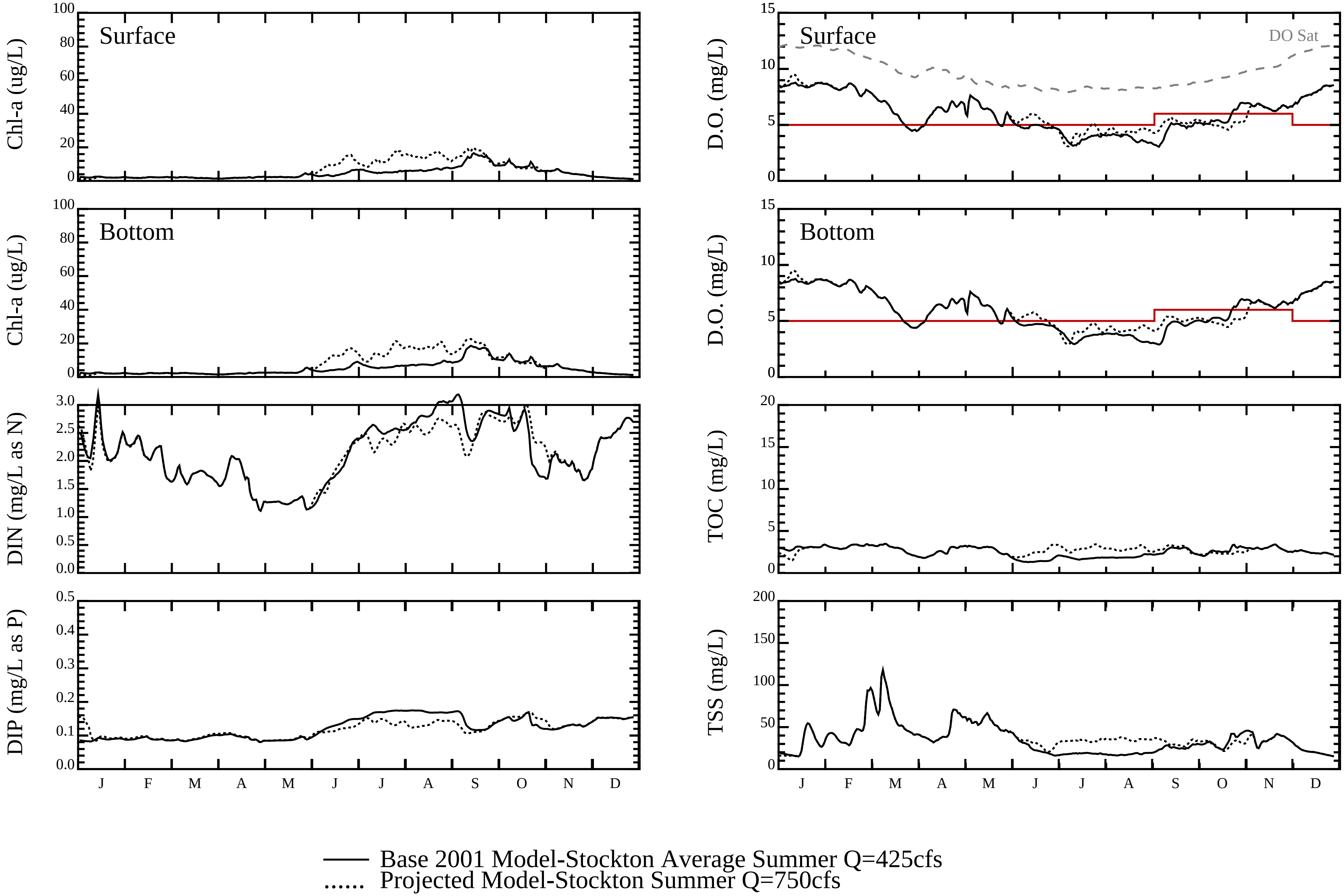

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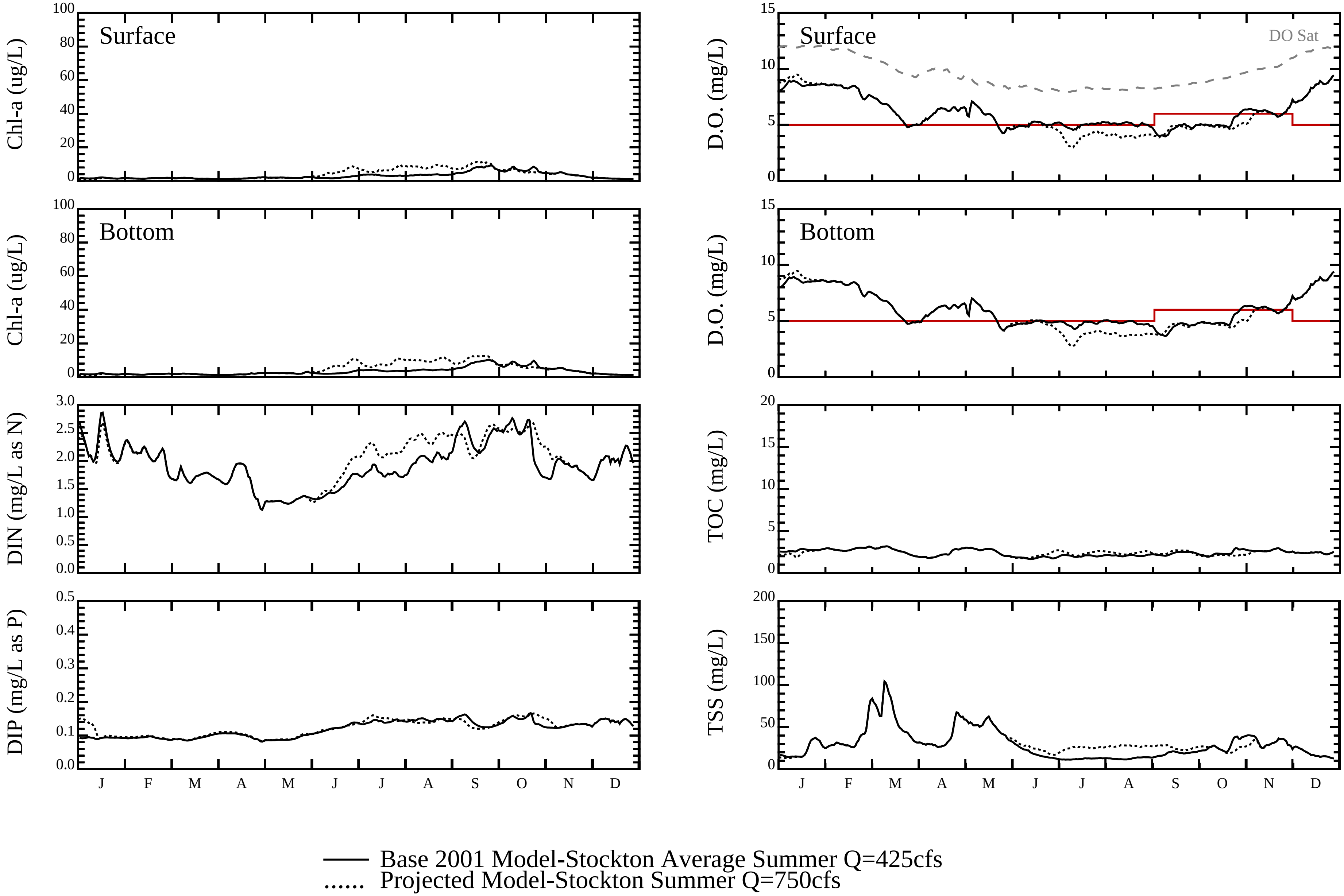

Comparison of Water Quality Model Base and Projection: SJR at R7

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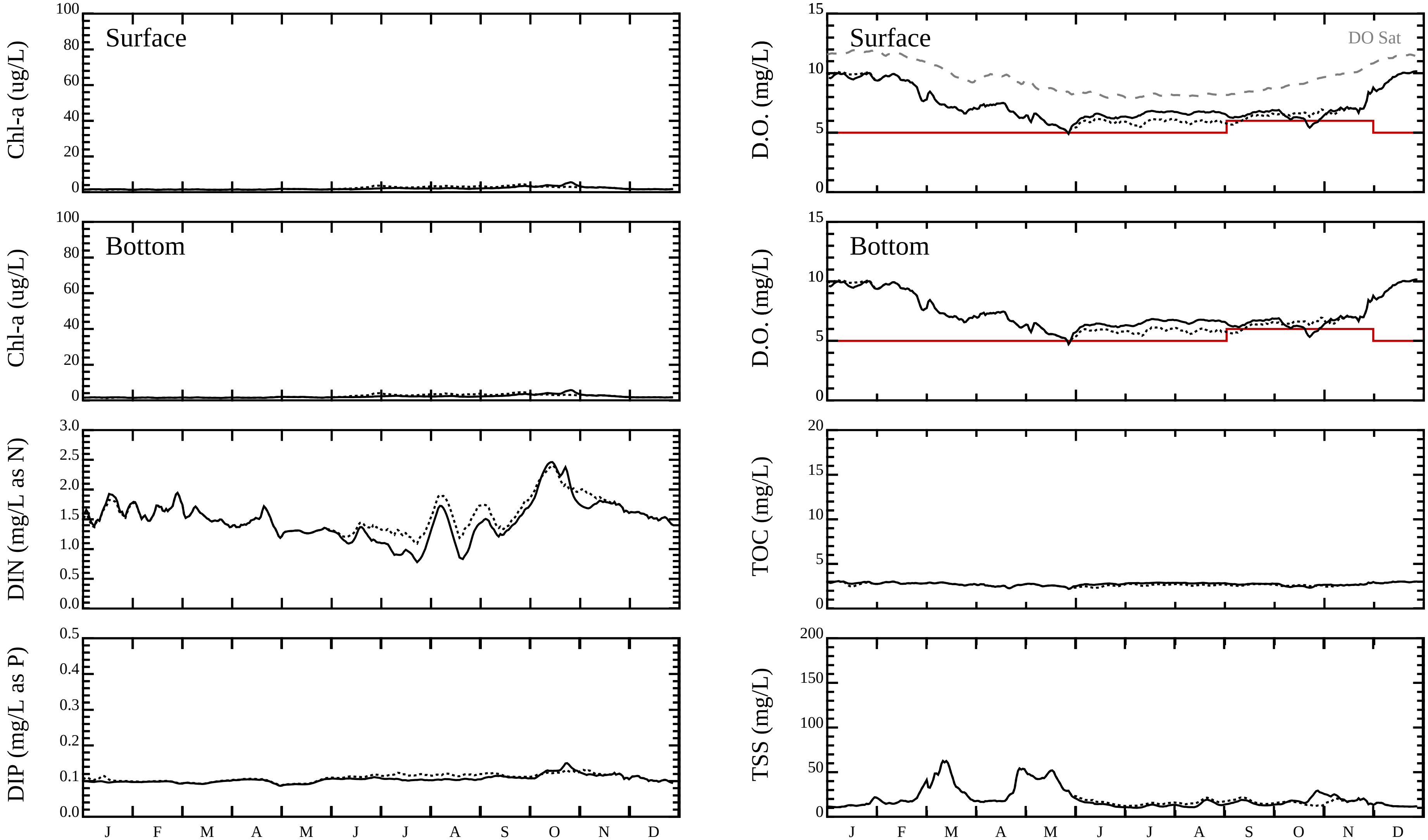

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Comparison of Water Quality Model Base and Projection: SJR at R8

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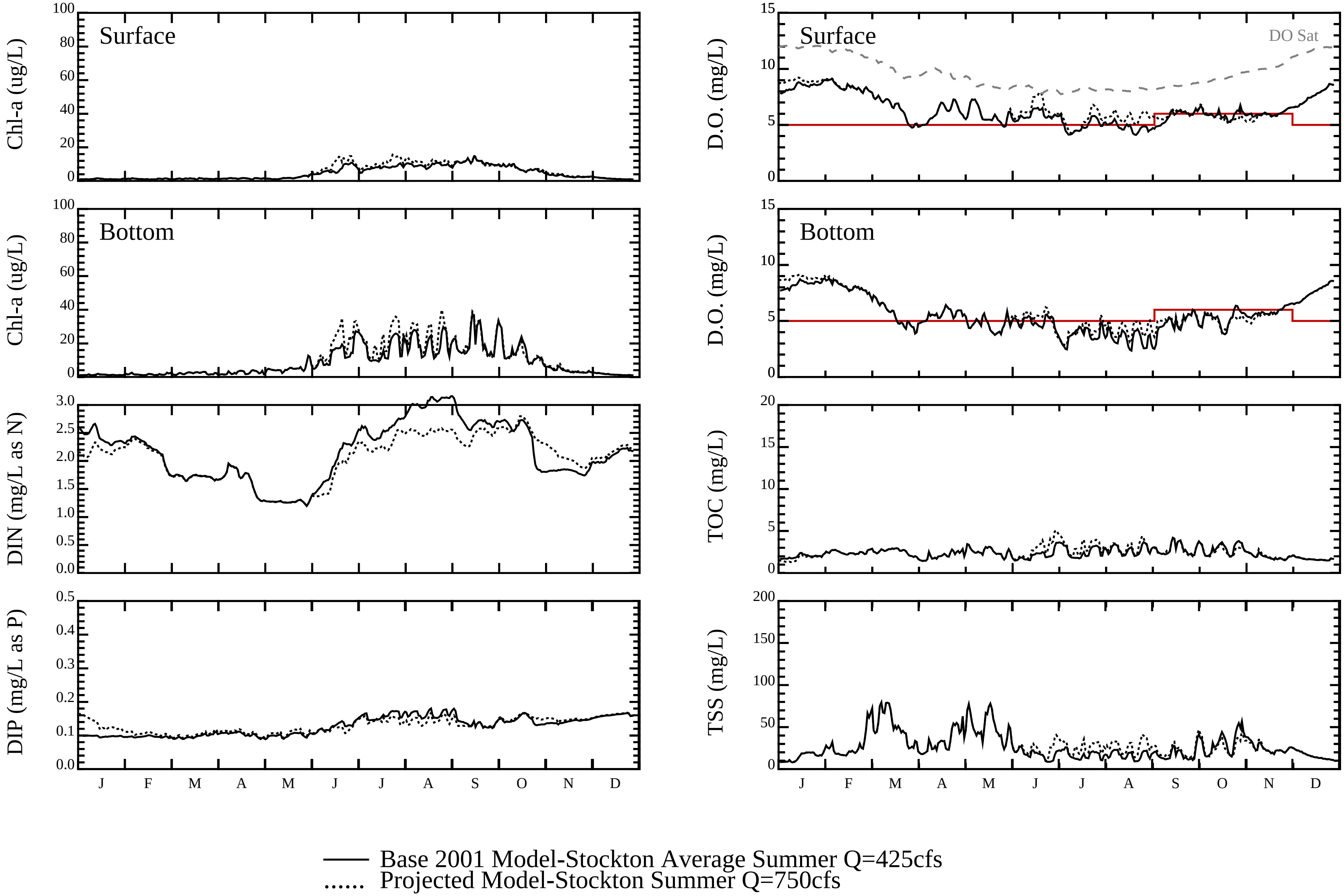

Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

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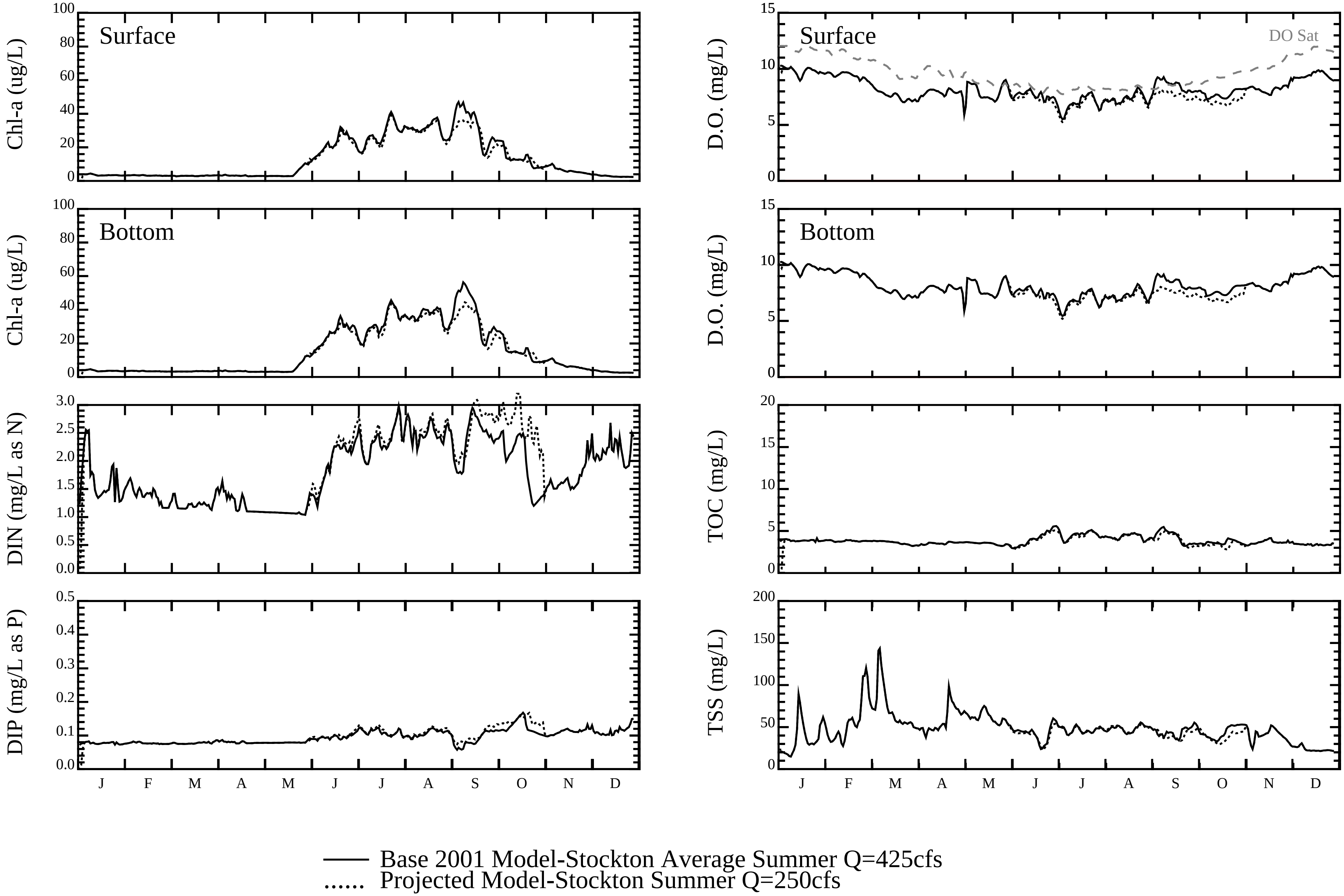

Comparison of Water Quality Model Base and Projection: SJR at R2

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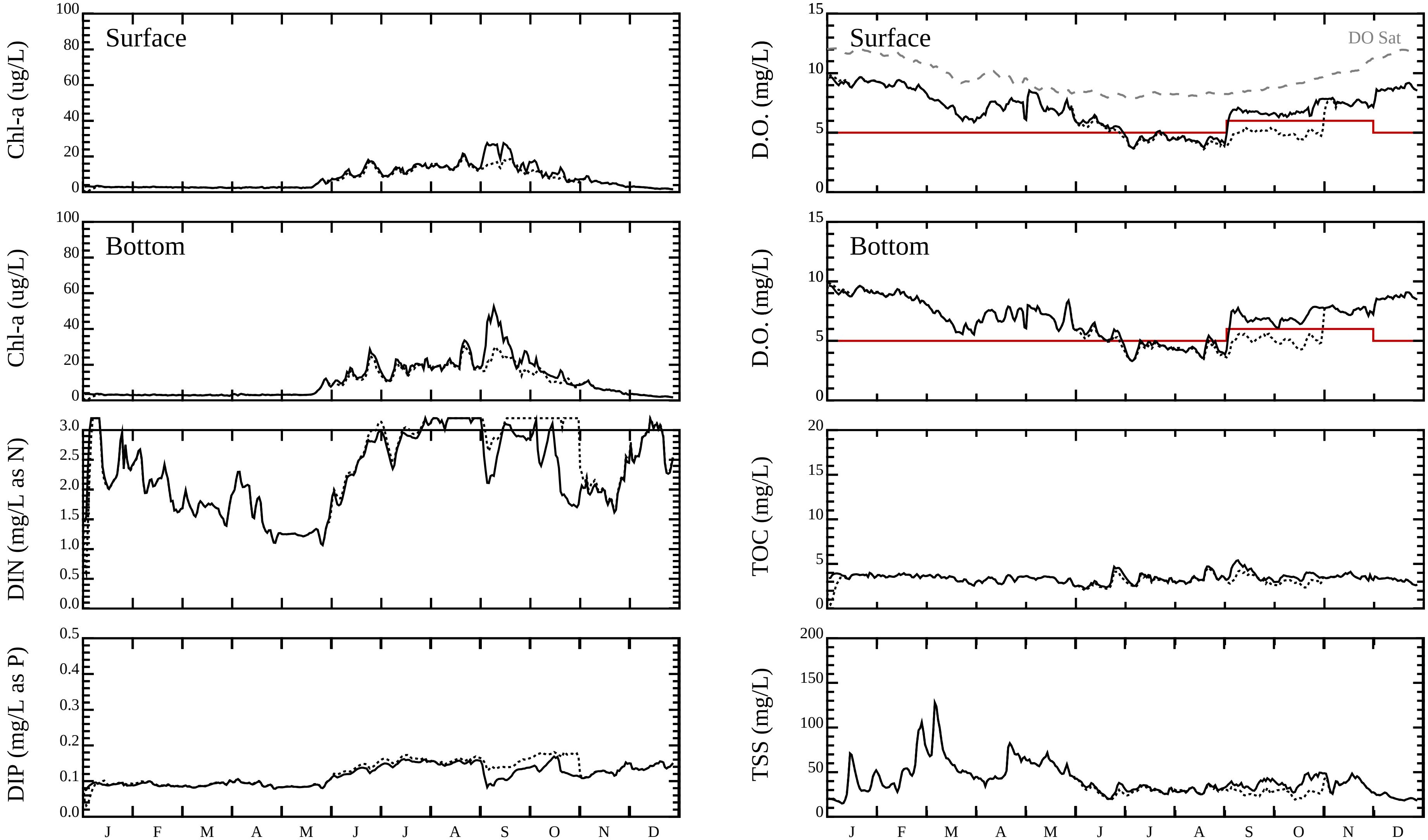

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Comparison of Water Quality Model Base and Projection: SJR at R3

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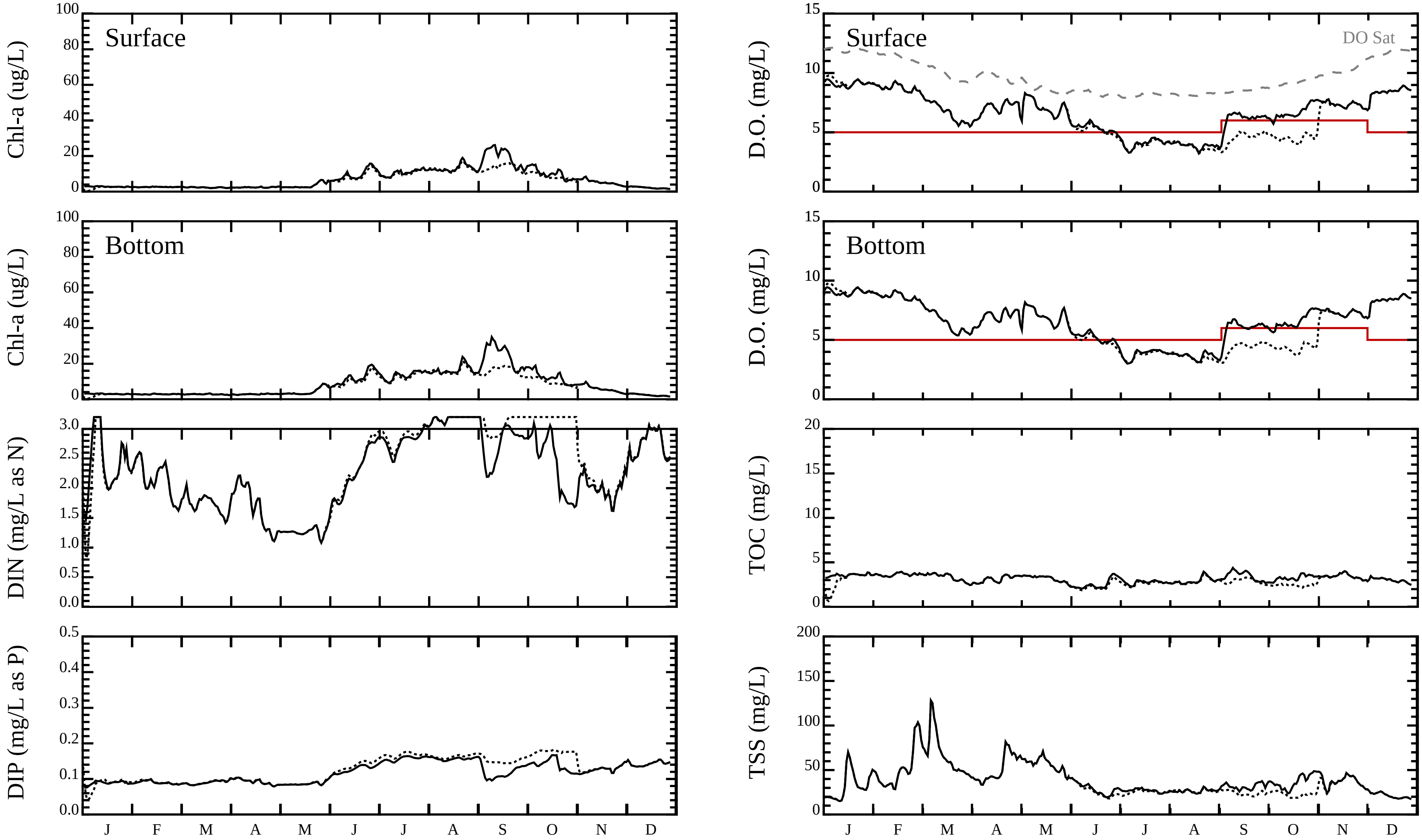

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Comparison of Water Quality Model Base and Projection: SJR at R4

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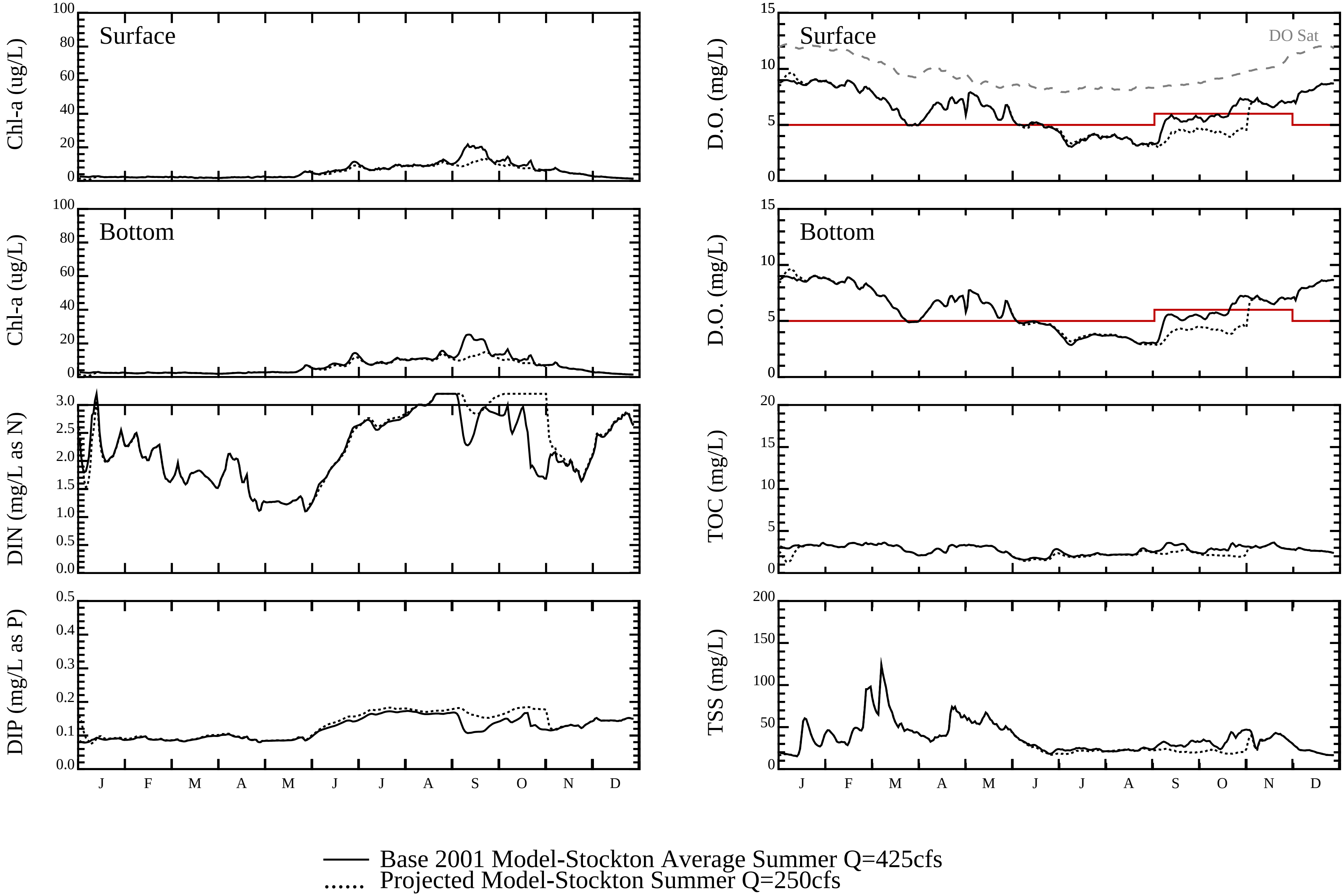

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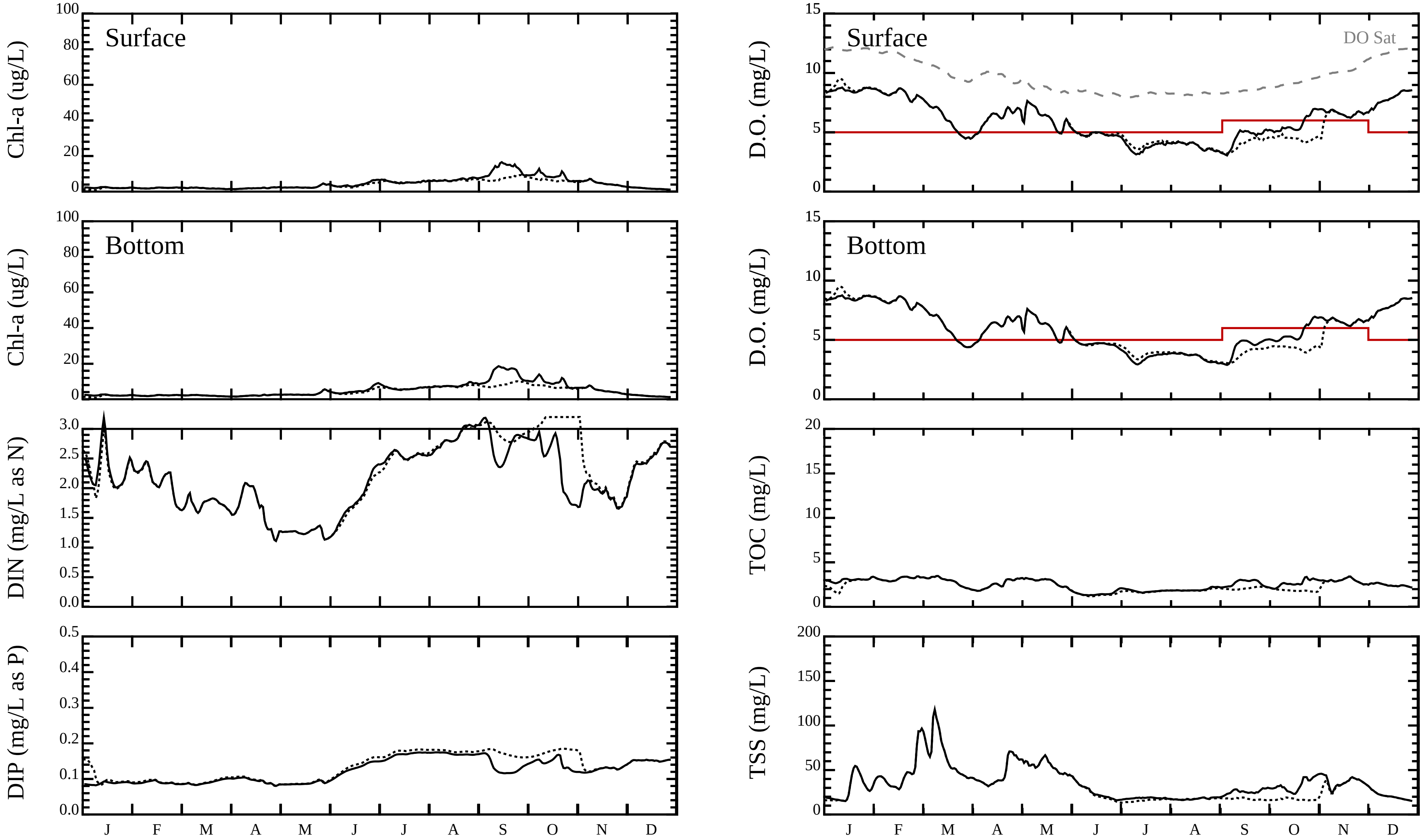

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Comparison of Water Quality Model Base and Projection: SJR at R6

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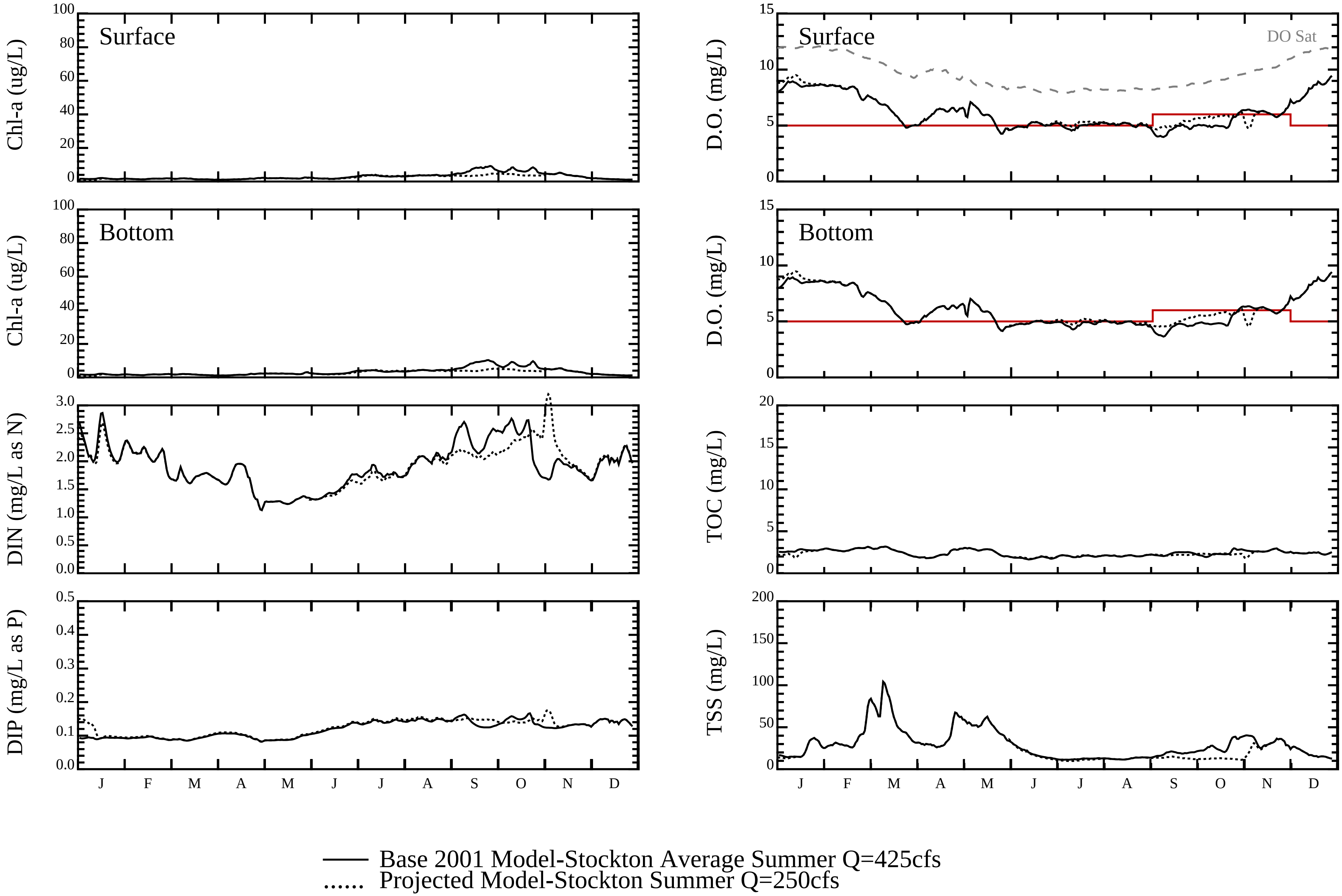

Comparison of Water Quality Model Base and Projection: SJR at R7

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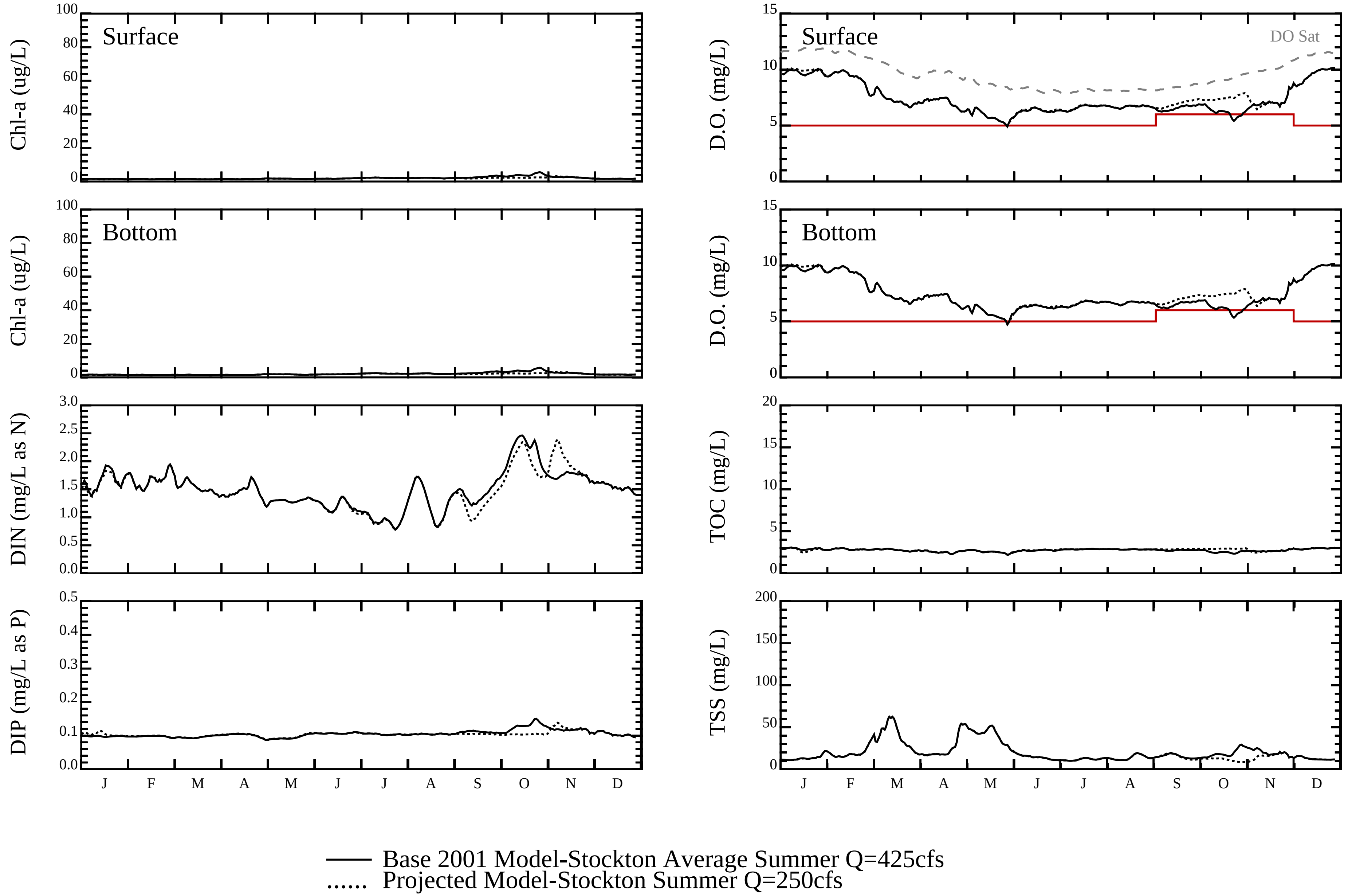

Comparison of Water Quality Model Base and Projection: SJR at R8

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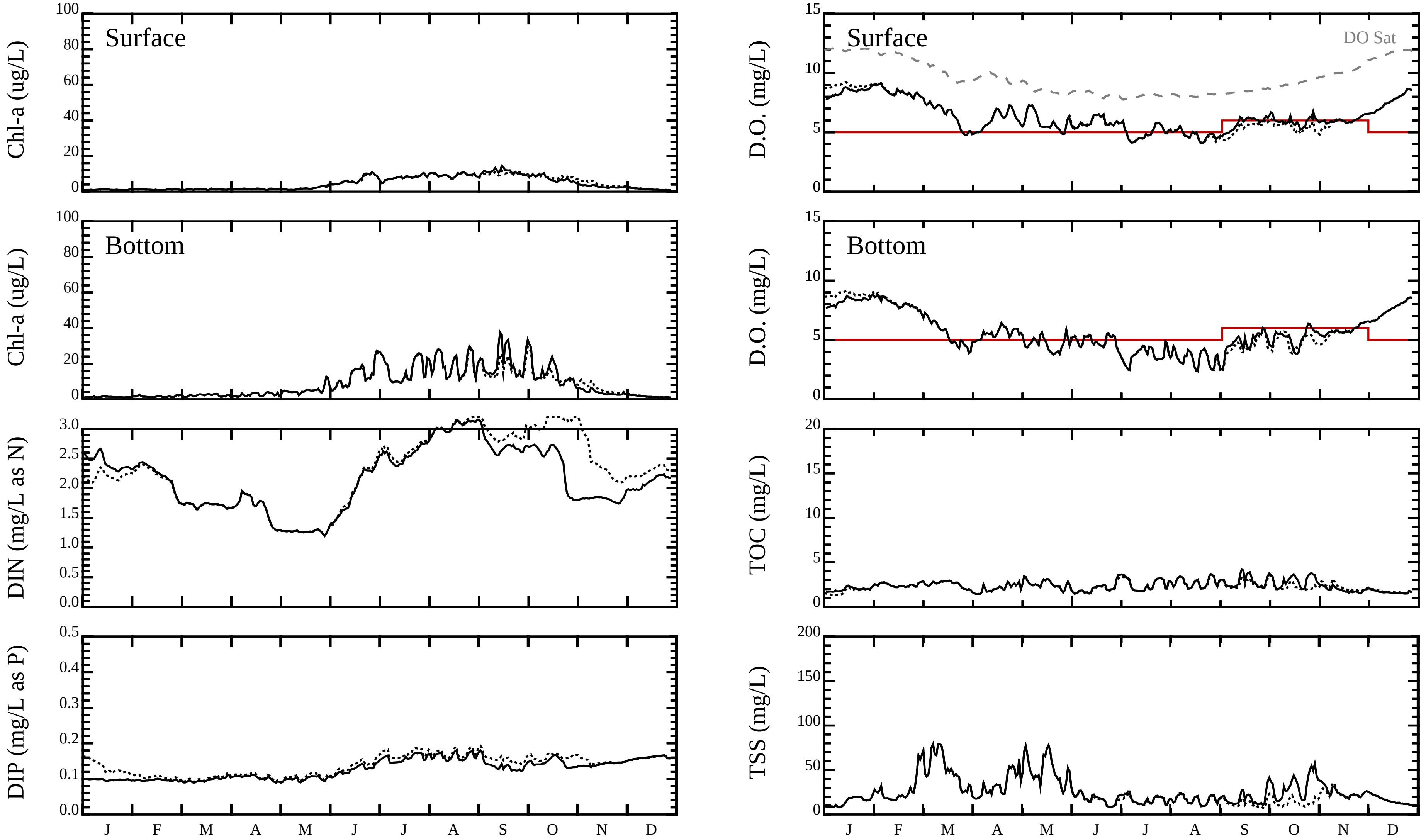

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Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

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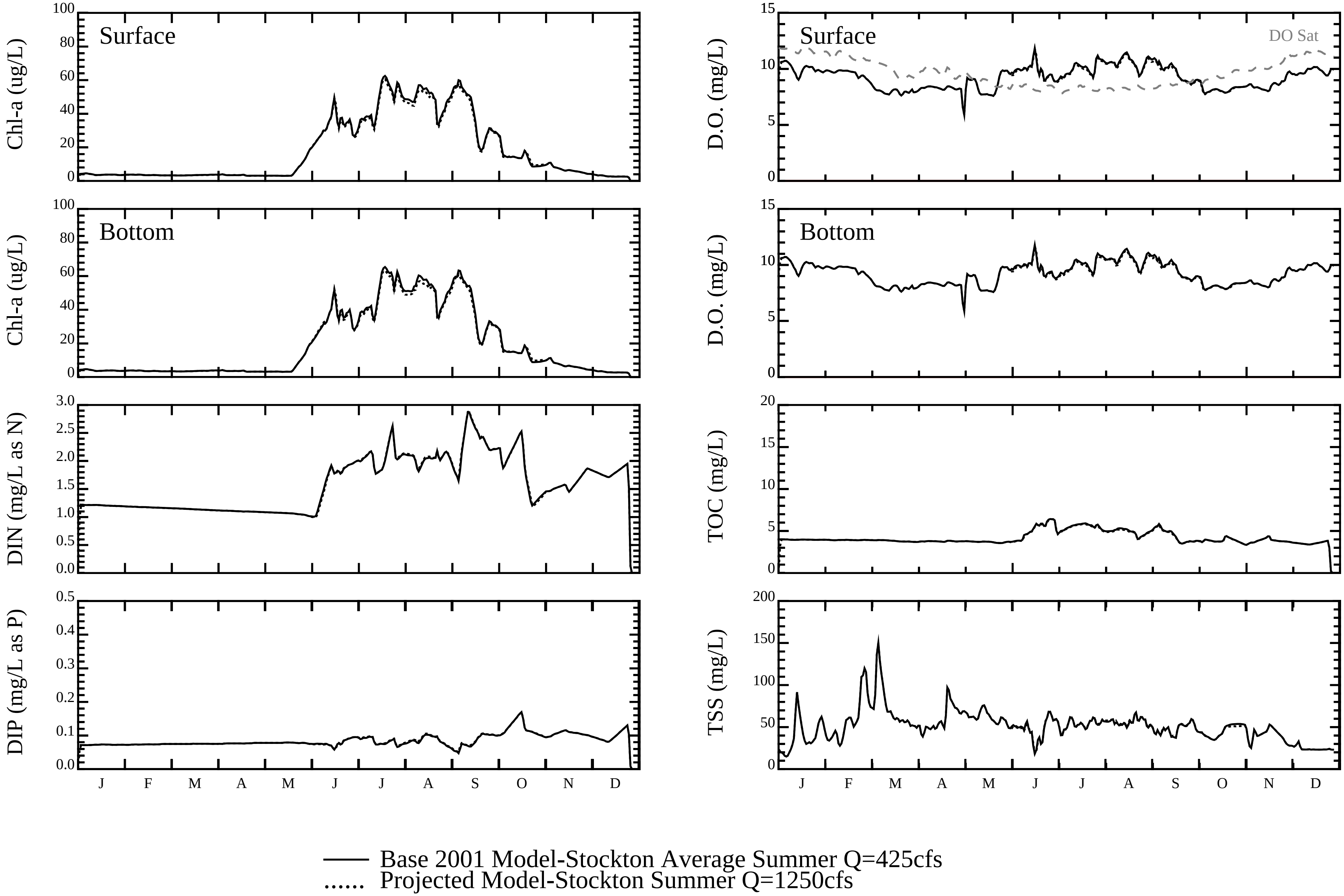

Comparison of Water Quality Model Base and Projection: SJR at Mossdale

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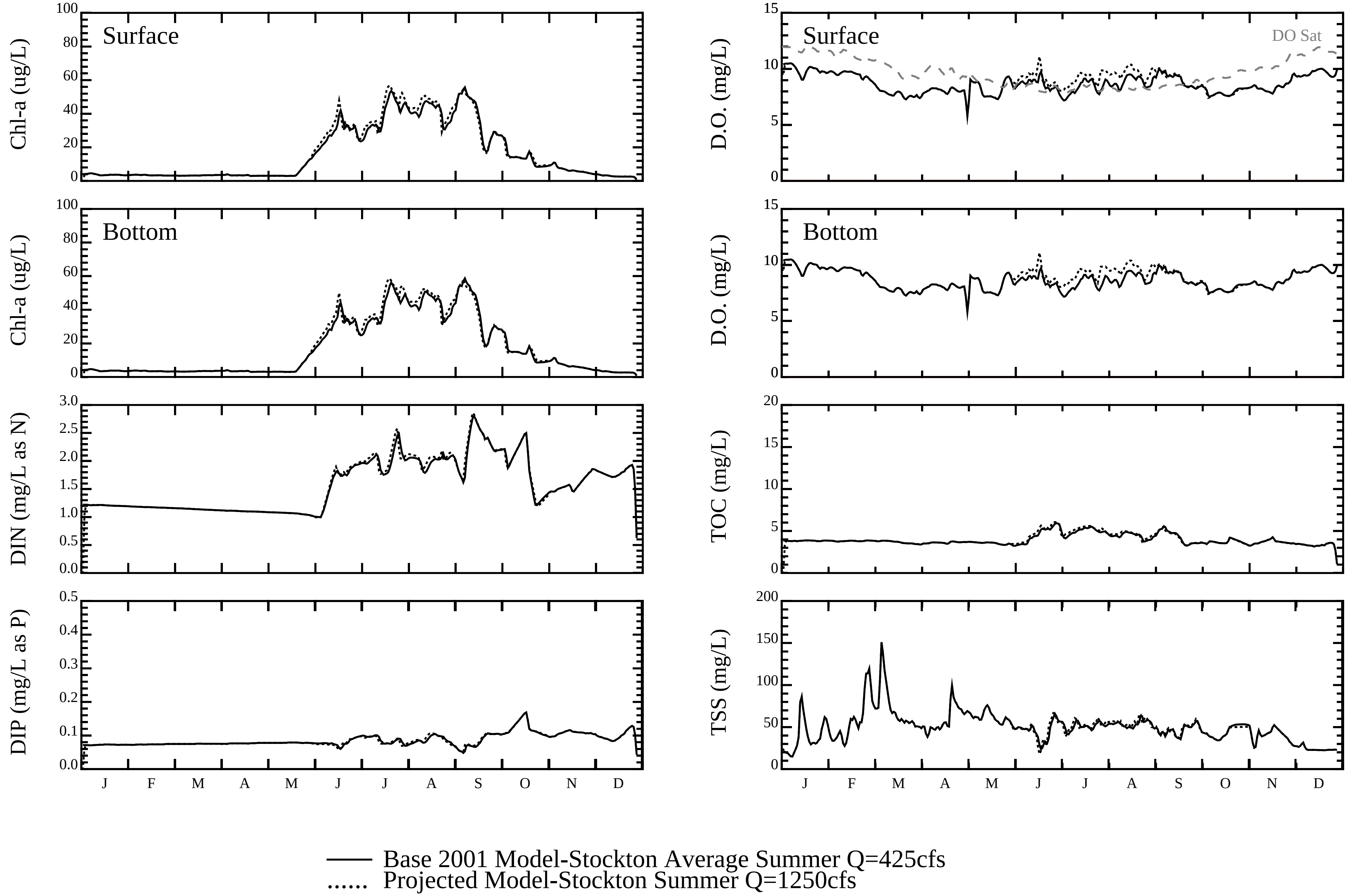

Comparison of Water Quality Model Base and Projection: SJR at R1

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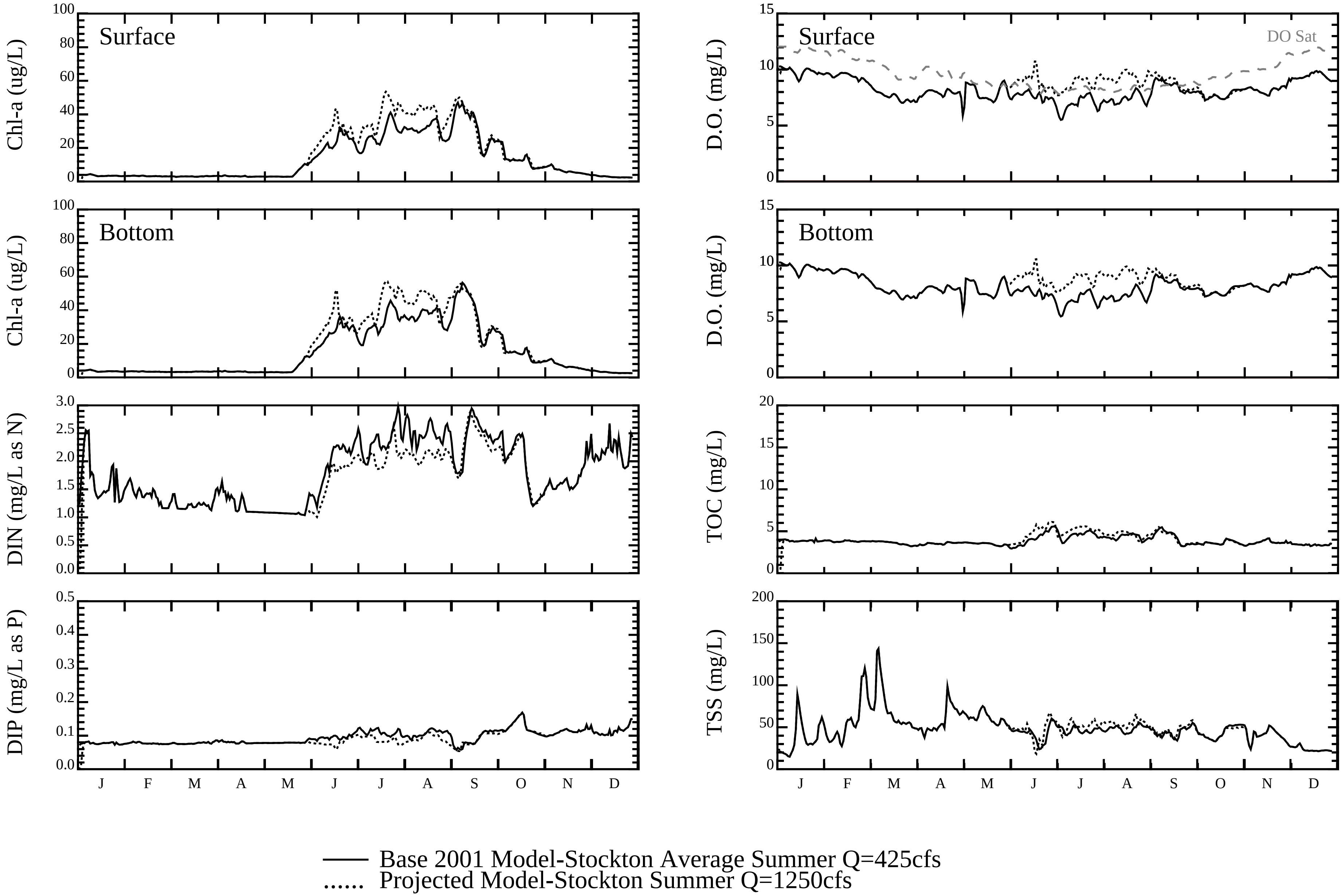

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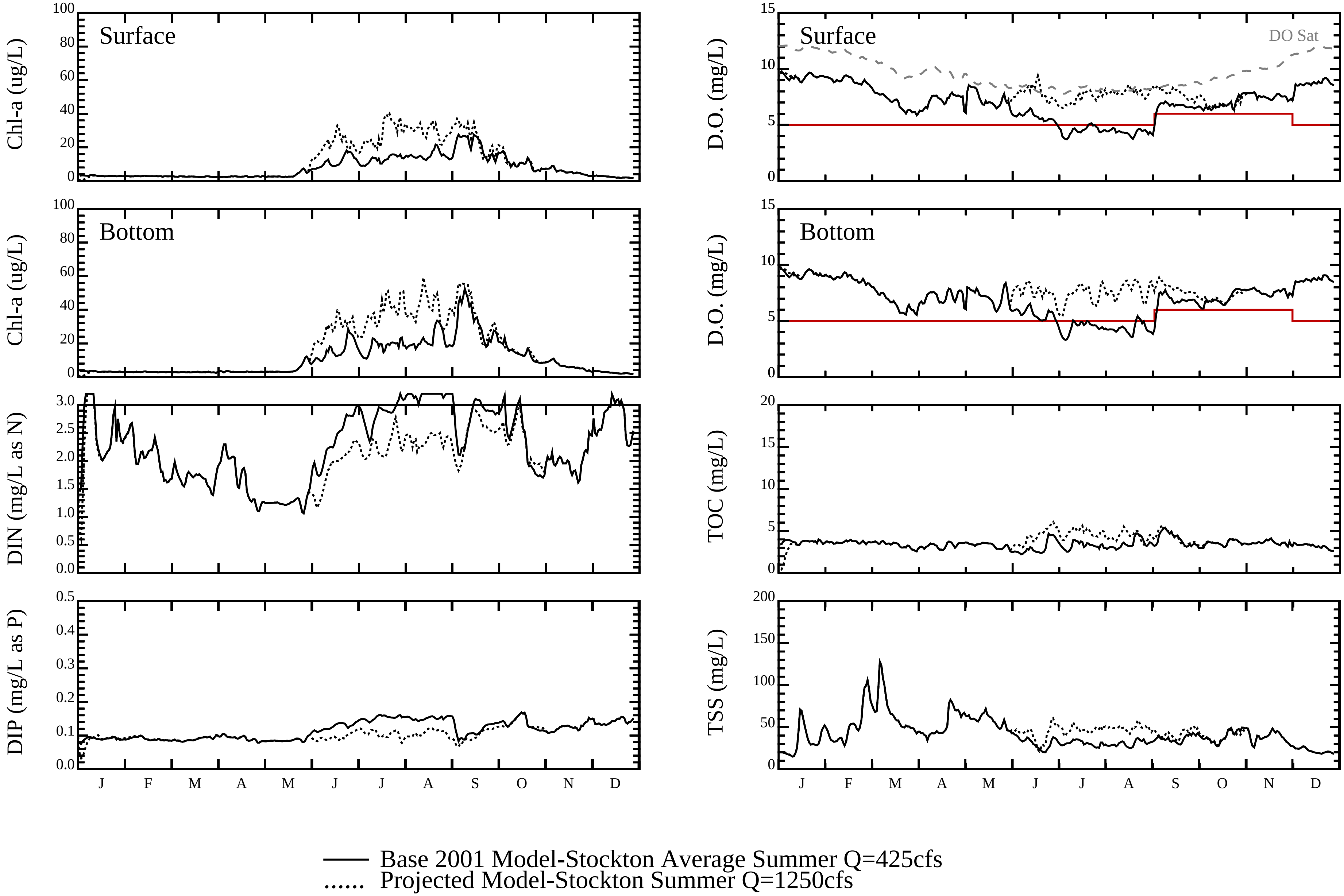

Comparison of Water Quality Model Base and Projection: SJR at R3

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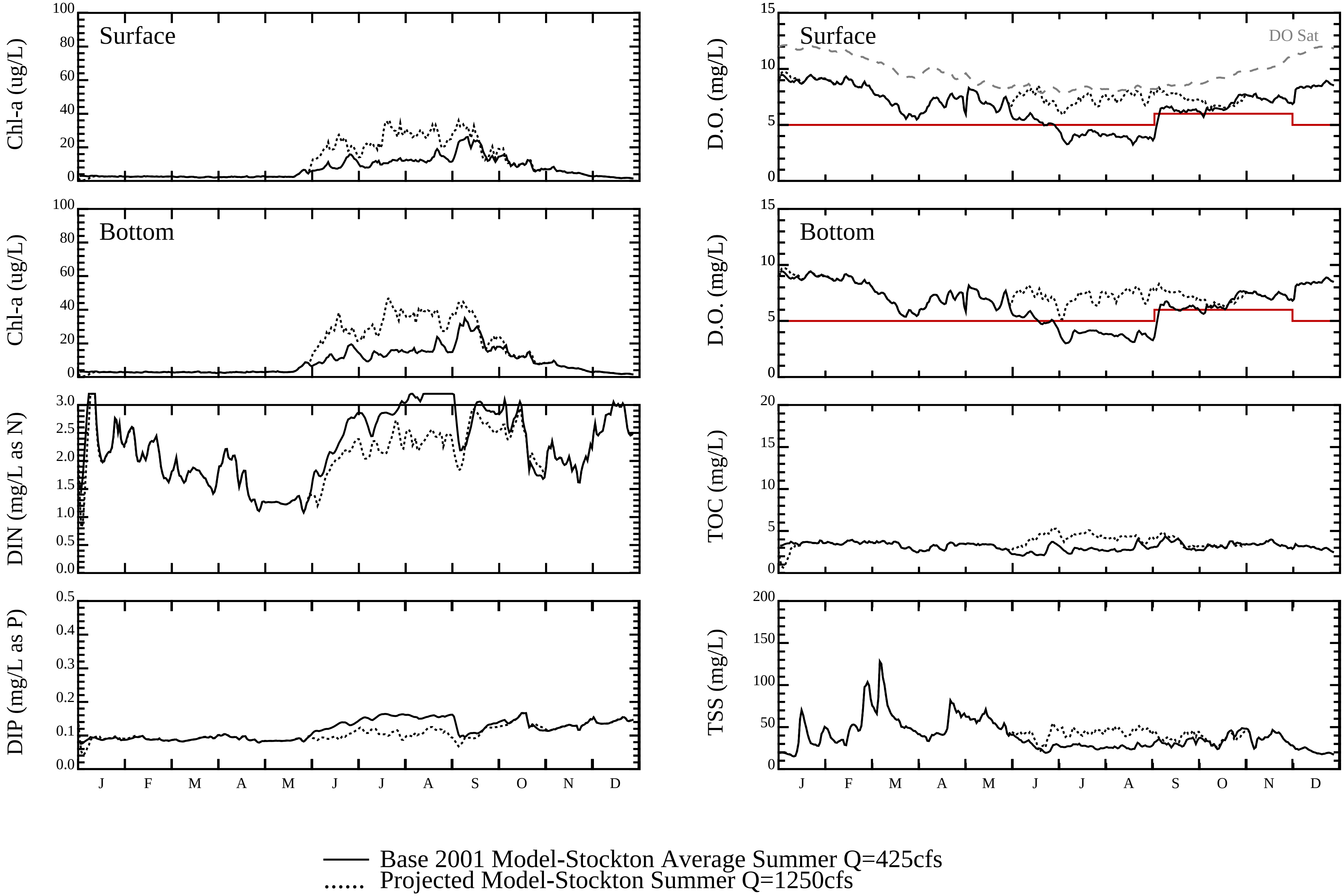

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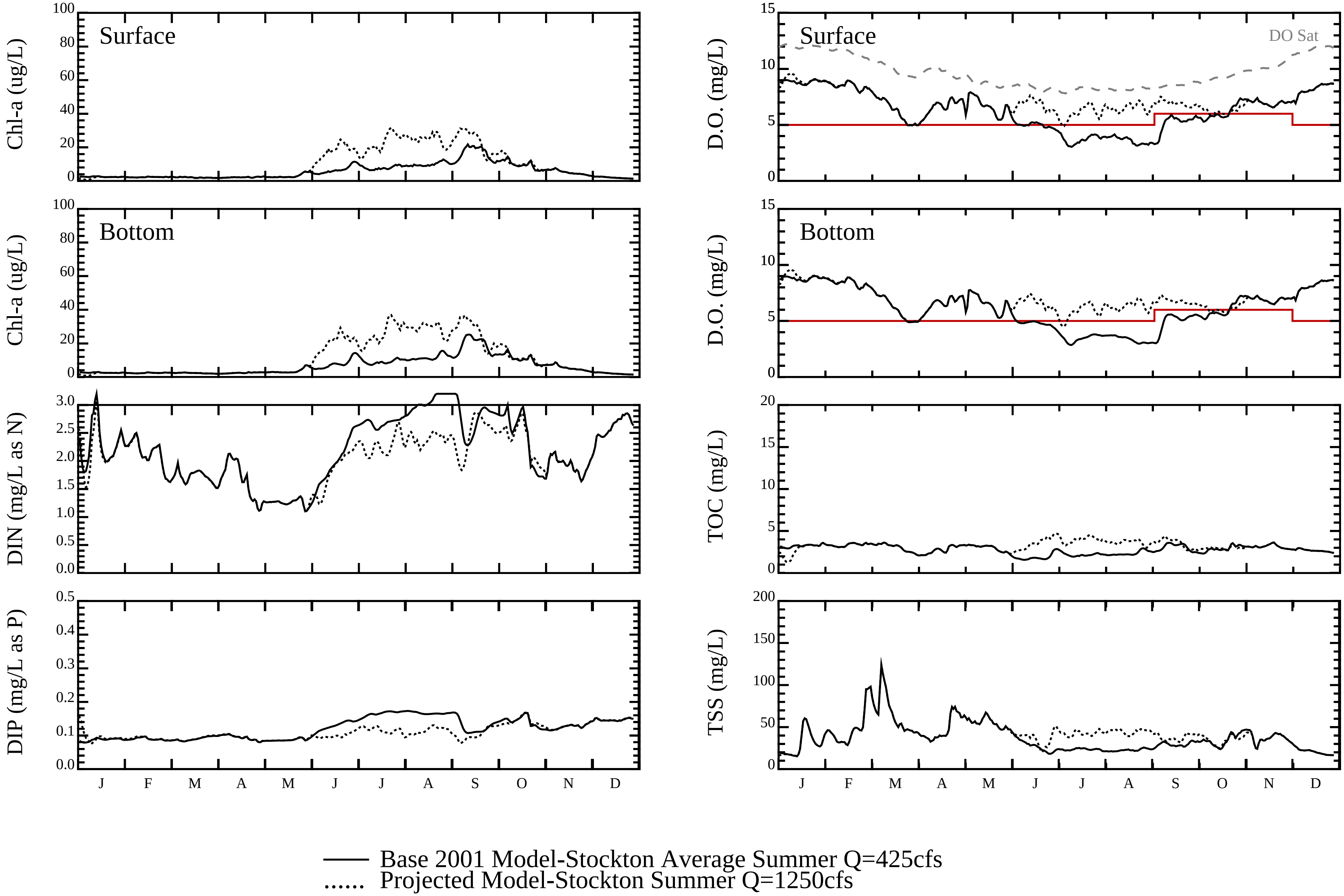

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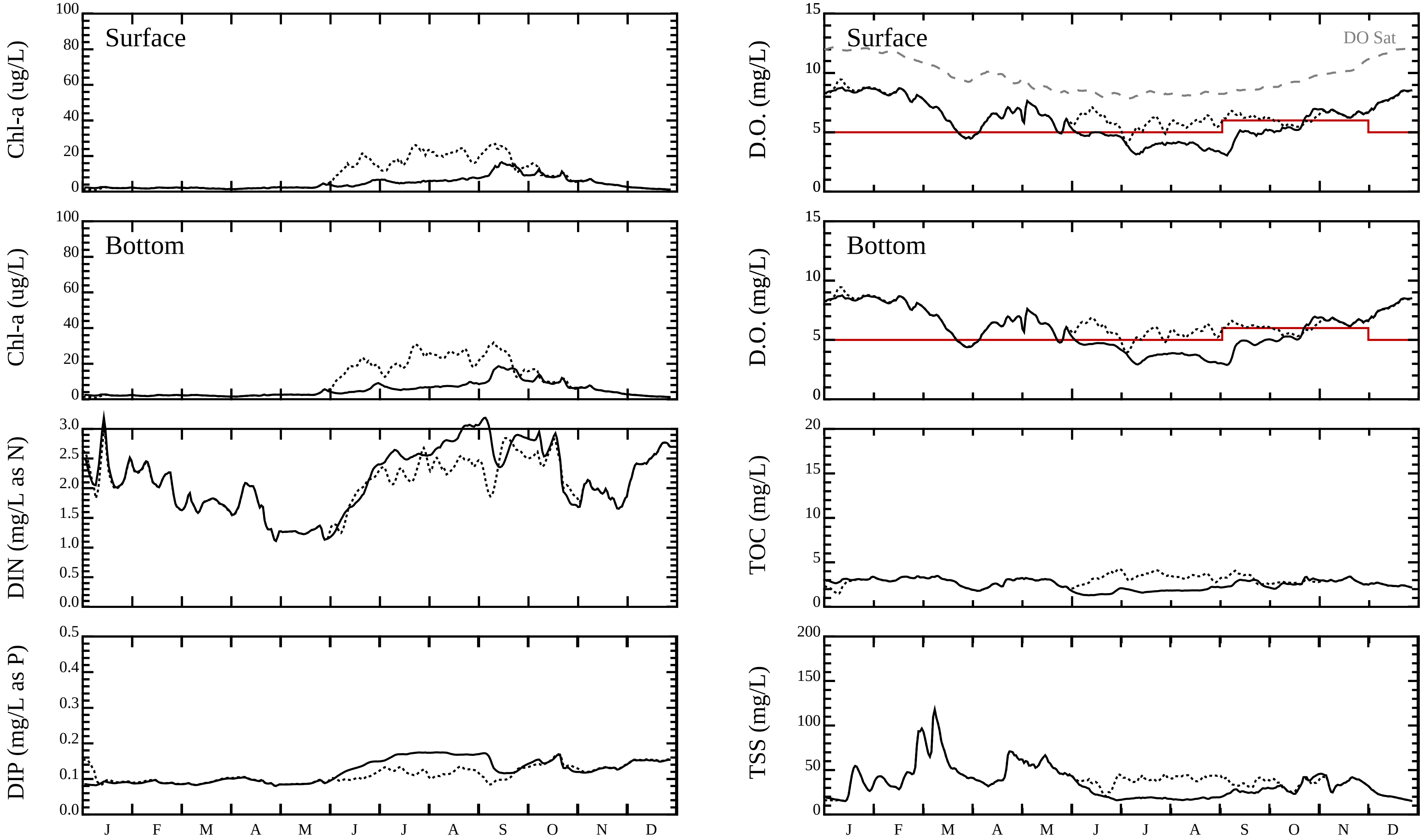

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Comparison of Water Quality Model Base and Projection: SJR at R6

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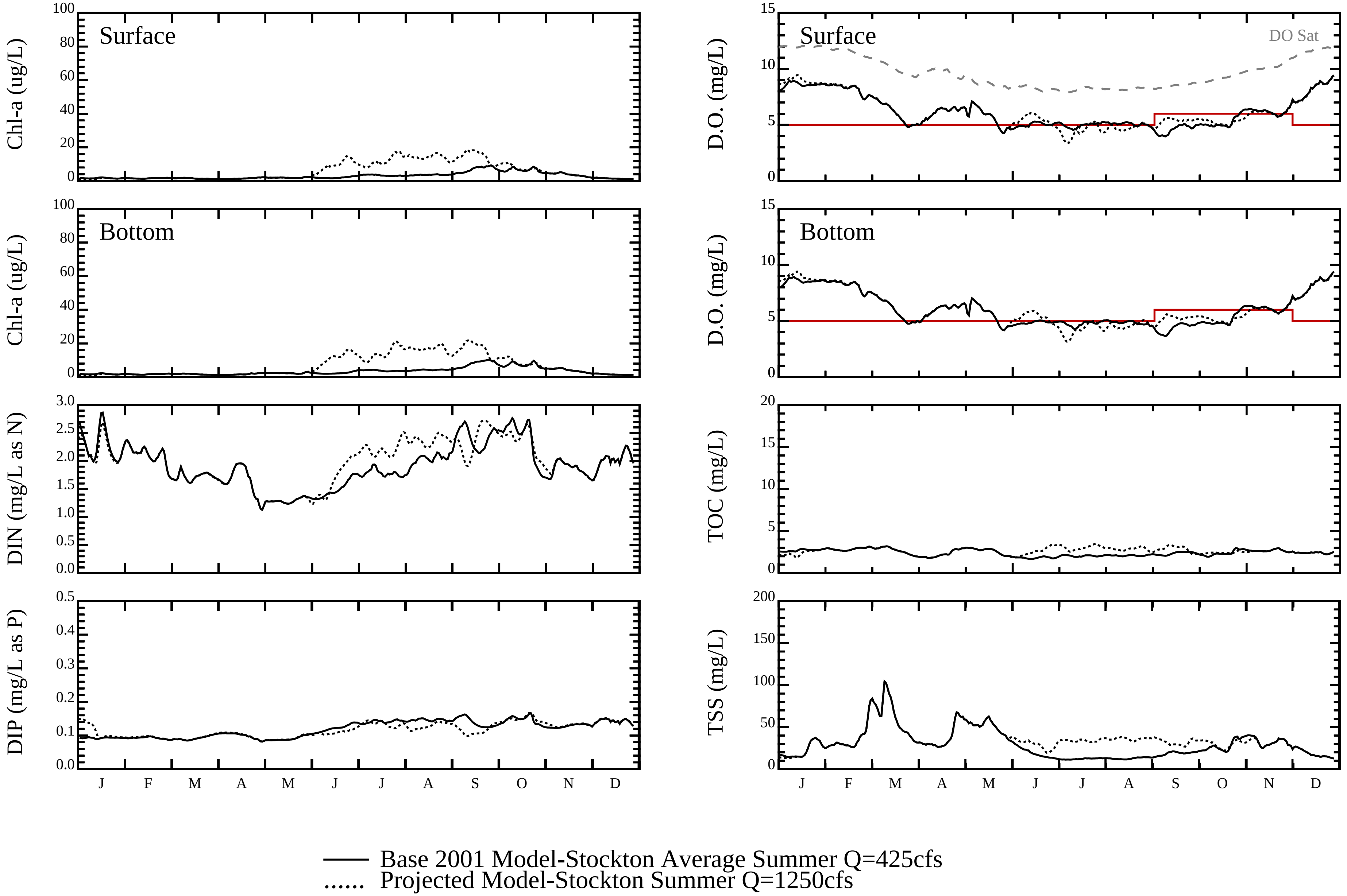

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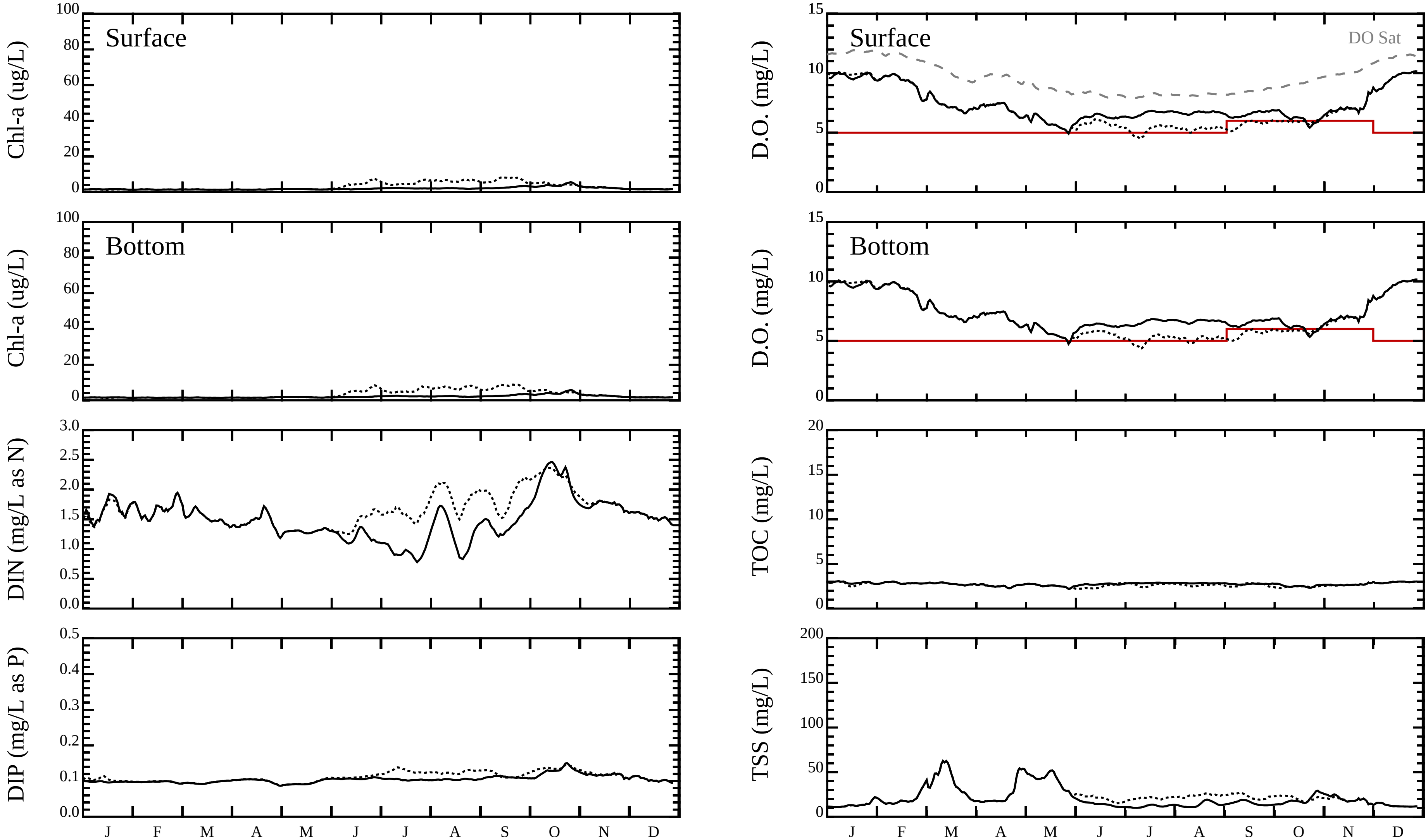

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Comparison of Water Quality Model Base and Projection: SJR at R8

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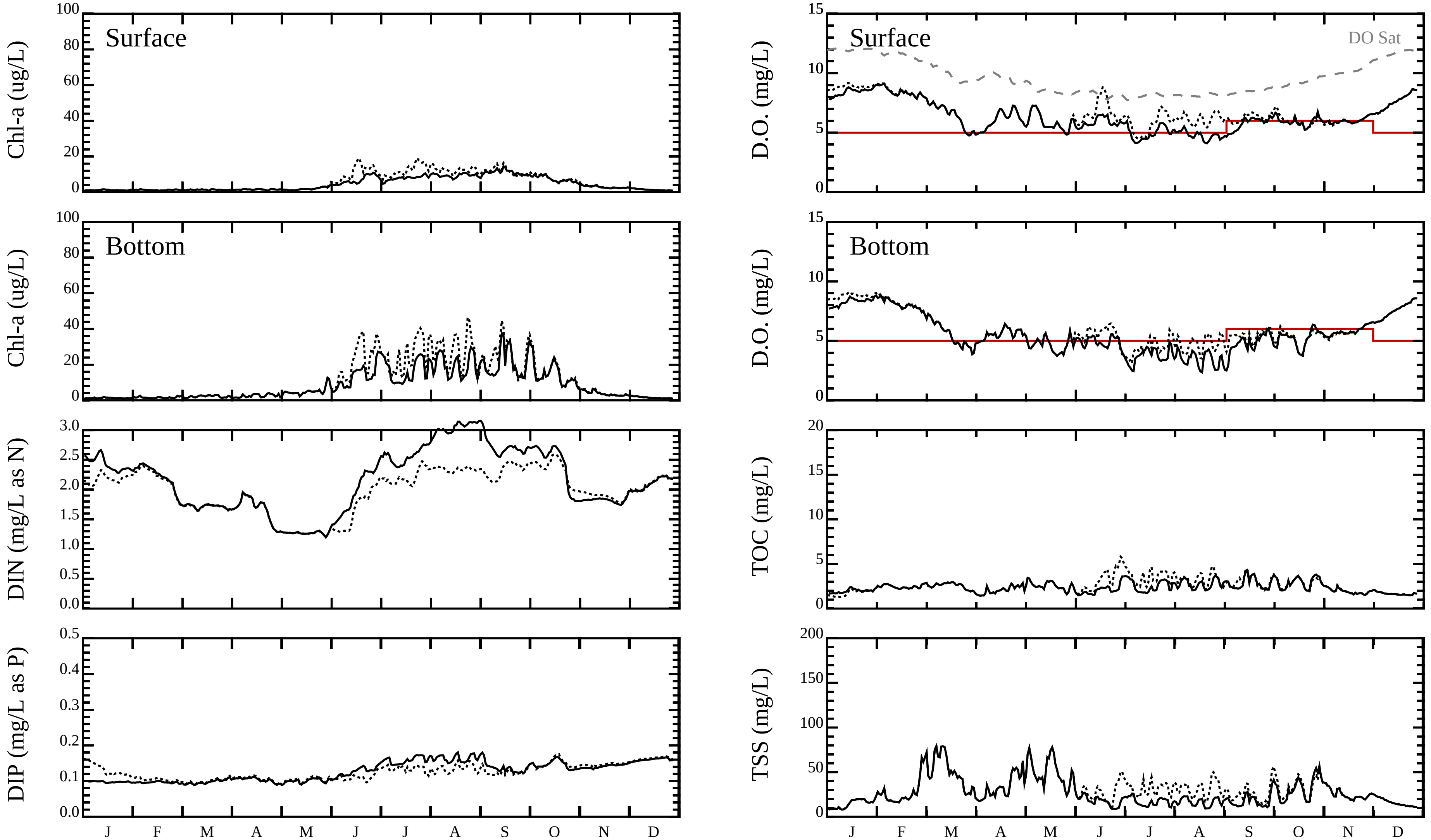

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Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

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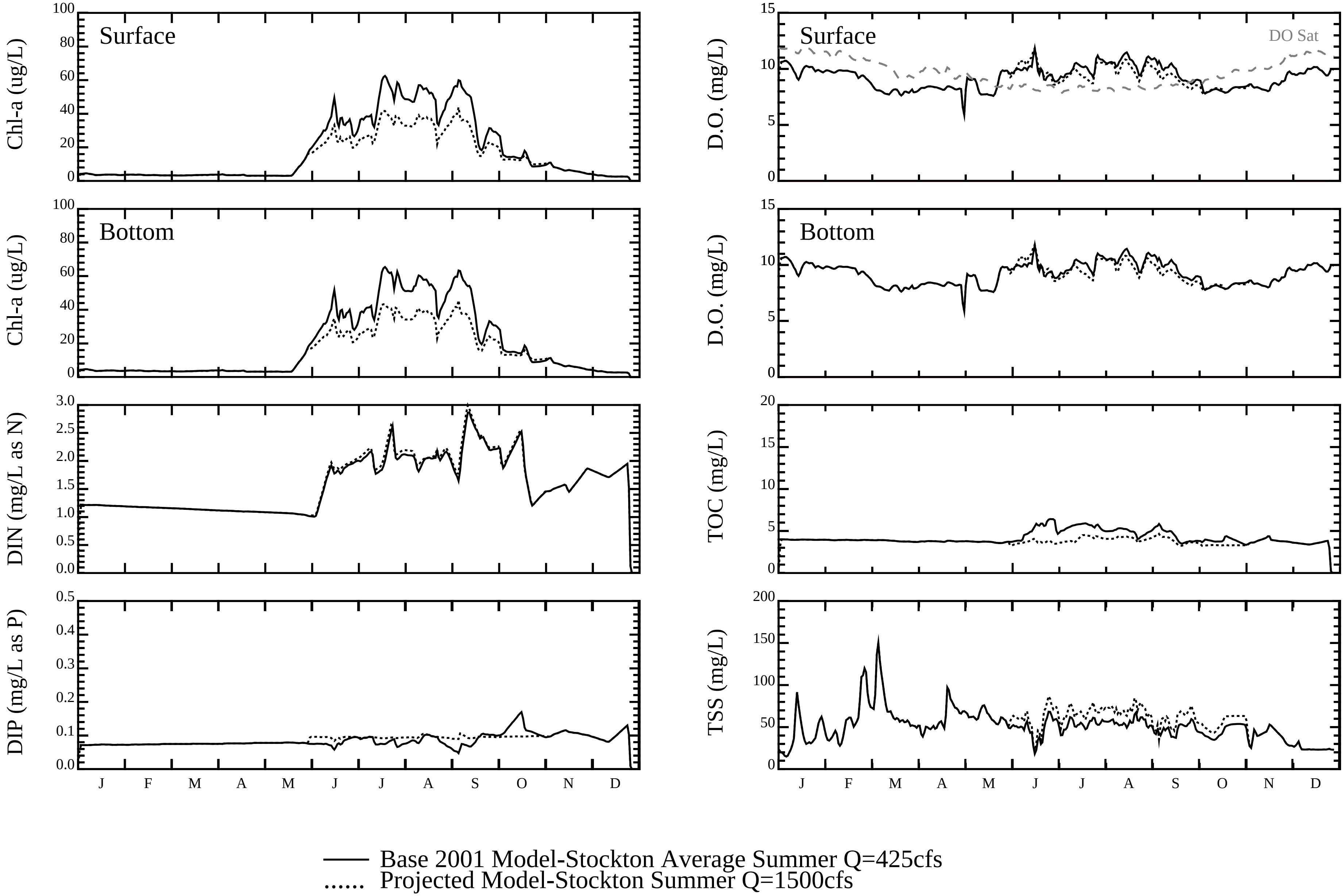
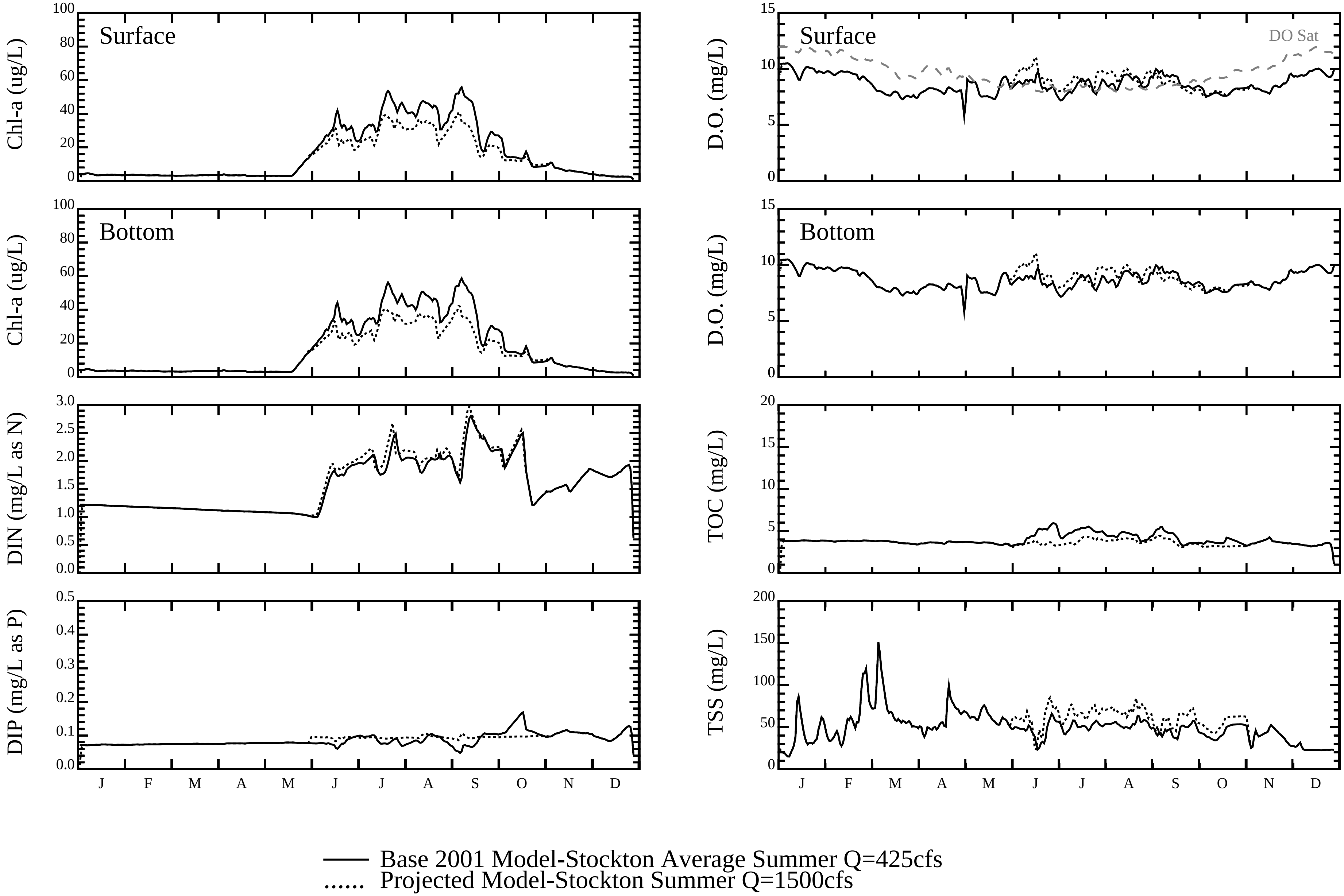


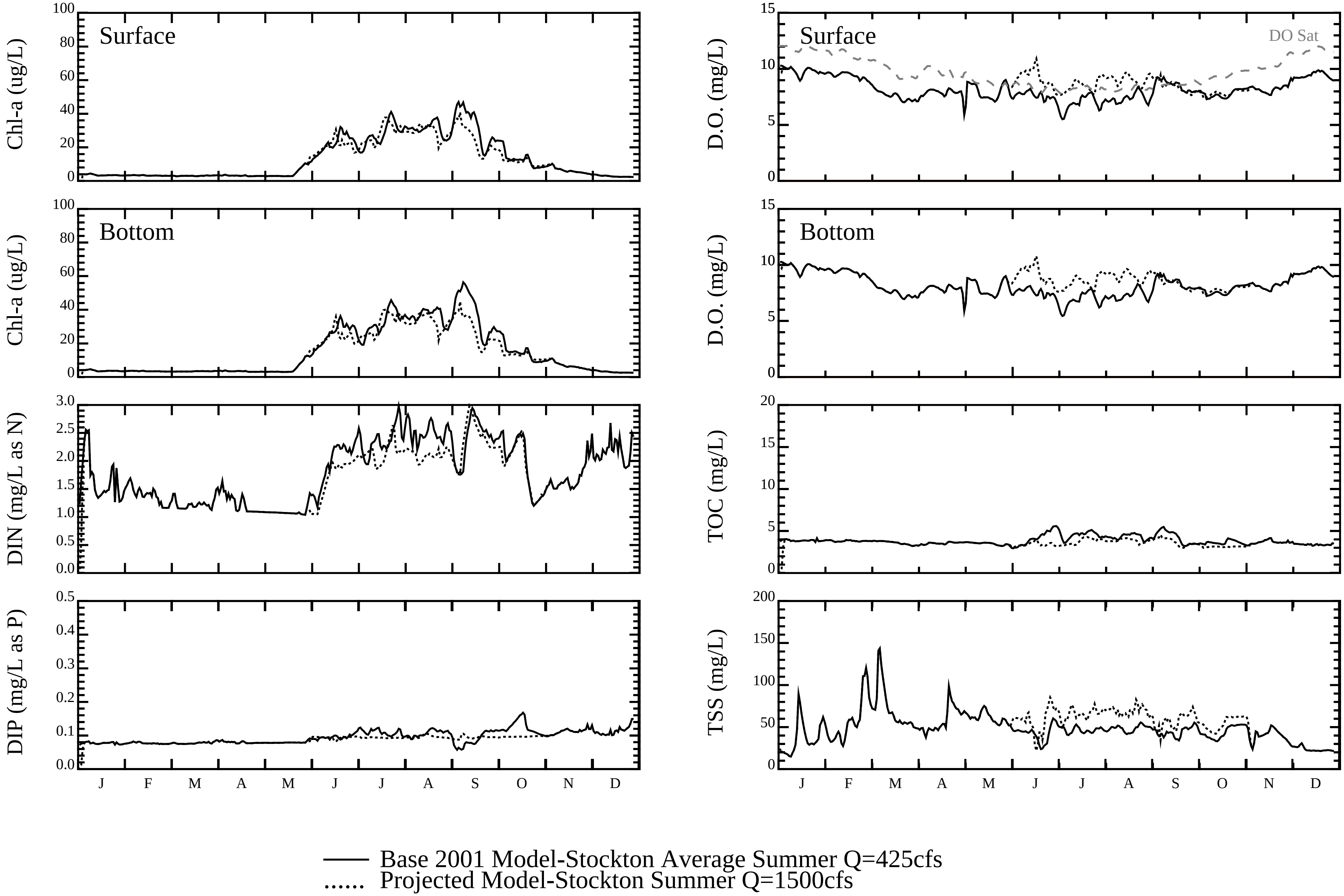
Comparison of Water Quality Model Base and Projection: SJR at Mossdale

DATE: 4/20/2006 TIME: 16: 6:36



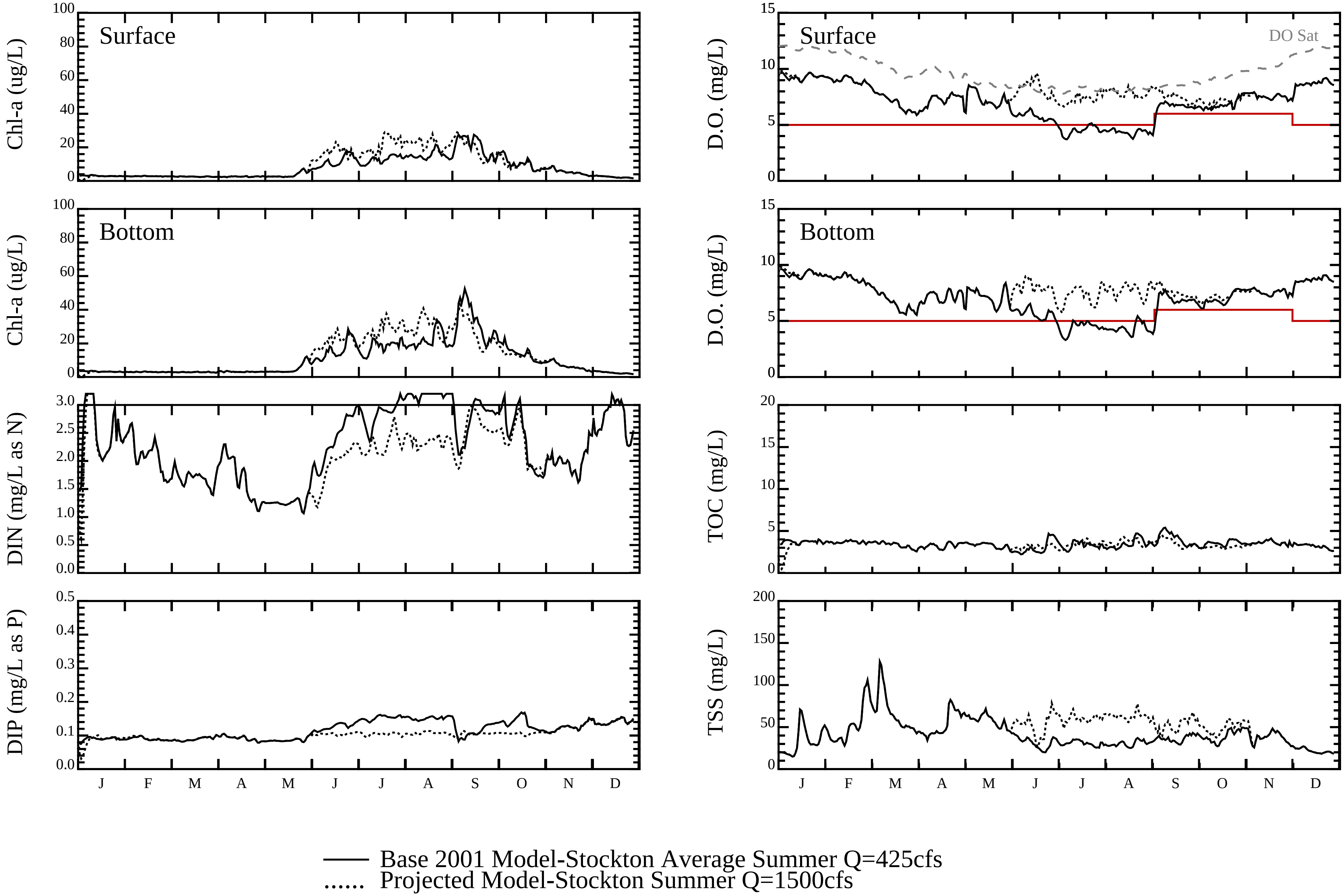
Comparison of Water Quality Model Base and Projection: SJR at R1

DATE: 4/20/2006 TIME: 16: 8:13



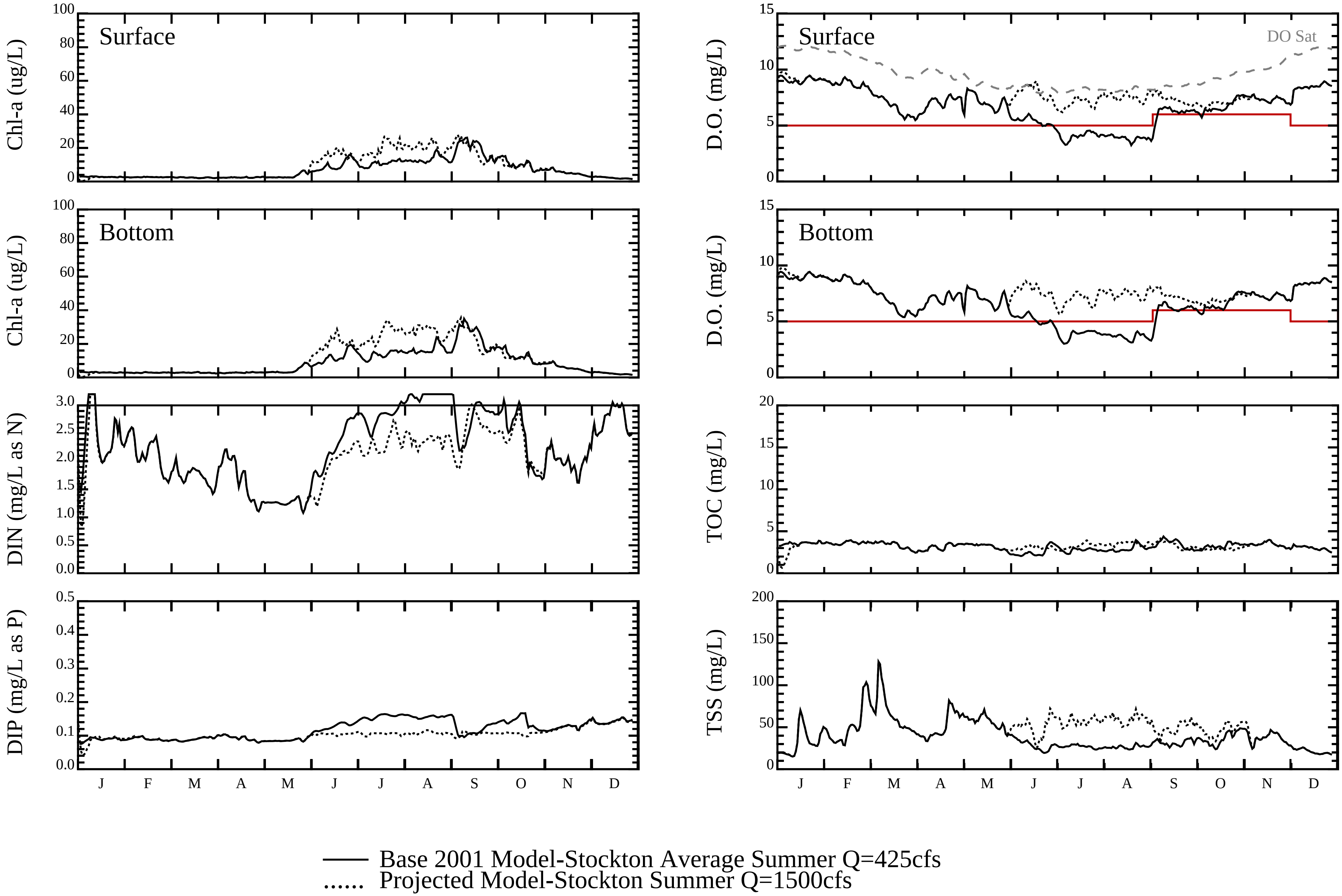
Comparison of Water Quality Model Base and Projection: SJR at R2

DATE: 4/20/2006 TIME: 16: 8:54



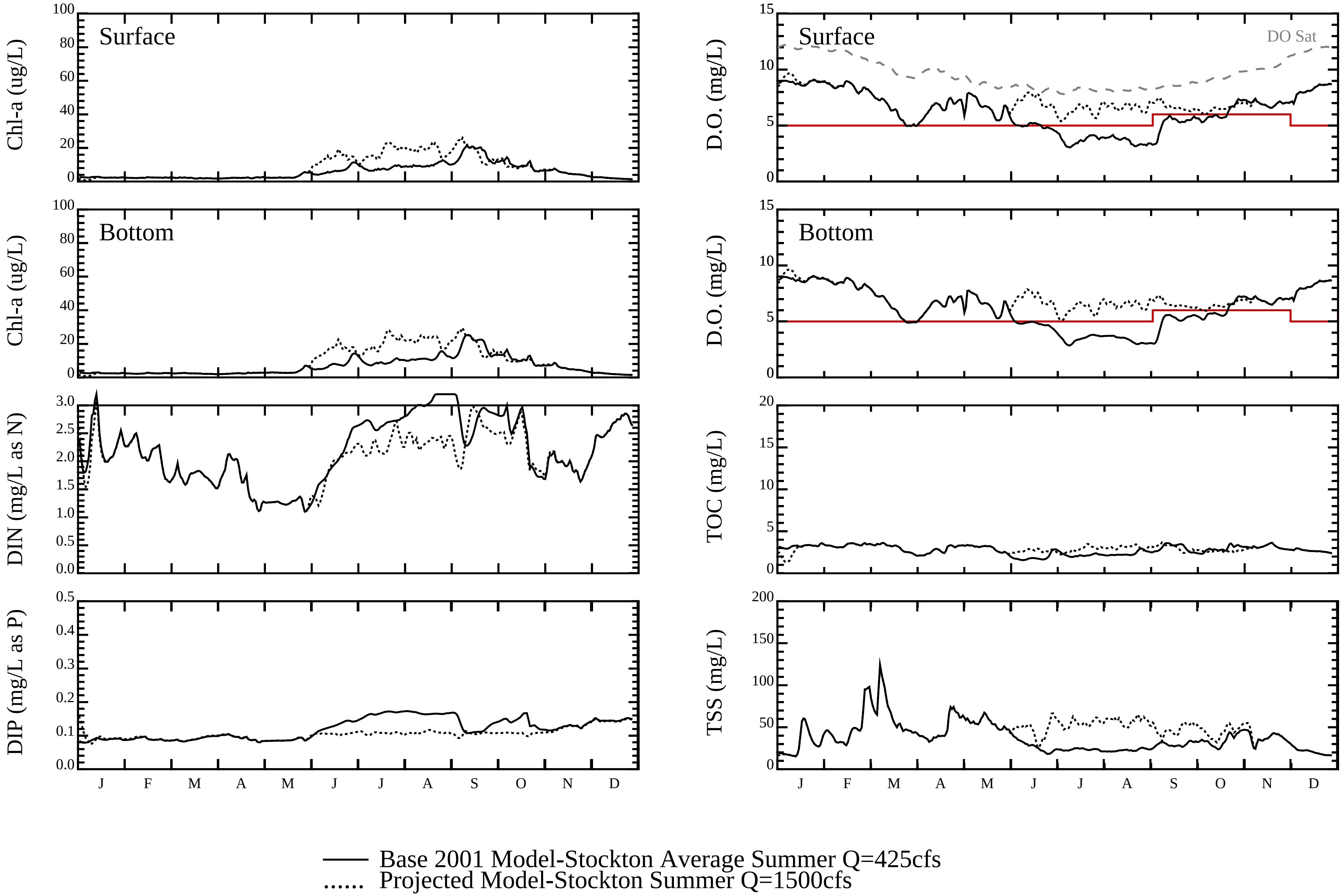
Comparison of Water Quality Model Base and Projection: SJR at R3

DATE: 4/20/2006 TIME: 16: 9:34



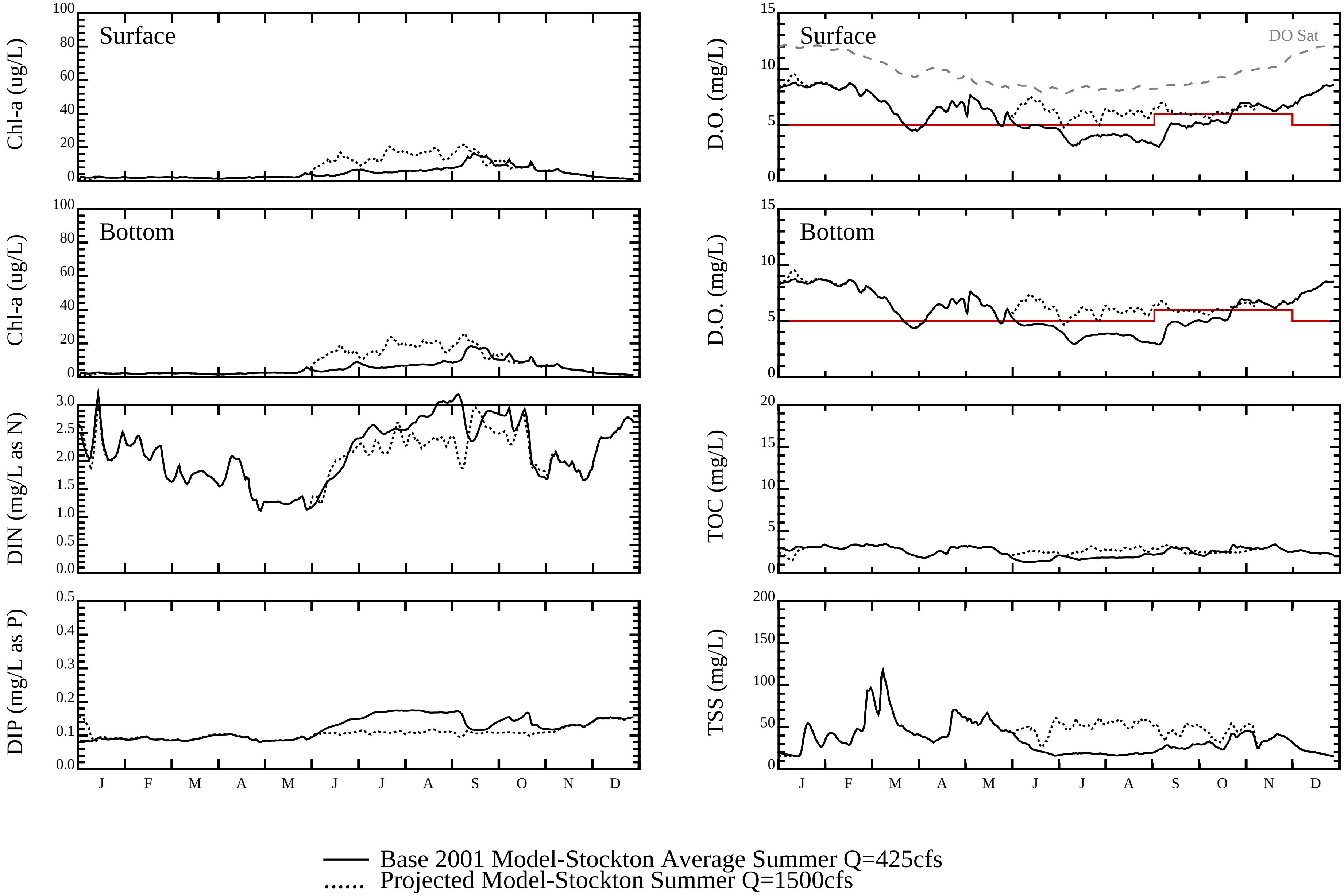
Comparison of Water Quality Model Base and Projection: SJR at R4

DATE: 4/20/2006 TIME: 16:10:15



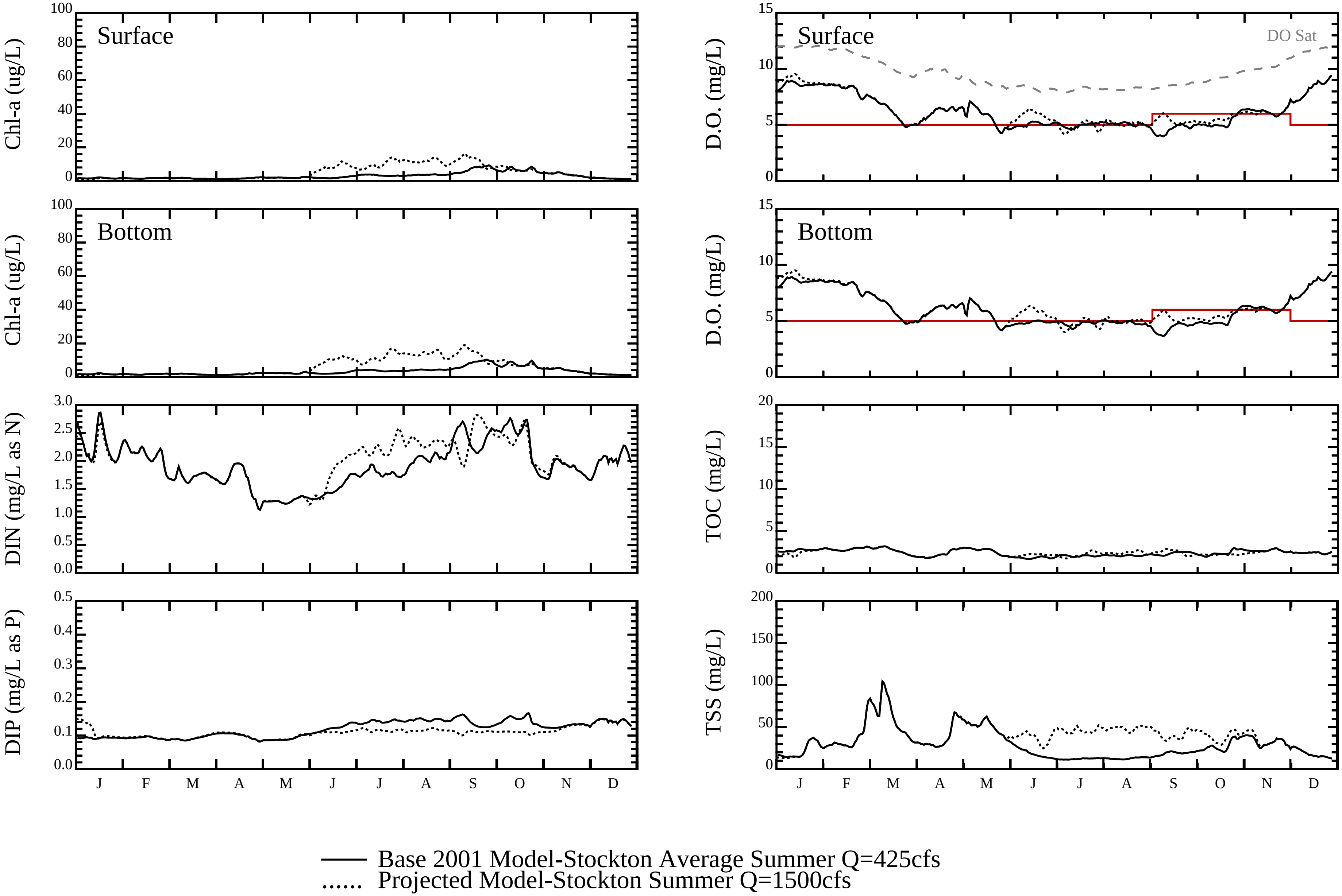
Comparison of Water Quality Model Base and Projection: SJR at R5

DATE: 4/20/2006 TIME: 16:10:55



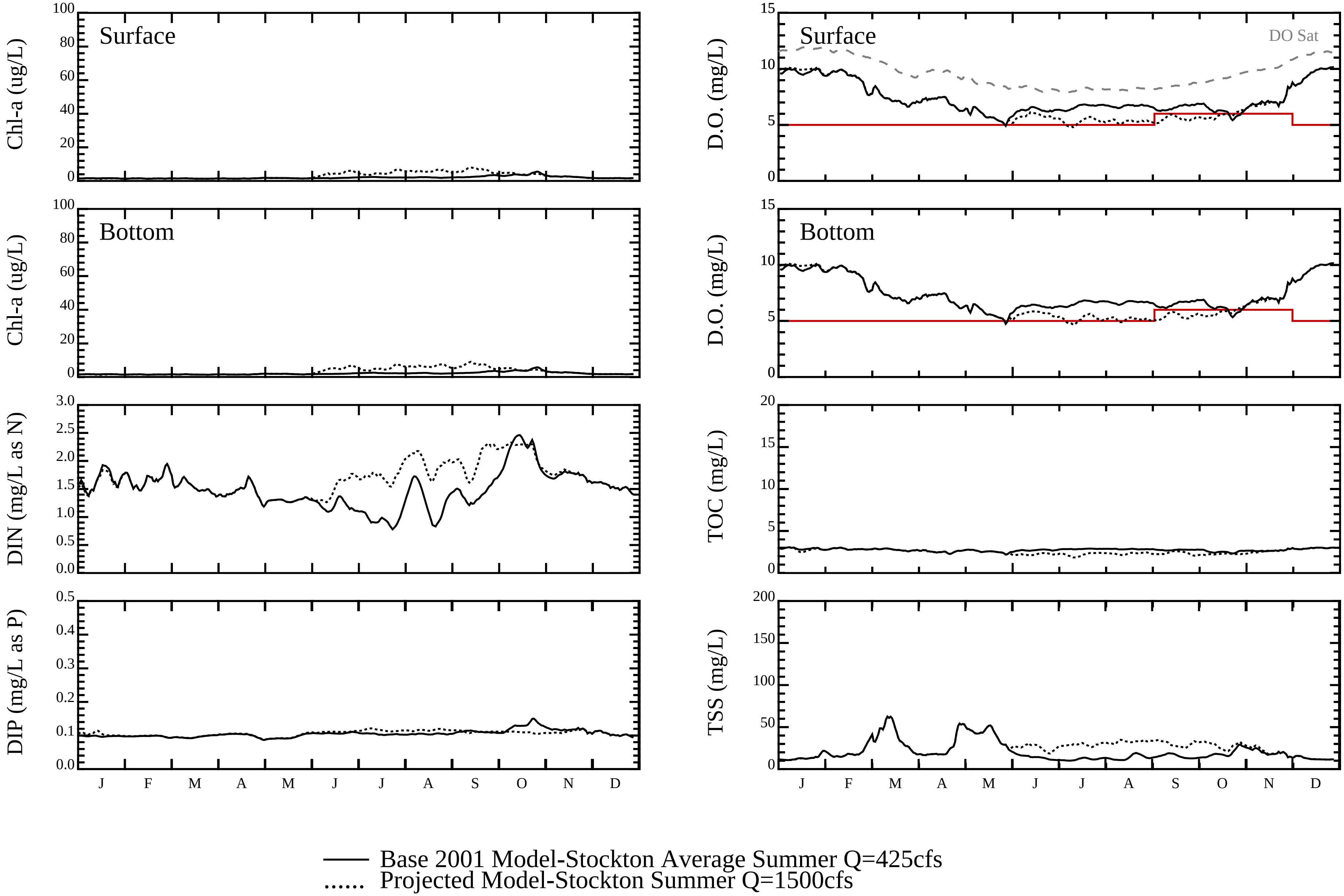
Comparison of Water Quality Model Base and Projection: SJR at R6

DATE: 4/20/2006 TIME: 16:11:35



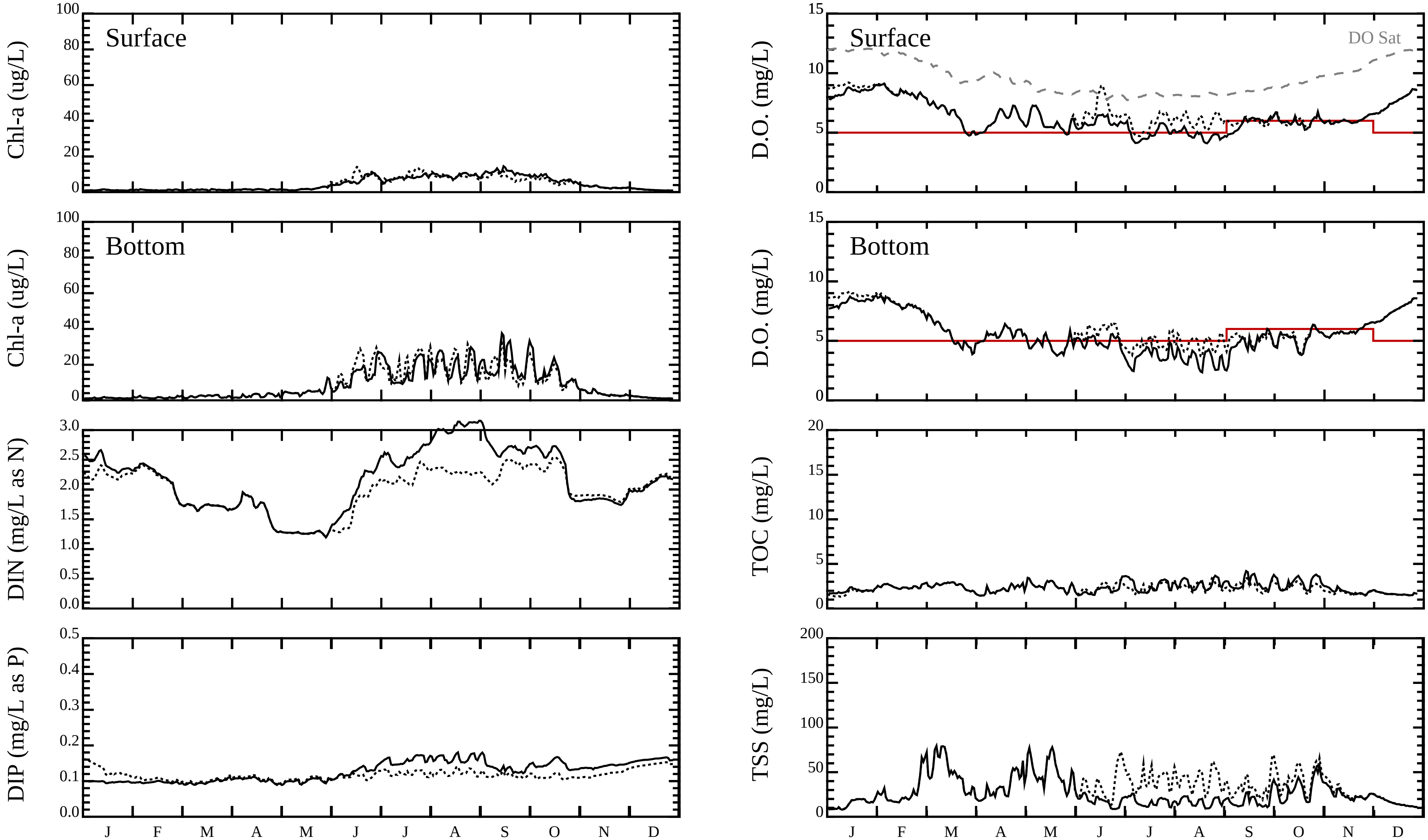
Comparison of Water Quality Model Base and Projection: SJR at R7

DATE: 4/20/2006 TIME: 16:12:16



Comparison of Water Quality Model Base and Projection: SJR at R8

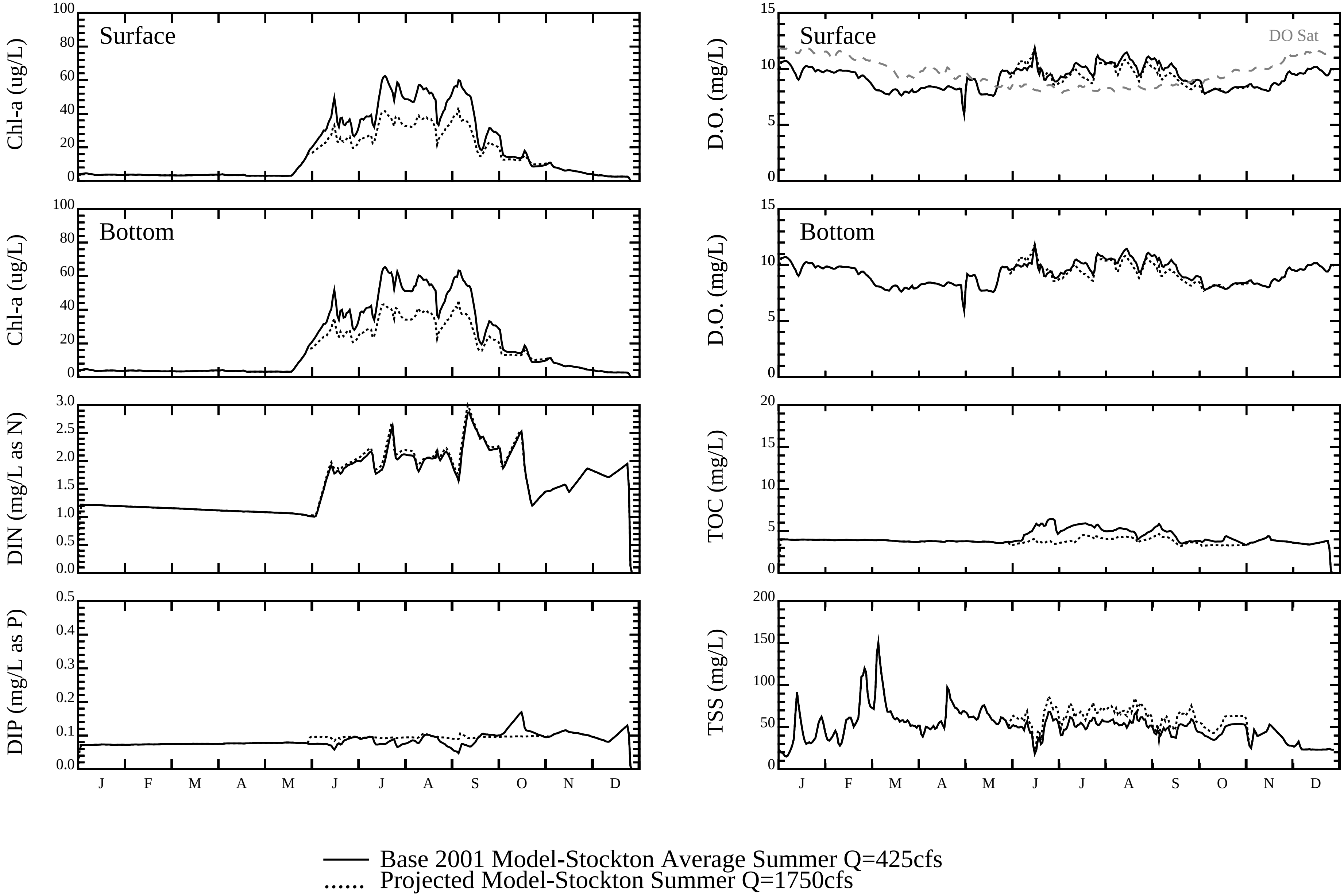
DATE: 4/20/2006 TIME: 16:12:56



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1500cfs

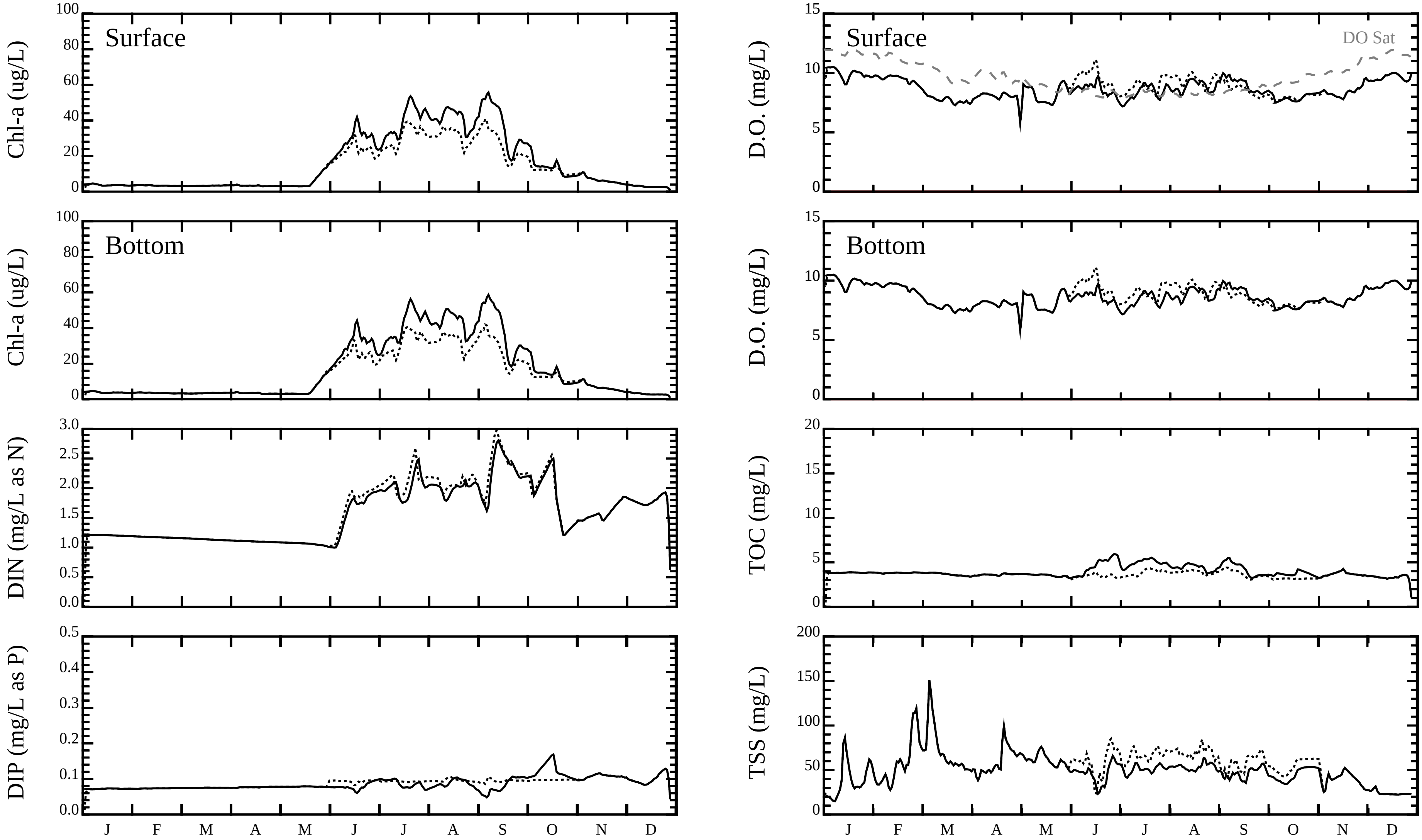
Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

DATE: 4/20/2006 TIME: 16: 7:33



Comparison of Water Quality Model Base and Projection: SJR at Mossdale

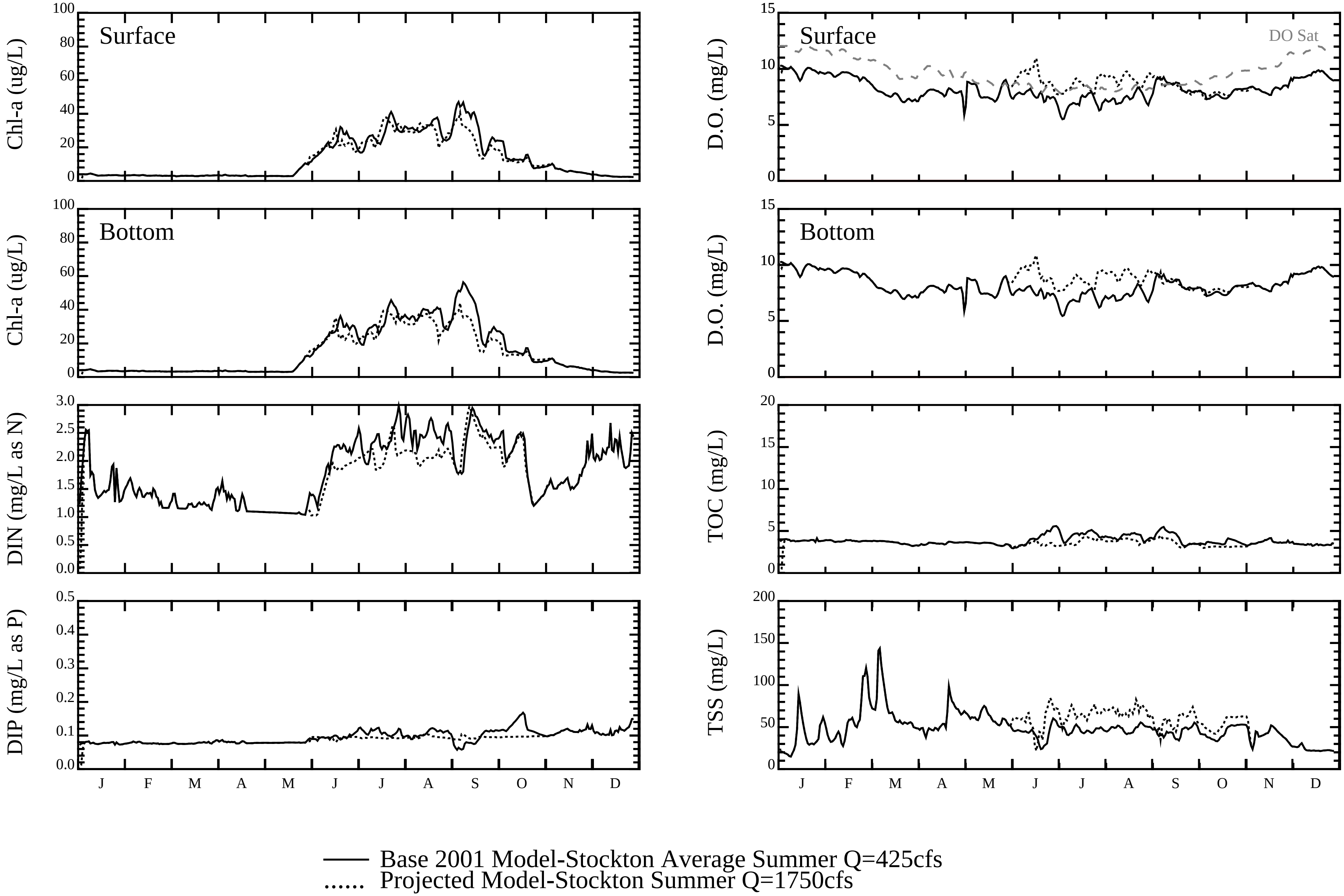
DATE: 4/20/2006 TIME: 16:13:38



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1750cfs

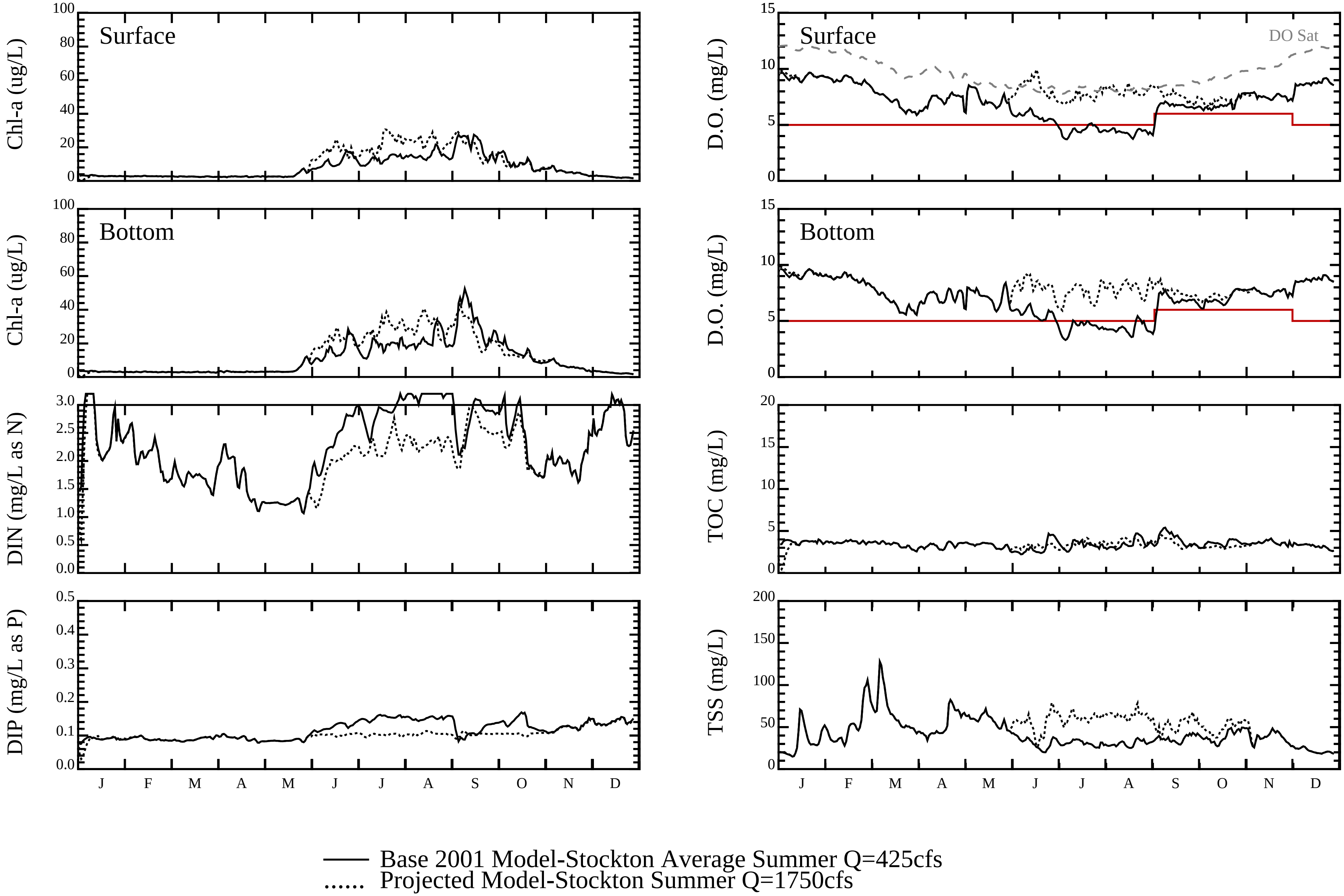
Comparison of Water Quality Model Base and Projection: SJR at R1

DATE: 4/20/2006 TIME: 16:15:15



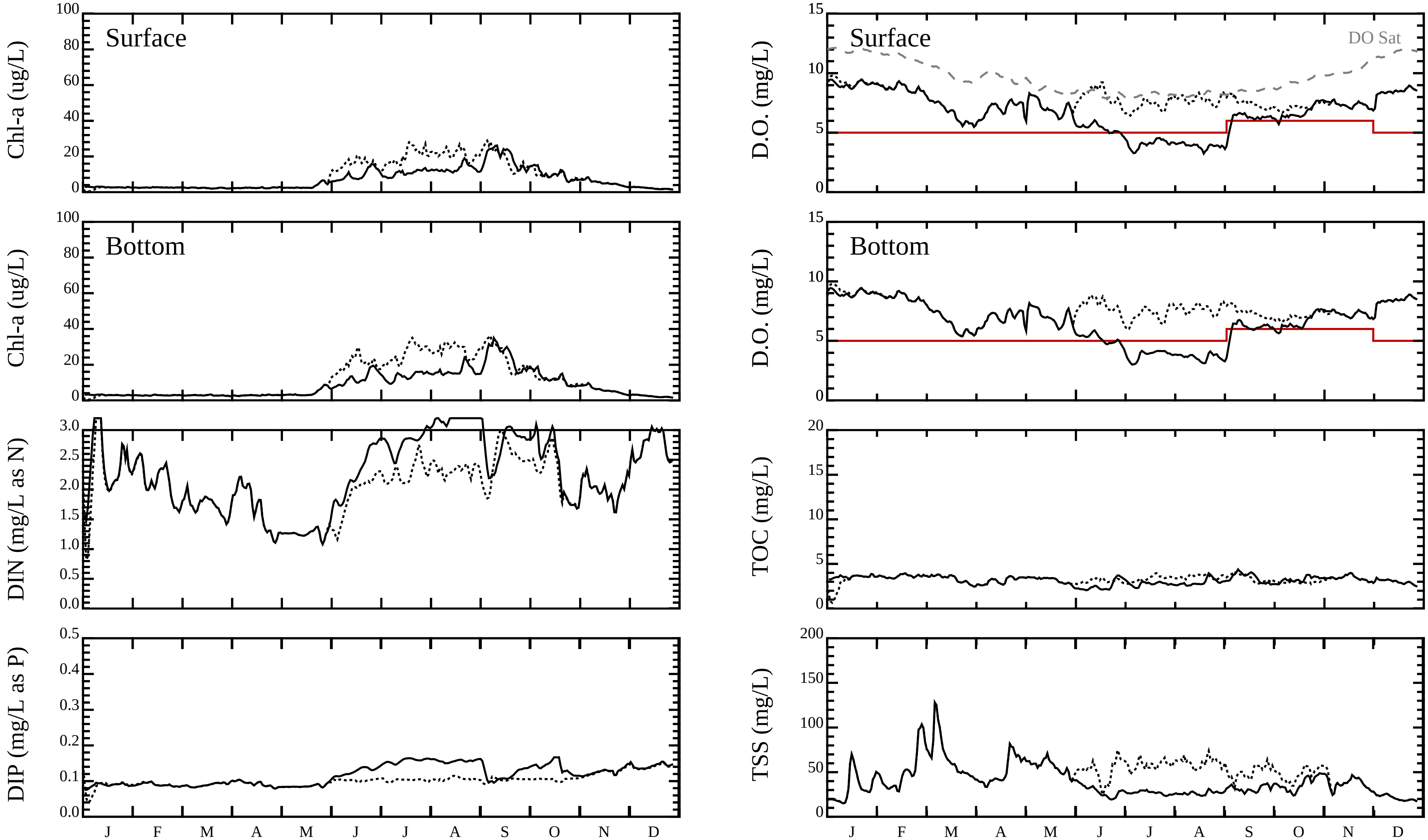
Comparison of Water Quality Model Base and Projection: SJR at R2

DATE: 4/20/2006 TIME: 16:15:55



Comparison of Water Quality Model Base and Projection: SJR at R3

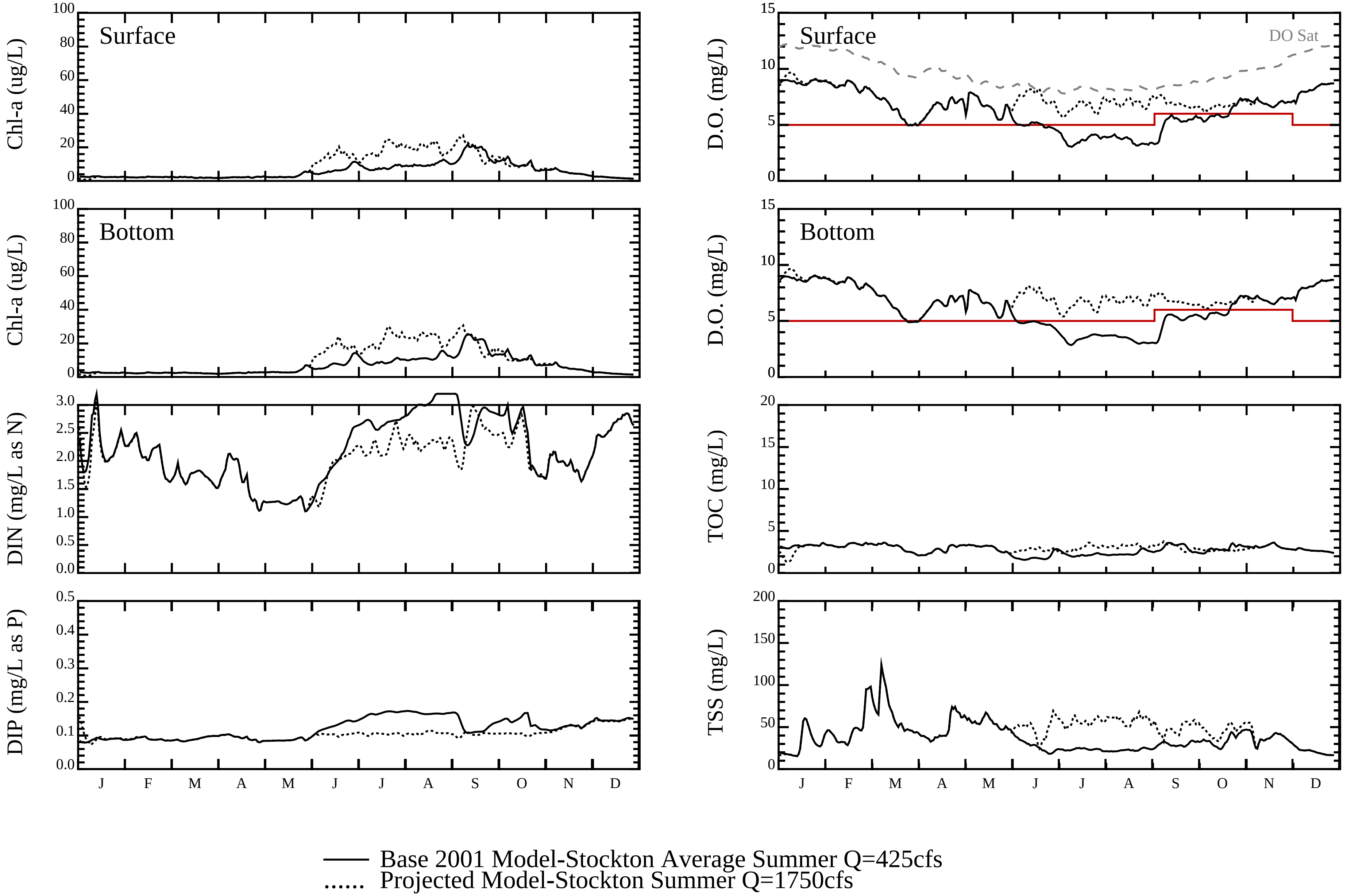
DATE: 4/20/2006 TIME: 16:16:36



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1750cfs

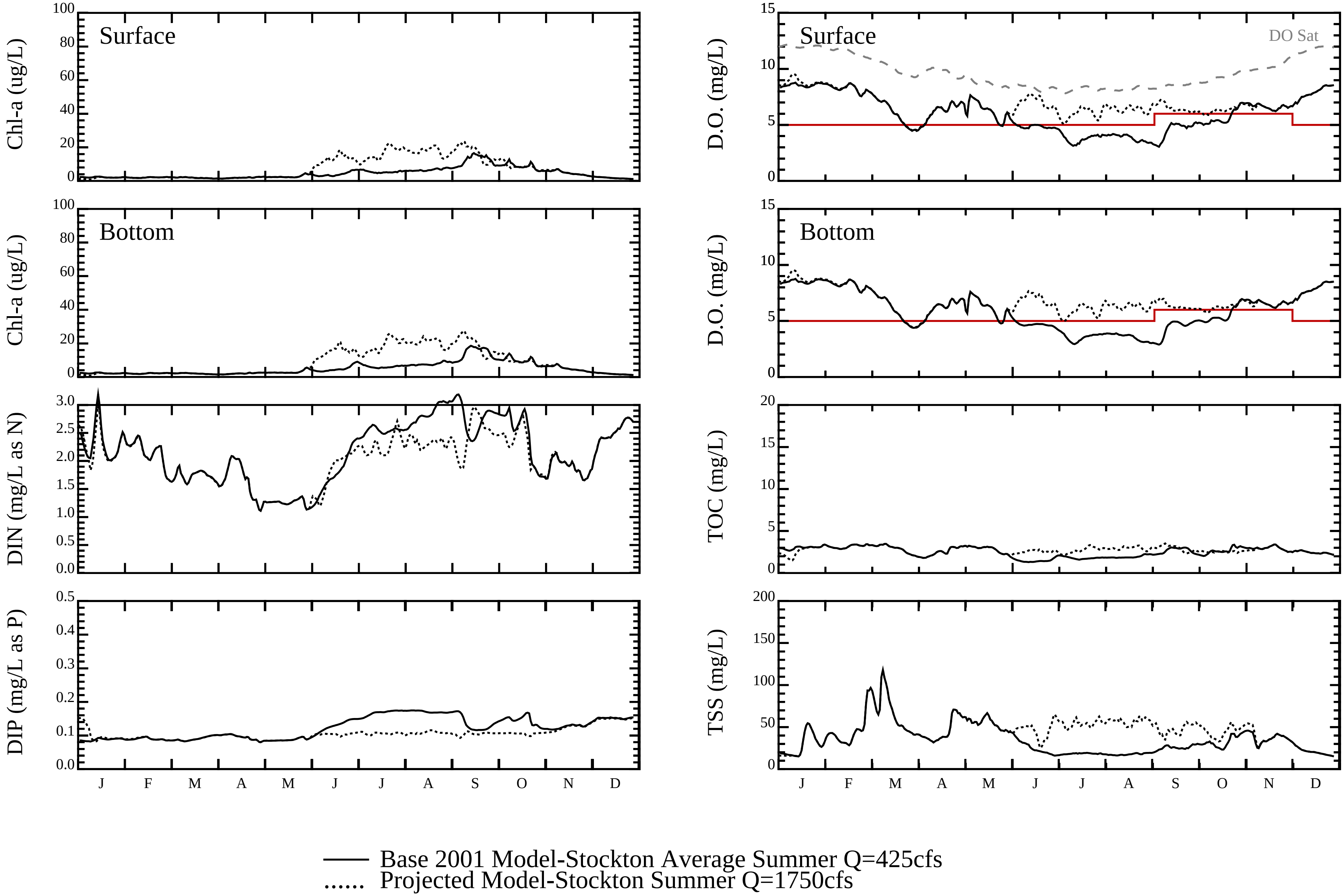
Comparison of Water Quality Model Base and Projection: SJR at R4

DATE: 4/20/2006 TIME: 16:17:16



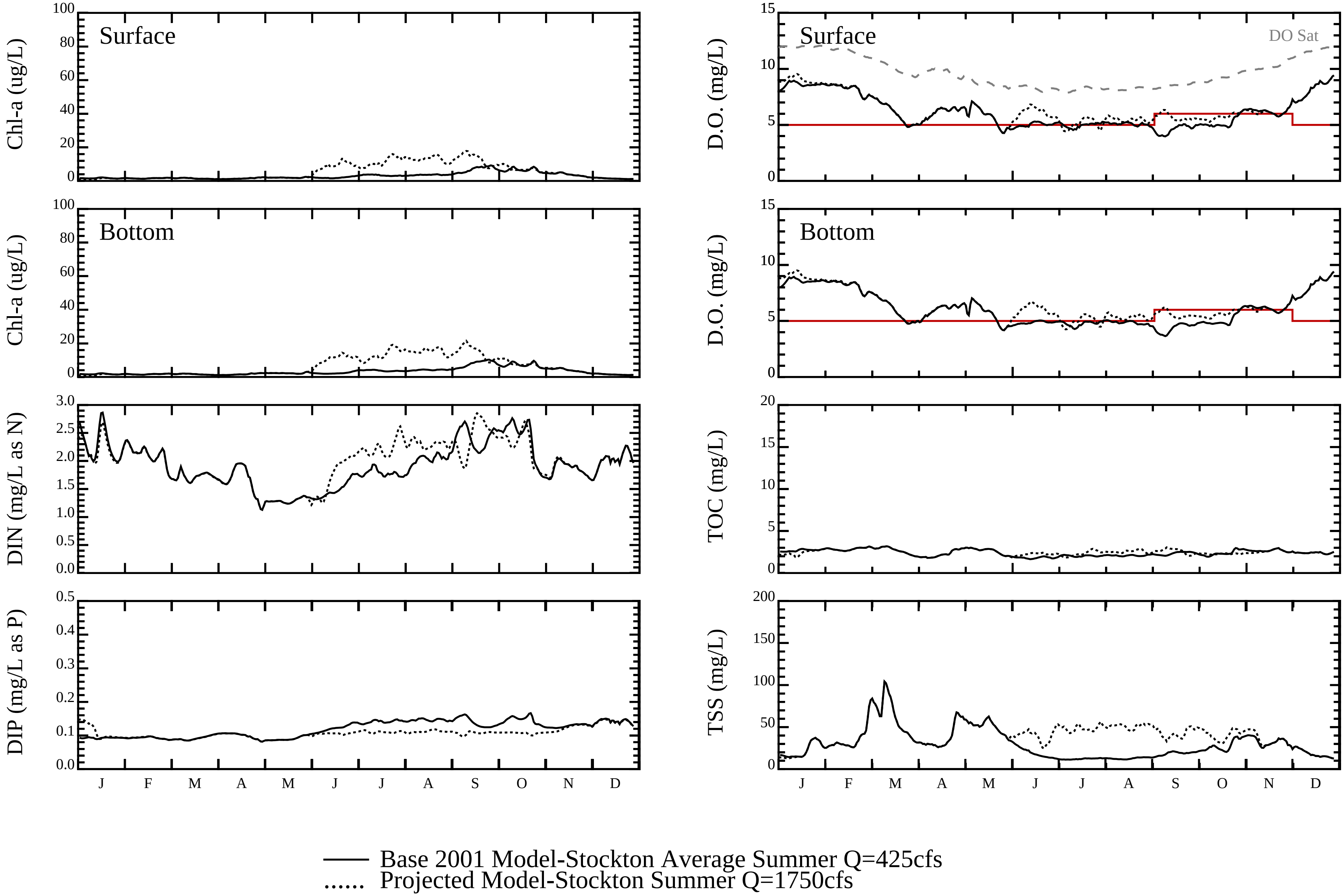
Comparison of Water Quality Model Base and Projection: SJR at R5

DATE: 4/20/2006 TIME: 16:17:57



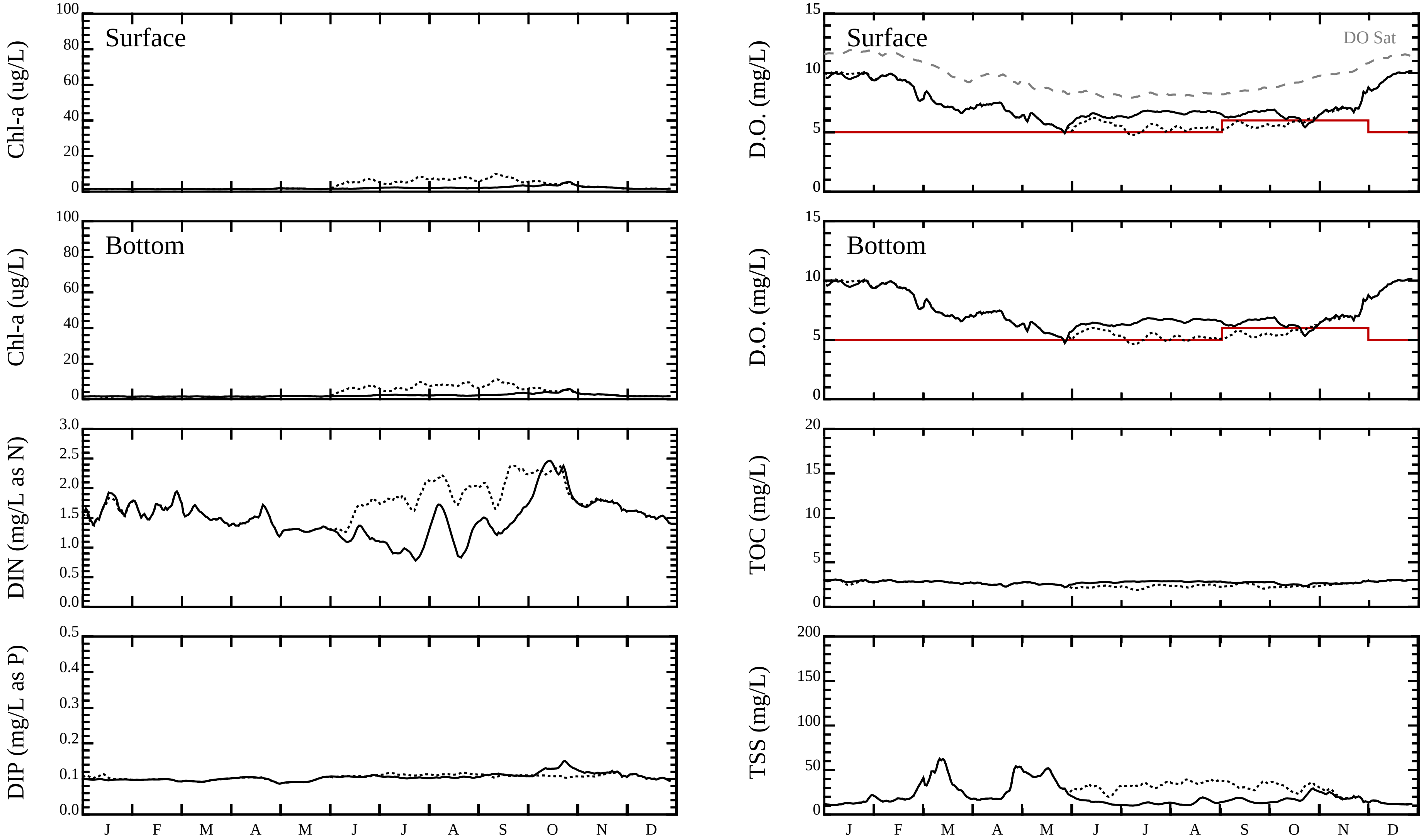
Comparison of Water Quality Model Base and Projection: SJR at R6

DATE: 4/20/2006 TIME: 16:18:37



Comparison of Water Quality Model Base and Projection: SJR at R7

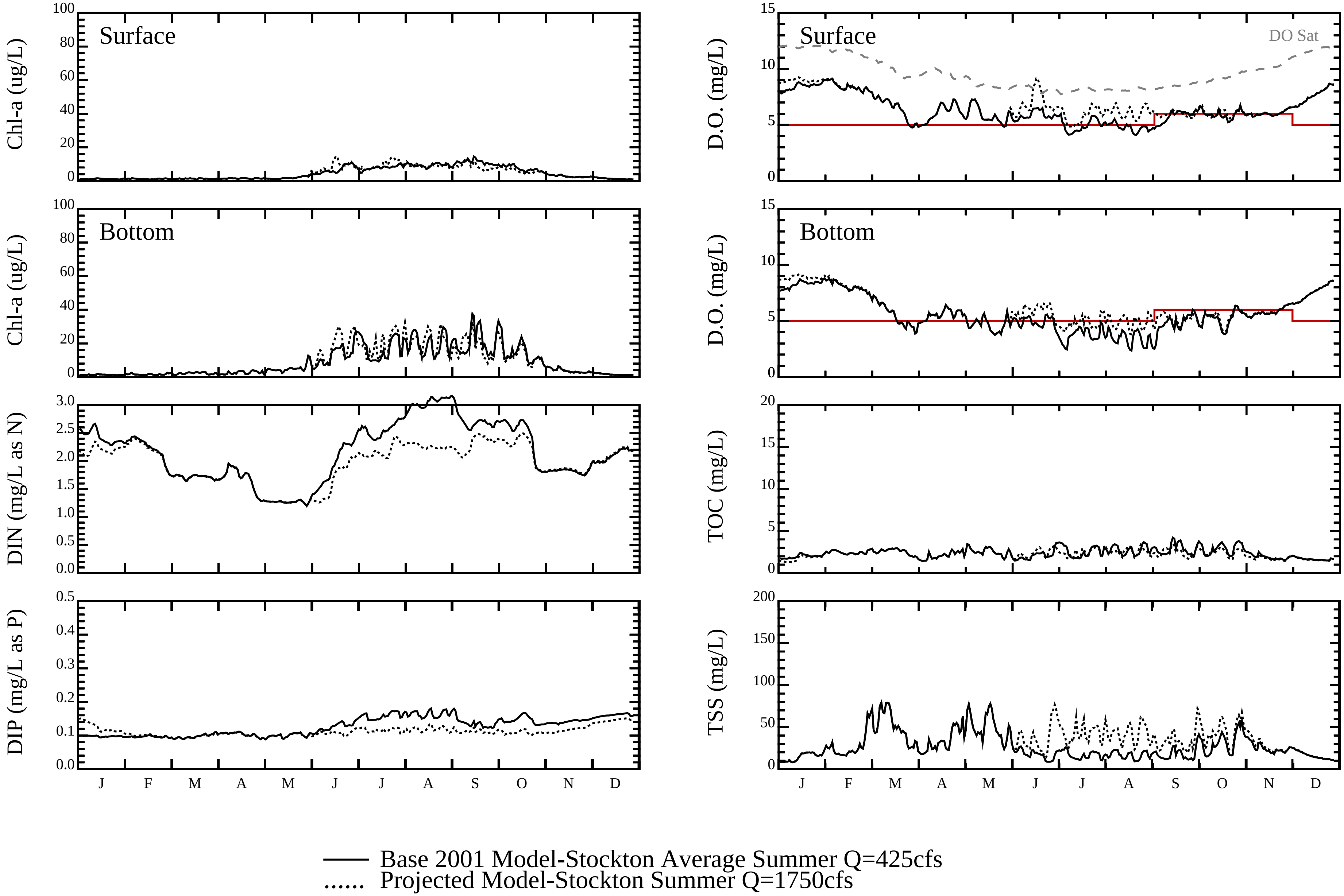
DATE: 4/20/2006 TIME: 16:19:17



— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1750cfs

Comparison of Water Quality Model Base and Projection: SJR at R8

DATE: 4/20/2006 TIME: 16:19:58

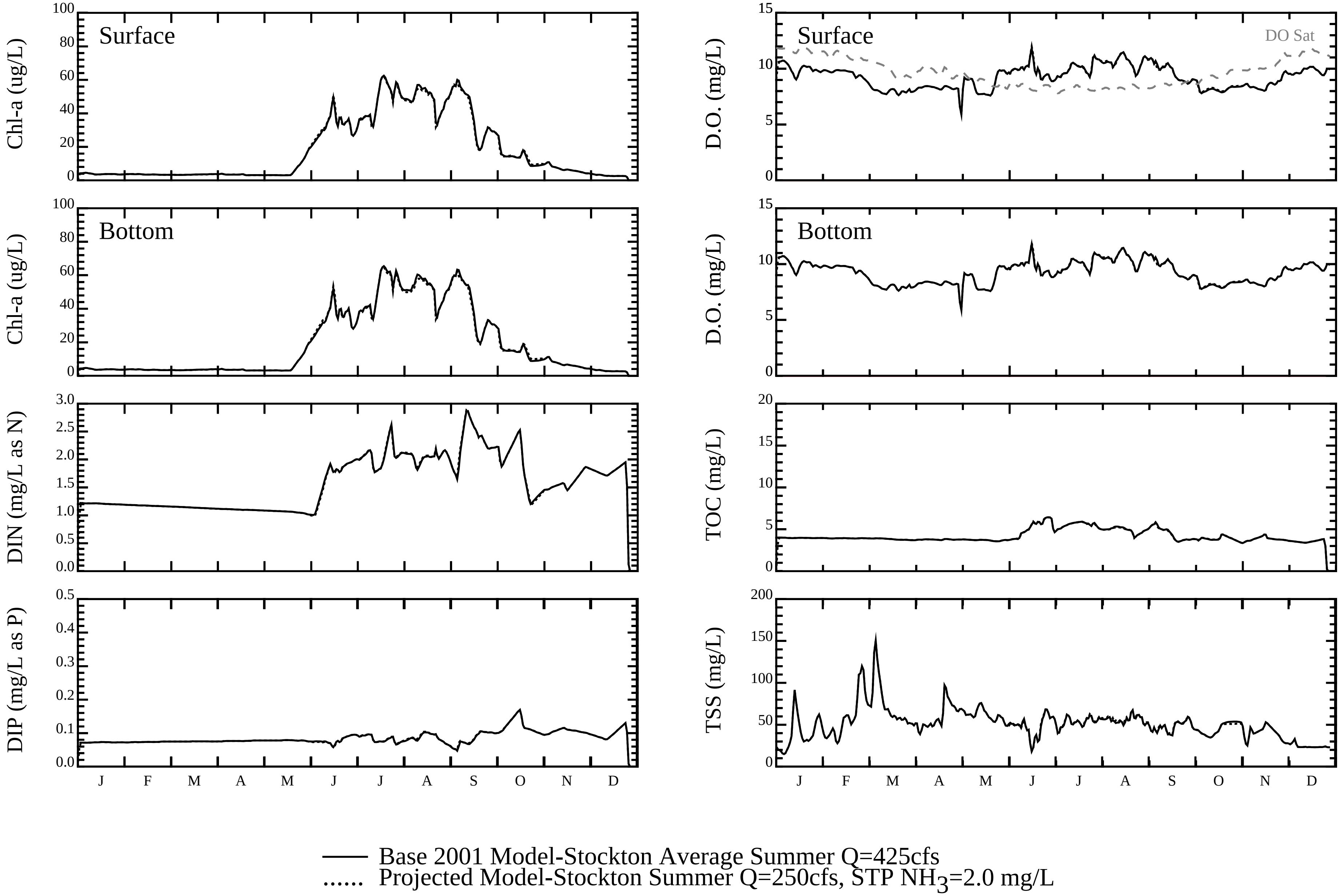


Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

DATE: 4/20/2006 TIME: 16:14:35

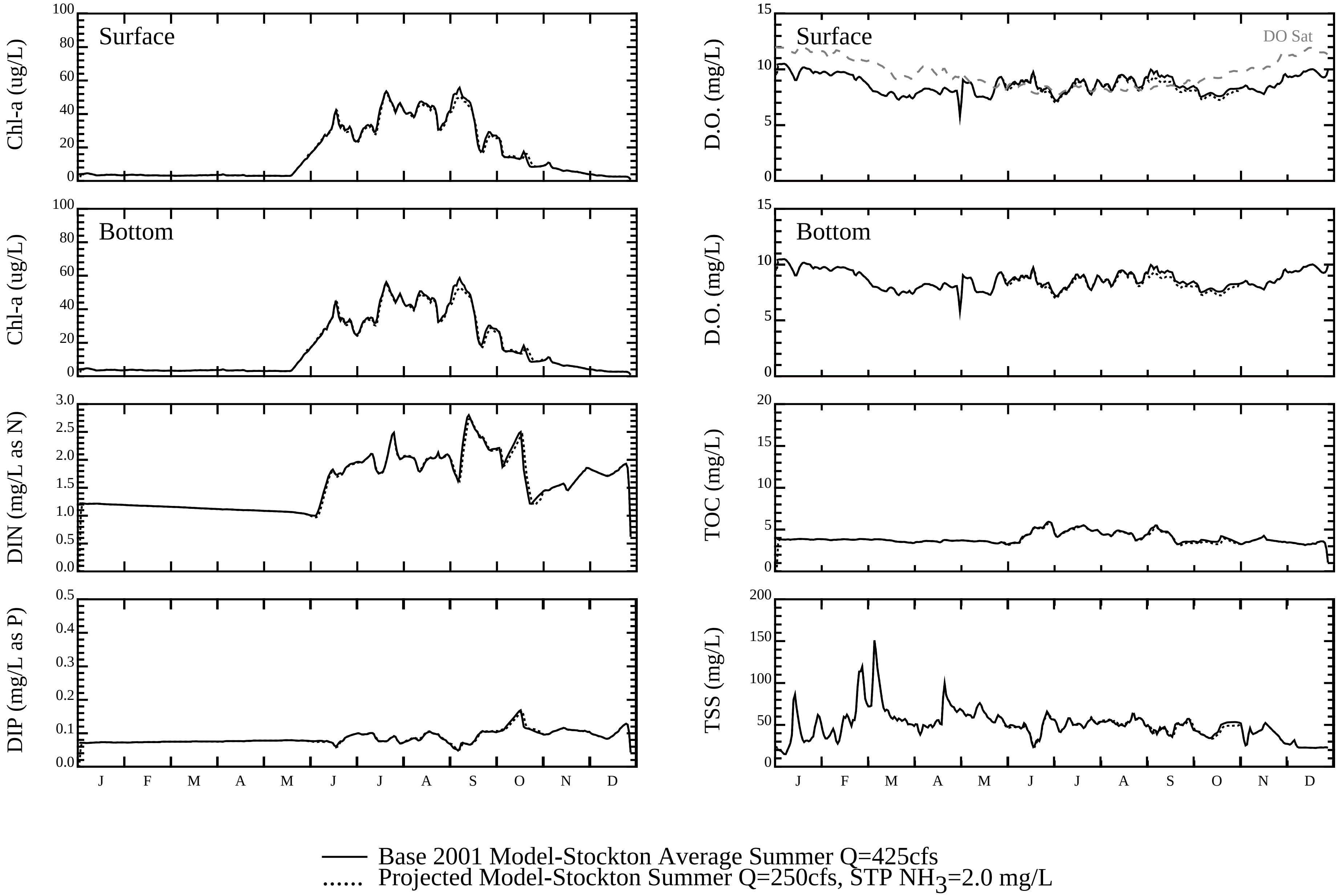
APPENDIX B

TEMPORAL PROFILE
COMPARISONS OF BASE MODEL AND PROJECTIONS
AT 250, 750, 1,250, 1,500 AND 1,750 CFS
AND WITH STOCKTON RWCF AMMONIA = 2.0 mg/L



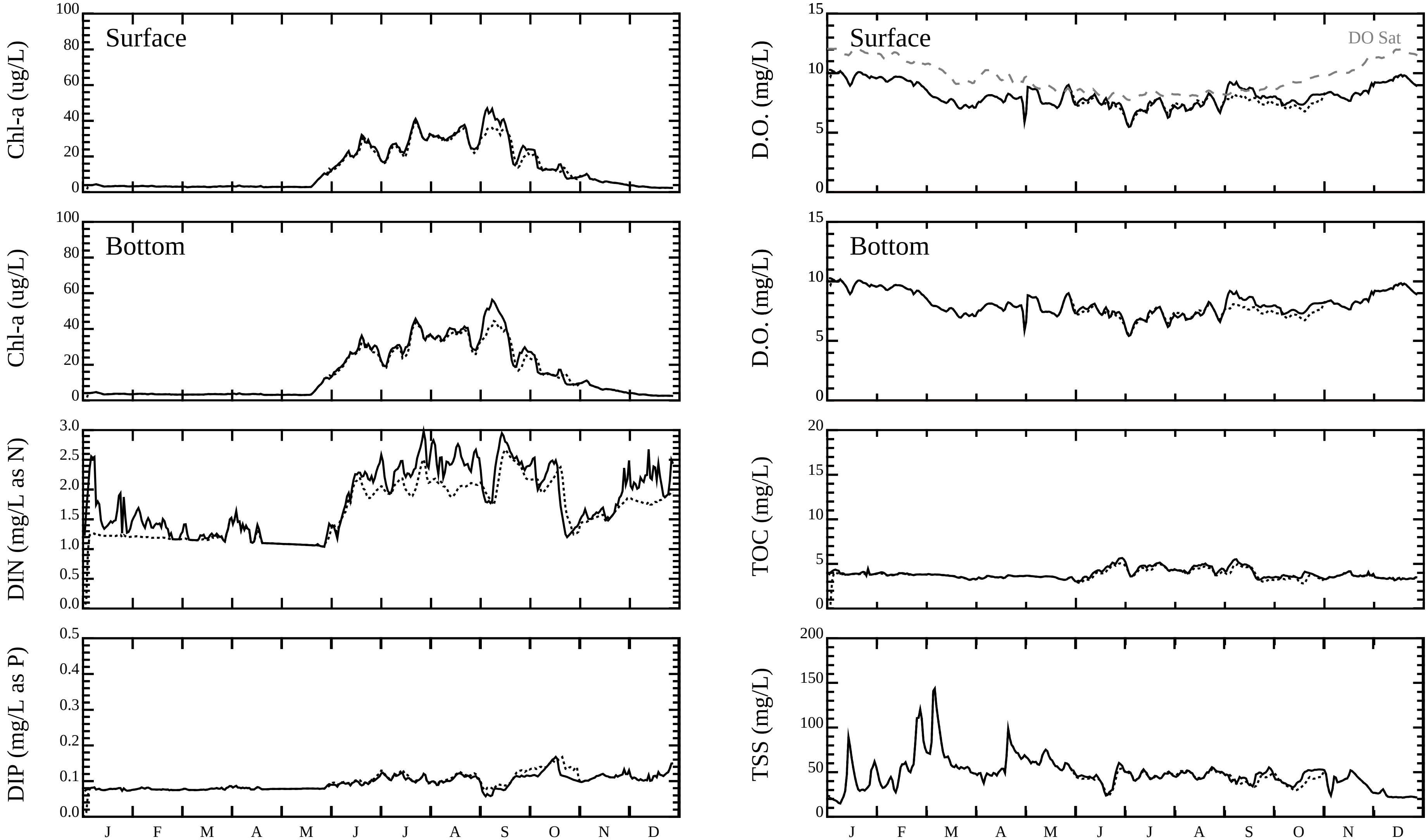
Comparison of Water Quality Model Base and Projection: SJR at Mossdale

DATE: 4/20/2006 TIME: 15: 7:57



Comparison of Water Quality Model Base and Projection: SJR at R1

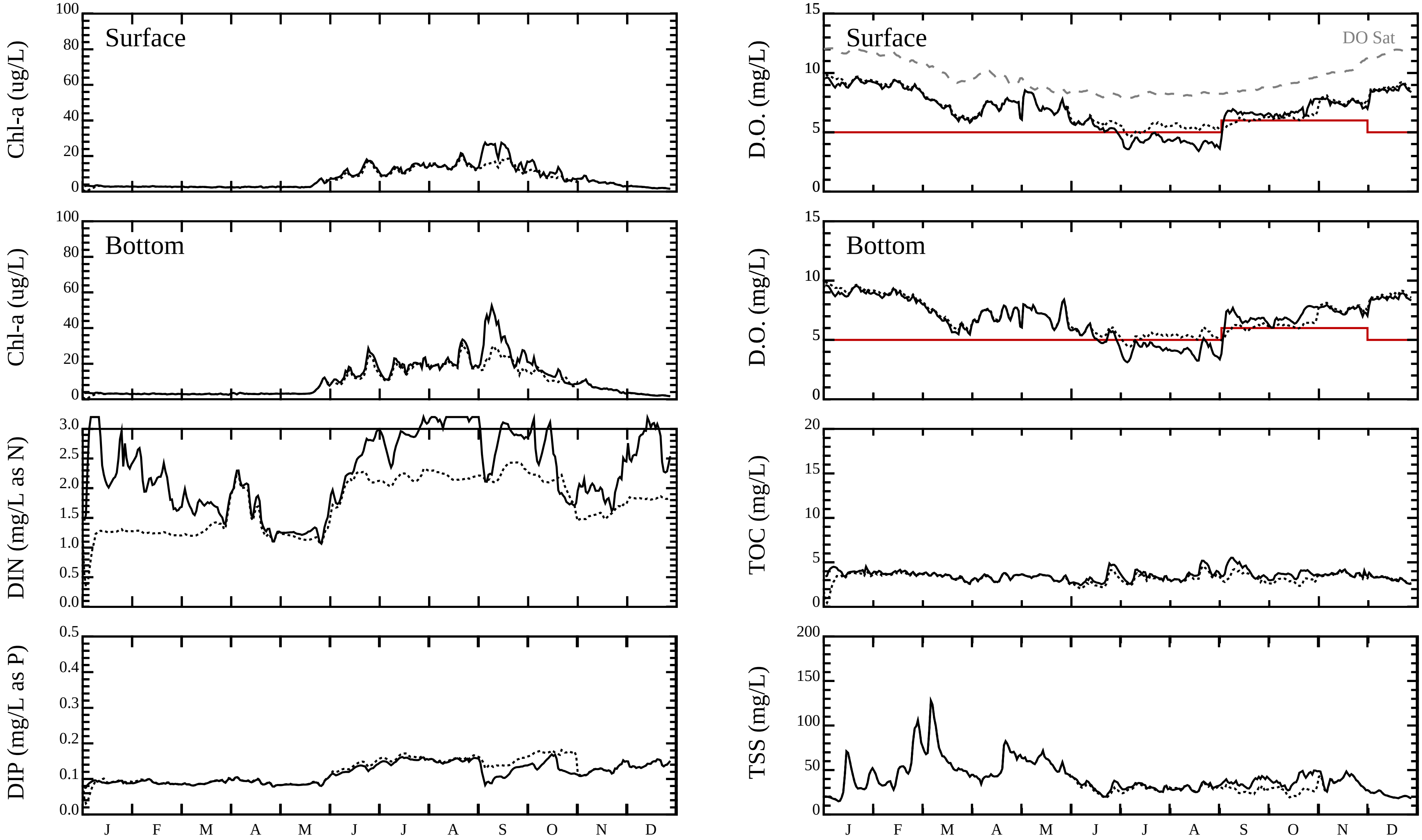
DATE: 4/20/2006 TIME: 15: 9:19



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R2

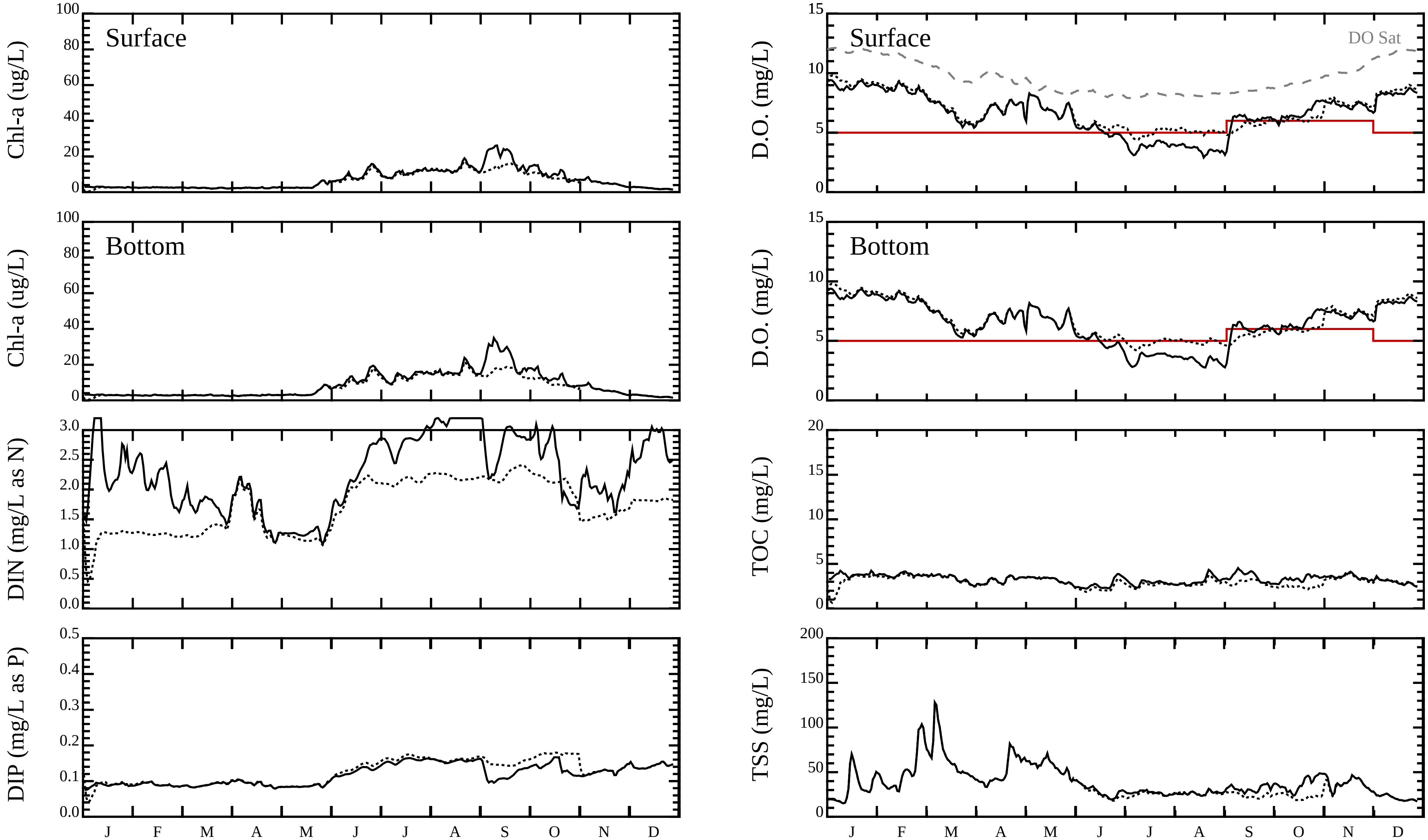
DATE: 4/20/2006 TIME: 15: 9:59



Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R3

DATE: 4/20/2006 TIME: 15:10:39

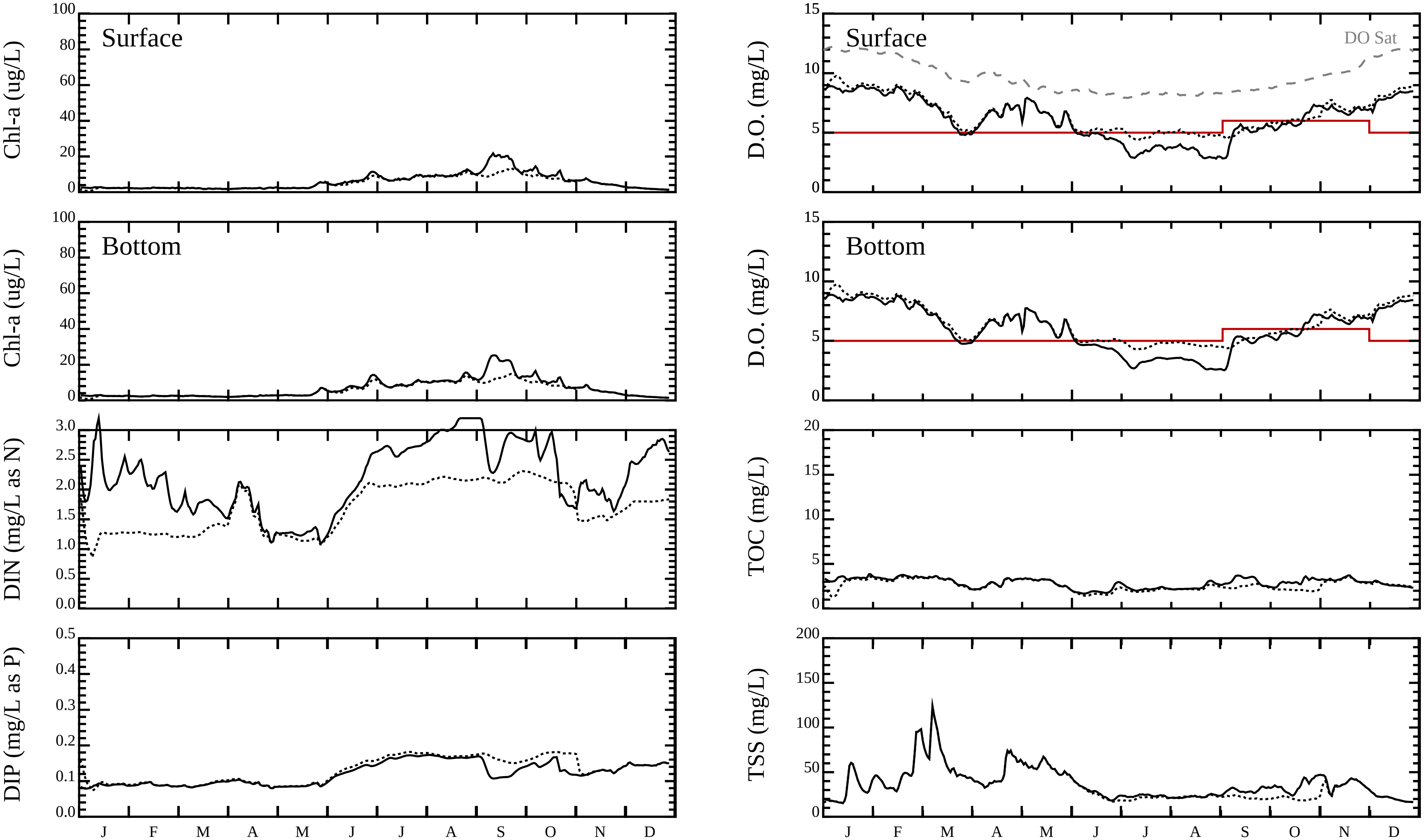


Base 2001 Model-Stockton Average Summer Q=425cfs

...... Projected Model-Stockton Summer Q=250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R4

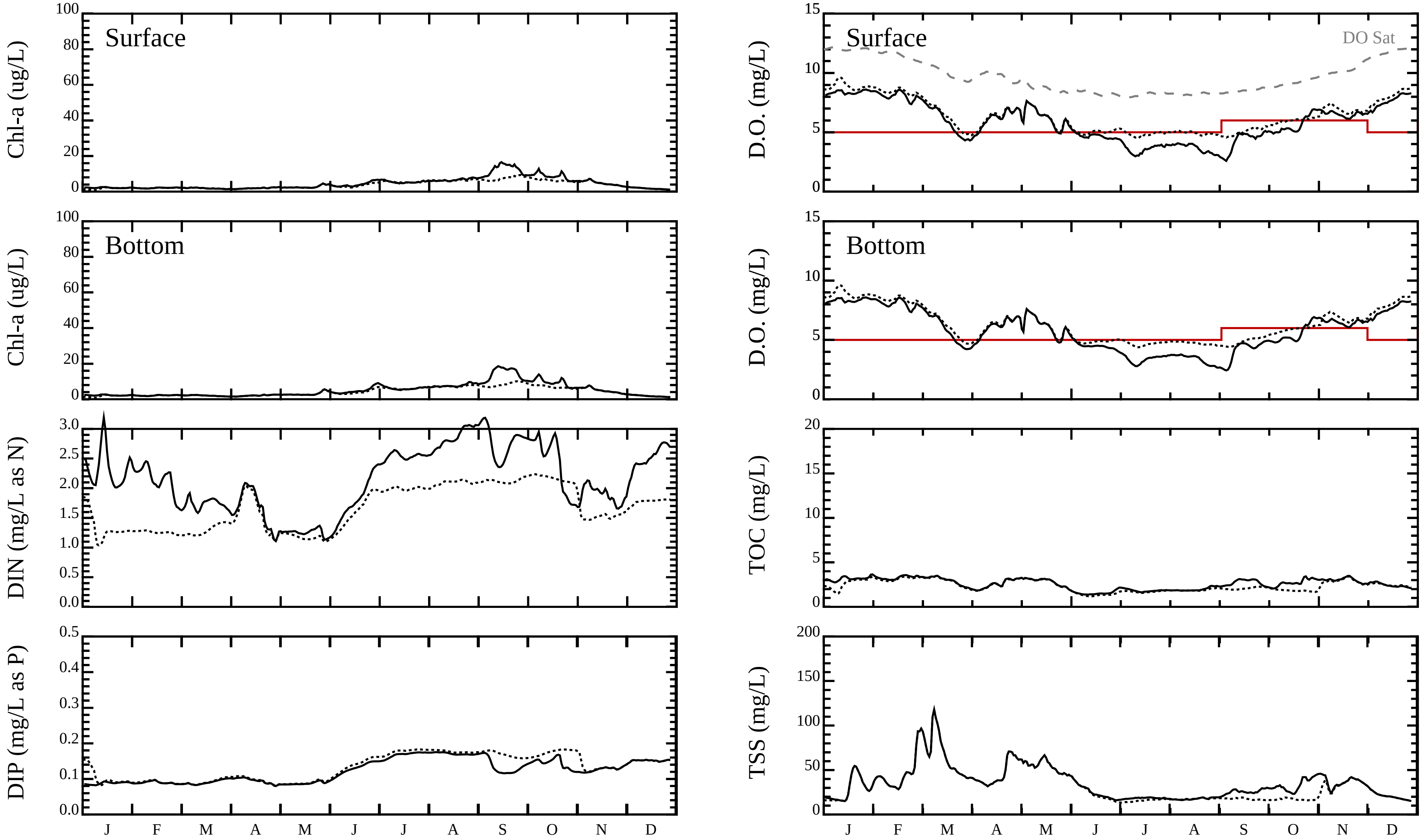
DATE: 4/20/2006 TIME: 15:11:20



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R5

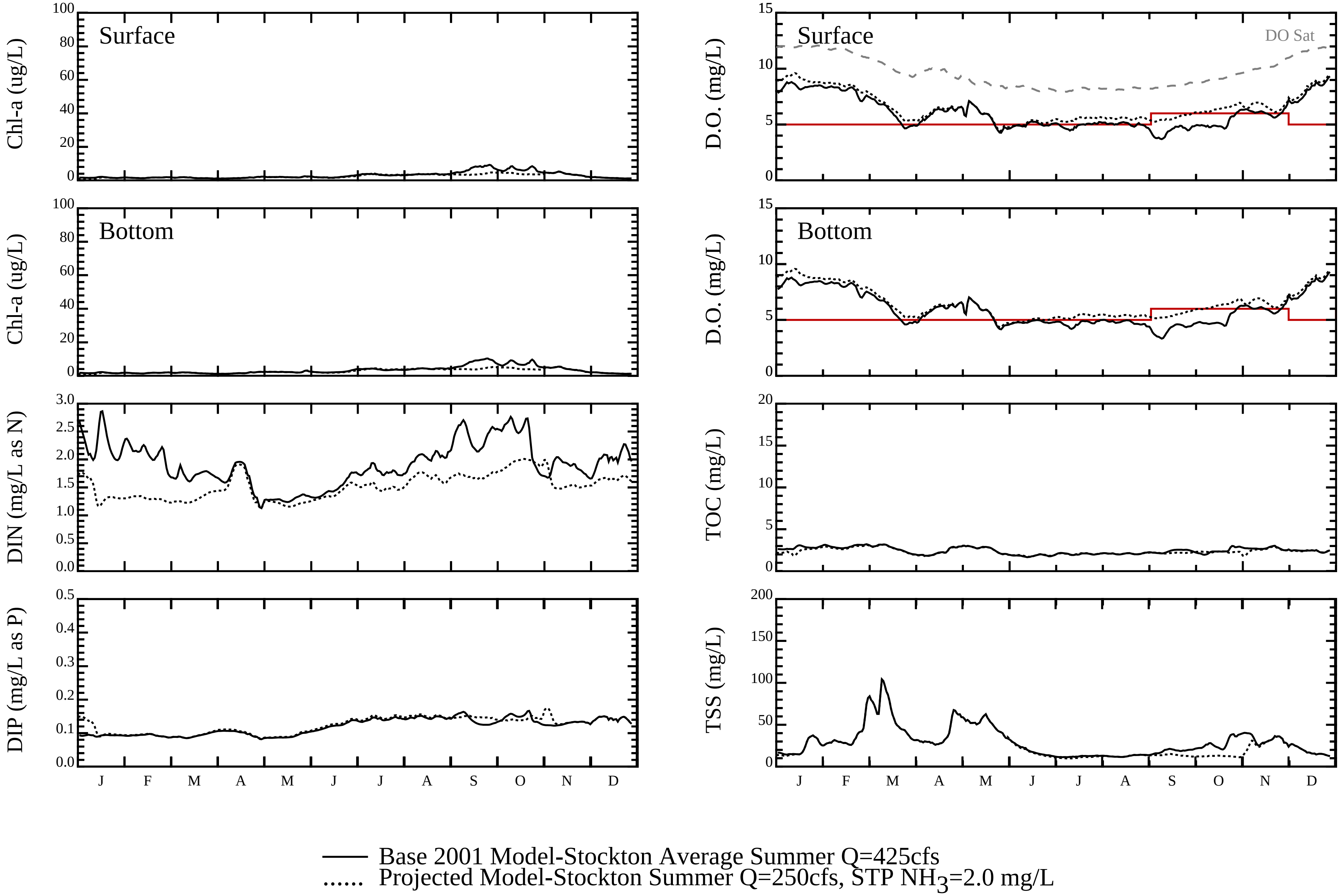
DATE: 4/20/2006 TIME: 15:12: 0



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=250cfs, STP NH_3=2.0 mg/L

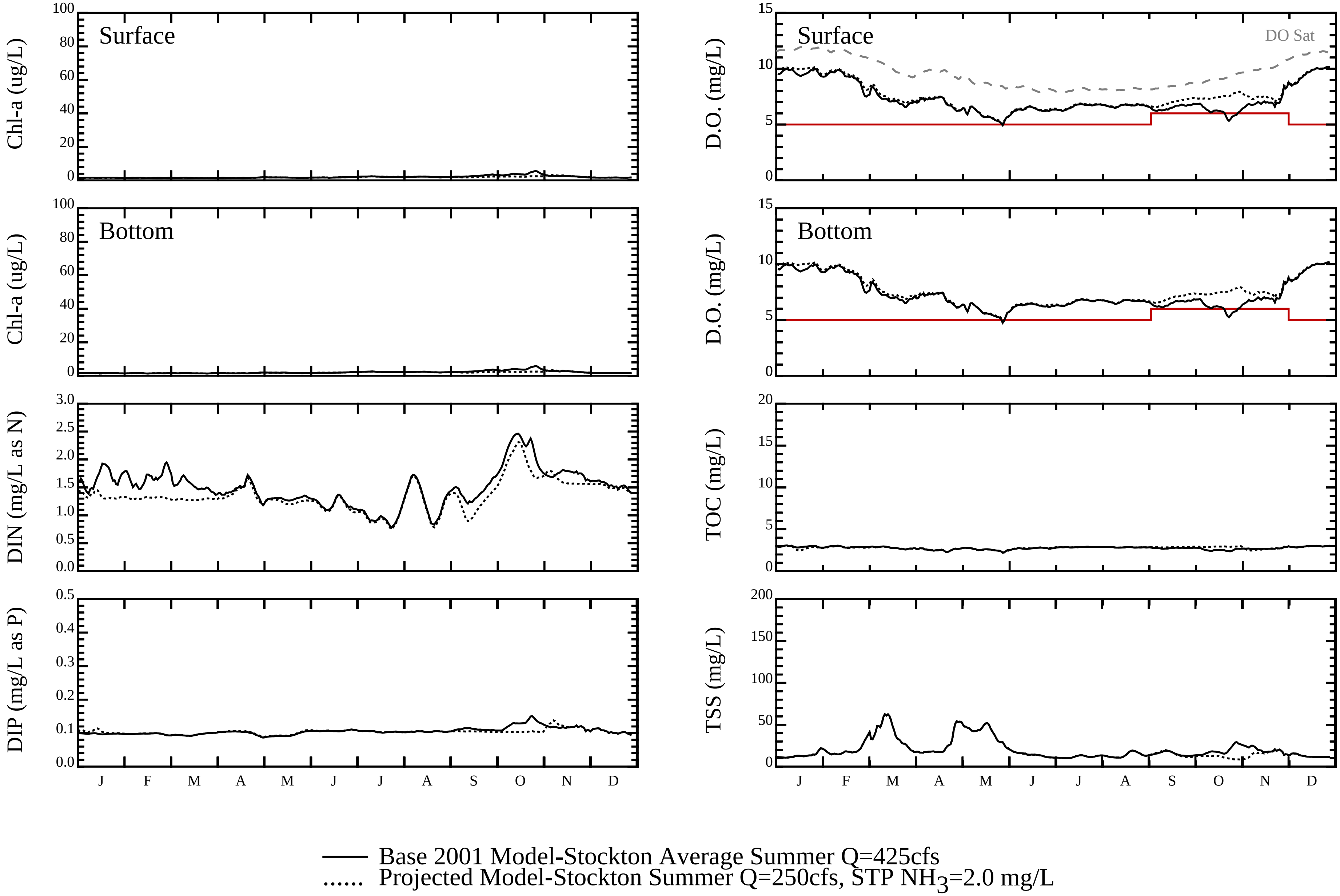
Comparison of Water Quality Model Base and Projection: SJR at R6

DATE: 4/20/2006 TIME: 15:12:41



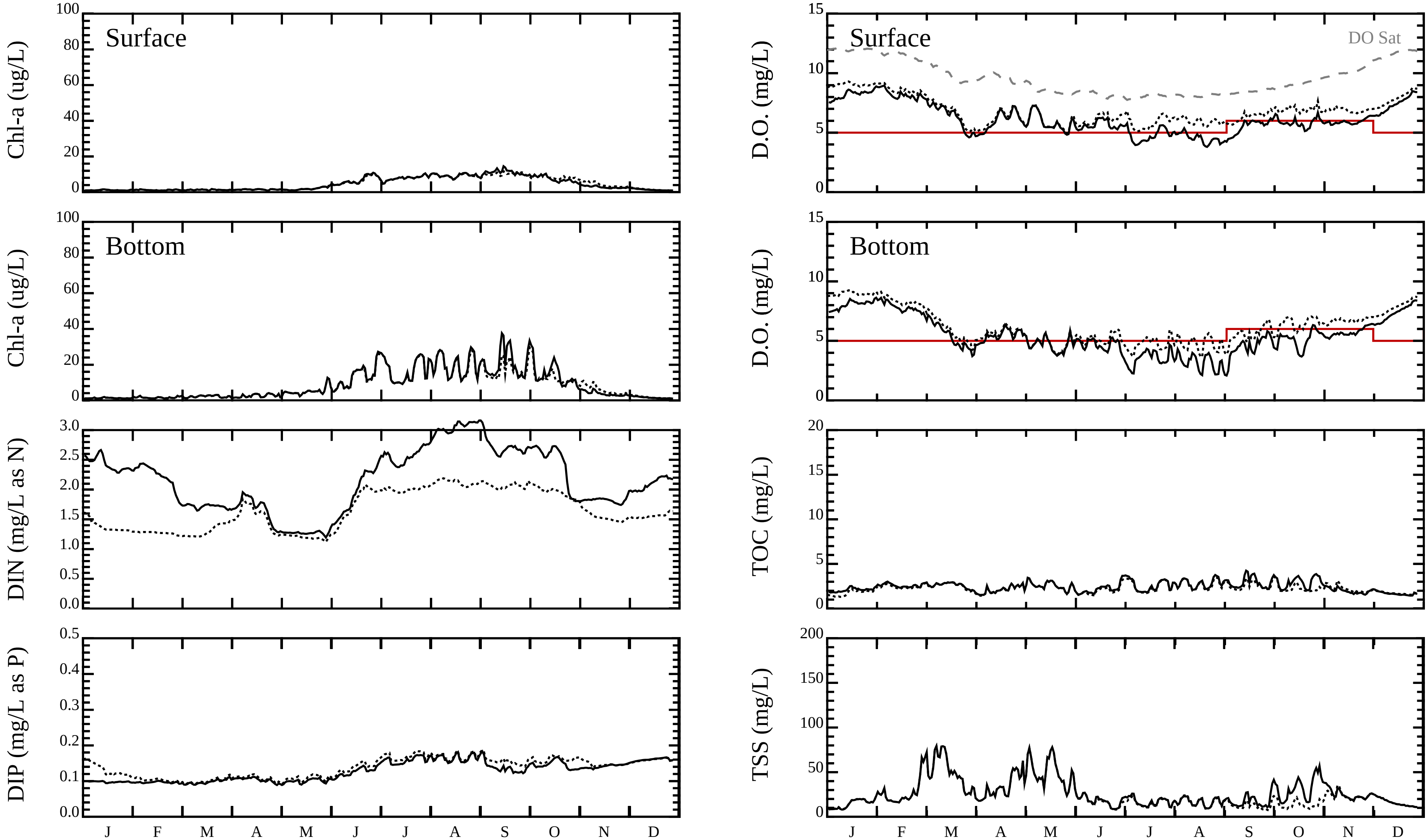
Comparison of Water Quality Model Base and Projection: SJR at R7

DATE: 4/20/2006 TIME: 15:13:21



Comparison of Water Quality Model Base and Projection: SJR at R8

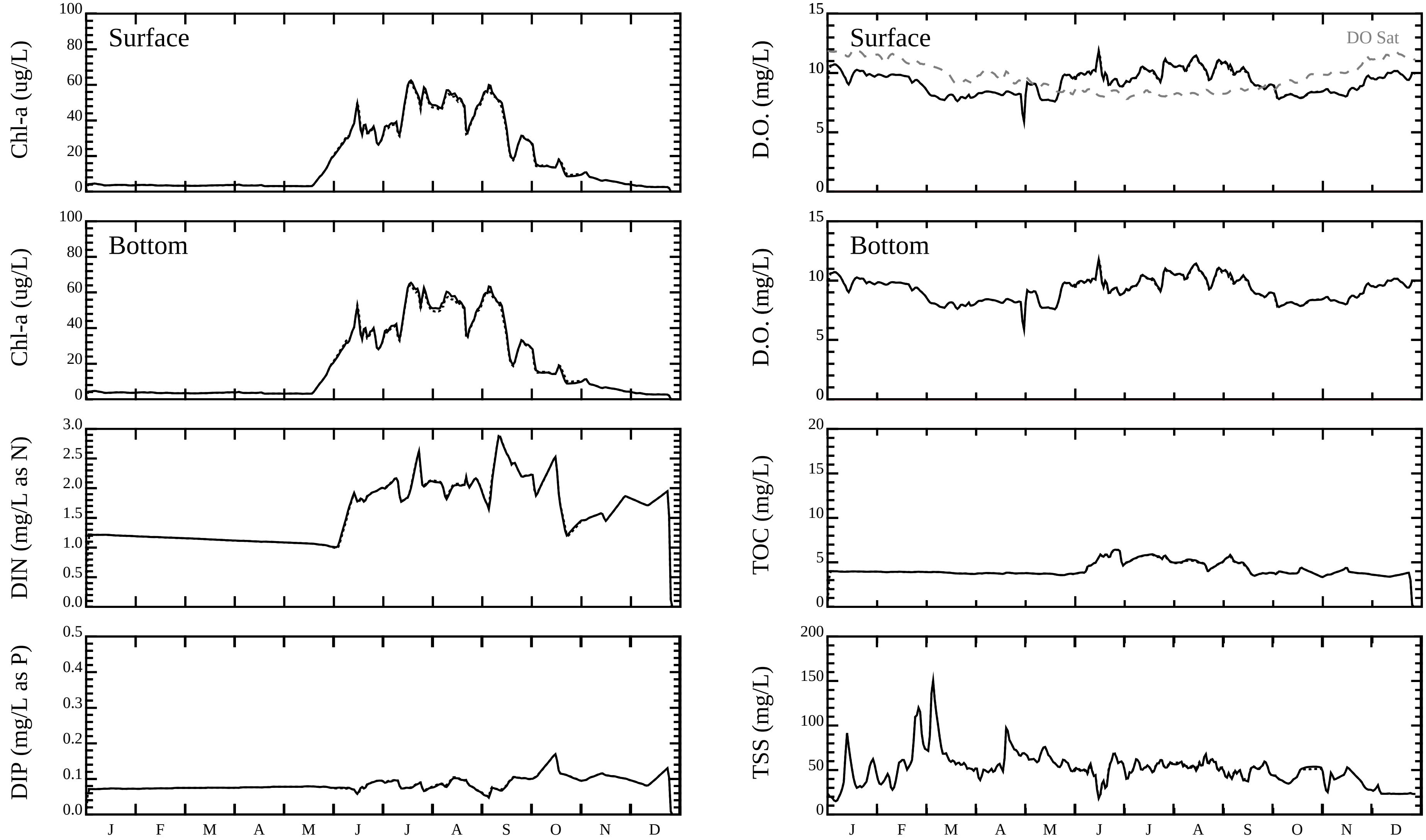
DATE: 4/20/2006 TIME: 15:14: 2



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

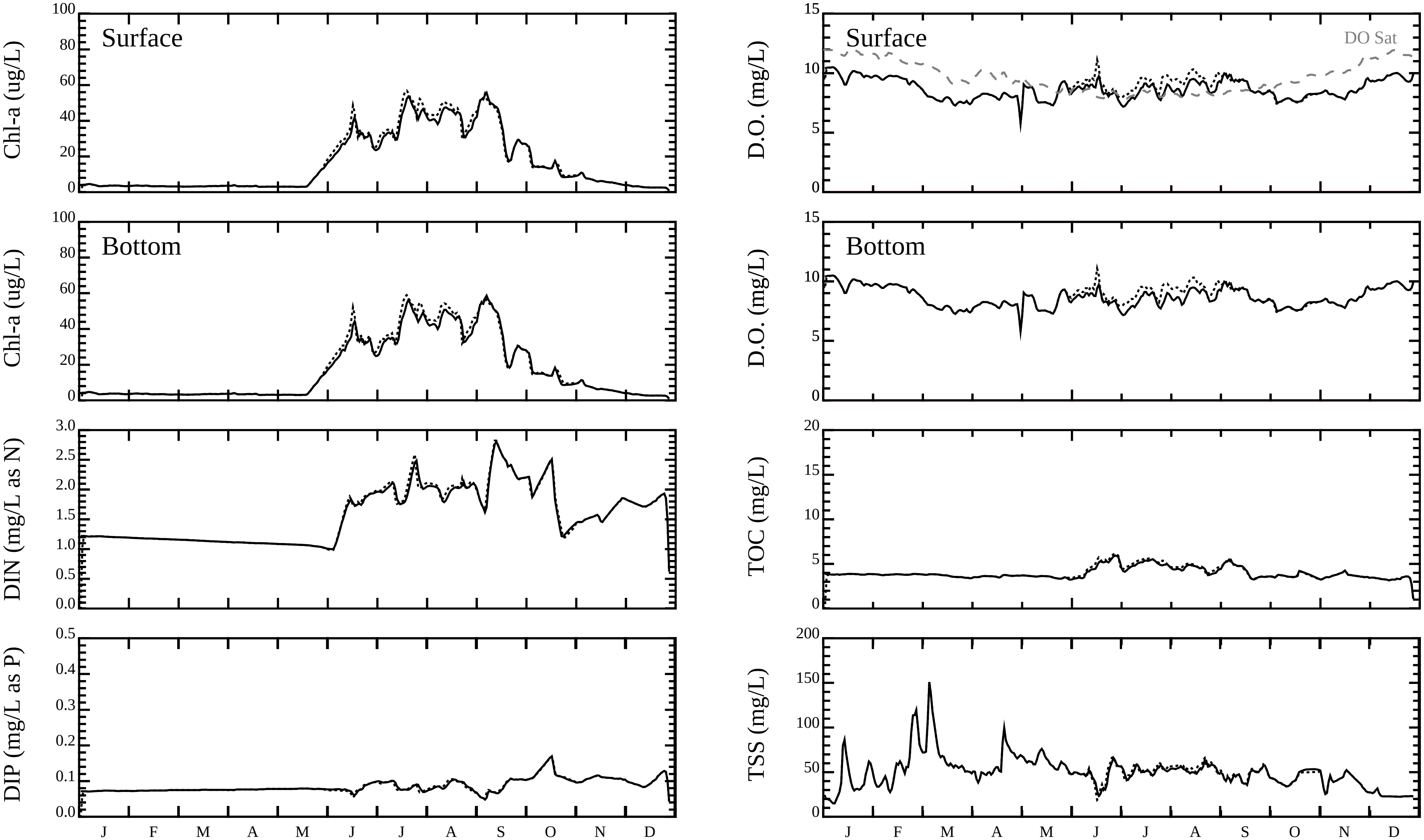
DATE: 4/20/2006 TIME: 15: 8:38



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=750cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at Mossdale

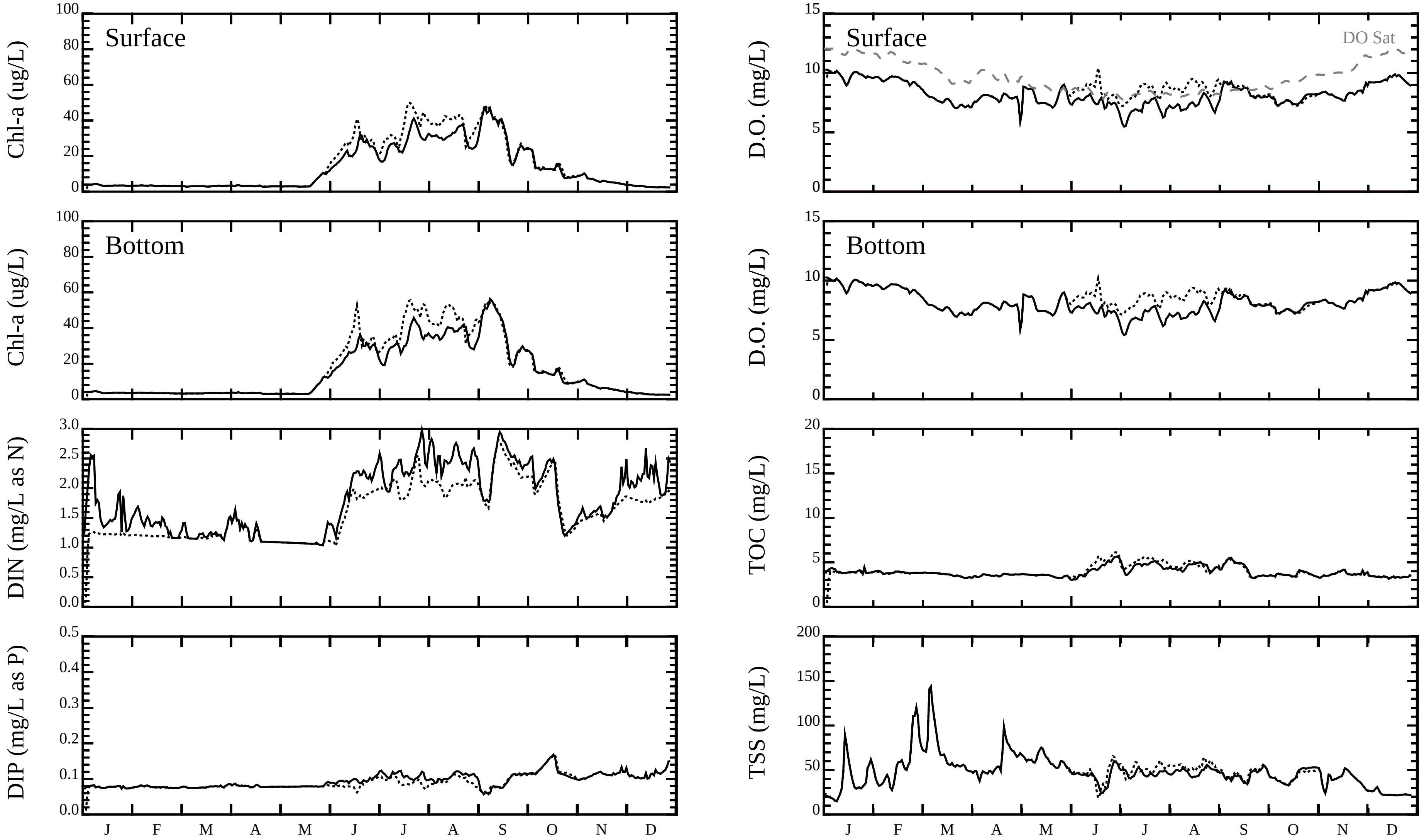
DATE: 4/20/2006 TIME: 15:14:43



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=750cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R1

DATE: 4/20/2006 TIME: 15:16: 4

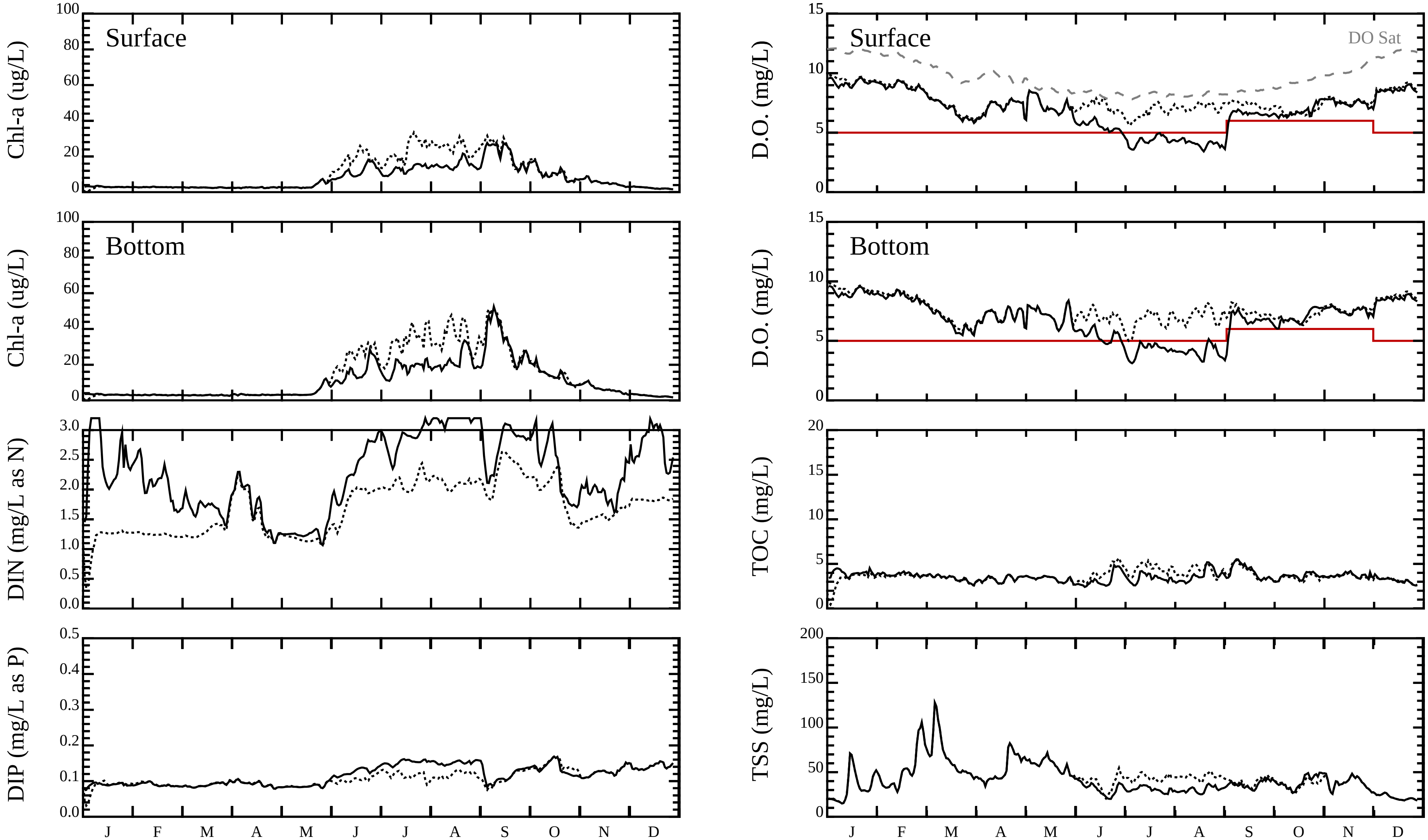


—— Base 2001 Model-Stockton Average Summer Q=425cfs

...... Projected Model-Stockton Summer Q=750cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R2

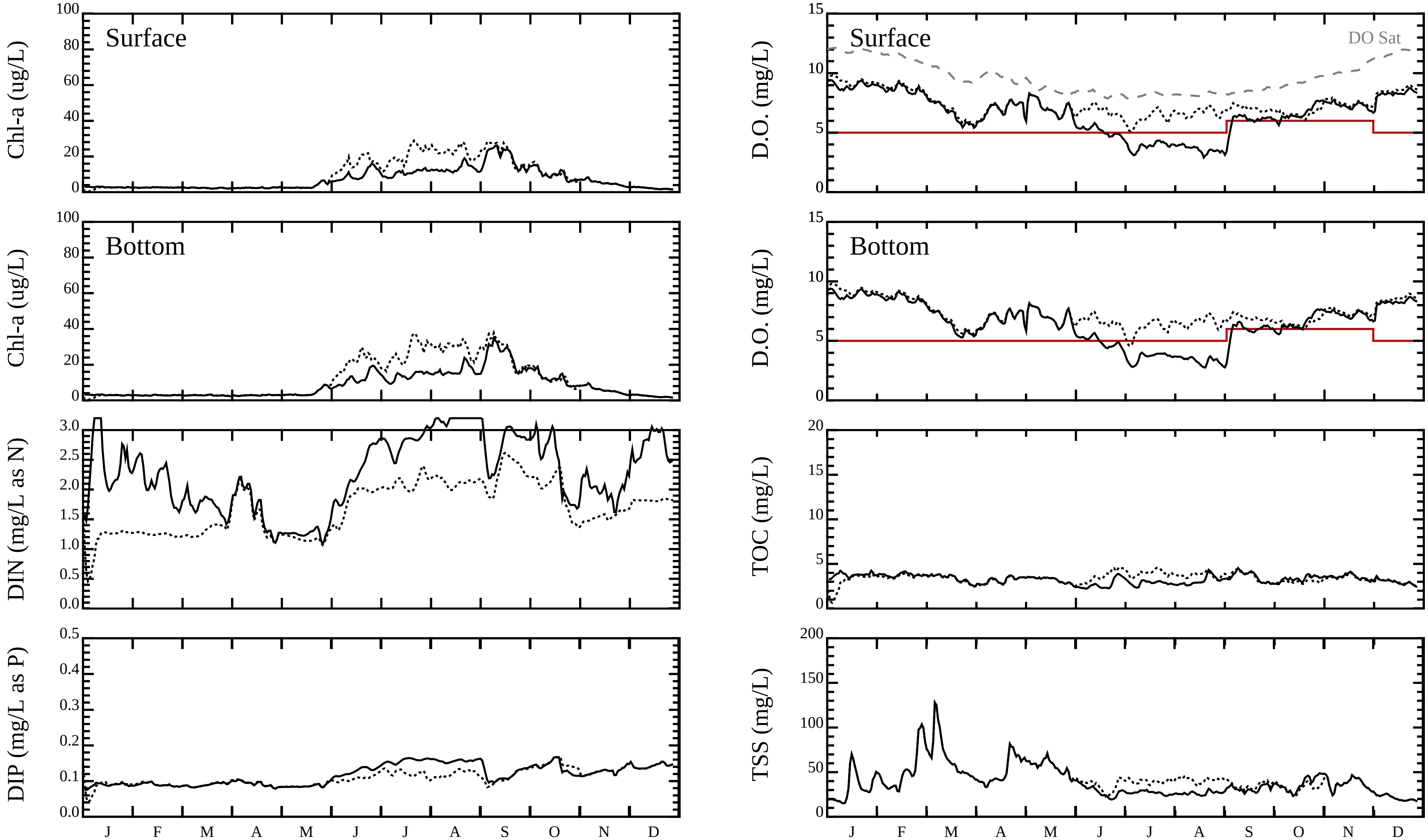
DATE: 4/20/2006 TIME: 15:16:45



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=750cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R3

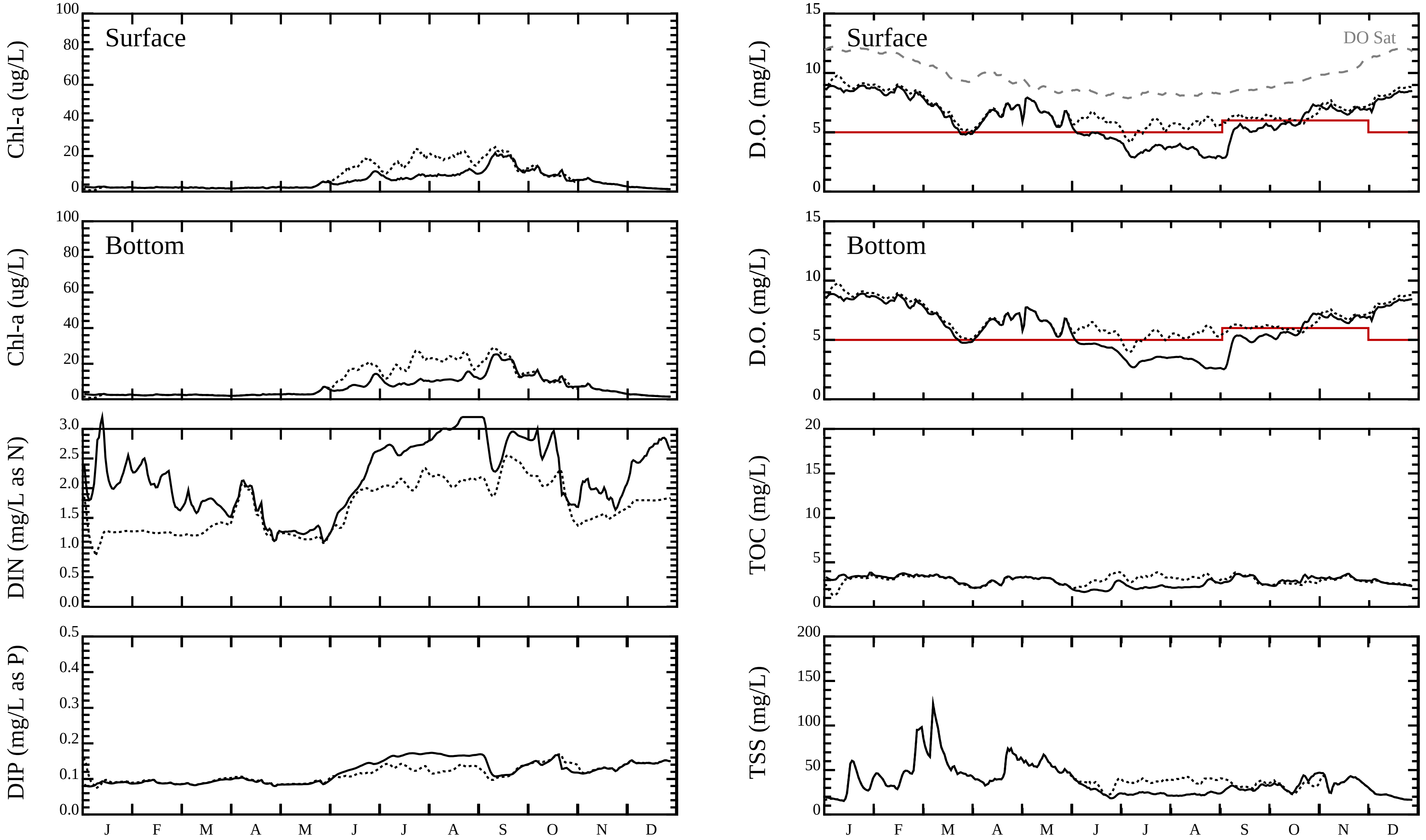
DATE: 4/20/2006 TIME: 15:17:25



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=750cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R4

DATE: 4/20/2006 TIME: 15:18: 5

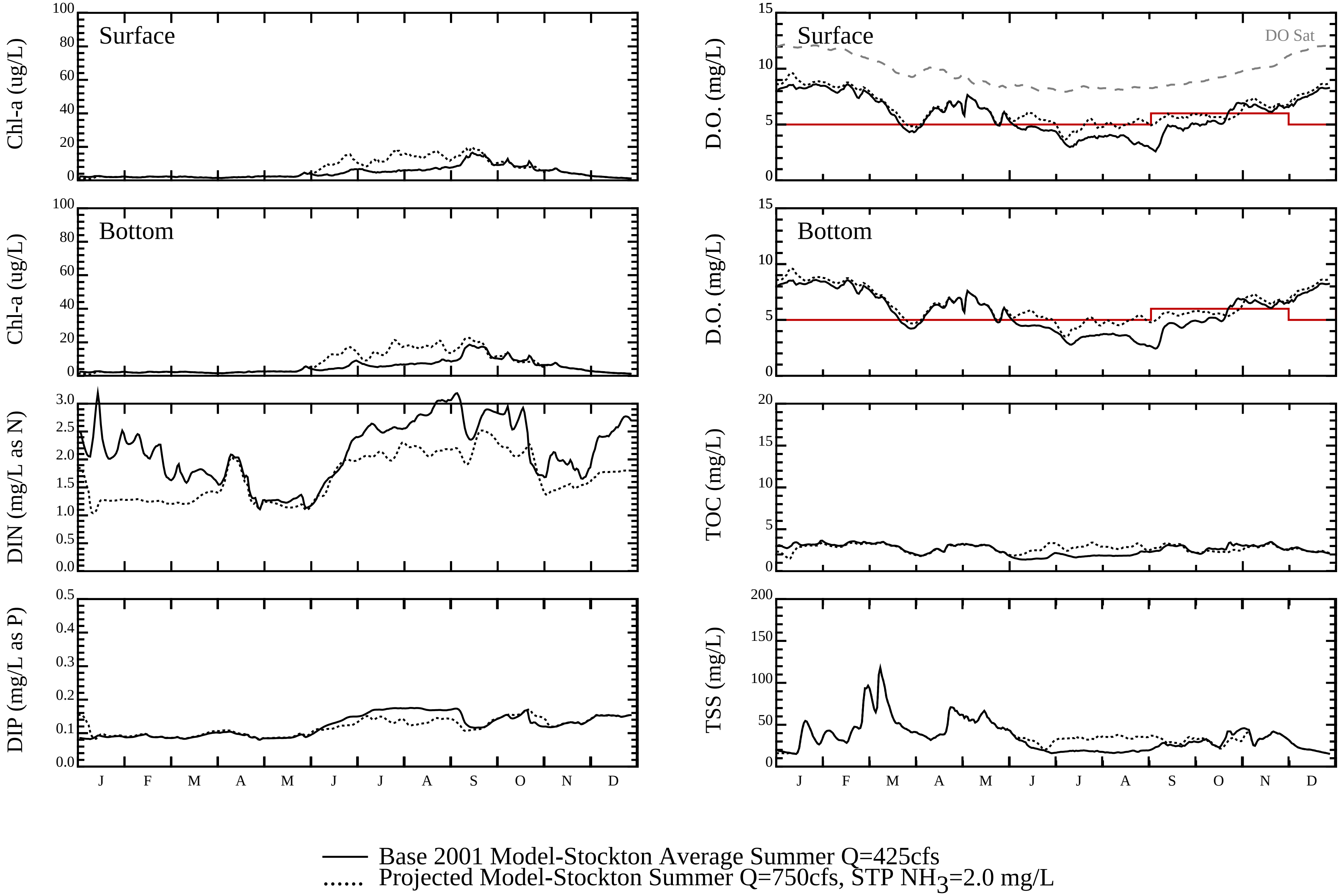


Base 2001 Model-Stockton Average Summer Q=425cfs

Projected Model-Stockton Summer Q=750cfs, STP NH_3=2.0 mg/L

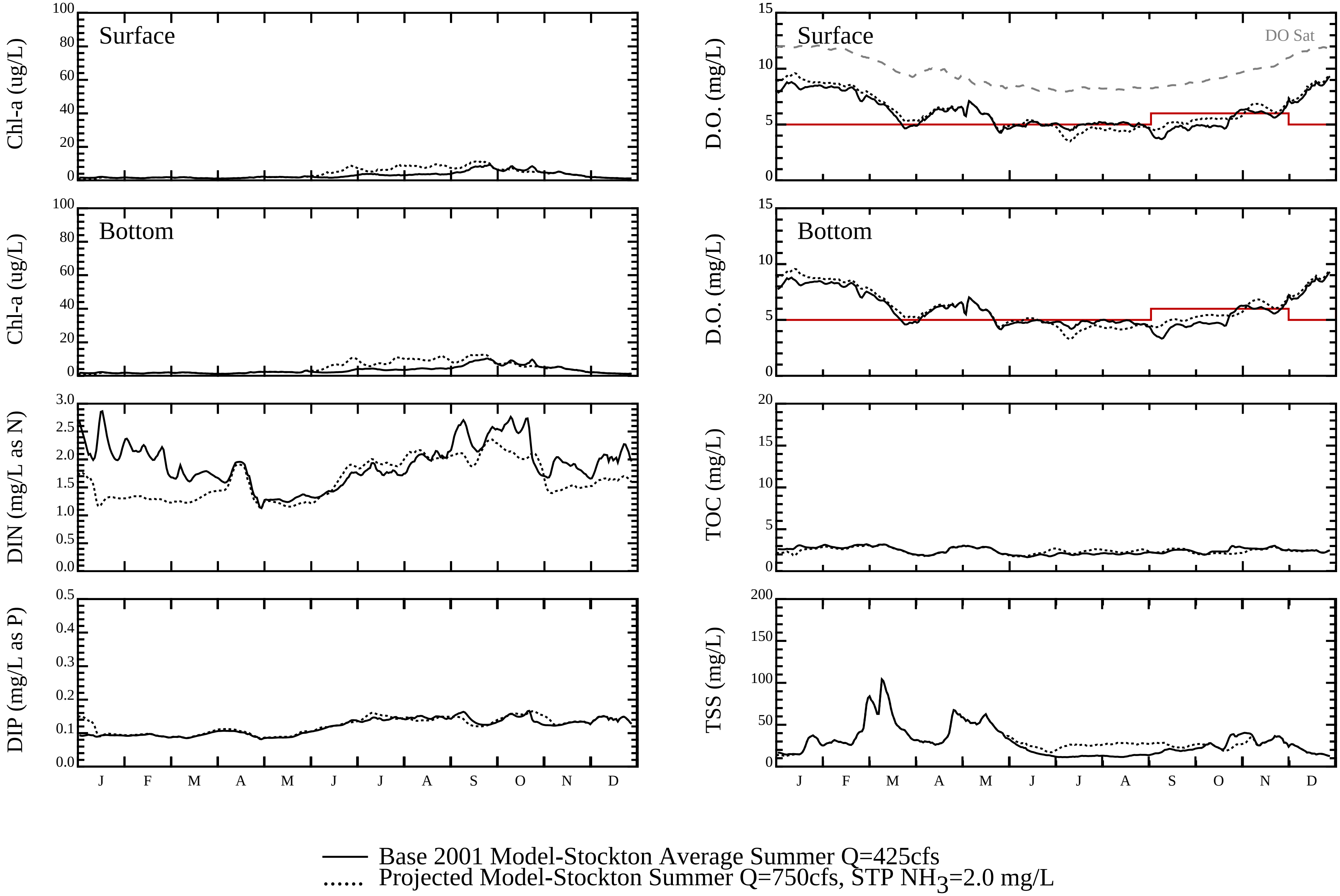
Comparison of Water Quality Model Base and Projection: SJR at R5

DATE: 4/20/2006 TIME: 15:18:46



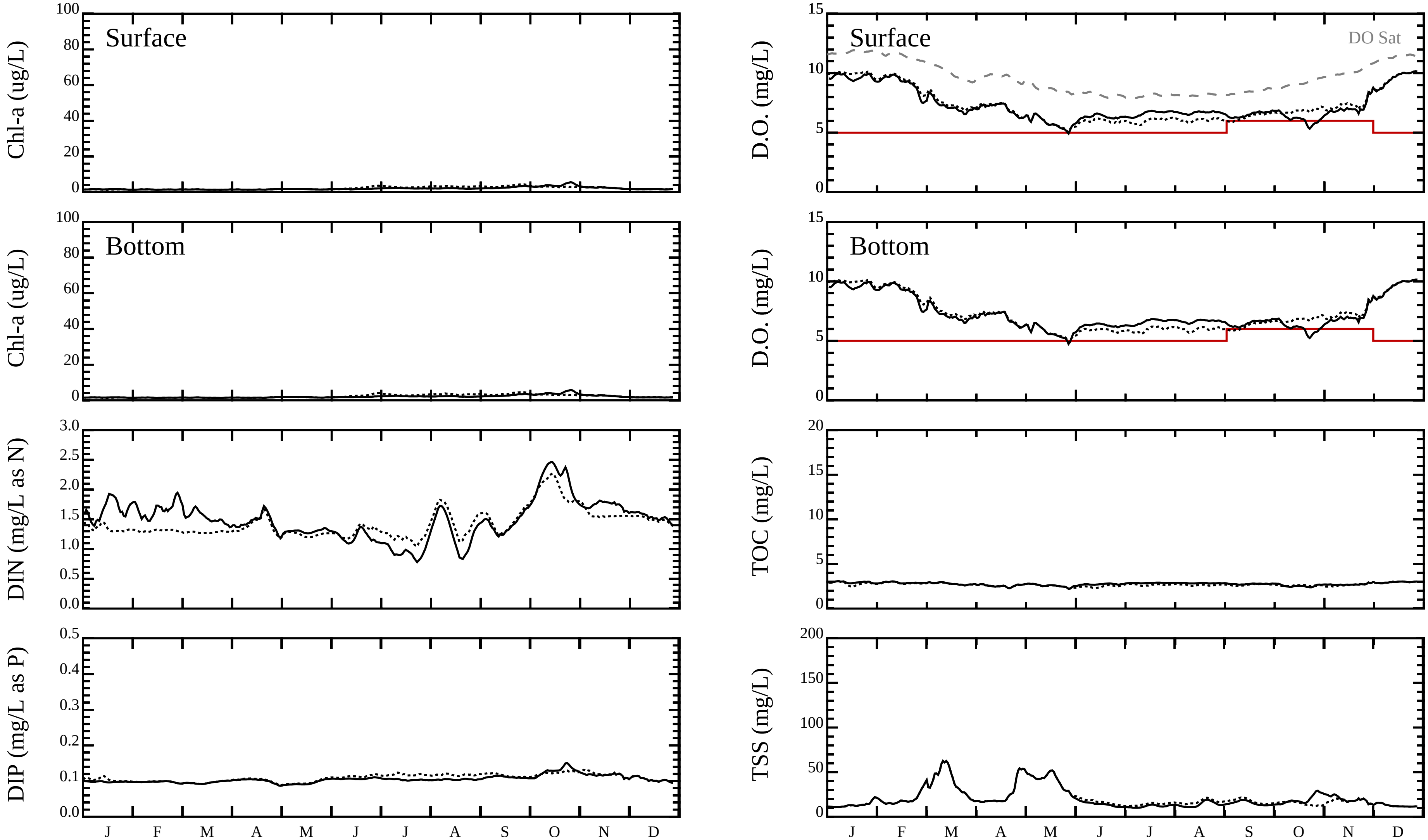
Comparison of Water Quality Model Base and Projection: SJR at R6

DATE: 4/20/2006 TIME: 15:19:26



Comparison of Water Quality Model Base and Projection: SJR at R7

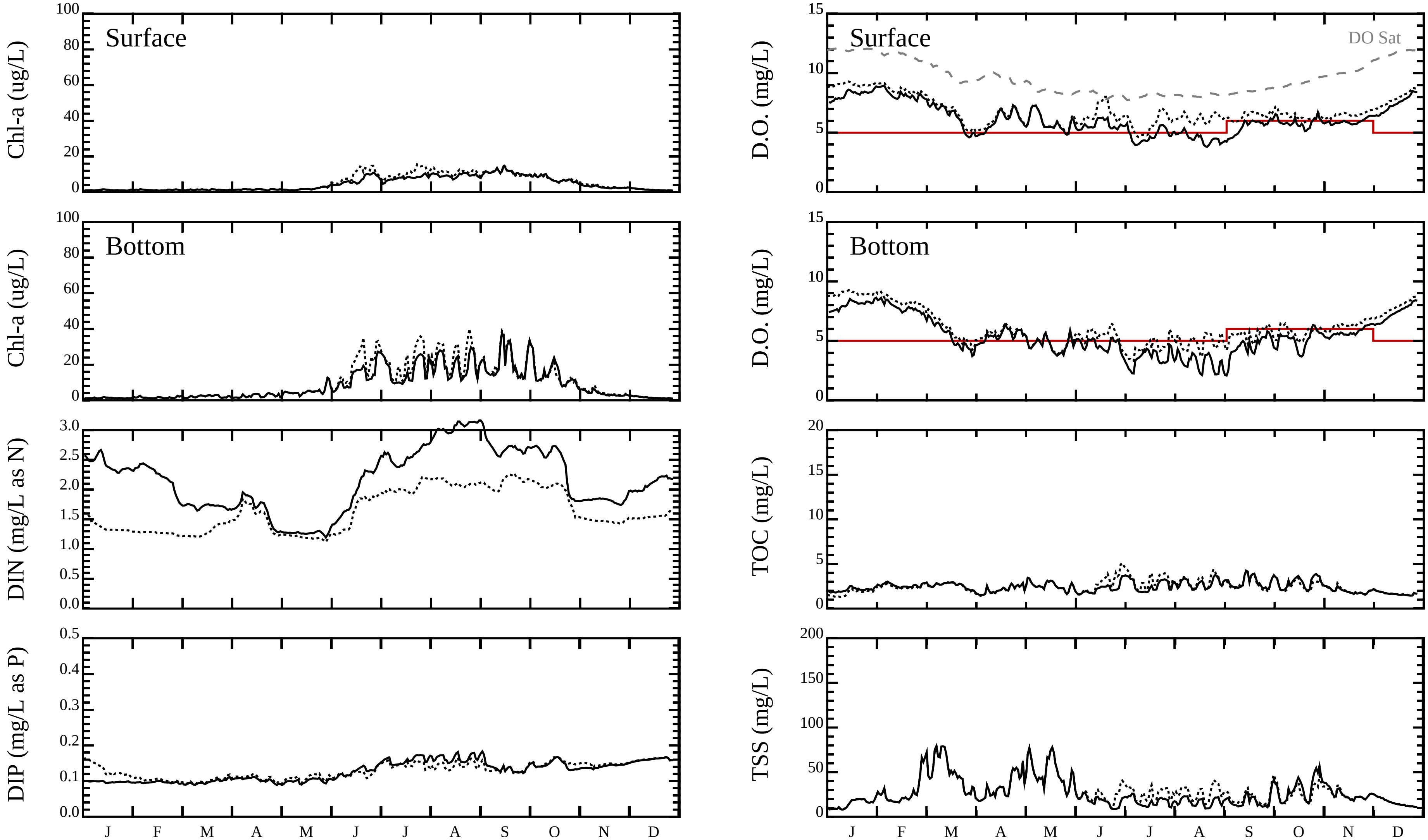
DATE: 4/20/2006 TIME: 15:20: 7



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=750cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R8

DATE: 4/20/2006 TIME: 15:20:47

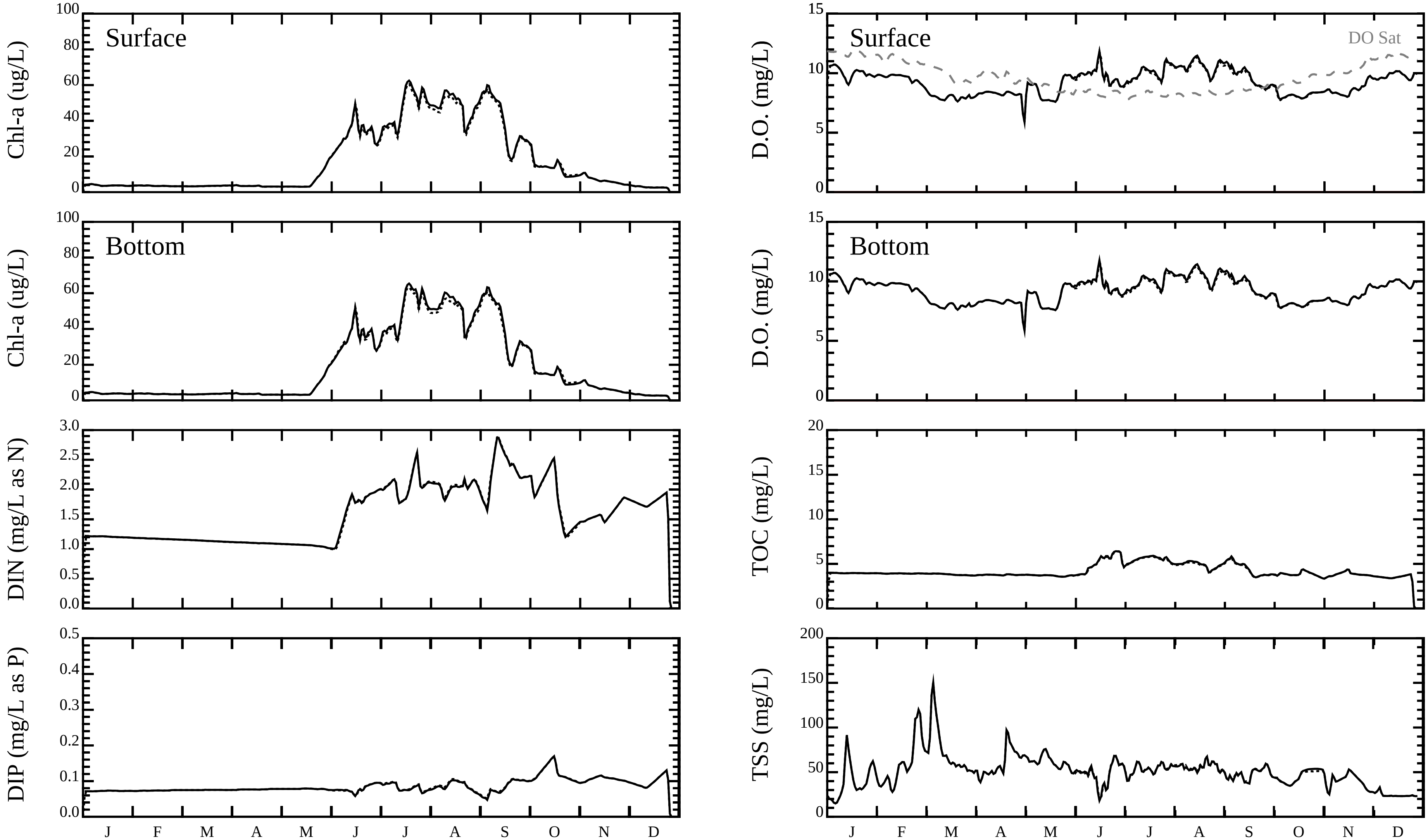


—— Base 2001 Model-Stockton Average Summer Q=425cfs

...... Projected Model-Stockton Summer Q=750cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

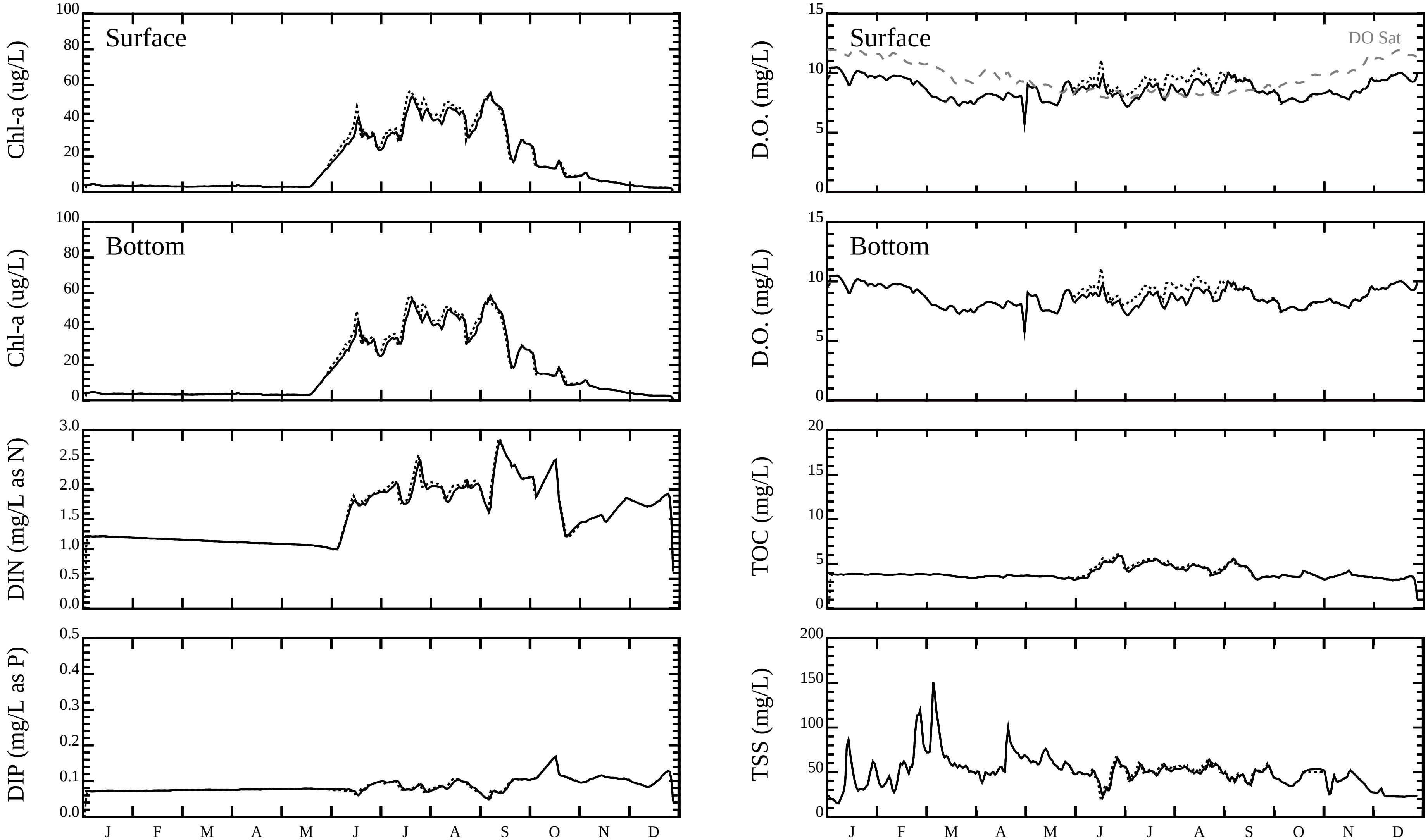
DATE: 4/20/2006 TIME: 15:15:24



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at Mossdale

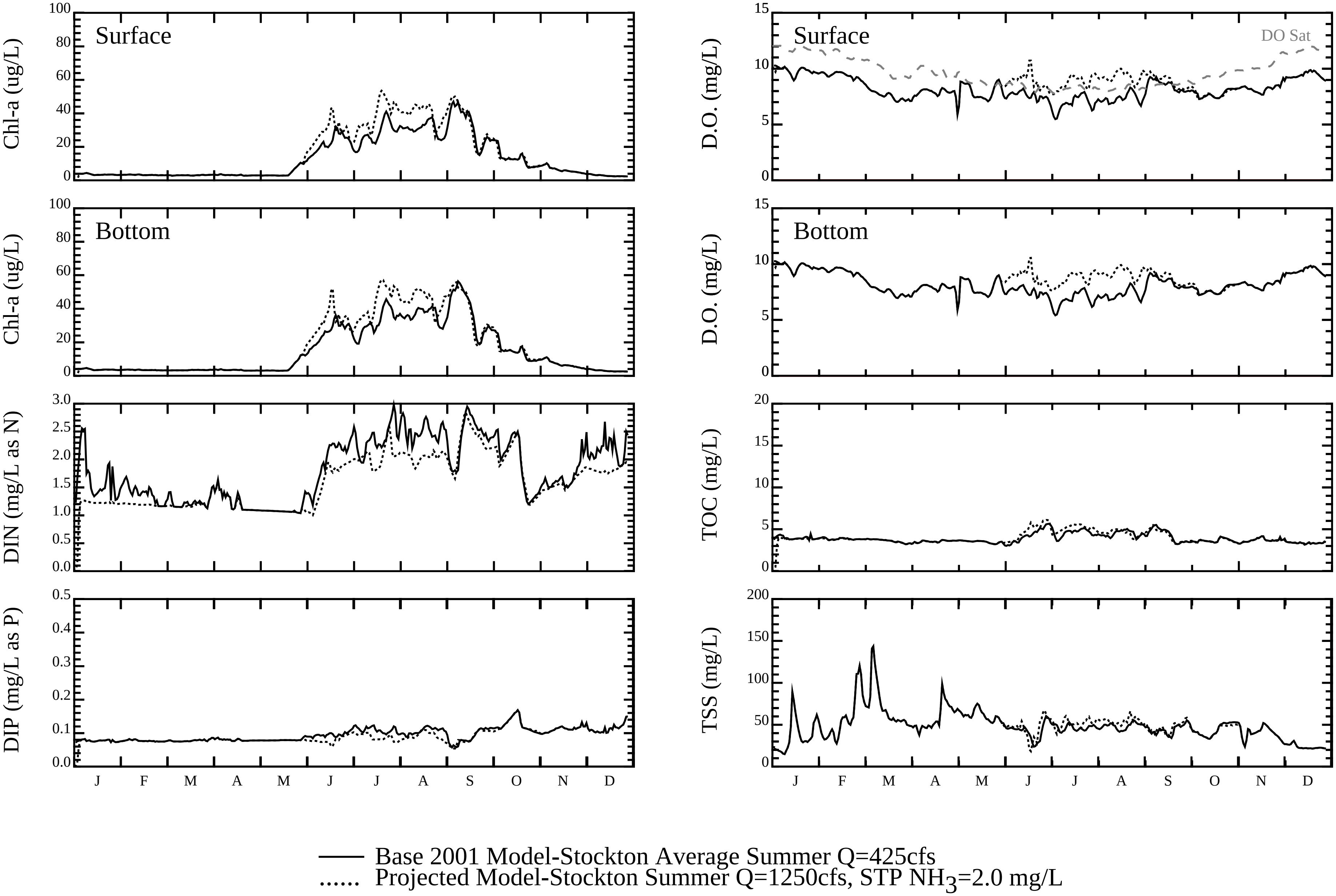
DATE: 4/20/2006 TIME: 15:21:28



Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1250cfs, STP NH_3=2.0 mg/L

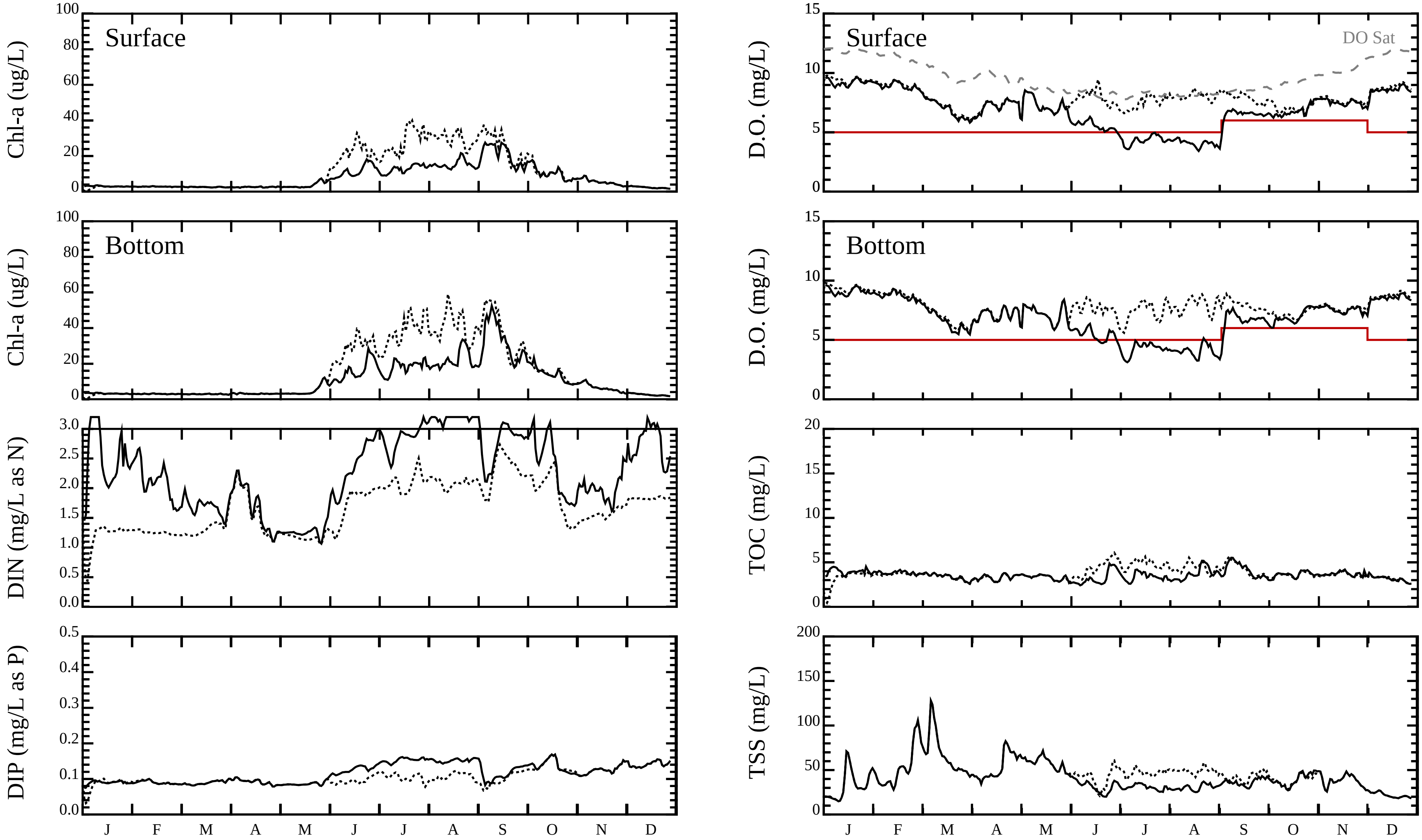
Comparison of Water Quality Model Base and Projection: SJR at R1

DATE: 4/20/2006 TIME: 15:23: 1



Comparison of Water Quality Model Base and Projection: SJR at R2

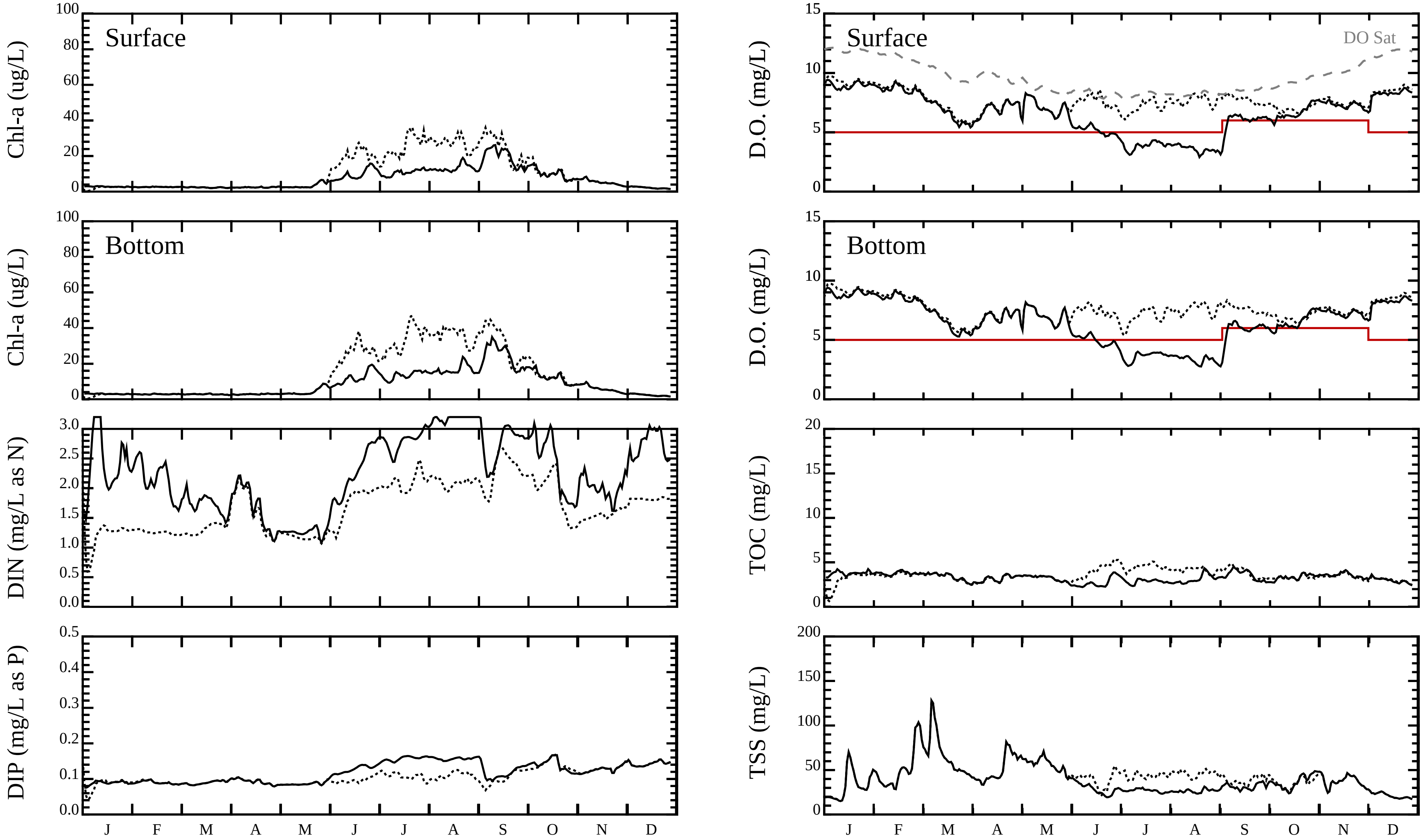
DATE: 4/20/2006 TIME: 15:23:41



Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R3

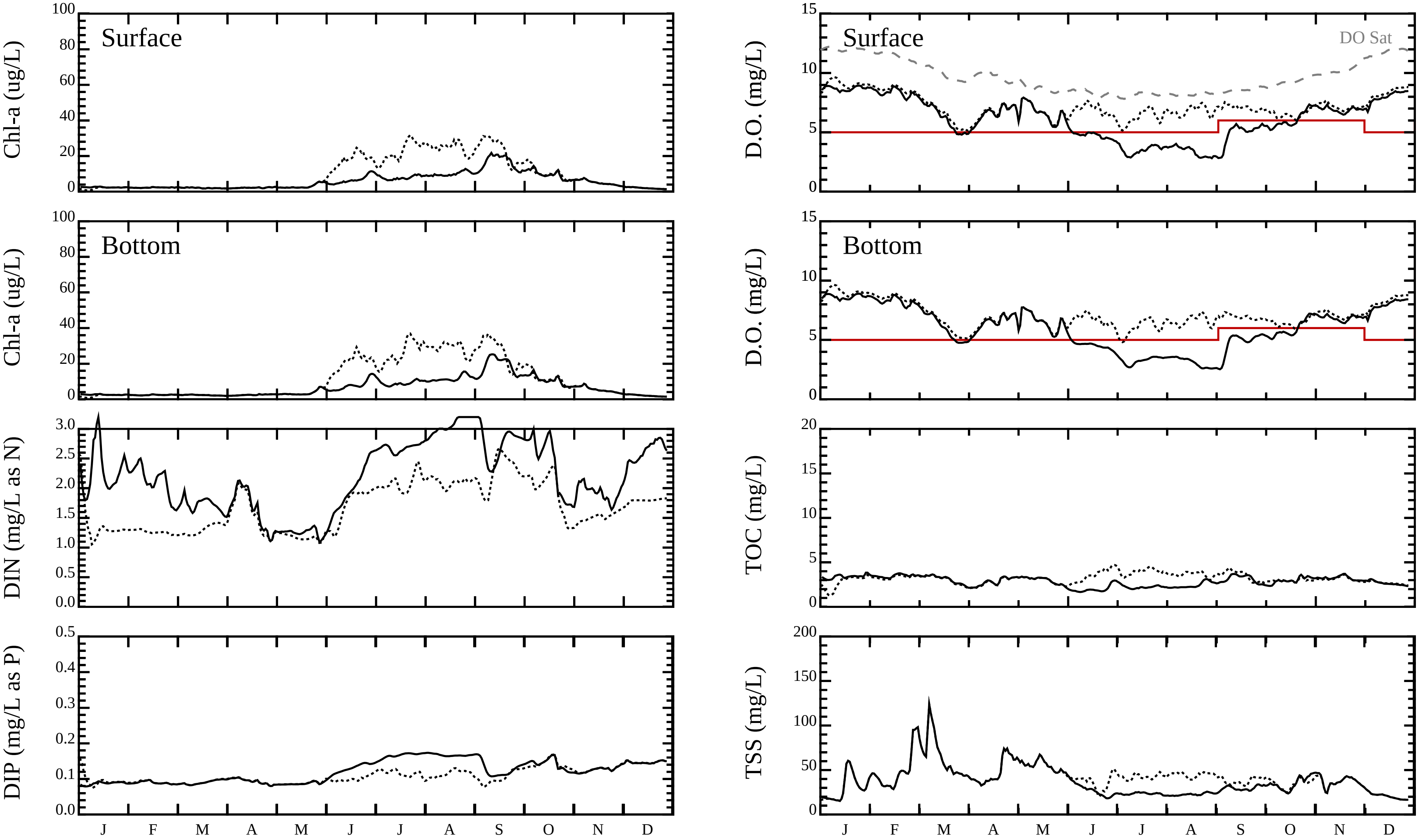
DATE: 4/20/2006 TIME: 15:24:22



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R4

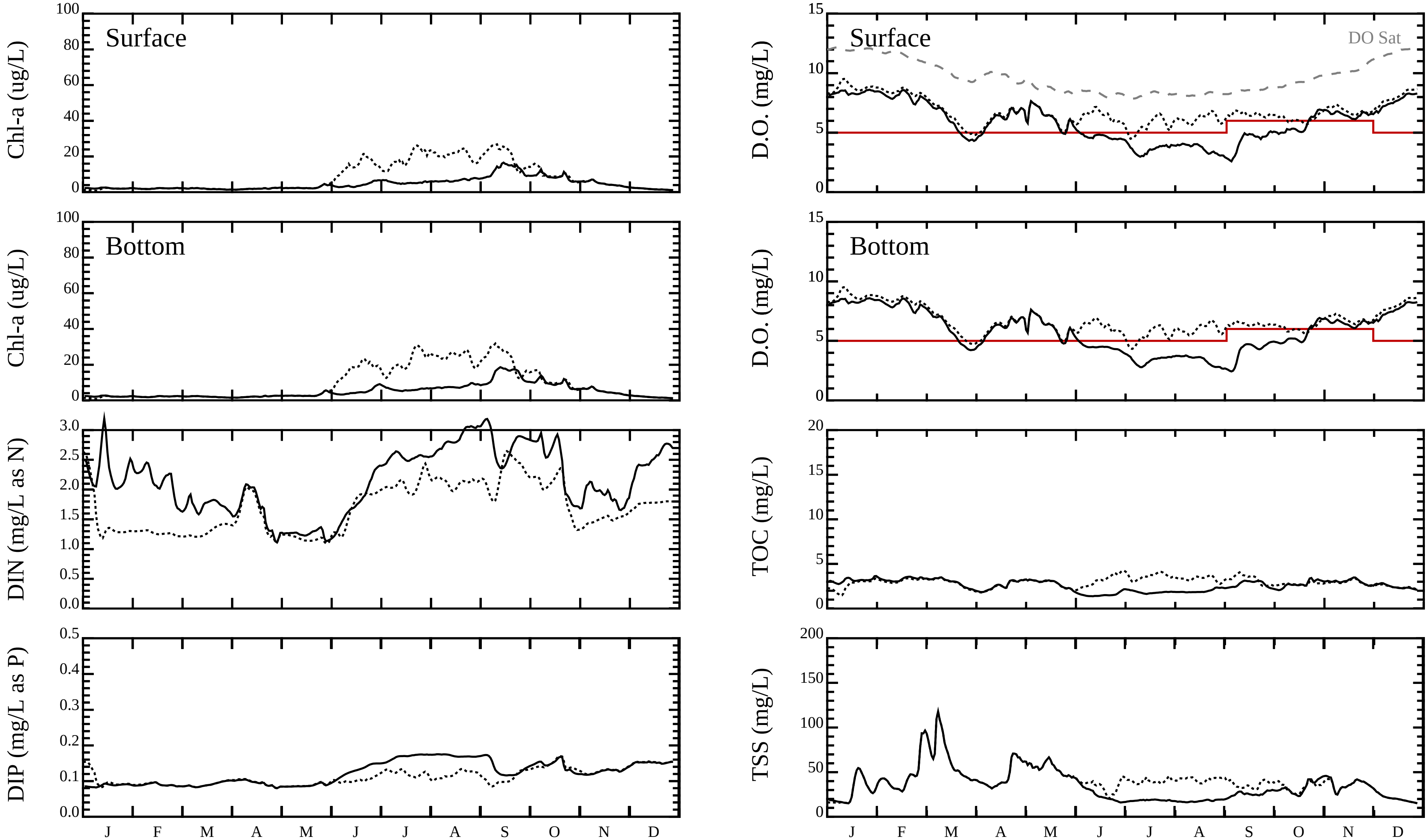
DATE: 4/20/2006 TIME: 15:25: 2



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R5

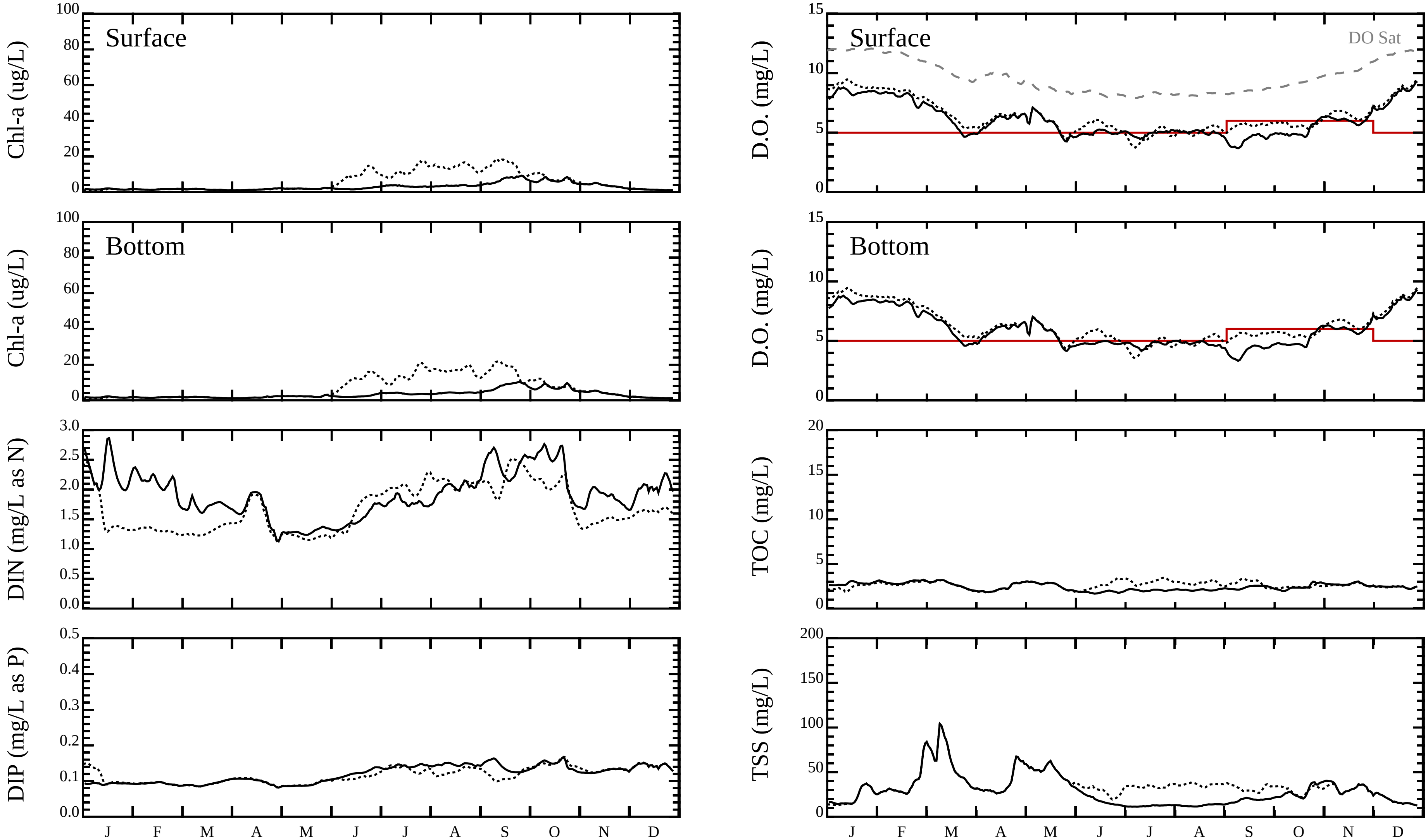
DATE: 4/20/2006 TIME: 15:25:42



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1250cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R6

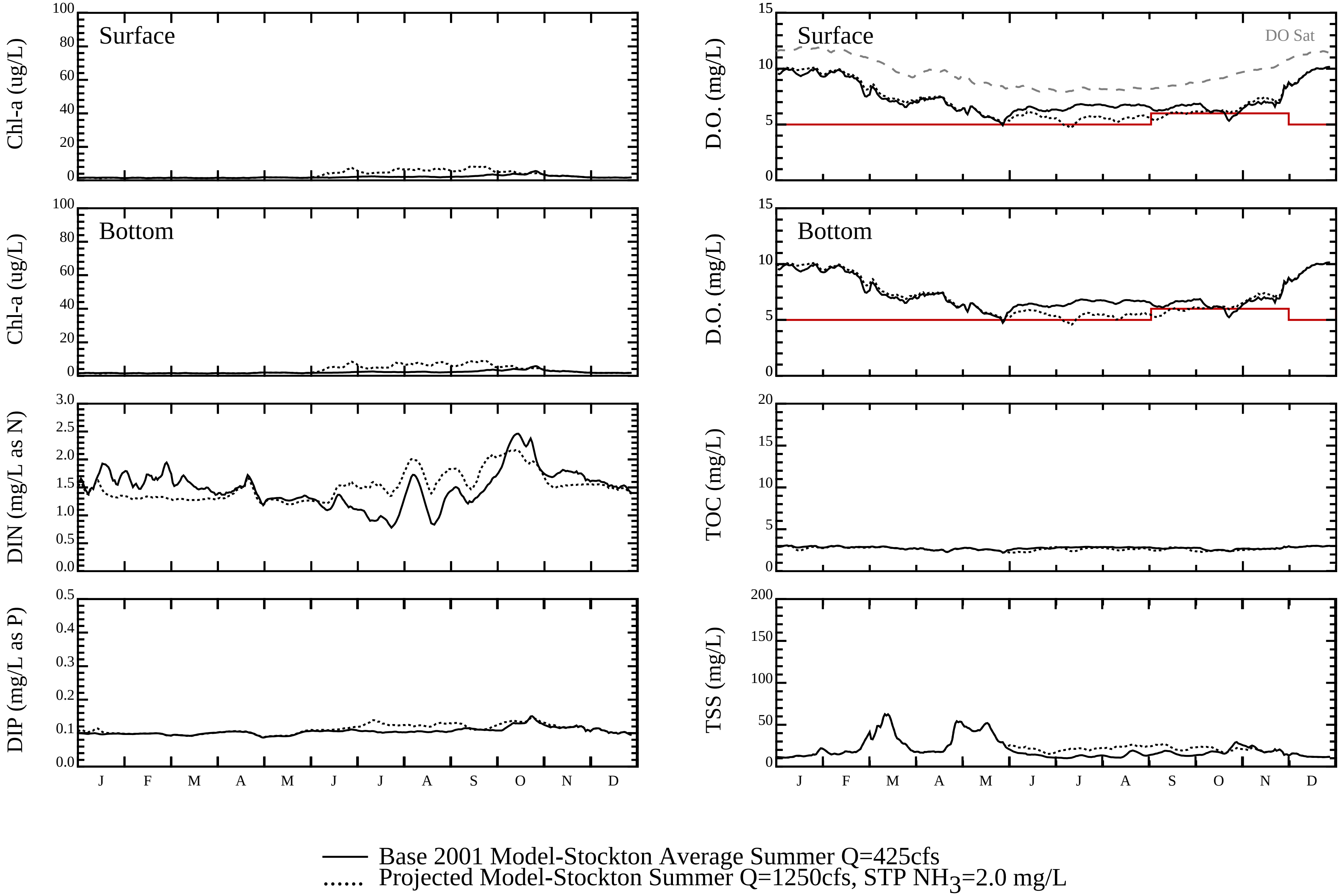
DATE: 4/20/2006 TIME: 15:26:22



Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1250cfs, STP NH_3=2.0 mg/L

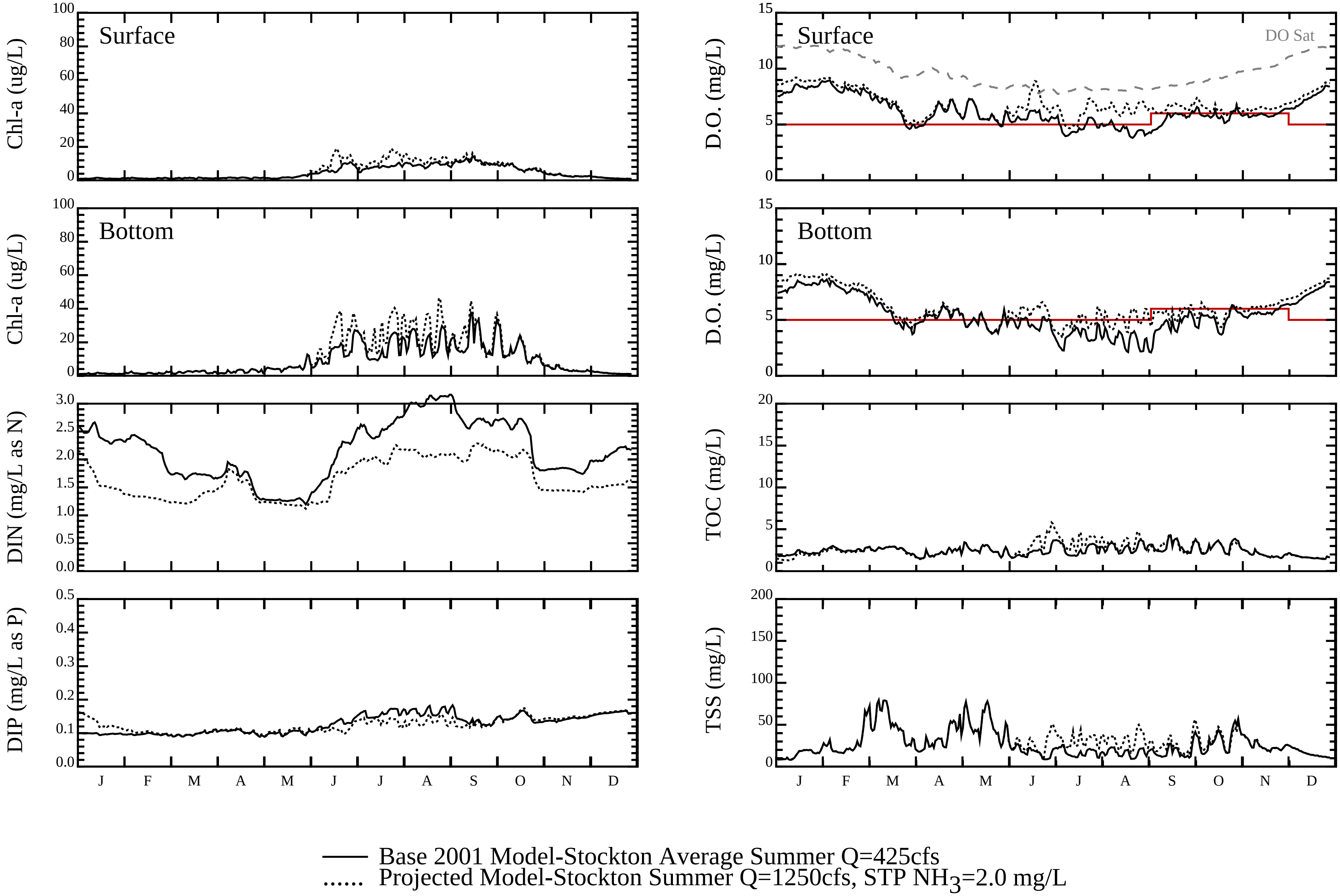
Comparison of Water Quality Model Base and Projection: SJR at R7

DATE: 4/20/2006 TIME: 15:27: 3



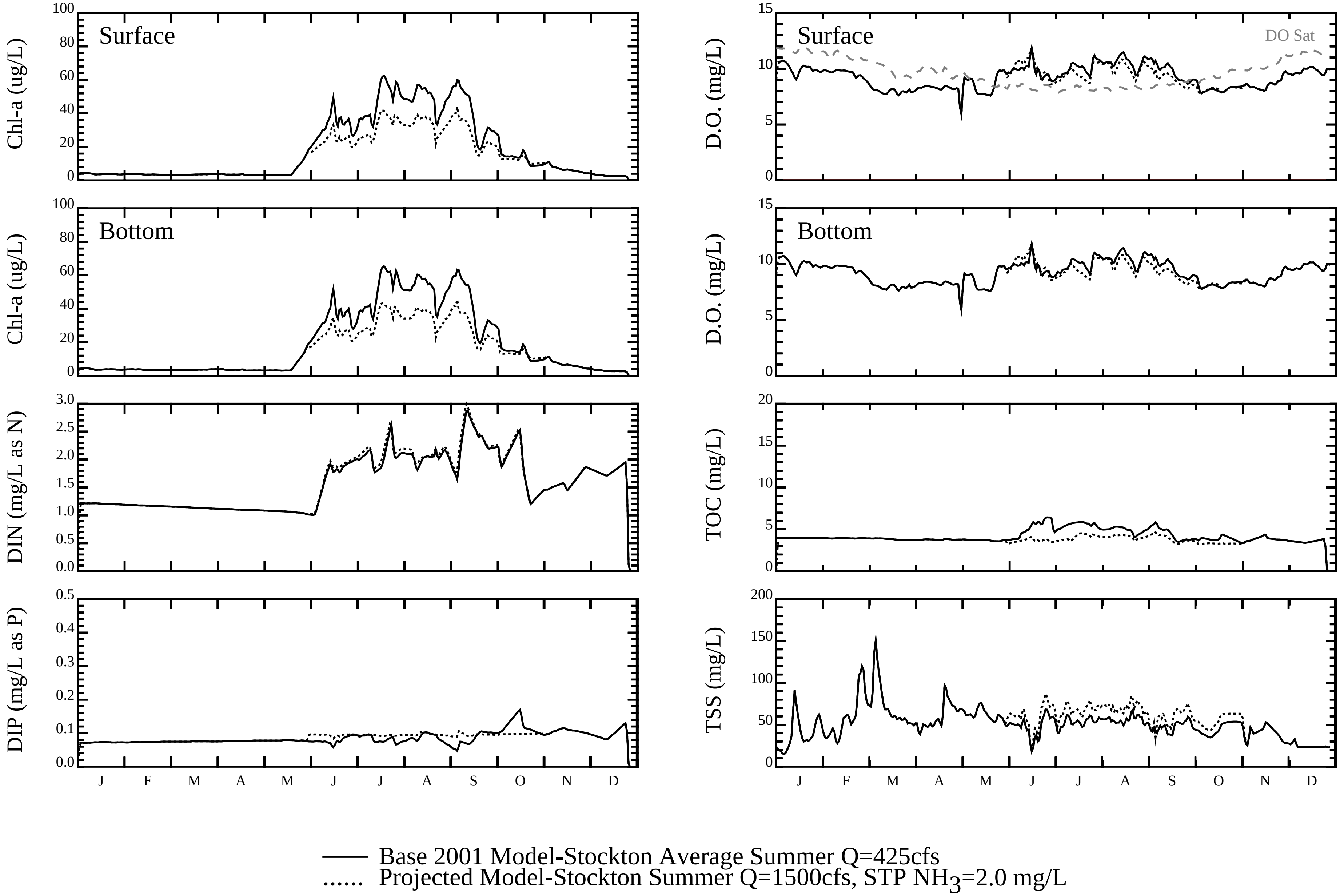
Comparison of Water Quality Model Base and Projection: SJR at R8

DATE: 4/20/2006 TIME: 15:27:43



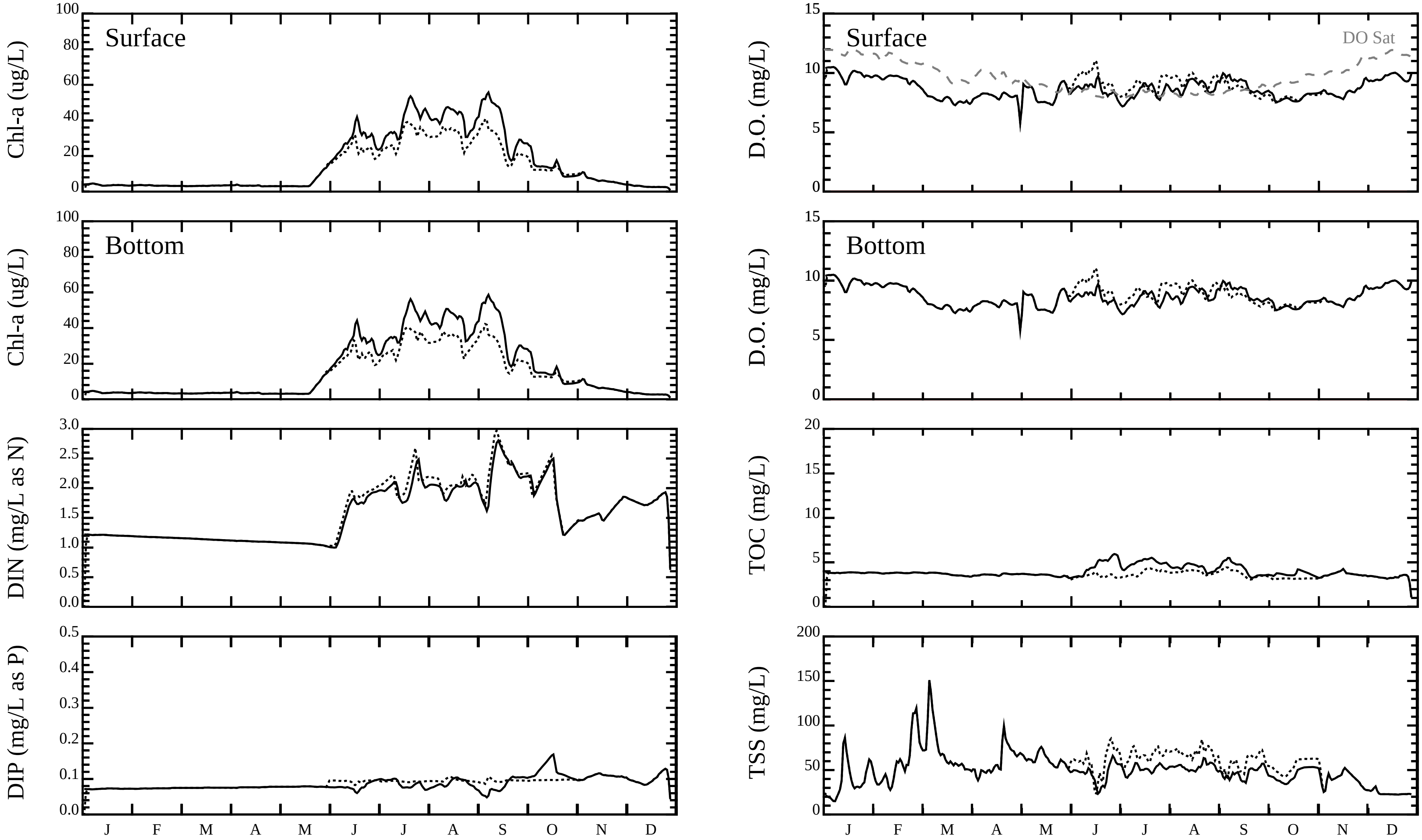
Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

DATE: 4/20/2006 TIME: 15:22:21



Comparison of Water Quality Model Base and Projection: SJR at Mossdale

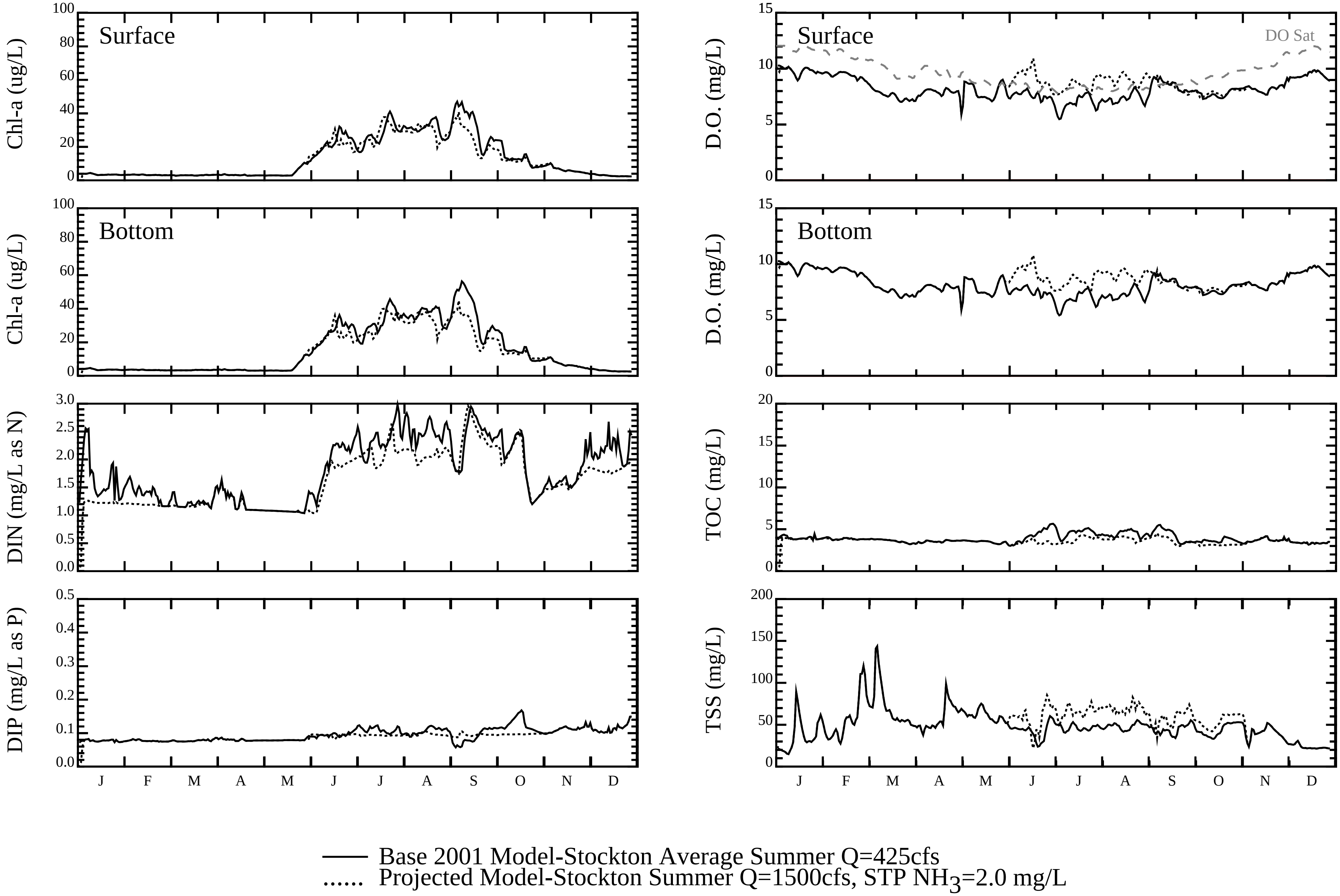
DATE: 4/20/2006 TIME: 15:28:24



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1500cfs, STP NH_3=2.0 mg/L

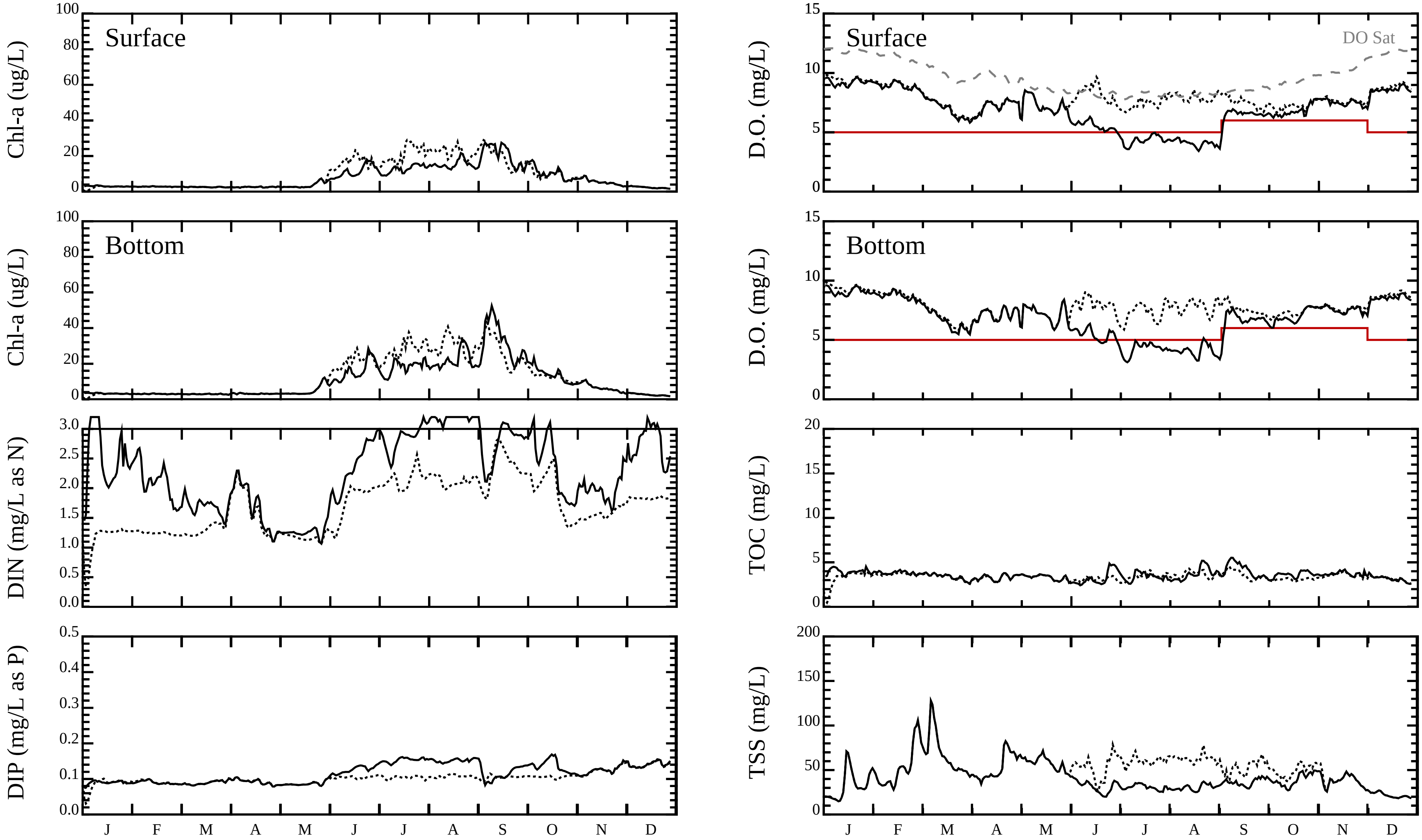
Comparison of Water Quality Model Base and Projection: SJR at R1

DATE: 4/20/2006 TIME: 15:30: 4



Comparison of Water Quality Model Base and Projection: SJR at R2

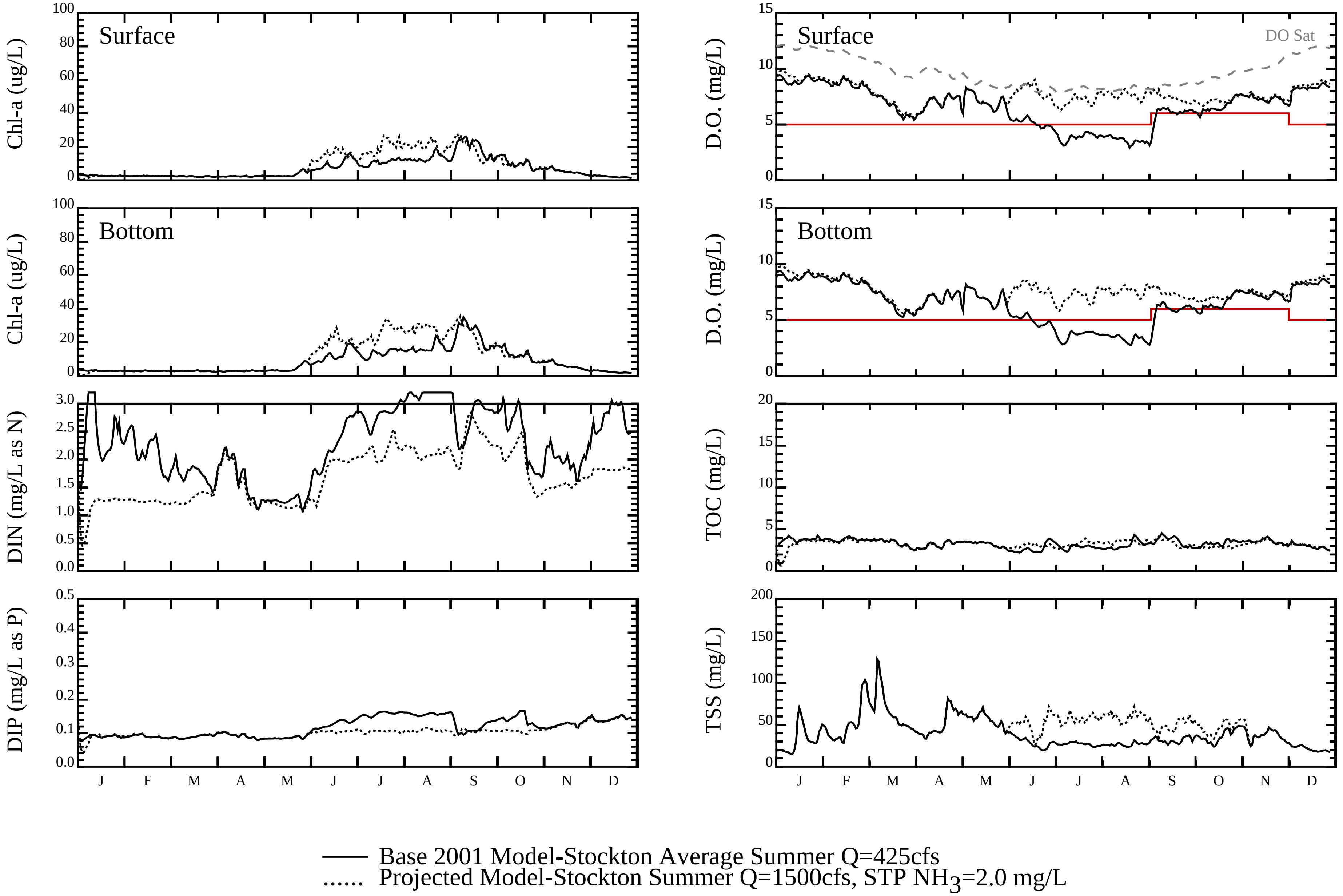
DATE: 4/20/2006 TIME: 15:30:44



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1500cfs, STP NH_3=2.0 mg/L

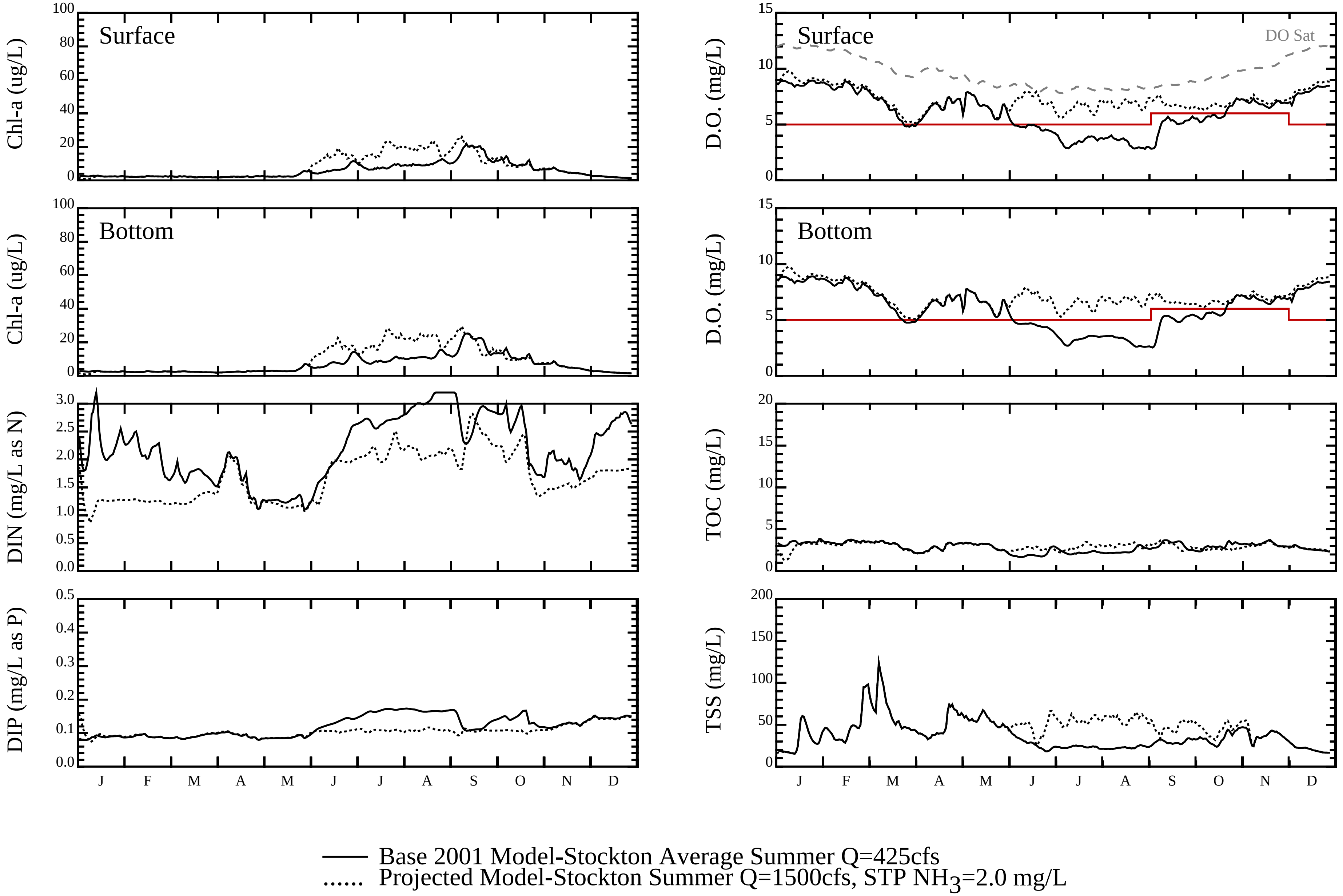
Comparison of Water Quality Model Base and Projection: SJR at R3

DATE: 4/20/2006 TIME: 15:31:25



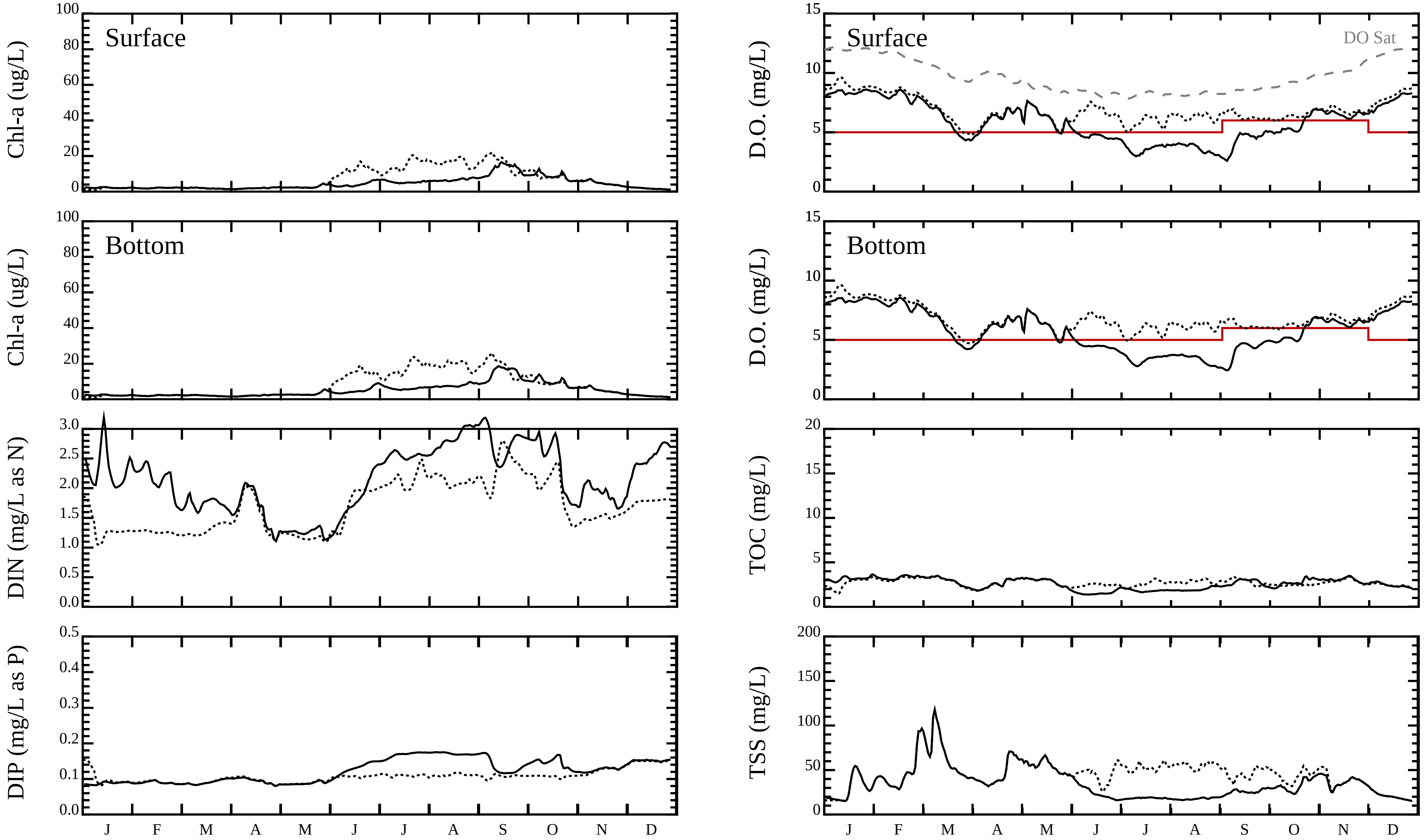
Comparison of Water Quality Model Base and Projection: SJR at R4

DATE: 4/20/2006 TIME: 15:32: 5



Comparison of Water Quality Model Base and Projection: SJR at R5

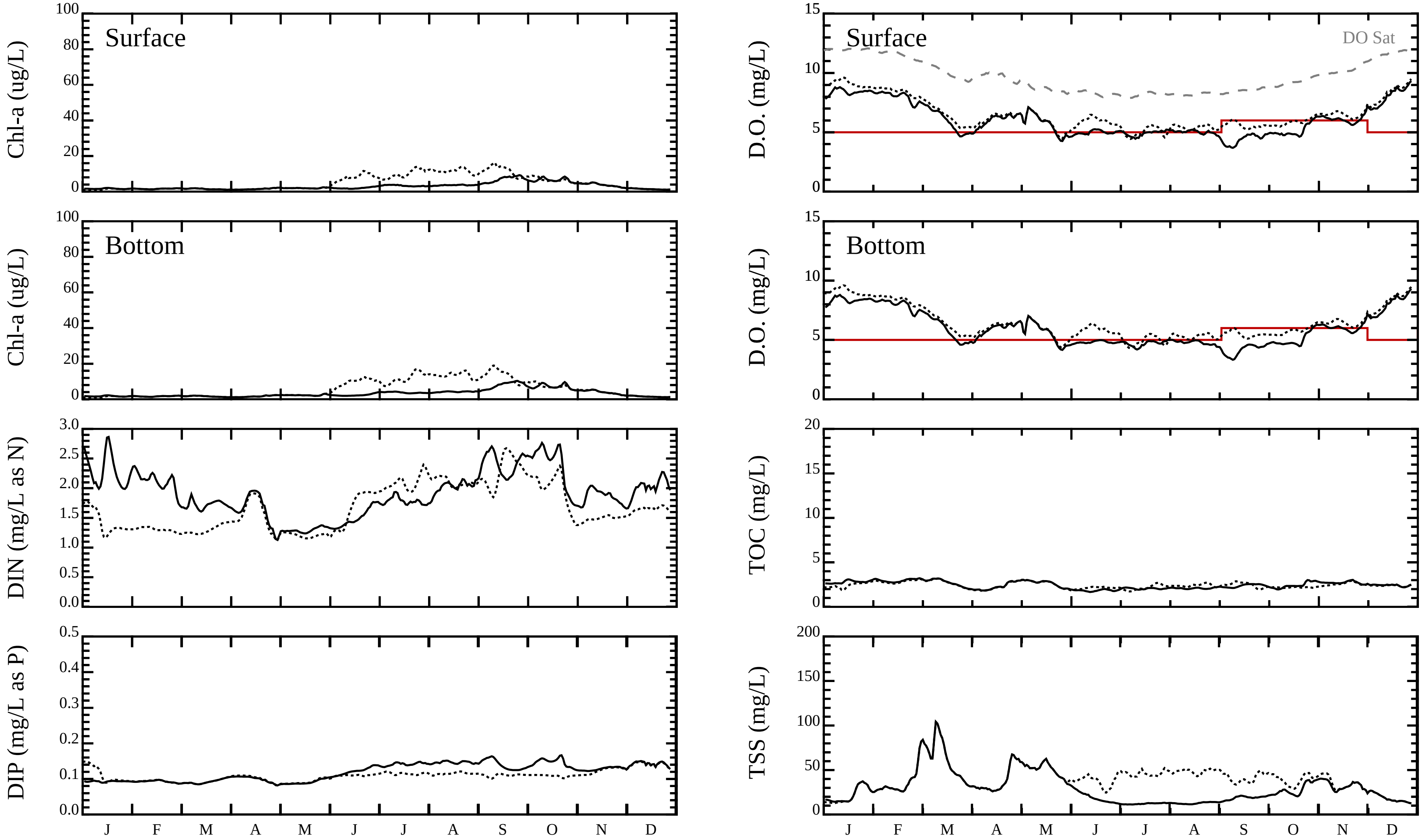
DATE: 4/20/2006 TIME: 15:32:46



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1500cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R6

DATE: 4/20/2006 TIME: 15:33:26

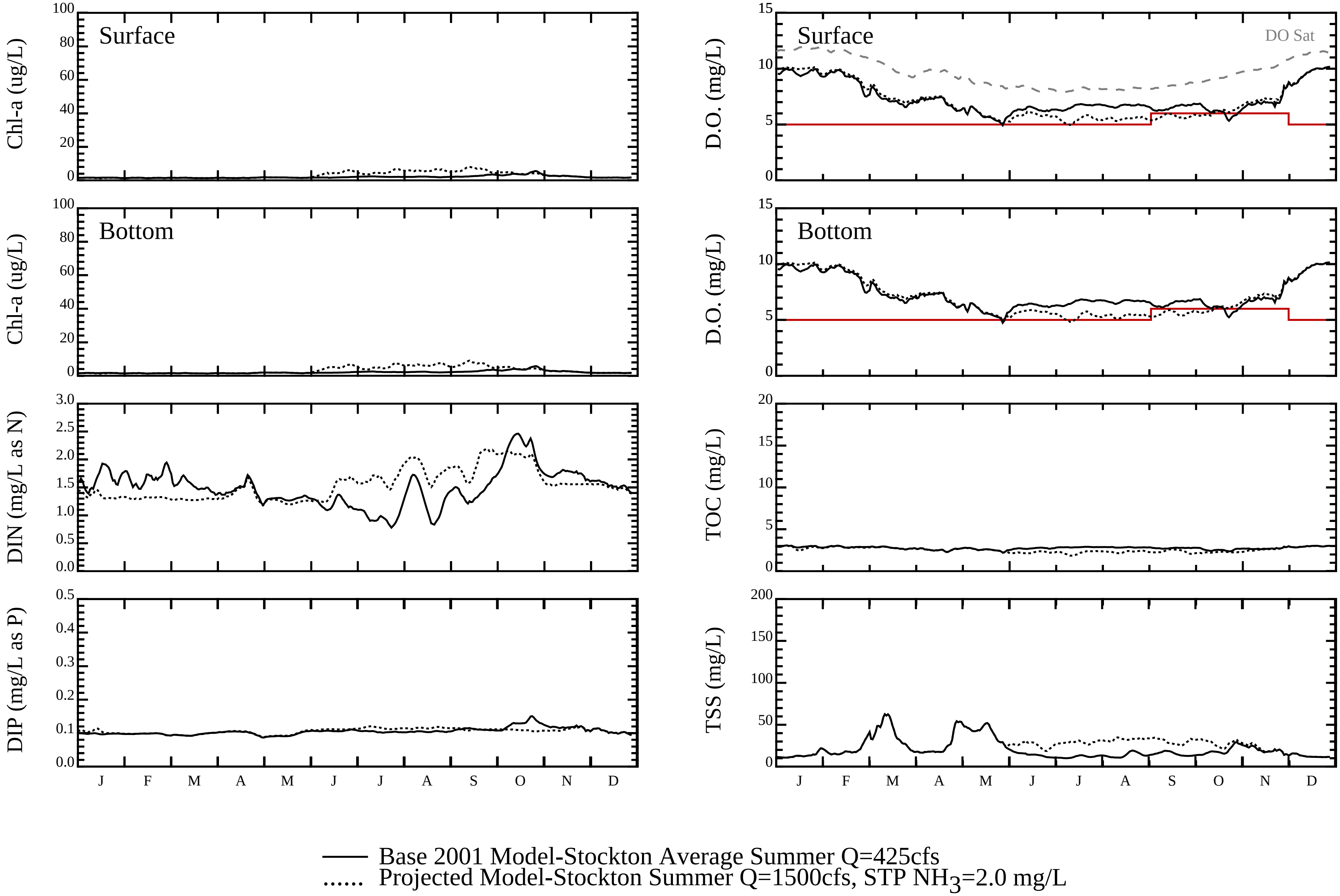


Base 2001 Model-Stockton Average Summer Q=425cfs

...... Projected Model-Stockton Summer Q=1500cfs, STP NH_3=2.0 mg/L

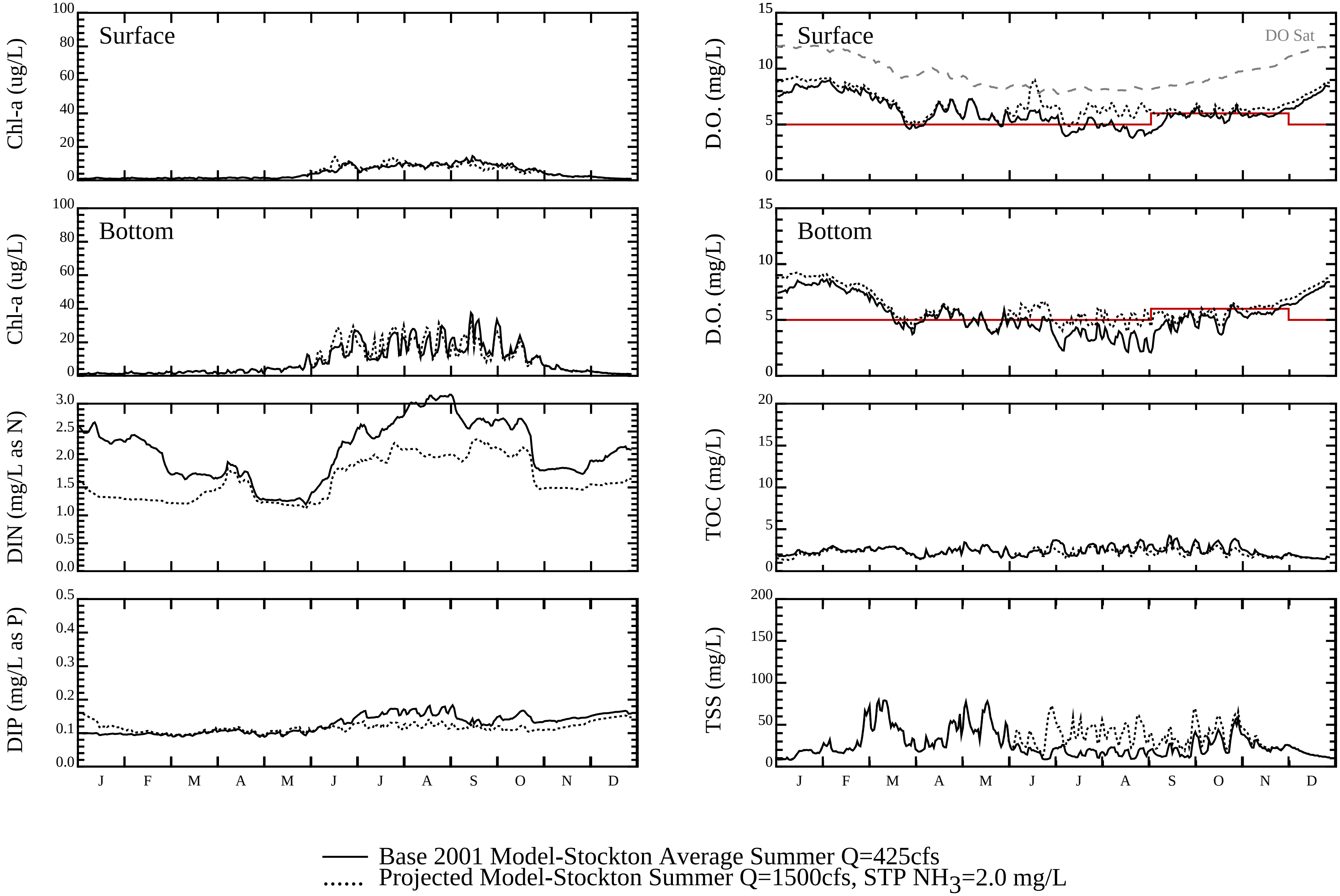
Comparison of Water Quality Model Base and Projection: SJR at R7

DATE: 4/20/2006 TIME: 15:34: 7



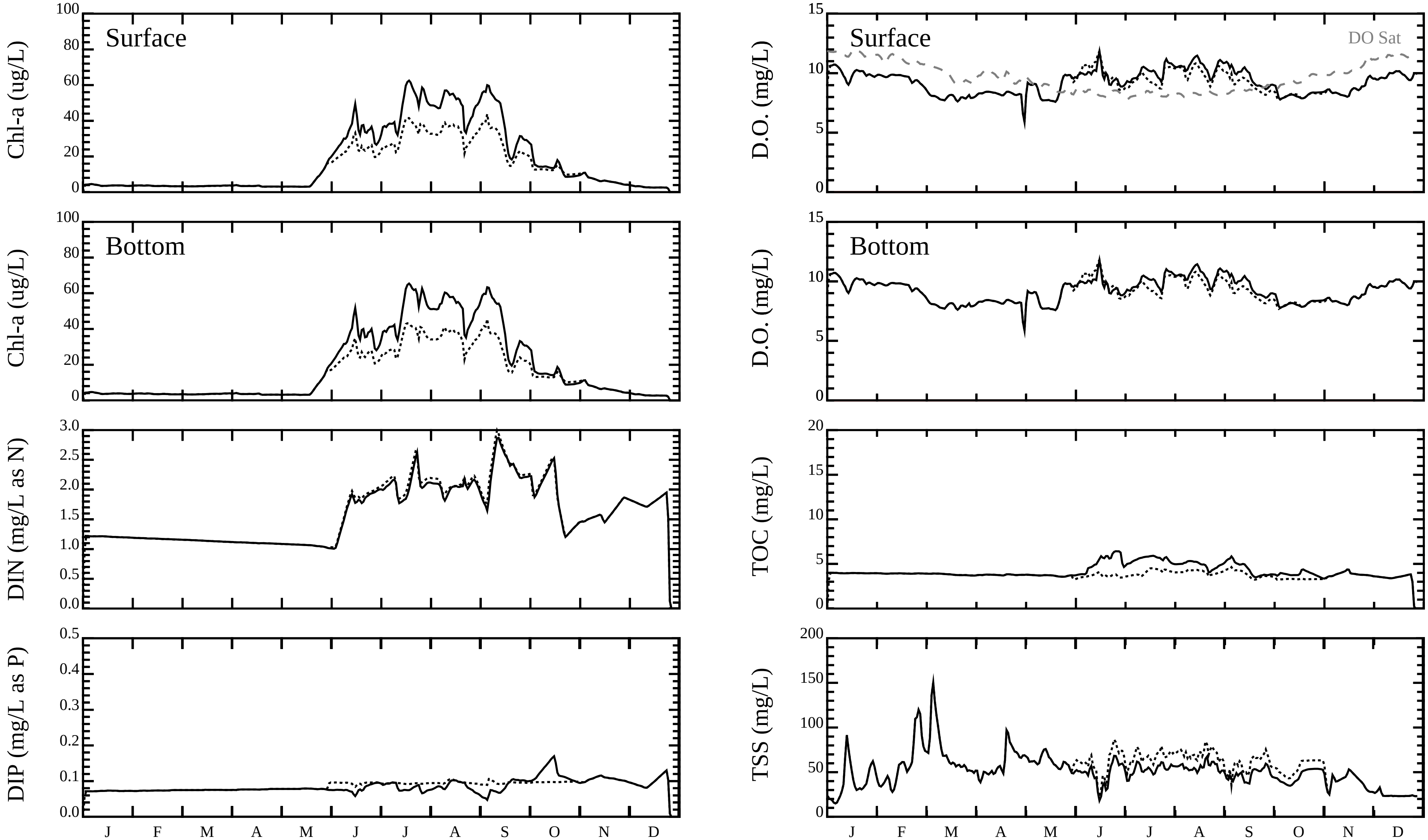
Comparison of Water Quality Model Base and Projection: SJR at R8

DATE: 4/20/2006 TIME: 15:34:47



Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

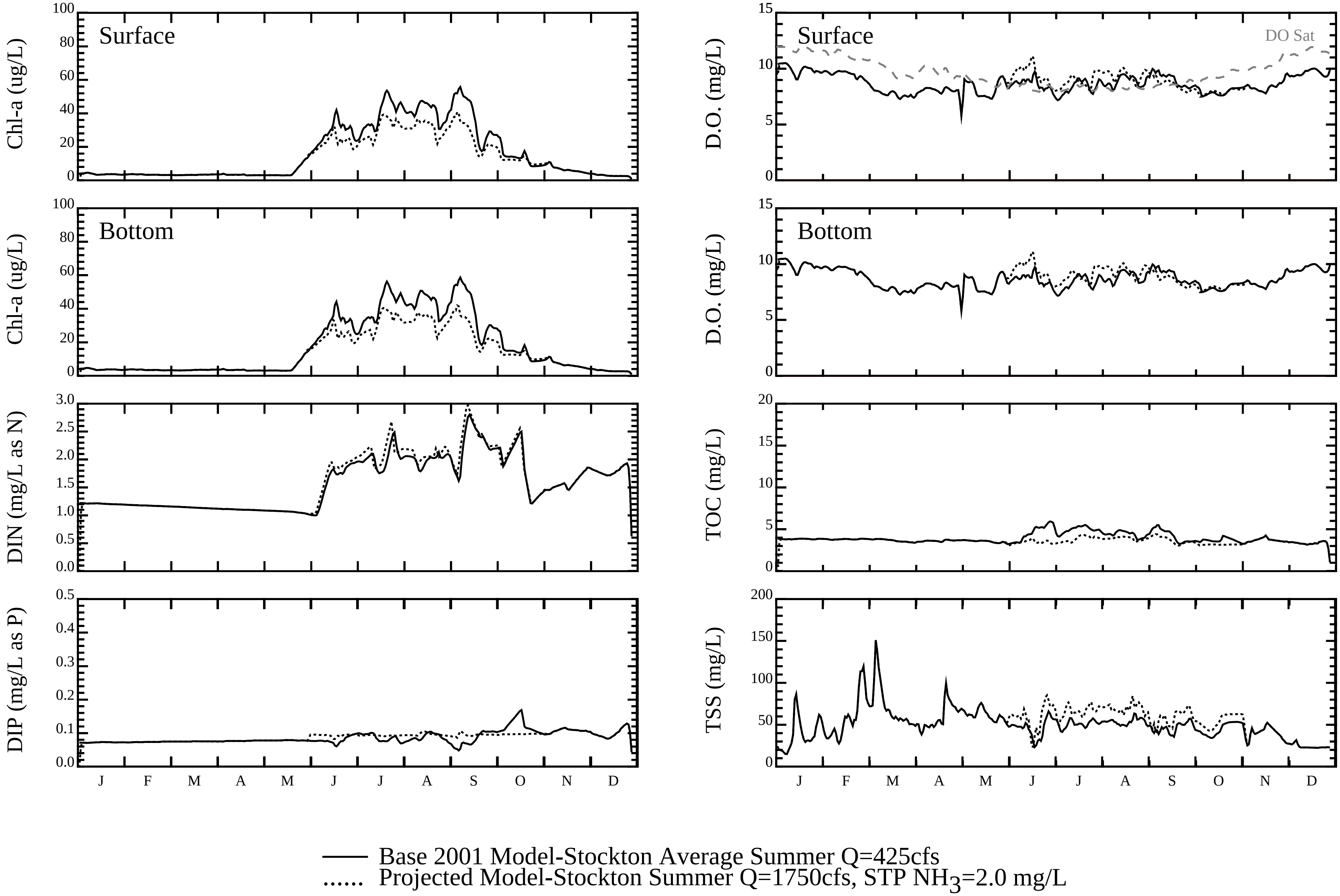
DATE: 4/20/2006 TIME: 15:29:24



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1750cfs, STP NH_3=2.0 mg/L

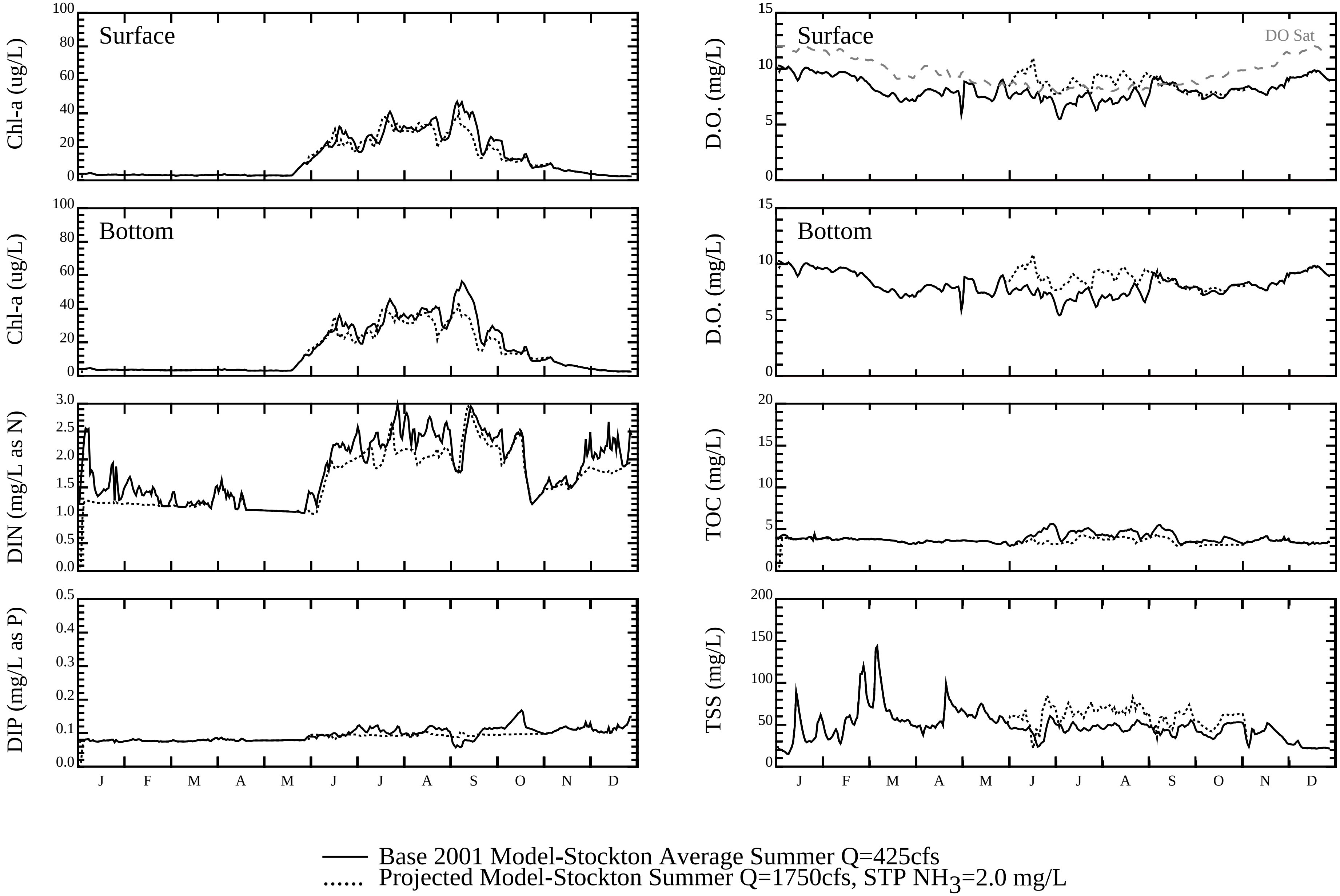
Comparison of Water Quality Model Base and Projection: SJR at Mossdale

DATE: 4/20/2006 TIME: 15:35:28



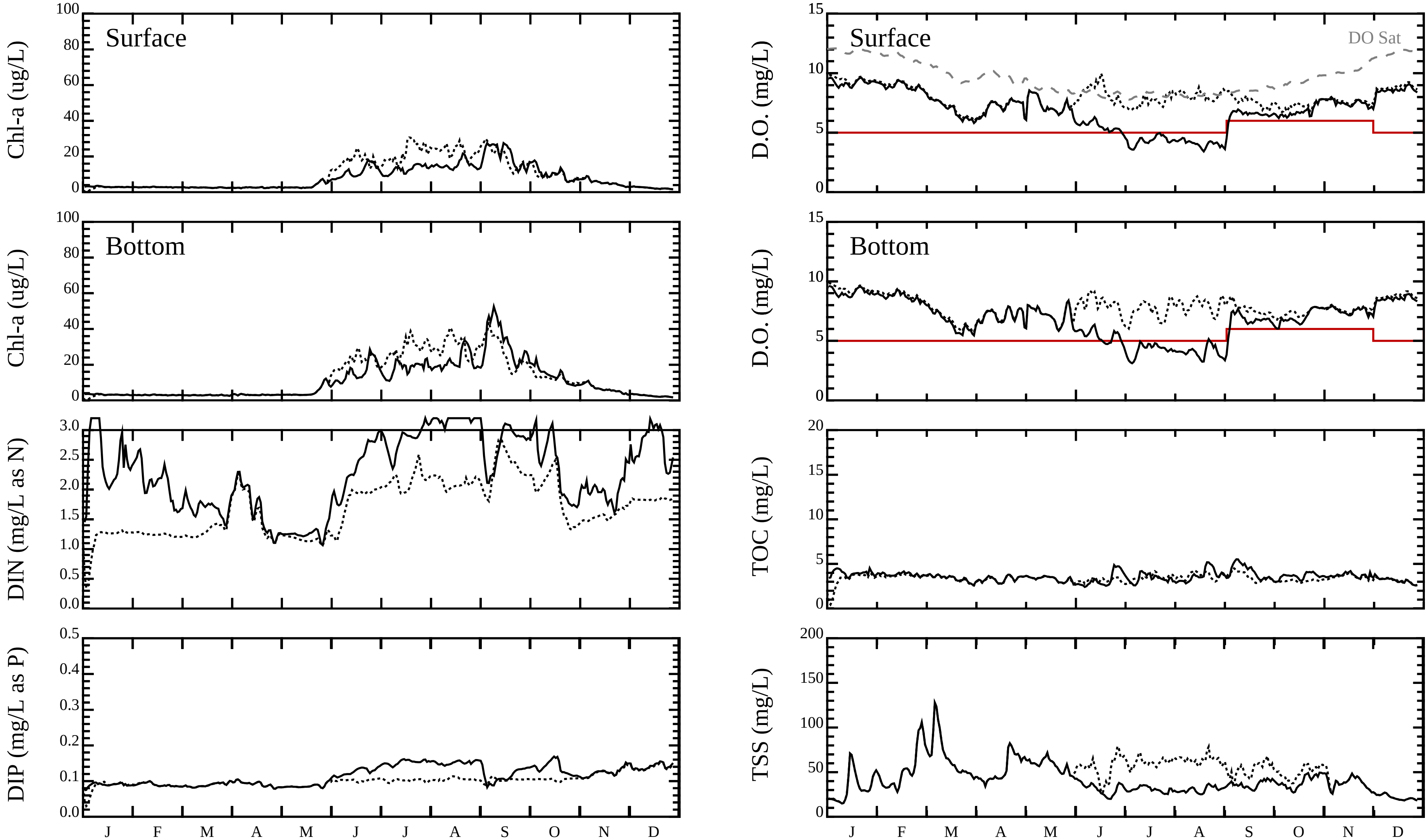
Comparison of Water Quality Model Base and Projection: SJR at R1

DATE: 4/20/2006 TIME: 15:36:48



Comparison of Water Quality Model Base and Projection: SJR at R2

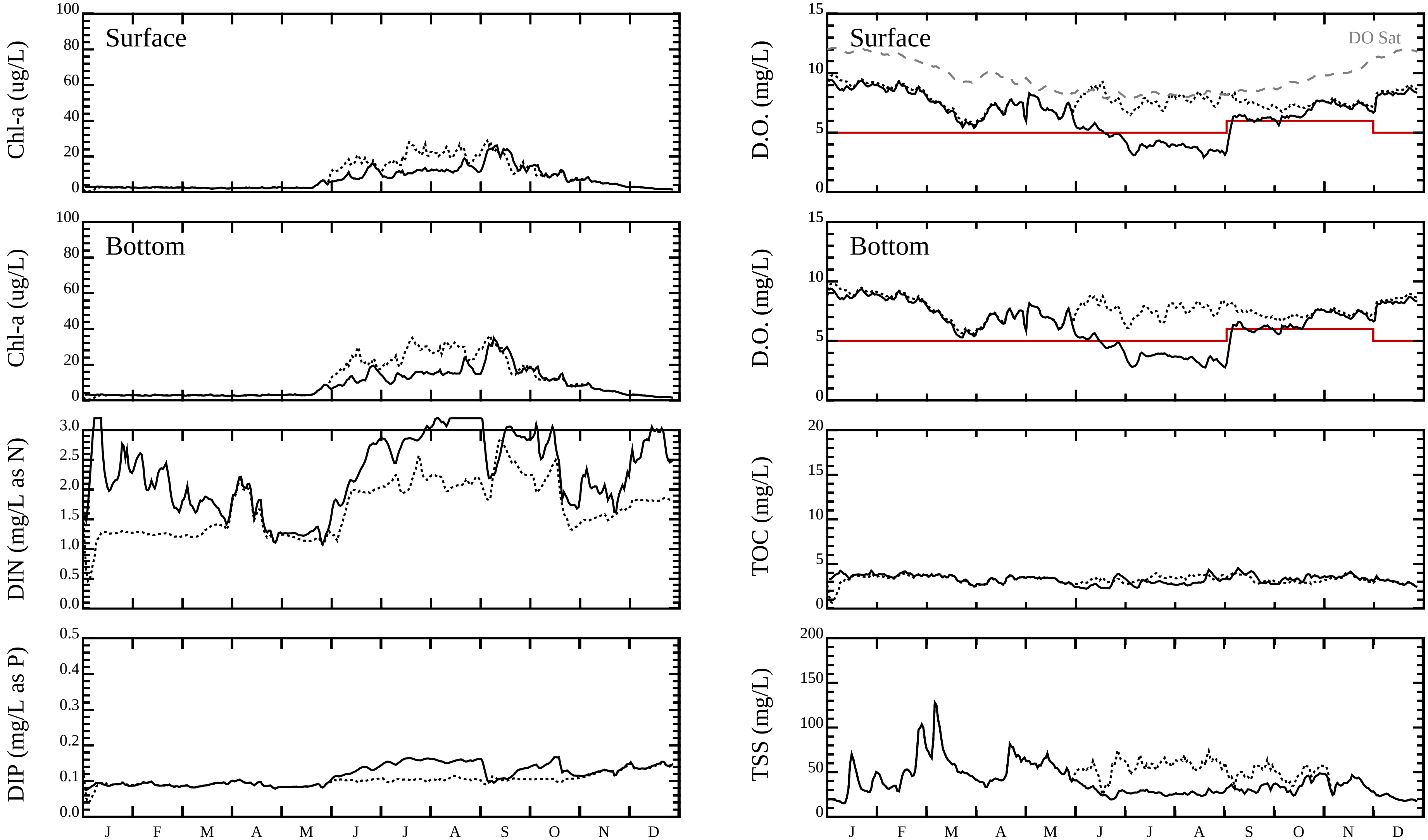
DATE: 4/20/2006 TIME: 15:37:29



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1750cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at R3

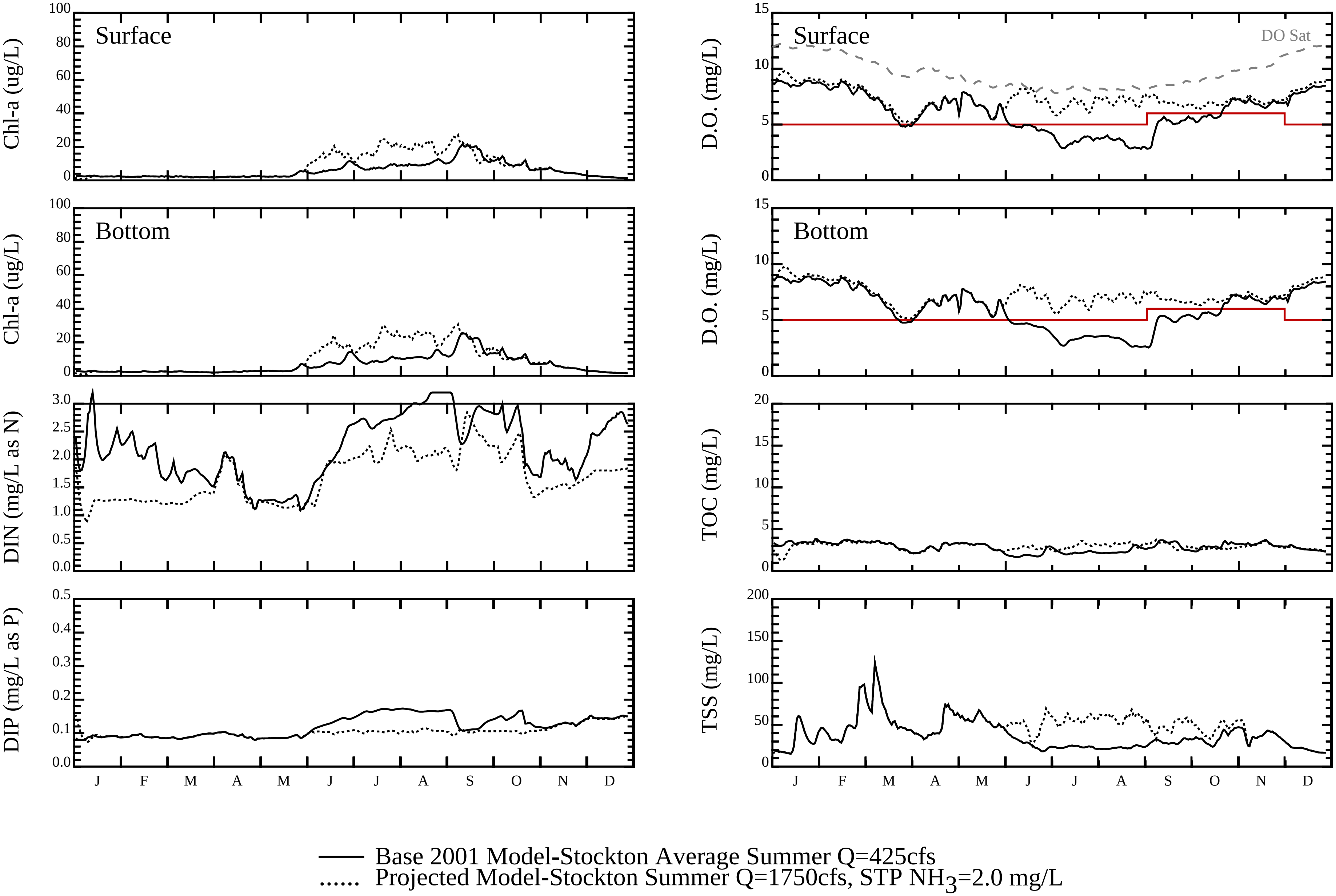
DATE: 4/20/2006 TIME: 15:38: 9



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1750cfs, STP NH_3=2.0 mg/L

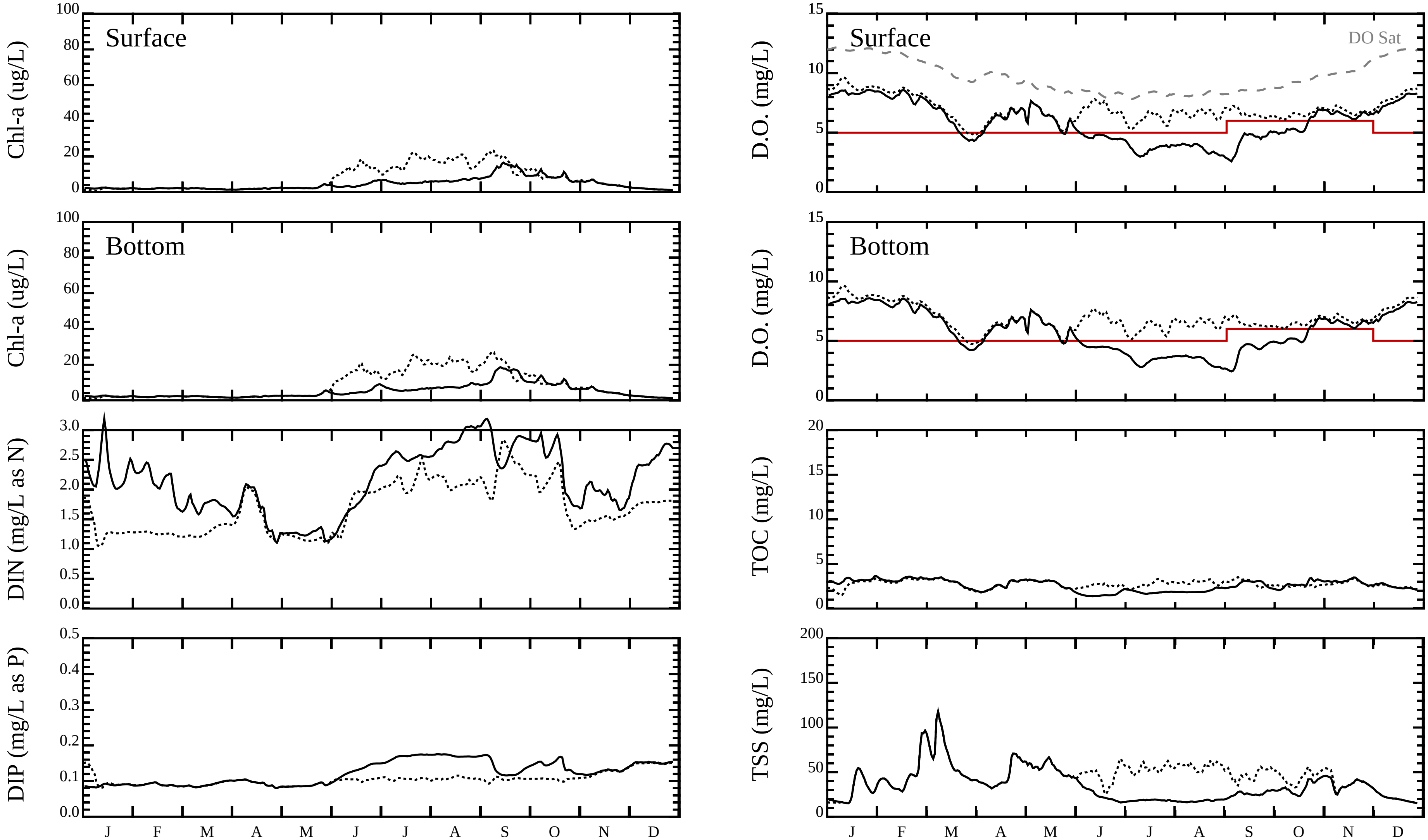
Comparison of Water Quality Model Base and Projection: SJR at R4

DATE: 4/20/2006 TIME: 15:38:49



Comparison of Water Quality Model Base and Projection: SJR at R5

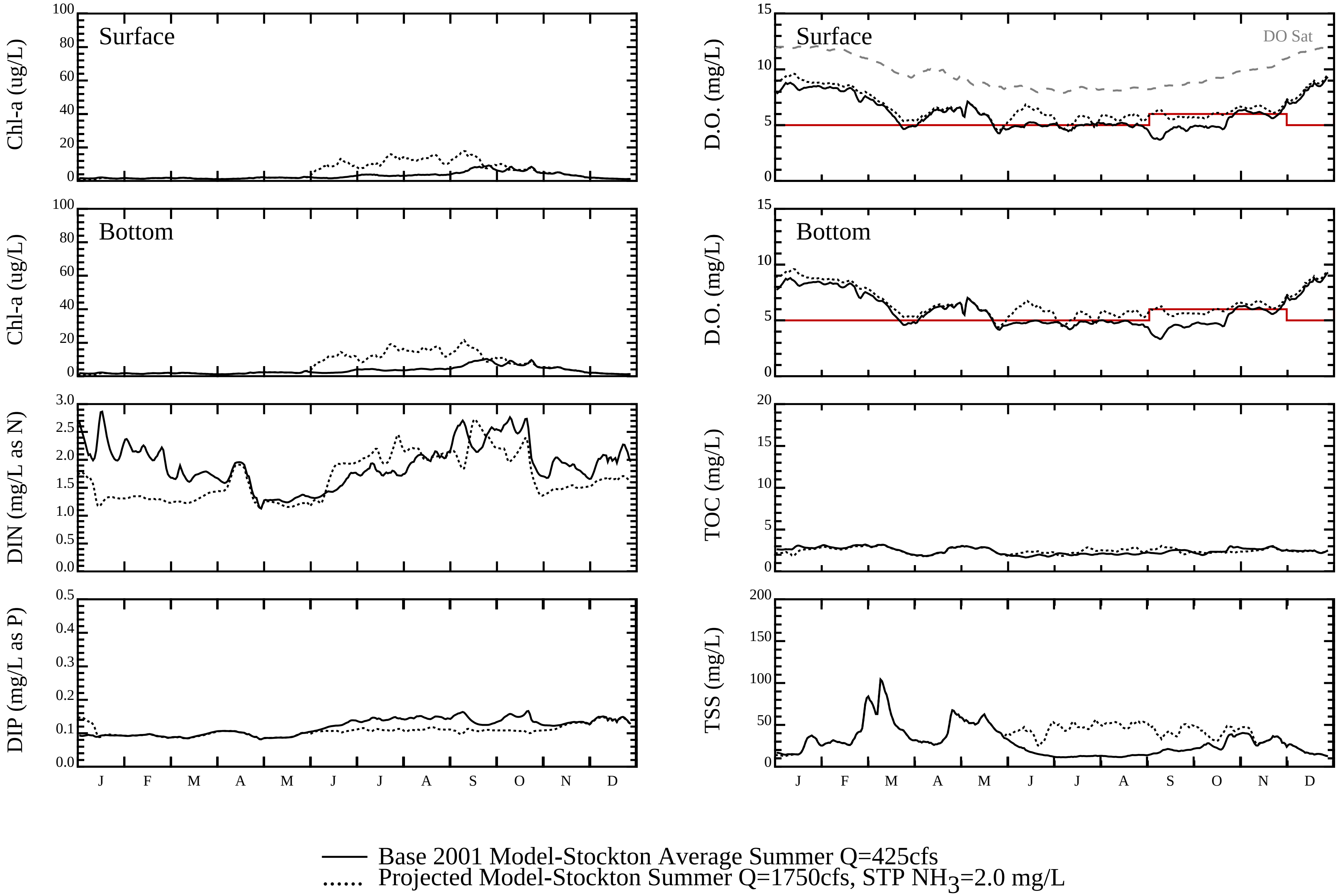
DATE: 4/20/2006 TIME: 15:39:30



—— Base 2001 Model-Stockton Average Summer Q=425cfs
...... Projected Model-Stockton Summer Q=1750cfs, STP NH_3=2.0 mg/L

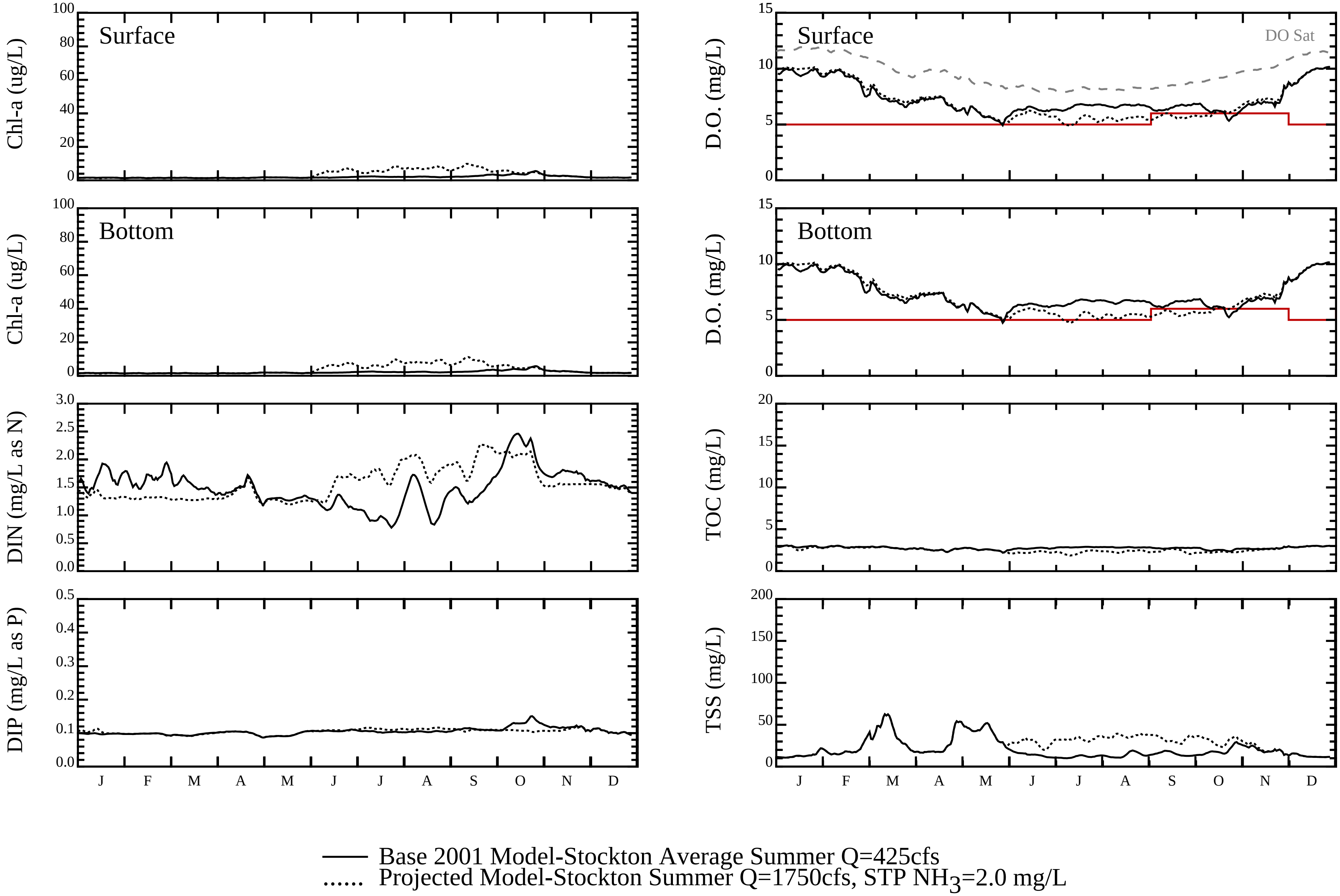
Comparison of Water Quality Model Base and Projection: SJR at R6

DATE: 4/20/2006 TIME: 15:40:10



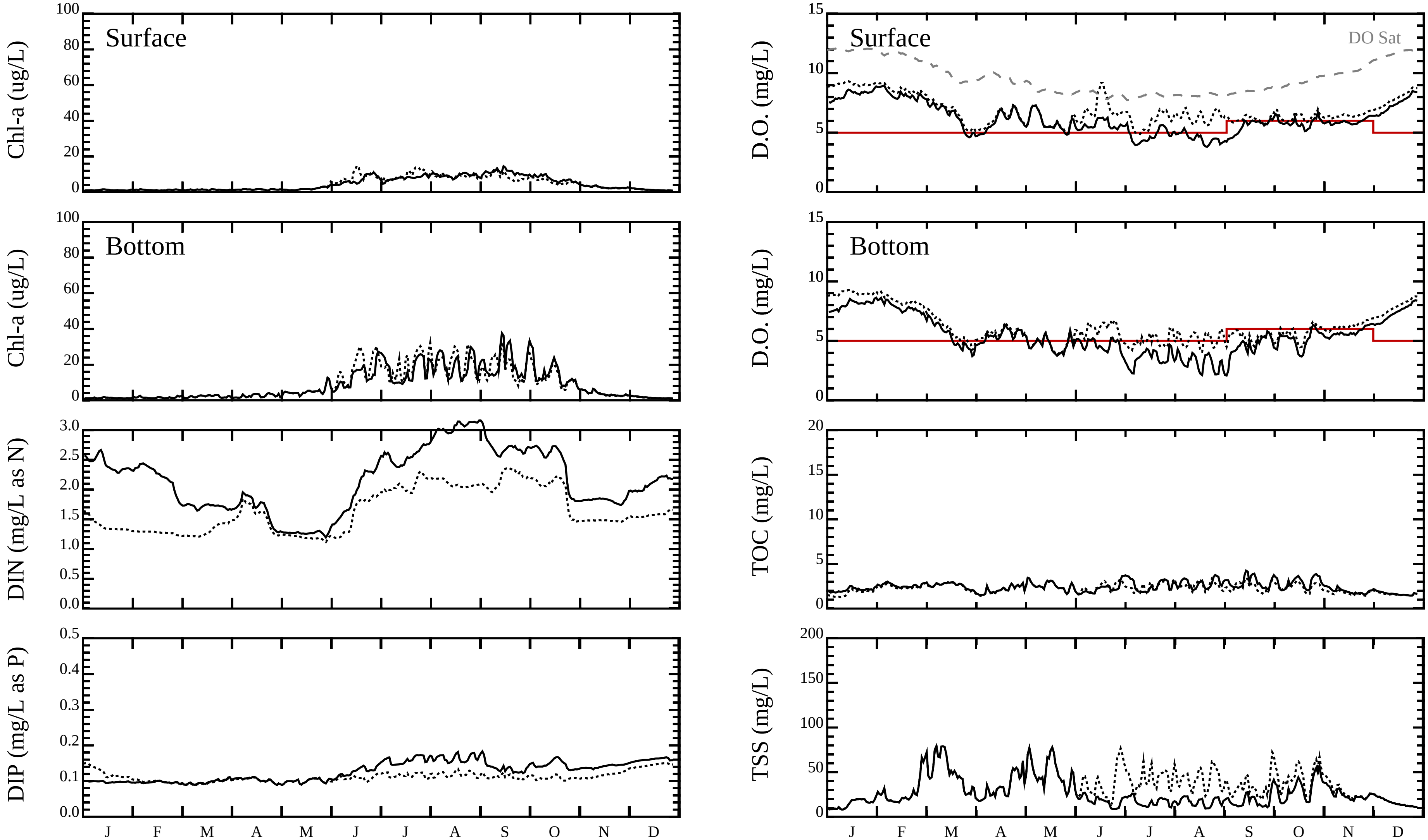
Comparison of Water Quality Model Base and Projection: SJR at R7

DATE: 4/20/2006 TIME: 15:40:50



Comparison of Water Quality Model Base and Projection: SJR at R8

DATE: 4/20/2006 TIME: 15:41:31



—— Base 2001 Model-Stockton Average Summer Q=425cfs

...... Projected Model-Stockton Summer Q=1750cfs, STP NH_3=2.0 mg/L

Comparison of Water Quality Model Base and Projection: SJR at Turning Basin

DATE: 4/20/2006 TIME: 15:36: 8