Appendix N

15 Minute Resolution Water Quality Monitoring with YSI SONDE 6600 Multi-Parameter Instruments During the 2006 and 2007 Summer Seasons

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Introduction

In an effort to determine the variance in water quality during the time between discreet grab sampling, several multi-parameter monitoring instruments were placed at key sampling locations along the mainstem (sites DO-5, 6, 7, 8, and 10) of the San Joaquin river and upstream tributaries (sites DO-18, 19 and 44) (Figure 1). YSI Sonde 6600 Multi-parameter instruments were set to record data at 15 minute intervals. Sensor values are time stamped and recorded to memory along with the instrument battery voltage. Instruments were deployed for two week intervals and exchanged with freshly calibrated instruments at the end of each interval. Grab samples were collected during deployment, collection and at least once in between, and brought back to the EERP laboratory for analysis. High temporal resolution data was sought to help calibrate the San Joaquin River WARMF model. With greater temporal resolution, algal growth rates (bio-kinetics) can be accurately determined and the validity of extrapolating data between grab sampling events verified.

Methods

The standard operating procedure (SOP) for deployment of continuously monitoring sonde equipment is described in detail in the EERP Field Protocol Book (Graham and Hanlon, 2008). Calibration, programming, and sensor set up were conducted the day prior to deployment at the EERP lab following the SOP. Dissolved oxygen calibration was performed in the field on the day of deployment using the wet-towel method, a technique where the sonde is placed in a tube with a wet-towel around the sensors and calibrated in a water-saturated air environment. The sensor cleaning wiper was fitted with a longer extended deployment brush to better keep the sensors free of algae and debris over the two week period. Sondes were programmed to run unattended for the length of deployment recording each parameter every 15 minutes. The parameters measured by the Sonde at each site include time, temperature (°C), electrical conductivity (mS/cm), total dissolved solids (g/L), dissolved oxygen (DO) percent, DO concentration (mg/L), DO charge, depth (ft), pH, turbidity (NTU), chlorophyll content (ug/L), chlorophyll-*a* fluorescence, and some instruments were set up to measure oxidation-reduction potential (mV). Flow data was compiled from the California Data Exchange Center on the world wide web. (http://cdec.water.ca.gov/)

At the field sites, the instruments were deployed in custom made PVC housings (Figure 2) for protection against vandalism, theft, etc. In general, the instruments in their housings were secured with cable to existing structures in the river. In 2006, at site DO-05, the instrument was deployed in the existing four inch PVC stilling well on the DWR monitoring platform on the San Joaquin river near Vernalis, but suspended from the platform by cable in its own housing (Figure 3) for part of the 2007 monitoring. Sites DO-06 and 07 were on the San Joaquin river at the pumping platforms for the El Solyo and Patterson Irrigation districts respectively (Figures 4 and 5). Site DO-08 was on the San Joaquin river at the fishing dock of the Turlock Sportsmans club, also the site for other agencies' (DWR) monitoring (Figure 6). The furthest upstream site on the San Joaquin River was DO-10, located under the Lander Ave. bridge. This site required wading into the river and driving a fence post into the river bottom to anchor the instrument and housing (Figure 7). Site DO-18 was on Mud Slough near the town of

Gustine, the same location as the USGS flow monitoring station. Here the instrument was hung from the small bridge over the slough (Figure 8). The DO-19 site was on Salt Slough where Lander Ave crosses, also at a USGS station. The instrument was attached to a fence post attached to the bottom of the slough (Figure 9). Site DO-44 was at the terminous of the San Luis Drain and the instrument was hung from the weir structure at the outlet (Figure 10)

As a check of the deployed Sonde, a second YSI 6600 multi-parameter Sonde connected to a YSI 650 MDS handheld data display was placed in the water next to the in-situ Sonde during both deployment and collection. The non-extended deployment sonde was set out in the sample water and programmed to log a reading for every parameter every four seconds for at least two minutes, providing a statistically significant sample size ($n > 30$). While the second Sonde logged water quality data, water quality grab samples were collected and incident sunlight and water-velocity were measured to document current field conditions.

Upon conclusion of the deployment, Sondes were retrieved and placed into ice chests with a small amount of water to keep them moist until post-calibration could be performed. Post-calibration, also covered in the SOP (Graham and Hanlon, 2008), was completed within twenty-four hours of retrieval. After being post-calibrated, sondes were cleaned up with water and mild soap, the DO membranes and batteries changed, and the extended deploy wipers were cleaned and replaced. Pre and post calibration values for all instruments deployed in 2006 and 2007 are included as Analyses 1 and 2 at the end of this document.

Results

Diurnal variations are seen at all sites in temperature, pH, dissolved oxygen, and chlorophyll fluorescence. San Joaquin river sites show a distinct diurnal cycling for turbidity as well, with low points occurring just before midnight and highpoints just after noon. This is seen particularly with the lower flow of 2007 (Figures 16, 24, 32, 40, and 48). Chlorophyll fluorescence measured simultaneously shows a similar sine wave-like cyclical pattern but at approximately 180 degrees out of phase with the turbidity values (Figures 17, 25, 33, 41, and 49). When chlorophyll fluorescence is at it's highest, turbidity is lowest and vice versa. Dissolved oxygen, temperature, and pH levels cycle on the same time frame as the chlorophyll, reaching a maximum each day around 6pm and minimum values at approximately 6am. Especially large swings in pH at DO-10 from 7.8 to 9.2 in late June 2007 correspond to similar patterns in chlorophyll fluorescence and is indicative of highly productive, or eutrophic systems.

The initial deployment for 2006 was from June 27 to July 13 during which time the San Joaquin river and it's major tributaries had nearly a 60% decrease in flow. For the rest of the 2006 and 2007 monitoring periods, flows were considerably more consistent (Figures 18, 26, 34, 42, 50, and 58). Electrical conductivity at DO-05 during that same period increased from less than 100 milliSemens (mS) to nearly 450 mS as the flow decreased.

Additional statistically correlated data from DWR was included in this report to supplement 2007 monitoring activities at DO-05 SJR at Vernalis (Letain et al., 2008).

These data included temperature and specific conductance from June 21 to July 12 and from August 21 to September 17.

Discussion

Instrument performance and reliability was reasonably good for both years but 2007 in particular yielded the most comprehensive data set. Additional instruments were available for deployment in 2007 which made it possible to simultaneously cover more sites and have calibrated instruments standing by in order to minimize data loss from downtime. The San Joaquin River at Patterson, Site DO-07, had a dissolved oxygen probe failure from July 6, 2007 until the instrument was replaced on July 12, 2007 (Figures 29 and 30). Values from the specific conductance sensor during this period also decline and both failures were attributed to biological activity. Sporadic spikes in turbidity and chlorophyll fluorescence were often caused by interference from the instruments sensor wiping system when it failed to properly park away from the optical sensor. These spikes were easy to identify as they tended to be an order of magnitude greater than measured data and were removed.

Battery failure was an issue when we temporarily switched from Duracell to Energizer batteries mid way through 2007. Several instruments intermittently shut down midway through the two week deployments in August, logging low battery voltages just before and after gaps in data. All of the instruments had recovered from the voltage drop by the time they were picked up and none of the batteries showed unusually low voltages when checked on a voltmeter back at the EERP lab. Fortunately the instruments managed to make at least a few measurements each day despite the low voltages, and after switching back to Duracell batteries the issue did not reoccur.

References

Graham, J., Hanlon, J., 2008. EERP Field Standard Operating Procedures Protocol Book. Environmental Engineering Research Program, Stockton, CA.

Letain, T. E., Hanlon, J. S., Stringfellow, W. T., 2008 Comparison of Continuous Temperature, Specific Conductivity, pH, Dissolved Oxygen, Chlorophyll Fluorescence, and Turbidity Monitoring Data Collected at the San Joaquin River at Vernalis by the University of the Pacific and the Department of Water Resources. Environmental Engineering Research Program, Stockton, CA.

Figure 1: Map of the study area and sampling locations.

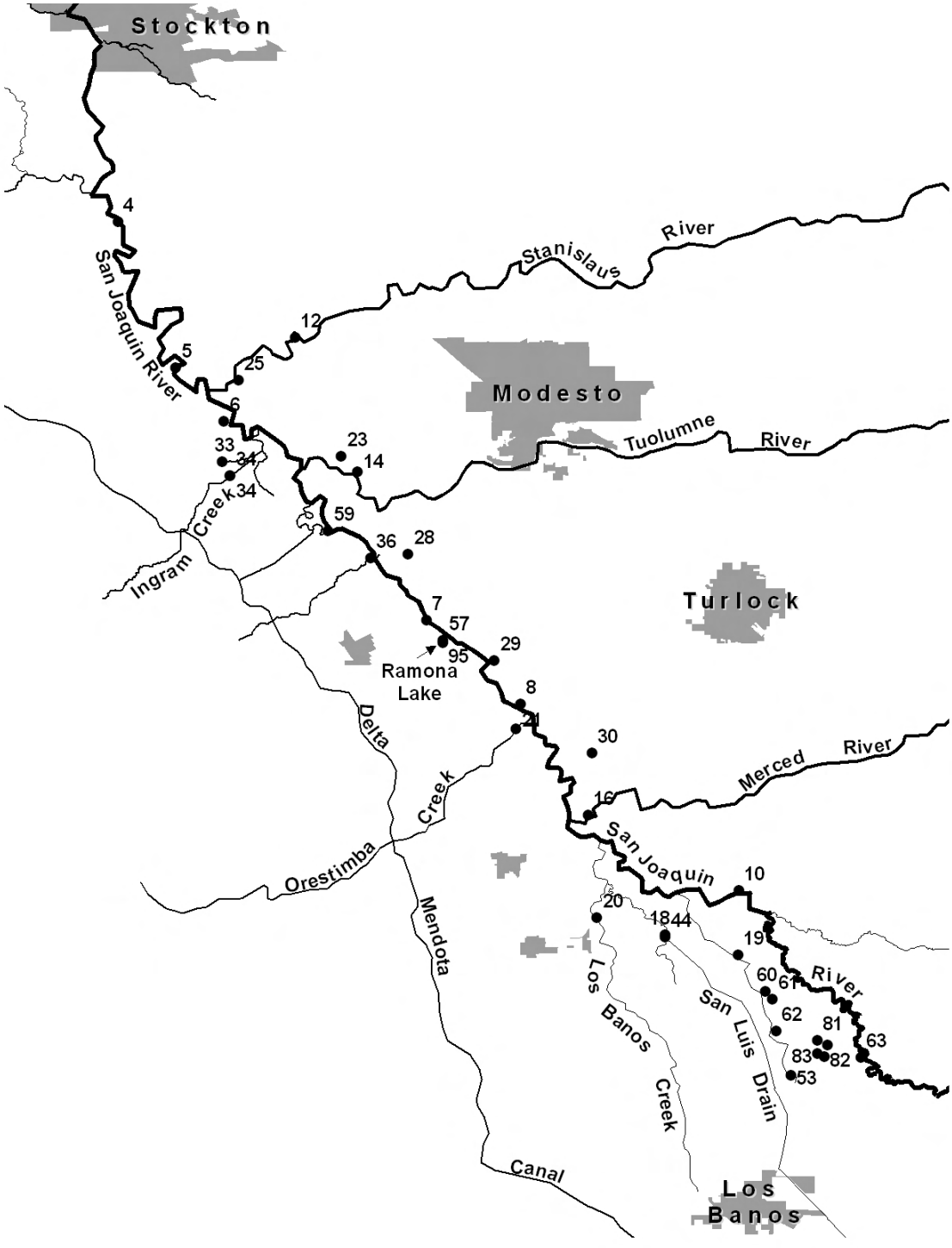


Figure 2: YSI Sonde 6600 with deployment housing.

Figure 3: View from DWR Vernalis platform DO-05 looking down at river and stilling wells.

Figure 4: Elsolyo water district intake structure on San Joaquin river, DO-06.

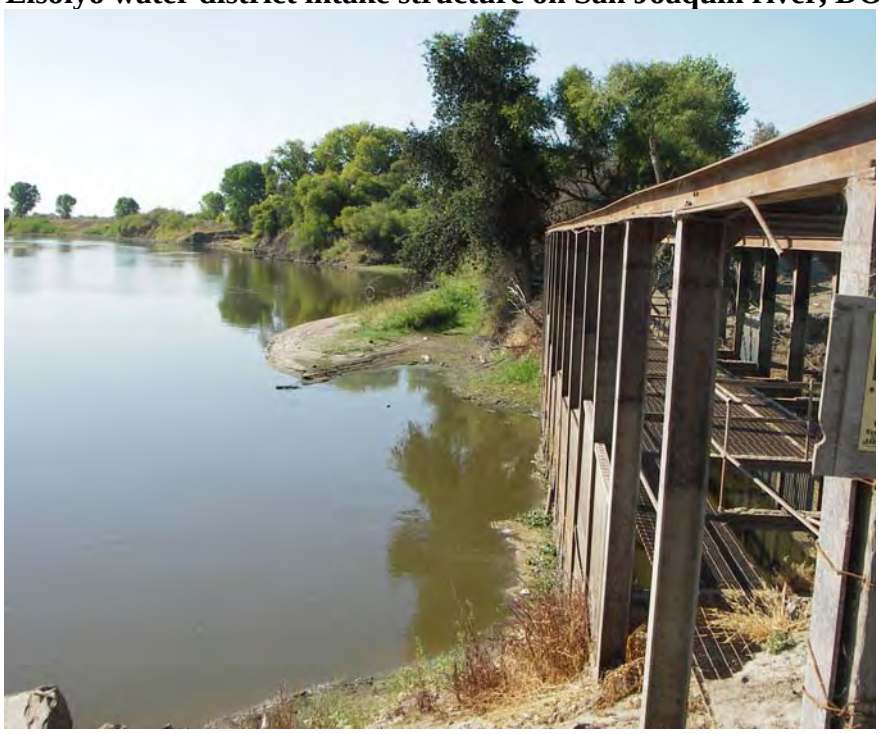


Figure 5: Patterson irrigation district intake structure on San Joaquin river, DO-07.

Figure 6: Turlock sportsmans club fishing dock, DO-08.

Figure 7: San Joaquin river at Lander Ave., DO-10.

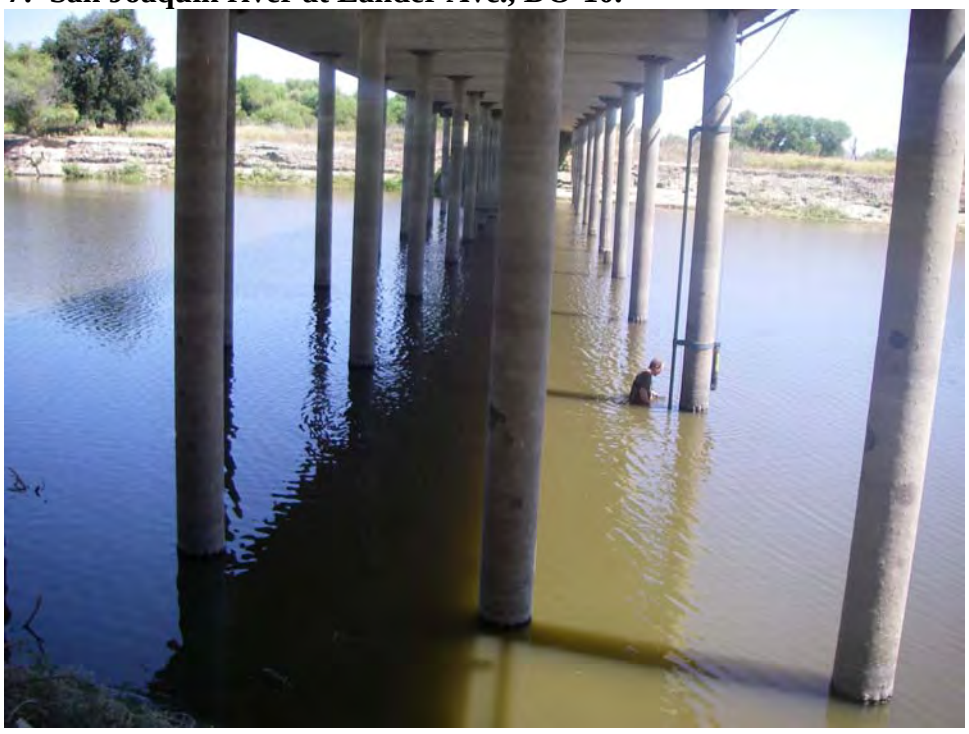
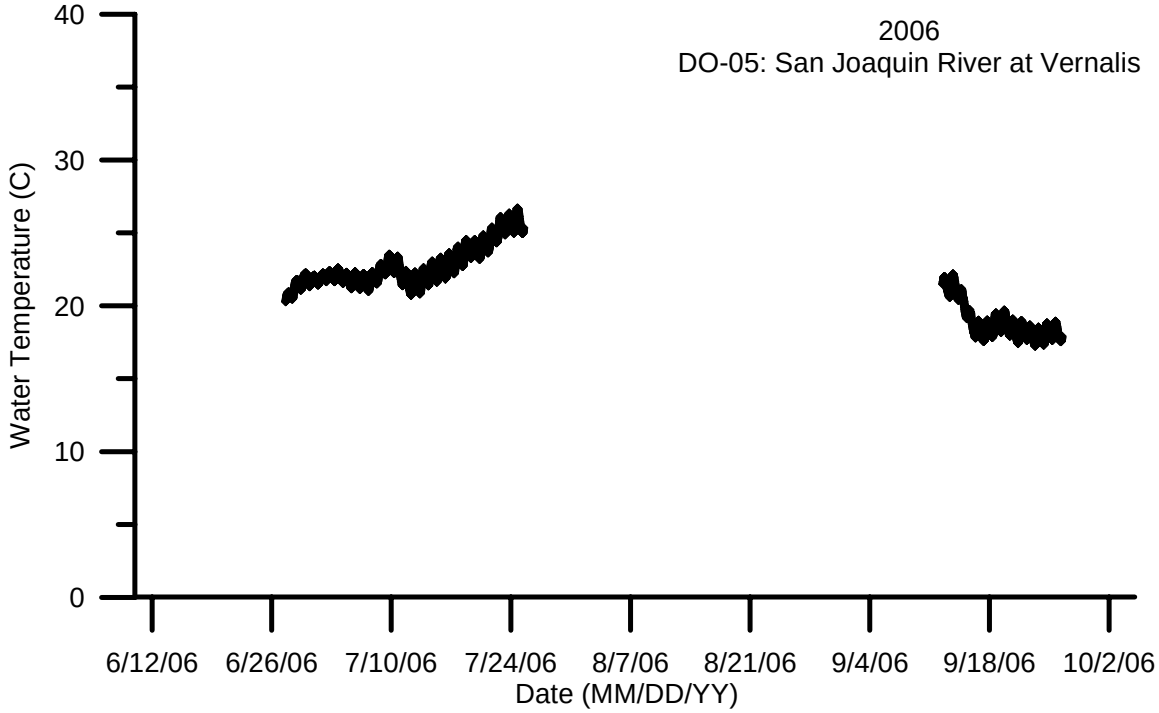


Figure 8: Mudslough near Gustine, DO-18.

Figure 9: Saltslough at Lander Ave., DO-19.

Figure 10: San Luis Drain terminous, DO-44.

Figure 11: Water temperature 15 minute data at DO-05 for 2006 and 2007.



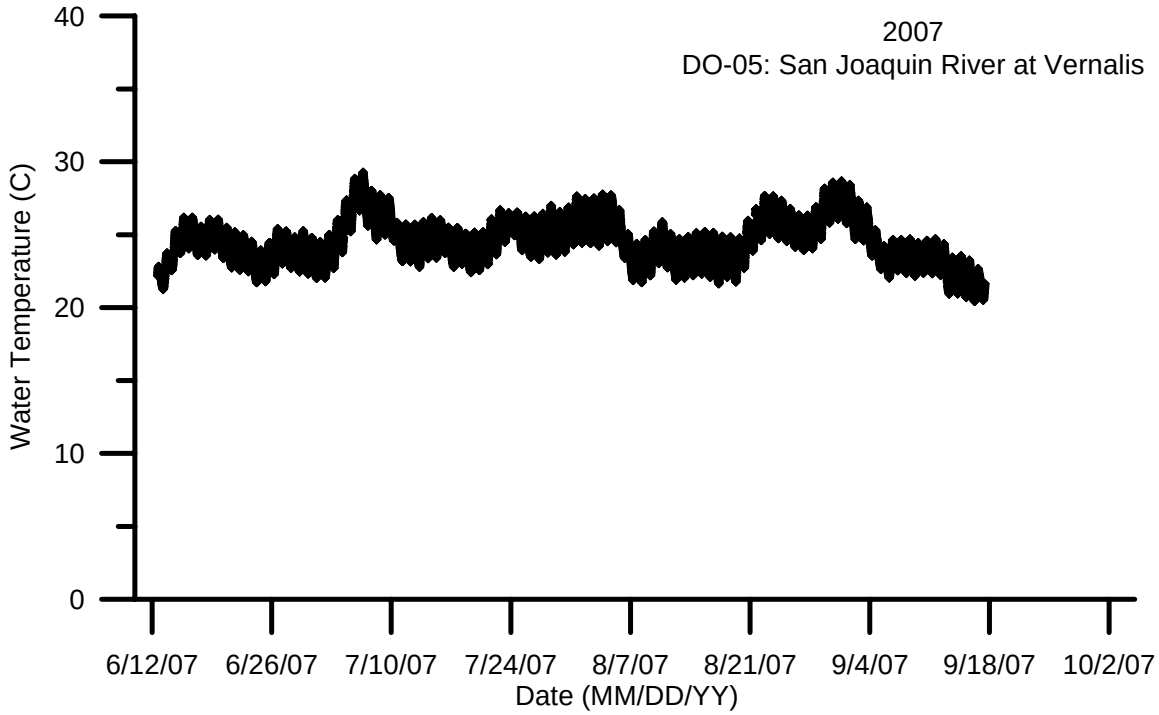
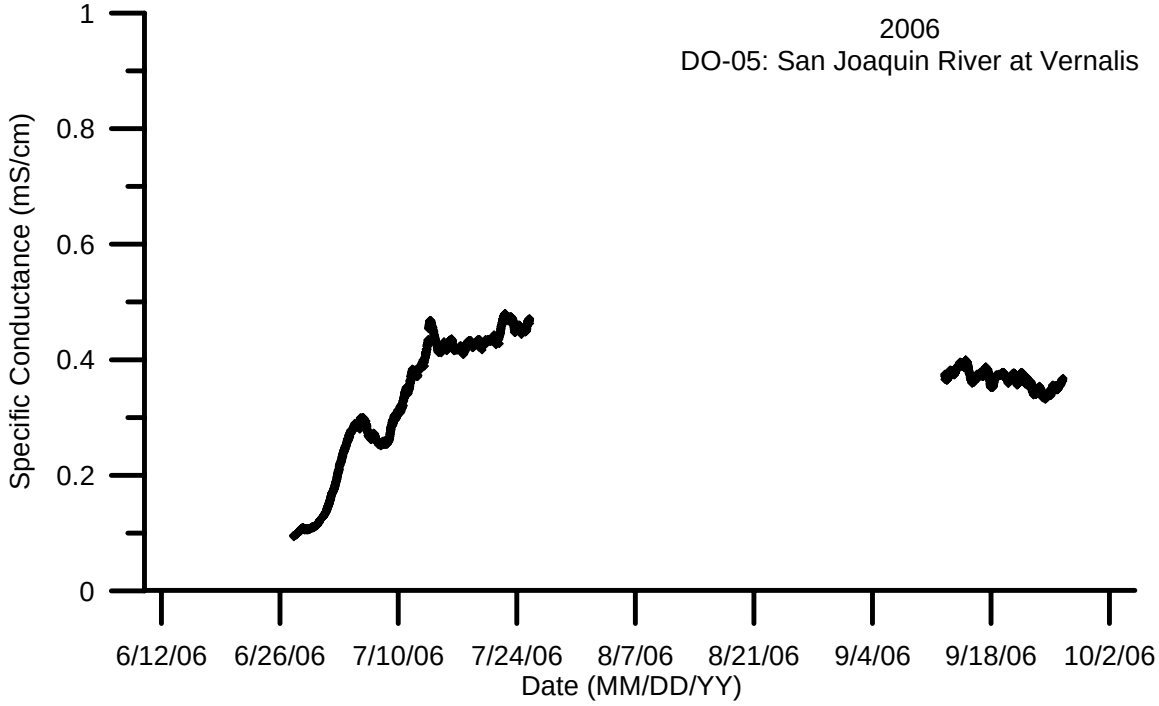


Figure 12: Specific conductance 15 minute data at DO-05 for 2006 and 2007.



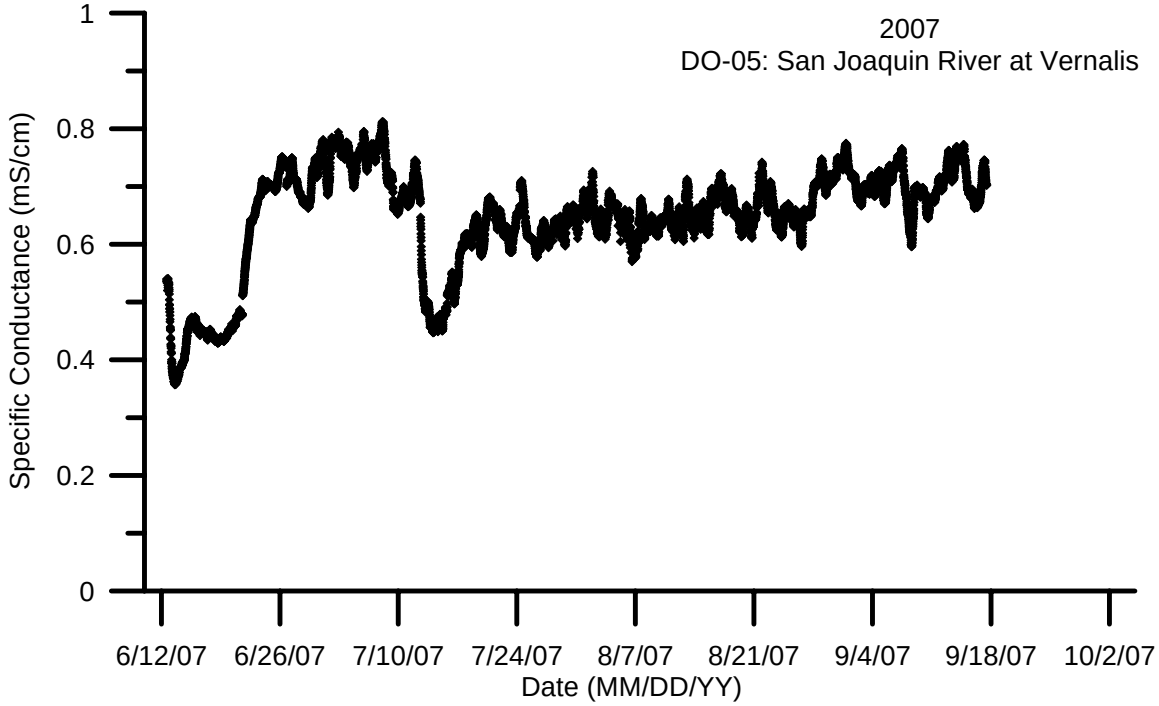
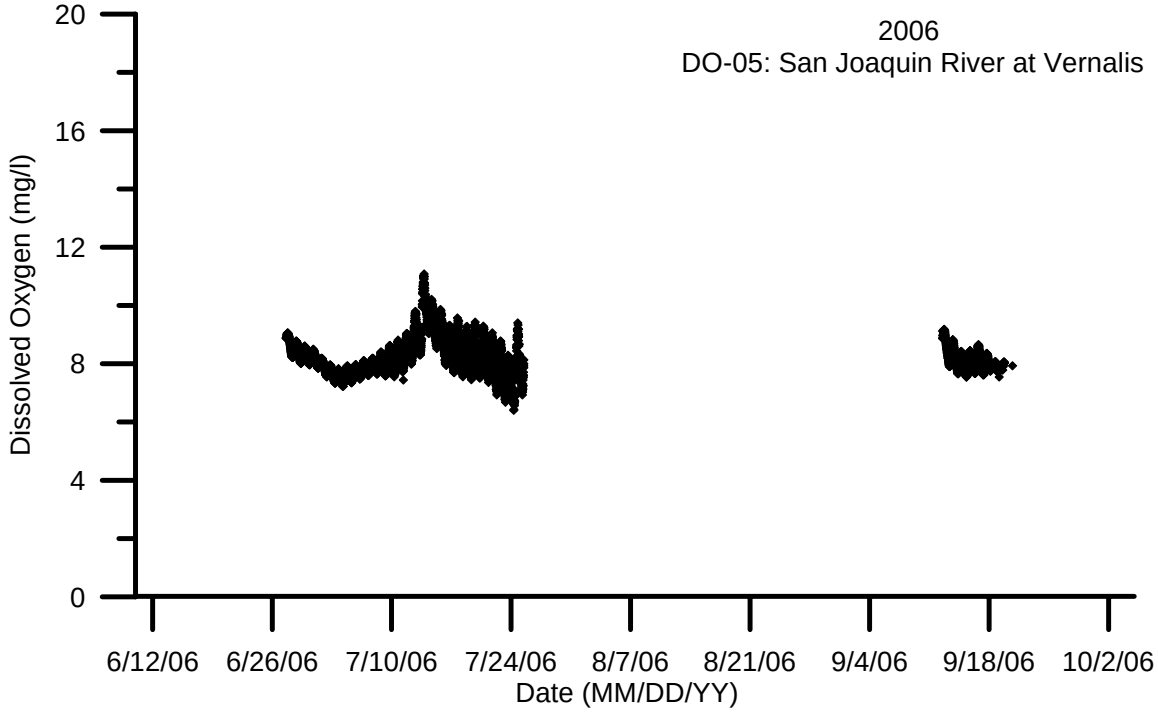


Figure 13: Dissolved oxygen concentration 15 minute data at DO-05 for 2006 and 2007.



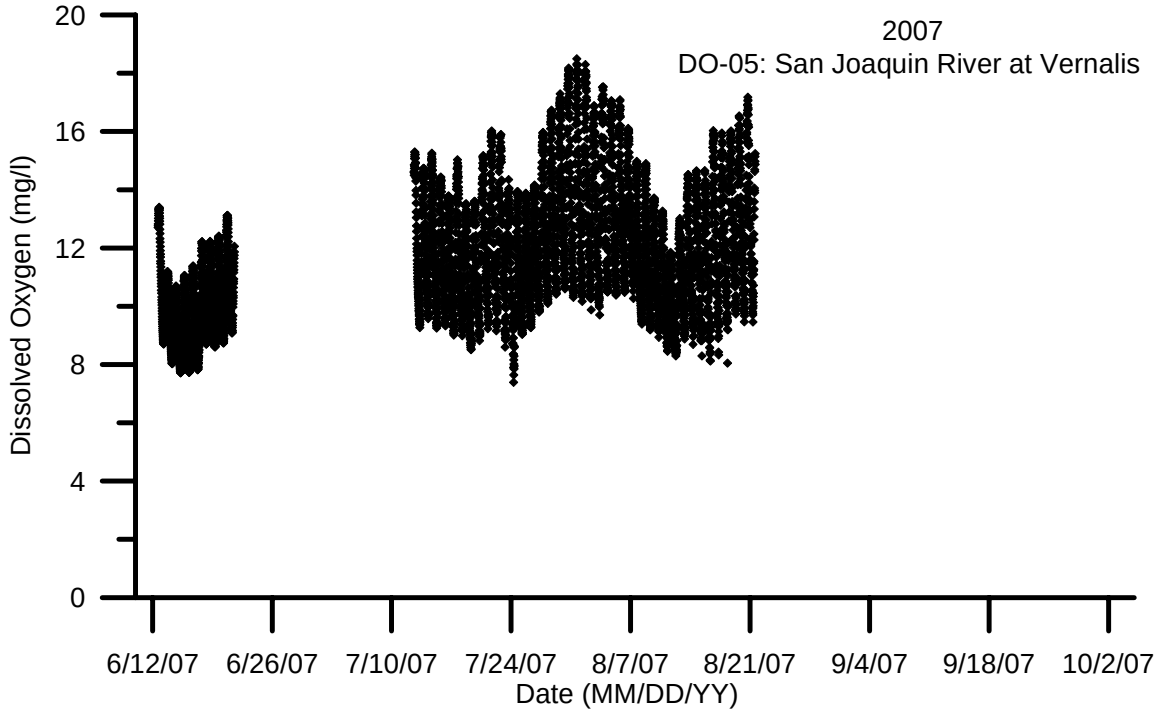
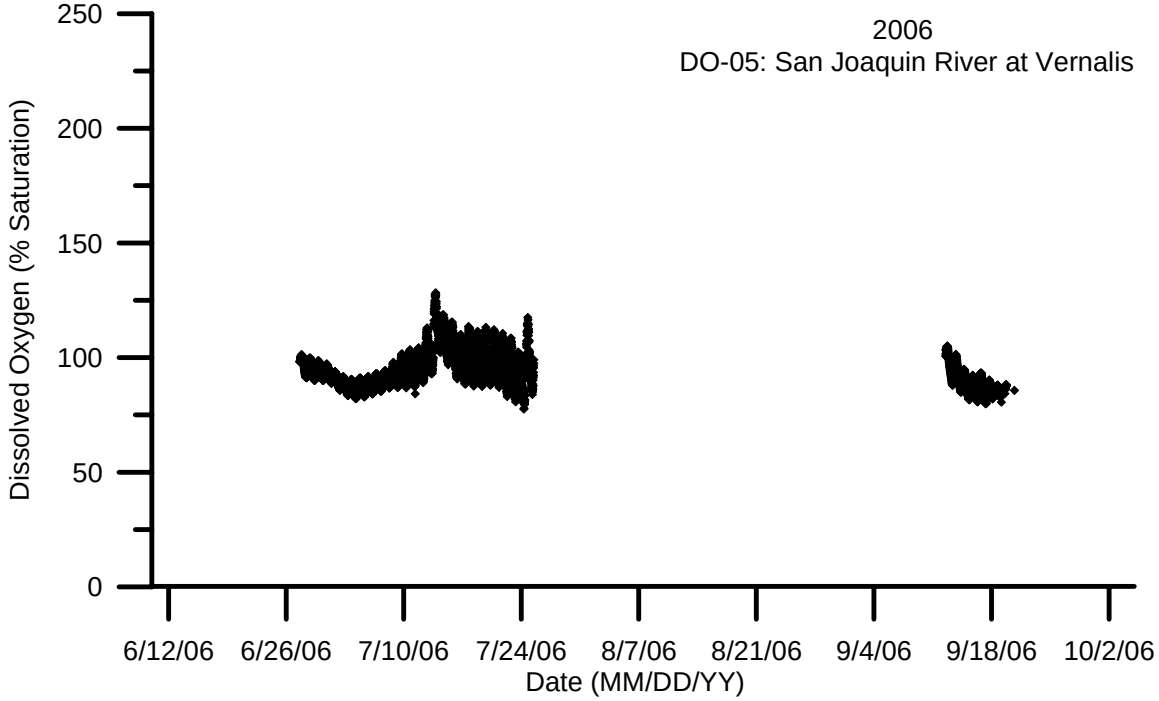


Figure 14: Dissolved oxygen percent of saturation 15 minute data at DO-05 for 2006 and 2007.



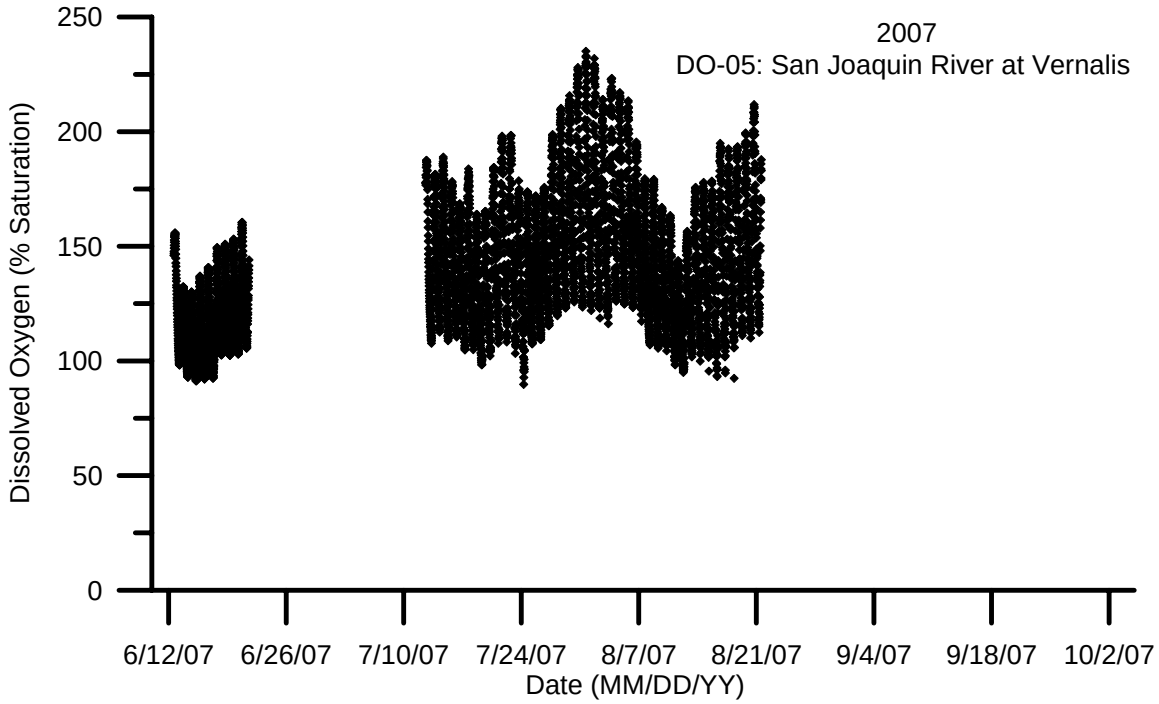
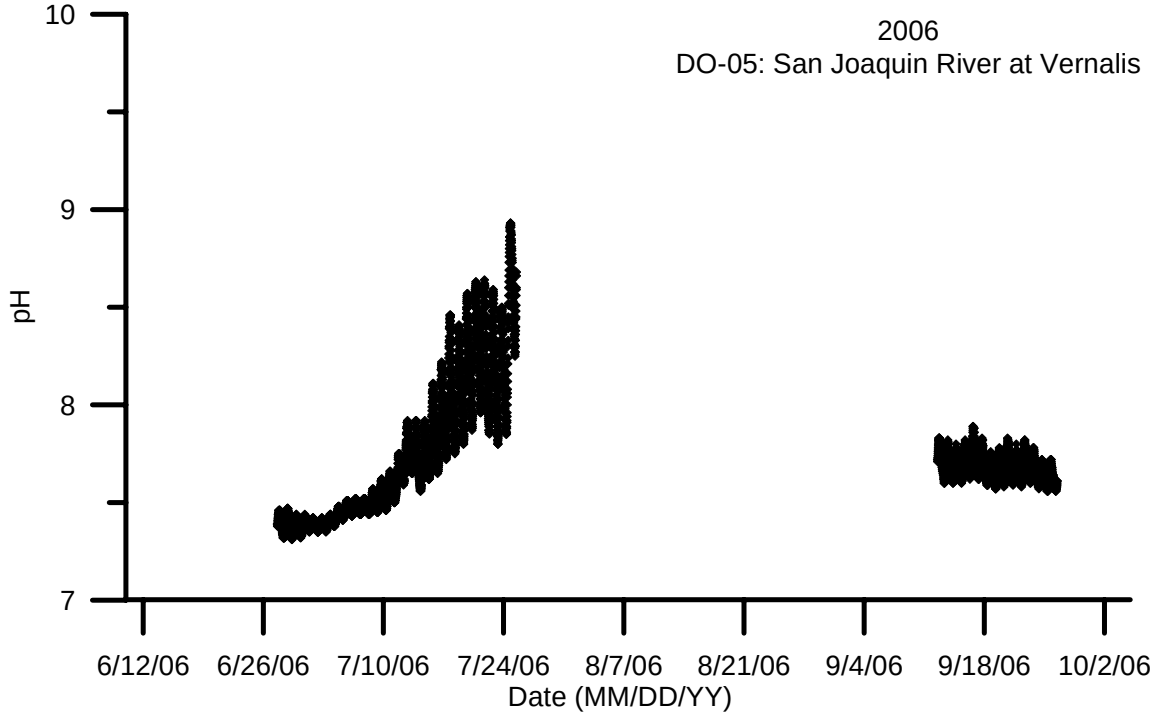


Figure 15: pH 15 minute data at DO-05 for 2006 and 2007.



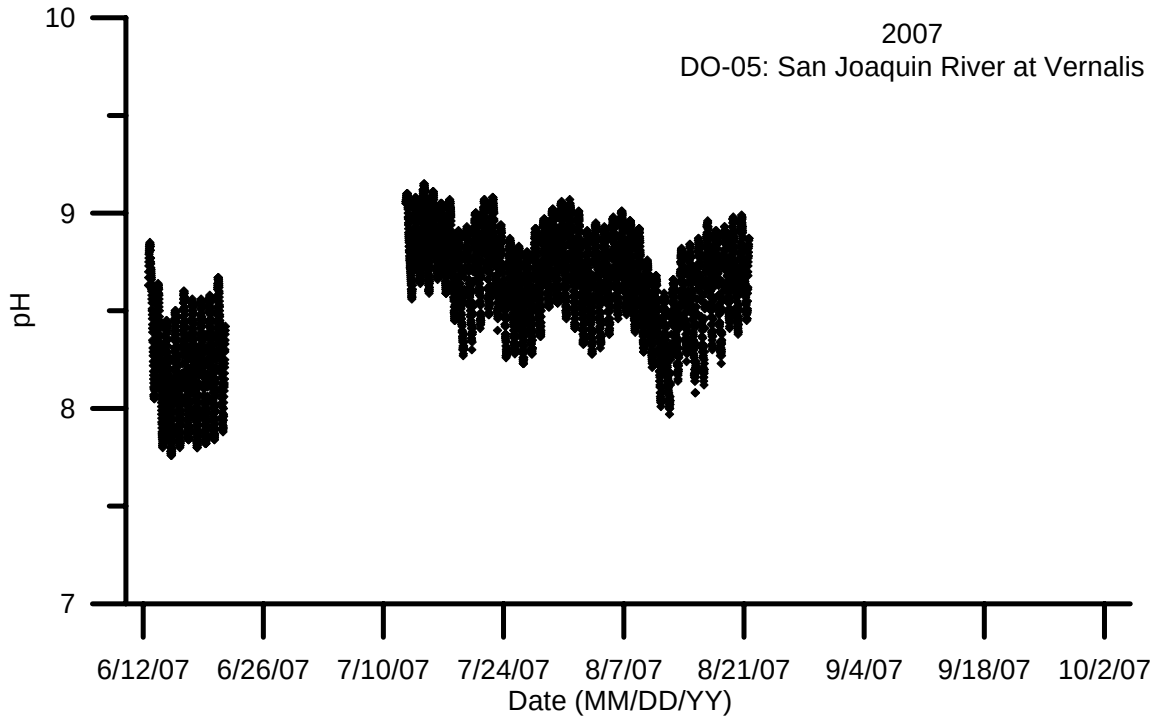
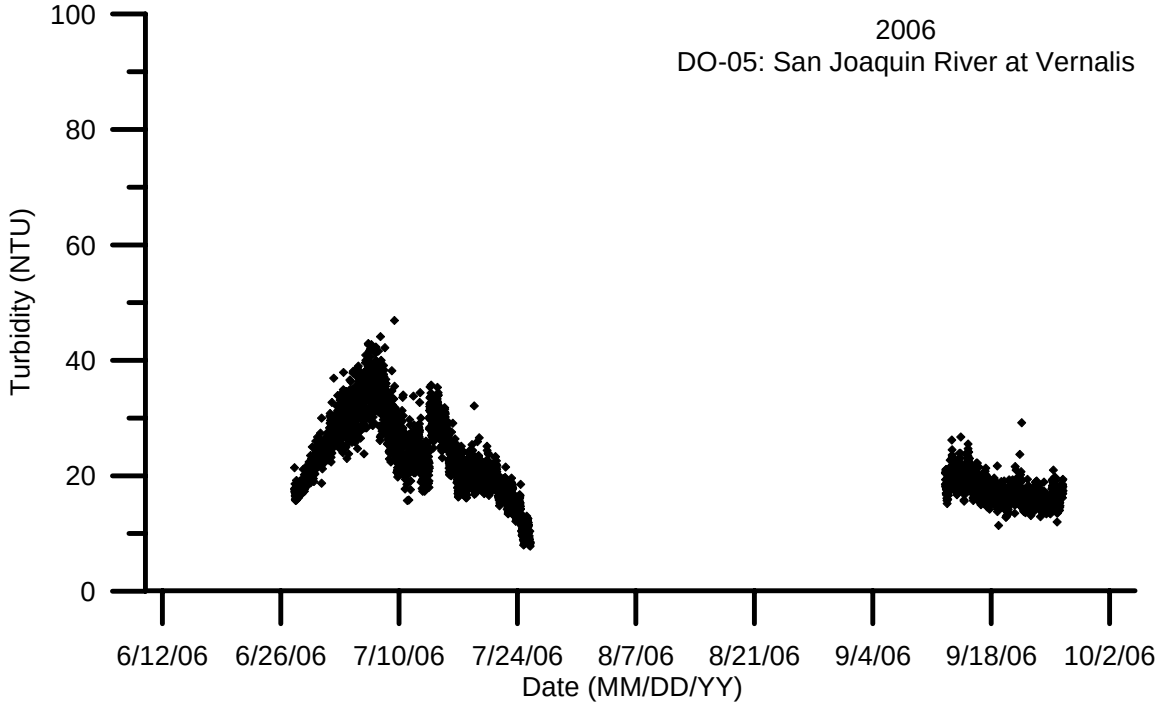


Figure 16: Turbidity 15 minute data at DO-05 for 2006 and 2007.



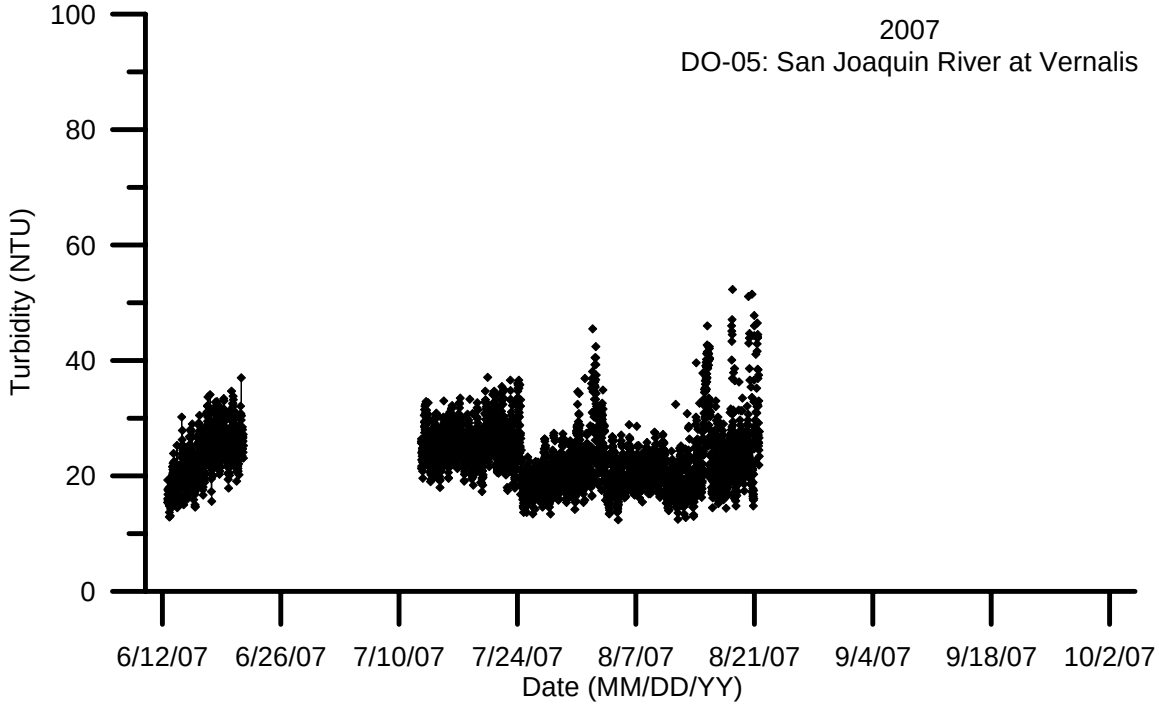
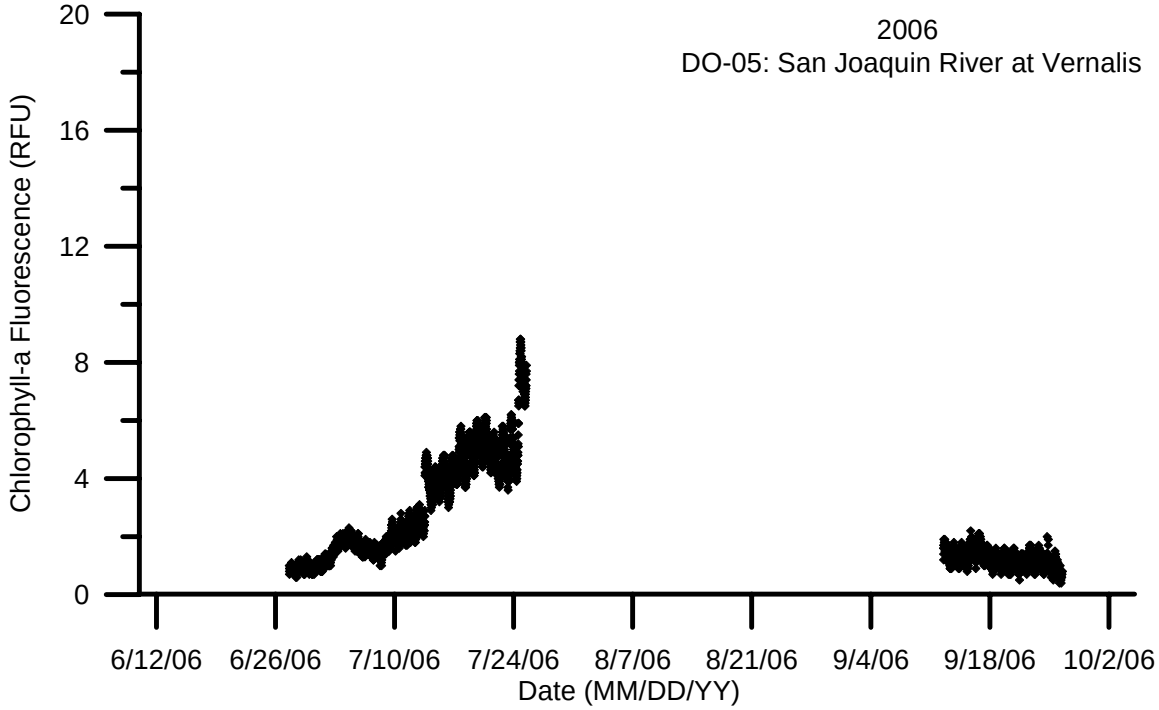


Figure 17: Chlorophyll-*a* fluorescence 15 minute data at DO-05 for 2006 and 2007.



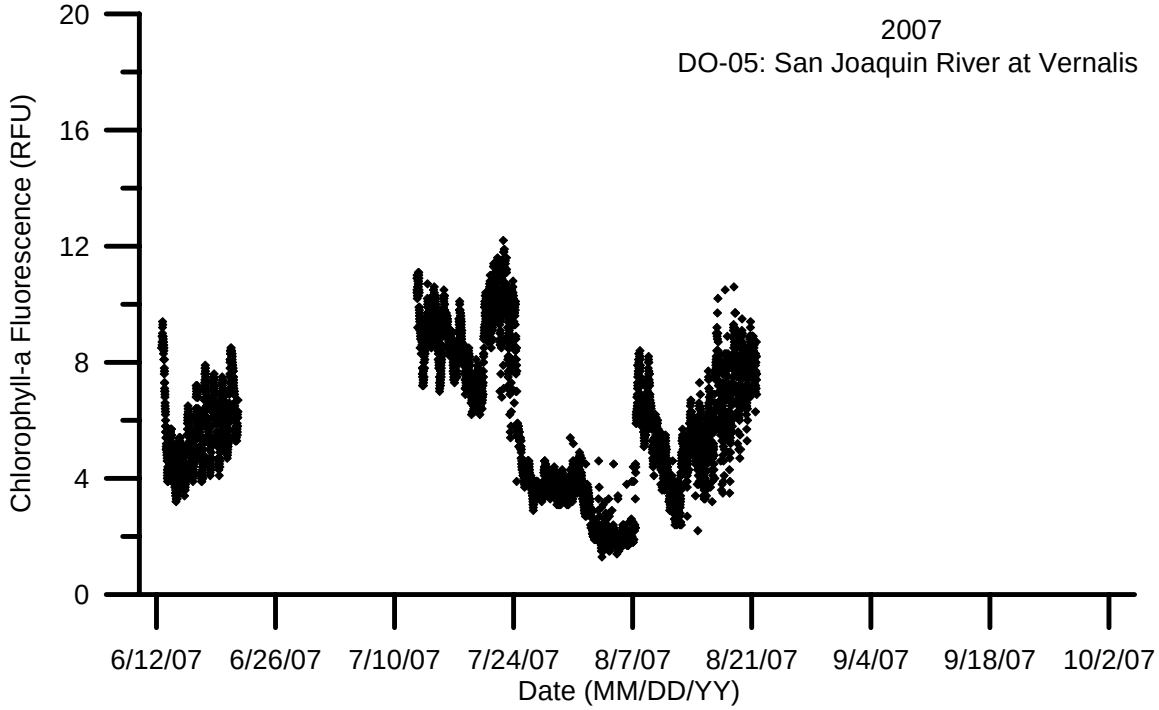
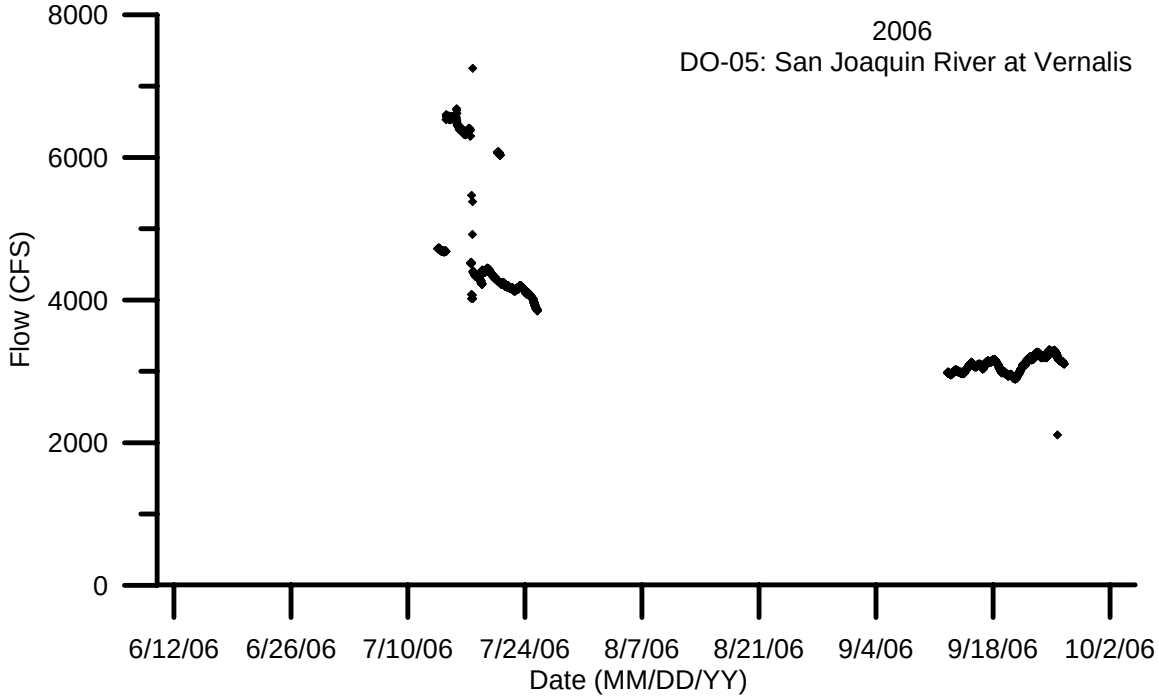


Figure 18: Flow 15 minute data at DO-05 for 2006 and 2007.



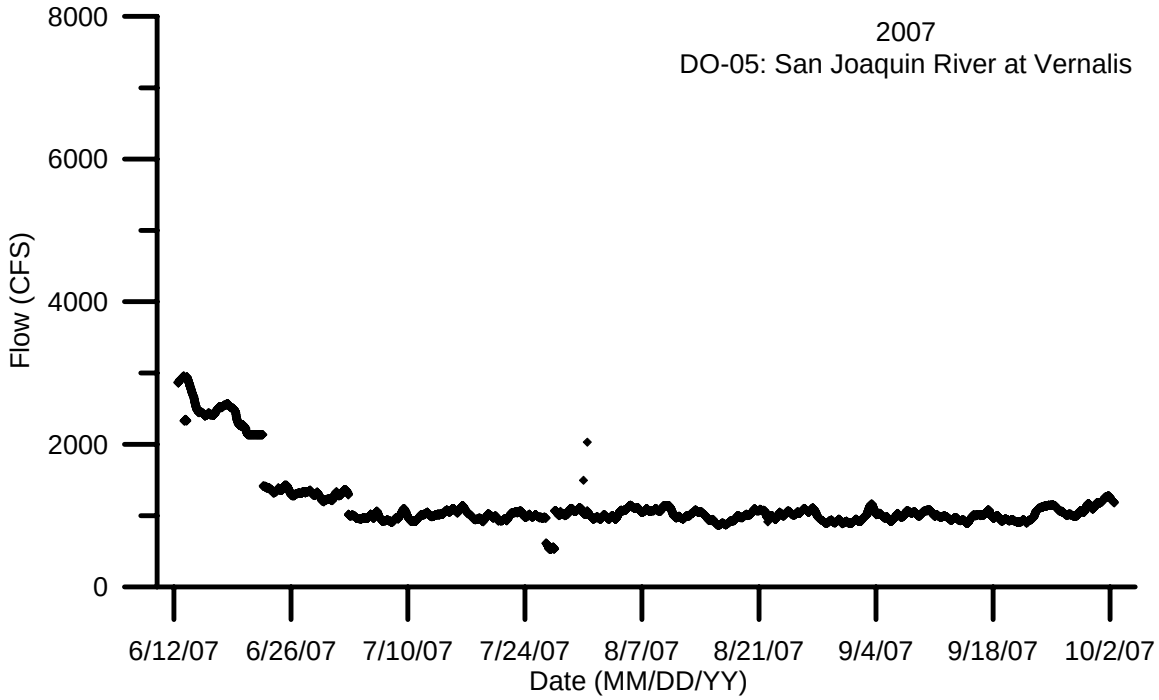


Figure 19: Water temperature 15 minute data at DO-06 for 2006 and 2007 (site not monitored in 2006).

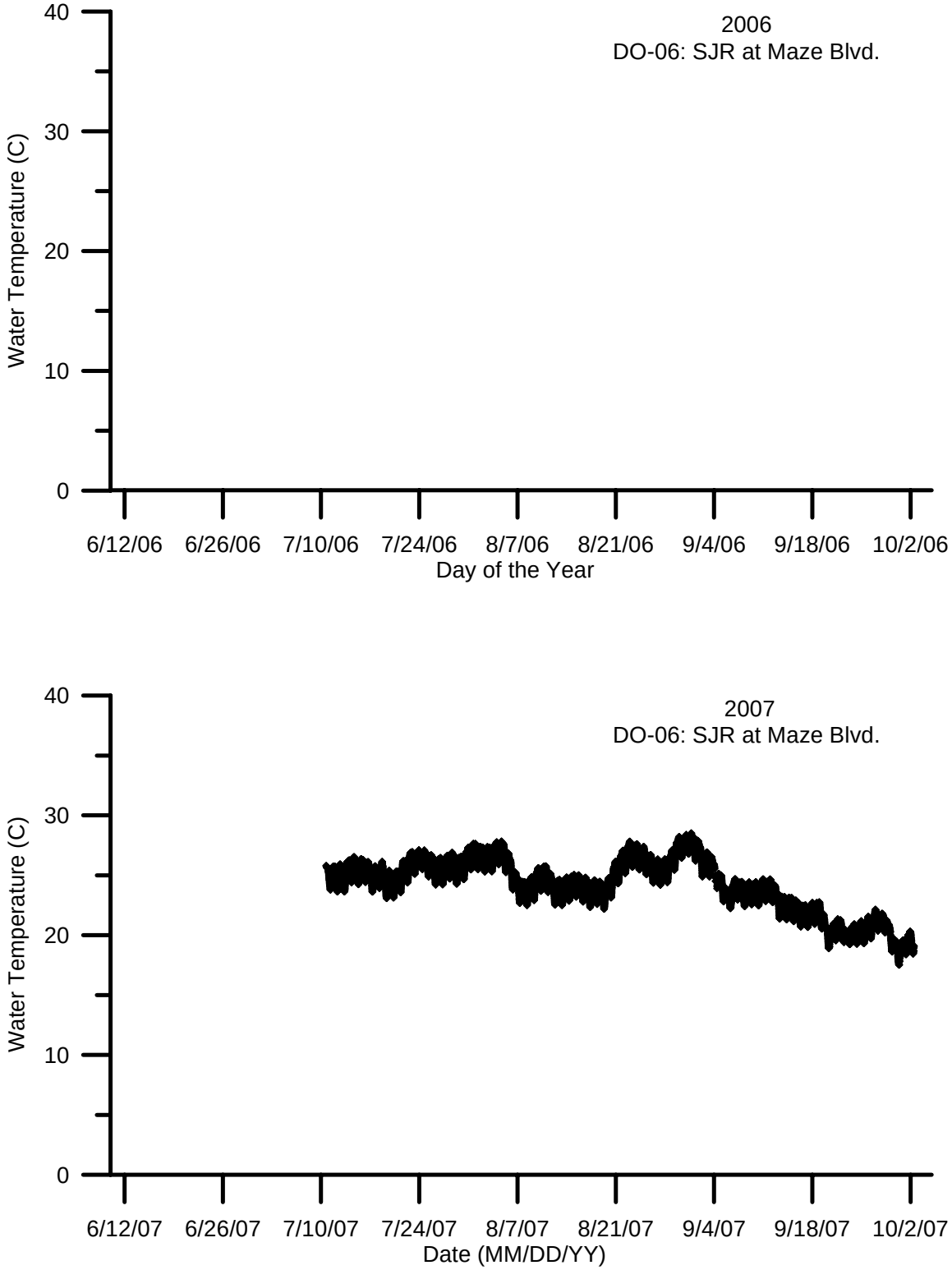
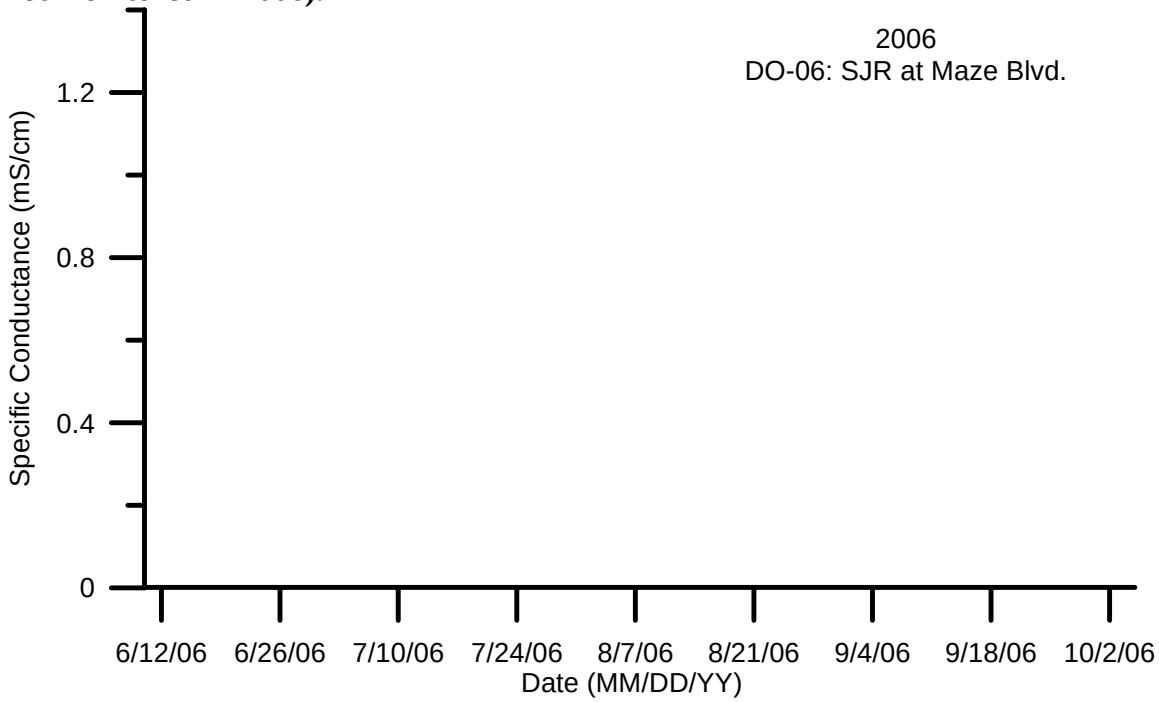


Figure 20: Specific conductance 15 minute data at DO-06 for 2006 and 2007 (site not monitored in 2006).



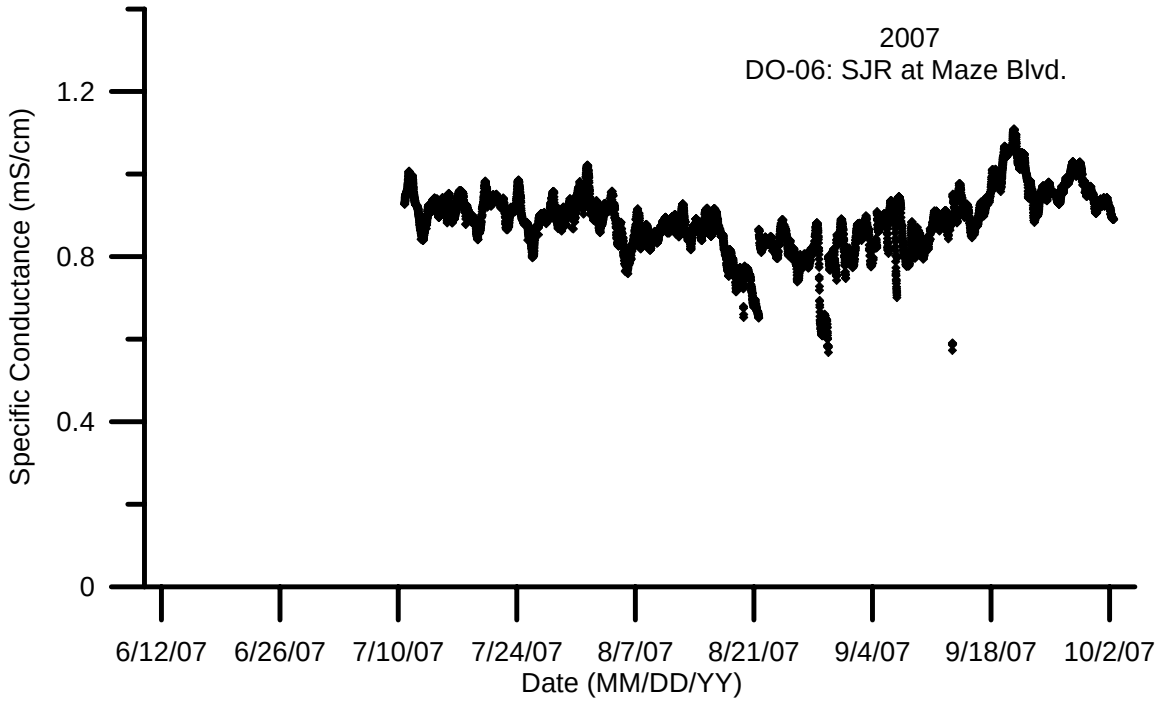
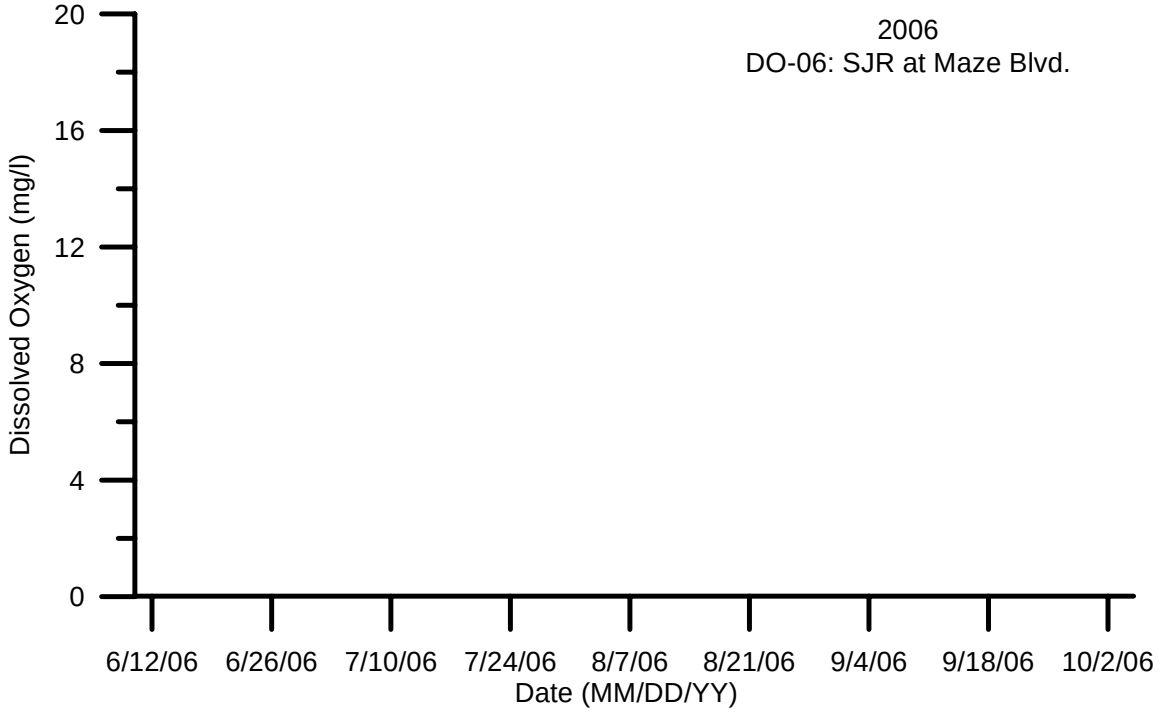


Figure 21: Dissolved oxygen concentration 15 minute data at DO-06 for 2006 and 2007 (site not monitored in 2006).



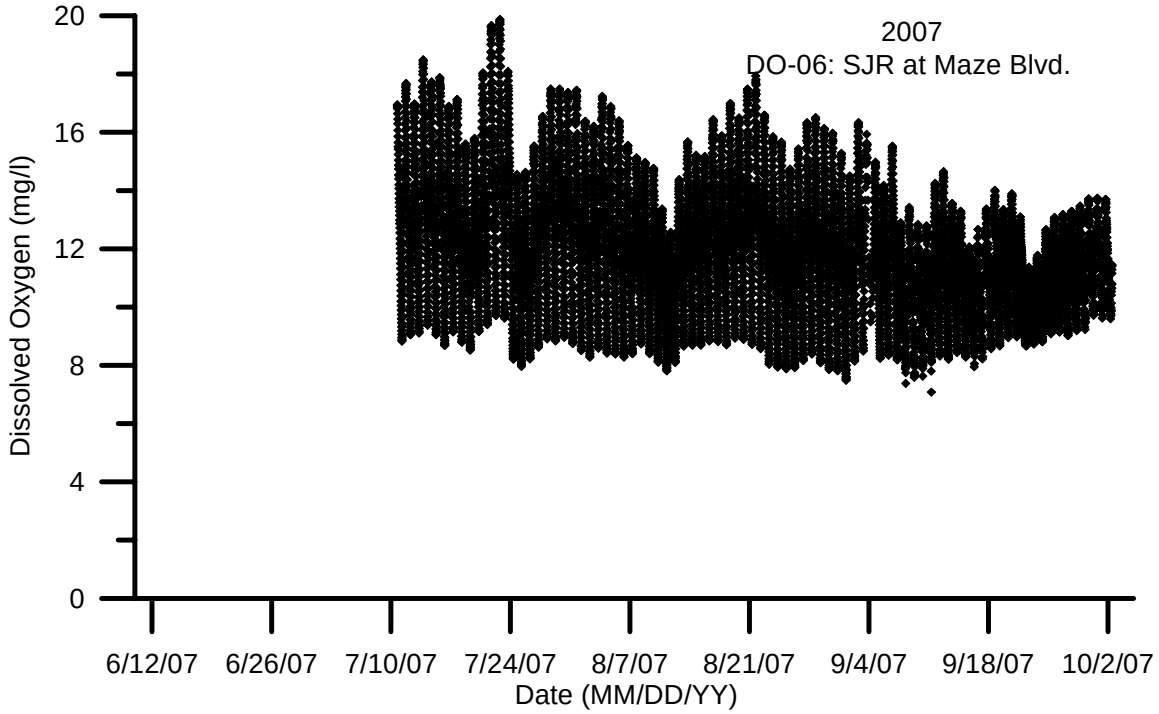
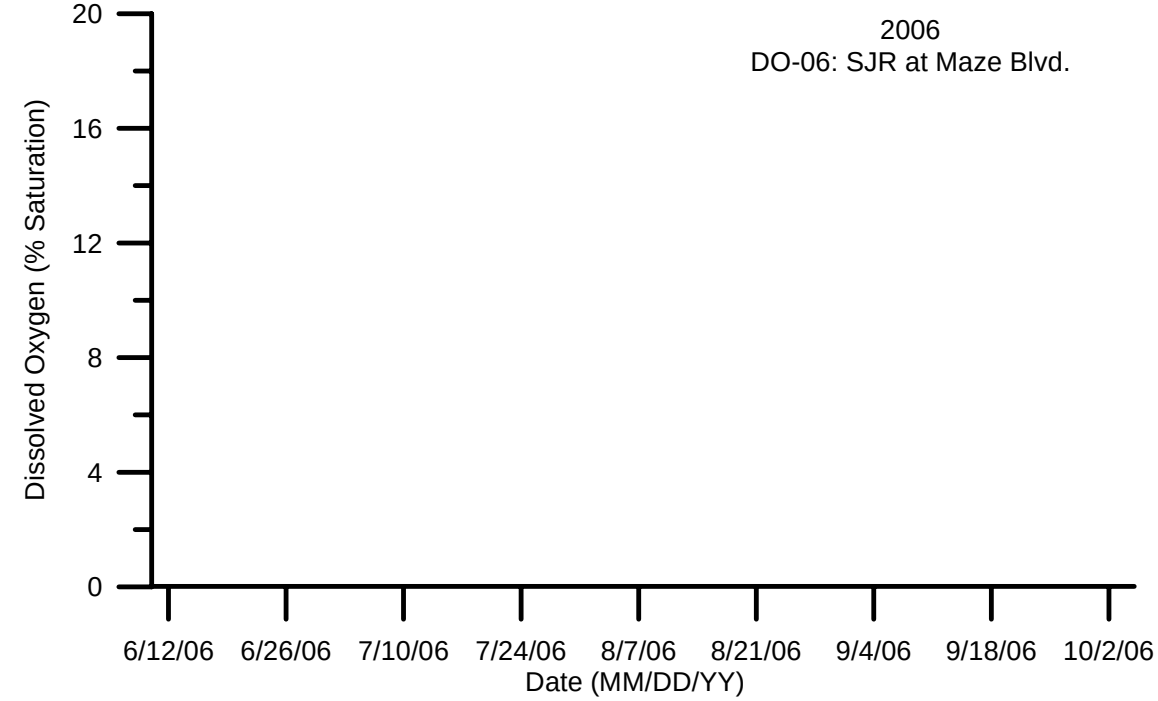


Figure 22: Dissolved oxygen percent of saturation 15 minute data at DO-06 for 2006 and 2007 (site not monitored in 2006).



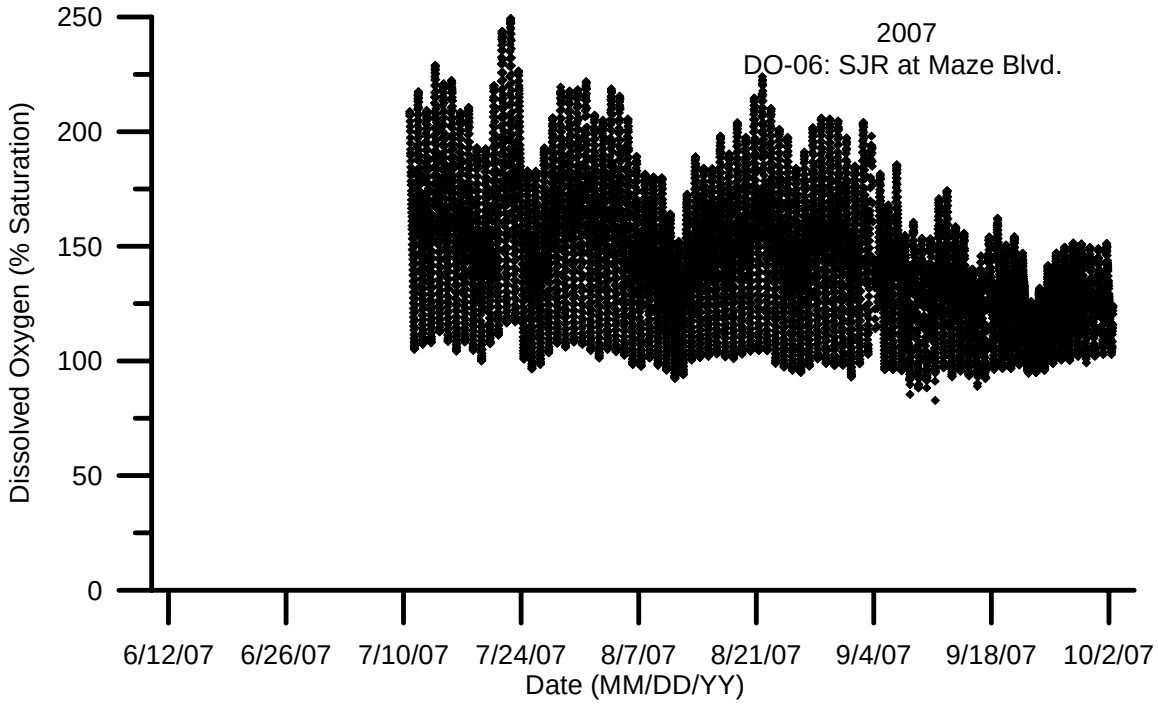
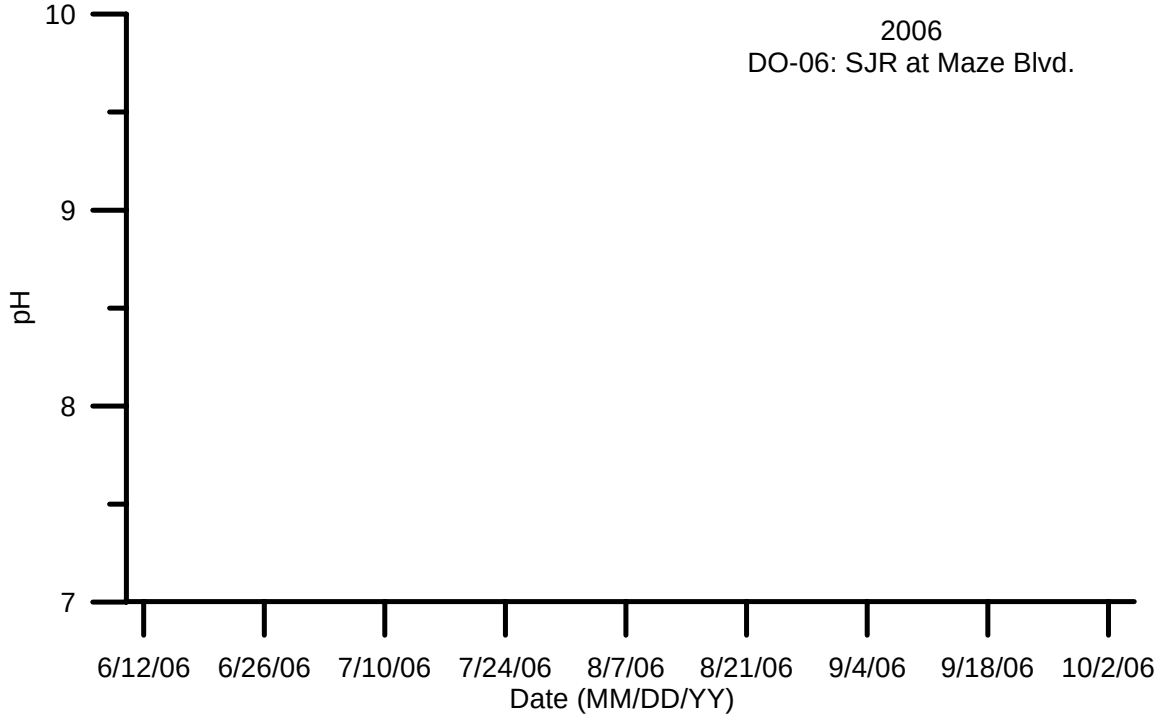


Figure 23: pH 15 minute data at DO-06 for 2006 and 2007 (site not monitored in 2006).



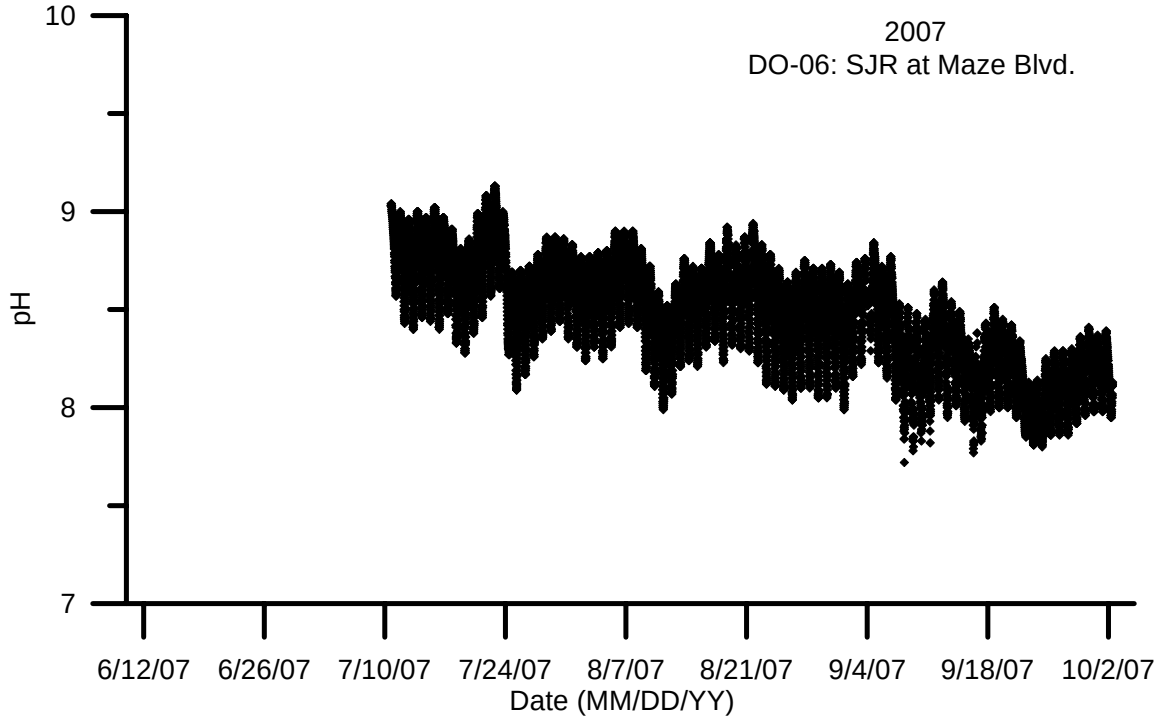


Figure 24: Turbidity 15 minute data at DO-06 for 2006 and 2007 (site not monitored in 2006).

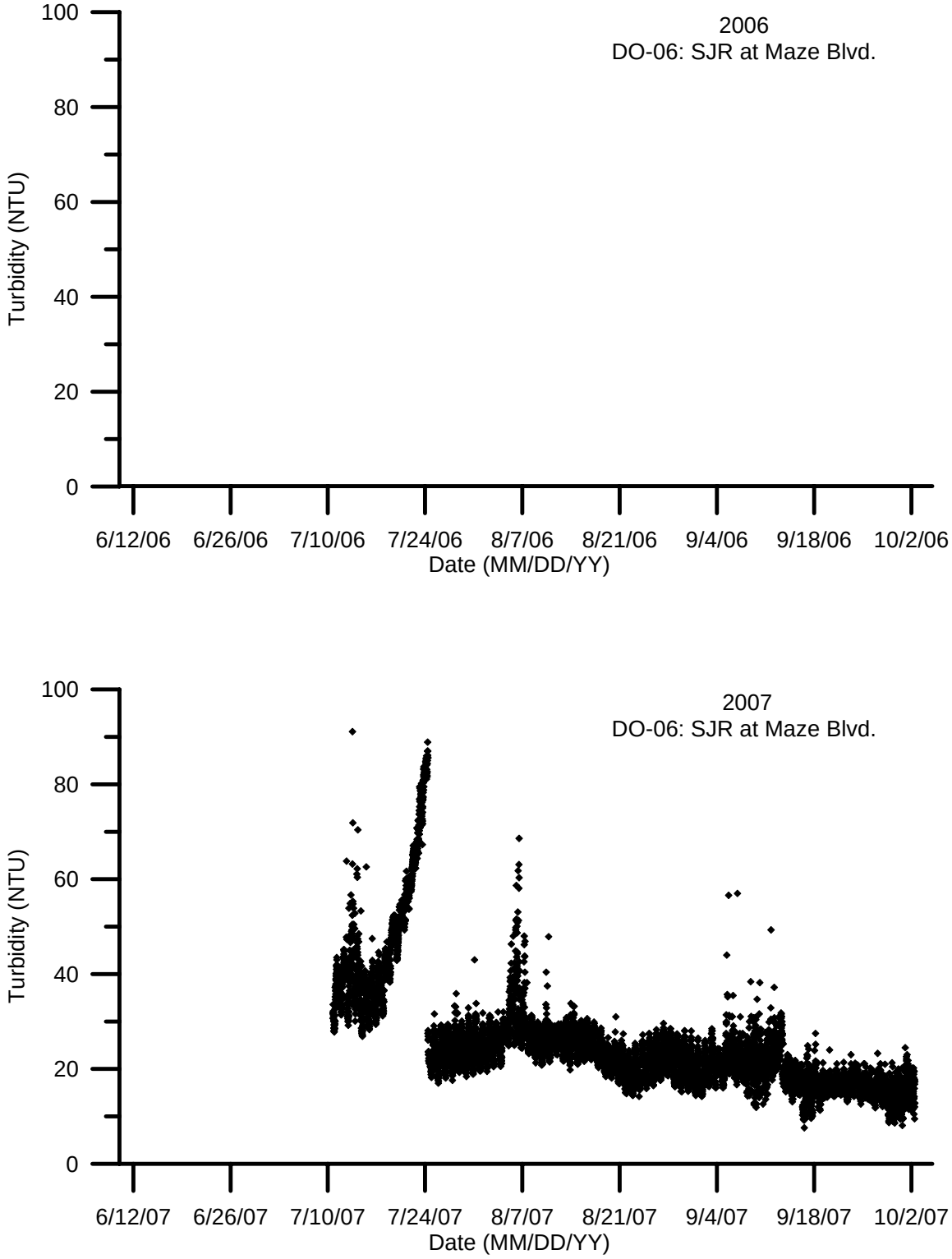
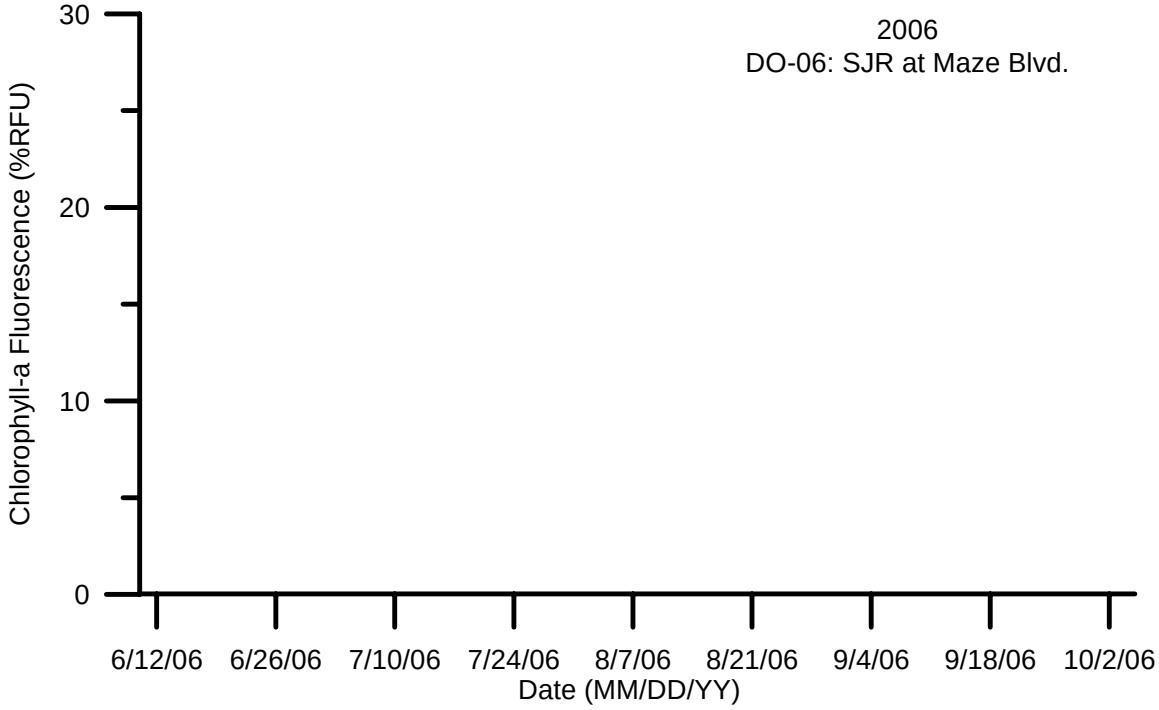


Figure 25: Chlorophyll-*a* fluorescence 15 minute data at DO-06 for 2006 and 2007 (site not monitored in 2006).



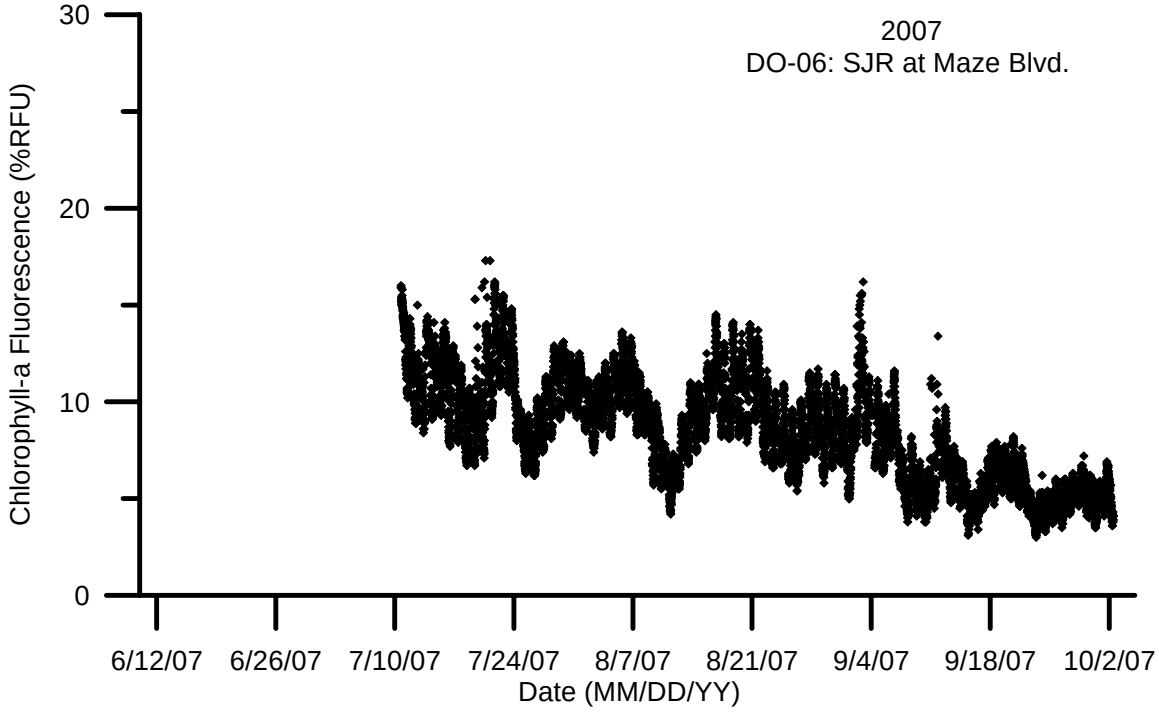
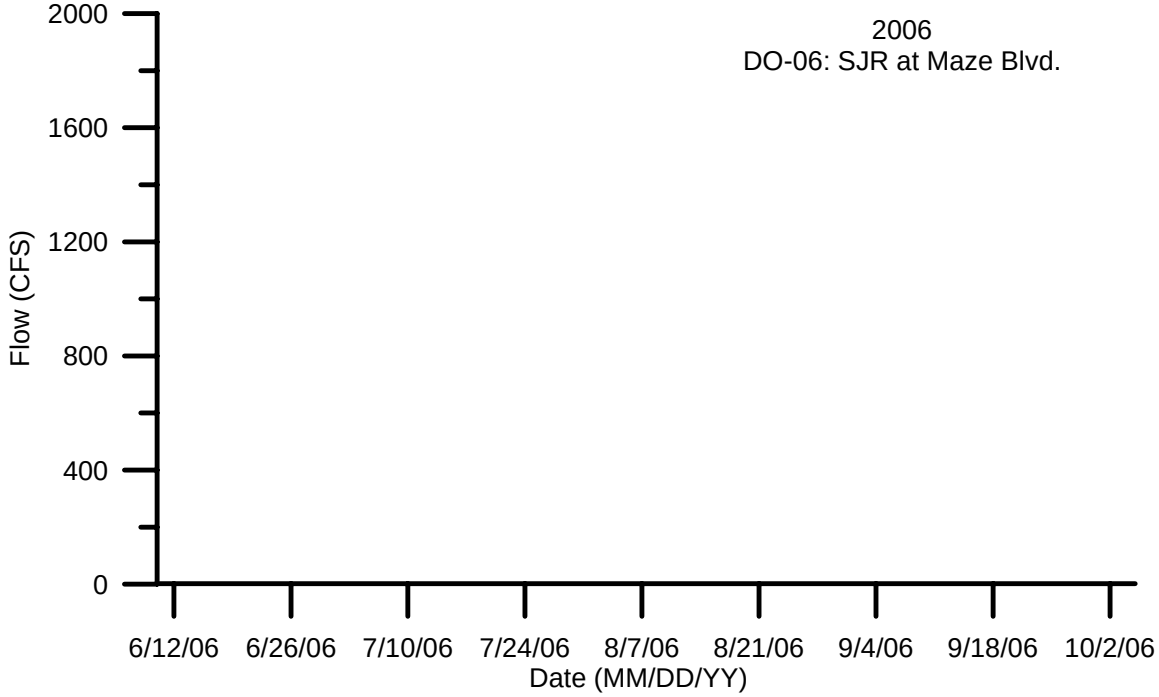


Figure 26: Flow 15 minute data at DO-06 for 2006 and 2007 (site not monitored in 2006).



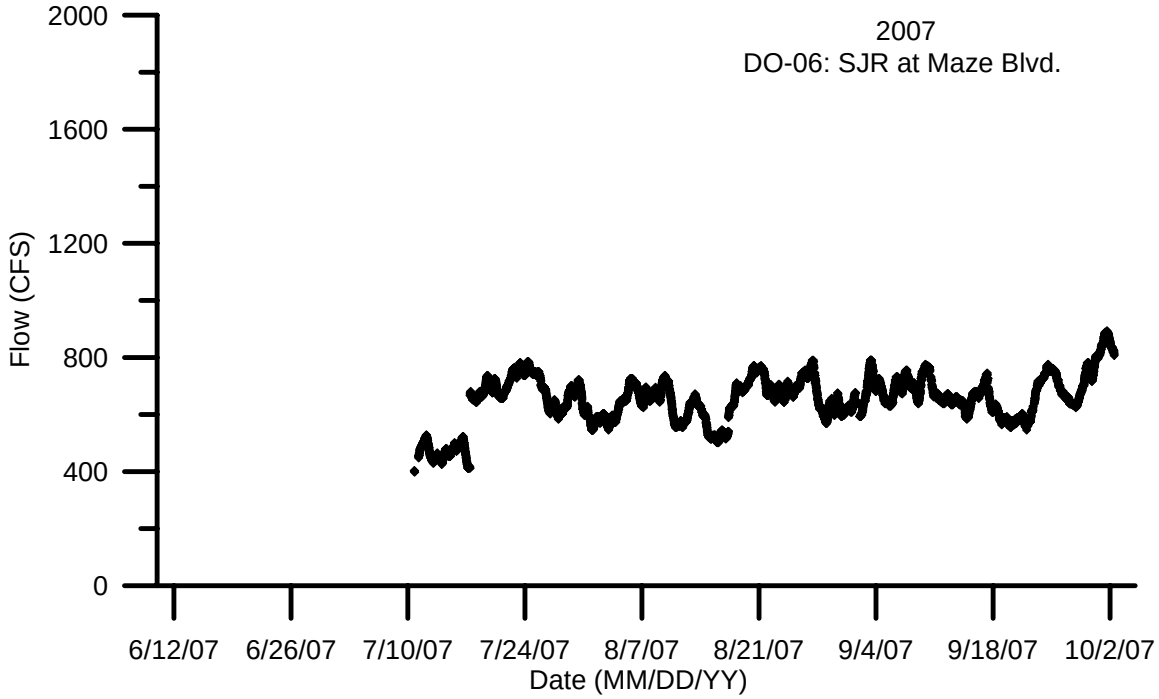
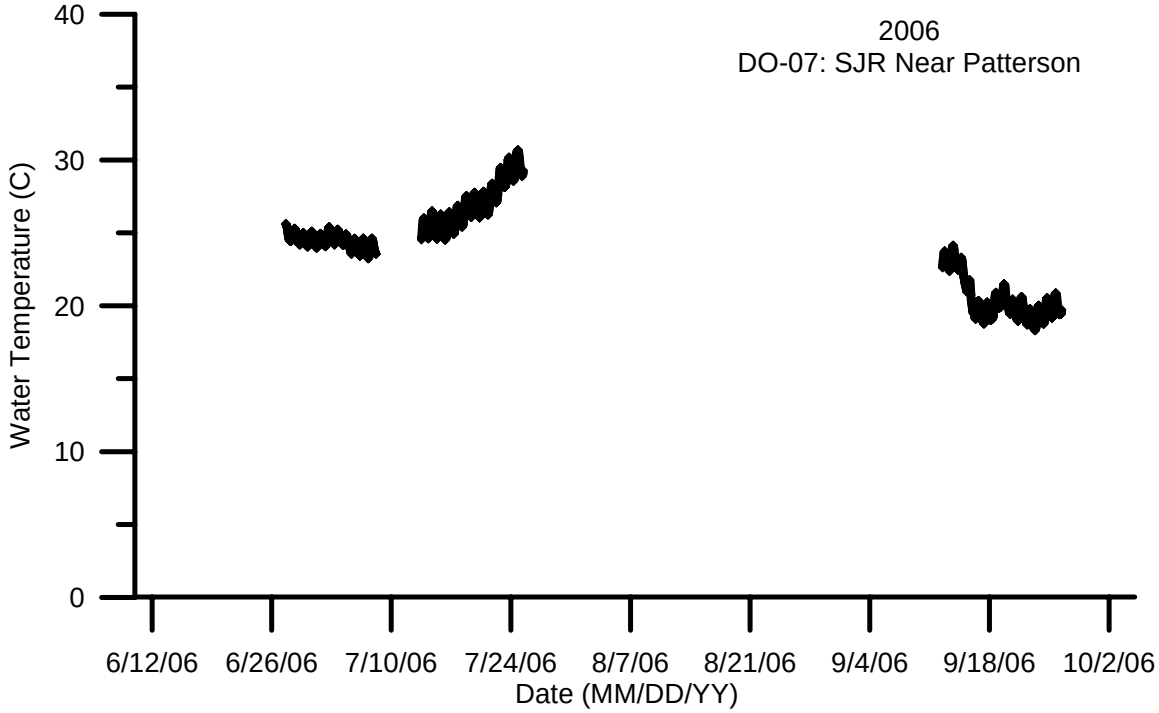


Figure 27: Water temperature 15 minute data at DO-07 for 2006 and 2007.



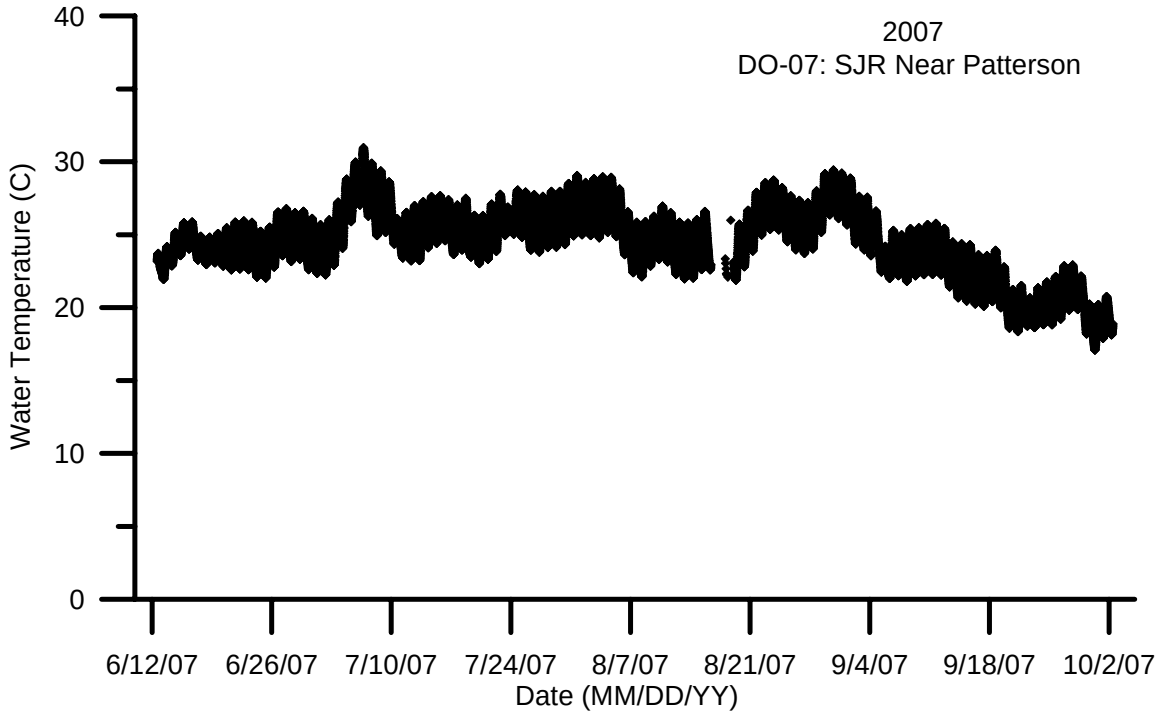
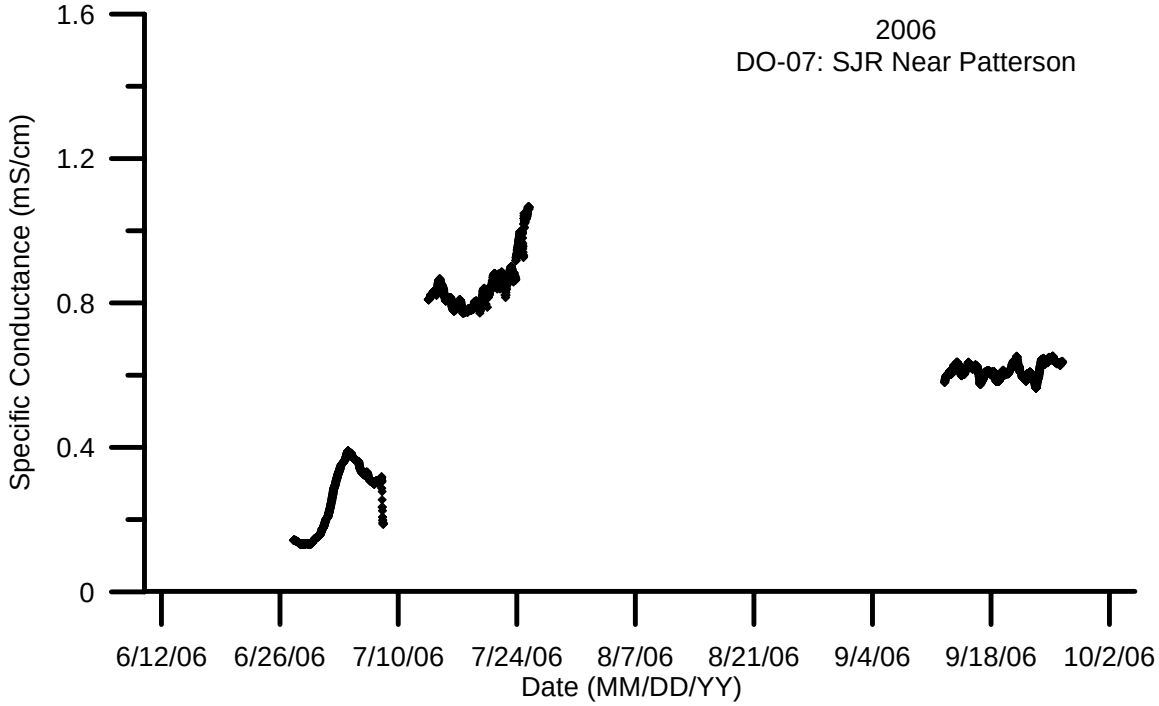


Figure 28: Specific conductance 15 minute data at DO-07 for 2006 and 2007.



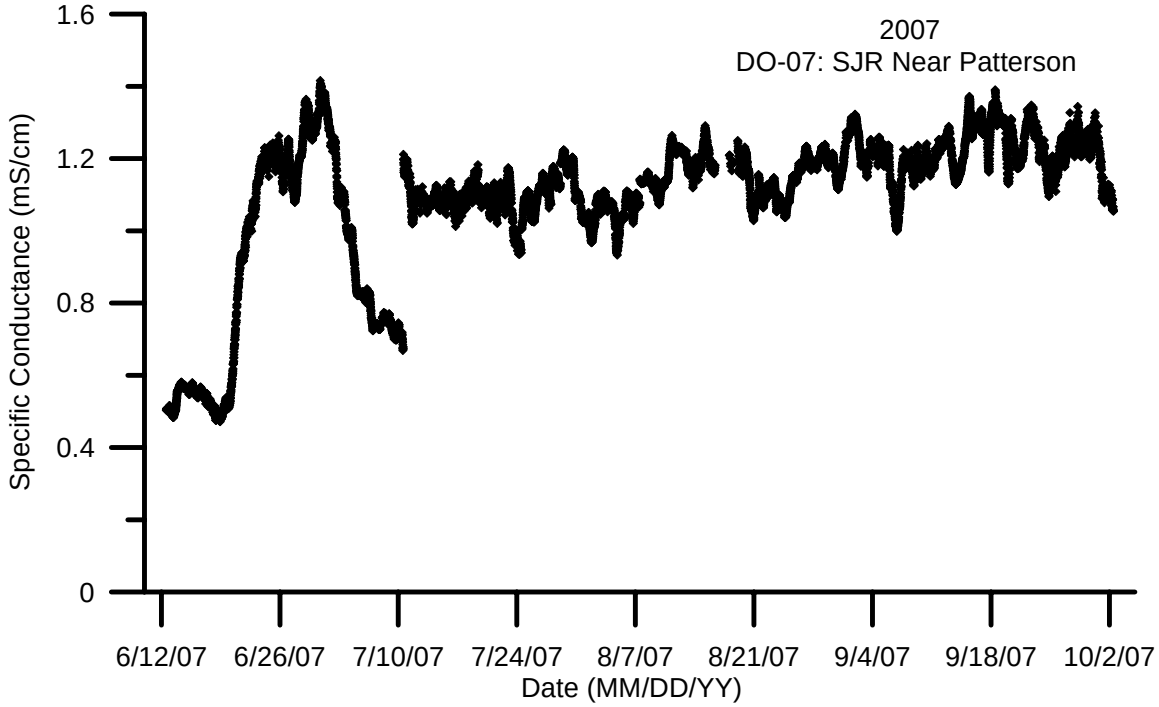
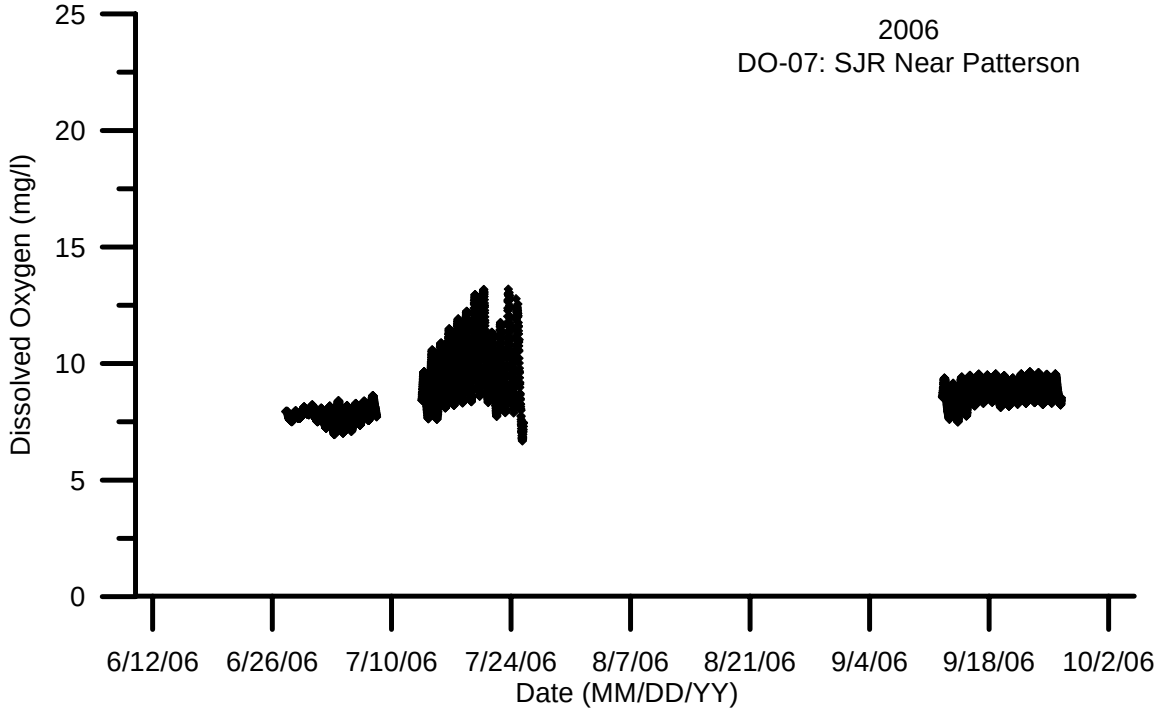


Figure 29: Dissolved oxygen concentration 15 minute data at DO-07 for 2006 and 2007.



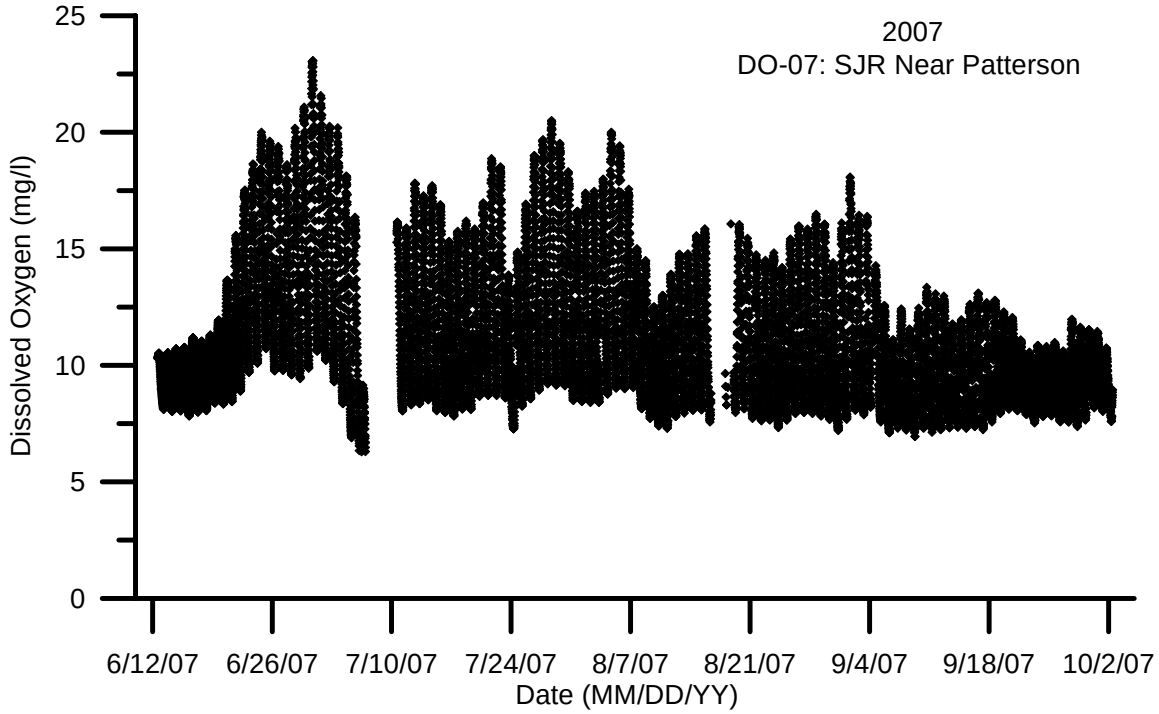
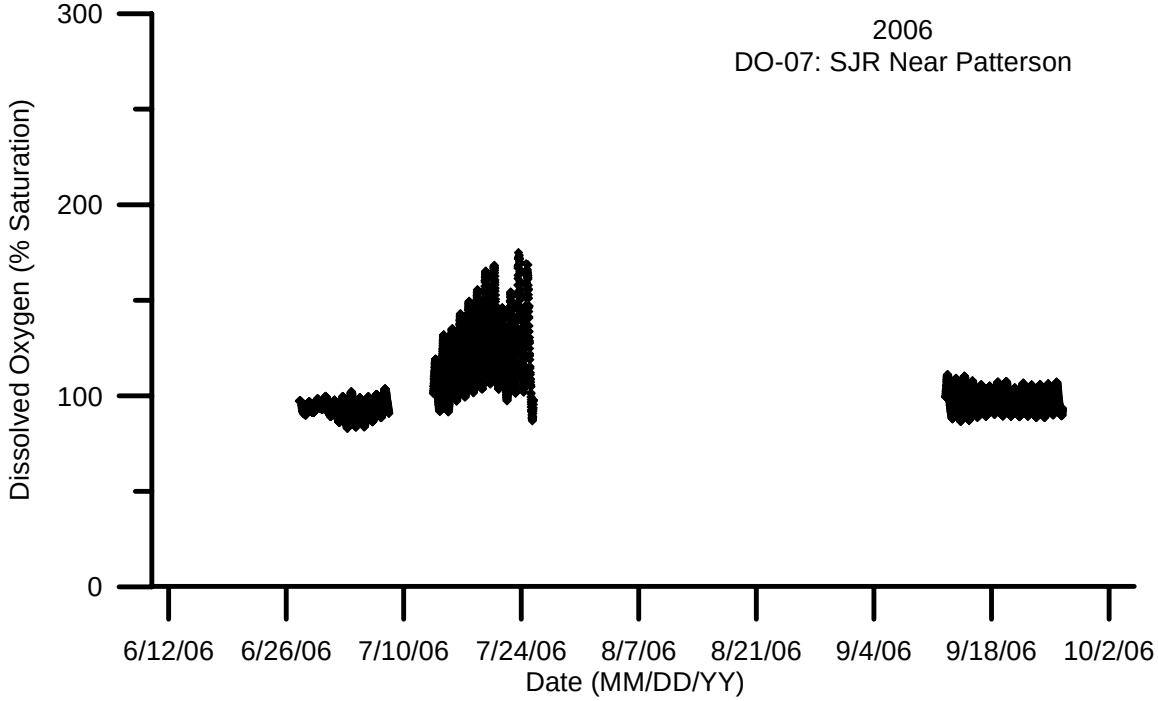


Figure 30: Dissolved oxygen percent of saturation 15 minute data at DO-07 for 2006 and 2007.



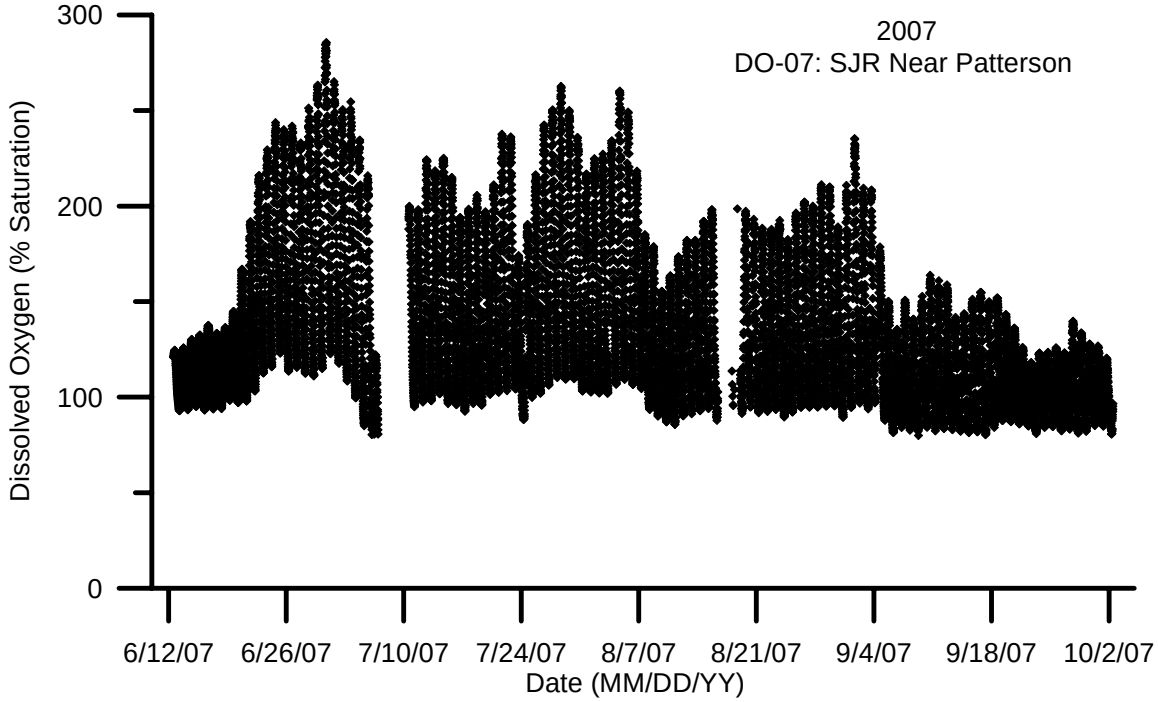
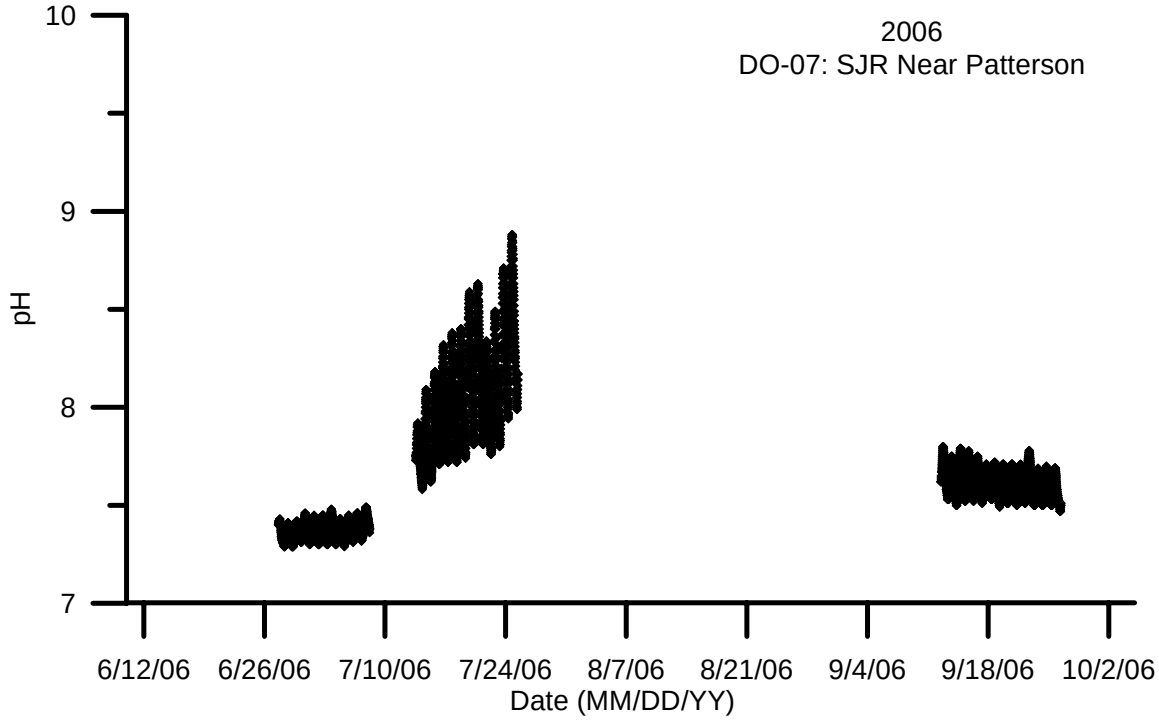


Figure 31: pH 15 minute data at DO-07 for 2006 and 2007.



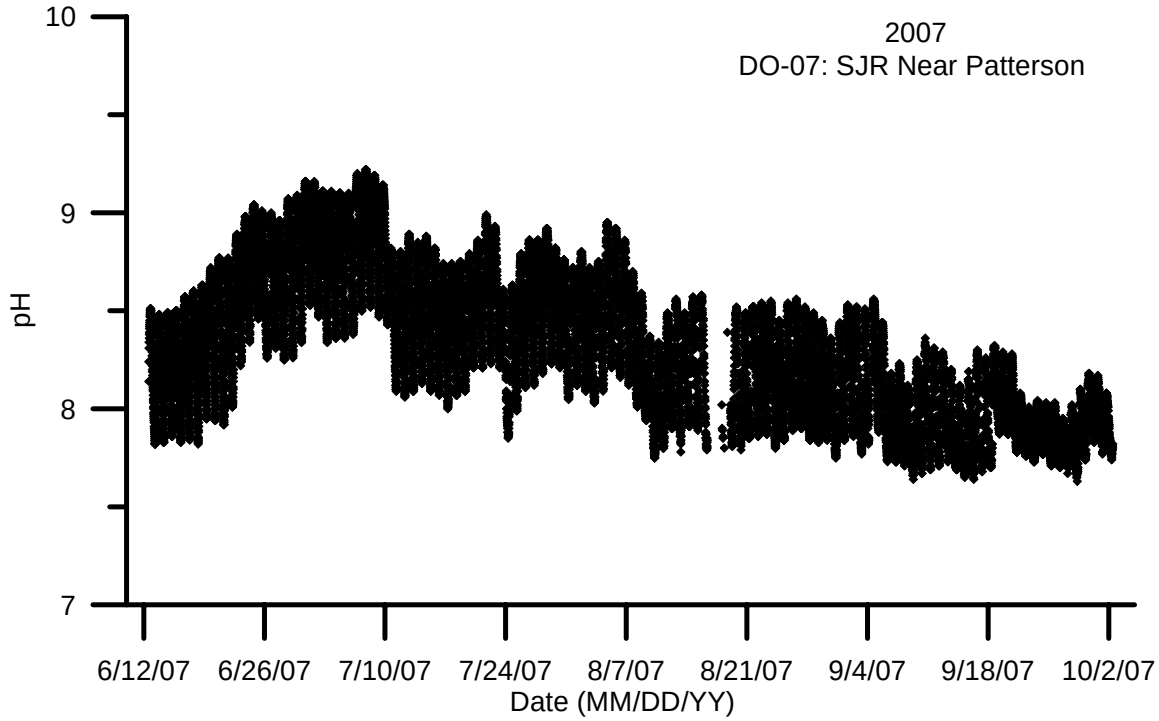
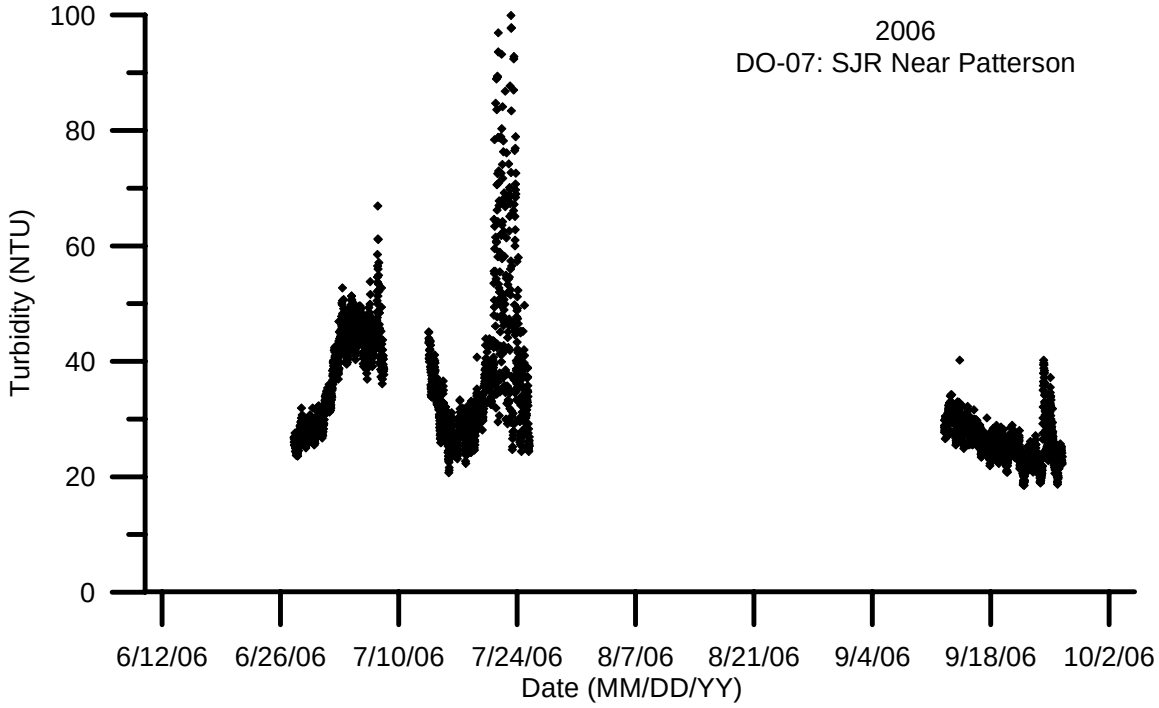


Figure 32: Turbidity 15 minute data at DO-07 for 2006 and 2007.



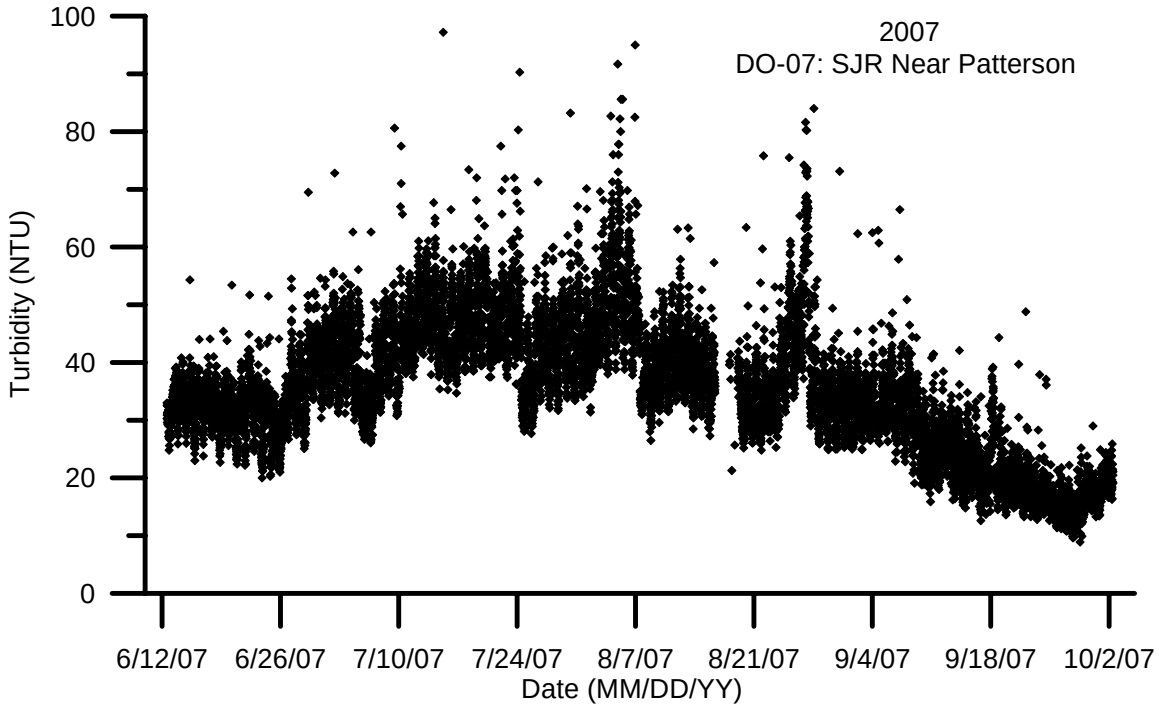


Figure 33: Chlorophyll-*a* fluorescence 15 minute data at DO-07 for 2006 and 2007.

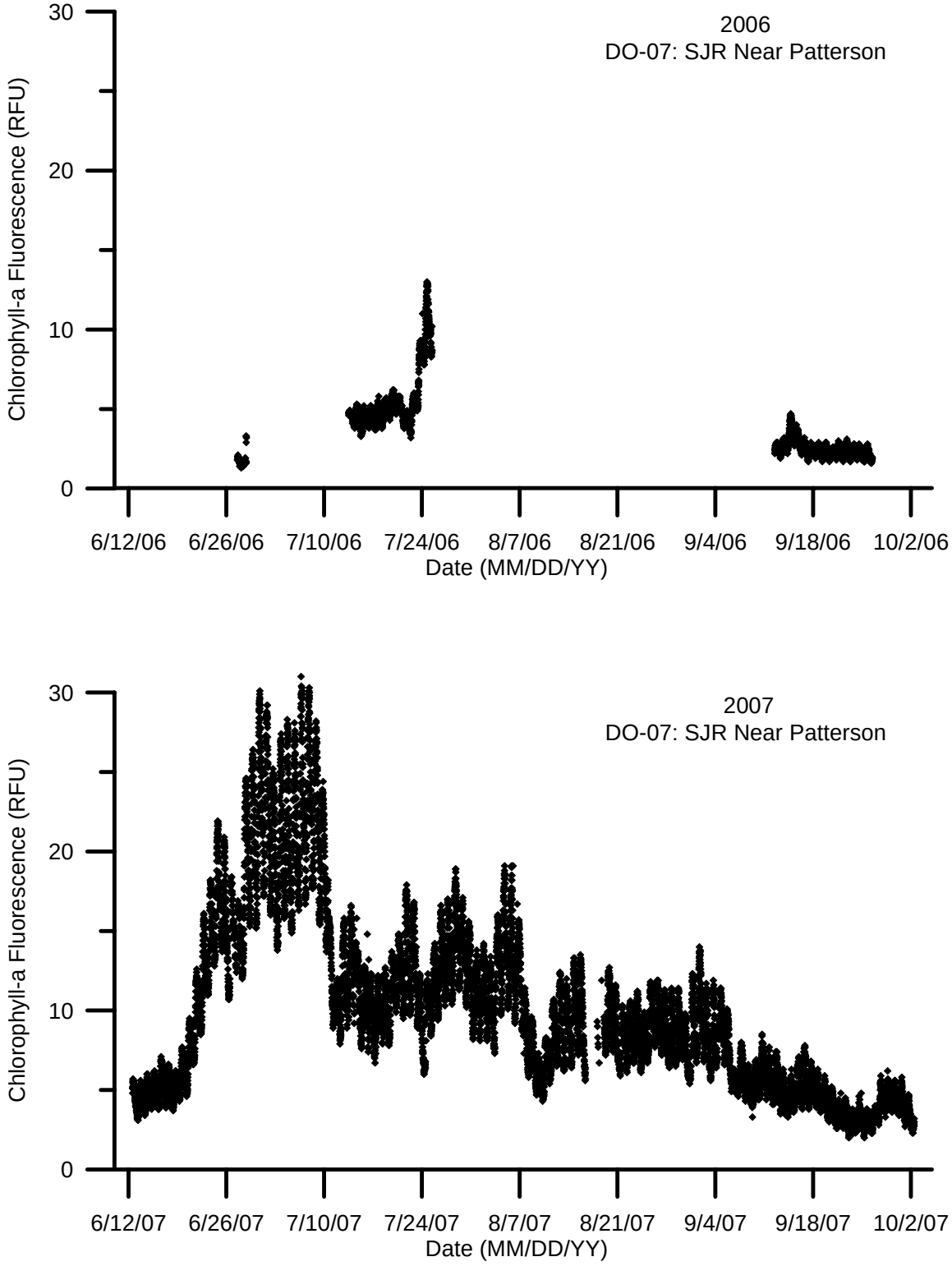
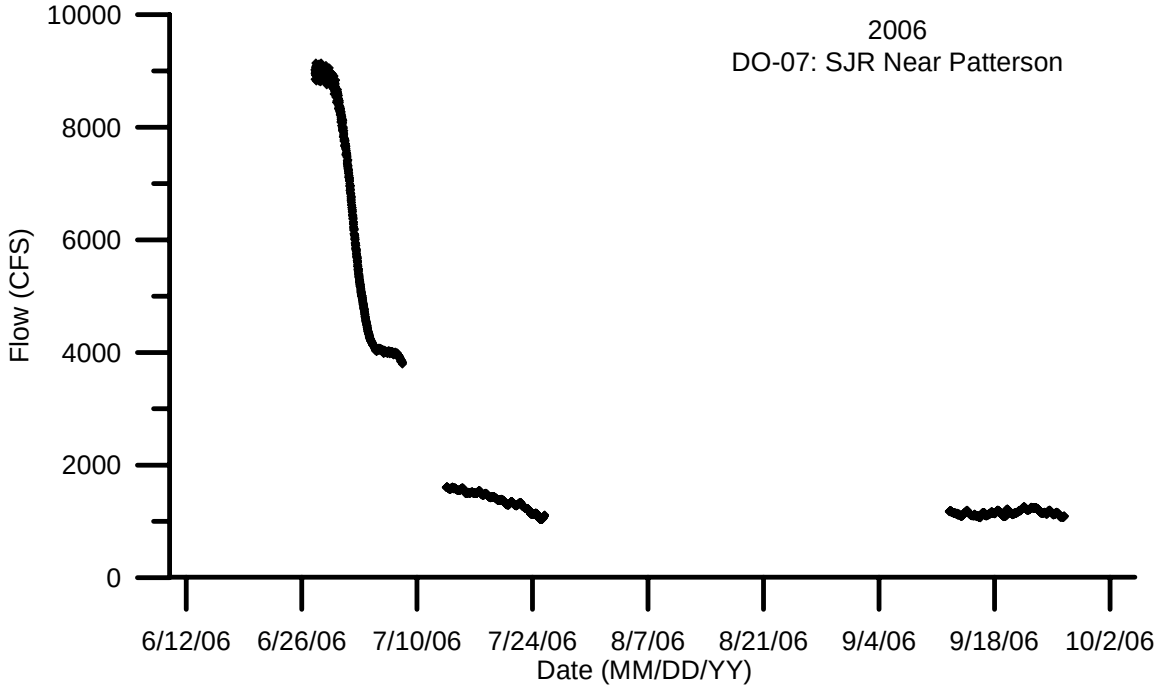


Figure 34: Flow data at DO-07 for 2006 and 2007.



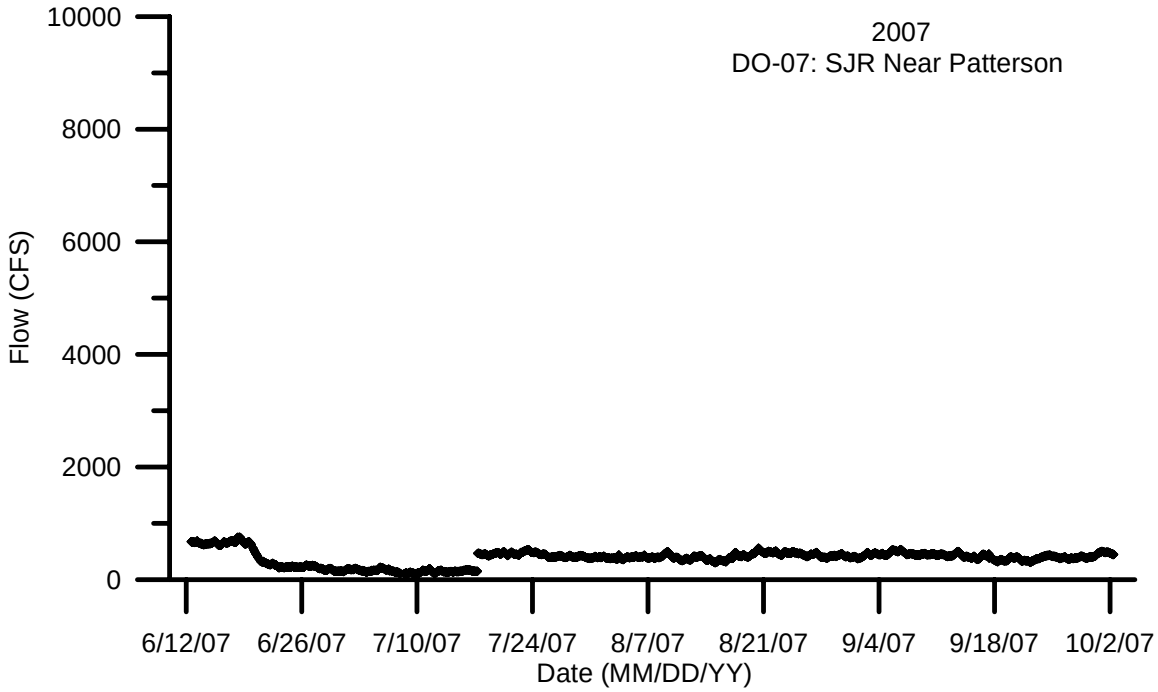
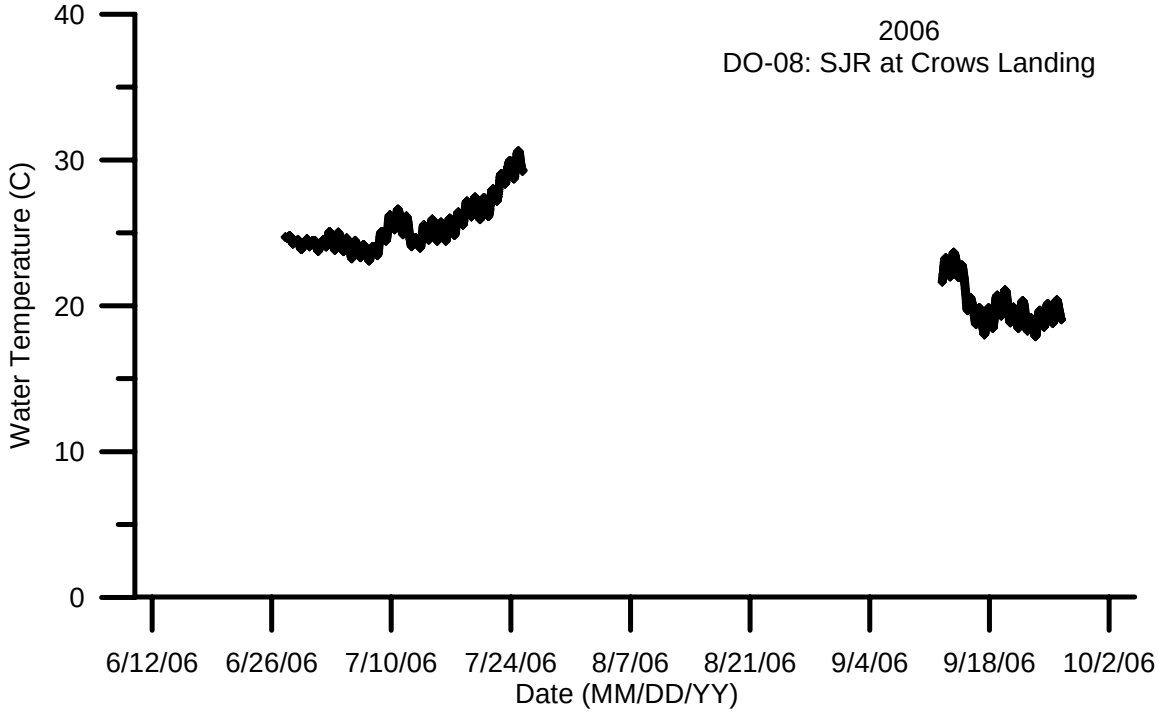


Figure 35: Water temperature 15 minute data at DO-08 for 2006 and 2007.



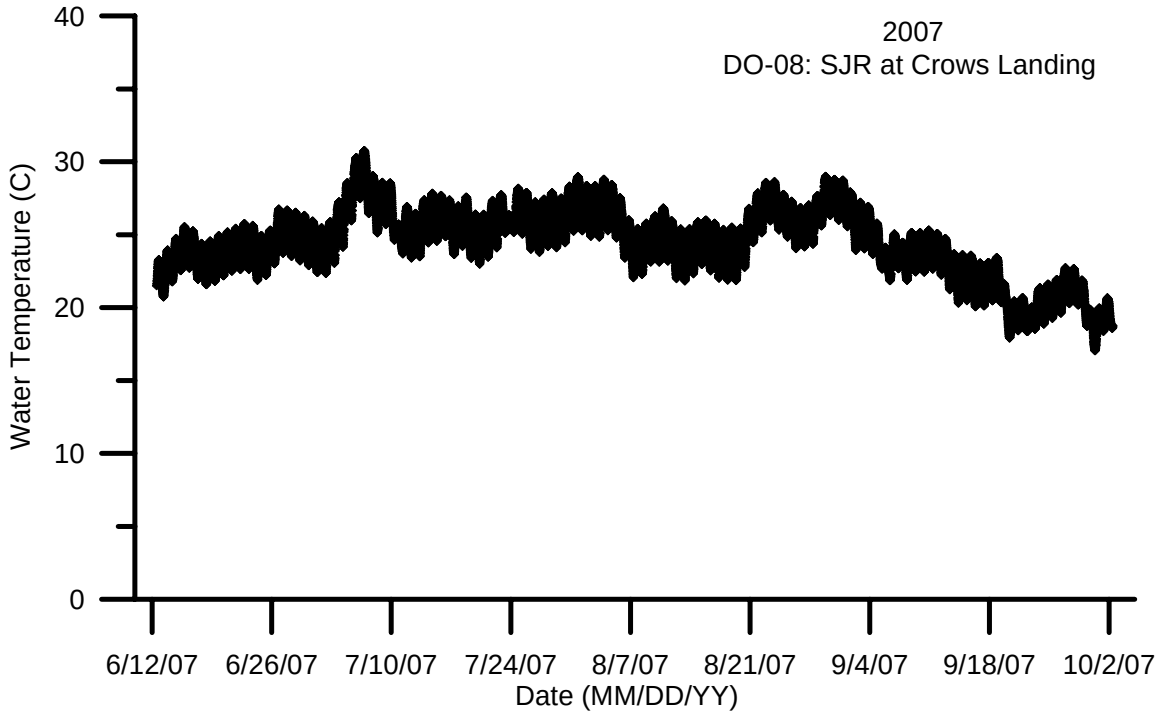
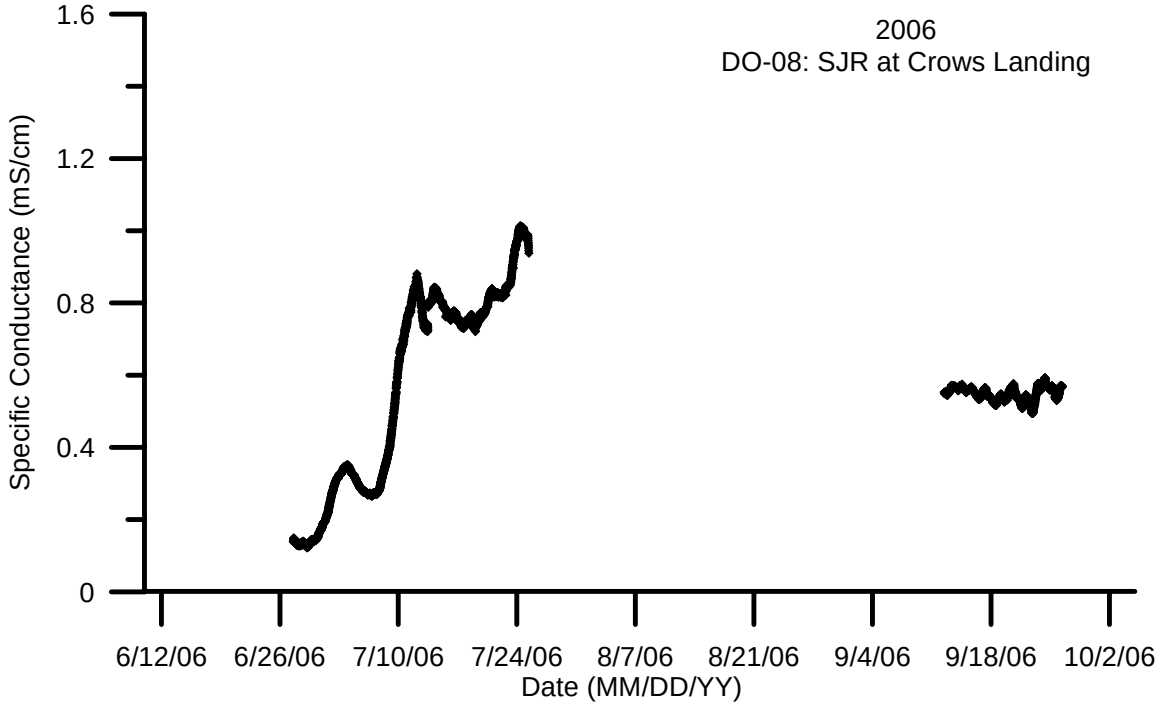


Figure 36: Specific conductance 15 minute data at DO-08 for 2006 and 2007.



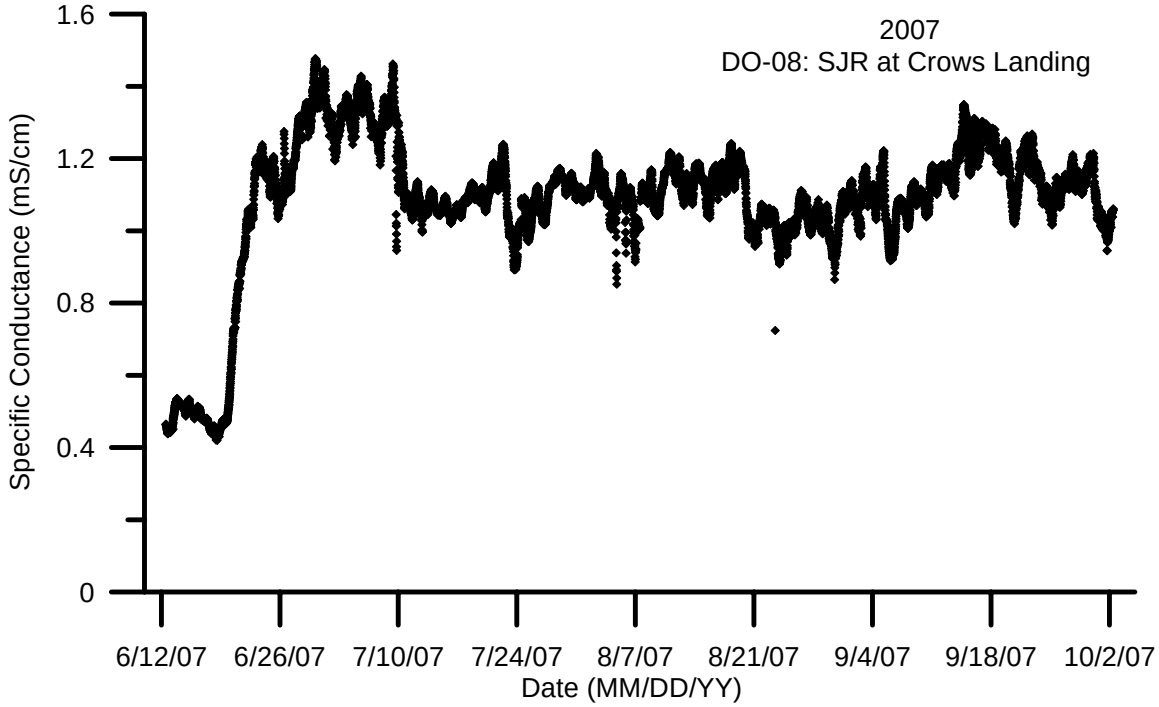
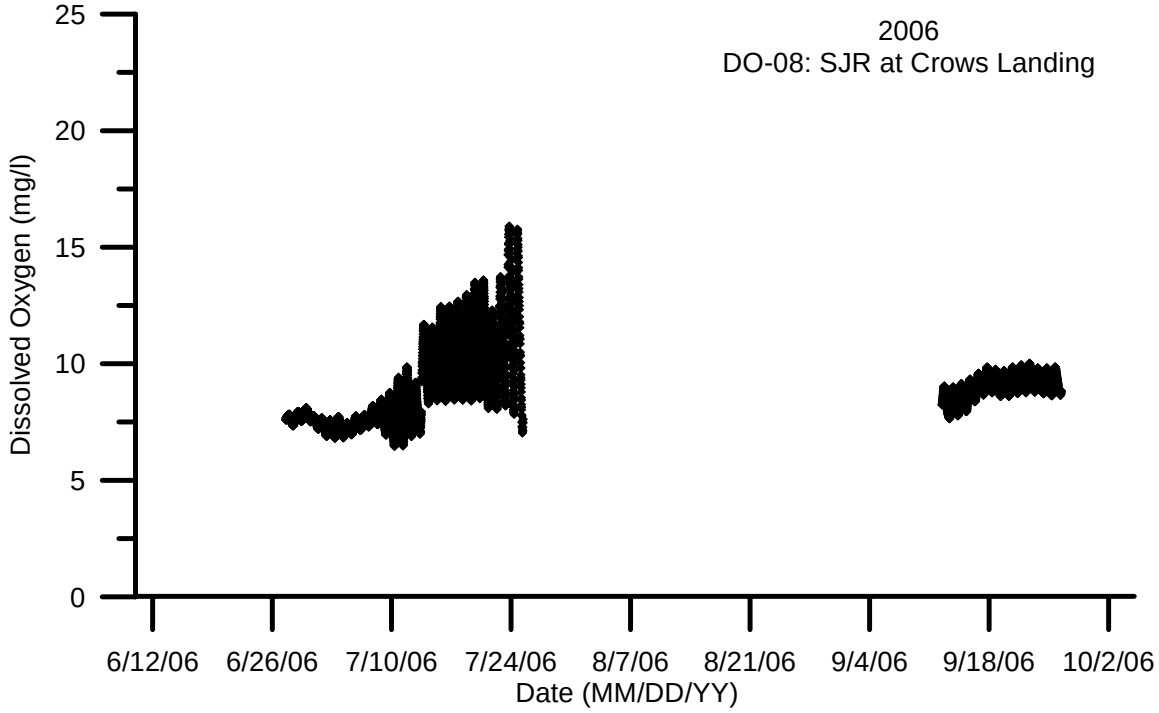


Figure 37: Dissolved oxygen 15 minute data at DO-08 for 2006 and 2007.



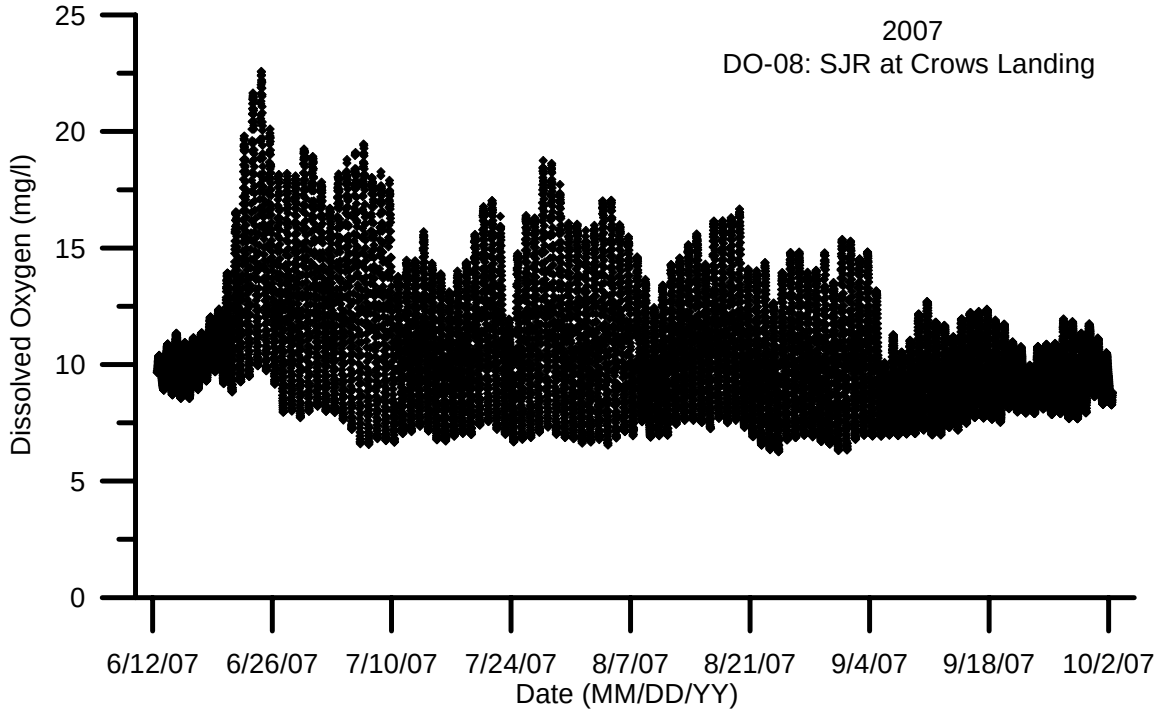
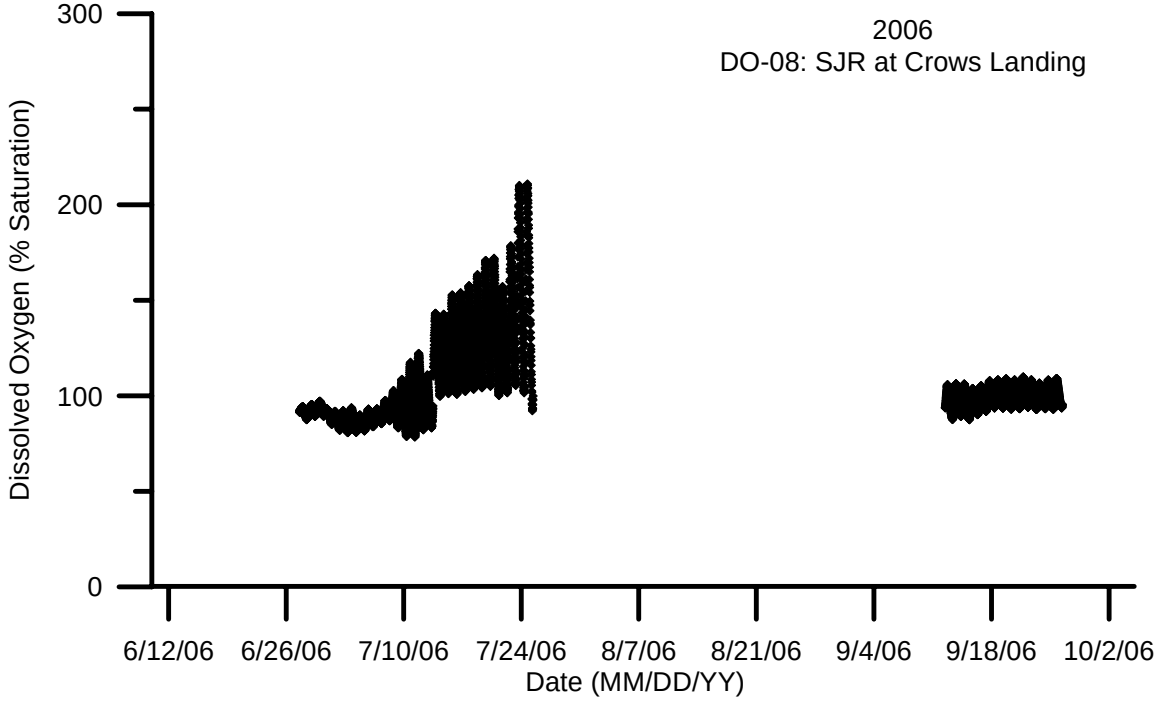


Figure 38: Dissolved oxygen percent of saturation 15 minute data at DO-08 for 2006 and 2007.



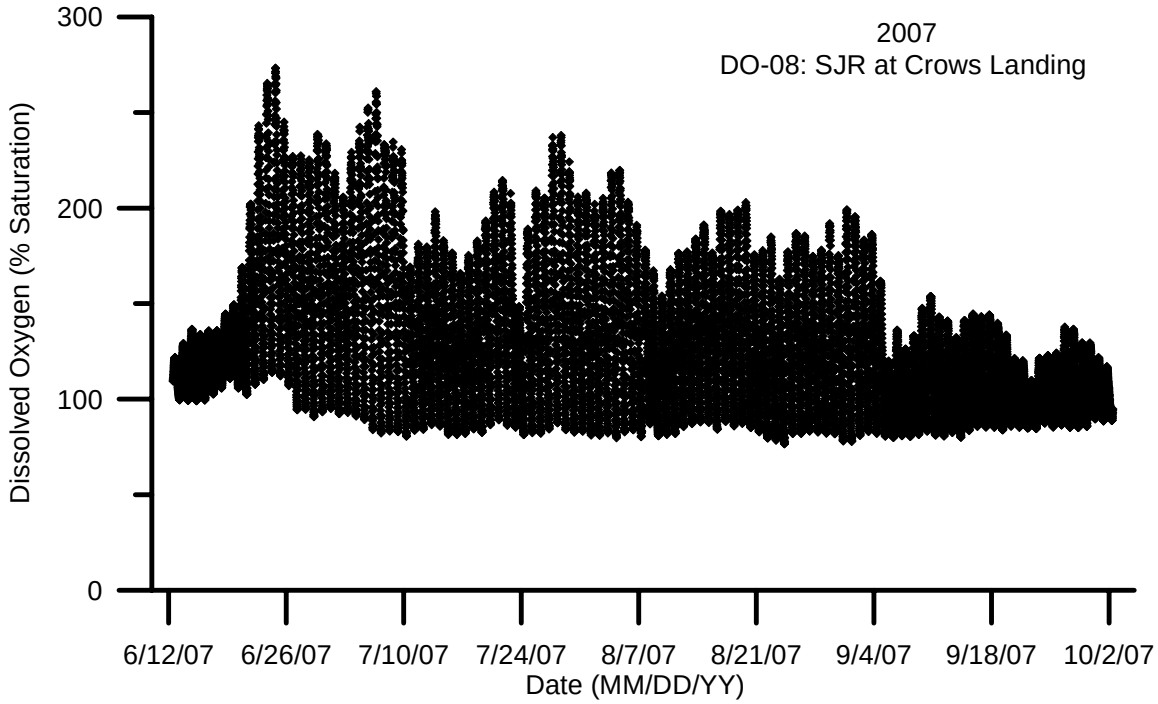
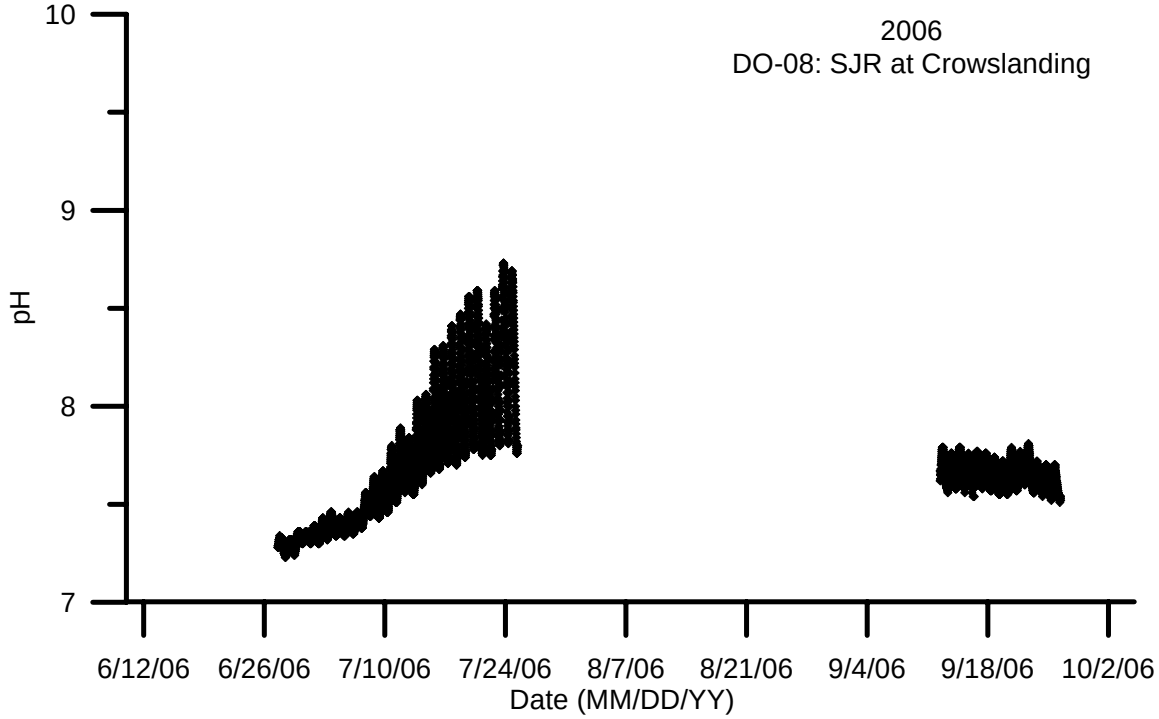


Figure 39: pH 15 minute data at DO-08 for 2006 and 2007.



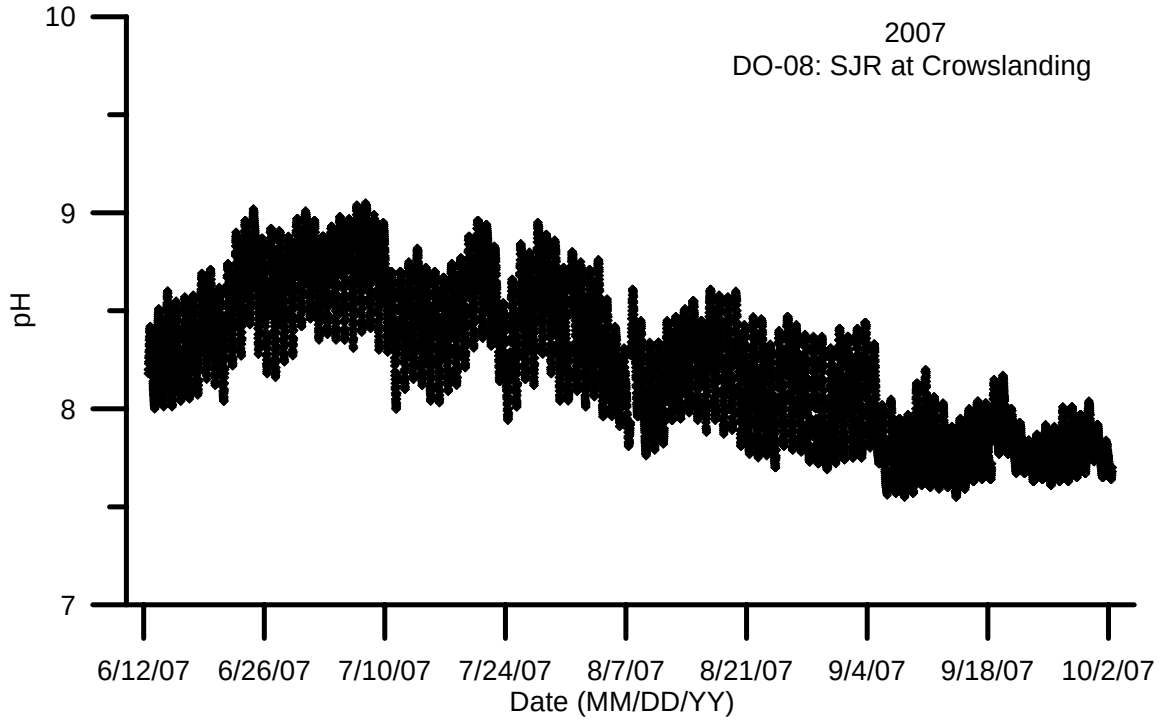
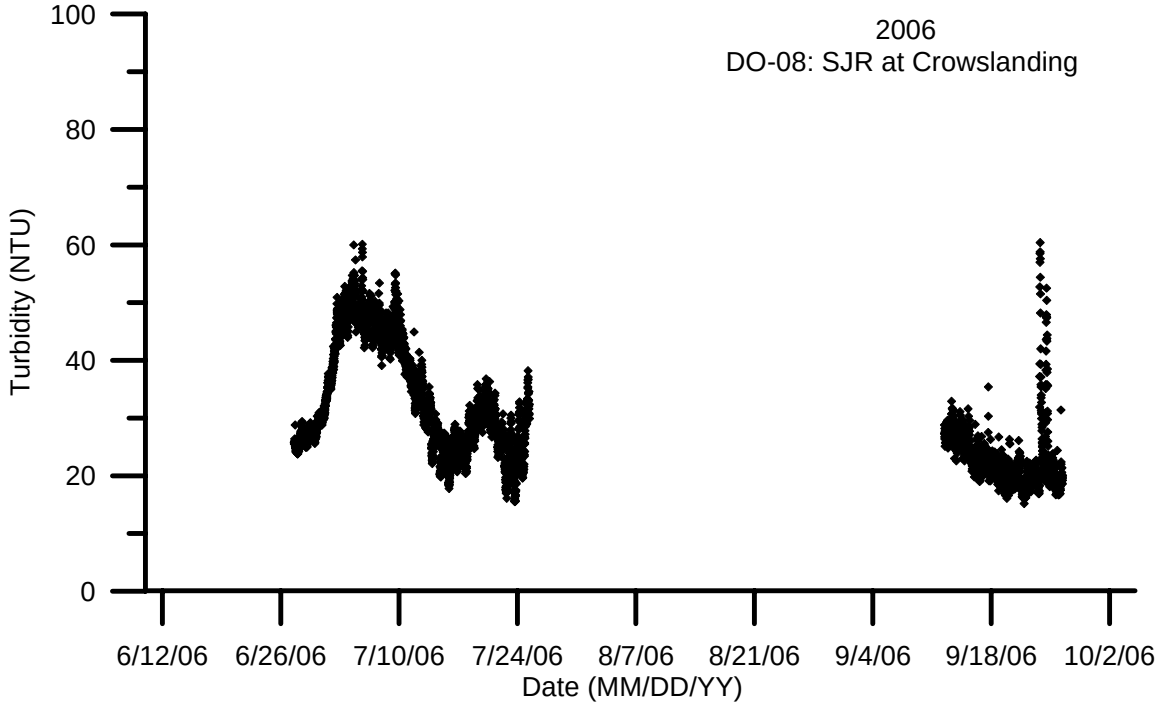


Figure 40: Turbidity 15 minute data at DO-08 for 2006 and 2007.



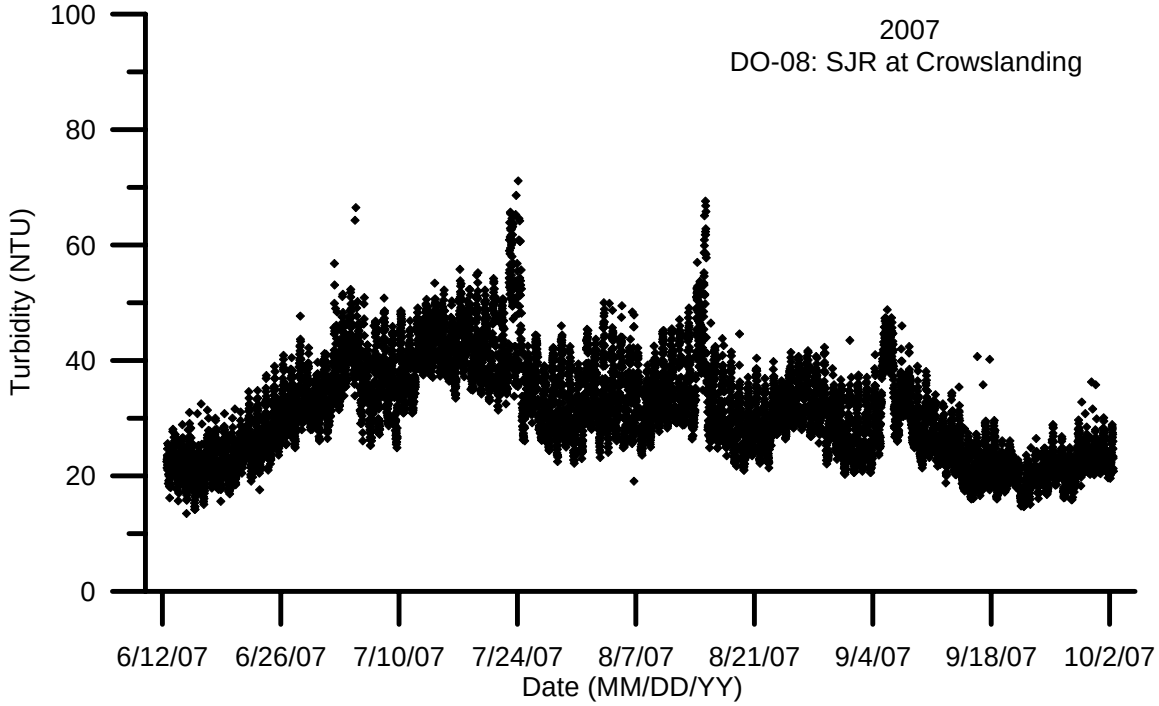
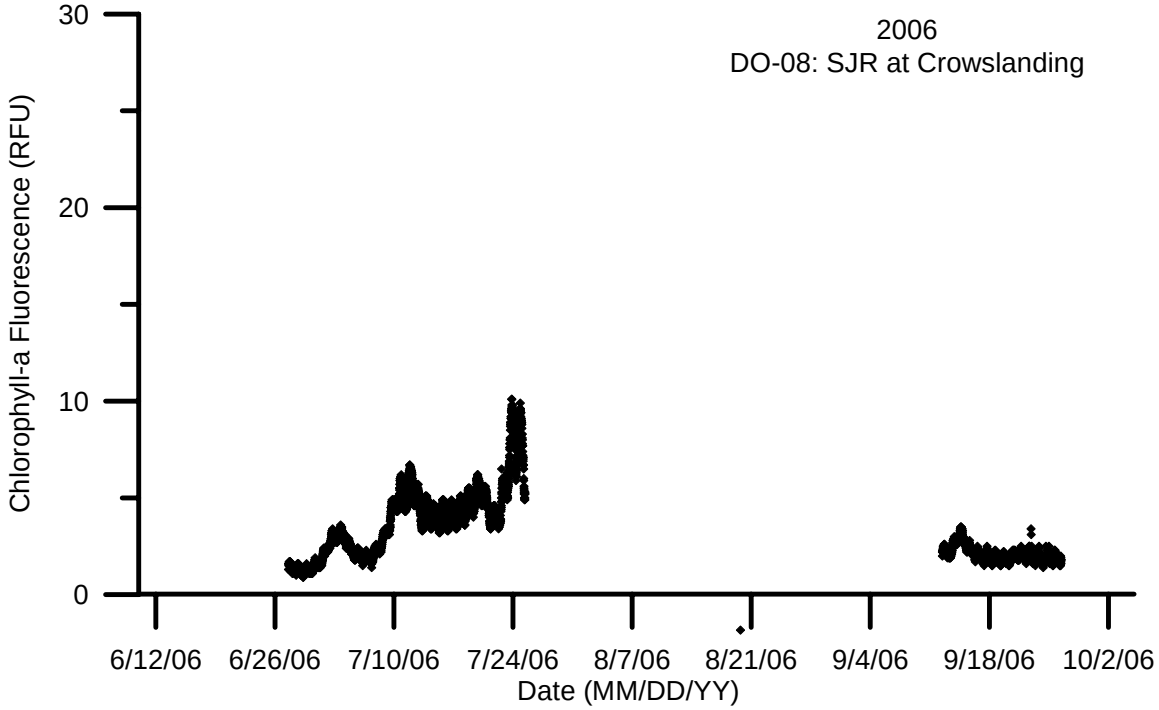


Figure 41: Chlorophyll-*a* fluorescence 15 minute data at DO-08 for 2006 and 2007.



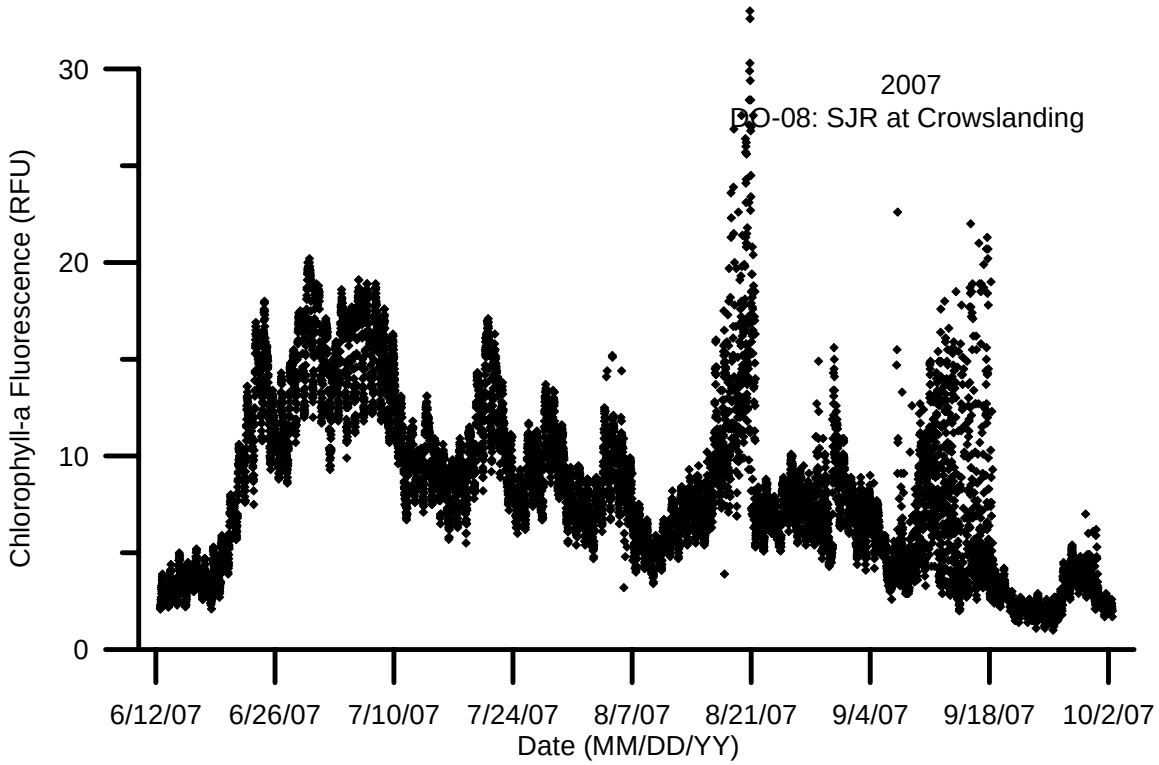
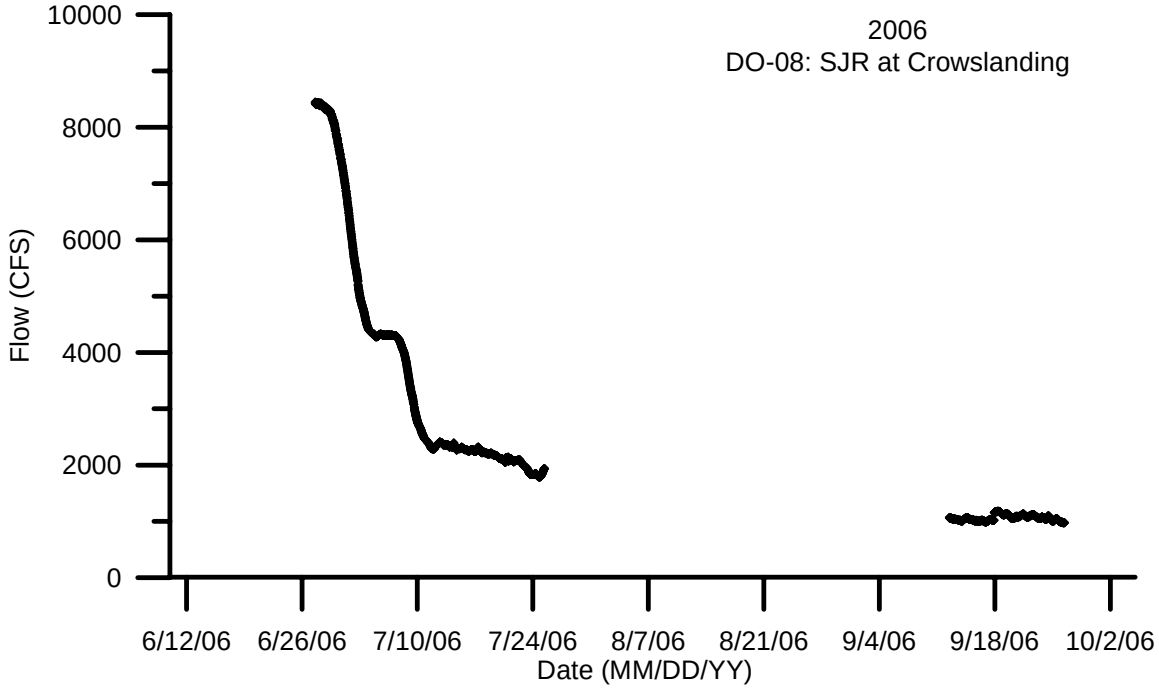


Figure 42: Flow 15 minute data at DO-08 for 2006 and 2007.



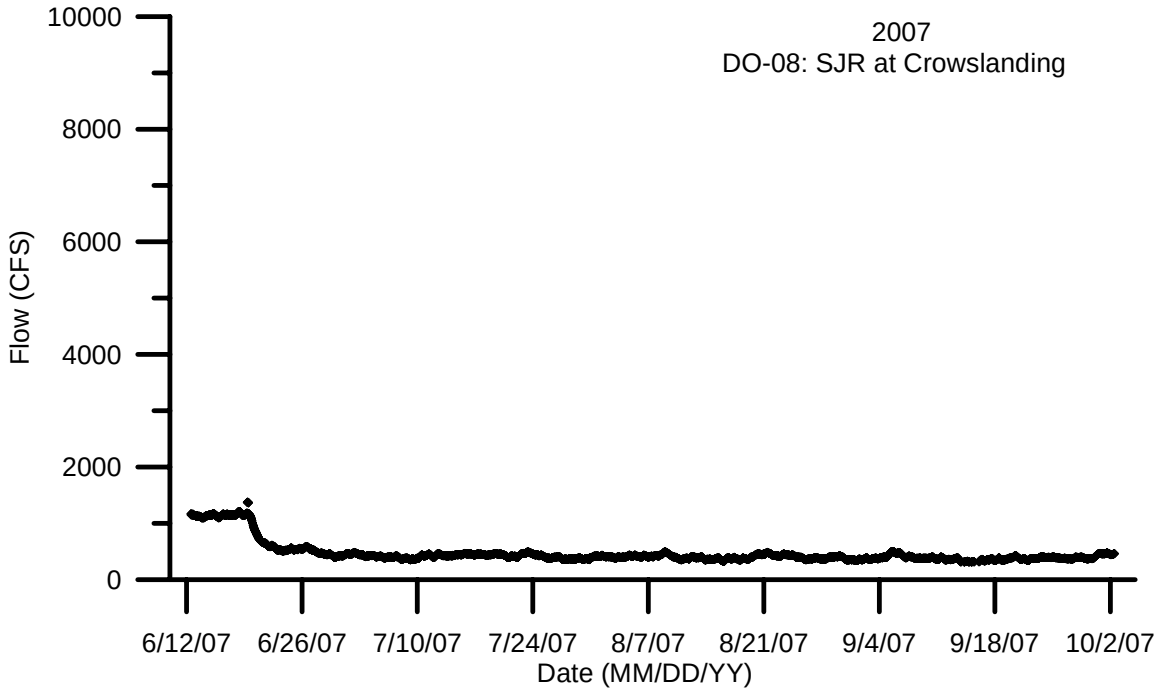


Figure 43: Water temperature 15 minute data at DO-10 for 2006 and 2007 (site not monitored in 2006).

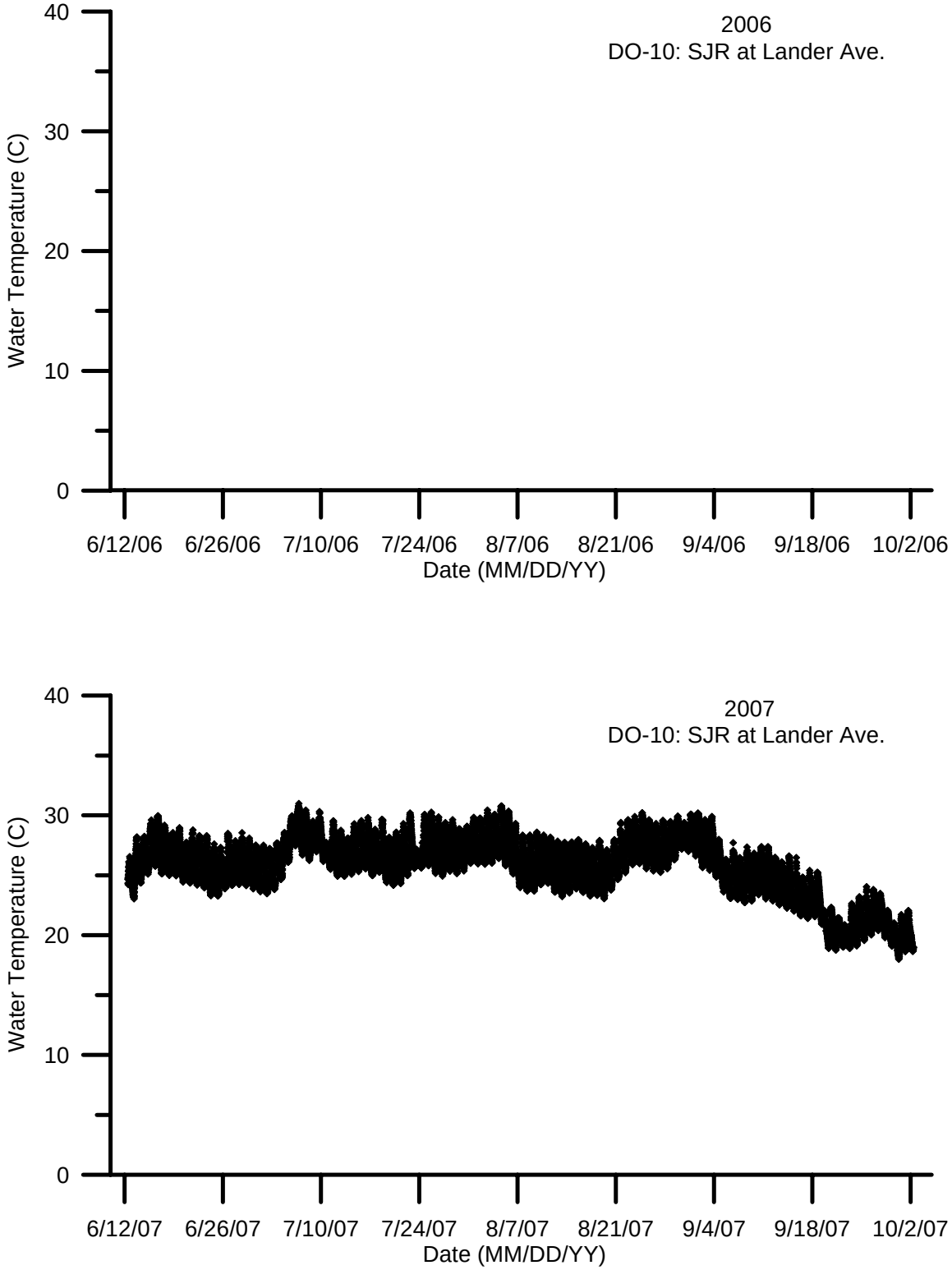
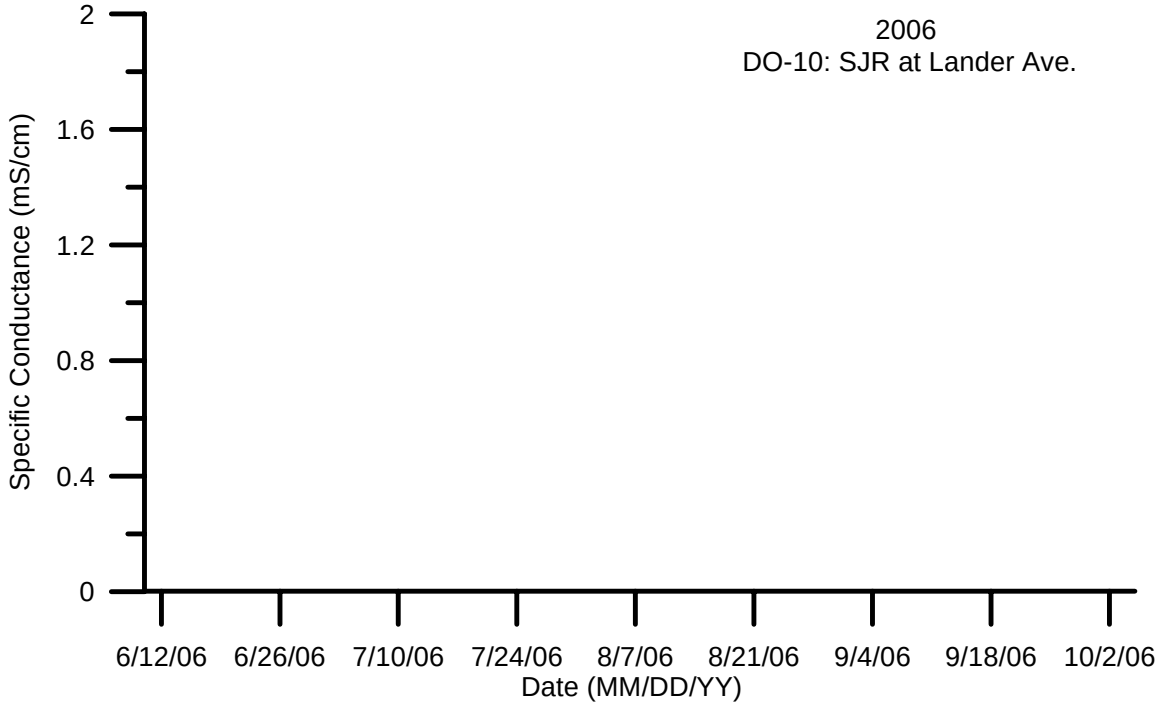


Figure 44: Specific conductance 15 minute data at DO-10 for 2006 and 2007 (site not monitored in 2006).



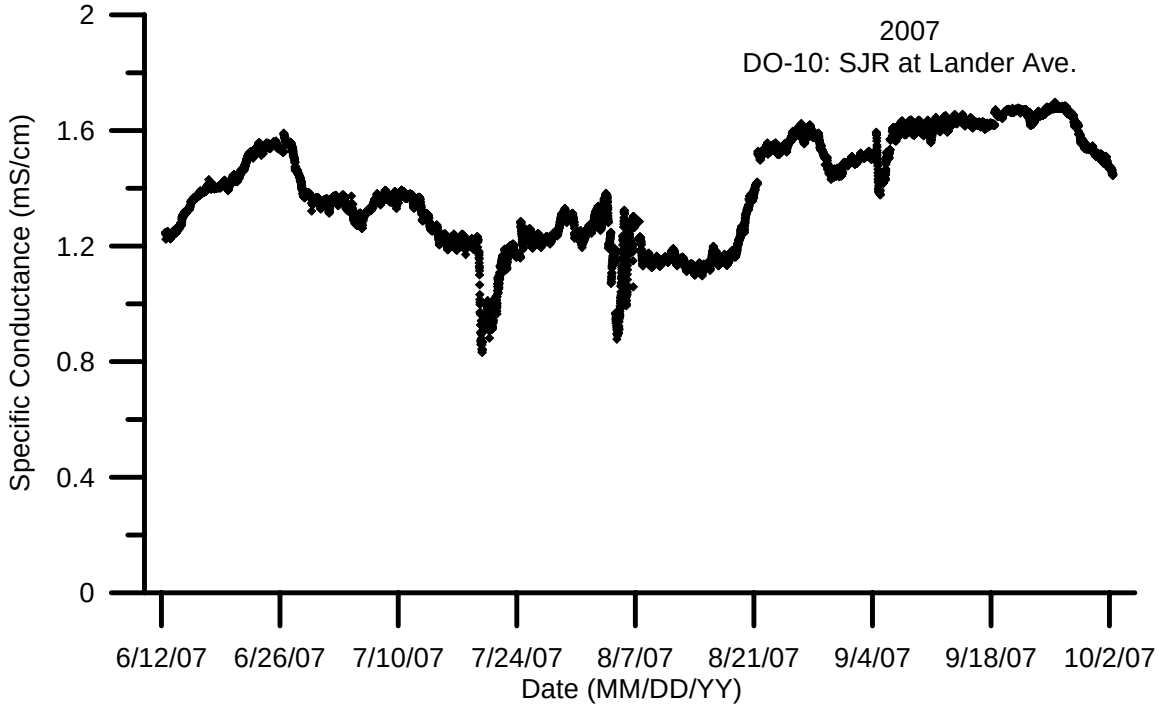


Figure 45: Dissolved oxygen concentration 15 minute data at DO-10 for 2006 and 2007 (site not monitored in 2006).

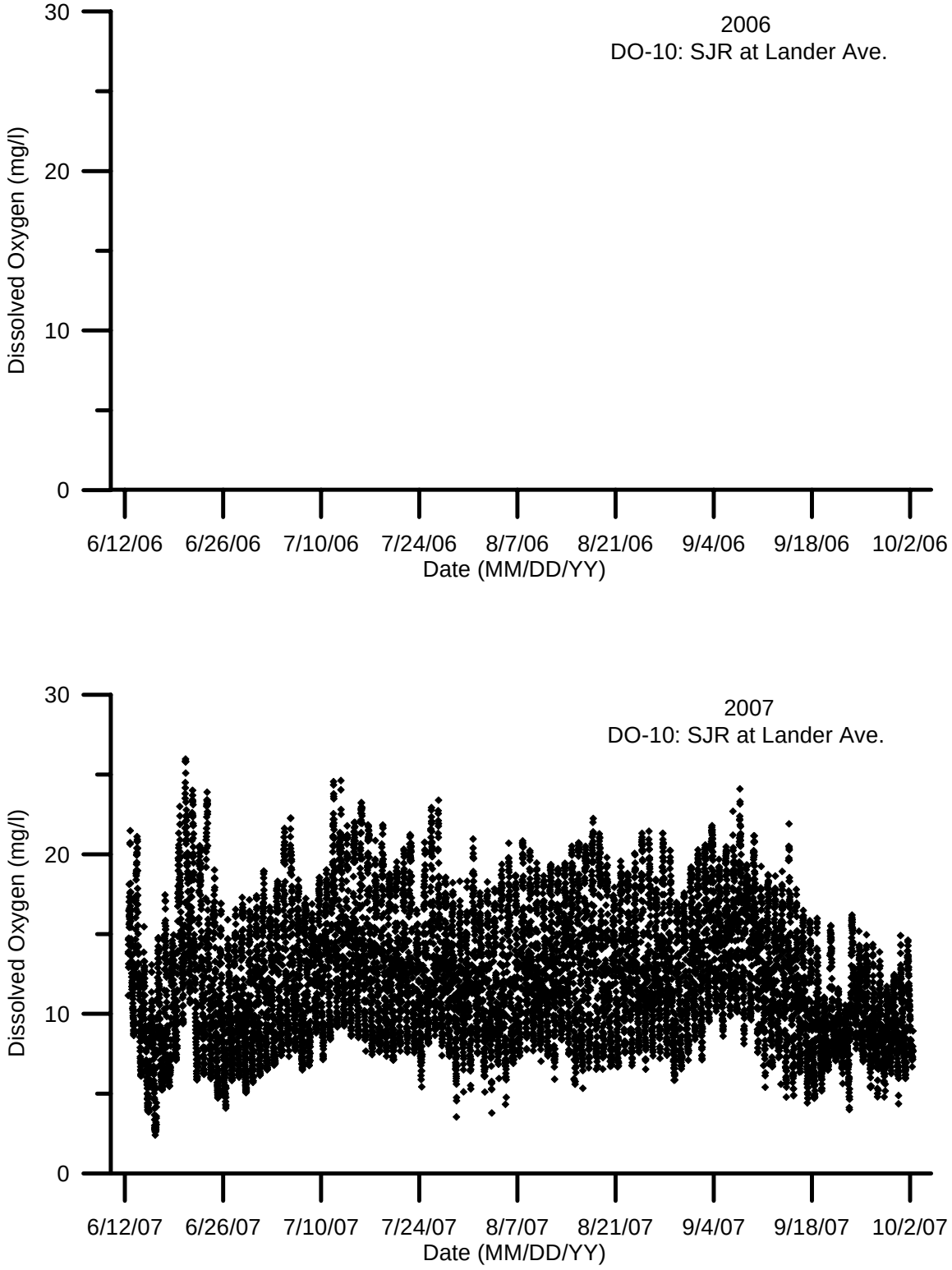
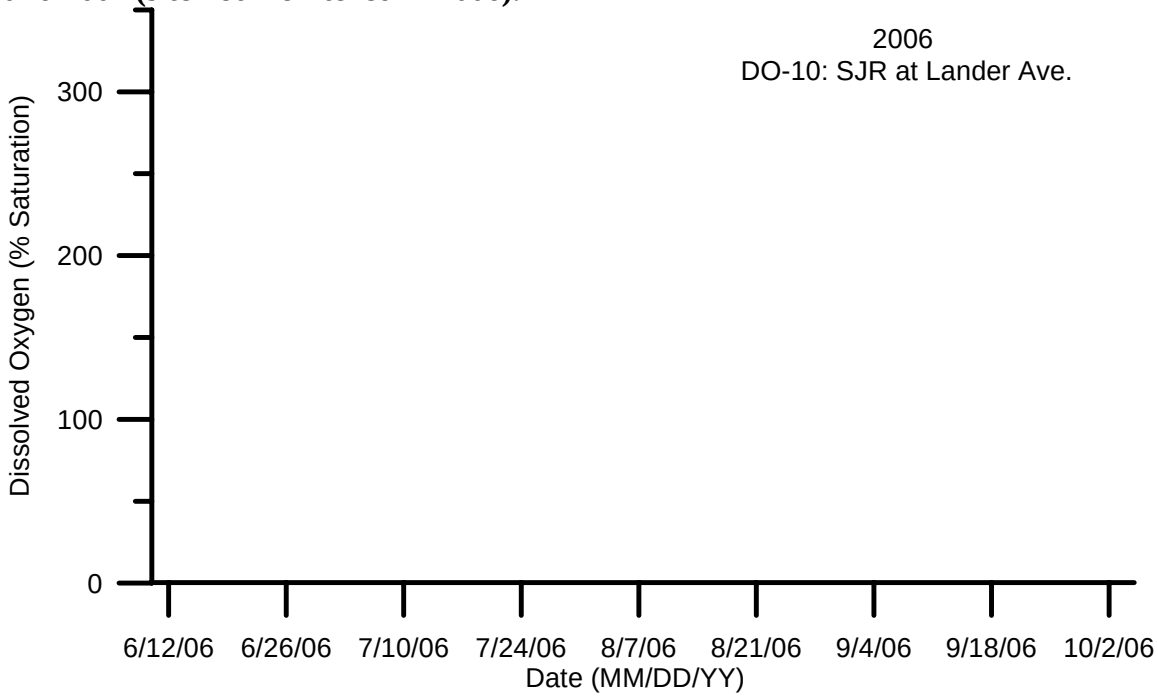


Figure 46: Dissolved oxygen percent of saturation 15 minute data at DO-10 for 2006 and 2007 (site not monitored in 2006).



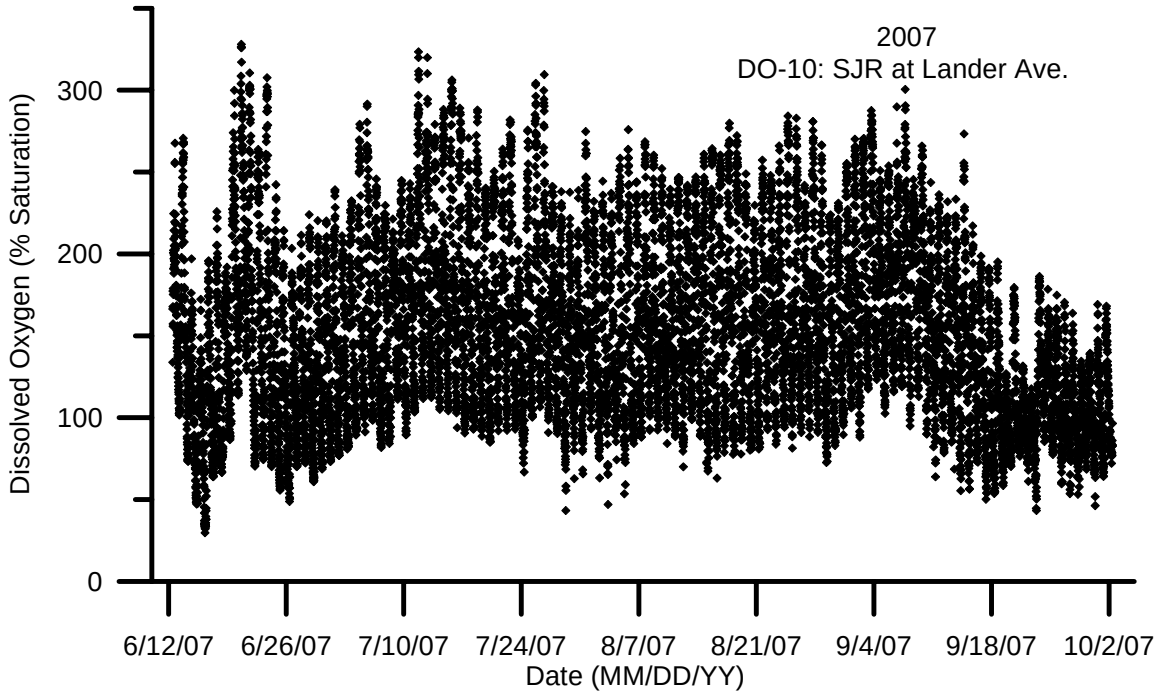
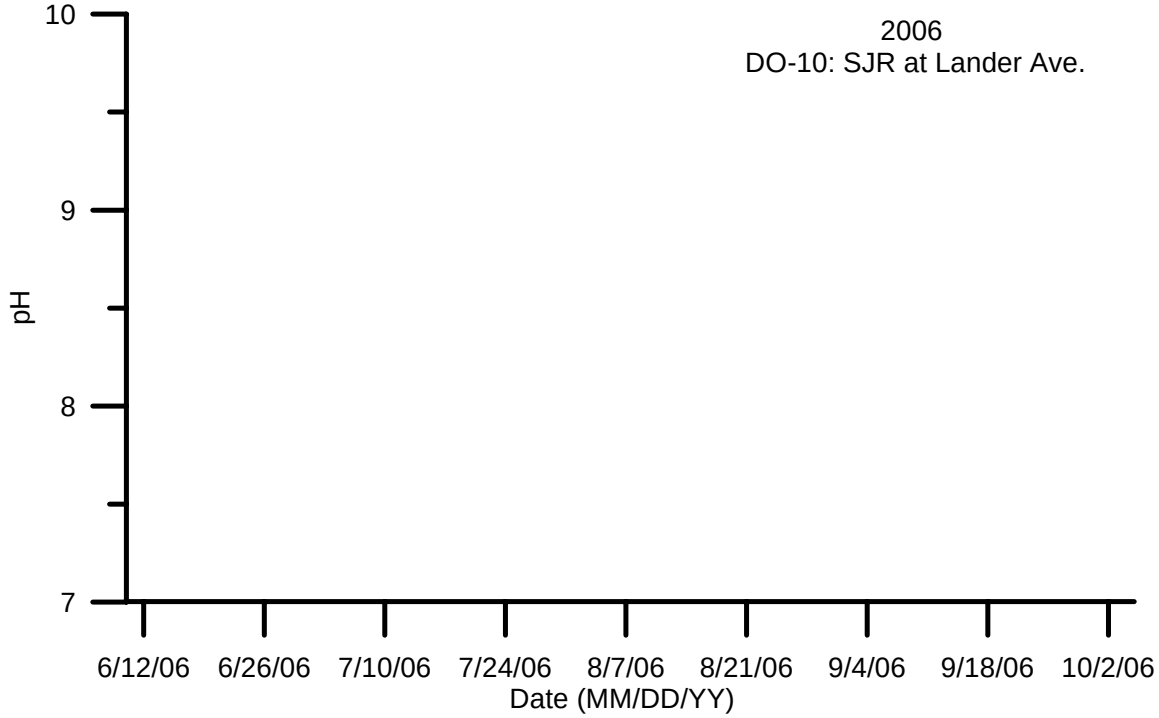


Figure 47: pH 15 minute data at DO-10 for 2006 and 2007 (site not monitored in 2006).



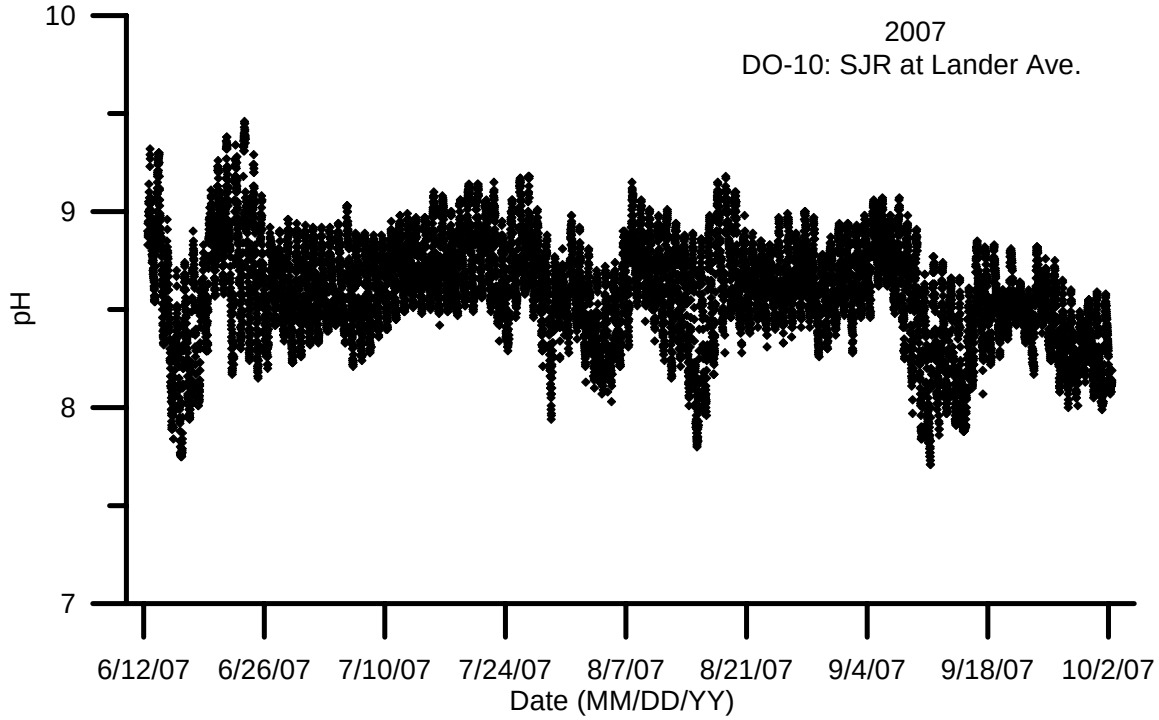


Figure 48: Turbidity 15 minute data at DO-10 for 2006 and 2007 (site not monitored in 2006).

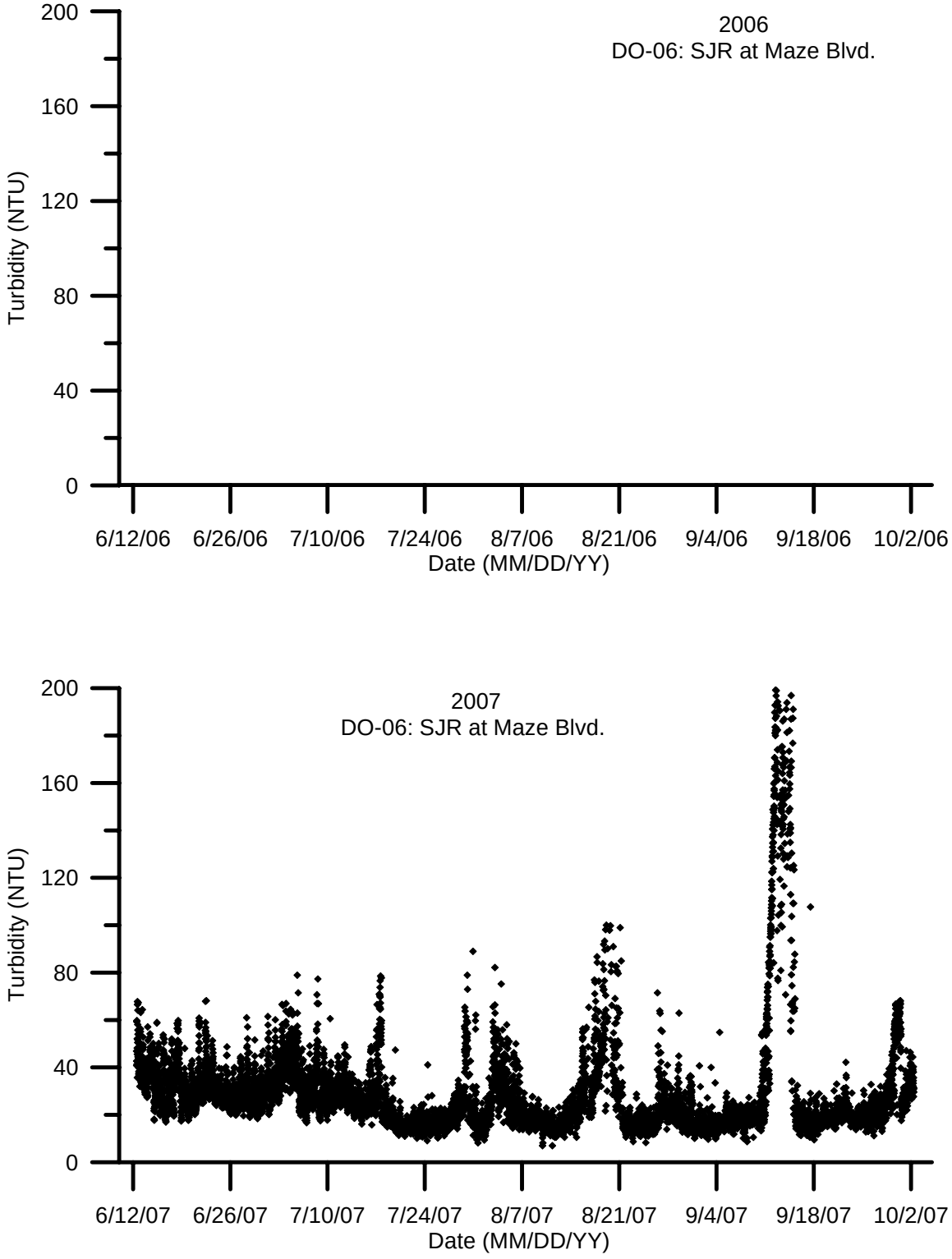
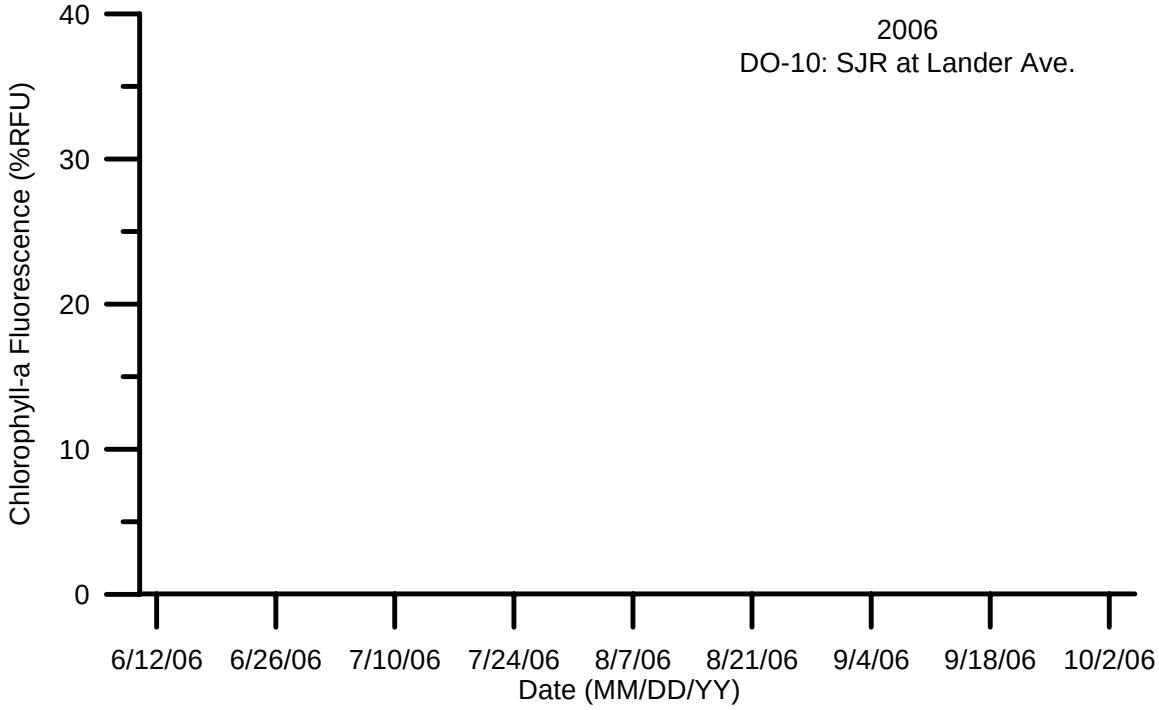


Figure 49: Chlorophyll-*a* fluorescence 15 minute data at DO-10 for 2006 and 2007 (site not monitored in 2006).



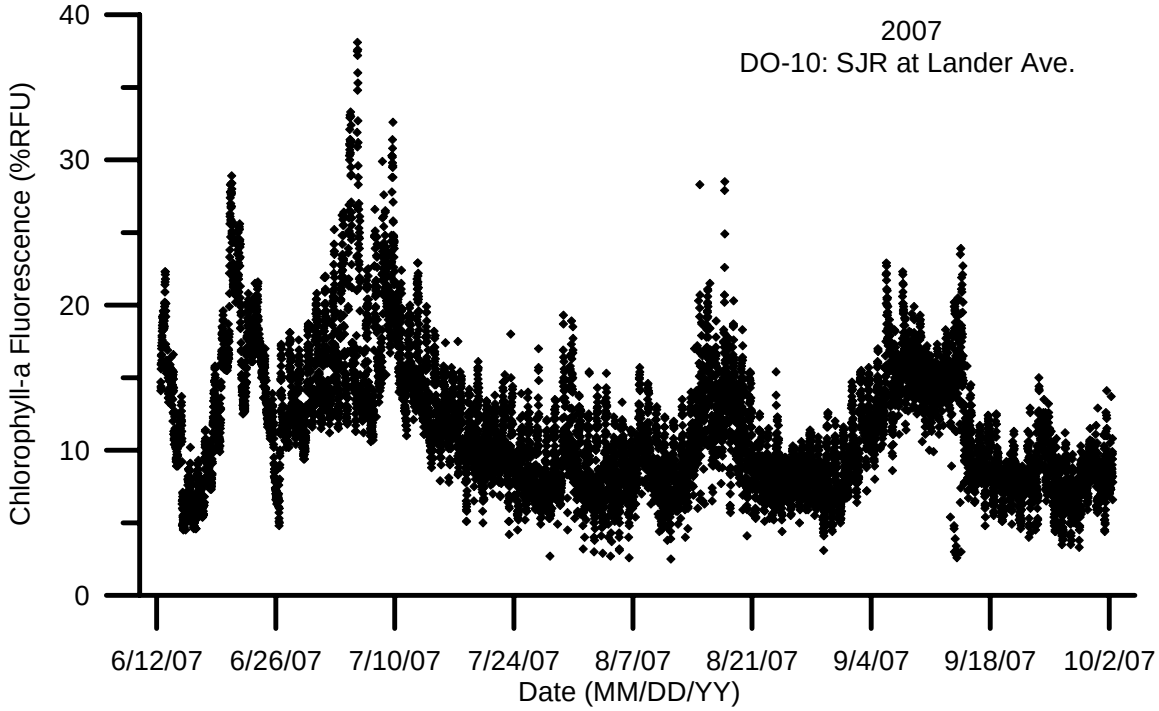


Figure 50: Flow 15 minute data at DO-10 for 2006 and 2007 (site not monitored in 2006).