Annual Report

2008 Annual Report on Performance of Iowa CREP Wetlands: Monitoring and Evaluation of Wetland Performance

William Crumpton
Associate Professor

Greg Stenback
Research Associate

David Green
Doctoral Student

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Iowa State University, Ames

Wetlands Monitoring and Evaluation

A unique aspect of the Iowa CREP is that nitrate reduction is not simply assumed based on wetland acres enrolled, but is calculated based on the measured performance of CREP wetlands. As an integral part of the Iowa CREP, a representative subset of wetlands (Figure 18) is monitored and mass balance analyses performed to document nitrate reduction. In addition to documenting wetland performance, this will allow continued refinement of modeling and analytical tools used in site selection, design, and management of CREP wetlands.

During 2008, eight wetlands were monitored for the Iowa CREP. These include BG, HS (north wetland), DJ, AL, RR, KS, DS, and VH wetlands. Flow was measured and autosampler composited daily samples were collected at all of these wetlands except RR Wetland. Weekly grab samples were collected at all of the monitored wetlands during 2008.

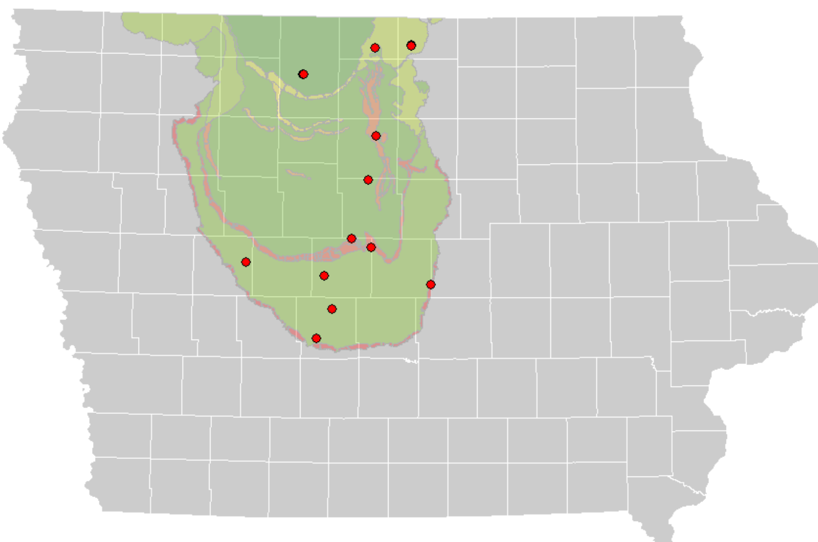

Figure 1. Wetlands monitored during 2004 to 2008.

For close interval monitoring of nitrate-nitrogen concentrations, wetlands were instrumented with automated samplers that collected daily composite water samples at wetland inflows and outflows. Grab samples were collected at an approximately weekly interval at inflow and outflow locations, and from within the wetland near the outflow location when there was no outflow. Selected wetland inflows and wetland outflows were instrumented with Doppler flow meters for continuous measurement of water depth and flow velocity. These were combined with channel profiles to calculate discharge. Wetland water levels were monitored continuously using stage recorders in order to calculate pool volume and discharge at outflow structures. Wetland water temperatures were recorded at five minute intervals for numerical modeling of nitrate loss rates.

By design, the wetlands selected for monitoring span the 0.5% - 2.0% wetland/watershed area ratio range approved for Iowa CREP wetlands. The wetlands also span a nearly five fold range in average inflow nitrate concentration (Table 19). The wetlands thus provide a broad spectrum of those factors most affecting wetland performance: hydraulic loading rate, residence time, nitrate concentration, and nitrate loading rate. Despite significant variation with respect to average nitrate concentrations and loading rates, the wetlands display similar seasonal patterns. Nitrate concentrations and mass loads are typically somewhat depressed during the winter, increase to their highest levels during high flow periods in spring and early summer, decline with declining flow in mid to late summer or fall, and may increase again if there is increased flow during late summer or fall. Winter wetland inflow concentrations are generally high, but somewhat lower than peak spring and summer concentrations (Figure 19). These nitrate concentration and flow patterns are representative of the patterns that are expected for future wetlands restored as part of the Iowa CREP.

Nitrate Loss from Wetlands

Mass balance analysis and modeling were used to calculate observed and predicted nitrate removal for wetlands where flow was measured. Inflow and outflow nitrate concentrations measured in wetlands are illustrated in Figure 19. In addition, Figure 19 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling with water budget, temperature, and nitrate concentration inputs and forcing functions.

Several equipment malfunctions and extreme flooding events resulted in loss of daily inflow water samples during some peak flow events at BG, DJ, KS, and VH wetlands during 2008. Because daily inflow nitrate concentrations are critical during peak flow events when a substantial portion of the total annual load may be delivered to the wetland, missing inflow concentrations during peak flow events were estimated so that the observed outflow concentration fell within or near the modeled outflow concentration range for that day. This generally resulted in low estimated inflow concentrations on peak flow days which is consistent with the expected dilution of nitrate associated with overland flow.

Table 1. Wetland flow-weighted average (FWA) nitrate concentration and percent nitrate removal.

Wetland ID	Year	Inflow FWA Nitrate-N (mg/L)	Outflow FWA nitrate-N (mg/L)	Percent nitrate removal
AL	2007	13.36	7.82	43.3
AL	2008	13.84	8.10	44.9
BG	2007	16.69	14.97	10.7
BG	2008	8.58	8.01	6.9
DJ	2007	10.50	8.59	19.8
DJ	2008	10.37	8.85	16.3
DS	2008	8.45	4.34	54.2
HM	2006	11.78	2.52	78.5
HS	2007	6.20	0.73	91.8
HS	2008	5.21	0.79	86.8
JR	2007	12.97	9.46	29.2
KS	2008	11.90	9.81	18.2
ND	2007	15.66	12.53	21.1
TI	2006	11.85	8.91	25.0
UML	2004	3.53	2.48	29.7
VH	2004	18.10	5.75	68.2
VH	2007	15.76	7.32	63.6
VH	2008	10.73	3.77	68.5

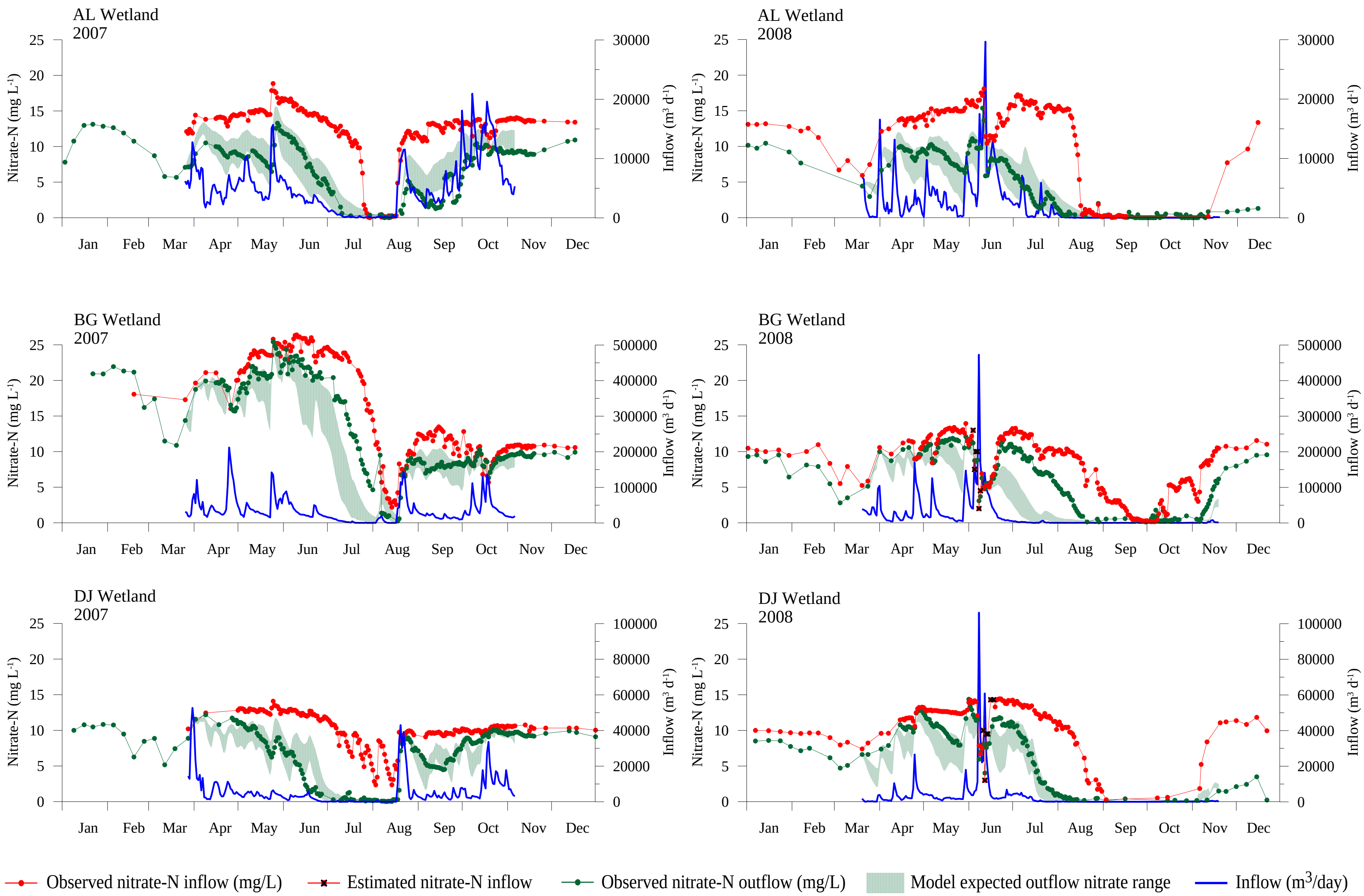

Figure 2. Measured and modeled nitrate concentrations and flows for selected wetlands monitored.

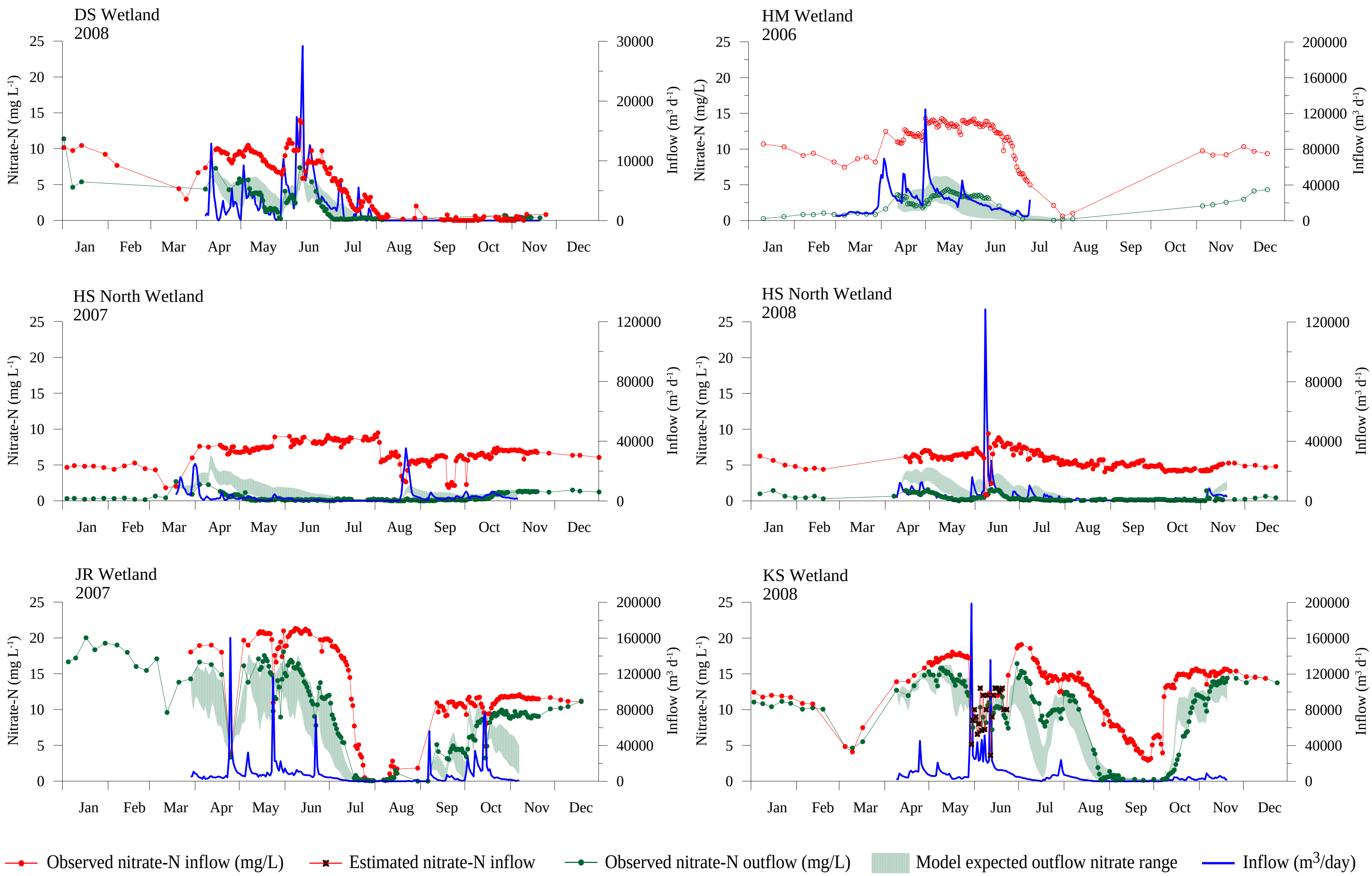

Figure 19 (continued). Measured and modeled nitrate concentrations and flows for selected wetlands monitored.

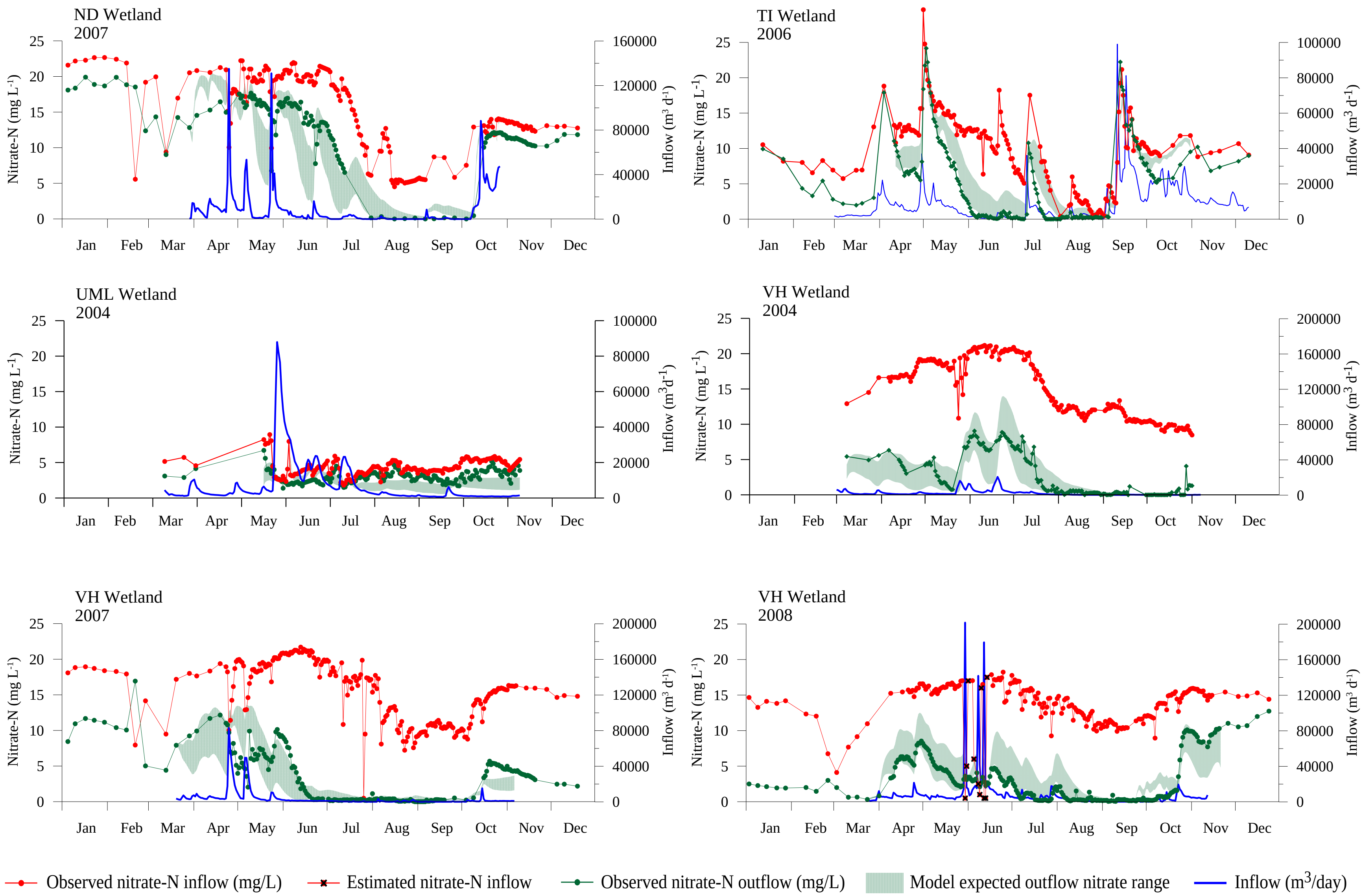

Figure 19 (continued). Measured and modeled nitrate concentrations and flows for selected wetlands monitored.

The monitored wetlands performed as expected with respect to nitrate removal efficiency (expressed as percent removal) and mass nitrate removal (expressed as Kg N ha^{-1} $year^{-1}$). Wetland performance is a function of hydraulic loading rate, hydraulic efficiency, nitrate concentration, temperature, and wetland condition. Of these, hydraulic loading rate and nitrate concentration are especially important for CREP wetlands. The range in hydraulic loading rates expected for CREP wetlands is significantly greater than would be expected based on just the four fold range in wetland/watershed area ratio approved for the Iowa CREP. In addition to spatial variation in precipitation (average precipitation declines from southeast to northwest across Iowa), there is tremendous annual variation in precipitation. The combined effect of these factors means that loading rates to CREP wetlands can be expected to vary by more than an order of magnitude, and will to a large extent determine nitrate loss rates for individual wetlands.

Mass balance modeling was used to estimate the variability in performance of CREP wetlands that would be expected due to spatial and temporal variability in temperature and precipitation patterns. The percent nitrate removal expected for CREP wetlands was estimated based on hindcast modeling over the 25 year period from 1980 through 2005 (Figure 3). For comparison, percent nitrate removal measured for wetlands monitored during 2004 to 2008 are also presented and illustrate reasonably good correspondence between observed and modeled performance. Due to factors including excess overland flow entering wetlands during a flood event, debris accumulation at outflow structures, and poor reconciliation of inflow and outflow measures, hydraulic loading rates could not be estimated with sufficient precision for several wetlands monitored during 2007 and 2008. Those wetlands for which the hydraulic loading rates could not be reliably determined were not included in Figure 19. Several of the 2007 and 2008 results show hydraulic loading rates greater than anticipated due to an unusually wet late summer and fall during 2007 and June of 2008. Percent nitrate removal is clearly a function of hydraulic loading rate (Figure 3).

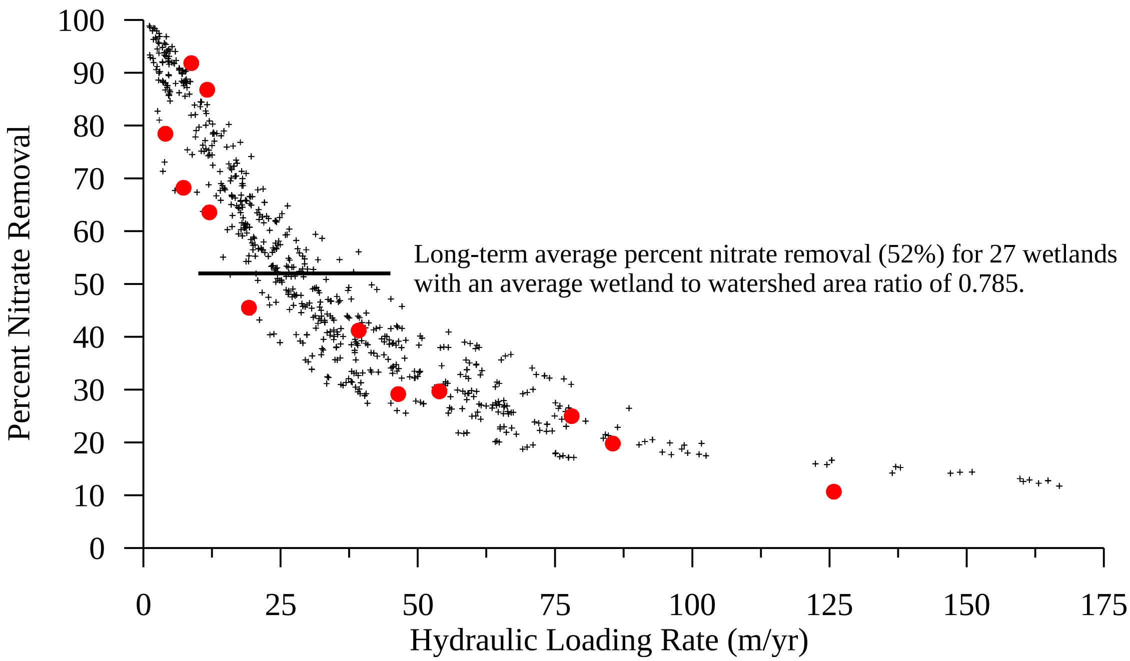

Figure 3. Modeled and observed nitrate removal efficiencies for CREP qualifying wetlands versus Hydraulic Loading Rate based on 1980 through 2005 input conditions.

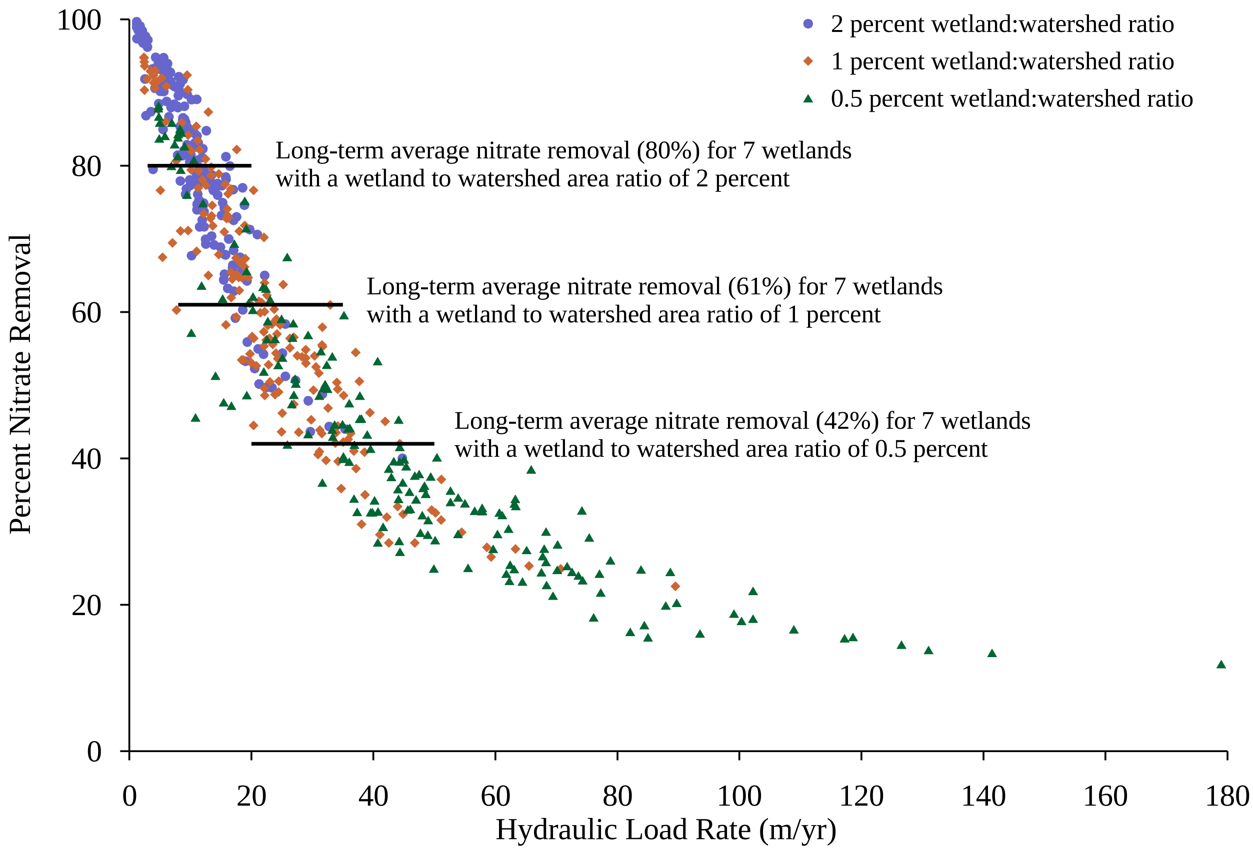

Figure 4. Modeled nitrate removal efficiencies for hypothetical wetlands evaluated at three wetland to watershed ratios, based on 1980 through 2005 input conditions.

Mass nitrate removal rates can vary considerably more than percent nitrate removal among wetlands receiving similar hydraulic loading rates. However, mass removal rates are predictable using models that integrate the effects of hydraulic loading rates, nitrate concentration, temperature, and wetland condition. Of particular interest in assessing the factors that affect potential long-term nitrate removal performance is evaluation of the role of wetland size in relation to the size of the encompassing watershed. Wetlands with relatively larger wetland to watershed ratios are expected to exhibit greater long-term nitrate removal performance than wetlands possessing lower ratios (0.5 to 2.0 percent representing the approved range of wetland to watershed area ratio for Iowa CREP wetlands). To evaluate the influence of wetland to watershed area ratio on long-term nitrate removal performance, we developed a set of 21 hydrological and nutrient mass balance simulation models for 7 hypothetical wetlands. Each wetland was evaluated with wetland to watershed area percentages of 2.0, 1.0, and 0.5. Inflow data were obtained from a set of 7 USGS stream gages, each representing inflow to a unique wetland, for the period of simulation spanning 1980 through 2005. Corresponding meteorological and temperature data were obtained from NWS weather stations nearest to the aforementioned stream gages. Each model was run with a constant inflow nitrate concentration equal to 14.3 mg NL^{-1}. Simulation results indicate that wetland to watershed ratio can exert profound influence on the expected long-term removal performance of constructed wetlands (Figure 21). Larger wetland to watershed ratios will promote significantly greater removal performance by reducing long-term hydraulic loading rates. Lower ratios, as illustrated in Figure

21, will produce significantly reduced removal performances and consistently higher hydraulic loading rates.

Crumpton et al. (2006) developed and applied a model that explicitly incorporates hydraulic loading rate, nitrate concentration, and temperature to predict performance of US Corn Belt wetlands receiving nonpoint source nitrate loads. This analysis included comparisons for 31 "wetland years" of available data (13 wetlands with 1-9 years of data each) for sites in Ohio, Illinois, and Iowa, including four IA CREP wetlands. The analysis demonstrated that the performance of wetlands representing a broad range of loading and loss rates can be reconciled by models explicitly incorporating hydraulic loading rates and nitrate concentrations (Crumpton et al., 2006). This model was updated to include the 2004 to 2008 Iowa CREP wetlands and exclude wetlands smaller than the 2.5 acre minimum size required by Iowa CREP criteria. The updated model (Figure 22) accounts for 88 percent of the observed variation in mass nitrate removed for the 33 wetland cases considered. The x-axis in Figure 22 is clipped to HLR <100 m/year, which excluded the 2007 BG wetland (HLR = 126 m/yr).

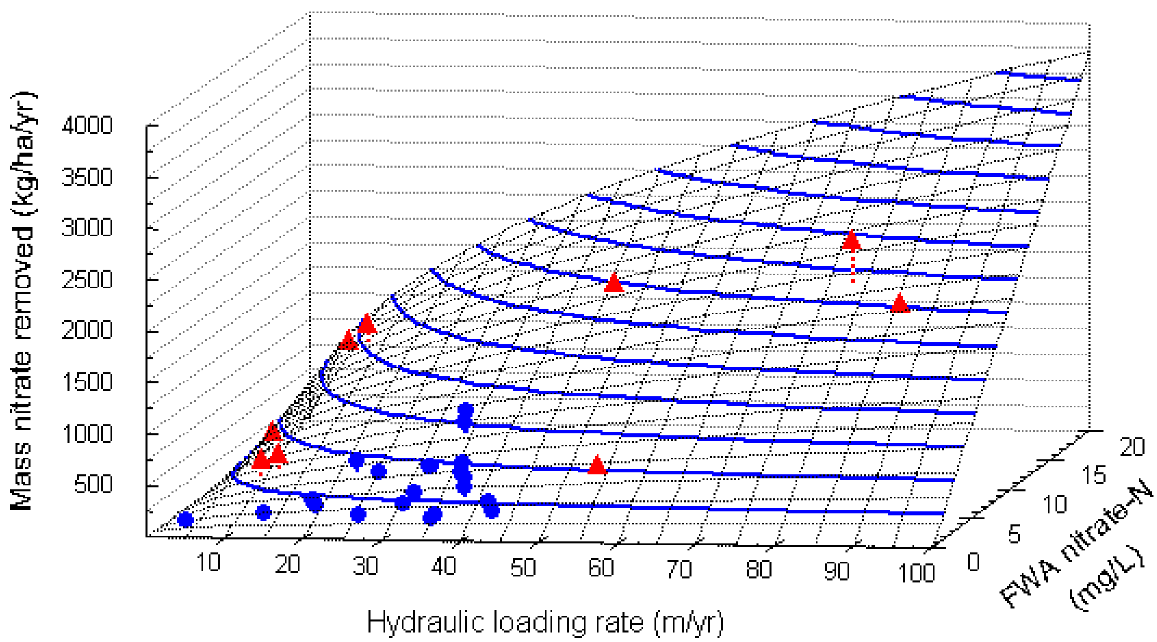

Figure 5. Observed nitrate mass removal includes Corn Belt wetlands representing 31 "wetland years" of data shown (adapted from Crumpton et al., (2006)). CREP and other Iowa wetland sites are shown as red triangles. Published results for Ohio and Illinois wetlands shown as blue circles.

References

Crumpton, W.G., G.A Stenback, B.A. Miller, and M.J. Helmers. 2006. Potential benefits of wetland filters for tile drainage systems: Impact on nitrate loads to Mississippi River subbasins. US Department of Agriculture, CSREES project completion report. Washington, D.C. USDA CSREES.