Annual Report

2007 Annual Report on Performance of Iowa CREP Wetlands: Monitoring and Evaluation of Wetland Performance

William Crumpton
Associate Professor

Greg Stenback
Research Associate

January 1, 2007 – December 31, 2007

Submitted to
Iowa Department of Agriculture and Land Stewardship

Submitted by
Department of Ecology, Evolution and Organismal Biology
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 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 2007, ten wetlands were monitored for the Iowa CREP (Figure 1). These include ND, BG, HS, DJ, AL, JR, RR, TI, KS, and VH wetlands. Flow was measured at all of these wetlands except RR and autosampler composited daily samples were collected at all except RR, KS, and TI Wetlands. Weekly grab samples were collected at all of the monitored wetlands during 2007.

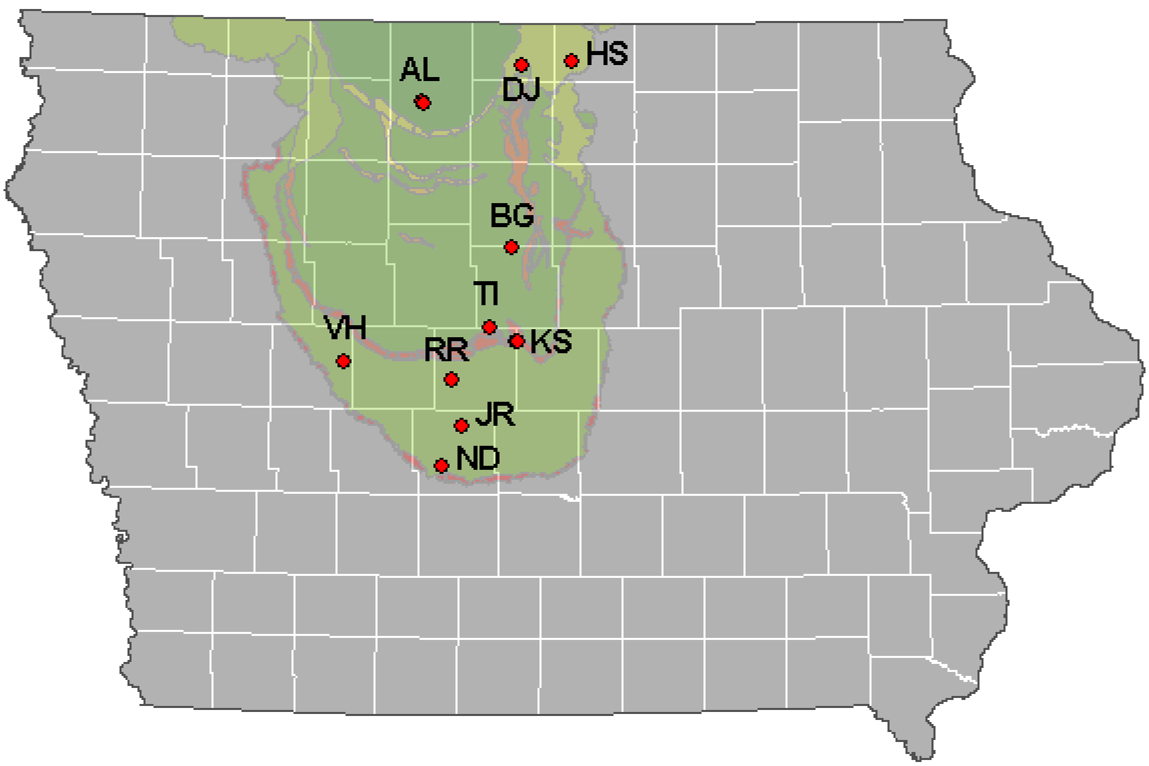

Figure 1. Wetlands monitored during 2007.

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. Eight wetland inflows and four 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 bathymetry was digitized allowing development of mathematical equations to model pool area and volume as functions of wetland depth at six wetlands. Wetland water temperatures were recorded continuously 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 2-3 fold range in average nitrate concentration. 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 late winter, increase to their highest levels during high flow periods in spring and early summer, decline with declining flow in mid to late summer, and may increase again if there is increased flow during late summer or fall. 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 2007 at DJ, AL, and JR Wetlands are illustrated in Figure 2. In addition, Figure 2 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling with 2007 water budget, temperature, and nitrate concentration inputs and forcing functions.

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.

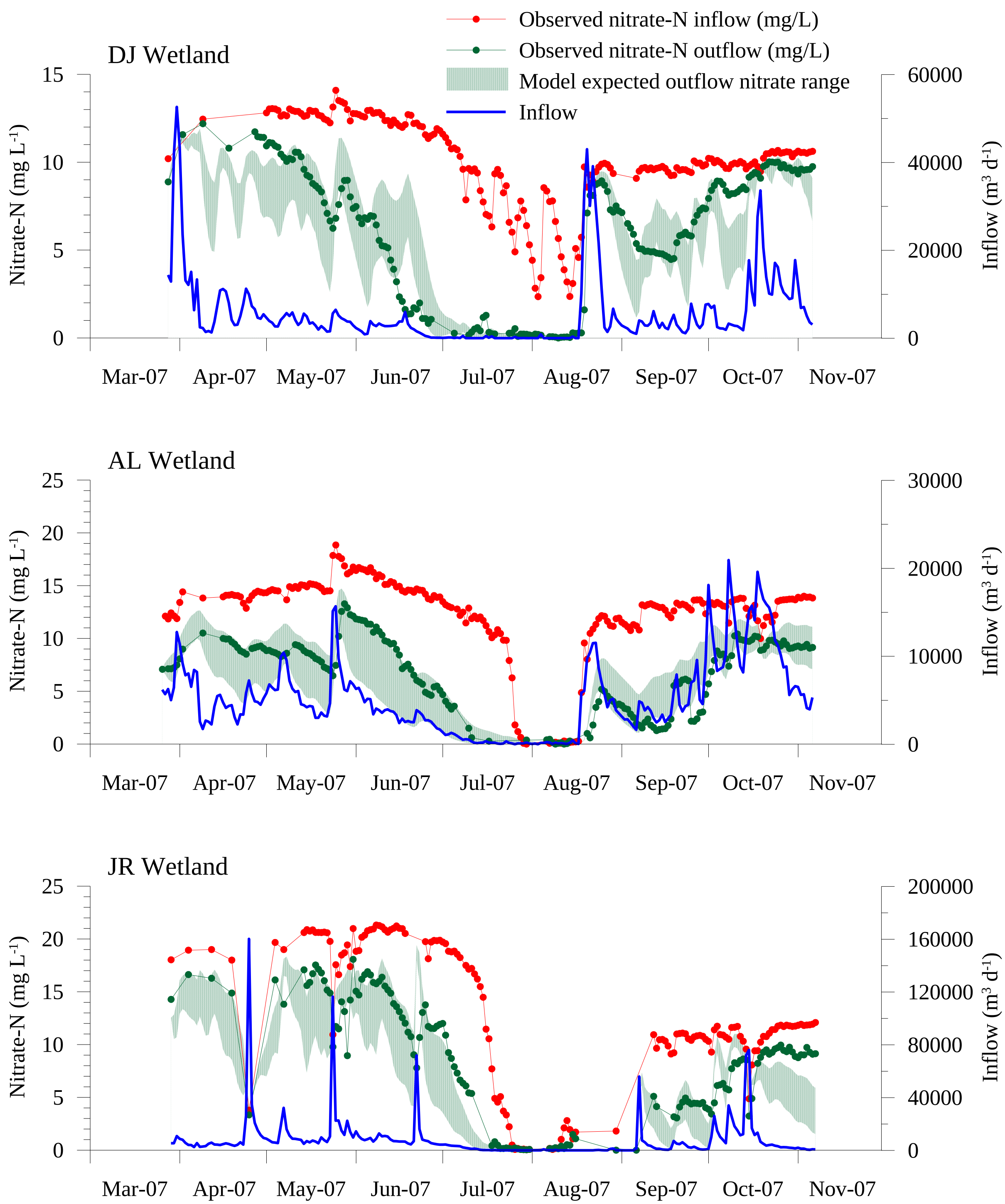

Figure 2. Measured and modeled nitrate concentrations and flows for selected wetlands monitored during 2007.

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 10 year period from 1996 through 2005 (Figure 3). For comparison, percent nitrate removal measured for wetlands monitored during 2007 is also presented and illustrates reasonably good correspondence between observed and modeled performance. Several of the 2007 results show hydraulic loading rates greater than anticipated due to an unusually wet late summer and fall during 2007. Percent nitrate removal is clearly a function of hydraulic loading rate (Figure 3).

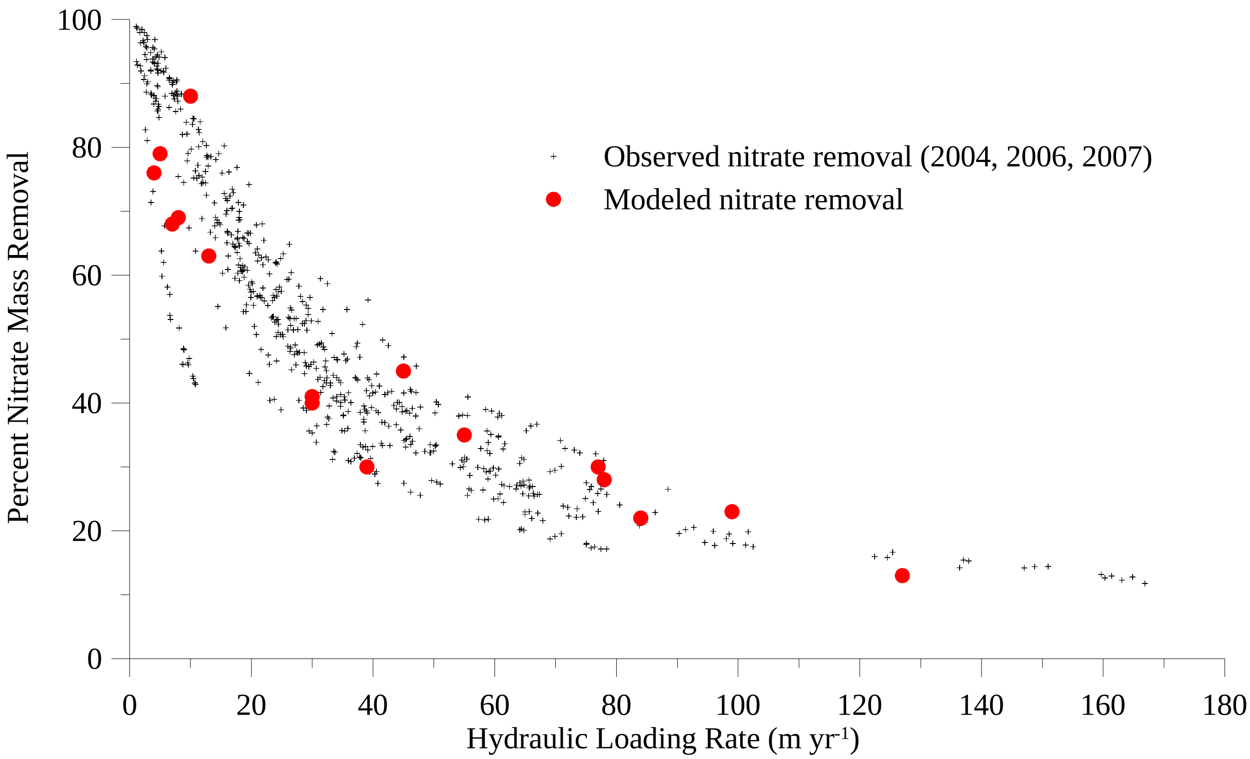

Figure 3. Modeled and observed nitrate removal efficiencies for CREP qualifying wetlands versus Hydraulic Loading Rate based on 1980 to 2005 input conditions.

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. 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 38 “wetland years” of available data (12 wetlands with 1-9 years of data each) for sites in Ohio, Illinois, and Iowa, including four IA CREP wetlands (2 low load and 2 high load sites). 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 2007 Iowa CREP sites and exclude wetlands smaller than the 2.5 acre minimum size required by Iowa CREP criteria. The updated model (Figure 4) accounts for 91 percent of the observed variation in mass nitrate removed for all of the wetland sites considered.

(The axes in Figure 4 are clipped to HLR <100 m/year and FWA <20 mg/L, which excluded one wetland.)

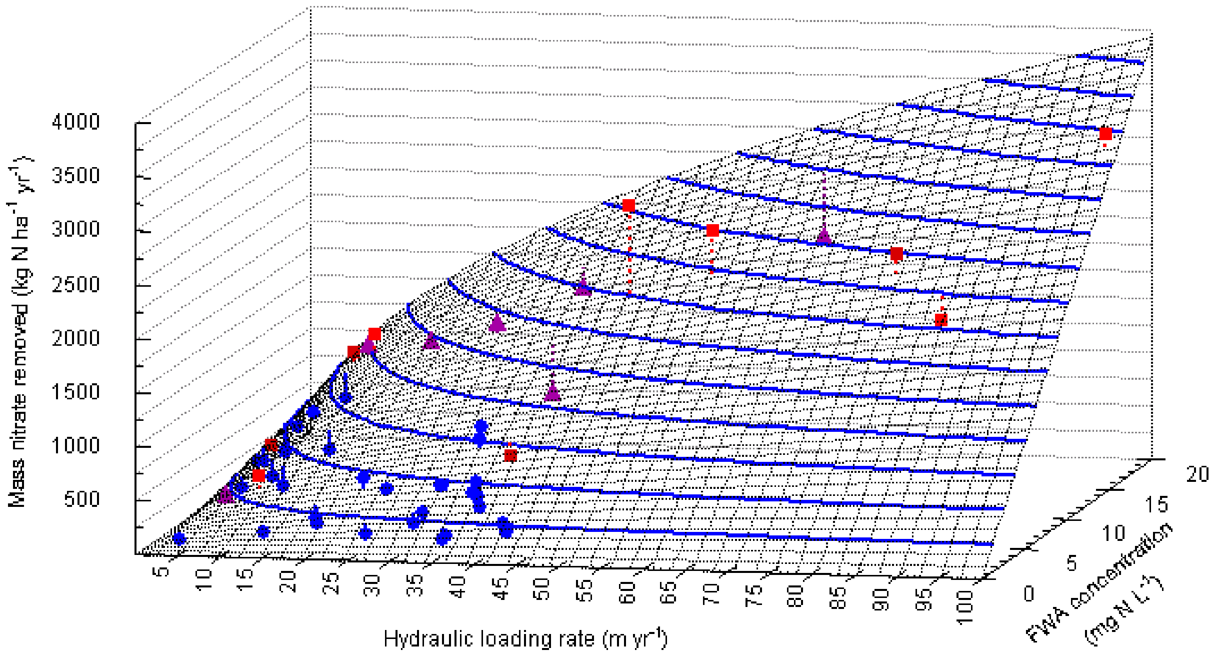

Figure 4. Observed nitrate mass removal includes eight Corn Belt wetlands representing 24 “wetland years” of data shown as blue circles (adapted from Crumpton et al. (2006)). 2007 CREP sites are shown as red squares (BG wetland not shown). Because the fall of 2007 was much wetter than normal resulting in unusually high hydraulic loading, the 2007 CREP wetland growing season (April through August) results are also shown (purple triangles).

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.