Annual Report

# 2014 Annual Report on Performance of Iowa CREP Wetlands: Monitoring and Evaluation of Wetland Performance


William Crumpton
Professor

Greg Stenback
Associate Scientist


January 1, 2014 – December 31, 2014

Submitted to
Iowa Department of Agriculture and Land Stewardship


Submitted by
Department of Ecology, Evolution and Organismal Biology
Iowa State University, Ames

## 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. By design, the wetlands selected for monitoring span the 0.5% to 2.0% wetland/watershed area ratio range approved for Iowa CREP wetlands. The wetlands also span a 2 to 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. In addition to documenting wetland performance, ongoing monitoring and research programs will allow continued refinement of modeling and analytical tools used in site selection, design, and management of CREP wetlands.

## Summary of 2014 Monitoring

Monitoring activities were conducted at 16 Iowa CREP wetlands and one mitigation wetland (DD15 north) during 2014 (Figure 1). Wetland monitoring included wetland inflow and/or outflow discharge, wetland pool elevation and water temperature measurements, and collection of weekly grab samples and daily composite water samples. Daily composite samples were collected using automated samplers programmed to collect and composite four six-hour subsamples at wetland inflows and outflows when temperatures were sufficiently above freezing to allow the equipment to function properly. The LP, DD8, DD15S, DD15N, DD178 and DD48-81 wetlands were drawn down approximately 0.5-1.5 feet below full pool to help establish vegetation in the shallow portions of the wetland pools. The inflows to five of the monitored wetlands (DD8, DD48, DD81, DD178, DD65, and DD15N) are part of the Pilot Project to monitor phosphorus and nitrogen nutrient yields from the catchment area landscape. The expected outflow from the MS wetland in Floyd County was altered when the landowner removed several stoplogs sometime during late June or early July. According to the landowner, the MS wetland stoplogs were reinstalled on September 1, 2014.

Wetland inflow and/or outflow stations were instrumented with submerged area velocity (SAV) Doppler flow meters and stage recorders for continuous measurement of flow velocity and stream depth, respectively. The SAV measurements were combined with cross-sectional channel profiles and stream depth to calculate discharge as the product of water velocity and wetted cross-sectional area. Wetland water levels were monitored continuously using stage recorders in order to calculate pool volume, wetland area, and discharge at outflow structures. The pool discharge equations and SAV based discharge measurements were calibrated using manual velocity-area based discharge measurements collected during 2014 and prior monitoring years. Manual velocity-area discharge measurements were determined using the mid-section method whereby the stream depth is determined at 10 cm intervals across the stream and the water velocity is measured at the midpoint of each interval. Velocity was measured with a hand held Sontek Doppler water velocity probe using the 0.6 depth method where the velocity at 0.6 of the depth from the surface is taken as the mean velocity for the interval. The product of the interval velocity and area is summed over intervals to give the total discharge.

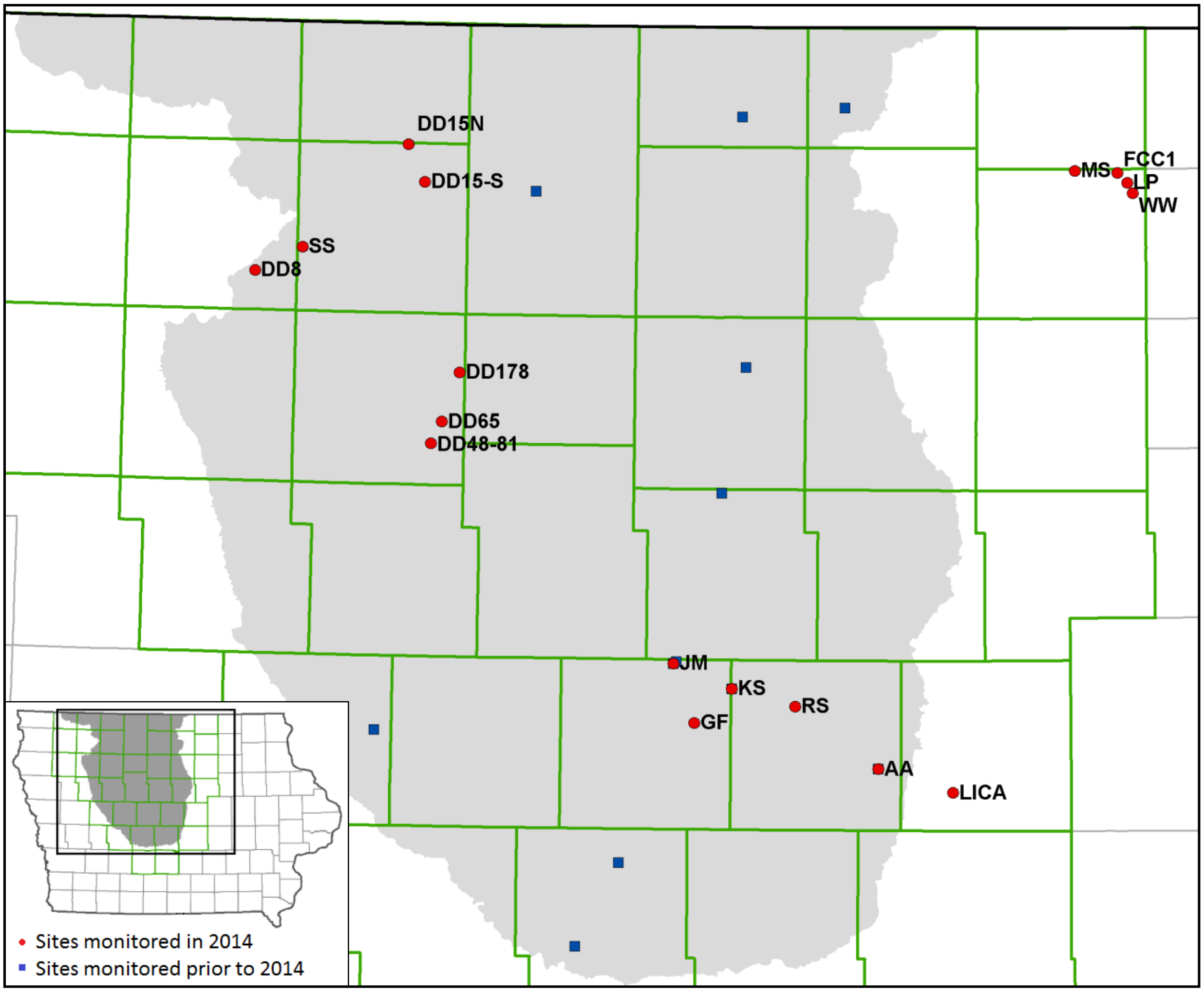


Figure 1. Wetlands monitored during 2014 (red circles, labeled) and wetlands monitored during prior years (blue squares). The shaded area represents the Des Moines Lobe in Iowa.

*Patterns in Nitrate Concentrations and Loads*

Despite significant variation with respect to nitrate concentration and loading rates, the wetlands display similar seasonal patterns and general relationships to varying discharge. Historically, nitrate concentrations are generally at moderate levels during the winter and discharge is low. Spring snow-melt often results in increased flow during late February or March but nitrate concentrations in the melt water and associated surface runoff are typically low to moderate. During 2014, nitrate concentrations increased to their highest levels during increased flow periods generally from mid-April or May through July, and generally declined with declining flow in July and August. A nitrate concentration decline is often observed during very high summer flow events and is thought to be associated with surface runoff having low nitrate concentration; however, nitrate concentrations often rebound within a few days of these high flow events. These nitrate concentration and flow patterns are consistent with those of CREP wetlands monitored in prior years and represent the likely patterns for future wetlands restored as part of the Iowa CREP.

*Patterns in Nitrate Loss from Wetlands*

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 both precipitation and water yield. The combined effect of these factors means that annual 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 analysis and modeling were used to calculate observed and predicted nitrate removal, respectively, for each wetland. Wetland bathymetry data were used to characterize wetland volume and area as functions of wetland depth. Wetland bathymetry for wetlands which had not previously been monitored by ISU was determined by ISU on the basis of wetland construction plans. These bathymetric relationships were used in numeric modeling of water budgets and nitrate mass balances to calculate nitrate loss, hydraulic loading, and residence times. Wetland water depth and temperatures were recorded at five minute intervals for numerical modeling of nitrate loss. The monitored wetlands generally performed as expected with respect to nitrate removal efficiency (percent removal) and mass nitrate removal (expressed as kg N $ha^{-1}$ $year^{-1}$). In addition to measured inflow and outflow nitrate concentrations, Figure 2 shows the range of outflow concentrations predicted for these wetlands by mass balance modeling using 2014 water budget, wetland water temperature, and nitrate concentration as model inputs.

Variability in wetland performance is in part due to differences in wetland characteristics and condition and partly due to differences in loading rates and temporal patterns. At a given HLR, differences in wetland condition and in timing of loading can result in significant differences in performance. Mass balance analysis and modeling was also used to examine the long term variability in performance of CREP wetlands including the effects of spatial and temporal variability in temperature and loading patterns. In addition to calculating the percent mass removal observed for wetlands monitored from 2004 through 2014, the percent nitrate removal expected for CREP wetlands was estimated based on hindcast modeling over the period from 1980 through 2005. The results illustrate reasonably good correspondence between observed and modeled performance and demonstrate that HLR is clearly a major determinant of wetland performance (Figure 3). Further analysis of the performance of wetlands monitored from 2004 through 2014 illustrates the combined effect of HLR and temperature and clearly shows the decline in percent nitrate loss with increasing hydraulic loading rate and the increase in percent loss when nitrate loading occurs during warmer periods (Figure 4). The apparently good performance of the DD65 wetland may be, at least in part, due to the relatively high water temperatures recorded in that wetland during 2014 and the improved hydraulic efficiency associated with the berms installed within that wetland (Figures 3 and 4).

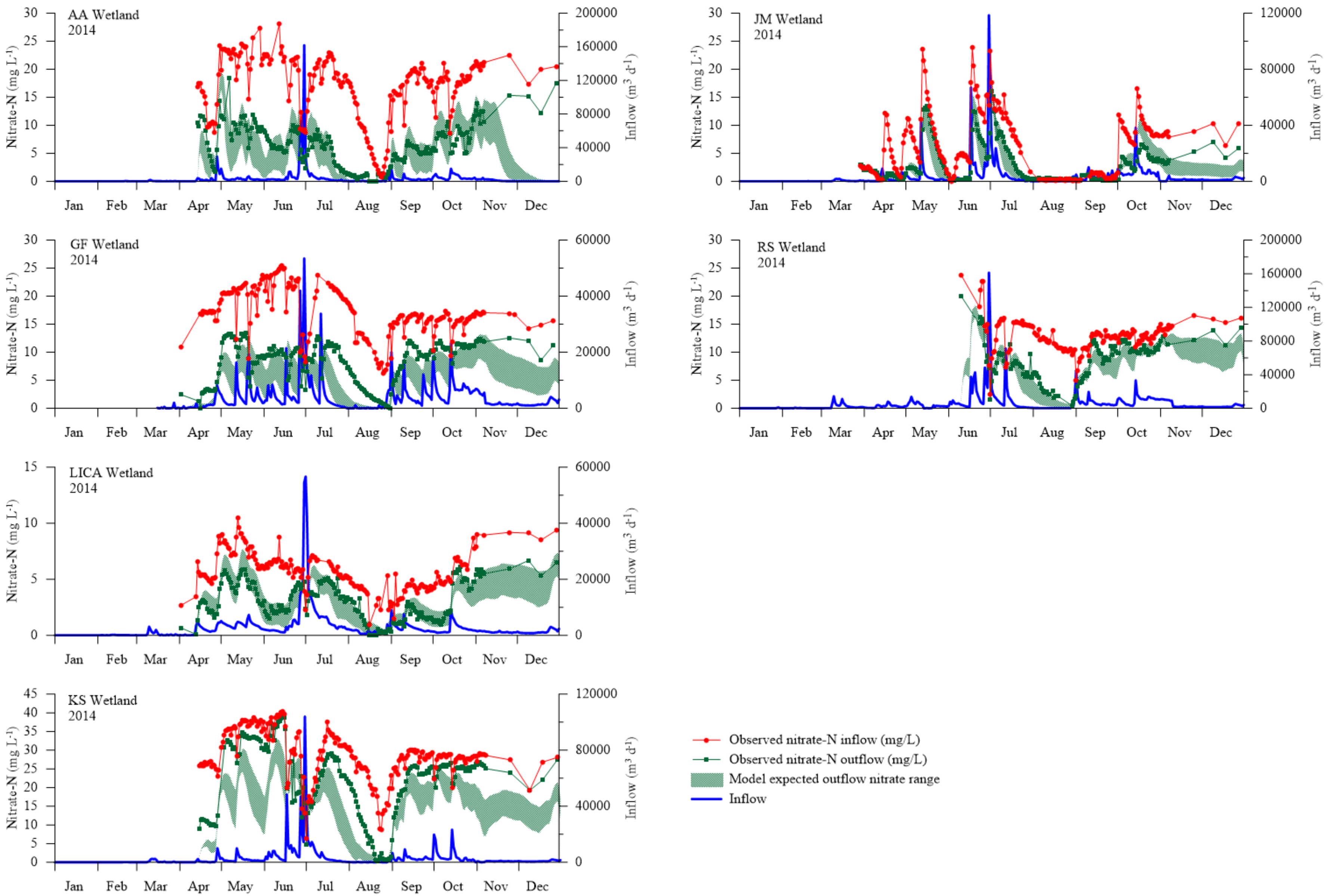


Figure 2. Measured and modeled nitrate concentrations and flows for central Iowa wetlands monitored during 2014.

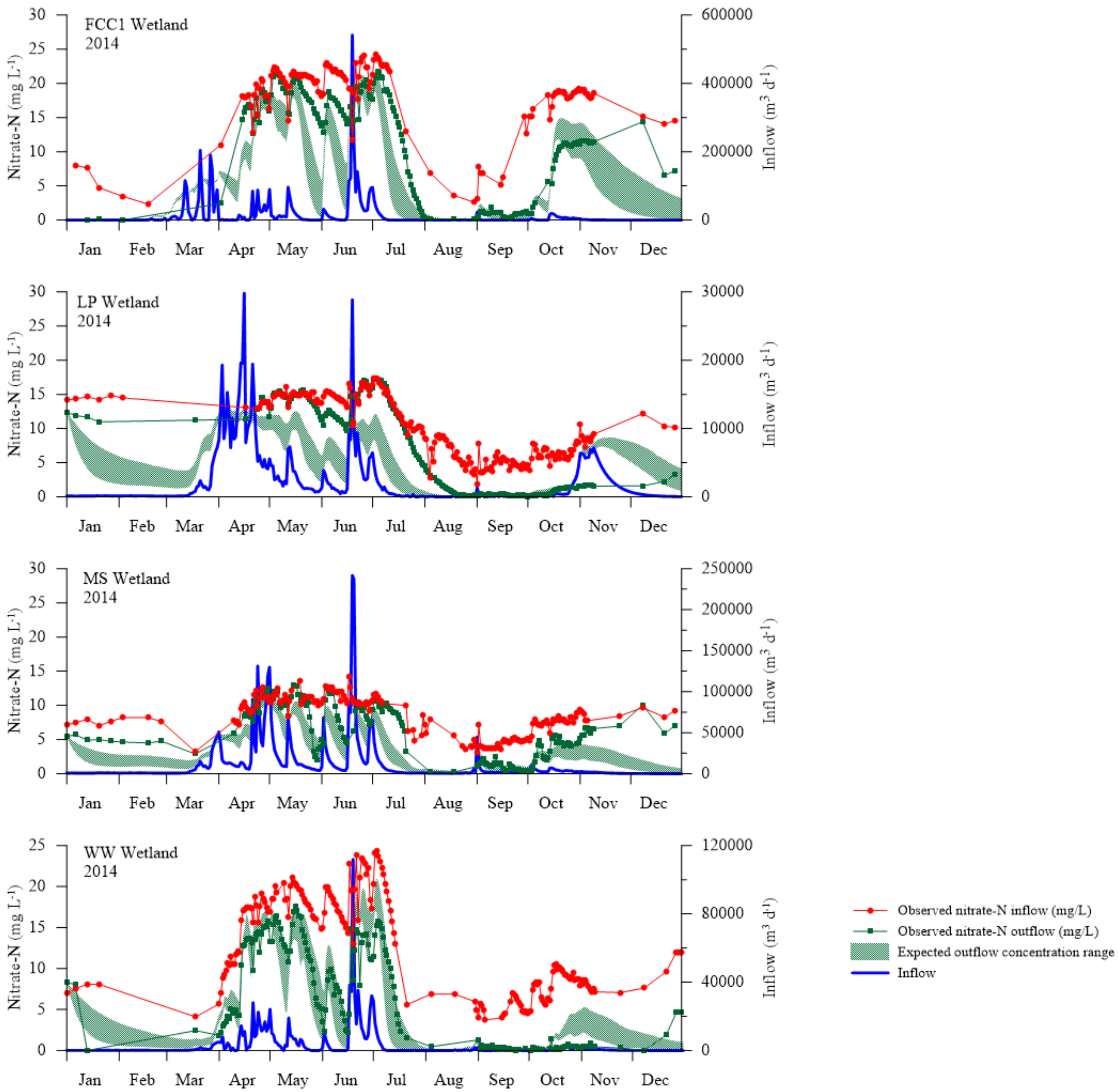


Figure 2 (Continued) Measured and modeled nitrate concentrations and flows for northeast Iowa wetlands monitored during 2014.

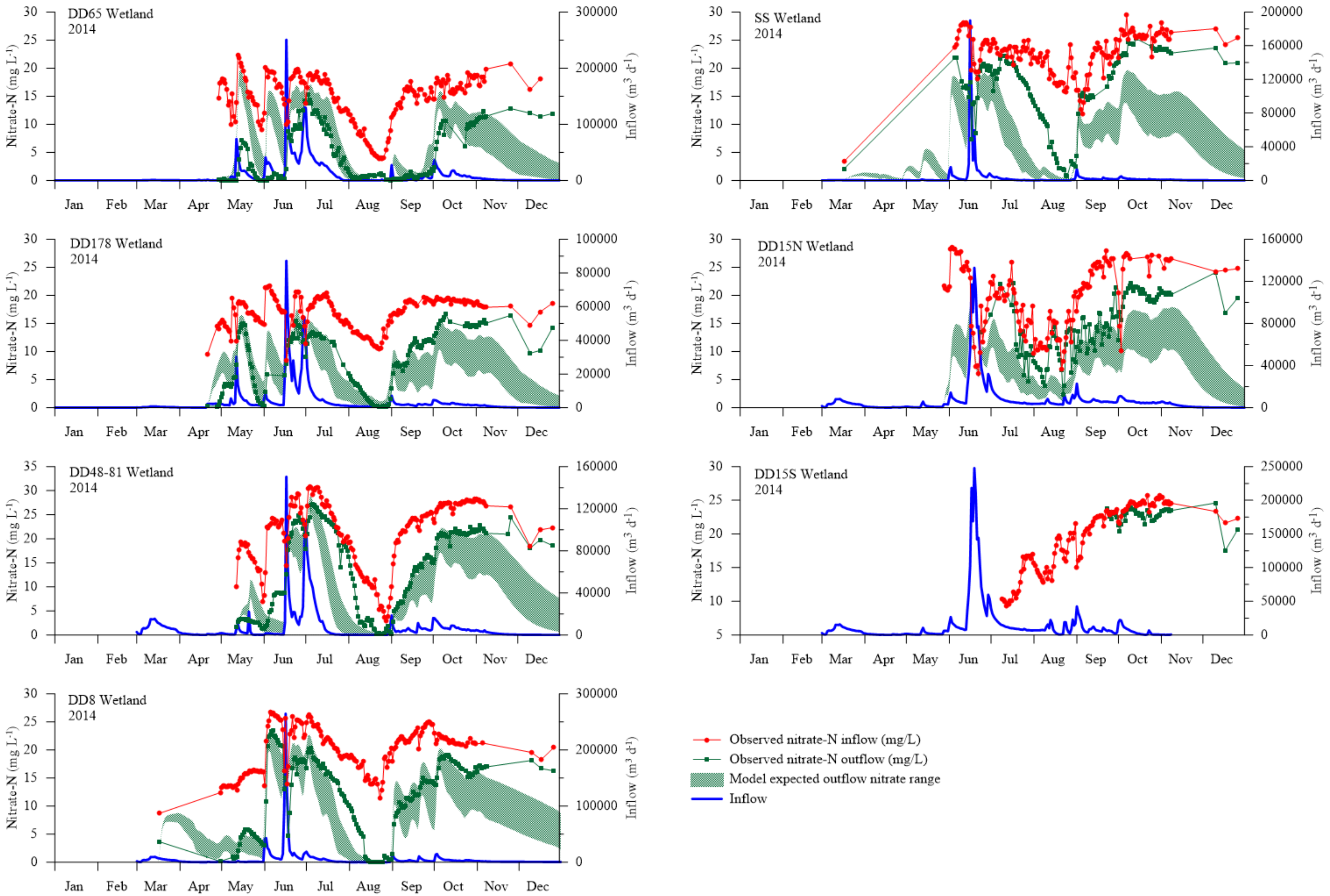


Figure 2 (Continued) Measured and modeled nitrate concentrations and flows for northwest Iowa wetlands monitored during 2014.

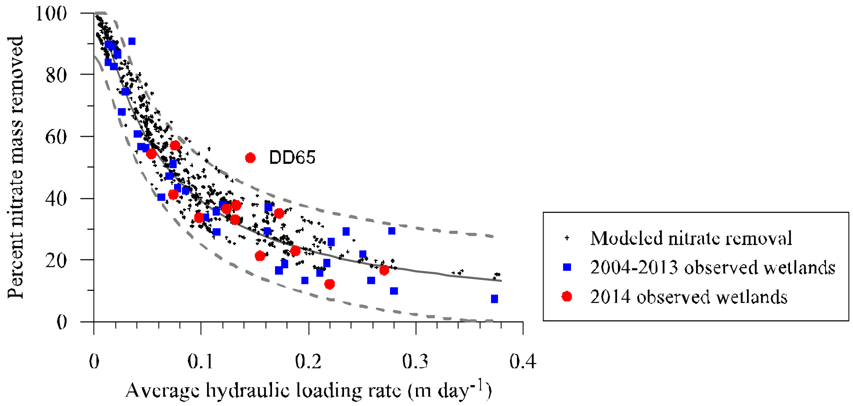


Figure 3. Modeled nitrate removal efficiencies for CREP wetlands based on 1980 to 2005 input conditions and measured nitrate removal efficiencies for CREP wetlands during 2004 to 2014. (*The high performance of the DD65 wetland during 2014 is thought to be at least partially due to high water temperature and the berms placed within the wetland to influence water flow through the wetland.*)

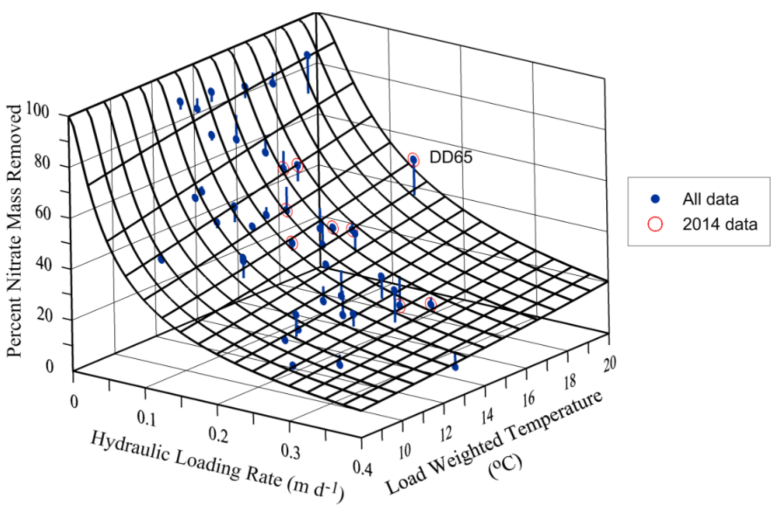


Figure 4. Percent nitrate mass loss versus hydraulic load rate and temperature ($R^2$ = 0.92; the model is based on three parameters (a decay rate constant; a temperature correction constant; and a wetland mixing parameter) all of which were statistically significant at the 0.01 level. (*Only nine 2014 wetlands has adequate temperature and nitrate concentration data to include in this analysis.*)

*Alternative Evaluation of CREP Wetland Performance*

The success of CREP wetlands in removing nitrate may also be illustrated by considering how much row crop land would have to be retired to achieve an equivalent reduction in nitrate mass exported from the watershed served by the wetland. We can estimate this under the assumption that the nitrate-N yield from the landscape is contributed uniformly from the row cropped land, and then calculating how much of that land would need to be retired to reduce the nitrate export to the removal measured for the wetland. This area is the nitrate-N mass removed by the wetland (lb) divided by the nitrate-N yield (lb/acre row crop) from the landscape. Alternatively, this is more simply just the product of the row crop land area and the fraction of nitrate mass removed by the wetland. The results of these calculations for those 39 CREP wetland years contained in

Figure 3 are listed in Table 1. These data show substantial variation in annual percent nitrate mass removal ranging from 8% to 91% among wetlands and years resulting primarily from variation in annual hydraulic loading rate, which is a function of both wetland to watershed area ratio and annual precipitation. The nitrate mass reductions show an average of 26% of the mass delivered to these wetlands was removed. Because wetland and watershed areas vary, this 26% mass reduction would require that about 35% of the row crop land in the watersheds served by these wetlands would have to have been taken out of production to have reduced nitrate mass export from the landscape in an amount equivalent to what these wetlands have removed. Comparison of the actual wetland area to the hypothetical retired land area shows the retired land area averages about 34 times the total wetland area.

Alternatively, consider a hypothetical 1000 acre catchment that is entirely row crop agriculture during an average year having 0.25 m water yield and an inflow nitrate-N concentration of 13 mg/L, the approximate average observed for CREP wetlands. For this scenario, the 1000 acre catchment will have a nitrate-N yield of 29.0 lb/acre. A typical 10 acre wetland on this 1000 acre catchment will remove about 1480 lb nitrate-N per acre (14,800 lb total removal), which is equivalent to retiring about 510 acres of row crop land. A typical 20 acre wetland on that same 1000 acre catchment will remove about 1020 lb nitrate-N per acre (20,400 lb total removal), which is equivalent to retiring about 700 acres of row crop land. From these considerations we see that the wetland removes this nitrate mass at a small fraction of the land area that would need to be retired to achieve a comparable nitrate-N mass reduction.

**Wetland Vegetation Survey**

Emergent vegetation surveys were initiated at CREP wetlands beginning in July of 2014. Wetlands of priority were those that had recently been seeded by IDALS. We have surveyed 32 wetlands this field season, with 24 of those having been recently seeded.

A standard surveying technique is utilized at each wetland. Starting on the left side of the dam looking toward the wetland, transects are run perpendicular to the shore, from the shore to the emergent edge-open water interface. The distance between transects was calculated based on the size of the wetland’s design pool acres resulting in approximately 15 to 20 transects at each wetland. For each transect, two surveying techniques were implemented. The first being the line intercept method, noting whether or not a plant was present at a given interval along the transect line. The length of each transect determined how many points were taken along each transect. The second method employed 1×1 meter quadrats. The length of each transect determined how many quadrats were taken. Both transect and quadrat data will allow estimation of the percent cover of the emergent edge vegetation for each wetland surveyed. Depth measurements were taken at each transect on the emergent edge-open water interface. The last transect taken at each wetland was at the right side of the dam.

Additionally, the emergent edge curvature throughout the entire wetland was documented. This was accomplished by taking a GPS point, including a depth measurement, wherever there was a significant deviation in the emergent band. All spatial data were collected with a Trimble Geo 7X GPS unit. Lastly, one plant specimen was collected for each species found at each wetland. All plants collected have been pressed, dried, and frozen for later confirmation of identification.

Table 1. Percent of row cropped land retirement necessary to produce equivalent wetland nitrate removal capacity.

| Wetland | Year | Wetland to watershed area ratio (%) | Watershed area (acre) | Percent of watershed in row crop | Wetland area (acre) | Landscape nitrate yield (lb N/row crop acre) | Mass nitrate removed (lb N/acre wetland) | Row crop land retirement required to match wetland nitrate removal (acre) |
|---|---|---|---|---|---|---|---|---|
| AA | 2011 | 0.96 | 1085 | 87 | 10.45 | 27.9 | 905 | 339 |
| AA | 2012 | 0.96 | 1085 | 87 | 10.45 | 10.8 | 600 | 578 |
| AA | 2013 | 0.96 | 1085 | 87 | 10.45 | 63.6 | 1706 | 281 |
| AA | 2014 | 0.96 | 1085 | 87 | 10.45 | 27.0 | 1424 | 551 |
| AL | 2006 | 1.11 | 539 | 86 | 6.0 | 42.0 | 1667 | 238 |
| AL | 2007 | 1.11 | 539 | 86 | 6.0 | 57.2 | 1693 | 178 |
| AL | 2008 | 1.11 | 539 | 86 | 6.0 | 36.2 | 1193 | 198 |
| AL | 2009 | 1.11 | 539 | 86 | 6.0 | 24.1 | 1052 | 262 |
| AL | 2010 | 1.11 | 539 | 86 | 6.0 | 36.0 | 1319 | 220 |
| AL | 2011 | 1.11 | 539 | 86 | 6.0 | 33.6 | 1132 | 202 |
| AL | 2012 | 1.11 | 539 | 86 | 6.0 | 7.8 | 548 | 423 |
| BG | 2008 | 0.52 | 2904 | 91 | 15.13 | 39.2 | 688 | 265 |
| DD178 | 2014 | 0.76 | 975 | 89 | 7.38 | 33.4 | 1268 | 280 |
| DD4881 | 2014 | 0.54 | 1969 | 90 | 10.7 | 24.2 | 710 | 314 |
| DD65 | 2013 | 0.64 | 2472 | 89 | 15.71 | 34.8 | 1812 | 818 |
| DD65 | 2014 | 0.64 | 2472 | 89 | 15.71 | 41.3 | 2973 | 1132 |
| DD8 | 2014 | 0.64 | 1228 | 94 | 7.8 | 35.8 | 1856 | 405 |
| DJ | 2007 | 0.59 | 590 | 86 | 3.5 | 44.0 | 1020 | 81 |
| DJ | 2008 | 0.59 | 590 | 86 | 3.5 | 33.5 | 915 | 96 |
| DJ | 2009 | 0.59 | 590 | 86 | 3.5 | 48.4 | 1343 | 97 |
| FCC1 | 2014 | 0.54 | 2692 | 83 | 14.63 | 45.7 | 693 | 222 |
| GF | 2014 | 1.19 | 1120 | 84 | 13.37 | 26.2 | 886 | 453 |
| JM | 2010 | 1.41 | 989 | 68 | 13.9 | 22.8 | 372 | 227 |
| JM | 2011 | 1.41 | 989 | 68 | 13.9 | 12.5 | 244 | 272 |
| JM | 2012 | 1.41 | 989 | 68 | 13.9 | 2.6 | 103 | 554 |
| JM | 2014 | 1.41 | 989 | 68 | 13.9 | 26.4 | 672 | 354 |
| JR | 2007 | 0.56 | 1430 | 89 | 8.0 | 42.3 | 1986 | 376 |
| KS | 2009 | 0.58 | 634 | 90 | 3.7 | 60.7 | 1256 | 77 |
| KS | 2010 | 0.58 | 634 | 90 | 3.7 | 61.9 | 718 | 43 |
| KS | 2011 | 0.58 | 634 | 90 | 3.7 | 31.5 | 812 | 96 |
| KS | 2012 | 0.58 | 634 | 90 | 3.7 | 22.7 | 1026 | 167 |
| KS | 2013 | 0.58 | 634 | 90 | 3.7 | 81.4 | 1710 | 78 |
| KS | 2014 | 0.58 | 634 | 90 | 3.7 | 58.7 | 1014 | 64 |
| LICA | 2014 | 0.50 | 847 | 81 | 4.27 | 10.6 | 617 | 249 |
| MS | 2014 | 0.63 | 3895 | 82 | 24.58 | 29.3 | 600 | 503 |
| ND | 2007 | 0.60 | 727 | 89 | 4.36 | 74.9 | 2472 | 144 |
| SS | 2014 | 1.08 | 505 | 86 | 5.45 | 67.6 | 1959 | 158 |
| TI | 2006 | 0.68 | 1081 | 63 | 7.3 | 87.8 | 2147 | 179 |
| WW | 2014 | 1.05 | 648.5 | 75 | 6.78 | 70.5 | 1782 | 171 |