2019 Annual Report on Performance of Iowa CREP Wetlands: Monitoring and Evaluation of Wetland Performance

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Introduction

Iowa State University monitors selected wetlands in Iowa as part of an ongoing monitoring effort associated with the Iowa Conservation Reserve Enhancement Program (CREP). The Iowa CREP is a targeted, performance-based strategy operated by the Iowa Department of Agriculture and Land Stewardship (IDALS for nitrate reduction in tile-drained agricultural landscapes). The monitored wetlands are selected to span a wide range in wetland-to-watershed area ratio and inflow nitrate concentrations in order to ensure a broad range in hydraulic and nitrate loading rates. This allows the characterization of wetland performance across a wide range of conditions which provides information necessary to properly target new wetland locations and sizing wetlands to maximize nitrate loss.

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 threefold 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. This report is part of a series of annual reports documenting the performance of Iowa CREP wetlands and summarizes results for the 2019 monitoring program.

Summary of 2019 Monitoring

Seventeen wetlands were monitored in 2019 (Figure 1), including 16 Iowa CREP wetlands and one mitigation wetland (DD15-N).

Monitoring was conducted at 14 wetlands that were monitored during 2018, plus three additional wetlands: PAN SE, PAN NW, and LICA 2 (Figure 1). Monitoring at the PAN SE and PAN NW wetlands was initiated during June, so the spring flow which typically carries the bulk of the annual nitrate load was not monitored. Accordingly, most of the nitrate loading was missed for 2019 at the PAN SE and PAN NW wetlands, however, the infrastructure is in place to obtain a full year of monitoring data at these sites at a future time. Similarly, monitoring at the LICA 2 wetland was initiated during May so the infrastructure is in place for future monitoring.

Wetland monitoring included measurements of wetland inflows, outflows, pool elevations and water temperature, and collection of weekly to biweekly water quality grab samples and daily automated samples. Daily samples were collected using automated samplers programmed to collect daily samples at wetland inflows and outflows when above freezing conditions allowed the equipment to function properly. Due to occasional equipment failure, some daily values are missing.

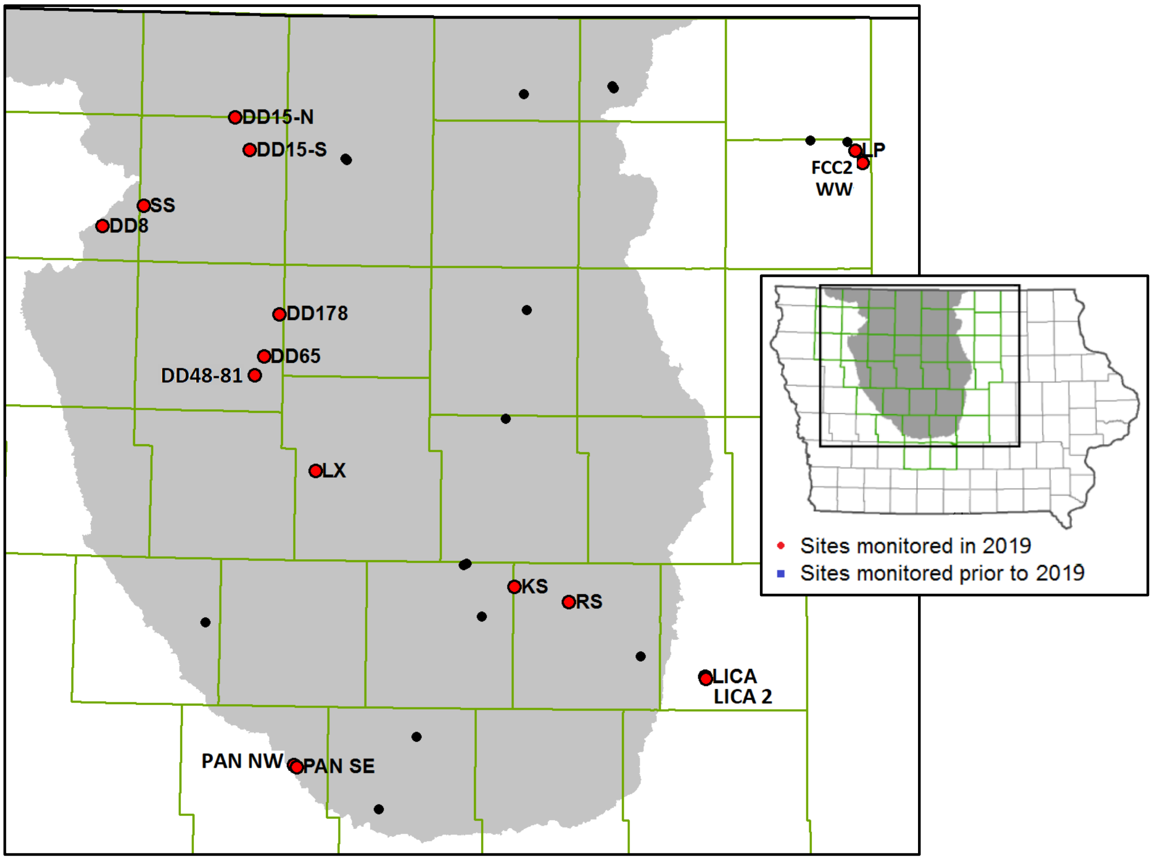

Figure 1. Wetlands monitored in 2019 (red circles, labeled) and additional wetlands monitored in prior years (blue squares). The shaded area represents the Des Moines Lobe in Iowa.

Wetland inflow and/or outflow channels were instrumented with submerged area velocity (SAV) Doppler flow meters and stage recorders for close-interval (every five minutes) 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. Water depth upstream of weir structures was monitored and discharge was calculated using calibrated weir equations. Wetland pool water levels were monitored continuously using stage recorders in order to calculate pool volume, pool area, and discharge at outflow structures. The discharge equations and SAV based discharge measurements are calibrated using manual velocity-area based discharge measurements collected during 2019 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 was 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 60% of the depth from the surface is taken as the mean velocity for the interval. The product of velocity and area summed over intervals gives the total discharge. Flow during winter periods having temperatures below which the monitoring instruments can function is estimated using water yields from nearby United States Geological Survey river gage station data scaled to the individual wetland watershed areas.

During 2019 a beaver dam was observed on the KS wetland outflow structure, the LX outflow structure, the WW outflow structure, the LICA inflow stream, the LICA outflow structure, and the DD65 outflow structure causing elevated water depths at those locations. These beaver dams are periodically removed by the field crew but are generally rebuilt within days. The PAN NW wetland was drained to allow upstream dredging during August.

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 discharge (Figure 2). Historically, inflow nitrate concentrations are variable during the winter. However, because winter flows are typically low, the winter nitrate loading is also low during most years. Snow-melt often results in increased flow during late February or March but nitrate concentrations in the melt water and associated runoff are typically low. Spring flow is usually high and shows the highest nitrate concentrations. Nitrate concentrations generally decline through July and August during dry periods, but may remain elevated as long as there is sufficient flow. Nitrate concentrations during large summer flow events often decline abruptly with peak flows 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.

Wetland Performance (Nitrate mass loss and removal efficiency)

Wetland performance is a function of hydraulic loading rate, hydraulic efficiency, nitrate concentration, temperature, and wetland condition. Of these, hydraulic loading rate (HLR) and nitrate concentration are especially important for CREP wetlands. The range in HLR 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 large annual variation in both precipitation and water yield. The combined effect of these factors results in annual loading rates to CREP wetlands that 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 monitored wetland. Wetland bathymetry data were used to characterize wetland volume and area as functions of wetland water depth. With the exception of three wetlands (LICA 2, PAN SE and PAN NW) wetland bathymetry has been determined by ISU on the basis of wetland construction plans and/or bathymetric surveys. These bathymetric relationships were used in both numeric modeling of water budgets and nitrate mass balances to calculate nitrate loss, hydraulic loading, and hydraulic residence time.

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} $year^{-1}$). However, the LICA 2 wetland showed virtually no nitrate loss, and although it is not clear why, this may be due in some part to potentially poor hydraulic efficiency of that wetland. Mass balances to assess nitrate loss for the PAN SE and PAN NW wetlands were not made because most of the high spring nitrate loading to those wetlands was not measured due to mid-June instrumenting of those wetlands – however, these wetlands clearly show a substantial reduction in nitrate concentration from inflow to outflow (Figure 2). 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 annual HLR, differences in wetland condition and in timing of loading can result in significant differences in performance (Figure 3).

Mass balance analysis and modeling has been 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. The results of the mass balance calculations for the 2019 and prior monitoring years (2004 through 2018) is illustrated in Figure 3. The results demonstrate that hydraulic loading rate (HLR, the total volume of water received per area of wetland surface per unit of time) is clearly a major determinant of wetland nitrate removal performance. Mass balance modeling was not conducted for the PAN NW and PAN SE wetlands due to lack of data during high spring flows and nitrate loading. The LICA 2 wetland was monitored after May 3 and had an estimated hydraulic loading rate of 0.17 m day^{-1} but showed no nitrate removal during 2019 and is not shown in Figure 3.

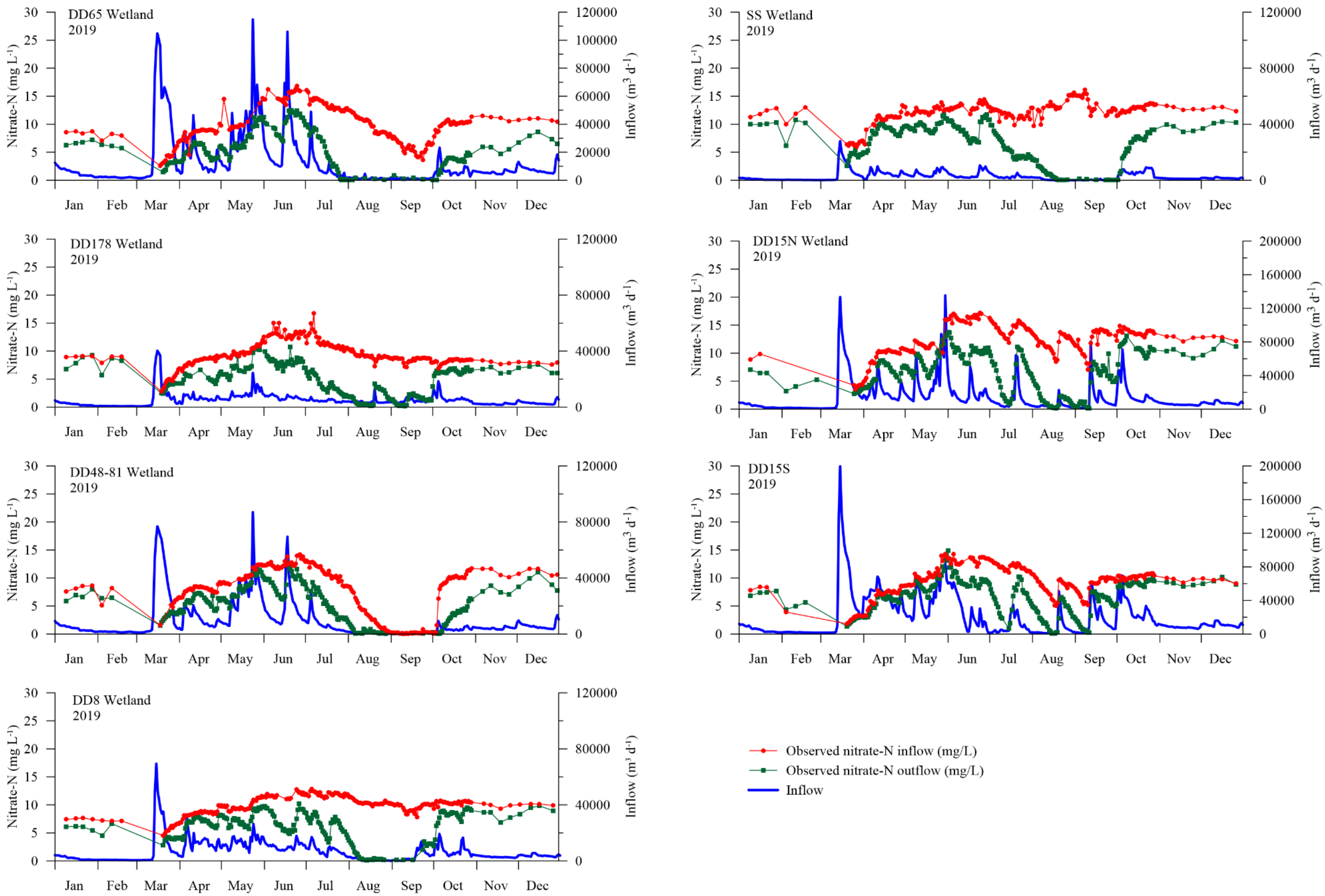

Figure 2. Measured nitrate concentrations and flows for northwest Iowa wetlands monitored during 2019.

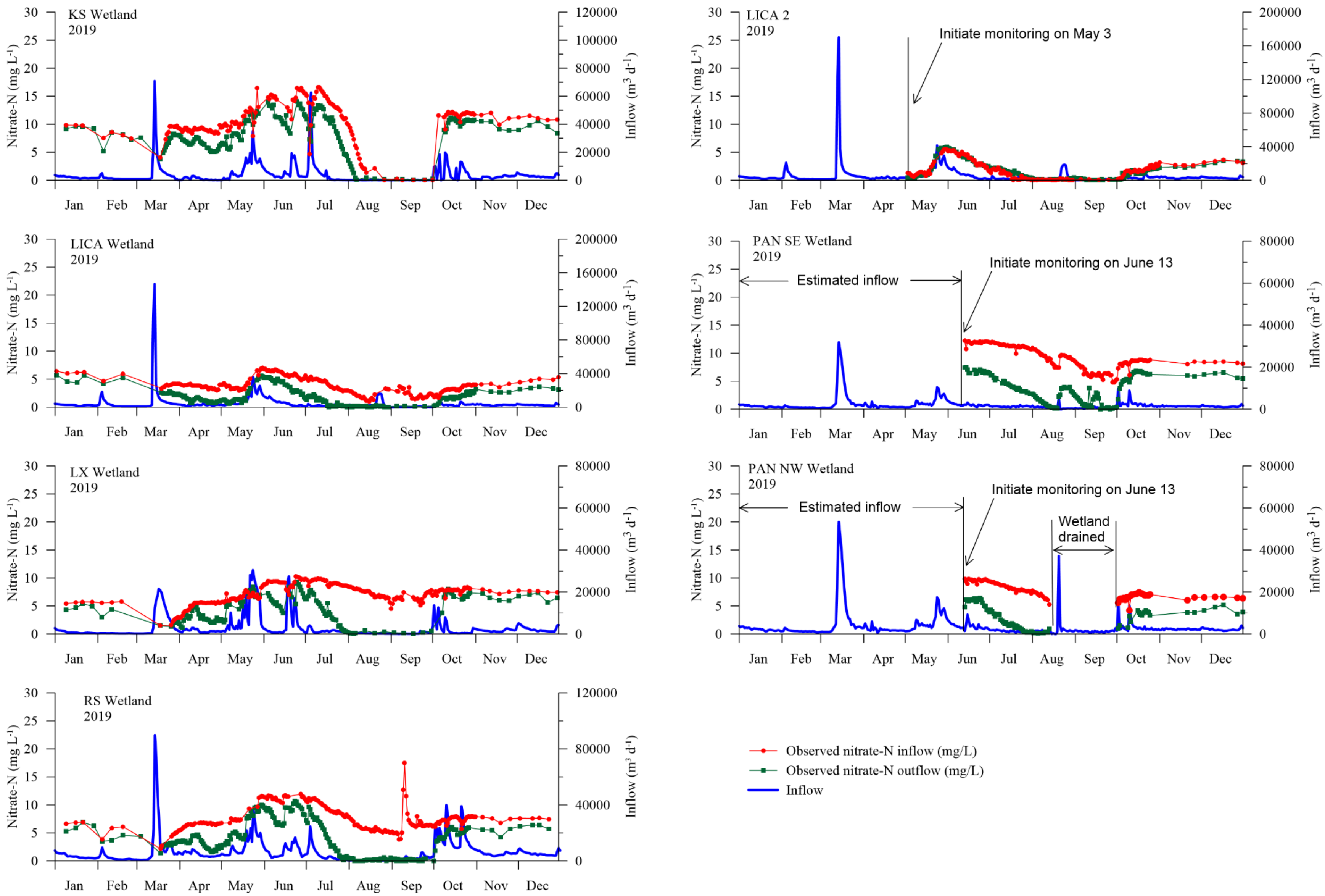

Figure 2. (Continued) Measured nitrate concentrations and flows for central Iowa wetlands monitored during 2019.

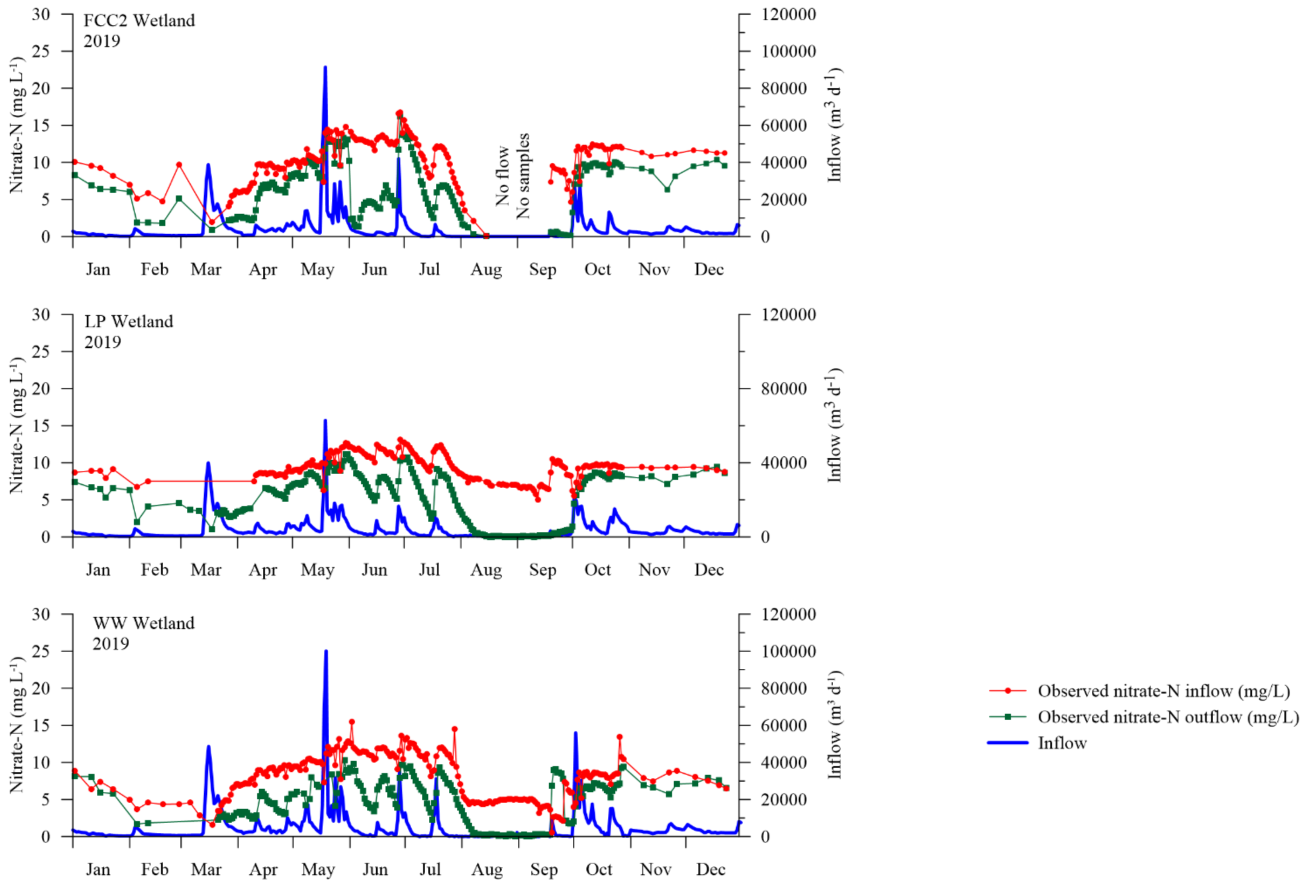

Figure 2. (Continued) Measured nitrate concentrations and flows for northeast Iowa wetlands monitored during 2019.

In addition to calculating the measured percent nitrate removal, the nitrate mass removal is also calculated. The expected average nitrate mass removal for CREP wetlands can be estimated based on inflow flow-weighted average (FWA) nitrate concentration, hydraulic loading rate, and the percent loss function shown in Figure 3. The expected mass removal is illustrated in Figure 3 for inflow FWA nitrate concentrations of 10, 15 and 20 mg N/L. The observed average nitrate mass removed for the monitored CREP wetlands over 2004 through 2019 is 1680 kg N ha^{-1} yr^{-1} (1490 lb N $acre^{-1}$ yr^{-1}). Inflow FWA nitrate concentrations for monitored CREP wetlands that don't have a wetland in the watershed above them average 14.3 mg N L^{-1} and range from 6.2 to 30 mg N L^{-1}. While the percent nitrate loss is high at low HLR, those cases tend to occur during drier years having low nitrate loads, and hence, low nitrate mass loss. Because of the non-linearity of the percent loss function, long term nitrate loss is disproportionately dominated by wetter years having high nitrate loads and high HLRs with lower percent removal.

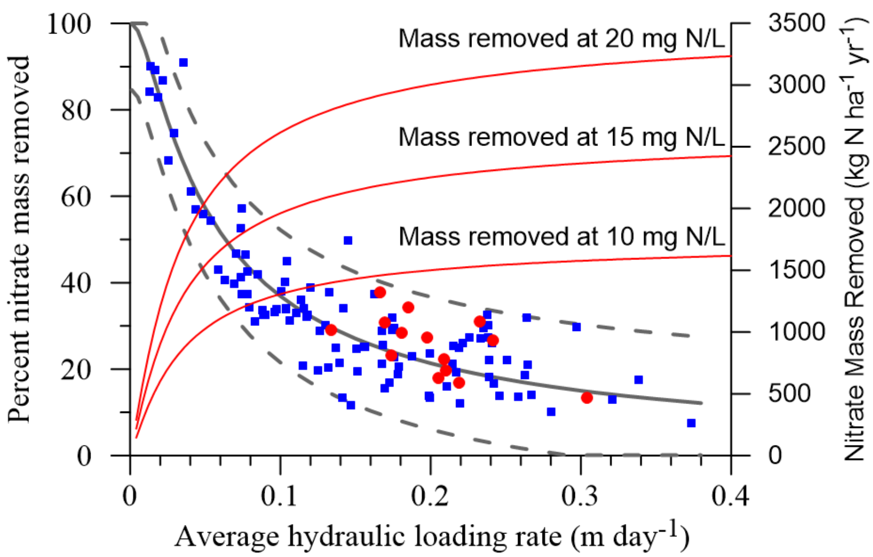

Figure 3. Percent nitrate removal performance for 2019 (red circles) and wetlands monitored during prior years (2004-2018, blue squares). The solid black line is the expected percent loss and the dashed gray lines indicate the range expected to contain 95% of similar wetlands in Iowa on the basis of the 2004 to 2015 monitored wetlands. The solid red lines (right y-axis) show the expected nitrate mass removal for FWA concentrations of 10, 15, and 20 mg N L^{-1}.