Calibration of the Oklahoma Rapid Assessment Method (OKRAM) in floodplain wetlands in Oklahoma

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Final Report

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EXECUTIVE SUMMARY

Rapid assessment methods (RAMs) provide a consistent, affordable approach for ambient monitoring programs to measure condition and to identify high quality wetlands in need of protection and degraded wetlands in need of restoration. Because RAMs are based on inferred relationships between metrics and ecosystem condition and require best professional judgment, it is critical that RAMs undergo calibration and validation to confirm that results are reflective of true wetland condition. RAMs are often calibrated and validated with landscape-scale assessments (e.g., Landscape Development Intensity Index [LDI]) and intensive measures of wetland condition (e.g., Floristic Quality Index [FQI]).

The Oklahoma Rapid Assessment Method (OKRAM) was developed to evaluate wetland condition based on the presence and severity of anthropogenic stressors. OKRAM is comprised of nine metrics divided among three attributes (hydrologic, water quality, and biotic condition). In previous studies, OKRAM was applied, calibrated, and validated at depressional wetlands across Oklahoma (Dvorett et al. 2014; Gallaway et al. 2019a). These studies confirmed that OKRAM is an effective tool for evaluating wetland condition and differentiating between high quality and low quality depressional wetlands. To broaden the applicability of OKRAM, the method needs further application and calibration in other wetland types, including riverine wetlands, a dominant wetland type in Oklahoma. Therefore, the overall goal of this project was to assess the applicability of OKRAM as an assessment tool for riverine wetlands. Specifically, our objectives were to: 1) evaluate the responsiveness of OKRAM to a range of riverine wetland conditions through a validation with Level 1 (e.g., LDI data) and Level 3 assessment data (e.g., vegetation and soil data) and 2) calibrate OKRAM to discern differences in riverine wetland condition along an anthropogenic disturbance gradient. To meet these objectives, our project was completed in two phases: calibration of OKRAM in central Oklahoma (Section I) and subsequently statewide OKRAM calibration (Section II).

Prior to application at riverine wetlands, we modified OKRAM hydrology metrics, initially designed for depressional wetlands, to account for specific stressors and processes unique to floodplain wetlands. Alternate metrics were also developed for water source, buffer filter, and habitat connectivity metrics. OKRAM was then applied at 30 floodplain wetlands sampled along a disturbance gradient in central Oklahoma in 2018. An LDI was calculated for each wetland and plant and soil data were collected alongside OKRAM application. We evaluated the ability of OKRAM to assess floodplain wetland condition by comparing OKRAM results with LDI, as well as with plant and soil data using linear regression models. We found strong relationships between OKRAM and LDI indicating that the method is effectively capturing disturbance within the surrounding landscape. We also found strong relationships between OKRAM and on-site measures of wetland condition, including FQI and soil chemistry parameters (e.g., phosphorus, ammonium, nitrogen, and potassium). This initial calibration study confirmed that the method is working properly, but certain modifications, including the

replacement of original metrics (e.g., water source, buffer filter, and habitat connectivity) with alternate metrics, and the removal of the sediment metric, may improve the ability of OKRAM to evaluate floodplain wetland condition.

Although OKRAM was shown to be an effective method for evaluating floodplain wetland condition in central Oklahoma, further calibration and validation were needed to confirm that the method can be applied statewide. In 2019, OKRAM was applied at 28 randomly-selected floodplain wetlands across the state. An LDI was calculated for each wetland, and plant and soil data were collected on site. We evaluated the ability of OKRAM to determine floodplain wetland condition statewide by examining the relationships between OKRAM and other measures of wetland condition (e.g., LDI and FQI) using linear regressions. Because in 2019, the study area was expanded to the entire state, we also evaluated the potential impact of longitude on OKRAM and FQI. The strong, consistent relationships between OKRAM and FQI we found in central Oklahoma were greatly reduced when expanding our study to a statewide calibration. Our results suggest that longitude is a better predictor of FQI scores than OKRAM or LDI at the state scale. A previous study of depressional wetlands in Oklahoma also noted significant spatial trends in FQI, with the longitudinal precipitation gradient being the primary driver of FQI scores (Gallaway et al. 2019b). Our statewide study also revealed weak relationships between OKRAM and LDI. The lack of relationships with LDI may be partially explained by limitations of the land-use dataset used to calculate condition scores.

We believe the diminished relationships between OKRAM and other measures of condition at the statewide scale are likely due to (1) a reduction in OKRAM score range due to alterations to the sample design (i.e., random sampling) in 2019 and (2) limitations of the calibration datasets due to longitude (FQI) and secondary data inaccuracies (LDI). Because OKRAM was successfully applied in central Oklahoma, and conceptually the metrics are designed to perform consistently across the state, we expect that OKRAM should provide consistent results statewide. However, the lack of strong correlations with other wetland assessments statewide warrants only trial applications of OKRAM on floodplain systems, until additional refinements can be made to secure greater confidence in the method. We also recommend that future efforts focus on improving the broad-scale application of our calibration and validation methods (i.e., LDI and FQI). For example, correcting for nuisance variables (e.g., precipitation and longitude) and the establishment of ecoregion-specific FQI reference criteria can improve the use of FQI for differentiating between high- and low-quality floodplain wetlands across Oklahoma. Furthermore, incorporating other land cover datasets and/or adjusting classifications through field reconnaissance can improve the accuracy of LDI. Increasing the applicability of LDI and FQI across the state will facilitate future OKRAM calibration and validation studies on floodplains, and ultimately help identify OKRAM metrics that may require additional modification.

Contents

INTRODUCTION

Ecosystem monitoring and assessment programs are critical for managing natural resources, developing and applying conservation actions, and guiding and evaluating restoration activities. Given the historical wetland losses experienced within the conterminous U.S. (>50% of wetlands have been lost [Dahl 2011]) and the continual loss and degradation of wetlands, development of wetland monitoring and assessment programs for managing, protecting, and restoring wetlands have received considerable attention during the last 20-30 years. Recognizing the need for flexibility, scientific rigor, and a focus on both landscape-level and intensive site-level assessments, the U.S. Environmental Protection Agency (USEPA) proposed a three-tiered framework for monitoring and assessing wetland condition known as Level 1-2-3. Under this framework, Level 1 relies on using available geographic information and remote sensing to conduct a landscape-scale assessment; Level 2 relies on rapid assessment methods (RAMs), which are structured tools that rely on the aggregation of field metrics (i.e., specific biological or physical attributes that reflect wetland condition and can be related to wetland functions) to define wetland condition based on the degree of deviation from the condition of least-disturbed wetlands; and Level 3 relies on more intensive sampling such as indices of biological integrity (IBIs) or hydrogeomorphic functional assessments (Kentula 2007). Of these three tiers, Level 2 assessments have emerged as a key component of wetland monitoring programs because they rely on less coarse data (i.e., remotely-sensed data) than Level 1 assessments and require less field time and expertise and are less expensive to implement compared to the more intensive Level 3 assessments (Stein et al. 2009). Moreover, RAMs seem to provide a more consistent, systematic, and repeatable approach that facilitates quantification of wetland condition through establishing baseline data on wetland extent, condition, and function that allows for a determination of trends in these parameters (USEPA 2006). Consequently, RAMs have now become a common tool of many state and regional wetland monitoring programs in the U.S. (e.g., California, [Collins et al. 2013], Colorado [Johnson et al. 2013], Delaware [Jacobs 2010], Kentucky [Guidugli-Cook et al. 2017], Montana [Apfelbeck and Farris 2005], Nebraska [LaGrange et al. 2015], New Mexico [Muldavin et al. 2011], North Carolina [Sutter et al. 1999], Ohio [Mack 2001], Oregon [Adamus et al. 2016], and Rhode Island [Kutcher 2011]).

Because RAMs rely upon inferred relationships between qualitative indicators (i.e., metrics) and ecological condition, RAM development must include two critical steps: calibration and validation. Calibration is the process of adjusting an assessment method to improve its ability to evaluate wetland condition along a disturbance gradient (Stein et al. 2009). This process often requires re-evaluating metrics and assessing their ability to track wetland condition, which may result in discarding or combining metrics (Stein et al. 2009). Validation follows calibration and involves documenting relationships between RAM results and independent measures of condition from Level 1 data (e.g., Landscape Development Intensity Index [LDI]; Brown and Vivas 2005, Mack 2006) and Level 3 data (e.g., IBIs, floristic quality indices [FQIs]; Swink and Wilhelm [1994], or other site-specific Level 3 data) in order to establish the defensibility of the RAM as a meaningful and repeatable measure of wetland condition (Fennessy et al. 2007). Following guidance from Fennessy et al. (2007), many states have completed RAM validations using abiotic measurements (e.g., soil and water chemistry) and biotic assemblage data such as bird, amphibian, macroinvertebrate, and vascular plant richness, diversity, abundance, and life-history traits (Mack et al. 2000, Micacchion 2004, Stapanian et al. 2004, Peterson and Niemi 2007, Stein et al. 2009, Garrison 2013, Wardrop et al. 2007). In particular, FQI has been shown to be an effective tool for validating the effectiveness of RAMs to determine wetland condition (Lopez and Fennessy 2002, Andreas et al. 2004, Miller and Wardrop 2006).

Oklahoma's Comprehensive Wetland Conservation Plan has set a goal "to conserve, enhance, and restore the quantity and biological diversity of all wetlands in the state" (OCC 2013, p 2). To facilitate meeting this goal, Oklahoma's Wetlands Program has placed a high priority on developing wetland assessment and monitoring tools that will allow the State to track local and statewide trends in wetland health and extent, prioritize high quality wetlands for protection and low quality wetlands for restoration, and provide guidance for compensatory mitigation projects (OCC 2013). More specifically, the Oklahoma Wetlands Program has been focused on developing an assessment method capable of identifying the condition of wetlands throughout the state that has applications ranging from water quality standard support, mitigation project tracking, and ambient monitoring. The Oklahoma Rapid Assessment Method (OKRAM) was developed as a stressor-based approach to evaluate wetland condition based on presence of anthropogenic stressors (i.e., includes 9 metrics designed to detect anthropogenic stressors impacting hydrologic, water quality, and biotic condition). Initially, we applied OKRAM to depressional wetlands in the Cimarron River Pleistocene Sand Dunes Ecoregion of central Oklahoma (Dvorett et al. 2014). Our initial calibration of OKRAM confirmed that all RAM requirements were met (i.e., the method can determine condition, is truly rapid, requires a site visit, and can be verified; USEPA 2006, Fennessy et al. 2007). Furthermore, we determined that OKRAM was capable of capturing condition along an anthropogenic disturbance gradient (at least, for depressional wetlands). Even though our initial calibration of OKRAM showed great promise as an effective and appropriate assessment tool for depressional wetlands in Oklahoma, its limited application due to testing wetlands from one ecoregion also meant that further refinement and validation was required. Therefore, we conducted a validation study of OKRAM on 28 depressional wetlands across the state within five of the state's ecoregions. Results from this study confirmed the utility and applicability of OKRAM as an assessment tool for determining the condition of depressional wetlands throughout the state (Gallaway et al. 2019a). Additionally, OKRAM was able to differentiate between high quality and low quality wetlands, which addressed an important objective of Oklahoma's Wetland Monitoring Program.

With the initial development and application of OKRAM for depressional wetlands completed, we focused our efforts on the broader applicability of OKRAM across Oklahoma's diverse ecoregions and wetland classes to meet the objective of developing an effective statewide assessment tool that can be applied to wetlands throughout the state. As such, our efforts initially targeted applicability of OKRAM for lacustrine fringe wetlands. Lacustrine fringe wetlands are one of the most abundant wetland classes in the state (Dvorett et al. 2012) and provide unique ecosystem services (e.g., erosion control, storm surge attenuation, habitat provisioning, etc.). We initially applied OKRAM to 30 lacustrine fringe wetlands in central Oklahoma. Unfortunately, our results indicated that OKRAM (at least, in its current version) may not be appropriate for lacustrine fringe wetlands and will require further refinement and modification to be an effective assessment tool that accounts for the unique characteristics of these wetlands (e.g., highly variable water management regimes, broad land-use impacts; Gallaway et al. 2016).

Riverine wetlands are another abundant wetland class (e.g., approximately 20,000 occur in the Cross Timbers and Central Great Plains Ecoregions [Dvorett et al. 2012]) that occur along rivers and streams throughout Oklahoma. These wetlands provide a host of important ecosystem services (e.g., nutrient cycling, flood mitigation, habitat provisioning, etc.), but are also frequently impacted from farming, development (e.g., industrial and residential construction, water development projects), and road/bridge construction activities. Moreover, riverine wetlands are more likely to fall under United States Army Corps of Engineers jurisdiction through Section 404 of the Clean Water Act. Consequently, it is critical that we assess the applicability of OKRAM in these wetlands. A wetland assessment method that accurately estimates ecosystem condition of riverine wetlands will help to ensure that mitigation projects are not only replacing the quantity of wetlands lost but the quality of those wetlands. Therefore, the overall goal of this project was to assess the applicability of OKRAM as an assessment tool for riverine wetlands. Our specific objectives were to:

1. Evaluate the responsiveness of OKRAM to a range of riverine wetland conditions through a validation with Level 1 (e.g., LDI data) and Level 3 assessment data (e.g., vegetation and soil data).

2. Calibrate OKRAM to discern differences in riverine wetland condition along an anthropogenic disturbance gradient.

To meet these objectives, our project was completed in a two-part process, in which our initial calibration study focused on the application of OKRAM in central Oklahoma (Section I), followed by an application of OKRAM statewide (Section II).

SECTION I: CALIBRATION OF OKRAM IN CENTRAL OKLAHOMA

The first section of this report focuses on the initial application and calibration of OKRAM at riverine wetlands in central Oklahoma in 2018. The objectives were to calibrate OKRAM to additional local and landscape measures of wetland condition specific to riverine wetlands and refine OKRAM metrics to improve OKRAM model output. Because Oklahoma has a variety of riverine wetlands (e.g., oxbows, beaver complexes, in-channel, riparian, and floodplain wetlands), our study wetlands were constrained to include only floodplain wetlands in an effort to reduce natural variability. Floodplain wetlands were defined as the flat, backwater area within a 5-year floodplain of a river/stream (Dvorett et al. 2012).

METHODS

Study Area

In 2018, the study area was restricted to the floodplains of the Deep Fork River which flows through the Cross Timbers Ecoregion, and the North Canadian River in the Central Great Plains and Cross Timbers Ecoregions (Figure 1). The Deep Fork and North Canadian Rivers were selected to represent two distinct types of river systems occurring in Oklahoma. The Deep Fork consists of steep muddy banks and clay channel beds, while the North Canadian River is a broad, sand-bed river with braided channels (Johnson 1998). Land-use in central Oklahoma primarily consists of cropland, cattle production, and rangeland with a mix of native prairies and woodlands (Omernik 1987; Woods et al. 2005).

Site Selection

In 2018, floodplain wetlands were identified for each of the two river systems by overlapping National Wetlands Inventory (NWI) maps onto 2017 National Agricultural Imagery Program (NAIP) imagery in ArcGIS 10.3. FEMA's National Flood Hazard Layer was used to exclude any wetlands falling outside of the 100-year floodplain. Floodplains were further filtered by only including NWI polygons intersecting soils that were frequently or occasionally flooded based on the NRCS Soil Survey Geographic Database (SSURGO). Study wetland selection was targeted to achieve a distribution of sites along an anthropogenic disturbance gradient. Level of expected anthropogenic disturbance was based on manual inspection and interpretation of surrounding land use within the upstream 12-digit Hydrologic Unit Code (HUC12) watershed. Land use was defined by the 2016 National Land Cover Dataset (NLCD), which classifies land cover into categories based on 30-m Landsat TM imagery. Wetlands with minimal land-use alterations within the upstream watershed were selected to represent reference condition (i.e., least-disturbed). Reference sites were confirmed in the field based on the absence of anthropogenic stressors. The remainder of sites were sampled along a range of conditions from moderately disturbed to severely disturbed. These included wetlands with obvious land use changes in the watershed, such as agriculture and urban development. Field reconnaissance was used to confirm that selected sites were in fact floodplain wetlands following HGM guidance (Brinson 1993; Smith et al. 1995) and a dichotomous key developed by Dvorett et al. (2012). Thirty floodplain wetlands were selected for assessment, with 15 sites on the Deep Fork River and its tributaries and 15 sites on the North Canadian River and its tributaries (Table 1). To maintain consistency between sites, a 0.5 ha assessment area (AA) was established within each wetland.

Level 1 Assessment

LDI was calculated for each study wetland based on the 2016 NLCD layer. The landscape area contributing to site LDI scores was defined as the intersection of a 1000m buffer and the upstream HUC 12 watershed, or in other words, the area within 1000m influencing site hydrology. Watersheds and buffers were delineated for each wetland in ArcGIS 10.3 using the 'watershed' and 'buffer' tools respectively. The percentage of each land use surrounding the wetland (e.g., agricultural, residential, industrial, commercial, transportation, natural areas, and open water) was recorded and, each land use type was assigned a predetermined coefficient representing the severity of anthropogenic disturbance (Brown and Vivas 2005; Mack 2006, Table 2). LDI Index scores were calculated using the equation (Brown and Vivas 2005):

$$\mathrm{LDI}_{\mathrm{total}} = \sum \%\mathrm{LU}_{\mathrm{i}} \times \mathrm{LDI}_{\mathrm{i}}$$

Where, LDI_{total} is the LDI ranking for a landscape unit (i.e., buffer zone or watershed), $\%LU_i$ is the percent of the total area in land use i, and LDI_i is the coefficient value for land-use i. LDI index scores range from 0 to 10, with higher scores representing a greater deviation from least-disturbed systems.

Level 2 Assessment

In the summer of 2018, OKRAM was completed at 30 floodplain wetlands to evaluate wetland condition. The method consists of nine metrics divided into three attributes (Appendix A). The hydrologic condition attribute assesses alterations to the wetland’s hydroperiod, water source, and hydrologic connectivity. The water quality attribute includes stressors, such as excessive nutrients, sediments, and contaminants, as well as the removal of intact buffer surrounding the wetland. The biotic condition attribute evaluates any stressors to the vegetation community and the amount of contiguous habitat surrounding the wetland. Each metric is scored independently, and all metrics are aggregated into an overall score ranging from 0 to 1, with 0 being complete degradation and 1 being ideal or least-disturbed condition.

Because OKRAM was initially developed and validated in depressional wetlands, modifications were needed prior to applying the tool to riverine wetlands to account for expected differences in wetland hydrology and resultant functions. For example, the primary water sources for depressional wetlands are precipitation and overland flow (Brinson 1993); therefore, the hydrologic connectivity metric was designed to evaluate the connectivity between a depressional wetland and its surrounding upland and identify any barriers to water flow in and out of the wetland (e.g., road grades and levees). In the case of floodplain wetlands, the primary water source is overbank flooding (Brinson 1993); therefore, the hydrologic connectivity metric was modified to assess the floodplain wetland's connectivity to the stream providing floodwaters. The modified hydrologic connectivity metric measures potential stressors at the stream bank that may influence the stream's ability to flood adjacent wetlands (e.g., vertical/sheer banks, un-vegetated banks, channelization, etc.). Also, as an alternate metric, we tested a modified version of the California Rapid Assessment Method (CRAM) hydrologic connectivity metric, which calculates the stream's entrenchment ratio as a measure of connectivity (Collins et al. 2013).

Alternative metrics were also developed for water source, buffer filter, and habitat connectivity metrics. The alternative water source metric was adjusted to include a severity multiplier for each type of stressor. For example, severity multipliers of 1.5 and 0.5 were applied to impervious surface and dryland agriculture, respectively, because of the greater potential impact of impervious surfaces to hydrologic dynamics in a wetland's watershed (Dunne and Leopold 1978; Arnold and Gibbons 1996). The original buffer filter metric evaluates the amount of intact buffer surrounding the wetland, while the alternative metric focuses only on the percentage of intact buffer upstream of the wetland. Lastly, the additional habitat connectivity metric allows for the inclusion of marginal habitats, such as hay meadows, forests converted to rangelands, and other types of land use that are altered but continue to provide wildlife habitat. OKRAM, including all metrics and alternate metrics, was completed within each AA and at the adjacent streambank (for hydrologic connectivity metrics) when accessible. Alternative metrics are also provided in Appendix A.

Level 3 Assessment

During the OKRAM assessment, we also collected soil samples and plant community data within each AA. We collected plant community data at each site following the National Wetlands Condition Assessment (NWCA) sampling protocols (USEPA 2011). The NWCA method involves the collection of plant data within five 100 m^2 plots placed along transects in the AA. Within each plot, percent cover of all plant species present was recorded. Unknown species were collected and identified to the lowest taxonomic group possible using dichotomous keys (Mohlenbrock 2005, 2006, 2008, 2010; Tyrl et al. 2010). To calculate FQI, each species was assigned a coefficient of conservatism (C-value) ranging from 0 to 10 based on the likelihood of the species to occur at a disturbed site (Andreas and Lichvar 1995; Taft et al. 1997). Generally, widespread species with a high tolerance for disturbance are assigned low c-values, whereas less tolerant species with narrow distributions are given higher c-values (Andreas and Lichvar 1995). C-values were assigned according to Oklahoma guidance (Ewing and Hoagland

2012). When species lacked a C-value on the Oklahoma taxonomic list (Ewing and Hoagland 2012), C-values developed for Kansas (Freeman and Morse 2002) and Missouri (Ladd 1993) were applied. FQI was calculated for each site using the following equation:

$$FQI = \left(\frac{\sum cc_i}{S}\right)\sqrt{S}$$

Where CC is the coefficient of conservatism for species *i* and S is species richness.

One composite soil sample was collected from each wetland, comprised of five subsamples taken to a depth of 10 cm from the center of each vegetation plot. Soil samples were immediately placed on ice and stored at 4°C until processing. Samples were thoroughly mixed in preparation for analysis by the Oklahoma State Soil Water and Forage Analytical Laboratory for nitrate (NO_3), ammonium (NH_4), sodium (Na), phosphorus (P), pH, organic matter, total soluble salts (TSS), and sodium adsorption ratio (SAR). Soil samples were analyzed according to procedures outlined in Gallaway et al. (2016). Phosphorous was extracted using the Mehlich III method, while sodium was extracted using a 1:1 soil to water extraction. Both phosphorous and sodium values were determined using inductively coupled plasma mass spectrometry. Nitrate and ammonium were extracted using a 1M KCL extraction and calculated using a flow injection analyzer. Sodium, nitrate, ammonium, phosphorous, and TSS are presented as parts per million (ppm) dry weight. Organic matter was calculated using a combustion analyzer and is presented as a percentage of dry weight (Gallaway et al. 2016).

Calibration Analysis

We evaluated the ability of OKRAM to assess floodplain wetland condition by comparing OKRAM results with Level 1 (LDI) and Level 3 (plant and soil) data using linear regression models. Strong, consistent correlations between OKRAM scores and LDI, as well as FQI, in expected directions were interpreted as evidence that OKRAM scores are reflective of wetland condition. Both OKRAM and OKRAM Alt were analyzed separately as response variables. OKRAM Alt included alternative variables for water source, buffer filter, and habitat connectivity metrics. We also examined the relationships between OKRAM scores (and OKRAM Alt scores) and LDI and FQI for subsets of the data using Spearman's non-parametric correlations to determine whether stream size (i.e., main stem or tributary) or stream type (e.g., braided vs. incised stream) had an impact on these relationships. Subsets included in this analysis were 1) Deep Fork River sites, 2) North Canadian River sites, 3) main stem sites and 4) tributary sites.

To determine whether individual OKRAM metrics are effectively capturing stressors impacting wetland condition, we used Spearman's non-parametric correlations to evaluate the relationships between OKRAM metric scores and Level 3 (FQI and soil) and Level 1 (LDI) data.

Finally, our analysis included a hypothesis testing approach for comparison of the original and alternate OKRAM metrics to FQI to determine which metric is more appropriate for use in floodplain wetlands. For each metric (i.e., water source, buffer filter, and habitat connectivity), we created competing models (original vs. alternate) for comparison using Akaike's information criterion (AIC_c) (Johnson and Omland 2004). If the models were within two AIC_c units of one another, the models were determined to be statistically similar. However, a model scoring two units less than the alternate model was considered the best model supported by the data. All analyses were completed in R 3.2.2. (Crawley 2013; R Core Development Team 2015).

RESULTS

OKRAM Relationships with Level 1 and Level 3 Data

Overall OKRAM scores represented a wide range of anthropogenic disturbance (i.e., most-disturbed to least-disturbed), with scores ranging from 0.43 to 0.98 for the original method (OKRAM) and 0.46 to 0.97 for the alternate method (OKRAM Alt) (Figure 2). Using a simple linear regression model, we found a significant negative relationship between OKRAM scores and LDI ($F_{1,28} = 23.43$, $p < 0.001$, $R^2 = 0.44$), as well as a significant negative relationship between OKRAM Alt scores and LDI ($F_{1,28} = 18.52$, $p < 0.001$, $R^2 = 0.38$). Additionally, we found a significant positive relationship between FQI and overall OKRAM scores ($F_{1,28} = 65.27$, $p < 0.001$, $R^2 = 0.69$), as well as with OKRAM Alt scores and FQI ($F_{1,28} = 48.69$, $p < 0.001$, $R^2 = 0.62$).

When evaluating the influence of stream size and stream type on the relationship between OKRAM and Level 1 and 3 data, we found differences between the data subsets. All subsets of OKRAM site scores were significantly correlated with FQI and LDI at the 0.05 level, except for main stem sites (Table 4). We found the strongest relationships between FQI and OKRAM and OKRAM Alt scores for tributary sites ($\rho = 0.89$, $p < 0.001$ and $\rho = 0.90$, $p < 0.001$, respectively). Similarly, the strongest relationships between LDI and OKRAM and OKRAM Alt were for tributary sites ($\rho = -0.64$, $p = 0.01$ and $\rho = -0.64$, $p = 0.01$, respectively).

Metric Performance

We evaluated individual OKRAM metrics by examining the correlations between metric scores and FQI. Six OKRAM metrics and their alternates were positively associated with FQI scores (Table 3). The strongest correlations with FQI were exhibited by the water source alternate ($\rho = 0.69$, $p < 0.001$), buffer filter ($\rho = 0.57$, $p = 0.001$), buffer filter alternate ($\rho = 0.55$, $p = 0.002$), and vegetation ($\rho = 0.55$, $p = 0.002$) metrics. We also found consistent relationships between OKRAM metrics and LDI, with the strongest correlations between LDI and the habitat connectivity alternate ($\rho = -0.67$, $p < 0.001$), buffer filter ($\rho = -0.56$, $p = 0.001$), and buffer filter alternate ($\rho = -0.56$, $p = 0.001$) metrics. When evaluating the relationship between OKRAM metrics with soil chemistry parameters, we found weak to moderate significant correlations between OKRAM metrics and phosphorus, ammonium, nitrogen, and potassium (Table 5). Three of the nine OKRAM metrics were not significantly correlated with LDI, FQI, or soil chemistry parameters, all of which are water quality metrics (nutrients, sediments, and contaminants). These weak relationships can be attributed to poor distributions of metric scores, as these stressors were only found at a few sites (Figure 3), or in the case of the sediment metric, stressors were not documented at any sites.

Relationships between OKRAM original and alternative metrics and FQI scores were evaluated using a hypothesis testing approach to determine which metric is a better predictor of FQI. The water source alternate metric outperformed the original water source metric in predicting FQI (AIC_c = 187.5 and 192.8, respectively). The original and alternate buffer filter metrics were statistically similar (AIC_c = 194.1 and 195.3, respectively). Lastly, the alternate habitat connectivity metric outperformed the original habitat connectivity metric (AIC_c = 180.3 and 185.4, respectively). These results are consistent with the correlations of the metrics and metric alternatives with FQI scores presented in Table 3.

DISCUSSION

OKRAM Relationships with Level 1 and Level 3 data

Because RAMs are based on inferred relationships and best professional judgment, it is critical to confirm that RAM results are reflective of actual wetland condition (Sutula et al. 2006). In a previous study, we found that OKRAM exhibited strong and consistent relationships with landscape-level and intensive on-site assessments of depressional wetland condition (Gallaway et al. 2019a). In this study, we found evidence that the application of OKRAM can be expanded to riverine wetlands in central Oklahoma, though additional modification and refinement is likely necessary.

LDI has been established as a reliable measure of wetland condition (Brown and Vivas 2005) and many studies have interpreted relationships between RAMs and LDI as support for RAM calibration and validation (Mack 2006; Reiss and Brown 2007; Margriter et al. 2014). For example, in a study of palustrine wetlands in Florida, Reiss and Brown (2007) found strong relationships between LDI and a RAM, the Wetland Rapid Assessment Procedure (WRAP). Our study revealed similar relationships between overall OKRAM scores and LDI. We recognize these correlations were expected given that several OKRAM metrics are scored at the landscape-scale. However, the relationships between OKRAM landscape-scale metrics (e.g., water source and habitat connectivity) and on-site condition measures (i.e., FQI and soil nutrients) provide additional support that OKRAM assesses the landscape in a way that is ecologically relevant.

Soil chemistry is commonly used to evaluate wetland condition because certain parameters can indicate the severity of human disturbance impacting wetlands. For instance, increased levels of phosphorus, nitrogen, and potassium typically correspond with increased agricultural activity, such as fertilizer application (Davis et al. 1981; Royer et al. 2004; David and Gentry 2000; Hubbard et al. 2011; Jacobson et al. 2011). Our comparison of landscape-scale metrics with soil chemistry parameters revealed similar patterns. As water source and habitat connectivity scores decreased (i.e., an indication of stress from land-use alteration), soil chemistry parameters, including phosphorus, nitrogen, and potassium increased. This suggests that watershed scale land-use conversion measured by OKRAM landscape metrics is impacting wetland chemistry.

In addition to using landscape-scale assessments, in-situ measures of biotic communities are also frequently used to calibrate and validate RAM results. Because the response of plant communities to anthropogenic disturbance has been well-documented (Wilcox 1995; Chipps et al. 2006; Tsai et al. 2012), vegetation-based methods such as IBIs are often recommended as a tool for defining wetland condition. For example, Mack et al. (2000) calibrated and validated the Ohio Rapid Assessment Method (ORAM) by comparing ORAM scores with a vegetation IBI. One of the most prevalent vegetation-based assessments is FQI, which has been widely accepted as a reliable measure of wetland condition and has been used in several studies to validate other wetland assessment methods (Miller and Wardrop 2006). Our comparison between OKRAM and FQI scores revealed strong, positive relationships, where wetlands with higher OKRAM scores (i.e., little to no stress) also had higher FQI scores, indicating high quality plant communities. These consistent relationships provide support for our RAM calibration and suggest that OKRAM is accurately capturing stressors impacting plant communities and overall wetland condition.

When comparing OKRAM scores to LDI and FQI using data subsets, we found similar relationships for sites along the North Canadian and Deep Fork Rivers. This suggests that OKRAM is not influenced by the natural differences between braided streams and incised-channel streams. However, when evaluating the potential influence of stream size on OKRAM, we found relationships with LDI and FQI were much stronger for floodplains on smaller tributaries when compared with mainstem North Canadian and Deep Fork floodplains. One potential explanation is that floodplain wetlands along tributaries are typically much narrower relative to expansive floodplains along large rivers (Rosgen 1994), and as such, AA boundaries are likely to include a larger portion of the wetland area for sites along tributaries. Expanding OKRAM assessment to include a greater areal proportion of a large wetland may increase the ability of OKRAM to detect stressors operating at broader scales, but influencing local function, structure and biotic communities. To more accurately characterize the condition of large wetlands, the California Rapid Assessment Method (CRAM) suggests averaging the scores from multiple AAs, when the study site size is 2 or more times the size of the preferred AA size (Collins et al. 2008). Sampling multiple OKRAM AAs and/or increasing the target AA size at large floodplain wetlands may result in a more accurate characterization of condition.

In addition to wetland size, the types of land-use activities (e.g., cattle production and cropland) occurring near streams may vary between tributaries and large rivers. For example, smaller streams typically undergo less frequent and less severe flooding, which may allow for easier access and use of the land adjacent to streams. This was supported by our data, with the four most-disturbed sites sampled along tributaries. Our data also demonstrate that sampling a larger disturbance gradient (i.e., least- to most-disturbed) resulted in a larger range of OKRAM and OKRAM Alt scores for wetlands along tributaries (OKRAM: 0.43 – 0.98, OKRAM Alt: 0.46 – 0.97) compared to wetlands in the floodplains of large rivers (OKRAM: 0.60 – 0.98, OKRAM Alt: 0.55 – 0.97). Because our sampling captured a greater disturbance gradient along tributaries, we would expect these relationships with other measurements of wetland condition (e.g., LDI and FQI) to be stronger and more consistent.

OKRAM Metric Modifications

Although our statistical analysis revealed strong relationships between overall OKRAM scores and independent measures of wetland condition (LDI and FQI), several metrics were found to be problematic in our evaluation of individual metric performance. The issues surrounding these metrics are outlined below:

a. Hydrology Condition Metrics

Hydrology is the primary driver of the physiochemical and biological processes of wetlands (Mitsch and Gosselink 2007), and therefore, an accurate assessment of wetland hydrology is a critical component of RAMs. Specifically, a wetland's hydroperiod (i.e., the frequency and duration of time that a wetland is saturated) can have a significant impact on wetland functions. For example, the influence of hydroperiod on plant communities is well-documented, with species composition affected by water depth, flow rates, and timing of inundation (Gosselink and Turner 1978; Wilcox 1995; Mitsch and Gosselink 2000; Euliss et al. 2004). Because wetland plant communities are closely tied to the hydroperiod, alterations to the hydroperiod, such as ditching or impoundments, can have a significant impact on plant community composition. Moreover, because FQI is based on the fidelity of plant species to undisturbed wetlands, a reduction in hydroperiod may increase terrestrial species cover (Euliss et al. 2004) and result in a lower FQI score, while prolonged hydroperiods may reduce diversity through establishment of monocultures and invasive species (Zedler and Kircher 2004).

The OKRAM hydroperiod metric is designed to identify potential alterations to the frequency and duration of inundation within a wetland, but currently the metric is structured to detect stressors that only occur within the AA boundary. Based on the narrow range of scores for the hydroperiod metric, with many sites receiving a score of one (ideal condition; Figure 3), it is likely that this metric is not sufficiently capturing the full extent of hydrological stressors impacting floodplain wetlands. Despite a poor distribution of hydroperiod scores, the metric was moderately correlated with FQI ($\rho = 0.54$); indicating that when alterations to the hydroperiod were present, the plant community also indicated stress with lower FQI scores. Anecdotally, the site with the lowest FQI score of zero also had the lowest hydroperiod score of

0.25. Based on our results, we believe OKRAM hydroperiod metric is capturing hydrological stressors that severely impact wetland plant communities at the local scale (i.e., within the AA). However, for riverine wetlands the metric may need to be restructured to detect hydrological stressors impacting wetlands at a larger scale (i.e., outside the AA).

The scale of hydrologic stressor identification developed for OKRAM at depressional wetlands may be less relevant for larger floodplain wetlands. Depressional wetlands in Oklahoma tend be relatively small and an OKRAM AA typically includes the entire wetland or a large portion of it; thus, the hydroperiod metric likely captures the full extent of hydrological alterations to depressional wetlands. For example, in the initial application of OKRAM at interdunal depressional wetlands in central Oklahoma the average study wetland size was approximately 0.75 ha (Dvorett et al. 2014). Alternatively, floodplain wetlands are generally larger and often extend beyond the AA boundary. The eight Deep Fork main stem wetlands included in this study exist within a wetland complex extending over 5,000 ha. Therefore, the scale at which hydrologic alterations may impact floodplain wetlands is potentially much greater.

Broadening the scale at which hydrologic stressors are identified will potentially improve the use of OKRAM in large wetlands, such as floodplains, by including spatially distant alterations that may still significantly influence wetland hydrologic process and function. For example, a ditch that occurs outside of an AA may still impact the wetland by draining the area and reducing the wetland’s hydroperiod. Because of the broad spatial scale at which the landscape can impact wetland hydrology, hydrological stressors may not always be obvious during field visits which focus on comparatively small assessment areas. A review of additional resources, such as historical imagery can assist in identifying potential hydrological stressors, including old agricultural tile drains and ditches. Potential stressors can then be verified on-site during the field visit. Because of the importance of hydrology on wetland condition, and the broad spatial scale at which hydrologic alterations can impact wetland processes, other RAMs assess hydrological alterations beyond the AA boundary. The Functional Assessment of Colorado Wetlands (FACWet) recommends reviewing geographic resources, such as topographical maps and aerial imagery to identify potential impacts, such as dams, ditches, and other impacts outside the AA that may alter the hydroperiod (Johnson et al. 2013). The Kentucky Wetland Rapid Assessment Method (KY-WRAM) also recommends using all available information including field visits, aerial imagery, and additional maps to determine potential alterations to hydrology, with consideration given to potential hydrological stressors outside of the AA that impact wetland hydrology (Kentucky Division of Water 2016). Additional studies may be necessary to determine the relevant distance at which hydrological alterations significantly impact wetland condition.

In addition to hydroperiod, both draft hydrologic connectivity metrics also proved to be problematic. The draft hydrologic connectivity metric, structured according to CRAM, involves a measurement of the stream’s entrenchment ratio (Collins et al. 2013), which is best assessed from within the stream channel. Physical access to the stream channel can be challenging and potentially unsafe on higher order streams due to a combination of sheer banks and high flows. In this study, this metric was only able to be safely and accurately assessed at 6 of the 30 sites, making it an unsuitable metric for larger Oklahoma streams. Hydrologic connectivity was also assessed by estimating indicators of reduced or increased flooding, which can be completed standing at the streambank. While this hydrologic conductivity metric was moderately well correlated with FQI, additional refinements are still needed. We were not able to assess two sites with this connectivity metric, one because of distance from the AA to the stream and one due to lack of access permission from a neighboring landowner. For sites where this metric was assessed, the most commonly encountered stressors were vertical/sheer banks, leaning riparian vegetation, and stream channelization. However, the presence of vertical banks may not be a good indicator of the hydrologic connectivity of floodplains along some Oklahoma rivers, which are highly incised but still regularly flood. For example, despite dramatic channel incision, the Deep Fork River continues to flood expansive areas of floodplain wetlands, including a large portion of the 10,000-acre Deep Fork River National Wildlife Refuge. This suggests that in a large watershed river system, vertical sheer banks alone may not severely alter hydrologic connectivity and impact the flooding frequency of adjacent wetlands.

Further evaluation of this metric is needed to determine which stressors have the greatest impact on altering hydrologic connectivity. Plant community wetness as determined by the percent cover of plants with facultative (FAC) or wetter wetland indicator statuses (FACW and OBL) may provide insight into the frequency and duration of flooding. Comparisons between plant community wetness measures and the presence of specific hydrologic stressors may then help elucidate which stressors to retain for assessment of hydrologic connectivity. Alternatively, as used in the application of KY-RAM, incorporating U.S. Army Corps of Engineers (USACE) regional hydrology indicator checklists into the assessment can assist in scoring hydrology metrics (Kentucky Division of Water 2016). Furthermore, in the West Virginia Wetland Rapid Assessment Method (WVWRAM), indicators of hydrology, such as water marks, flood deposits (e.g., sediment, debris, flood wrack, etc.), absence of leaf litter under deciduous trees, and flattened vegetation are used as evidence of flooding and hydrologic connectivity to the stream (West Virginia Department of Environmental Protection 2020).

Lastly, an alternate metric was proposed for the remaining hydrology metric, water source. This metric calculates the percentage of altered land in the wetland's watershed up to 2 km upstream. Because all land use changes are not equal in the severity of their impact to downstream wetlands, the alternate metric includes a severity multiplier for land use, such as impervious cover, that may have a greater negative effect on a wetland's water source. The impact of impervious surface on wetland ecosystems has been well-documented, including its influence on wetland hydrology (Dunne and Leopold 1978; Arnold and Gibbons 1996). Based on the stronger response between the alternate water source metric and FQI, the alternate metric may be a more reliable measure of wetland condition and will be used for future OKRAM assessments.

b. Water Quality Metrics

Water quality metrics (nutrients, sediment, contaminants, and buffer filter) are designed to capture stressors to the wetland's water quality and soil chemistry, as well as quantify the area of intact buffer surrounding the wetland to mediate these impacts. Despite our efforts to sample highly disturbed sites, water quality stressors were not frequently encountered during assessments. For example, nutrient stressors were found in only three of the 30 sites, and chemical contaminants were identified at only one site. The lack of relationships between nutrient and contaminant metrics and soil chemistry parameters is likely due to the poor distribution of metric scores, and we would expect this relationship to improve as more degraded sites are sampled. In previous studies in depressional wetlands, we found moderate to strong relationships between the OKRAM water quality attribute and soil phosphorus and ammonium (Dvorett et al. 2014; Gallaway et al. 2019b). Nutrient and contaminant stressors may be easier to identify in depressional wetlands because they are typically small basins (relative to floodplain wetlands) that more easily collect water from the surrounding landscape allowing for a more likely detection of stressors such as a eutrophication and oil sheens. Although these stressors were not found often in our sampled floodplain wetlands, when present, nutrient stressors, such as heavy cattle activity, and chemical contaminants, such as a nearby oil spill, certainly negatively impact water quality and overall wetland condition. As such, nutrients and contaminant metrics will be retained; however, further refinement may be needed to better represent the severity and extent of these stressors in floodplain systems.

The sediment stressor was not documented at any of the sites, which certainly presents a problem with applying this metric to floodplain wetlands. Although excessive sedimentation has been shown to be an important indicator of stress for depressional wetlands (Skagen et al. 2016), it may not be an appropriate metric to characterize floodplain wetland condition. Sediment deposition in floodplain wetlands is a natural, well-documented occurrence with overbank flooding (Jacobson and Coleman 1986; Noe and Hupp 2005; Pierce and King 2008). In fact, sediment deposition is necessary for streams to maintain a dynamic equilibrium between discharge, slope, sediment load, and sediment size (Lane 1995). Furthermore, sediment and nutrient retention in floodplain wetlands is widely recognized as a valuable wetland function (Mitsch and Gosselink 2007). Although we recognize that sediment aggradation is a stressor that can impact wetland functions, it can be difficult to differentiate between natural sedimentation and excessive sedimentation, or sedimentation beyond what would normally be expected for a floodplain wetland. Removing this metric for floodplain wetland assessment, will likely increase the interpretability of the method and potentially improve the overall relationship between OKRAM scores and other measures of wetland condition (i.e., FQI and LDI).

Lastly, we evaluated which metric performed better between the original buffer filter metric and the alternate metric. Based on our results, the two metrics were very similar. However, because the alternate buffer filter metric only evaluates the amount of intact buffer that occurs upslope of the wetland, it is more appropriate for floodplain wetlands as the land use downslope does not directly impact the quality of the wetland. As a result, the alternate metric will be retained for future assessments.

c. Biotic Condition Metrics

The biotic condition attribute includes vegetation and habitat connectivity metrics, which assess the degree of anthropogenic impact to the quality of the vegetation community within a wetland and the habitat surrounding a wetland. The strong relationships between the vegetation metric and FQI were anticipated, given that both variables are a measure of disturbance to plant communities. However, the strong relationship between the vegetation metric and LDI suggest that the metric is accurately capturing stress within and around the wetland. Lastly, the alternate habitat connectivity metric was shown to be a better predictor of wetland condition, as measured by FQI. This alternate metric was revised to include marginal habitats, such as hay meadows, that are more disturbed than natural areas, but continue to provide habitat for wildlife. The revised metric also improved the overall interpretability and repeatability of this metric because prior to this revision it was unclear in OKRAM documentation whether hay meadows and other marginal habitats should be included in this metric.

FIGURES

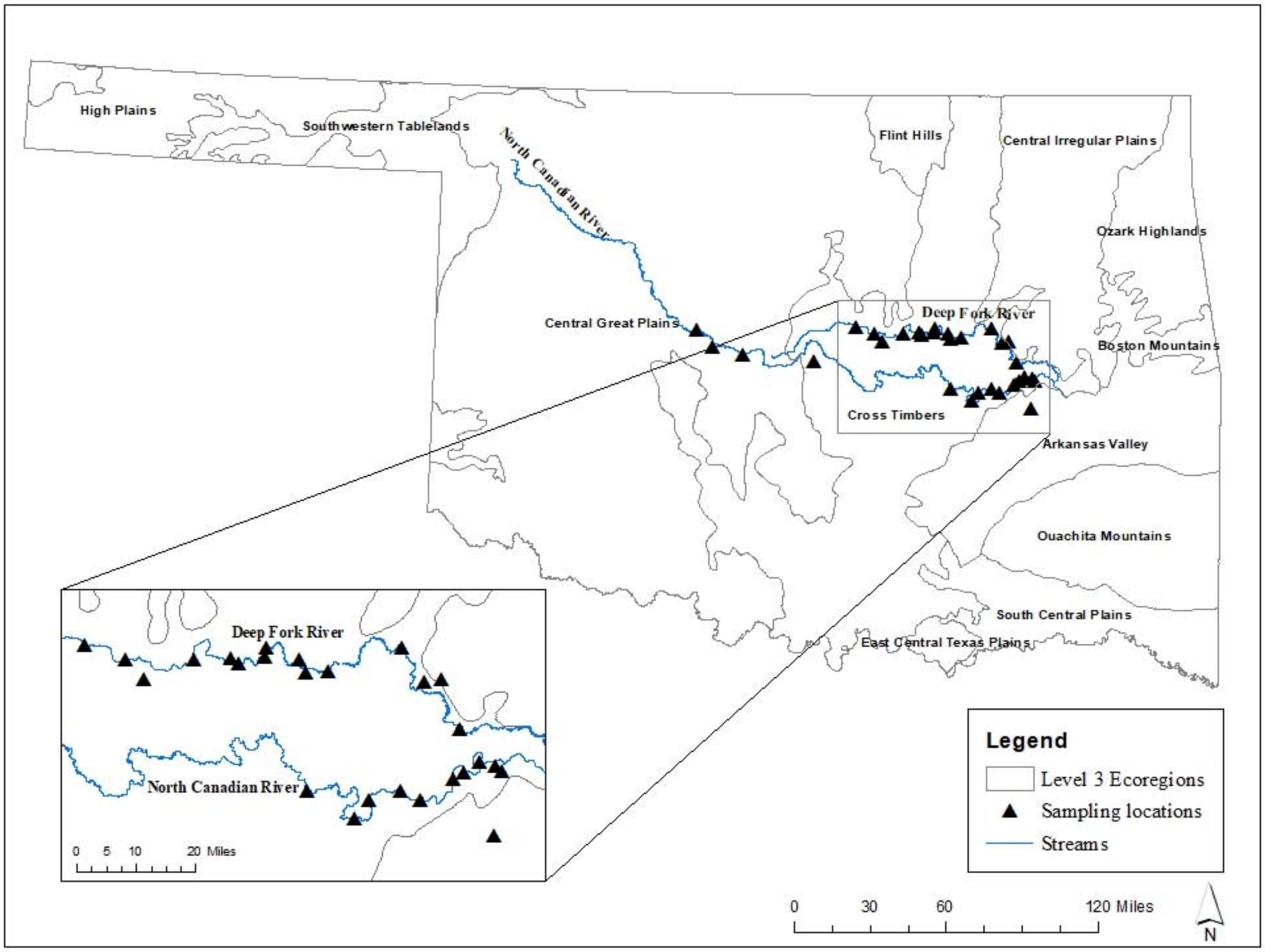
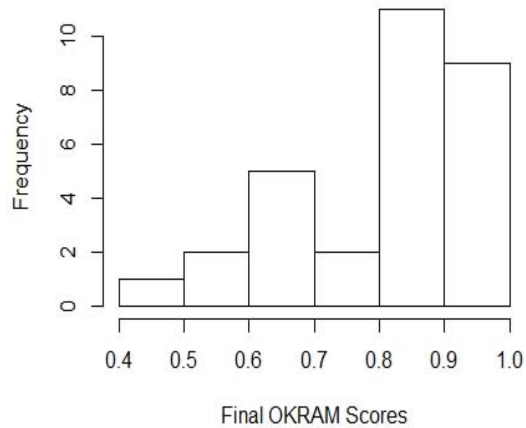


Figure 1: Study area and locations of floodplain wetlands sampled in central Oklahoma during 2018.



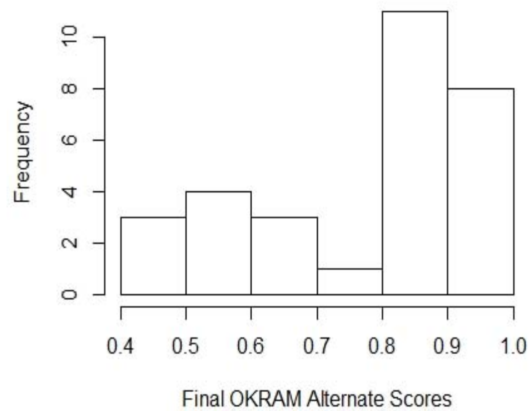


Figure 2: Histograms of overall Oklahoma Rapid Assessment Method (OKRAM) and OKRAM Alternate scores of floodplain wetlands in central Oklahoma.

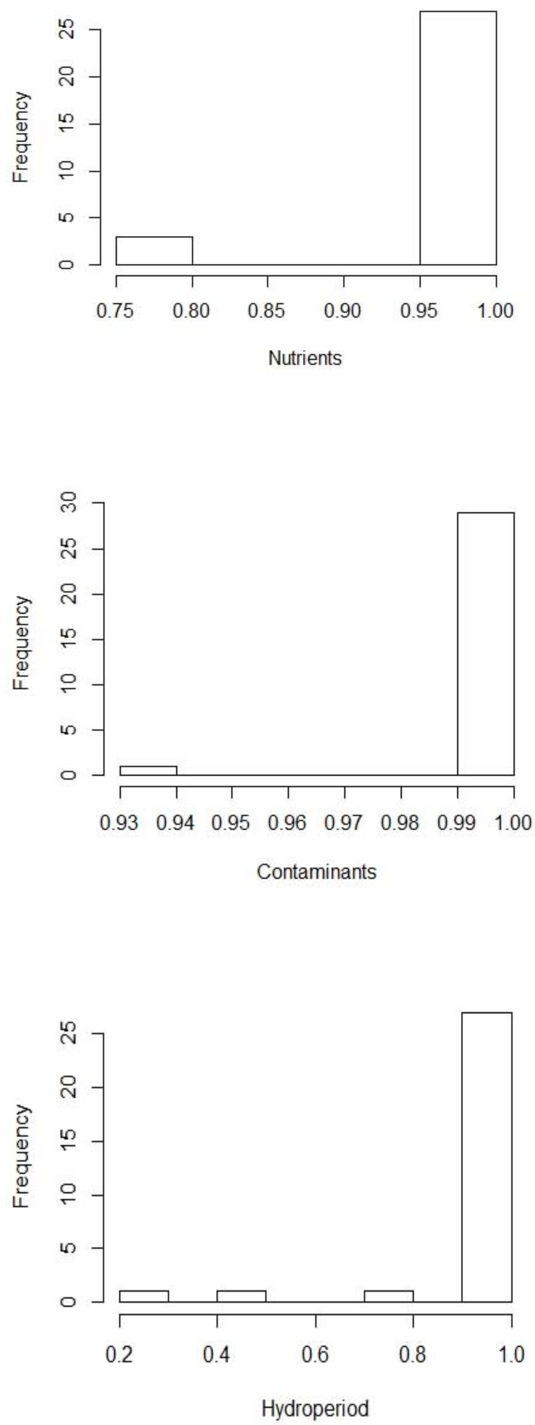


Figure 3: Histograms of Oklahoma Rapid Assessment Method (OKRAM) metrics with a narrow range of scores, including nutrients, contaminants, and hydroperiod, in floodplain wetlands in central Oklahoma.

(a)

(b)

Figure 4: Examples of (a) high quality and (b) low quality floodplain wetlands on the Deep Fork River in Creek and Lincoln county respectively and sampled in 2018

TABLES

Table 1: Descriptions of floodplain riverine wetlands sampled in 2018 in central Oklahoma.

River System	Stream Segment	Number of Wetlands
North Canadian	Main stem	8
North Canadian	Tributary	7
Deep Fork	Main stem	7
Deep Fork	Tributary	8

Table 2: Oklahoma land-use classes defined by National Land Cover Database (NLCD) and corresponding coefficients used to calculate Landscape Development Intensity Index (LDI) scores (Brown and Vivas 2005; Mack 2006).

Land-use Classification	LDI Coefficient
Natural System	1.00
Open Water	1.00
Hay/Pasture	3.41
Developed, Open Space	6.92
Cropland	7.00
Developed, Low Intensity	7.55
Barren Land	8.32
Developed, Medium Intensity	9.42
Developed, High Intensity	10.00

Table 3: Correlations of Oklahoma Rapid Assessment Method (OKRAM) metric and final scores with Floristic Quality Index (FQI) and Landscape Development Intensity Index (LDI) for floodplain wetlands in central Oklahoma. Correlations are presented in terms of Spearman's r (ρ) and significance codes are 0.05 > " * " $\geq$ 0.01 > " ** " $\geq$ 0.001 > " *** " $\geq$ 0.

	FQI	LDI
Hydroperiod	0.54**	-0.40*
Water Source	0.52**	-0.26
Water Source Alternate	0.69***	-0.47**
Hydrologic Connectivity	0.42*	-0.06
Nutrients	0.33	-0.33
Sediment	NA	NA
Contaminants	0.23	-0.25
Buffer Filter	0.57**	-0.56**
Buffer Filter Alternate	0.55**	-0.56**
Vegetation	0.55**	-0.44*
Habitat Connectivity	0.44**	-0.54**
Habitat Connectivity Alternate	0.53**	-0.67***
Final OKRAM	0.74***	-0.51**
Final OKRAM Alternate	0.73***	-0.52**

Table 4: Correlations between Oklahoma Rapid Assessment Method (OKRAM) and OKRAM alternate (OKRAM Alt) scores with Floristic Quality Index (FQI) and Landscape Development Intensity Index (LDI) Scores for data subsets. Subsets include 1) Deep Fork sites, 2) North Canadian sites, 3) main stem sites, and 4) tributary sites. Correlations are presented in terms of Spearman's r (ρ) and significance codes are $0.05 \geq$ " * " $\geq 0.01 >$ " ** " $\geq 0.001 >$ " *** " ≥ 0.

	FQI	LDI
OKRAM - Deep Fork	0.71**	-0.59*
OKRAM Alt - Deep Fork	0.68**	-0.60*
OKRAM - North Canadian	0.76**	-0.51*
OKRAM Alt - North Canadian	0.75**	-0.53*
OKRAM - Main Stem	0.48	-0.35
OKRAM Alt - Main Stem	0.48	-0.33
OKRAM – Tributaries	0.89***	-0.64*
OKRAM Alt – Tributaries	0.90***	-0.64*

Table 5: Correlations between Oklahoma Rapid Assessment Method (OKRAM) metric and final scores with soil parameters, including phosphorus (P), ammonium (NH4), nitrogen (N), and potassium (K) for floodplain wetlands in central Oklahoma. Correlations are presented in terms of Spearman's r (ρ) and significance codes are 0.05 ≥ " * " ≥ 0.01 > " ** " ≥ 0.001 > " *** " ≥ 0.

	P (lbs/A)	NH4	N (lbs/A)	K (lbs/A)
Hydroperiod	-0.06	0.12	-0.26	-0.13
Water Source	-0.61***	0.43*	-0.37*	-0.40*
Water Source Alternate	-0.35*	0.17	-0.47**	-0.34
Hydrologic Connectivity	0.02	-0.19	-0.18	-0.08
Nutrients	0.28	-0.08	0.02	0.06
Sediments	NA	NA	NA	NA
Contaminants	-0.10	0.25	-0.09	-0.16
Buffer Filter	0.15	-0.11	-0.25	-0.15
Buffer Filter Alternate	0.13	-0.11	-0.24	-0.16
Vegetation	-0.01	0.03	-0.32	-0.26
Habitat Connectivity	-0.26	0.06	-0.41*	-0.33
Habitat Connectivity Alternate	-0.08	-0.05	-0.44*	-0.35
Final OKRAM	-0.13	0.00	-0.43*	-0.36*
Final OKRAM Alternate	-0.10	-0.03	-0.40*	-0.34

SECTION II: STATEWIDE OKRAM CALIBRATION

In 2018, OKRAM was successfully applied and calibrated in floodplain wetlands in central Oklahoma. Following data collection and analyses in 2018, our objectives were to identify problem metrics, refine data collection methods, and improve overall protocol performance prior to a statewide validation. However, due to extensive flooding in the spring and summer of 2018, data collection was delayed until late summer. This delay required an adjustment of our data analysis timelines, and although we were able to make minor adjustments to the method (e.g., selecting alternate metrics, removal of the sediment metric), time did not allow for a full refinement of the floodplain OKRAM assessment prior to the 2019 sampling season. Therefore, 2019 data were treated as additional statewide calibration data for analyses, rather than a true validation dataset.

METHODS

Study Area

In 2019, the study area was expanded to floodplain wetlands across the entire state, including six Level 3 Ecoregions in Oklahoma: Arkansas Valley, Central Great Plains, Central Irregular Plains, Cross Timbers, South Central Plains, and Southwestern Tablelands (Figure 1). These ecoregions are highly variable in climate and growing conditions (i.e., precipitation, temperature, length of growing season, etc.). For example, average annual precipitation varies greatly across the study area ranging from 20 inches in western counties to 52 inches in the southeastern part of the state (Oklahoma Climatology Survey 2012). The types of common land-uses also vary across ecoregions. The Central Great Plains and Southwestern Tablelands primarily consist of agricultural crops, including wheat, rye, alfalfa and sorghum, whereas land use in the Arkansas Valley and South Central Plains is dominated by poultry production, timber harvest, and pastureland (Omernik 1987; Woods et al. 2005).

Site Selection

In 2019, the entire population of potential Oklahoma floodplain wetlands was identified by first overlapping National Wetlands Inventory (NWI) maps onto 2017 National Agricultural Imagery Program (NAIP) imagery in ArcGIS 10.3. Additionally, FEMA's National Flood Hazard Layer was used to exclude any wetlands falling outside of the 100-year floodplain. Floodplains were further filtered by only including NWI polygons intersecting soils that were frequently or occasionally flooded based on the NRCS Soil Survey Geographic Database (SSURGO). Floodplain wetlands were then randomly selected across the entire state for sampling. Field reconnaissance was used to confirm that selected sites were in fact floodplain wetlands following HGM guidance (Brinson 1993; Smith et al. 1995) and the dichotomous key developed by Dvorett et al. (2012). For 2019, 28 floodplain wetlands were selected for sampling

(Table 1). To maintain consistency between sites, a 0.5 ha assessment area (AA) was established within each wetland.

Level 1, 2, and 3 Assessments

Level 1, 2, and 3 assessments were completed following the same protocols outlined in our initial calibration study (Section I). An LDI was calculated for each floodplain wetland using the intersection of a 1000 m buffer and the upstream watershed as the contributing landscape following Brown and Vivas (2005; Table 2). In the summer of 2019, an updated version of OKRAM was applied in each of the 28 floodplain wetlands. This updated version included adjustments to the water source, buffer filter, and habitat connectivity metrics, as well as the removal of the sediment metric (Section I). Additionally, plant community data were collected in each AA following NWCA sampling protocols (USEPA 2011) and an FQI was calculated for each wetland (Andreas and Lichvar 1995). Soil samples were collected and processed according to the methods detailed in Section I.

Calibration Analysis

Following methods outlined in Section I, we evaluated the ability of OKRAM to determine wetland condition in floodplains statewide, by examining the relationships between OKRAM and other measures of wetland condition (e.g., LDI and FQI) using linear regressions. We evaluated the relationships between (1) FQI and OKRAM overall, (2) FQI and OKRAM vegetation metric, (3) OKRAM and LDI, and (4) FQI and LDI. Because in 2019, the study area was expanded to the entire state, we also wanted to evaluate the potential impact of longitude on OKRAM and FQI. To meet this objective, we evaluated the improvement to the above models with the addition of longitude as an explanatory variable using multiple linear regression. We also examined the relationships between individual OKRAM metrics and LDI, FQI and soil metrics using Spearman's rank correlation. Strong relationships in expected directions were interpreted as supporting evidence that the method is accurately characterizing wetland condition. All analyses were completed in R 3.2.2. (Crawley 2013; R Core Development Team 2015).

RESULTS

OKRAM Relationships with LDI and FQI

Overall OKRAM scores ranged from 0.67 to 1.00, with a mean of 0.86, LDI scores ranged from 1.00 to 3.31, with a mean of 1.57, and FQI scores ranged from 6.00 to 30.26, with a mean of 15.82 (Figure 2). Using a linear regression model, we determined that the relationship between overall OKRAM scores and LDI was not significant and the model explained little of the variance in our data ($F_{1,26} = 0.44$, $p = 0.51$, adj. $R^2 = -0.02$; Table 3). Subsequently, adding longitude as an explanatory variable into the OKRAM~LDI model allowed us to evaluate any potential longitudinal effects on OKRAM scores, while accounting for spatial heterogeneity in land-use across the state. We found a significant relationship between OKRAM scores and longitude ($p = 0.007$), and including longitude improved the model fit (adj. $R^2 = 0.21$).

We then evaluated the relationship between FQI and overall OKRAM score as well as the OKRAM vegetation metric. We found significant relationships between FQI and both overall OKRAM score ($F_{1,26} = 5.52$, $p = 0.03$) and OKRAM vegetation metric ($F_{1,26} = 8.74$, $p = 0.006$) but both models explained little variance (adj. $R^2 = 0.14$ and 0.22 respectively). Adding longitude as an explanatory variable improved the fit of both models (adj. $R^2 = 0.55$ and 0.57 respectively). We did not find a significant relationship between FQI and LDI ($F_{1,26} < 0.1$, $p = 1$, adj. $R^2 = -0.04$); however, including longitude improved the model ($F_{2,25} = 20.61$, $p < 0.001$, adj. $R^2 = 0.59$).

When evaluating the relationships between individual OKRAM metrics and independent measures of wetland condition (e.g., LDI and FQI), we did not find consistent relationships across OKRAM metrics (Table 4). For instance, we only found weak to moderate relationships between FQI and two OKRAM metrics (nutrients: $\rho = 0.39$, $p = 0.04$, vegetation: $\rho = 0.65$, $p < 0.001$). Also, we only found a moderate relationship between LDI and one OKRAM metric (habitat connectivity: $\rho = -0.52$, $p = 0.004$). We found few significant correlations between OKRAM scores and soil nutrients (buffer filter and phosphorous $\rho = -0.44$, $p = 0.03$; overall OKRAM and potassium $\rho = -0.48$, $p = 0.01$; Table 5).

DISCUSSION

Based on our initial calibration study, OKRAM was shown to be an effective method for evaluating the condition of floodplain wetlands in central Oklahoma. However, because Oklahoma is ecologically diverse, it is critical to evaluate the method's performance across the entire state. Although we found significant relationships between OKRAM, LDI, and FQI within central Oklahoma, these relationships were not consistent at the statewide scale. We believe that the diminution in the correlation among assessment methods for the statewide study is the result of (1) a reduction in OKRAM score range due to alterations to the sample design (i.e., random sampling) in 2019 and (2) limitations of the calibration datasets due to longitude (FQI) and secondary data inaccuracies (LDI).

The probabilistic or random sampling used to locate study sites in 2019 likely resulted in a reduction in the overall range of OKRAM scores. In 2018, we used a targeted site selection approach in an effort to sample the entire anthropogenic disturbance gradient from least-disturbed to most-disturbed. In 2019 the OKRAM scores ranged from 0.67 to 1.00, compared to 2018 with scores ranging from 0.46 to 0.97. The restricted range in OKRAM scores has the potential to reduce correlations with additional measures of wetland condition (e.g., FQI, LDI, soil nutrients) because the response signal is truncated (Bland and Altman 2011). The restricted range appears to be due to the loss of the most highly disturbed sites. Sampling fewer disturbed sites may be due to a greater difficulty in gaining permission to access disturbed wetlands. In fact, private landowners are less likely to grant access permission for ecosystem assessment when land management has caused degradation (Dyson et al. 2019). Additionally, there may be a greater proportion of moderately disturbed wetlands across the state, and because we did not explicitly select highly degraded sites, wetlands in fair and good condition were more likely to be selected. In fact, a 2017 intensification study for the NWCA estimated that the majority of central Oklahoma wetlands exhibited minimal stress in all six physical stressor categories (e.g., damming, filling, vegetation removal, ditching) and moderate stress from non-native plant stressor indicators (OCC 2019).

While the restricted range in OKRAM scores is likely in large part due to our random sampling approach and the population distribution along the disturbance gradient, it is possible that metric modifications may improve the range as well. Alterations to the hydrology and the water quality metrics outlined in Section I may also assist with future calibration and validation efforts at the state scale. In particular, expansion of the hydroperiod metric beyond the confines of the delineated AA may identify critical stressors to wetland hydrology (Johnson et al. 2013; Kentucky Division of Water 2016).

OKRAM Relationships with FQI

While the probabilistic sampling in 2019 caused a reduction in the potential OKRAM response signal due to a restricted range (Bland and Altman 2011), the broader spatial application of OKRAM across Oklahoma introduced more noise into relationships with FQI. The strong, consistent relationships between OKRAM and FQI we found in central Oklahoma (Section I) were greatly reduced when expanding our study to a statewide calibration. Our results suggest that longitude is a better predictor of FQI scores than OKRAM or LDI at the state scale. While FQI can be an accurate predictor of wetland condition at smaller spatial scales (Bried et al. 2014; Gallaway et al. 2019b), the influence of natural variability has been shown to confound the ability of FQI to predict wetland condition when studies are conducted at broad spatial scales. A previous statewide study on depressional wetlands of Oklahoma noted significant spatial trends in FQI scores (Gallaway et al. 2019b). Results from the study concluded that the longitudinal precipitation gradient across Oklahoma was the primary driver of FQI scores in reference wetlands, with higher mean annual precipitation driving higher scores in the eastern Oklahoma and lower mean annual precipitation and frequent drought cycles resulting in lower scores in the western Oklahoma. Our study revealed a similar trend for floodplain wetlands where higher FQI scores occurred in eastern sites (12.6 – 30.26) and lower FQI scores occurred in western sites (6.0 – 12.25) with no overlap in scores between regions.

Response of FQI scores to natural gradients has been documented in large spatial scale applications of the method in other regions. For example, a study of coastal emergent wetlands along the Great Lakes found that FQI scores increased along a latitudinal gradient, which was attributed to both differences in the degree of human disturbance, as well as natural variability (e.g., differences in mean annual temperature and length of growing season; Johnston et al.

2010). Johnston et al. (2008) also acknowledged the difficulty in differentiating between the effects of human disturbance and the effects of natural environmental variation, especially when the region has a wide range of climatic, geologic, hydrologic, and disturbance conditions. Based on the well documented wide range of climatic and disturbance conditions across Oklahoma, including a strong longitudinal precipitation gradient, FQI may not be an appropriate method for statewide calibration and validation without the establishment of ecoregion-specific reference criteria.

The premise of FQI is that plant taxa vary in their response to stress and as such, the proportion of conservative vs. tolerant species can be used as a measure of wetland condition (Andreas and Lichvar 1995). FQI evaluates wetland condition based on the presence or absence of stress tolerant species, therefore, the method relies on the assumption that plant species are responding to anthropogenic stress (e.g., agricultural practices, urban runoff, herbicide application, etc.), rather than being influenced by natural disturbance. Because the OKRAM vegetation metric is an on-site assessment of anthropogenic disturbance to wetland plant communities (e.g., mowing, herbicide application, etc.), we would expect this metric to be correlated with FQI. Landscape measures of anthropogenic stress such as LDI have also been proven to be good predictors of wetland FQI (Gallaway et al. 2019b). Given that on-site measures of human disturbance to the vegetation community and measures of landscape disturbance like LDI only explained a relatively small amount of variance in FQI, it is likely that other factors, such as natural variability in climate (Gallaway et al. 2019b), are influencing FQI scores.

Despite the confounding influence of longitude, we found some evidence that FQI and OKRAM exhibit similar trends. In the statewide assessment, we found a moderate relationship based on Spearman correlation coefficient between OKRAM and FQI. Although, using a correlation method that ranked OKRAM scores (i.e., Spearman) prior to comparison with FQI scores likely helped alleviate the restricted range issue, however, it potentially overestimated the strength of the relationship. This is evident by the low percentage of variance in FQI scores explained by OKRAM (14%) in the linear regression. Strengthening this relationship between OKRAM and FQI to document method validation will likely result as much (or more) from controlling for longitudinal effects on plant communities (as well as ensuring an adequate distribution along a disturbance gradient in the validation dataset), as modifying OKRAM methods.

OKRAM Relationships with LDI

Landscape-scale assessment methods are frequently used to evaluate wetland condition, as they typically require less time and fewer resources compared to intensive on-site assessments. Landscape assessments, such as LDI, have been used successfully to assist with rapid assessment method calibration and validation (Stein et al. 2009, Mack 2020). We found significant relationships between OKRAM and LDI when our study area was confined to central

Oklahoma floodplain wetlands (Section I) and in previous studies in Oklahoma on depressional wetlands (Gallaway et al. 2016). Consequently, we would expect LDI scores to be correlated with FQI scores, as stressors in the surrounding landscape impact the condition of local wetland plant communities. For example, Cohen et al. (2004) found that FQI scores for depressional wetlands in Florida were significantly correlated with LDI scores, indicating that FQI scores were reflective of anthropogenic stress within the surrounding landscape. However, our statewide calibration study revealed weak relationships between LDI and OKRAM as well as FQI.

The lack of relationships with LDI may partially be explained by limitations of the land-use dataset used to calculate condition scores. Landscape-scale methods, such as LDI, rely heavily on the accuracy of a remotely sensed input data, such as the NLCD layer. Therefore, land-use misclassification can result in an overestimation or underestimation of the extent and severity of landscape stressors impacting a wetland. For example, if the land-use surrounding a wetland is broadly classified as herbaceous, but the site may actually be an intensively managed hay field (i.e., regularly hayed and sprayed with herbicides), the land use assessment will not coincide with an on-site assessment of the wetland and its plant community. This mismatch of site-level and broad-scale assessments may be greater issue for assessing floodplain wetlands in western and southwestern Oklahoma compared to central Oklahoma where we conducted our calibration efforts (Section I).

We found many of the floodplains in the western part of the state were dominated by salt cedar (*Tamarix* spp.) and frequently grazed by cattle (Figure 3). However, based on the NLCD classification, these areas are classified as shrub-scrub, because shrubs less than five meters tall constitute 20% or more of the total vegetation cover (Jin et al. 2019). Although technically an accurate classification according to NLCD methods, the difference in LDI coefficients for a natural scrub-shrub system (coefficient of 1) and hay/pasture (coefficient of 3.41) could dramatically alter LDI model output. In other words, the LDI scores will be significantly lower (i.e., indicating less stress) when classified as shrub-scrub as opposed to the actual land-use category of hay field or pasture encroached by salt cedar. This issue was encountered in all but three of the wetlands sampled in western and southwestern counties (7 of 10 sites). Our results demonstrate this disagreement between assessment methods, where western Oklahoma sites with relatively low LDI scores (i.e., indicating good condition) ranging from 1.00 to 2.00 received relatively lower OKRAM scores (0.72 – 0.87) and low FQI scores (7.92 – 12.25), indicating high stress and lower quality plant communities. Margriter et al. (2014) highlighted similar issues in a study using LDI to characterize wetland condition in Hawaii, where inaccuracies in land use designations were primarily due to using broad classifications, such as bare land, grasslands and scrublands to categorize pasture, golf course, urban park, and wild grasslands. Because natural land-use categories are assigned a coefficient of one (i.e. least impacted), this type of land-use confusion in remotely-sensed datasets can often result in improved LDI scores, but do not accurately reflect the extent and severity of anthropogenic landscape stress.

In addition to land use classification inaccuracies, LDI may also be prone to disagreement with local-scale assessments when the ability of a local wetland buffer to mitigate for landscape-level impacts is not considered. This may not be an issue when assessing LDI at a smaller scale, such as a 100 m buffer, but at greater scales such as 3 km buffers, which are commonly used for determining LDIs, this mismatch with local-scale assessments may be an issue (Rooney et al. 2012). In 5 of the 28 sites sampled in 2019, we found that even though the surrounding landscape indicated a high level of stress in the 1,000 m upstream watershed, the wetland likely had a sufficient buffer to mitigate these impacts. This resulted in a disagreement between methods where sites with relatively high LDI scores (i.e., higher stress) ranging from 1.66 to 2.42 had high OKRAM scores (0.90 – 0.96), as well as high FQI scores (17.8 – 26.3), suggesting the wetlands experienced little to no stress and had high quality plant communities (Figure 4). Mack (2006; 2020) also found differences between LDI at 1,000 m and other assessment methods (i.e., Ohio Rapid Assessment Method and a vegetation IBI) and attributed the differences to local on-site factors outweighing landscape-scale stressors.

OKRAM and Longitudinal Effects

An advantage of wetland condition assessments that rely on indicators of stress, especially when compared to using biological communities, is that they should be less impacted by species distribution response to natural environmental gradients. However, some regionalization of methods is likely still necessary to account for unique wetland types or spatially relevant stressors (Fennesey et al. 2007). Understanding the spatial scale at which RAMs are effective or require adjustment is a critical step prior to broad application of these tools. To assess the suitability of OKRAM as a broad statewide assessment tool for floodplain wetlands, we attempted to quantify the impact of longitude on OKRAM scores. Accounting first for landscape alteration throughout the state using LDI, we found a significant but weak relationship between longitude and OKRAM score. However, given the limitations of the NLCD dataset used to calculate LDI, the relationship exhibited between OKRAM and longitude may still represent a real gradient in condition, with more disturbed sites occurring in the western part of the state.

Because land-use disturbance varies longitudinally across the state, we would expect OKRAM's landscape-scale metrics to follow a similar trend. For example, anthropogenic disturbance in western Oklahoma is primarily agricultural cropland (83% of total disturbed land), whereas in eastern Oklahoma pastureland and hay meadows account for 67% of total disturbed land (Gallaway et al. 2016; NLCD 2011). While all land-use changes likely impact wetland condition, certain types of land-use may result in greater stress to wetlands. For example, wetlands in western Oklahoma may be more severely impacted as they are embedded within an agriculturally intensive landscape. Our results support this assumption, with more severely altered wetland plant communities occurring in western Oklahoma (average OKRAM vegetation score = 0.44) compared to eastern Oklahoma (average OKRAM vegetation score = 0.89).

Although OKRAM scores are moderately correlated with longitude, the actual effect may be overestimated due to a real longitudinal conditional gradient across Oklahoma. A portion of the variance in FQI scores explained by longitude in this study may also result from a real spatial condition gradient. Although, the influence of longitude on FQI was much stronger than OKRAM, and FQI is known to be impacted by natural variation at large spatial scales (Gallaway et al. 2019 b; Johnson et al. 2008, 2010), Additional studies to sample a greater population of wetlands across the state may be needed to further define the range of expected condition scores across the state as well as allow us to better understand the impacts of natural and anthropogenic impacts on OKRAM scores given the challenges we encountered with our validation study.

CONCLUSION

Prior to implementation in monitoring and mitigation programs, it is imperative that wetland assessment methods are calibrated and validated across their applicable region to confirm that results are reflective of actual wetland condition (Fennesey et al. 2007). Our initial calibration of OKRAM demonstrated that the method can be applied in central Oklahoma to accurately evaluate wetland condition and differentiate between high quality and low quality floodplain wetlands. Overall, the method is working properly, but certain modifications, such as the replacement of the original water source, buffer filter, and habitat connectivity metrics with alternate metrics, and the removal of the sediment metric, may improve the ability of OKRAM to evaluate floodplain wetland condition.

Although OKRAM was shown to be effective in central Oklahoma, our study at the statewide scale did not reveal the same consistent relationships between OKRAM, LDI and FQI. Because OKRAM was successfully applied in central Oklahoma, and conceptually the metrics are designed to perform consistently across the state, we expect that OKRAM should provide consistent results statewide. Moreover, OKRAM uses a stressor-based approach to evaluate wetland condition and as such, the method is not susceptible to changes in natural gradients (e.g., precipitation, temperature, etc.) in the way that other measures of wetland condition, such as FQI, may be influenced. However, the lack of strong correlations with Level I and Level III assessments statewide warrants only trial applications of OKRAM on floodplain systems, until additional refinements can be made to secure greater confidence in the method.

While some improvement to OKRAM output should be achieved by pursuing alterations to hydrology and water chemistry metrics outlined in Section I, greater improvements will likely be made through updates to the study design. Therefore, rather than making substantial changes to OKRAM, we recommend that future efforts focus on improving the broad-scale application of our calibration and validation methods (i.e., LDI and FQI). For example, correcting for nuisance variables (e.g., precipitation and longitude) and establishing ecoregion-specific FQI reference criteria can improve the use of FQI for differentiating between high- and low-quality floodplain wetlands across Oklahoma. Furthermore, incorporating other land cover datasets and/or adjusting classifications through field reconnaissance can improve the accuracy of LDI.

Increasing the applicability of LDI and FQI across the state will facilitate future OKRAM calibration and validation studies. Additionally, supplementing random sampling through stratification or targeted sampling may help to ensure that an adequate range of OKRAM scores is included in future calibration and validation efforts.

FIGURES

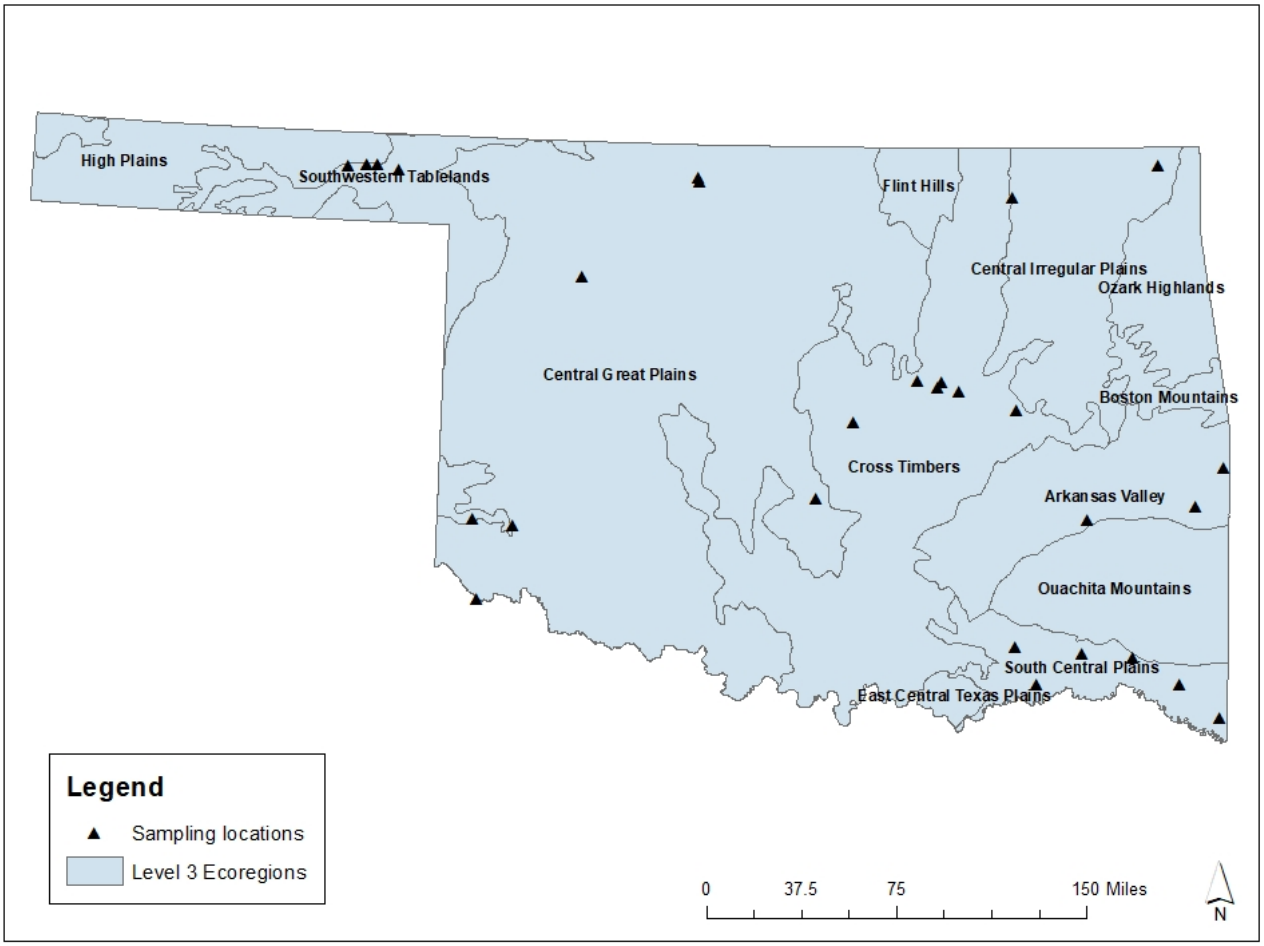


Figure 1: Study area for floodplain riverine wetlands sampled in 2019

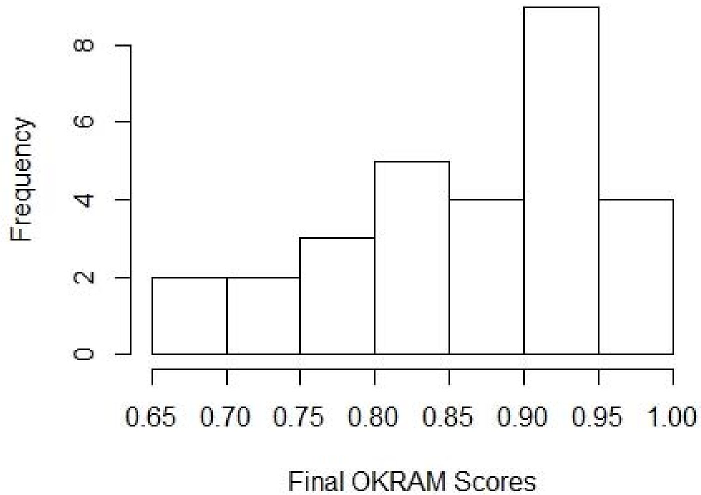


Figure 2: Histogram of Oklahoma Rapid Assessment Method (OKRAM) final scores for floodplain wetlands sampled in 2019

Figure 3: Site photo from Beaver County, Oklahoma depicting a floodplain wetland with the National Land Cover Dataset (NLCD) classification of shrub-scrub due to the presence of salt cedar (Tamarix spp.), indicating a natural undisturbed landscape. However, this site was confirmed to have heavy cattle activity during field reconnaissance.

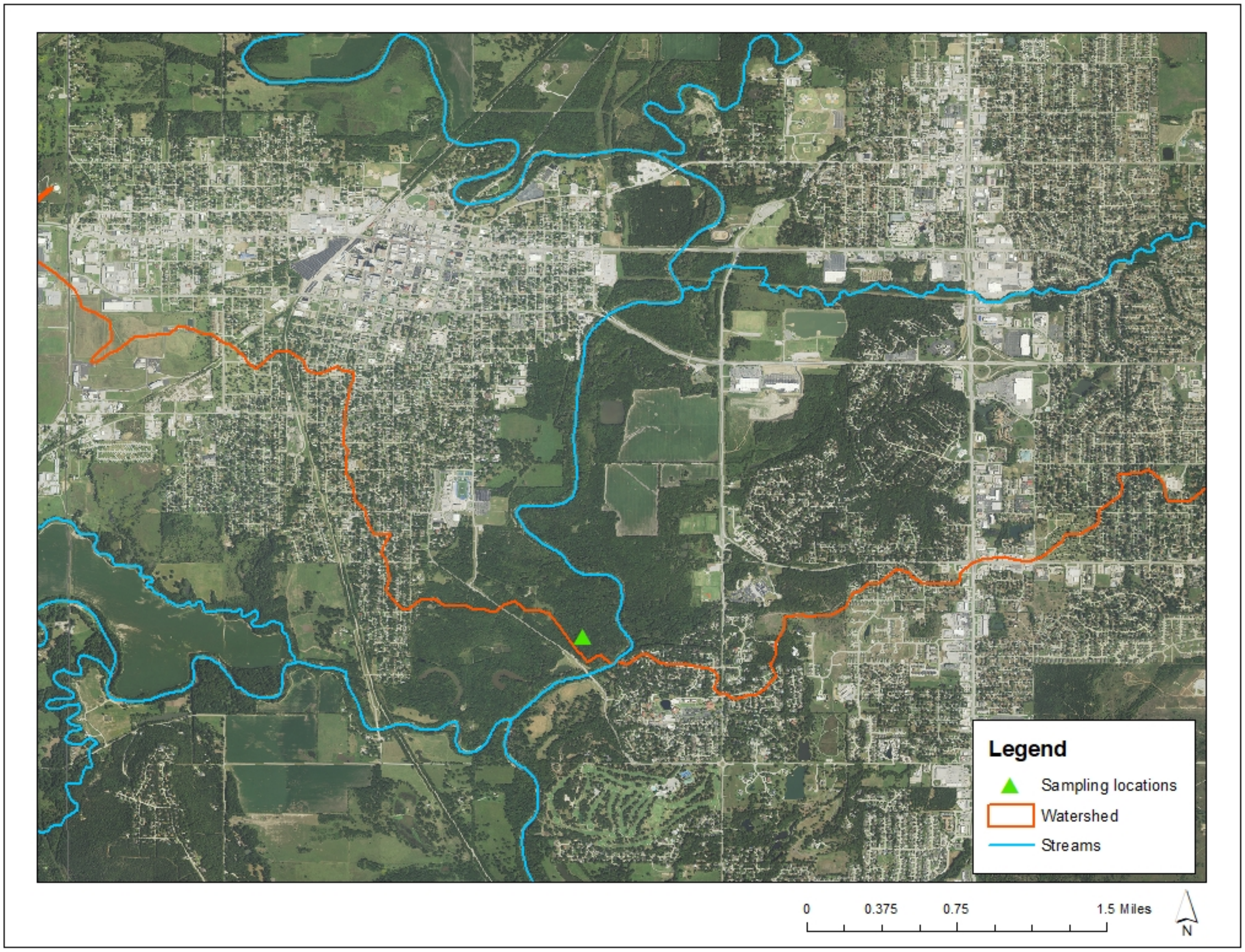


Figure 4: Floodplain wetland site sampled along the Caney River south of Bartlesville, Oklahoma in Washington County. This map depicts a high level of anthropogenic stress in the site's upstream watershed. Although landscape stressors are present, the sampling site is surrounded by extensive buffer, which can mitigate impacts to the wetland.

TABLES

Table 1: Distribution of floodplain wetlands sampled in 2019 in Oklahoma by Ecoregion

Level 3 Ecoregion	Number of Wetlands
Arkansas Valley	3
Central Great Plains	6
Central Irregular Plains	2
Cross Timbers	6
South Central Plains	6
Southwestern Tablelands	5

Table 2: Oklahoma land-use classes defined by National Land Cover Database (NLCD) and corresponding coefficients used to calculate Landscape Development Intensity Index (LDI) scores (Brown and Vivas 2005; Mack 2006).

Land-use Classification	LDI Coefficient
Natural System	1.00
Open Water	1.00
Hay/Pasture	3.41
Developed, Open Space	6.92
Cropland	7.00
Developed, Low Intensity	7.55
Barren Land	8.32
Developed, Medium Intensity	9.42
Developed, High Intensity	10.00

Table 3: Linear regression analysis between Floristic Quality Index (FQI), Oklahoma Rapid Assessment method (OKRAM), OKRAM vegetation scores, Landscape Development Intensity Index (LDI) scores and longitude for floodplain wetlands in Oklahoma.

	Adj. R^2	F	df	P
FQI ~ OKRAM	0.14	5.53	1, 26	0.03
FQI ~ OKRAM + longitude	0.55	17.74	2, 25	< 0.001
OKRAM ~ LDI	-0.02	0.45	1, 26	0.51
OKRAM ~ LDI + longitude	0.20	4.37	2, 25	0.02
FQI ~ LDI	-0.04	<0.01	1, 26	1.0
FQI ~ LDI + longitude	0.59	20.61	2, 25	< 0.001
FQI ~ OKRAM Vegetation	0.22	8.74	1, 26	0.006
FQI ~ OKRAM Vegetation + longitude	0.57	19.13	2, 25	< 0.001

Table 4: Correlations of Oklahoma Rapid Assessment Method (OKRAM) metric and final scores with Floristic Quality Index (FQI) and Landscape Development Intensity Index (LDI) for floodplain wetlands in Oklahoma. Correlations are presented in terms of Spearman's r (ρ) and significance codes are $0.05 >$ " * " $\geq 0.01 >$ " ** " $\geq 0.001 >$ " *** " ≥ 0.

	FQI	LDI
Hydroperiod	-0.30	0.11
Water Source	0.32	-0.23
Hydrologic Connectivity	0.09	0.19
Nutrients	0.39*	0.33
Contaminants	0.32	0.18
Buffer Filter	0.02	-0.24
Vegetation	0.65***	0.06
Habitat Connectivity	-0.04	-0.52**
Final OKRAM	0.55**	-0.02

Table 5: Correlations between Oklahoma Rapid Assessment Method (OKRAM) metric and final scores with soil parameters, including phosphorus (P), ammonium (NH4), nitrogen (N), and potassium (K) for floodplain wetlands in Oklahoma. Correlations are presented in terms of Spearman's r (ρ) and significance codes are 0.05 ≥ "*" ≥ 0.01 > "**" ≥ 0.001 > "***" ≥ 0.

	P (lb/ac)	TopN	NH4	K (lbs/A)
Hydroperiod	0.09	-0.10	-0.01	0.06
Water Source	-0.30	-0.28	0.11	-0.21
Hydrologic Connectivity	-0.07	-0.13	0.26	-0.25
Nutrients	-0.22	-0.27	0.12	-0.40*
Contaminants	-0.23	0.13	0.16	-0.30
Buffer Filter	-0.44*	-0.28	-0.18	-0.02
Vegetation	-0.34	-0.15	0.30	-0.42*
Habitat Connectivity	-0.22	-0.34	-0.25	-0.17
Final OKRAM	-0.37	-0.27	0.31	-0.48*

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APPENDICES

Appendix A: OKRAM datasheets

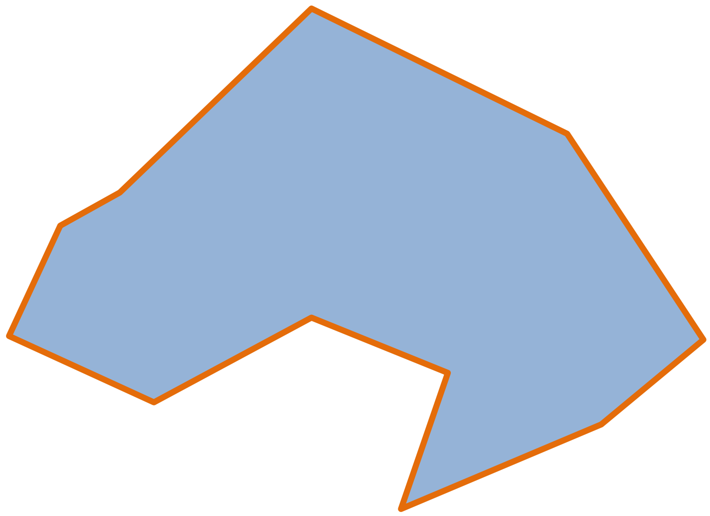
The Oklahoma Rapid Assessment Method (OKRAM) for Wetlands
IN THE OFFICE
Step 1: Assemble all the materials necessary to complete the assessment. Necessary geographic information systems (GIS) frame materials include: topographic quadrangles, aerial photographs, national wetlands inventory (NWI) maps, and land-use datasets. Additional relevant GIS data may be helpful and include soil maps, vegetation maps, geologic maps, hydrologic feature maps etc.
Step 2: Classify the wetland into the appropriate Hydrogeomorphic (HGM) subclass using the included dichotomous key (Worksheet II)
Step 3: Determine the boundary of the Assessment Area (AA). Ideally the assessment area will be 1 hectare. However, any AA size ranging from 0.1 to 1 hectares is acceptable. Delineate the boundary of the wetland. This can be completed using NWI maps or through visual assessment of aerial photography. The wetland boundary should only include one HGM subclass. If the entire wetland boundary is less than 1 hectare and greater than 0.1 hectare, conduct the assessment on the entire wetland. If the wetland is greater than 1 hectare randomly assign a point along the wetland boundary and delineate a 1 hectare AA within the wetland that contains that point. See worksheet III for assessment area diagrams.
Step 4: Complete the site description sheet, and metrics: 1b. Water Source, 2d. Buffer Filter, and 3b. Habitat Connectivity using GIS frame materials.
IN THE FIELD
Step 5. Ensure that the AA boundaries are appropriate, within the wetland and within one HGM subclass. Adjust the boundaries as necessary so AA is entirely contained within one HGM subclass and as close to 1 hectare as possible.
Step 6. Complete all OKRAM metric sheets. Check the accuracy of the metrics completed in the office and make changes to scores as necessary.
Step 7. Calculate the final site score by combining all the metrics on Worksheet 4: Condition Score. Attribute scores are calculated for hydrology, water quality and biota. These attribute scores are then combined to produce a maximum condition score of 1.
Step 8. In worksheet 5 record where you believe the assessment was inaccurate and how the assessment could be improved for future users.
Step 9. Enter hard copies of data into an electronic format in excel and GIS. Archive hard copies.

Hydrogeomorphic Wetland Subclassification Dichotomous Key

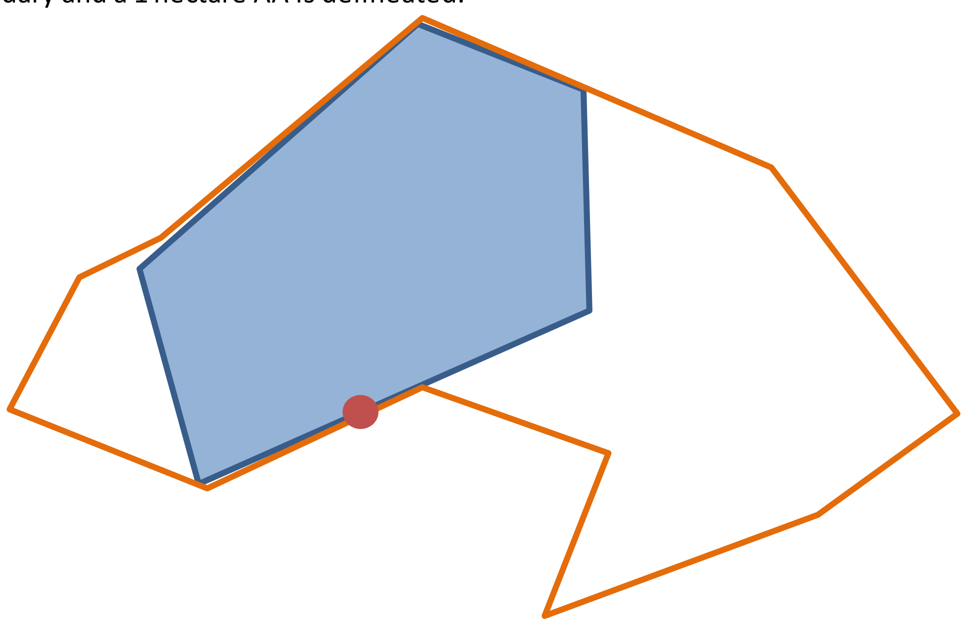
1. Wetland is within the 5 year floodplain of a river but not fringing an impounded water body.	*Riverine*(5)
1. Wetland is associated with a topographic depression, flat or slope.	2
2. Wetland is located on a topographic slope (slight to steep) and has groundwater as the primary water source. Wetland does not occur in a basin with closed contours.	*Slope* (16)
2. Wetland is located in a natural or artificial (dammed/excavated) topographic depression or flat.	3
3. Wetland is located on a flat without major influence from groundwater.	*Flat* (**Hardwood Flat**)
3. Wetland is located in a natural or artificial (dammed/excavated) topographic depression.	4
4. Topographic depression has permanent water greater than 2 meters deep.	*Lacustrine Fringe* (10)
4. Topographic depression does not contain permanent water greater than 2 meters.	*Depression*(12)
5. The wetland is a remnant river channel that is periodically hydrologically connected to a river or stream every 5 years or more frequently.	**Connected Oxbow**
5. The wetland is not an abandoned river channel.	6
6. The hydrology of the wetland is impacted by beaver activity.	**Beaver Complex**
6. The hydrology of the wetland is not impacted by beaver activity.	7
7. The wetland occurs within the bankfull channel.	**In-channel**
7. The wetland occurs on the floodplain or is adjacent to the river channel.	8
8. The wetland occurs within a depression on the floodplain.	**Floodplain Depression**
8. The wetland occurs on a flat area on the floodplain or is adjacent to the river channel.	9
9. Wetland water source primarily from overbank flooding that falls with the stream water levels or lateral saturation from channel flow.	**Riparian**
9. Wetland water source is primarily from overbank flooding that remains in the wetland due to impeded drainage after stream water level falls.	**Floodplain**
10. Wetland is associated with a remnant river channel that is hydrologically disconnected from the stream or river of origin.	**Disconnected Oxbow**
10. Wetland is associated with a reservoir or pond created by impounded or excavation.	11
11. Wetland water source is primarily from a permanent river.	**Reservoir Fringe**
11. Wetland water source is primarily from a draw or overland flow.	**Pond Fringe**
12. Wetland was created by human activity.	13
12. Wetland was not created by human activity.	14
13. Wetland does not have discernible water outlets.	**Closed Impounded Depression**
13. Wetland has discernible water outlet.	**Open Impounded Depression**
14. Wetland primary water source is groundwater.	**Groundwater Depression**
14. Wetland primary water source is surface water.	15
15. Wetland does not have any discernible water outlets.	**Closed Surface Water Depression**
15. Wetland has discernible water outlets.	**Open Surface Water Depression**
16. Wetland is hydrologically connected to a low order (Strahler <=4), high gradient, or ephemeral stream.	**Headwater Slope**
16. Wetland is hydrologically connected to a high order (Strahler >=5), low gradient river. Slope may be imperceptible or extremely gradual (includes wet meadows).	**Low Gradient Slope**

Assessment Area Diagrams

When a wetland is smaller than 1 hectare the entire wetland is the Assessment Area



When a wetland is greater than 1 hectare, a point is randomly assigned along the wetland boundary and a 1 hectare AA is delineated.



Legend

Wetland boundary   Assessment Area   Randomly selected point

Site Description

Site Name						
Date of Assessment						
Assessor Name(s)						
Assessor Affiliation(s)						
Site Latitude						
Site Longitude						
Coordinate System						
Ecoregion						
Directions						
Size of Wetland						
Assessment Area size						
Reason for Assessment						
Dominant Water Source	Surface flow	Precipitation			Groundwater	Overbank flooding
Hydrodynamics	Unidirectional	Bidirectional			Vertical	
Geomorphic Setting	Depression	Flat			Fringe	Slope
HGM Class	**Depression**	**Flat**	**Slope**		**Lacustrine**	**Riverine**
Regional Subclass	*Closed Impounded*	*Hardwood*	*Headwater*		*Disconnected Oxbow*	*Connected Oxbow*
	Open Impounded		*Low-gradient*		*Reservoir Fringe*	*Beaver Complex*
	Groundwater				*Pond Fringe*	*In-Channel*
	Open Surface Water					*Floodplain*
	Closed Surface Water					*Floodplain Depression*
						Riparian
Cowardin Class (four most dominant and area as a % of AA)	Class				% AA	
	Class				% AA	
	Class				% AA	
	Class				% AA	
Notes						

1. Hydrologic condition

a. Hydroperiod

Instructions:
1. On an aerial photograph in the field outline all areas within the AA where hydroperiod has been altered and severity of alteration. For calculations, sketches on aerial photographs can be converted to GIS or estimated from aerial photos.
2. Severity of alteration is based on indicator severity on the following worksheet.
3. Fill in the area as a percent of the AA and severity for each indicator of altered hydroperiod. Overlapping areas of indicators are only counted once and for the highest level of severity. Describe the indicator and circle all indicators on the indicator worksheet.
4. The metric is calculated by applying severity weights to the impacted area. For example a severity weight of 0.25 is applied to minor sources of impacted hydroperiod. If 50% of the AA is affected by a minor source of altered hydroperiod, the metric score would be 0.875 (1-[0.50*0.25] = 0.875).

Indicators of Reduced hydroperiod	**Minor**	**Moderate**	**Major**	**Complete Loss**	**Indicator Description**
Fill/sedimentation					
Water pumping out of the wetland					
Water control structures					
Culverts, discharges, ditches or tile drains out of the wetland					
Beaver dam removal					
Indicators of increased hydroperiod	**Minor**	**Moderate**	**Major**	**Complete Loss**	**Indicator Description**
Excavation/Dredging/Mining					
Water pumping into the wetland					
Water control structures					
Culverts, discharges, diversions or ditches into wetland					
TOTAL IMPACTED AREA	**0**	**0**	**0**	**0**	
SEVERITY WEIGHT	**0.25**	**0.5**	**0.75**	**1**	
SEVERITY WEIGHTED AREA	**0**	**0**	**0**	**0**	
METRIC SCORE 1A					**1**

1. Hydrologic condition

a. Hydroperiod	Severity			
Indicators of Reduced hydroperiod	**Minor**	**Moderate**	**Major**	**Complete Loss**
1. Fill/sedimentation	Silt covered vegetation, extremely turbid water, rills on adjacent uplands	Sediment splays, completely buried vegetation, silt deposits around trees	Silt deposits or fill that have greatly reduced wetland volume	Complete loss of basin.
2. Water pumping out of the wetland	Water level is properly manipulated for wetland management activities including slow, cool-season drawdowns. Desirable annual moist soil plants present.	Water is pumped out of the wetland for agricultural or other human uses *or* Water level is poorly manipulated for wetland management activities including rapid, warm-season drawdowns. Undesirable weedy plants present (e.g. cocklebur).	n/a	n/a
3. Water control structures	Water level is properly manipulated for wetland management activities including slow, cool-season drawdowns. Desirable annual moist soil plants present.	Water level is poorly manipulated for wetland management activities including rapid, warm-season drawdowns. Undesirable weedy plants present (e.g. cocklebur).	n/a	n/a
4. Culverts, discharges, ditches or tile drains out of the wetland	Old drainages present that appear to have minor influences on current wetland hydrology (e.g. old ditches that have sedimented in or tile drains that have been damaged)	Water drained only during high water events.	Water is drained from wetland at all times of the year but still retains wetland hydrology	Wetland completely dried
5. Beaver dam removal	n/a	n/a	Still retains wetland hydrology	Wetland completely dried
6. Center of wetland excavated to dry remainder of wetland	n/a	n/a	Still retains wetland hydrology	Wetland completely dried
Indicators of increased hydroperiod	**Minor**	**Moderate**	**Major**	**Complete Loss**
7. Excavation/ Dredging/ Mining	n/a	n/a	Wetland excavated but still retains wetland hydrology. Hydroperiod substantially lengthened.	Wetland converted to permanent deepwater
8. Water pumping into the wetland	Water level is properly manipulated for wetland management activities including slow, cool-season drawdowns. Desirable annual moist soil plants present.	Water level is poorly manipulated for wetland management activities including rapid, warm-season drawdowns. Undesirable weedy plants present (e.g. cocklebur).	n/a	n/a
9. Water control structures	Water level is properly manipulated for wetland management activities including slow, cool-season drawdowns. Desirable annual moist soil plants present.	Water level is poorly manipulated for wetland management activities including rapid, warm-season drawdowns. Undesirable weedy plants present (e.g. cocklebur).	n/a	n/a
10. Culverts, discharges, irrigation, diversions or ditches into wetland	Old drainages present that appear to have minor influences on current wetland hydrology (e.g. old ditches that have sedimented in)	Water enters wetland from culverts, diversions or ditches only during large storm events. Water is consistently discharged into wetland from agricultural irrigation.	Water from culvert, diversion, irrigation or ditch is the dominant water source for the wetland.	Wetland converted to permanent deepwater

1. Hydrologic condition

b. Water Source

Instructions:

1. Follow the stream from the wetland location to the stream headwaters or the HUC 8 watershed boundary. Identify the distance to the nearest impoundment on the stream that supplies water to the wetland. Impoundments within 500m will receive a score reduction of 0.3, within 5km will receive a score reduction of 0.2 and within the HUC 8 boundary will receive a score reduction of 0.1. Score reductions reduce the total possible score for this metric. For example a wetland with an upstream impoundment at 300m from the wetland will have a maximum possible score of 0.7 or 1.0-0.3.
2. Repeat step 1 but follow the river downstream to it's confluence or until the HUC 8 boundary is reached. Measure the distance to any portion of the river or stream that shows a clear indicator of influence from a downstream impoundment (e.g. widening or lack of flow). Use the same distance thresholds for applying score reductions.
3. Fill in the % Cover of each of the indicators of altered water source within the HUC 12 watershed for which the wetland is contained. Each area is then multiplied by the severity multiplier listed for that indicator of altered water source.
4. The percentage of altered land within the HUC 12 watershed is scaled to the maximum possible score determined by impoundment score reductions and subtracted from the best possible score for that wetland based on the impoundment score reductions. ((100*(1-(HUC 8 score reductions)))-(Total Altered cover*(HUC 8 score reductions)))/100. Because some severity multipliers are greater than 1, it is possible to have a score less than 0. Scores less then 0 are

HUC 8 Upstream Indicators of altered water source	**Distance**	**Score Reduction**
Upstream Impoundment		
Downstream Impoundment		

HUC 12 Indicators of altered water source	**% Cover**	**Description**
Impervious surface (paved roads, parking lots, structures and compacted gravel and dirt roads)		
Irrigated agricultural land (center pivot, ditch, flood etc.)		
Dryland agricultural land that is tilled		
Woody encroachment (e.g. eastern red cedar (*Juniperus virginiana*) and salt cedar (*Tamarix* sp.))		
Impounded water		
Topographic alteration (leveling, excavation, mining)		
Total Altered Cover		
METRIC SCORE 1b		1

1. Hydrologic condition

b. Water Source Alternate

Instructions:

1. Follow the stream from the wetland location to the stream headwaters or the HUC 8 watershed boundary. Identify the distance to the nearest impoundment on the stream that supplies water to the wetland. Impoundments within 500m will receive a score reduction of 0.3, within 5km will receive a score reduction of 0.2 and within the HUC 8 boundary will receive a score reduction of 0.1. Score reductions reduce the total possible score for this metric. For example a wetland with an upstream impoundment at 300m from the wetland will have a maximum possible score of 0.7 or 1.0-0.3.

2. Repeat step 1 but follow the river downstream to it's confluence or until the HUC 8 boundary is reached. Measure the distance to any portion of the river or stream that shows a clear indicator of influence from a downstream impoundment (e.g. widening or lack of flow). Use the same distance thresholds for applying score reductions.

3. Fill in the % Cover of each of the indicators of altered water source within the HUC 12 watershed for which the wetland is contained. Each area is then multiplied by the severity multiplier listed for that indicator of altered water source.

4. The percentage of altered land within the HUC 12 watershed is scaled to the maximum possible score determined by impoundment score reductions and subtracted from the best possible score for that wetland based on the impoundment score reductions. ((100*(1-(HUC 8 score reductions)))-(Total Altered cover*(HUC 8 score reductions)))/100. Because some severity multipliers are greater than 1, it is possible to have a score less than 0. Scores less then 0 are changed to 0.

HUC 8 Upstream Indicators of altered water source	**Distance**	**Score Reduction**
Upstream Impoundment		
Downstream Impoundment		

HUC 12 Indicators of altered water source	**% Cover**	**Severity Multiplier**	**Description**
Impervious surface (paved roads, parking lots, structures and compacted gravel and dirt roads)		1.5	
Irrigated agricultural land (center pivot, ditch, flood etc.)		1.5	
Dryland agricultural land that is tilled		0.5	
Woody encroachment (e.g. eastern red cedar (*Juniperus virginiana*) and salt cedar (*Tamarix* sp.))		0.5	
Impounded water		2	
Topographic alteration (leveling, excavation, mining)		1	
Total Altered Cover			0
METRIC SCORE 1b			**1**

1. Hydrologic condition

c. Hydologic Connectivity

Instructions: 1. If river access is possible find the closest point in the river to the wetland. This metric will be assessed 100 m upstream and 100 m downstream of that point. If this metric is scored from a bridge crossing, use a range finder to determine the maximum distance visible upstream and downstream. The stream will be assessed for the maximum visible distance. In the field estimate the length of stream assessed and impacted by the indicators of channel degradation or aggradation listed below. For each meter of stream, only count one indicator. 2. The metric is scored simply as the percentage of unaltered stream length assessed. For example a channel length of 100m that has 10 meters of undercut banks and 5 meters of leaning riparian vegetation would score 1-((10+5)/100)		
Channel Length	1	
Indicators of Reduced Connectivity	**Channel Length Impacted**	**Indicator Description**
Vertical/Sheer banks		
Undercut banks		
Bank slumps or slides		
Lower banks uniformly scoured and un-vegetated		
Riparian vegetation leaning or declining		
Channel bed scoured to bedrock/dense clay		
Braided stream coallesced into one channel		
Channel has knickpoints indicating headward erosion		
Channel straightening		
Indicators of Aggradation	**Channel Length Impacted**	**Indicator Description**
Active floodplain with fresh splays of coarse sediment deposited in the current or previous year		
Partially buried living tree trunks or shrubs along banks		
Bed is planar (flat or uniform gradient) overall; lacks well defined pools or poolsare evenly spaced		
Partially buried or sediment choked culverts		
Perennial terrestrial or riparian vegetation is encroaching into the channel or onto channel bars below the bankfull contour		
Avulsion channels on the floodplain or adjacent valley floor		
TOTAL IMPACTED AREA	**0**	
METRIC SCORE 1A	**1**	

2. Water Quality Condition

a. Nutrients/Eutrophication

1. On an aerial photograph in the field outline all areas within the AA where nutrient cycling has been altered and severity of alteration. For calculations, sketches on aerial photographs can be converted to GIS or estimated from aerial photos.
2. Severity of alteration is based on indicator severity on the following worksheet.
3. Fill in the area as a percent of the AA and severity for each indicator of altered nutrient cycling. Overlapping areas of indicators are only counted once and for the highest level of severity. Describe the indicator and circle all indicators on the indicator worksheet.
4. The metric is calculated by applying severity weights to the impacted area. For example a severity weight of 0.25 is applied to minor sources of impacted nutrient cycling. If 50% of the AA is affected by a minor source of altered nutrient cycling, the metric score would be 0.875 (1-[0.50*0.25] = 0.875).

Indicators of Altered Nutrient Cycling	Minor	Moderate	Major	Indicator Description
Livestock/animal waste				
Septic/sewage discharge				
Excessive algae or Lemna sp. (Do not count this metric if algae or Lemna blooms are a result of evapoconcentration of nutrients as wetland is drying.)				
TOTAL IMPACTED AREA	**0**	**0**	**0**	
SEVERITY WEIGHT	**0.25**	**0.5**	**0.75**	
SEVERITY WEIGHTED AREA	**0**	**0**	**0**	
METRIC SCORE 2a				**1**

2.Water Quality

a. Nutrients	**Severity**		
Indicators of Altered Nutrient Cycling	**Minor**	**Moderate**	**Major**
Livestock/animal waste	Sparse domestic animal feces (e.g. cow pies), evidence of sparse feral pig activity (rooting, wallows, feces)	High concentration of domestic animal feces (e.g. cow pies), evidence of large scale feral pig activity (rooting, wallows, feces)	Runoff from wastewater lagoons into wetland, Evidence of manure piles, poultry litter piles draining to wetland
Septic/sewage discharge	Residential dwellings within 200 meters of wetland	Residential dwellings within 50 meters of wetland	Discharge from sewage treatment plant
Excessive algae or Lemna sp. (Do not count this metric if algae or *Lemna* blooms are a result of evapoconcentration of nutrients as wetland is drying.)	Sparse mats or blooms of filamentous algae, Lemna, or cyanobacteria. Small contiguous patches are less than 200 square meters	Mats or blooms of filamentous algae, *Lemna* , or cyanobacteria may cover large areas but will not be contiguous for more than 0.1 hectares and will contain intermittent gaps where no mats or blooms or present.	Mats or blooms of filamentous algae, *Lemna* , or cyanobacteria that are contiguous for areas larger than 0.1 hectares.

2. Water Quality Condition

b. Sediment

1. On an aerial photograph in the field outline all areas within the AA where sediment loading has been altered and severity of alteration. For calculations, sketches on aerial photographs can be converted to GIS or estimated from aerial photos.
2. Severity of alteration is based on indicator severity on the following worksheet.
3. Fill in the area as a percent of the AA and severity for each indicator of altered sediment loading. Overlapping areas of indicators are only counted once and for the highest level of severity. Describe the indicator and circle all indicators on the indicator worksheet.
4. The metric is calculated by applying severity weights to the impacted area. For example a severity weight of 0.25 is applied to minor sources of impacted sediment loading. If 50% of the AA is affected by a minor source of altered sediment loading, the metric score would be 0.875 (1-[0.50*0.25] = 0.875).

Indicators of Altered Sediment loading	Minor	Moderate	Major	Indicator Description
Sedimentation (e.g. presence of sediment plumes, fans or deposits, turbidity, silt laden vegetation)				
Upland erosion (e.g. gullies, rills)				
TOTAL IMPACTED AREA	**0**	**0**	**0**	
SEVERITY WEIGHT	**0.25**	**0.5**	**0.75**	
SEVERITY WEIGHTED AREA	**0**	**0**	**0**	
METRIC SCORE 2b		**1**		

2.Water Quality

b. Sediment	Severity		
Indicators of Altered Sediment Loading	**Minor**	**Moderate**	**Major**
Sedimentation (e.g. presence of sediment plumes, fans or deposits)	Excessive turbidity (in excess of expectation for the system), silt laden vegetation	Sediment plumes or fans, silt deposits less than 0.5 centimeters in thickness	Silt deposits greater than 0.5 centimeters in thickness
Upland erosion (e.g. gullies, rills)	Sparse rills connecting upland to wetland. Sediment washing down cattle/wildlife trails.	Dense rills connecting upland to wetland	Gullies connecting upland to wetland

2. Water Quality Condition

c. Chemical contaminants

1. On an aerial photograph in the field outline all areas within the AA where chemical contaminants have been introduced and severity of alteration. For calculations, sketches on aerial photographs can be converted to GIS or estimated from aerial photos.
2. Severity of alteration is based on indicator severity on the following worksheet.
3. Fill in the area as a percent of the AA and severity for each indicator of introduced chemical contaminants. Overlapping areas of indicators are only counted once and for the highest level of severity. Describe the indicator and circle all indicators on the indicator worksheet.
4. The metric is calculated by applying severity weights to the impacted area. For example a severity weight of 0.25 is applied to minor sources of chemical contaminants. If 50% of the AA is affected by a minor source of chemical contaminants, the metric score would be 0.875 (1-[0.50*0.25] = 0.875).

Indicators of Chemical Contaminants	Minor	Moderate	Major	Indicator Description
Point source discharge (wastewater plant, factory etc.)				
Stormwater inputs (discharge pipes, culverts, adjacent impervious surface or railroads)				
Increased salinity (e.g. salt crust)				
Industrial spills or dumping				
Oil sheen*				
TOTAL IMPACTED AREA	**0**	**0**	**0**	
SEVERITY WEIGHT	**0.25**	**0.5**	**0.75**	
SEVERITY WEIGHTED AREA	**0**	**0**	**0**	
METRIC SCORE 2c				**1**

Notes:

*Oil sheen can result from petroleum spills or from a natural phenomena. If the oil sheen does not break apart when hit with a stick, it is a result of a petroleum spill and should be counted as an indicator of chemical contaminants. If the oil sheen does break apart when hit, do not count it as a chemical contaminant.

2.Water Quality

c. Contaminants	Severity		
Indicators of Chemical Contaminants	**Minor**	**Moderate**	**Major**
Point source discharge (wastewater plant, factory etc.)	n/a	Discharge from wastewater/sewage treatment plant or industrial factor to adjacent water body that is intermittently connected to wetland	Direct discharge from wastewater treatment plant or industrial factory
Stormwater inputs (discharge pipes, culverts, adjacent impervious surface or railroads)	Adjacent impervious surfaces such as paved roads or railroads (within 10 meters of wetland)	Stormwater inputs from culverts or discharge pipes	n/a
Increased salinity (e.g. salt crust, excessively high conductivity)	Oil and gas exploration within 30 meters of wetland (e.g. pumpjacks, tank batteries)	Salt crust present on soil surface (excludes saline wetlands such as those in the Great Salt Plains of Alfalfa County)	n/a
Industrial spills or dumping	55 gallon drums present but otherwise no signs of chemical contamination, metal objects or other potentially harmful trash dumped within the wetland. Evidence of drilling mud application.	n/a	Knowledge or evidence of industrial spill within or directly adjacent to the wetland
Oil sheen	Oil sheen present but not contiguous over areas exceeding 200 square meters, likely a result of motorcraft use within or adjacent to the wetland	Oil sheen contiguous over moderate areas within the wetland exceeding 200 square meters, likely a result of a spill or adjacent exploration	Oil sheen contiguous over large areas within the wetland exceeding 0.1 hectares, likely a result of a spill or adjacent exploration

2. Water Quality Condition

d. Buffer filter

Instructions:

1. On an aerial photograph or in GIS, draw eight evenly spaced 250 m lines emanating from the AA boundary starting at due North. If the AA is directly adjacent to permanent open water exclude that portion of the boundary from buffer calculations.

2. Calculate the distance to human impacted land-use (see table below). First observe the distance to high impact land-use. For high impact land-use the buffer must be 250 m in length to be fully functioning. If no high impact land-use is encountered, observe the distance to moderate impact land-use. The buffer must be 100 m to moderate impact land-use be fully functioning. If no high or moderate land-use is encountered, observe the distance to low impact land-use. The buffer must be 30 m to low impact land-use to be considered fully functioning.

3. For each buffer line calculate the percentage of intact buffer distance. For example if the buffer is intact for 80 meters before intersecting a golf course the buffer is 80% of fully functioning (80/100). On the other hand, if the buffer is intact for 80 meters before intersecting a feedlot the buffer is only 32% functioning (80/250). If no altered land-use is encountered on a buffer line both the required distance and intact distance are recorded as 250.

4. For the overall buffer filter score, take the average of all eight buffer lines.

Land-uses that can be included in a functioning buffer: natural uplands, water bodies not directly adjacent to AA, wildland parks, bike trails, foot trails, horse trails, gravel/dirt roads, railroads

Land use category	**Types of Land-use Beyond Buffer**	**Buffer width**
High Impact	Intensive livestock (feedlot, dairy farm, pig farm) or urban area	250m
Moderate Impact	Conventional tilled agriculture, landscaped park, golf course, suburban area, active construction sites, areas of vegetation removal, earth moving operations	100m
Low Impact	No till agriculture, hay meadow, active paved road, minimal use recreation area, improved pasture	30m

Buffer	Required Distance (based on first encountered land-use)	Intact Distance
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
METRIC SCORE 2d	**1**	

2. Water Quality Condition

d. Buffer filter Alternate

Instructions:

1. On a topographic map or in GIS, observe the topography of the area surrounding the wetland. Approximate the area that drains to the wetland using the available contour maps. Draw eight evenly spaced 250 m lines emanating from the portion of the AA boundary downslope of the surrounding area. For example, if 100 meters of the AA boundary is at a higher elevation than the surrounding area it is excluded from this metric. The eight buffer lines would then be spaced evenly in the remaining area. If the AA is directly adjacent to permanent open water exclude that portion of the boundary from buffer calculations.
2. Calculate the distance to human impacted land-use (see table below). First observe the distance to high impact land-use. For high impact land-use the buffer must be 250 m in length to be fully functioning. If no high impact land-use is encountered, observe the distance to moderate impact land-use. The buffer must be 100 m to moderate impact land-use be fully functioning. If no
3. For each buffer line calculate the percentage of intact buffer distance. For example if the buffer is intact for 80 meters before intersecting a golf course the buffer is 80% of fully functioning (80/100). On the other hand, if the buffer is intact for 80 meters before intersecting a feedlot the buffer is only 32% functioning (80/250). If no altered land-use is encountered on a buffer line both the required distance and intact distance are recorded as 250.
4. For the overall buffer filter score, take the average of all eight buffer lines.

Land-uses that can be included in a functioning buffer: natural uplands, water bodies not directly adjacent to AA, wildland parks, bike trails, foot trails, horse trails, gravel/dirt roads, railroads

Land use category	**Types of Land-use Beyond Buffer**	**Buffer width**
High Impact	Intensive livestock (feedlot, dairy farm, pig farm) or urban area	250m
Moderate Impact	Conventional tilled agriculture, landscaped park, golf course, suburban area, active construction sites, areas of vegetation removal, earth moving operations	100m
Low Impact	No till agriculture, hay meadow, active paved road, minimal use recreation area, improved pasture	30m

Buffer	Required Distance (based on first encountered land-use)	Intact Distance
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
METRIC SCORE 2d	**1**	

a. Vegetation condition

Instructions:

1. Conduct a visual assessment of the percent cover of each vegetation layer and % cover of indicators of altered vegetation community in each vegetation layer.
2. Vegetation condition score is based on the percent of unimpacted vegetation cover relative to the overall vegetation cover. Percent cover of a layer is assessed as what would be present if disturbance had not occurred. For example if tree stumps are present throughout the AA, the percent cover of the tree layer would include an estimate of what would be present prior to tree removal. The indicators of altered vegetation community are then assessed as a percentage of that layer impacted from 0 to 100%.

	Vegetation Layers			
Indicators of altered vegetation community (% cover in each layer)	**Tree**	**Shrub/sapling**	**Herbaceous/ Emergent**	**Submergent/ Floating leaved**
Invasive species and crop/pasture grasses*	0	0	0	0
Native monoculture (only emergent and submergent layers) **	0	0	0	0
Vegetation removal (e.g. tree harvest, brush hogging, haying, mowing, animal trampling, animal rooting) ***	0	0	0	0
Excessive grazing (only emergent and submergent) ****	0	0	0	0
Herbicide impacted area	0	0	0	0
Mechanical disturbance from structures (e.g. rip-rap, right of ways and roads etc.)	0	0	0	0

Percent Cover of Layer	0	0	0	0
Percent disturbed cover per layer	0	0	0	0
METRIC SCORE 4a	1			

Notes:

* Invasive species include all plant species listed on the Oklahoma Non-Native Invasive Plant Species List developed by OK Native Plant Society, OK Biological Survey and OSU Natural Resource Ecology and Management. A species is considered invasive if it is listed as a problem in border states as well. http://ok-invasive-plant-council.org/images/OKinvasivespp.pdf

** Native monocultures occur when more than 50% of a an assessment area is covered by one native perennial species including cattails (*Typha* sp.)*, river bulrush (Schoenoplecuts fluviatis)*, giant cutgrass (*Zizaniopsis miliacea)*, and reed canary grass (*Phalaris arundinacea).* Native monoculture cover is scored as the percent cover greater than 50%. For example a wetland with 70% cover reed canary grass would receive a score of 20% (70-50= 20).

*** Vegetation removal can be an effective management strategy for improving the quality of wetland vegetation by removing invasive species or native monocultures. Vegetation removal for invasive species or monoculture control should not be included in this field. Vegetation removal resulting from normal flood events is not considered a stressor and should not be listed.

**** Excessive grazing represents areas where vegetation is eaten to the ground. Grazing can be an effective management strategy for improving the quality of wetland vegetation by removing invasive species or native monocultures. Grazing for invasive species or monoculture control should not be included in this field.

3. Biotic Condition

b. Habitat connectivity

Instructions: 1. On an aerial photograph or in GIS delineate the connected habitat surrounding the AA within a 2500 m buffer. Connected habitat does not include any of the dispersal barriers below. 2. Calculate the metric by dividing the total connected area by the total area in the 2500 m buffer.	
Included in connected habitat	
open water	
other wetlands	
natural uplands	
nature or wildland parks	
bike trails	
railroads	
roads not hazardous to wildlife	
swales and ditches	
vegetated levees	
open range land	
Dispersal Barriers not included in connected habitat	
Commercial Developments	
Fences that interfere with animal movements	
intensive agriculture (e.g. row crops, orchards, vineyards)	
dryland farming	
paved roads	
lawns	
parking lots	
intensive livestock production (e.g. horse paddocks, feedlots, chicken ranches etc.)	
residential areas	
sound walls	
sports fields	
traditional golf courses	
urbanized parks with active recreation	
pedestrian/bike trails with near constant traffic	
Energy development	
Area of Connected Habitat	0
Area within 2500 m buffer	0
METRIC SCORE 4c	1

3. Biotic Condition

b. Habitat connectivity

Instructions: 1. Land use surrounding the wetland is divided into three categories, connected, marginal, and dispersal barriers. This metric is scored as the average of two measures of connectivity. One measure includes all connected and marginal habitat and the second only includes connected habitat. On an aerial photograph or in GIS delineate the connected habitat types surrounding the AA within a 1000 m buffer. 2. Calculate connected and marginal habitat (connected habitat area+ marginal habitat area)/total area)	
3. Calculate connected habitat (connected habitat/total area)	
3. Calculate the total metric by averaging the scores derived in steps 2 and 3	
Connected habitat	
open water	
other wetlands	
natural uplands	
nature or wildland parks	
railroads	
roads not hazardous to wildlife	
swales and ditches	
vegetated levees	
open range land	
Marginal Habitat	
hay meadows	
pine plantations	
pedestrian/bike trails with near constant traffic	
forests converted to rangeland	
Dispersal Barriers not included in connected habitat	
Commercial Developments	
Fences that interfere with animal movements	
intensive agriculture (e.g. row crops, orchards, vineyards)	
dryland farming	
heavily managed pasture lands	
paved roads	
lawns	
parking lots	
intensive livestock production (e.g. horse paddocks, feedlots, chicken ranches etc.)	
residential areas	
sound walls	
sports fields	
traditional golf courses	
urbanized parks with active recreation	
Energy Development	
Area of Connected and Marginal Habitat	
Area of Connected Habitat	
Area within 1000 m buffer	
METRIC SCORE 4c	1

	Metric	Score		
1	***Hydrology***			
1a.	Hydroperiod	1		
1b.	Water source	1		
1b.	Water source- Alt	1		
1c.	Hydrologic Connectivity	1		
1c.	Hydrologic Connectivity-Alt	1		
	Hydrology Attribute	**1**	**Hydrology Attribute Alternative**	**1**
	(metric 1a +metric 1b + metric 1c)/3			
2	***Water Quality***			
2a.	Nutrients	1		
2b.	Sediment	1		
2c.	Contaminants	1		
2d.	Buffer Filter	1		
2d.	Buffer Filter-Alt	1		
	Water Quality Attribute	**1**	**Water Quality Attribute Alternati**	**1**
	(metric 2a +metric 2b + metric 2c + metric 2d)/4			
3	***Biota***			
3a.	Vegetation	1		
3b.	Habitat Connectivity	1		
3b.	Habitat Connectivity-Alt	1		
	Biota Attribute	**1**	**Biota Attribute Alternative**	**1**
	(metric 3a + metric 3)/2			
Overall Condition Score		**1**	**Overall Condition Score (Alt)**	**1**

Appendix B: List of plant species collected from 30 floodplain wetlands in central Oklahoma in 2018 and c-values assigned according to Oklahoma guidance (Ewing and Hoagland 2012). When species lacked a C-value on the Oklahoma taxonomic list, c-values developed for Kansas (Freeman and Morse 2002), and Missouri (Ladd 1993) were applied.

Scientific Name	Coefficient of Conservatism	Number of Sites
Acalypha rhomboidea	1*	12
Acer negundo	1	21
Acer saccharinum	2*	3
Ageratina altissima	1*	2
Allium canadense	3	1
Amaranthus tuberculatus	0*	3
Ambrosia artemisiifolia	3	2
Ambrosia psilostachya	3	3
Ambrosia trifida	2	11
Amorpha fruticose	6	2
Amorpha laevigata	6	1
Ampelopsis arborea	4	6
Ampelopsis cordata	2	3
Andropogon virginicus	0*	2
Apios americana	6	1
Argythamnia humilis	8*	1
Arisaema dracontium	6	1
Aristida desmantha	6*	2
Aristolochia tomentosa	7*	4
Asclepias incarnata	5	1
Asclepias viridiflora	6*	1
Asclepias viridis	1*	1
Betula nigra	3	3
Boehmeria cylindrica	6	12
Botrychium biternatum	10**	5
Bromus racemosus	0	1
Broussonetia papyrifera	0	1
Campsis radicans	3	20
Cardiospermum halicacabum	0	4
Carex arkansana	7*	1
Carex bulbostylis	8*	1
Carex cherokeensis	6	1
Carex crus-corvi	7	6
Carex debilis	9	1
Carex frankii	5	1
Scientific Name	**Coefficient of Conservatism**	**Number of Sites**
Carex gracilescens	7**	2
Carex grisea	3*	1
Carex hyalinolepis	5	2

Carex hystericina	7	1
Carex leavenworthii	2*	1
Carex lupuliformis	8	1
Carex microdonata	7	1
Carex muhlenbergii	6*	1
Carex squarrosa	7	2
Carex tribuloides	4	10
Carya cordiformis	4*	3
Carya illinoinensis	6	20
Celtis laevigata	5*	18
Celtis occidentalis	5	2
Celtis reticulata	5*	1
Cephalanthus occidentalis	4	3
Cercis canadensis	2*	2
Chamaesyce maculata	3	1
Chamaesyce prostrata	0*	1
Chasmanthium latifolium	4	15
Chenopodium album	0*	1
Chenopodium incanum	6*	1
Chenopodium pallescens	1*	1
Chenopodium pratericola	3*	1
Chenopodium simplex	3	1
Chenopodium standleyanum	3	1
Cirsium altissimum	2*	2
Cirsium carolinianum	8**	1
Clematis pitcher	4*	1
Cocculus carolinus	3	7
Commelina erecta	4	6
Conoclinium coelestinum	4	2
Convolvulus arvensis	0	1
Conyza canadensis	0*	8
Coreopsis tinctoria	1	1
Cornus drummondii	3	5
Cornus florida	6*	3
Crataegus viridis	4*	2
Croton glandulosus	1*	2
Croton texensis	1*	1
Cynanchum leave	2	5

Scientific Name	**Coefficient of Conservatism**	**Number of Sites**
Cynodon dactylon	0	11
Cyperus acuminatus	3	1
Cyperus odoratus	3	4

Cyperus reflexus	4	1
Cyperus retrorsus	4*	2
Desmodium paniculatum	4*	4
Desmodium pauciflorum	8*	1
Dichanthelium oligosanthes	5	4
Digitaria ciliaris	0*	1
Digitaria sanguinalis	0	1
Diospyros virginiana	2	6
Dysphania ambrosioides	0*	3
Echinochloa crus-galli	0	1
Echinochloa muricata	0	5
Eclipta prostrata	3	1
Elephantopus carolinianus	4*	8
Elymus canadensis	5*	2
Elymus virginicus	3*	11
Erigeron strigosus	4*	1
Eriochloa contracta	0*	2
Erodium texanum	1*	2
Euonymus fortunei	0	1
Eupatorium serotinum	3	2
Euphorbia dentata	0*	1
Euphorbia exstipulata	0*	1
Euphorbia hexagona	2*	1
Euphorbia marginata	0*	1
Festuca paradoxa	7*	2
Festuca subverticillata	4*	2
Festuca versuta	9*	1
Fleischmannia incarnata	9**	2
Forestiera acuminata	7	9
Fraxinus americana	6	1
Fraxinus pennsylvanica	3	16
Galactia regularis	6**	1
Gamochaeta purpurea	3	1
Geum canadense	1*	2
Gleditsia triacanthos	2	7
Glycine max	0	1
Gonolobus suberosus	7**	6
Helenium amarum	1	1

Scientific Name	**Coefficient of Conservatism**	**Number of Sites**
Helianthus petiolaris	1*	1
Heliotropium indicum	0	2
Heterotheca subaxillaris	2*	1

Scientific Name	Coefficient of Conservatism	Number of Sites
Hieracium gronovii	5*	1
Ilex decidua	5	14
Impatiens capensis	5	2
Ipomoea lacunose	2	7
Iva angustifolia	1*	1
Iva annua	1*	4
Juglans nigra	4	1
Juncus interior	2*	1
Juniperus virginiana	1*	4
Koeleria macrantha	6*	1
Kummerowia stipulacea	0	1
Kummerowia striata	0	2
Lactuca canadensis	2	1
Lactuca floridana	3*	1
Lactuca serriola	0	2
Lathyrus hirsutus	0	1
Leersia virginica	4	4
Lepidium densiflorum	0*	2
Lepidium virginicum	0*	1
Leptochloa panicea	3	1
Lespedeza cuneata	0	5
Lespedeza repens	5*	1
Lespedeza stuevei	4*	1
Leucospora multifida	0	1
Ligustrum sinense	0	1
Lindera benzoin	7	1
Lobelia cardinalis	6	1
Lonicera japonica	0	7
Lycopus americanus	4	1
Maclura pomifera	0	1
Melothria pendula	1	5
Mollugo verticillata	1	4
Monarda punctata	5*	1
Morus alba	0	11
Morus rubra	5*	5
Ostrya virginiana	5*	1
Oxalis corniculate	0*	8
Panicum anceps	4*	1
Panicum coloratum	0	4
Panicum philadelphicum	4*	1
Parthenocissus quinquefolia	2	14

Paspalum dilatatum	0	1
Paspalum floridanum	5	2
Paspalum pubiflorum	4	2
Passiflora incarnata	4*	2
Perilla frutescens	0	3
Phyla lanceolata	3	4
Physalis longifolia	2*	2
Physalis pubescens	4*	3
Phytolacca americana	0*	2
Pilea pumila	2	2
Platanus occidentalis	4	8
Pluchea odorata	4	1
Poa compressa	0	1
Polygonella americana	10**	3
Polygonum erectum	1*	1
Polygonum hydropiperoides	4	10
Polygonum lapathifolium	4	1
Polygonum pensylvanicum	2	2
Polygonum punctatum	4	12
Polygonum ramosissimum	1	1
Polygonum setaceum	5	1
Polygonum virginianum	2*	5
Polypremum procumbens	4**	1
Populus deltoides	1	9
Portulaca oleracea	0	1
Prunus americana	3*	1
Prunus angustifolia	3	3
Prunus Mexicana	3*	1
Pyrrhopappus carolinianus	3	1
Quercus macrocarpa	4*	7
Quercus michauxii	9**	2
Quercus muehlenbergii	5*	1
Quercus nigra	5**	2
Quercus palustris	3*	2
Quercus phellos	4	1
Quercus rubra	6*	4
Quercus shumardii	6*	1
Quercus stellate	4*	2

Scientific Name	**Coefficient of Conservatism**	**Number of Sites**
Ranunculus abortivus	4	1
Robinia pseudoacacia	1	1
Rotala ramosior	4	1

Rumex latissimus	0	2
Rumex crispus	0	5
Salix nigra	2	9
Salsola tragus	0	1
Sanicula canadensis	2	1
Sapindus drummondii	3*	4
Scutellaria lateriflora	5	1
Setaria faberi	0	2
Setaria pumila	0	7
Sida spinosa	0	3
Sideroxylon lanuginosum	5	5
Smilax bona-nox	5	21
Smilax tamnoides	2*	7
Solanum carolinense	1	6
Solidago canadensis	3	1
Solidago gigantea	3*	2
Solidago speciosa	7*	4
Sorghum halepense	0	8
Spiranthes cernua	5	4
Strophostyles helvola	3*	1
Strophostyles leiosperma	3*	1
Symphoricarpos orbiculatus	1	9
Symphyotrichum drummondii	2*	1
Symphyotrichum subulatum	4	4
Symplocos tinctoria	6*	2
Teucrium canadense	3	6
Toxicodendron radicans	1	17
Tridens flavus	1	2
Tridens strictus	6*	1
Tridens x oklahomensis	0	1
Trifolium pratense	0	1
Trifolium repens	0	2
Ulmus alata	3	5
Ulmus americana	2	15
Ulmus rubra	3	15
Urtica chamaedryoides	8*	5
Verbena urticifolia	3	2
Verbesina alternifolia	4	1
Scientific Name	**Coefficient of Conservatism**	**Number of Sites**
Verbesina encelioides	1*	1
Vernonia missurica	4	1
Viburnum rufidulum	5*	2

Vicia caroliniana	6*	1
Vicia sativa	0	1
Vitis acerifolia	5*	5
Vitis aestivalis	4	4
Vitis cinera	4	1
Vitis riparia	4	5
Vitis vulpine	3*	6
Xanthium strumarium	0	5
Zizaniopsis miliacea	9	2

Notes: * Kansas c-value; ** Missouri c-value

Appendix C: Oklahoma Rapid Assessment Method (OKRAM), Floristic Quality Index (FQI), and Landscape Development Intensity Index (LDI) scores for 30 floodplain wetlands sampled in 2018 along the Deep Fork (DF) and North Canadian (NC) rivers in central Oklahoma.

Site	Stream	Stream Size	Hydroperiod	Water Source	Water Source Alt	Hydro Connectivity	Att 1: Hydrology	Att 1: Hydrology Alt	Nutrients	Sediment	Contaminants	Buffer Filter	Buffer Filter Alt	Att 2: WaterQuality	Att 2: WQ Alt	Vegetation	Habitat Connectivity	Habitat Conne Alt	Att 3: Biota	Att 3: Biota Alt	Final OKRAM	Final OKRAM Alt	FQI	LDI
01_18	DF	Main	1.00	0.79	0.74	0.26	0.68	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.77	0.77	0.87	0.87	0.85	0.84	22.61	1.24
02_18	DF	Main	1.00	0.79	0.77	1.00	0.93	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.97	18.44	1.02
03_18	DF	Main	1.00	0.80	0.79	0.00	0.60	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.87	0.94	0.94	0.85	0.84	19.80	1
04_18	DF	Main	1.00	0.80	0.78	0.00	0.60	0.59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.94	0.97	0.97	0.86	0.85	17.44	1
05_18	DF	Trib	1.00	0.79	0.75	0.50	0.76	0.75	1.00	1.00	1.00	0.38	0.00	0.84	0.75	0.18	0.61	0.33	0.40	0.25	0.67	0.58	18.07	2.17
06_18	NC	Trib	1.00	0.06	0.29	0.00	0.35	0.43	1.00	1.00	1.00	0.00	0.00	0.75	0.75	0.40	0.00	0.00	0.20	0.20	0.43	0.46	3.18	4.04
07_18	NC	Main	1.00	0.80	0.79	1.00	0.93	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.93	0.97	0.97	0.97	0.97	15.72	1.04
08_18	NC	Main	1.00	0.79	0.78	0.27	0.69	0.68	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	0.99	0.90	0.89	15.69	1.16
09_18	NC	Main	1.00	0.79	0.77	0.00	0.60	0.59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.82	0.78	0.89	0.87	0.83	0.82	16.28	1.73
10_18	NC	Main	1.00	0.80	0.80	0.00	0.60	0.60	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00	1.00	0.96	0.96	0.85	0.85	13.35	1.32
11_18	NC	Main	1.00	0.80	0.79	0.21	0.67	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.87	1.00	0.93	0.89	0.87	21.67	1.25
12_18	NC	Main	1.00	0.77	0.72	0.75	0.84	0.82	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.81	0.95	0.91	0.93	0.91	17.85	1.58
13_18	NC	Trib	0.25	0.54	0.45	0.10	0.30	0.27	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.47	0.23	0.23	0.12	0.51	0.46	0.00	3.53
14_18	DF	Main	1.00	0.80	0.80	0.66	0.82	0.82	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.56	0.51	0.78	0.76	0.87	0.86	22.29	1.06
15_18	NC	Main	0.75	0.78	0.73	0.00	0.51	0.49	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.63	0.32	0.32	0.16	0.61	0.55	4.49	1.26
16_18	DF	Main	0.50	0.76	0.64	1.00	0.75	0.71	0.75	1.00	0.94	0.00	0.00	0.67	0.67	0.60	0.16	0.13	0.38	0.37	0.60	0.58	7.06	2.69
17_18	DF	Trib	0.98	0.88	0.65	0.30	0.72	0.64	0.75	1.00	1.00	0.00	0.00	0.69	0.69	0.66	0.76	0.73	0.71	0.69	0.71	0.67	11.20	2.97
18_18	DF	Main	1.00	0.79	0.72	0.50	0.76	0.74	1.00	1.00	1.00	0.00	0.00	0.75	0.75	0.84	0.00	0.00	0.42	0.42	0.64	0.64	5.00	1.3
19_18	NC	Main	1.00	0.80	0.79	0.50	0.77	0.76	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.91	0.99	0.96	0.92	0.91	23.61	1.66
20_18	DF	Trib	1.00	0.80	0.80	0.33	0.71	0.71	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.74	0.93	0.93	0.83	0.83	0.85	0.85	18.35	1
21_18	DF	Trib	1.00	0.89	0.80	0.00	0.63	0.60	0.75	1.00	1.00	0.00	0.00	0.69	0.69	0.02	0.99	0.50	0.51	0.26	0.61	0.51	14.70	1.35
22_18	DF	Trib	1.00	0.90	0.89	0.65	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.88	0.95	0.94	0.93	0.93	23.22	1.73

Site	Stream	Stream Size	Hydroperiod	Water Source	Water Source Alt	Hydro Connectivity	Att 1: Hydrology	Att 1: Hydrology Alt	Nutrients	Sediment	Contaminants	Buffer Filter	Buffer Filter Alt	Att 2: WaterQuality	Att 2: WQ Alt	Vegetation	Habitat Connectivity	Habitat Conne Alt	Att 3: Biota	Att 3: Biota Alt	Final OKRAM	Final OKRAM Alt	FQI	LDI
23_18	DF	Trib	1.00	0.90	0.87	0.00	0.63	0.62	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.88	1.00	0.94	0.88	0.86	16.53	1.05
24_18	DF	Trib	1.00	0.90	0.82	0.63	0.84	0.81	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	0.99	0.95	0.94	21.67	1
25_18	DF	Trib	1.00	0.51	0.39	0.00	0.50	0.46	1.00	1.00	1.00	0.00	0.00	0.75	0.75	0.08	0.95	0.48	0.51	0.28	0.59	0.50	13.06	1.79
26_18	NC	Trib	1.00	0.50	0.48	0.00	0.50	0.49	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.89	0.57	0.94	0.78	0.81	0.76	16.06	1.28
27_18	NC	Trib	1.00	0.89	0.85	0.50	0.80	0.78	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.88	1.00	0.94	0.93	0.91	21.36	1.75
28_18	NC	Trib	1.00	0.90	0.87	0.88	0.92	0.91	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.60	0.54	0.80	0.77	0.91	0.89	21.54	2.34
29_18	NC	Trib	1.00	0.90	0.89	0.93	0.94	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.93	0.99	0.96	0.98	0.97	23.33	1.1
30_18	NC	Trib	1.00	0.85	0.28	0.00	0.62	0.43	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	0.29	0.28	0.64	0.64	0.75	0.69	11.85	2.08

Appendix D: Soil chemistry parameters for samples collected in 30 floodplain wetlands in central Oklahoma in 2018.

Site	TopN (lbs/A)	P (lbs/A)	K (lbs/A)	NH4	Na (ppm)	pH	K (ppm)	TDS (ppm)	SAR (%)	OM (%)
01_18	3.00	27.00	268.00	13.40	9.80	6.20	28.00	530.64	0.30	3.24
02_18	3.00	47.00	229.00	14.10	13.40	7.90	32.00	457.38	0.46	1.55
03_18	2.00	70.00	379.00	42.40	32.60	7.60	24.00	910.80	0.75	3.41
04_18	11.00	48.00	453.00	22.10	71.10	6.60	19.00	954.36	1.74	4.27
05_18	10.00	55.00	579.00	18.70	15.80	6.00	50.00	999.90	0.34	3.85
06_18	59.00	68.00	686.00	21.10	30.80	7.90	37.00	1433.52	0.55	2.46
07_18	7.00	41.00	450.00	9.90	13.30	7.90	26.00	712.80	0.34	1.33
08_18	4.00	37.00	222.00	5.70	9.70	8.10	26.00	447.48	0.34	0.75
09_18	3.00	36.00	223.00	6.20	9.30	8.00	25.00	487.08	0.30	0.60
10_18	2.00	20.00	115.00	3.10	6.10	8.30	14.00	267.70	0.28	0.23
11_18	10.00	36.00	390.00	12.70	21.00	7.90	29.00	926.64	0.47	2.29
12_18	7.00	44.00	364.00	10.70	17.30	8.00	30.00	714.78	0.45	1.67
13_18	62.00	183.00	912.00	16.00	128.00	6.60	46.00	1827.54	2.28	5.51
14_18	20.00	30.00	483.00	12.30	47.90	6.30	20.00	960.30	1.12	4.28
15_18	20.00	33.00	316.00	14.10	15.40	8.20	26.00	762.30	0.40	2.02
16_18	13.00	42.00	484.00	8.30	22.30	6.70	28.00	1150.38	0.44	3.64
17_18	6.00	9.00	213.00	33.90	20.30	5.70	30.00	566.28	0.68	2.61
18_18	9.00	35.00	151.00	11.00	5.20	7.20	29.00	341.35	0.22	1.05
19_18	15.00	50.00	312.00	14.30	16.30	8.30	26.00	635.58	0.48	1.15
20_18	13.00	39.00	502.00	31.30	34.60	6.40	20.00	906.84	0.82	5.30
21_18	9.00	19.00	340.00	40.60	19.50	6.40	18.00	518.76	0.63	3.74
22_18	34.00	43.00	508.00	72.40	17.80	6.40	38.00	1069.20	0.39	8.00
23_18	1.00	19.00	172.00	18.70	9.80	7.30	18.00	331.65	0.41	1.30
24_18	25.00	24.00	451.00	39.70	18.90	6.20	16.00	627.66	0.57	5.21
25_18	19.00	27.00	524.00	21.00	47.00	6.00	12.00	493.02	1.93	5.04
26_18	61.00	142.00	691.00	35.80	246.30	6.80	80.00	2585.88	3.95	8.85
27_18	2.00	32.00	277.00	41.10	22.40	6.60	16.00	433.62	0.82	2.48
28_18	1.00	20.00	216.00	21.10	16.20	5.80	13.00	331.06	0.71	3.23
29_18	1.00	17.00	153.00	29.20	7.90	7.10	14.00	270.67	0.39	2.27
30_18	84.00	20.00	403.00	54.20	32.20	7.30	30.00	1607.76	0.58	6.50

Appendix E: List of plant species collected from 28 floodplain wetlands across Oklahoma in 2019 and c-values assigned according to Oklahoma guidance (Ewing and Hoagland 2012). When species lacked a C-value on the Oklahoma taxonomic list, c-values developed for Kansas (Freeman and Morse 2002), and Missouri (Ladd 1993) were applied.

Scientific Name	Coefficient of Conservatism	Number of Sites
Acalypha rhomboidea	1*	1
Acalypha virginica	0*	3
Acer negundo	1	8
Acer rubrum	6	4
Acer saccharinum	2*	3
Albizia julibrissin	0	4
Amaranthus albus	0	1
Amaranthus hybridus	0*	1
Ambrosia artemisiifolia	3	3
Ambrosia psilostachya	3	5
Ambrosia trifida	2	2
Amorpha fruticosa	6	2
Ampelopsis cordata	2	3
Amphiachyris dracunculoides	2*	1
Anemone berlandieri	8*	1
Aristida oligantha	0*	1
Arundinaria gigantea	7	1
Asclepias arenaria	7*	2
Asclepias verticillata	1*	1
Asimina triloba	4*	1
Baccharis salicina	4*	1
Bassia scoparia	0*	1
Berchemia scandens	6**	2
Betula nigra	3	3
Bidens frondosa	2	3
Boehmeria cylindrica	6	13
Boltonia asteroides	4	1
Botrychium biternatum	10**	1
Bromus catharticus	0	2
Bromus commutatus	0	1
Broussonetia papyrifera	0	1
Brunnichia ovata	6	4
Campsis radicans	3	6
Cardiospermum halicacabum	0	3
Carex aureolensis	5*	3
Carex crus-corvi	7	1

Scientific Name	**Coefficient of Conservatism**	**Number of Sites**
Carex davisii	4*	1
Carex debilis	9	1
Carex grisea	3*	1
Carex hystericina	7	3
Carex lupulina	6	2
Carex praegracilis	3	1
Carex squarrosa	7	1
Carex tribuloides	4	5
Carpinus caroliniana	6**	2
Carya aquatica	9	1
Carya cordiformis	4*	2
Carya glabra	6**	1
Carya illinoinensis	6	9
Carya ovata	5*	2
Carya texana	6*	1
Catalpa speciosa	1	1
Celtis laevigata	5*	11
Celtis occidentalis	5	3
Cenchrus incertus	0*	1
Cenchrus longispinus	0*	1
Cephalanthus occidentalis	4	8
Cercis canadensis	2*	1
Chamaesyce maculata	0*	2
Chamaesyce prostrata	0*	1
Chamaesyce serpens	0*	1
Chasmanthium latifolium	4	10
Chenopodium album	0*	1
Chenopodium pratericola	3*	1
Chionanthus virginicus	10**	1
Clematis terniflora	0	1
Cocculus carolinus	3	3
Coleataenia longifolia	5*	2
Commelina communis	0	3
Commelina erecta	4	2
Conoclinium coelestinum	4	3
Conyza canadensis	0*	6
Cornus drummondii	3	2
Cornus florida	6*	1
Corydalis micrantha	0*	1
Cotinus obovatus	9**	1
Crataegus marshallii	9**	1

Scientific Name	Coefficient of Conservatism	Number of Sites
Crataegus mollis	4*	2
Croton glandulosus	1*	2
Croton lindheimerianus	8*	1
Croton texensis	1*	1
Cynodon dactylon	0	8
Cyperus acuminatus	3	3
Cyperus compressus	2	1
Cyperus polystachyos	8	2
Cyperus setigerus	6	1
Cyperus strigosus	4	3
Dactylis glomerata	0	2
Descurainia pinnata	1*	1
Diarrhena americana	9**	3
Dichanthelium commutatum	7**	1
Dichanthelium dichotomum	8*	3
Dichanthelium latifolium	7*	1
Dichanthelium ovale	3*	1
Dicliptera brachiata	6	3
Digitaria sanguinalis	0	1
Diodia virginiana	4	4
Dioscorea villosa	6*	1
Diospyros virginiana	2	8
Distichlis spicata	4	3
Duchesnea indica	0	1
Echinochloa crus-galli	0	2
Echinochloa muricata	0	2
Echinodorus berteroi	8	2
Echinodorus cordifolius	8	1
Eclipta prostrata	3	6
Eleocharis lanceolata	7	1
Eleocharis obtusa	4	1
Elephantopus carolinianus	4*	6
Elymus canadensis	5*	2
Elymus glabriflorus	3*	1
Elymus villosus	5*	2
Elymus virginicus	3*	2
Equisetum laevigatum	3	2
Eragrostis frankii	6	1
Eragrostis hirsuta	4**	2
Eragrostis lehmanniana	0	1
Erigeron canus	7*	1

Scientific Name	Coefficient of Conservatism	Number of Sites
Eriochloa contracta	0*	1
Eryngium prostratum	6*	1
Euonymus fortunei	0	4
Euphorbia cyathophora	3*	1
Forestiera acuminata	7	6
Fraxinus americana	6	1
Fraxinus pennsylvanica	3	15
Fuirena simplex	6	1
Geranium molle	0	1
Geum canadense	1*	6
Gleditsia triacanthos	2	9
Gymnocladus dioicus	4*	1
Helianthus annuus	1	1
Heliotropium indicum	0	5
Heliotropium procumbens	3	1
Heliotropium tenellum	7*	1
Heterotheca subaxillaris	2*	2
Heuchera americana	7**	1
Hibiscus laevis	4	2
Hibiscus moscheutos	4	1
Hordeum jubatum	2	1
Hordeum pusillum	1	1
Hypericum hypericoides	8*	3
Hypericum mutilum	4	1
Ilex decidua	5	13
Ilex opaca	7**	1
Impatiens capensis	5	1
Iresine rhizomatosa	4	1
Iva annua	1	5
Juncus coriaceus	5	2
Juncus diffusissimus	5	1
Juncus effusus	5	1
Juncus marginatus	4	1
Juncus scirpoides	7	1
Juniperus virginiana	1	3
Kummerowia striata	0	1
Kyllinga brevifolia	6	1
Lactuca serriola	0	1
Lamium amplexicaule	0	1
Lappula occidentalis	2*	1
Leersia lenticularis	7	3

Scientific Name	Coefficient of Conservatism	Number of Sites
Leersia virginica	4	8
Lespedeza cuneata	0	2
Limonium limbatum	6	2
Liquidambar styraciflua	6**	4
Lonicera japonica	0	6
Ludwigia glandulosa	5	2
Ludwigia palustris	5	2
Lycopus virginicus	5	1
Maclura pomifera	0	5
Melothria pendula	1	3
Menispermum canadense	4	1
Mikania scandens	5	3
Mollugo verticillata	1	1
Morus alba	0	9
Morus rubra	5*	1
Nekemias arborea	4	6
Nothoscordum bivalve	3*	1
Nyssa sylvatica	5**	2
Ostrya virginiana	5*	1
Oxalis dillenii	0*	1
Panicum capillare	1	2
Panicum coloratum	0	2
Panicum miliaceum	0	1
Panicum obtusum	2*	1
Panicum virgatum	4	6
Parthenocissus quinquefolia	2	13
Pascopyrum smithii	2*	2
Paspalum dilatatum	0	2
Paspalum floridanum	5	2
Paspalum pubiflorum	4	1
Passiflora incarnata	4*	2
Penthorum sedoides	5	1
Perilla frutescens	0	1
Phyla lanceolata	3	2
Phyla nodiflora	3	2
Physalis angulata	3	4
Phytolacca americana	0*	2
Plantago patagonica	1*	1
Plantago rhodosperma	2*	1
Platanus occidentalis	4	3
Pluchea odorata	4	5

Scientific Name	Coefficient of Conservatism	Number of Sites
Polygonum hydropiper	0	1
Polygonum hydropiperoides	4	2
Polygonum pensylvanicum	2	1
Polygonum persicaria	0	1
Polygonum punctatum	4	8
Polygonum virginianum	2*	4
Polypremum procumbens	4**	1
Populus deltoides	1	2
Portulaca oleracea	0*	1
Pseudognaphalium obtusifolium	0*	2
Quercus lyrata	7	2
Quercus macrocarpa	4*	3
Quercus nigra	5**	7
Quercus palustris	3*	3
Quercus phellos	4	6
Quercus rubra	6*	3
Quercus shumardii	6*	3
Quercus stellata	4*	1
Quercus velutina	5	2
Rorippa palustris	3	1
Rorippa sessiliflora	3	1
Rotala ramosior	4	1
Ruellia pedunculata	5**	1
Ruellia strepens	4*	6
Rumex crispus	0	2
Saccharum alopecuroides	7	1
Saccharum brevibarbe	5*	2
Sacciolepis striata	6	1
Salix nigra	2	7
Salsola tragus	0	1
Sapindus drummondii	3*	3
Schizachyrium scoparium	5*	1
Schoenoplectus pungens	4	2
Schoenoplectus tabernaemontani	6	2
Scutellaria lateriflora	5	1
Setaria pumila	0	2
Sideroxylon lanuginosum	5	2
Smilax bona-nox	5	15
Smilax tamnoides	2*	5
Solanum carolinense	1	2
Solanum elaeagnifolium	3*	2

Scientific Name	**Coefficient of Conservatism**	**Number of Sites**
Solanum ptychanthum	1*	1
Solidago caesia	7**	1
Solidago canadensis	3	1
Sorghum halepense	0	4
Spartina pectinata	6	1
Sporobolus cryptandrus	0*	1
Sporobolus texanus	8*	1
Suaeda calceoliformis	4*	1
Symphoricarpos orbiculatus	1	6
Symphyotrichum drummondii	2*	1
Symphyotrichum falcatum	3*	1
Symphyotrichum subulatum	4	2
Tamarix ramosissima	0	2
Teucrium canadense	3	10
Toxicodendron radicans	1	13
Trachelospermum difforme	6	4
Tridens strictus	6*	1
Trifolium repens	0	3
Ulmus alata	3	7
Ulmus americana	2	12
Ulmus rubra	3	1
Verbesina alternifolia	4	1
Vernonia gigantea	5*	1
Vitis acerifolia	5*	2
Vitis palmata	5	2
Vitis riparia	4	2
Vitis rotundifolia	10**	1
Vitis vulpina	3*	4
Xanthium strumarium	0*	5

Notes: * Kansas c-value; ** Missouri c-value

Appendix F: Oklahoma Rapid Assessment Method (OKRAM), Floristic Quality Index (FQI), and Landscape Development Intensity Index (LDI) scores for 28 floodplain wetlands sampled in 2019 across Oklahoma.

Site	Hydroperiod	Water Source	Hydrologic Connectivity	Att 1: Hydrology	Nutrients	Contaminants	Buffer Filter	Att 2: Water Quality	Vegetation	Habitat Connectivity	Att 3: Biota	Final OKRAM Scores	FQI	LDI
01_19	1.00	0.69	0.00	0.56	1.000	1.000	1.00	1.00	0.67	0.72	0.70	0.75	7.92	2.00
02_19	1.00	0.86	0.00	0.62	0.998	1.000	1.00	1.00	0.96	1.00	0.98	0.87	10.96	1.00
03_19	1.00	0.77	0.00	0.59	0.988	1.000	1.00	1.00	0.47	0.74	0.61	0.73	8.33	1.34
04_19	1.00	0.79	0.55	0.78	1.000	1.000	1.00	1.00	1.00	1.00	1.00	0.93	17.48	1.00
05_19	1.00	0.59	0.60	0.73	1.000	1.000	0.89	0.96	1.00	0.67	0.83	0.84	14.32	1.57
06_19	1.00	0.74	0.00	0.58	0.998	1.000	1.00	1.00	1.00	0.89	0.94	0.84	15.40	1.43
07_19	1.00	0.60	0.50	0.70	1.000	1.000	0.97	0.99	0.85	0.78	0.81	0.83	13.00	3.07
08_19	1.00	0.80	0.43	0.74	1.000	1.000	1.00	1.00	1.00	0.95	0.98	0.91	18.63	1.68
09_19	0.13	0.99	0.12	0.41	0.988	1.000	0.88	0.95	0.31	0.87	0.59	0.65	26.45	1.18
10_19	1.00	0.78	1.00	0.93	1.000	1.000	1.00	1.00	1.00	0.96	0.98	0.97	15.75	1.52
11_19	1.00	0.97	0.42	0.80	1.000	1.000	1.00	1.00	0.97	0.83	0.90	0.90	23.17	2.15
12_19	1.00	1.00	0.67	0.89	1.000	1.000	1.00	1.00	1.00	0.85	0.92	0.94	23.21	1.00
13_19	1.00	1.00	1.00	1.00	1.000	1.000	1.00	1.00	1.00	0.98	0.99	1.00	30.26	1.25
14_19	1.00	0.78	0.55	0.78	1.000	1.000	1.00	1.00	1.00	1.00	1.00	0.93	24.05	1.01
15_19	1.00	0.70	0.75	0.82	0.988	1.000	1.00	1.00	0.62	0.98	0.80	0.87	6.55	1.01
16_19	1.00	0.57	1.00	0.86	1.000	1.000	1.00	1.00	1.00	0.78	0.89	0.91	17.83	2.11
17_19	1.00	0.80	0.63	0.81	1.000	1.000	1.00	1.00	0.98	0.93	0.95	0.92	17.50	1.57
18_19	1.00	0.71	0.88	0.86	1.000	0.875	1.00	0.96	0.04	0.99	0.51	0.78	6.00	1.05
19_19	1.00	0.70	0.75	0.82	0.998	1.000	0.50	0.83	0.75	0.49	0.62	0.76	11.55	1.23
20_19	1.00	0.90	1.00	0.97	1.000	1.000	1.00	1.00	1.00	0.83	0.92	0.96	18.40	1.74

Site	Hydroperiod	Water Source	Hydrologic Connectivity	Att 1: Hydrology	Nutrients	Contaminants	Buffer Filter	Att 2: Water Quality	Vegetation	Habitat Connectivity	Att 3: Biota	Final OKRAM Scores	FQI	LDI
21_19	1.00	0.85	1.00	0.95	0.975	1.000	1.00	0.99	0.00	0.99	0.50	0.81	11.68	1.14
22_19	1.00	1.00	0.76	0.92	1.000	1.000	1.00	1.00	0.57	0.99	0.78	0.90	6.26	2.21
23_19	1.00	0.79	0.91	0.90	1.000	1.000	1.00	1.00	1.00	1.00	1.00	0.97	14.68	1.12
24_19	1.00	0.81	1.00	0.94	0.998	1.000	1.00	1.00	0.20	0.91	0.56	0.83	9.94	1.26
25_19	1.00	0.58	1.00	0.86	0.998	1.000	0.00	0.67	0.00	0.86	0.43	0.65	12.60	3.31
26_19	1.00	0.70	1.00	0.90	1.000	1.000	1.00	1.00	1.00	0.89	0.95	0.95	22.46	1.66
27_19	1.00	0.60	0.34	0.65	0.998	1.000	1.00	1.00	0.15	0.91	0.53	0.72	12.25	1.00
28_19	1.00	0.77	0.80	0.86	1.000	1.000	1.00	1.00	1.00	0.84	0.92	0.93	26.28	2.42

Appendix G: Soil chemistry parameters for samples collected in 28 floodplain wetlands in Oklahoma in 2019.

Site	TopN (lbs/A)	P (lbs/A)	K (lbs/A)	NH4	Na (ppm)	pH	K (ppm)	TDS (ppm)	SAR (%)	OM (%)
01_19	21.00	29.00	706.00	6.40	62.90	8.00	136.00	1580.04	1.21	2.86
02_19	18.00	34.00	928.00	30.60	2748.70	8.10	115.00	11503.80	33.86	5.38
03_19	22.00	30.00	1253.00	18.50	237.50	8.20	105.00	1884.96	4.70	4.87
04_19	16.00	29.00	529.00	9.30	45.60	7.00	21.00	1017.72	0.96	4.67
05_19	50.00	124.00	903.00	9.90	48.70	7.80	89.00	1740.42	0.81	4.37
06_19	7.00	31.00	454.00	6.80	12.10	7.30	29.00	756.36	0.29	3.72
07_19	34.00	124.00	463.00	64.40	142.50	8.10	68.00	1671.12	2.76	3.65
08_19	5.00	8.00	117.00	12.80	26.90	4.70	9.00	368.28	1.28	4.68
09_19	17.00	18.00	324.00	14.60	47.50	5.70	55.00	691.02	1.61	2.67
10_19	2.00	8.00	90.00	17.30	32.70	4.70	17.00	415.80	1.51	6.17
11_19	16.00	29.00	192.00	12.00	33.40	5.60	16.00	633.60	1.03	5.28
12_19	16.00	10.00	233.00	27.40	69.90	5.10	20.00	754.38	2.31	5.62
13_19	23.00	14.00	180.00	55.30	23.80	5.00	14.00	544.50	0.95	6.81
14_19	3.00	3.00	114.00	6.90	17.20	7.00	11.00	253.24	0.96	
15_19	60.00	50.00	900.00	6.00	338.00	8.10	39.00	2340.36	6.12	4.31
16_19	24.00	28.00	575.00	62.90	9.40	7.10	42.00	728.64	0.25	9.23
17_19	5.00	13.00	565.00	14.40	30.30	5.50	18.00	502.92	1.12	4.37
18_19	6.00	49.00	935.00	7.60	355.20	8.30	31.00	1993.86	7.30	3.75
19_19	5.00		460.00	26.10	1971.00	8.40	109.00	10078.20	17.96	2.01
20_19	15.00	42.00	438.00	66.80	18.20	6.30	25.00	696.96	0.49	8.32
21_19	17.00		850.00	19.00	92.80	8.00	126.00	6197.40	0.68	3.51
22_19	1.00		156.00	5.80	8198.60	8.70	50.00	29264.40	65.46	0.45
23_19	6.00	34.00	175.00	17.10	38.10	7.50	10.00	566.28	1.23	2.76
24_19	6.00	21.00	581.00	4.30	341.00	8.50	40.00	1639.44	10.60	1.31
25_19	21.00	76.00	156.00	16.60	85.40	6.20	14.00	825.66	2.54	4.93
26_19	11.00	6.00	148.00	14.30	22.50	5.70	9.00	401.94	0.78	3.91
27_19	7.00	8.00	333.00	5.50	62.00	8.30	51.00	817.74	1.71	1.76
28_19	4.00	6.00	140.00	26.70	36.50	5.40	10.00	449.46	1.57	4.04