DEVELOPMENT OF THE OKLAHOMA RAPID ASSESSMENT METHOD FOR FLOODPLAIN WETLANDS

By

ANTHONY WAYNE THORNTON

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Thesis Approved:

Craig Davis

Thesis Adviser

Andy Dzialowski

Dan Dvorett

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Abstract: Wetlands provide many important services to society, but degradation of wetlands reduces their ability to provide those services. Loss and degradation of wetlands have been ongoing in Oklahoma since settlement though recent efforts may have begun to reverse some of the damage. To ensure these efforts are working, we need to monitor the ecological condition of wetlands in the state. The Oklahoma Rapid Assessment Method (OKRAM) has been developed as a way to accomplish this goal and has been proven to be an effective tool for measuring the condition of depressional wetlands. OKRAMs intended use is to assess any wetland in the state so it will need to be calibrated for and validated in each wetland type in the state. The goal of this study was to calibrate OKRAM to Riverine Floodplain Wetlands to account for the unique biotic and abiotic conditions within them by altering or changing metrics and/or their scoring. Calibration of OKRAM will serve to prepare it for a statewide validation for Floodplain Wetlands. We performed Level 1, 2, and 3 assessments at 30 wetlands within the North Canadian and Deep Fork River Watersheds and used Level 1 and 3 data to assess Level 2 metrics. Our evaluation showed consistent relationships of OKRAM to Level 1 (e.g., Landscape Development Intensity index) and Level 3 (e.g., Floristic Quality Index) data at 30 floodplain wetland sites within the Deep Fork River and North Canadian River Watersheds of Oklahoma. This study shows that OKRAM can be used as an effective tool to assess floodplain wetlands rapidly and affordably. OKRAM still needs further calibration before I would recommend its use in wetland monitoring programs. I present recommendations for improving poor performing metrics and directions for future research in floodplain wetlands in Oklahoma.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER I

DEVELOPMENT OF A RAPID ASSESSMENT METHOD FOR DETERMINING THE CONDITION OF FLOODPLAIN WETLANDS IN OKLAHOMA

ABSTRACT

Wetlands provide many important services to society, but degradation of wetlands reduces their ability to provide those services. Loss and degradation of wetlands have been ongoing in Oklahoma since settlement though recent efforts may have begun to reverse some of the damage. To ensure these efforts are working, we need to monitor the ecological condition of wetlands in the state. The Oklahoma Rapid Assessment Method (OKRAM) has been developed as a way to accomplish this goal and has been proven to be an effective tool for measuring the condition of depressional wetlands. OKRAMs intended use is to assess any wetland in the state so it will need to be calibrated for and validated in each wetland type in the state. The goal of this study was to calibrate OKRAM to Riverine Floodplain Wetlands to account for the unique biotic and abiotic conditions within them by altering or changing metrics and/or their scoring. Calibration of OKRAM will serve to prepare it for a statewide validation for Floodplain Wetlands. We performed Level 1, 2, and 3 assessments at 30 wetlands within the North Canadian and Deep Fork River Watersheds and used Level 1 and 3 data to assess Level 2 metrics.

Our evaluation showed consistent relationships of OKRAM to Level 1 (e.g., Landscape Development Intensity index) and Level 3 (e.g., Floristic Quality Index) data at 30 floodplain wetland sites within the Deep Fork River and North Canadian River Watersheds of Oklahoma. This study shows that OKRAM can be used as an effective tool to assess floodplain wetlands rapidly and affordably. OKRAM still needs further calibration before I would recommend its use in wetland monitoring programs. I present recommendations for improving poor performing metrics and directions for future research in floodplain wetlands in Oklahoma.

INTRODUCTION

Well-functioning wetlands provide many important services. Wetlands provide flood mitigation, improved drinking water quality and quantity, long-term storage of carbon in soils and vegetation, and habitat for multiple species of plants and animals (Boyd and Wainger 2002, Hoehn et al. 2003, Zedler and Kercher 2005). Wetland loss and degradation can reduce or eliminate many of these ecological services. Unfortunately, wetland loss has been ongoing and prevalent since European colonization of North America. Between the 1780's and the 1980's, the lower 48 states lost about 53% of their wetlands (Dahl 1990). U.S. Fish and Wildlife Service reports, covering the period between 2004 and 2009, show a loss of over 185,000 acres of wetland in the United States (Dahl 2011) and the EPA's 2011 National Wetland Condition Assessment (NWCA) found that 55% of wetlands in the Interior Plains were in fair or poor condition (USEPA 2016a). In short, wetlands provide many important services, but loss and degradation are a continuing problem in the United States.

To halt or mitigate for the loss and degradation of wetlands, we need to be able to accurately monitor the condition of wetlands. Wetland condition is a measure of the ability of a wetland to carry out its natural functions in comparison to similar wetlands that have not experienced human alteration (Fennessy et al. 2007). One way to monitor the condition of wetlands is by conducting wetland assessments. The EPA recognizes 3 levels of Wetland assessment that range from broad landscape scale assessments to labor intensive, site-specific assessments. Landscape scale assessments, or Level 1 assessments, provide a broad-scale synopsis of wetland condition by analyzing remote-sensing datasets. For example, the Landscape Development Intensity Index (LDI), uses coefficients applied to land uses within a user-specified area to create an index of potential human disturbance based on the percentage of area of each land-use. LDI analysis can be accomplished using aerial imagery or land cover/use datasets in GIS. Although LDI can provide insight into wetland condition, they can overlook significant local factors affecting wetlands including hydrologic connectivity, chemical contaminants, and invasive vegetation.

Level 3 assessments such as Indices of Biotic Integrity (IBIs) (Tangen et al. 2003, Lunde and Resh 2012) and Floristic Quality Indexes (FQIs) (Taft et al. 1997, Lopez and Fennessy 2002, Miller and Wardrop 2006) are intensive data collection efforts that quantify one or several aspects of ecosystem condition such as disturbance, isolation, and habitat quality using one or more organisms (e.g., plants, invertebrates, mammals, and birds) as biological indicators. For example, Lund and Resh (2012) found that community structure of macroinvertebrates is a useful indicator of disturbance (urbanization) for wetlands in California. These assessments can be cost prohibitive because they require intensive fieldwork and considerable expertise in sampling, processing, and identifying specific taxa. FQIs are a valuable tool for tracking wetland condition but can be influenced by size of area being assessed, natural disturbance, and environmental gradients, all of which must be considered when conducting this assessment. An examination of FQIs in Oklahoma found that FQI scores decreased along a precipitation gradient from the east to the west of the state, regardless of disturbance (Gallaway et al. 2019b). Environmental gradient biases must be considered when using FQIs in large geographical areas.

Level 2 assessments, also known as Rapid Assessment Methods (RAMs), are an assessment type becoming more commonly used in monitoring programs. RAMs provide consideration of local factors (e.g., hydrology, sedimentation, salinity) that are often disregarded when applying Level 1 assessments and are less costly and time intensive than Level 3 methods (Reiss and Brown 2007). RAMs can assess wetland function, values, stressors, and other drivers of ecological condition. RAMs use metrics to record observable field indicators such as vegetation, topography, and alterations to the wetland's hydrology (e.g., sedimentation, dikes, ditches, etc.). These metrics provide qualitative measurements of a biological (e.g., vegetation) or physical (e.g., topographic or hydrologic) attribute that reflects ecological condition (Sutula et al. 2006). Individual metric scores are aggregated into an overall condition score that assesses the degree of anthropogenic disturbance. RAMs provide a consistent, affordable approach for ambient monitoring programs to measure condition and to identify degraded wetlands in need of restoration as well as high quality wetlands in need of protection.

While RAMs can be useful in management applications (Fennessy et al. 2007), they rely on inferred relationships between qualitative indicators and ecological condition. As such, it is critical that RAMs are calibrated and validated with independent measures of wetland condition. It is necessary to confirm that qualitative RAM condition scores are reflected in quantifiable measures of ecosystem condition, such as IBIs or FQIs (Stein et al. 2009). Calibration is the process of adjusting the assessment method by re-scaling or re-scoring metrics to improve the RAM's ability to discern differences in wetland condition. This sometimes requires re-evaluating metrics and either discarding or combining them, so the method better captures ecologic condition. Validation is the process of documenting relationships between RAM results and independent measures of condition to establish the RAM's defensibility as a meaningful and repeatable measure of wetland condition (Stein et al. 2009). This usually involves statistical correlation of RAM scores with scores from IBIs, FQIs, or other level 3 assessments. Following the recommendations from Fennessy et al. (2007), many states have completed RAM validations using various abiotic measurements (e.g., soil and water chemistry) and biotic assemblages such as bird, amphibian, macroinvertebrate, and vegetation communities (Mack et al. 2000, Micacchion 2004, Stapanian et al. 2004, Peterson and Niemi 2007, Wardrop et al. 2007, Stein et al. 2009, Garrison 2013). In each case, RAM comparisons with Level 3 assessment data either confirmed the RAM was valid or provided insight for further calibration to assure the method can capture wetland condition.

Wetland losses have been extensive in Oklahoma since statehood (Dahl 1990). The Oklahoma Comprehensive Wetlands Conservation Program (OCC 1996: ii) set the goal "to conserve, enhance, and restore the quantity and biological diversity of all wetlands in the state". In 2013 the Oklahoma's Wetland Program Plan outlined the development of a rapid assessment method (RAM) to meet that goal (OCC 2013). The Oklahoma Rapid Assessment Method (OKRAM) is the result of that plan. OKRAM is a stressor-based RAM and assumes that a wetland's ecological condition varies along a stressor gradient which can be evaluated based on a set of visible field metrics (Sutula et al. 2006). Alexander (1999) defines ecological stress as a physical factor that has an adverse impact on an ecosystem or its biotic components. Therefore, when discussing the condition of wetlands, wetland stressors include physical (mechanical), chemical, or biological disturbances that adversely affect the ecological condition of a wetland. A stressor-based RAM reduces the need to scale variables related to the structure and complexity of biotic and abiotic ecosystem components across the broad range of reference states that may exist among the diverse ecoregions and wetland types of Oklahoma and enables the identification of sources of wetland degradation during assessment application (OWRB 2015).

OKRAM consists of nine metrics based on metrics from California Rapid Assessment Method (CRAM; Collins et al. 2013a) and Functional Assessment of Colorado Wetlands (FacWET; Johnson et al. 2013), but adjusted for characteristics and stressors of typical wetlands within Oklahoma. OKRAM metrics are aggregated into three attributes: hydrology, water chemistry, and biota (OWRB 2015). Each metric is designed to assess stressors related to a particular aspect of its associated attribute. For example, the hydroperiod metric of the hydrology attribute assesses whether the duration and frequency of inundation within a wetland has been reduced or increased. Either of these changes can affect how wetlands function. OKRAM metrics scores are combined to produce an overall score between 0.0 and 1.0 which represents the ecological condition of the wetland. A score of 0 would indicate that the wetland is highly impacted by anthropogenic disturbance and its functioning is severely impaired, while a score of 1 would indicate a wetland that is least impacted by stressors and is in its natural (reference) state.

To control for potential geographic variability, the initial application of OKRAM was completed in 2013 and 2014 on interdunal depressional wetlands within a relatively small region of central Oklahoma (i.e., Cimarron River Pleistocene Sand Dunes Ecoregion; OWRB 2015). This first application of OKRAM confirmed that it met the requirements laid out by Fennessey et al. (2007) to be considered a rapid assessment. OKRAMs metrics are aggregated into a single score as a quantitative measure of ecological condition, can be completed by two people in half a day of field work and half a day of office preparation and data analysis, consists of a field portion conducted on-site, and can be validated using empirical data such as that gathered in a Level 3 assessment. The validation portion was demonstrated by the correlation of OKRAM attributes and overall scores with Level 3 data (vegetation and soil chemistry), demonstrating OKRAMs ability to evaluate wetland condition (OWRB 2015). Subsequently, OKRAM was applied at 30 lacustrine fringe wetlands and 28 depressional wetlands statewide (Gallaway 2019a). The second application of OKRAM validated the method in depressional wetlands statewide and confirmed its repeatability between users. However, the method proved difficult to validate at lacustrine wetlands, indicating that specific metrics may need to be developed for different wetland types (Gallaway 2019a).

With the development of OKRAM complete for depressional wetlands (Gallaway 2019a), further application for other Oklahoma wetland types was needed. Riverine wetlands, which include floodplain wetlands, cover more than 348,434 hectares (USGS 1996) within Oklahoma. Floodplain wetlands have declined statewide due to timber harvest, channelization, reservoir construction, urbanization, and conversion of wetlands to agriculture (Wilkinson et al. 1987, Farley et al. 2002). Floodplain wetlands provide a variety of ecosystem services including timber for wood products, educational opportunities, and recreational opportunities (i.e., hunting, fishing, hiking, wildlife observation) (Wilkinson et al. 1987). They reduce flood peaks by dispersing flood waters and slow the release of that water back to streams reducing the severity of floods (Wilkinson et al. 1987). Floodplain wetlands also trap sediment and absorb nutrients and toxins improving the water quality of streams and rivers (USGS 1996). Finally, they provide important habitat for many species including fish (for spawning during floods), waterfowl (for migration and overwintering), and game birds (such as American woodcock (Scolopax minor) and wild turkey (Meleagris gallopavo)). Non-game birds such as raptors, wading birds, woodpeckers, and migrating passerines make frequent use of floodplains. Several species of mammals including raccoon (Procyon lotor), muskrat (Ondatra zibethicus), swamp rabbit (Sylvilagus aquaticus), mink (Mustela vison), river otter (Lutra canadensis), and beaver (Castor canadensis) rely on floodplains for habitat (Wilkinson et al. 1987). The extent and importance of these wetlands make them a prime candidate for further development of OKRAM.

As Gallaway et al. (2019a) found at lacustrine wetlands, the metrics used for depressional wetlands may not be appropriate for assessing riverine wetlands or at least may require modifications. Therefore it is critical to assess OKRAM specifically in floodplain wetlands to determine its applicability. Since floodplain wetlands vary considerably from depressional wetlands, OKRAM metrics may need to be adjusted to account for those differences. The biggest difference between these wetland types is hydrology. Depressional wetland hydrology is primarily determined by surface runoff and precipitation and unpredictable, leading to very different vegetation communities from year to year. In riparian floodplain wetlands the hydrology is primarily determined by overbank flooding with surface runoff and precipitation being secondary inputs. Since these wetlands are hydrologically connected to streams they tend to have more consistent access to water year-to-year leading to more stable vegetation communities. Intense flooding does sometimes wipe out the existing vegetation community making assessments challenging during and following these extreme events. The goal of this study was to calibrate OKRAM for use at riverine floodplain wetlands to account for the unique biotic and abiotic conditions within them by altering or changing metrics and/or their scoring. The calibration will serve to prepare the RAM for a statewide validation for this wetland type.

METHODS

Study Area

The study area consists of the watersheds of the North branch of the Canadian River (the North Canadian River) which flows through the Central Great Plains and Cross Timbers Ecoregions and the Deep Fork of the Canadian River (the Deep Fork River) which is entirely within the Cross Timbers Ecoregion (Figure 1). The Deep Fork and North Canadian Rivers were selected because they represent different river types in Oklahoma. The Deep Fork consists of steep muddy banks and clay channel beds that change course slowly, while the North Canadian River is a broad, sand-bed river with braided channels characteristic of many of the rivers of the state (Johnson 1998). Both river systems in this study have reservoirs created by damming; Lakes Optima and Canton located on the North Canadian and Lake Arcadia located on the Deep Fork. The confluence of these systems is also a dammed reservoir, Lake Eufaula. There are hundreds of smaller dams on the tributaries of these systems. These dams, along with conversion to canals in urban areas, riverbank levees, and channel straightening, may have changed the hydrology and flood regime of these rivers.

The area of the Central Great Plains through which the North Canadian River flows consists of sand dunes and level to slightly rolling plains in the west which become broken plains in the east. The streams of this region range from low gradient, broad, shallow, and sandy or silty channels to incised streams with rocky or muddy beds (Woods et al. 2007). Floodplain wetlands on this portion of the North Canadian are composed mostly of scrub/shrub or grassland but contain a significant portion of forested wetlands as well (Stinnett et al. 1987). Native vegetation communities are primarily mixed to tall grass prairie and Cross Timbers communities. Areas of sand dunes are dominated by sand sagebrush (Artemisia filifolia) with mixed grasses, bare sand patches, and stabilized dunes. This area transitions from oak savannah and mixed-grass prairie in the west to tall grass prairie/Crosstimbers transitional vegetation in the east. Western uplands transition to scattered oak (Quercus spp.), hickory (Carya spp.), and eastern redcedar (Juniperus viginiana). Wetland species are commonly found in depressions between dunes. Riparian areas support eastern cottonwood (Populus deltoides), willow (Salix spp.), ash (Fraxinus spp.), and elm (Ulmus spp.). Land use includes grazing, farming, and oil and gas development. The main crops are grain sorghum, wheat, alfalfa, cotton, and soybeans (Woods et al. 2007).

The majority of the study sites were within the Cross Timbers, which contains rolling hills with many being cuestas. Streams are mostly shallow with sandy substrates, but deep pools, riffles, and bedrock, boulder, cobble, or gravel substrates are found in some reaches. Bottomland hardwoods are the most common floodplain wetlands on the Deep Fork and the eastern reaches of the North Canadian and are a type of forested wetland that floods intermittently or only during the wettest part of the year (USGS 1996). Native vegetation of the Cross Timbers consists primarily of post oak, blackjack oak, big bluestem (Andropogon gerardii), little bluestem (Schizachyrium scoparium), switchgrass (Panicum virgatum), and Indiangrass (Sorghastrum nutans) transitioning to oak - hickory forests in the east. Riparian areas feature common hackberry, American elm, post oak, black walnut (Juglans nigra), green ash (Fraxinus pennsylvanica), willow, American sycamore (Platanus occidentalis), and eastern cottonwood (Woods et al. 2007). Fire suppression and lack of management have allowed woodlands to expand beyond historical ranges. Prior to European settlement, fire, both natural and that set by Native Americans, was a common occurrence on prairies and served to check the expansion of woody vegetation. Since European settlement, however, fire suppression and livestock grazing have served to encourage woody species, especially eastern redcedar, to expand in range and canopy closure (Hoagland et al. 1999)

Mean annual precipitation within the study area increases from west to east and varies from approximately 89 cm to 117 cm. The months of April, May, and June show the highest long-term average for precipitation within the state, each month receiving more than 8.5 cm annually. Similar to precipitation, average annual temperatures increase from West to East in the study area with an average of 15ºC in the West and 16ºC in the East (Oklahoma Climatology Survey 2020). More than two-thirds of all annual floods occur from April through July. Flooding is less common during December (USGS 2021).

Site Selection

To identify floodplain wetlands on the two river systems, we initially relied upon National Wetlands Inventory (NWI) maps, topographic imagery, and 2017 National Agricultural Imagery Program (NAIP) aerial photographs using ArcGIS 10.1 to locate potential wetland sites. We used the Federal Emergency Management Agency's National Flood Hazard Layer to exclude any wetlands that fell outside the 100-year floodplain of the river systems in the study. Prior to inclusion, we field-verified each site to determine whether the site was a floodplain wetland following HGM guidance (Brinson 1993; Smith et al. 1995) and a dichotomous key developed by Dvorett et al. (2012). This dichotomous key defines a floodplain wetland as the flat, backwater area within a 5-year floodplain of river/stream. Non-floodplain wetlands were excluded from this study. Floodplain wetlands were selected on both rivers and their associated tributaries to assess method was applicability for floodplain wetlands of multiple stream orders. One of the biggest limits on available sites was permission for access. Land in Oklahoma is primarily privately owned. Of 115 private landowners whom we contacted, only 40 granted permissions for access with 17 of those sites identified as suitable for inclusion in our study. The other 13 sites were on public lands.

To determine whether OKRAM could correctly assess wetland condition across the expected regional disturbance gradient, we selected sites that represented reference (least disturbed or best attainable) and highly disturbed ecological conditions. As we identified sites in GIS and gained permission to access them, we assigned them to a priori condition categories of reference or high disturbance based on their proximity to anthropogenic disturbance such as agriculture, urban development, and transportation corridors. During field verification, we identified indications of disturbance such as the presence of invasive species, signs of feral pig activity, and signs of direct human influence such as ATV trails through the wetland to reinforce our a priori classification. In total, we were able to identify and assess 30 wetlands evenly distributed between the Deep Fork and North Canadian River systems (Figure 2). We attempted an even distribution of sites among all permutations of river system (Deep Fork and North Canadian), stream size (tributary and mainstem), and disturbance category but were unable to because of limited access to suitable sites. The final site distribution included in this study can be found in Table 1.

Data Collection

We completed Level 1, 2, and 3 assessments at all 30 study sites. At each site we established a 0.5-ha circular assessment area (AA) following the guidelines of the National Wetlands Condition Assessment (NWCA) vegetation protocol (USEPA 2016b). We assessed each AA as representative of the whole wetland. The same size AA was used to provide consistent representative samples from all sites regardless of extent of the wetland being assessed (Fennessey et al. 2007).

Level 1 Assessment-- We calculated the LDI of each study site within a 1000 m buffer surrounding each AA using ArcGIS, because Gallaway et al. (2019a) found 1000 meters to be the most effective scale to evaluate land-use for depressional wetlands. The percentage of each land-use type surrounding the AA (e.g., agricultural, residential, industrial, commercial, transportation, natural areas, and open water) was recorded within the buffer. Each land-use type was weighted by land-use coefficients representing the level of disturbance (Brown and Vivas 2005; Mack 2006; Table 2). LDI Index scores were calculated using the equation (Brown and Vivas 2005):

$$LDItotal = \sum (\%LUi * LDIi)$$

Where, LDItotal is the LDI ranking for a landscape unit (i.e., buffer zone or watershed), %LUi is percent of the total area in land-use i, and LDIi is the coefficient value for land-use i. The scores for each land use type are then summed. Higher LDI Index scores represent greater deviations from least-disturbed systems.

Level 2 Assessment--OKRAM was applied to 30 floodplain wetlands between July and September 2018. OKRAM is a stressor-based rapid assessment method which uses nine metrics divided among three attributes (hydrologic condition, water quality, and biotic condition) as seen in Table 3. Each metric identifies the presence and severity of stressors impacting wetlands. Since OKRAM was initially developed for depressional wetlands, some alternative metrics were developed to improve the method and to account for differences between depressional and floodplain wetlands. Those metrics which included alternatives were Water Source, Hydrologic Connectivity, Buffer Filter, and Habitat Connectivity.

Instructions and spreadsheets for calculating OKRAM are presented in Appendix A but are also briefly described here. The Hydrologic Condition attribute identifies alterations to the hydroperiod, water source, and hydrologic connectivity. Hydroperiod stressors include fill and excavation of soil or sediment, water pumped in or out, water control structures, beaver dam removal, and features that divert water into the wetland. We also added cattle trails which convey storm water to this metric. Water source stressors are indicative of altered water source such as impoundments up or down stream, impervious surfaces, agricultural irrigation, tilled agricultural land, woody encroachment, impounded water on the surrounding landscape, and topographic alteration. We moved the upstream and downstream dam indicators from the Hydroperiod metric to the Water Source metric. We also created an alternative Water Source metric which included severity multipliers for each stressor in order to capture a broader range of scores. A severity multiplier weights certain stressors based on the idea that they have a greater effect on wetland disturbance than other stressors. For example, in the Water Source alternative metric, the percentage of irrigated agricultural land is multiplied by a severity multiplier of 1.5, while the percentage of dryland agriculture has a severity multiplier of 0.5. This is because irrigated agricultural land alters the water source more than dryland agriculture. The Hydrologic Connectivity metric has been altered to account for geomorphological differences between depressional and riverine wetlands. Two different Hydrologic Connectivity metrics were initially included in our study in order to determine which metric correlated better. One of the Hydrologic Connectivity metrics was based on the stream entrenchment ratio from the CRAM (Collins et al. 2013b), while the alternative was based on visible indicators of stream side aggradation and reduction of connectivity. Indicators of aggradation include excess sediment on the floodplain and vegetation encroaching on the stream channel. Indicators of reduced connectivity include sheer banks and straightened channels.

The Water Quality attribute identifies inputs of excessive nutrients, sediment, chemical contaminants, and the ability of the surrounding landscape to buffer these contaminants. Nutrient-based stressors include animal or human waste products and excessive algae or Lemna spp. The

Sediment metric details indicators of excess sedimentation and upland erosion. Chemical Contaminants can include point source and storm water discharge, signs of unusually high salinity, and petroleum sheen. The Buffer Filter metric uses indicators of surrounding landscape change such as agricultural fields and urban indicators to rate the condition of the buffer surrounding the AA. The alternative metric for the Buffer Filter metric only looks at the buffer upslope of the AA.

Finally, the Biotic Condition attribute evaluates anthropogenic disturbance to vegetation within the AA and the percentage of contiguous habitat surrounding the AA. Vegetation condition stressors include alterations to the natural vegetation regime such as invasive species or signs of anthropogenic alteration to the vegetation. Two Habitat Connectivity metrics were used during the study. Both used habitat categories of 'connected habitat' and 'dispersal barriers not included in connected habitat'. The alternate metric also includes temporary dispersal barriers or marginal habitat which did not reduce the metric score as severely as dispersal barriers not included in connected habitat. This alternative was included to improve the range of scores obtained for the metric. We used both the original and alternative metrics in the study with the intention of changing the metric for depressional wetlands as well if the alternative proved more effective.

Once the assessment for each site was complete, each metric was assigned a score ranging from 0 to 1. Metrics, such as buffer and habitat connectivity, are scored as a percentage of intact area. The remaining metrics are scored based on a weighted severity of impact using minor, moderate, and major categories (i.e., 0.25, 0.50, and 0.75, respectively). The area impacted by stressors (e.g., sedimentation, chemical spills, livestock manure, etc.) is multiplied by the severity of that stressor. The metrics are then aggregated into an overall OKRAM score ranging from 0 (complete degradation) to 1 (least-disturbed condition) (Gallaway 2019a).

Level 3 Assessment--Along with OKRAM data, we also collected Level 3 vegetation and soil data within each AA. This level 3 data was used as a benchmark for the calibration of the RAM. Vegetation community data were collected using the NWCA method (USEPA 2016a) in which north-south and east-west transects radiate from the center of the AA with five 100 m2 plots placed along the transects (Figure 3). Within each plot, we identified all plant species and recorded their percent cover. Plant species were identified based on professional knowledge and dichotomous keys (Tyrl et al. 2008, Little 2015, Ryburn et al. 2018). Plants that were not identified in the field were pressed and dried for later identification. Using the vegetation data, we calculated species richness (total number of species in the AA), native species richness (total number of native species in the AA), and FQI. FQI uses plant species richness and coefficients of conservatism (C-values) to infer wetland condition (Andreas and Lichvar 1995). C-values indicate tolerance to anthropogenic disturbance and are typically assigned to plants by regional experts. We primarily used C-values calculated by Ewing and Hoagland (2012), and where not available used c-values developed for other states and regions based on their proximity to Oklahoma; Kansas (Freeman 2012), Missouri (Ladd and Thomas 2015), Louisiana (Reid 2016), and the Southeastern United States (Gianopulos 2014),. These C-values, ranging from 0 to 10, are based on the likelihood of a species occurring at a disturbed site within a given region. Non-native and opportunistic species are usually given a rank of zero, while plant species with a high degree of fidelity to a narrow range of synecological parameters are generally assigned a rank of 10 (Andreas and Lichvar 1995). We calculated FQI using the following equation (Andreas and Lichvar 1995):

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

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

As an abiotic measure of wetland condition, we collected five soil subsamples to a depth of 10 cm from the center of each vegetation plot. These five samples were combined and mixed to create a composite sample for each site. Soil samples were immediately labeled, placed on ice, and stored at 4°C until later analysis. Prior to analysis, we thoroughly mixed each soil sample. Soil analyses were conducted by the Oklahoma State Soil Water and Forage Analytical Laboratory (SWFAL) and included determining soil pH, ammonium (NH4-N), phosphorus (P), organic matter, nitrate (NO3), sodium (Na), and sodium adsorption ratio (SAR). Prior to analysis, all soil samples are dried at 65ºC overnight and ground to pass through a 2mm sieve. Soil pH was measured by glass electrode in a 1:1 soil:water suspension. Soil NH4-N was extracted with a 1 mol KCl (potassium chloride) solution and quantified by a Flow Injection Autoanalyzer (LACHAT 1994). Plant available P was extracted using Mehlich 3 (Mehlich 1984) solution and quantified by a Spectro Blue ICP spectrometer (Soltanpour et al. 1996). Soil organic carbon and NO3-N were determined using a LECO Truspec dry combustion carbon analyzer (Nelson and Sommers 1996). Soil salinity was characterized with 1:1 soil to water extraction. For determination of sodium, 100 ml of de-ionized water was added to 100 grams of the ground, oven-dried soil sample to create a suspension (USDA 1954). After 4 hours to equilibrate, an extract was obtained from the suspension using the low-pressure filter press apparatus. The extract was analyzed for sodium using a Spectro Blue ICP and converted to the saturated paste equivalent. SAR was calculated using the formula from USDA (1954).

Calibration Analysis

An important part of developing a RAM is making sure that metrics capture the range of natural conditions present, and that the metrics are not overly redundant. Range is the ability of a metric to capture the distribution of conditions found in natural wetlands, while redundancy assesses how closely different metrics measure the same elements of condition (Stein et al. 2009). Range and redundancy help to inform us about which metrics might need to be adjusted so that the method will more accurately capture the condition of wetlands.

To determine the range of scores among our study sites, we created histograms for each metric and qualitatively assessed the distribution of their scores. These histograms help us to determine if OKRAM overall and metric scores track with known measures of disturbance. In our case we expected OKRAM overall and metric scores to track LDI and FQI scores along a gradient of disturbance from “least disturbed” to “highly disturbed”. If any metric consistently scores within a narrow range it provides minimal data to improve the separation of OKRAM scores between reference and disturbed wetlands. For example, if the range of scores for a metric is 0.0 to 1.0 and the metric consistently scores between 0.9 and 1.0 then the metric is not differentiating between least disturbed and highly disturbed sites. Metrics which show this narrow range of scores should be evaluated and either excluded from the RAM or their scoring should be altered to provide a broader range of scores.

To measure metric redundancy, we used Spearman’s ρ correlations to examine relatedness of OKRAM metrics. The higher the statistically significant Spearman’s ρ value, the more likely a set of metrics are to measure the same environmental variable. Strong correlation between metrics is used to interpret the results and inform decisions on whether to make changes in the method such as eliminating and/or combining metrics (Stein et al. 2009). A Spearman’s ρ value of 0.70 or higher is considered to be a strong correlation in mathematics.

We evaluated OKRAM’s ability to define wetland condition by comparing overall OKRAM and attribute scores with Level 3 intensive data using Spearman’s ρ correlations (Crawley 2013, R Core Development Team 2020). Significant correlations in expected directions are interpreted as evidence of the method’s ability to discern differences in wetland condition (Stein et al. 2009). We evaluated the relationships of OKRAM metrics to Level 3 and LDI scores to provide additional support for calibration. Consistent relationships with LDI can demonstrate the ability of OKRAM metrics to capture levels of disturbance within the surrounding landscape while relationships to Level 3 data can show the ability of OKRAM metrics to capture disturbance locally.

We also compared the Water Source, Hydrologic Connectivity, Buffer Filter, and Habitat Connectivity metrics with their alternative metrics to further evaluate their effectiveness. We compared each metric to level 1 and level 3 data to identify the metric best supported with independent measures of wetland condition. We were unable to complete the CRAM method for Hydrologic Connectivity at most of our sites due to unusually high-water levels throughout the season, so this metric was excluded from the rest of our evaluation.

OKRAM is expected to be used on floodplain wetlands of streams throughout Oklahoma. Therefore, we also examined the applicability of OKRAM across different stream sizes (e.g., headwater, creek, large river) and river systems (Deep Fork River, North Canadian River). To better assess the effectiveness of OKRAM on different stream systems, we evaluated OKRAM scores within each river system (Deep Fork River, North Canadian River) and within main channels and tributaries of each river system. We used Spearman's ρ to determine correlations between OKRAM and Level 1 and 3 data for subsets of study streams (i.e., mainstem, tributary, Deep Fork, etc; Table 4). Lower correlation may indicate that improvements could be made to the metrics to reflect condition more accurately for wetlands associated with that stream system type.

RESULTS

OKRAM Responsiveness to LDI and Level 3 Data

We initially examined OKRAM responsiveness to Level 1 landscape data (Tables 4 and 5). LDI scores within the 1,000 m circular buffer around each AA ranged from 1.02 to 5.62 with a mean of 1.92 (SE = 0.19) showing that an anthropogenic disturbance gradient occurred within the landscape surrounding our sites. Overall OKRAM scores ranged from 0.46 to 0.97 with a mean of 0.79 (SE = 0.03) and were negatively correlated with LDI scores ($\rho = -0.657$, $P < 0.001$). The histogram for LDI shows site scores occurring along a broad range but only two of the sites occurred in the "highly disturbed" end of the score range. The histogram for OKRAM also showed a skew toward "least disturbed" sites, all of the sites were clustered on that half of the score range (Figure 4).

When evaluating the influence of stream order and stream type on the relationships between OKRAM and LDI, as well as the relationships between OKRAM and FQI, we found differences between data subsets (Table 4). OKRAM overall scores had significant negative correlations to LDI for the data subsets consisting of all main channel sites for both rivers ($\rho = -0.657$, $P = 0.008$), all tributary sites for both river systems ($\rho = -0.668$, $P = 0.007$), all sites of the North Canadian River system ($\rho = -0.793$, $P < 0.001$), North Canadian River system tributary sites ($\rho = -0.964$, $P < 0.001$), all sites of the Deep Fork River system ($\rho = -0.807$, $P < 0.001$), and Deep Fork River main channel sites ($\rho = -0.857$, $P = 0.014$). OKRAM and LDI were not significantly correlated for the data subsets consisting of the North Canadian River main channel sites and the Deep Fork River tributary sites.

OKRAM overall scores were significantly and consistently correlated to FQI, Native Species Richness, and soil nitrate (Tables 5 and 6). FQI scores, which represent the level of anthropogenic impact on the vegetation community, ranged from 0 to 23.67 with a mean of 15.34 (SE = 1.18). We found significant correlations between OKRAM overall scores and FQI scores ($\rho = 0.726$, $P < 0.001$). As with LDI, OKRAM scores showed a different range of values than did FQI (Figure 4). Native Species Richness, which has been used as an indicator of wetland disturbance, ranged from 1 to 43 species per site and was significantly correlated with OKRAM overall scores ($\rho = 0.436$, $P = 0.016$). Soil nitrate was the only soil chemistry data showing a significant correlation to OKRAM overall scores and had a negative correlation ($\rho = -0.389$, $P = 0.034$).

FQI and overall OKRAM scores were significantly correlated for the data subsets (Table 4) consisting of all tributary sites for both river systems ($\rho = 0.864$, $P < 0.001$), all sites of the North Canadian River system ($\rho = 0.875$, $P < 0.001$), North Canadian River main channel sites ($\rho = 0.690$, $P = 0.058$), North Canadian River system tributary sites ($\rho = 1.000$, $P = 0.000$), all sites of the Deep Fork River system ($\rho = 0.621$, $P = 0.013$), and Deep Fork River system tributary sites ($\rho = 0.738$, $P = 0.037$). OKRAM was not significantly correlated to FQI for the data subsets consisting of all main channel sites or Deep Fork River main channel sites. Soil data correlations to OKRAM were not consistent across the data subsets. Overall OKRAM scores were only significantly correlated to soil nitrate for the data subsets consisting of all North Canadian River system sites ($\rho = -0.682$, $P = 0.005$) and North Canadian River tributary sites ($\rho = -0.757$, $P = 0.049$).

Evaluation of OKRAM Metrics

OKRAM attributes and metrics showed significant correlations to Level 1 and Level 3 data with a few exceptions. LDI scores were significantly negatively correlated with all OKRAM attribute scores (Table 5): Hydrologic Condition ($\rho = -0.480$, $P = 0.008$), Water Quality Condition ($\rho = -0.464$, $P = 0.010$), and Biotic Condition ($\rho = -0.663$, $P < 0.001$). FQI was also correlated with individual attribute scores for all sites: Hydrologic Condition ($\rho = 0.575$, $P < 0.001$), Water Quality Condition ($\rho = 0.577$, $P < 0.001$), and Biotic Condition ($\rho = 0.558$, $P = 0.001$). The Biotic Condition attribute was also significantly correlated with Native Species Richness ($\rho = 0.381$, $P = 0.038$) and significantly negatively correlated with Soil nitrate ($\rho = -0.447$, $P = 0.013$).

Both LDI and FQI showed significant correlations (LDI: $\rho \geq -0.396$, $P \leq 0.030$; FQI: $\rho \geq 0.461$, $P \leq 0.010$) to all OKRAM metrics except for Hydrologic Connectivity, Nutrients, and Chemical Contaminants (Table 5). Stressors for Nutrients and Chemical Contaminants were only recorded at a few sites making it difficult to derive any meaningful correlations about theses metrics.

Stressors for the Sediment metric were not found at any site, so no correlations were calculated. Soil nitrate was significantly negatively correlated with the Water Source (ρ = -0368., P = 0.045), Water Source alternative (ρ = -0475., P = 0.008), Habitat Connectivity (ρ = -0.408, P = 0.025), and Habitat Connectivity alternative (ρ = -0.483, P = 0.007) metrics (Table 6).

If metrics are working correctly, we would expect them to show a range and pattern of scores similar to independent measures of wetland condition (Figures 5-7). The Hydrologic Condition attribute showed a narrower range of scores than FQI but was still positively skewed. It's metrics, Hydroperiod, Water Source, and Water Source alternative all showed a broad range of scores, and all were positively skewed. The hydroperiod metric was much more skewed than the Water Source metrics. The other Hydrologic Condition metric, Hydrologic Connectivity, had a broader range of scores, but did not show patterns similar to FQI (Figures 4 and 5). The Water Quality Condition attribute had a narrow range of score clustered toward the least disturbed end of the scale and all of its metrics were positively skewed. Nutrients and Chemical Contaminants had very narrow score ranges, all on the high end of the range. The Buffer Filter metric and its alternative had scores at each end of the score range with the majority being on the high end. The Biotic Condition attribute and it's metrics (Vegetation, Habitat Connectivity, and Habitat Connectivity alternative) showed a broad range of scores and were positively skewed.

In evaluating the redundancy of the metrics, we found that none of the metrics showed any unexpected correlations. If two metrics have a strong, statistically significant correlation ($\rho \geq$ 0.70, $P \leq 0.05$) to one another, we would have to consider whether they might be measuring similar ecological condition values making the metrics redundant. The metrics with the highest correlations were the Habitat Connectivity alternative and the Buffer Filter metrics (ρ = 0.628, $P < 0.001$), the Habitat Connectivity alternative and the Buffer Filter alternative metrics (ρ= 0.629, $P < 0.001$), and the Habitat Connectivity alternative and Vegetation metrics (ρ = 0.665, $P < 0.001$) (Table 7).

DISCUSSION

Based on the correlation of OKRAM to LDI and FQI, it can differentiate between least impacted and highly impacted Riverine Floodplain Wetlands. OKRAM still needs to be better calibrated to increase its efficacy in these wetlands. We ran into several issues during this calibration attempt.

Responsiveness of OKRAM to Level 1 Data

To provide support for the utility of OKRAM in floodplain wetlands, we needed to ensure OKRAM was responsive to anthropogenic disturbance in the surrounding landscape. Responsiveness is the ability of a RAM to discern between reference and highly impacted wetlands and can be evaluated by the correlation of its overall and attribute scores to LDI (Stein et al. 2009). The negative correlation of LDI to OKRAM and OKRAM attribute scores in our study demonstrate that OKRAM is responsive to anthropogenic disturbance at local and landscape scales.

The negative correlations to water quality and biotic condition were expected. Water quality is strongly tied to the ability of the surrounding landscape to act as a buffer. Intact buffers act to filter out contaminants and sediment which might have a negative impact on the wetland (Rickerl et al. 2000, Sweeney and Newbold 2014). Biotic Condition is partly based on habitat surrounding the wetland and, like LDI, looks at landscape use within a 1000m buffer around the assessment area leading to similar condition scores. These relationships are consistent with findings in depressional wetlands by OWRB (2015) and Gallaway et al. (2019a). The consistency in these very different wetland types suggests that OKRAM will score similarly compared to LDI for other wetland types.

Responsiveness of OKRAM to Level 3 Data

Fennessy et al. (2007) evaluated several existing RAMs and concluded that each RAM should be calibrated and validated to Level 3 data. Correlating RAM scores to independent, intensive measures of condition provides evidence for the scientific defensibility of the method (Sutula et al. 2006). Vegetation communities have been found to shift in response to anthropogenic disturbance with native species decreasing with increased disturbance (Chipps et al. 2006). The correlation of OKRAM scores to FQI and native species richness highlights this shift. As ecological condition decreases so do FQI and the prevalence of native species. The correlation of OKRAM scores to FQI and native species richness suggests that OKRAM is capturing the gradient of ecological condition present in our study wetlands.

Native species richness and FQI were both correlated to the biotic condition attribute. As Gallaway et al. (2019a) discussed, this was expected since vegetation is a measured value of the attribute. Also, as in Gallaway et al. (2019a), the hydrologic condition and water quality attributes were correlated to FQI indicating that OKRAM is detecting alterations to hydrology and stressors to water quality. The similarities in correlations between these studies highlight the capacity of OKRAM to assess different wetland types providing support for the efficacy of OKRAM as a statewide assessment method.

While OKRAM did correlate well with FQI, there were some sites which did not follow the pattern. For example, of the four sites with the highest OKRAM score (0.97), three of them had relatively low FQI scores, but had also suffered scouring floods prior to sampling. This may point to effects on FQI due to the flooding. Other authors have found that natural processes such as drought or flood can have a greater influence on wetland vegetation communities than anthropogenic alteration (Guimond 2001, Euliss and Mushet 2011). This inability to distinguish natural disturbance regimes from anthropogenic disturbance is a drawback of FQI. OKRAM attributes were chosen to specifically target anthropogenic stressors to wetland condition so as not to undervalue wetlands based on temporal stressors such as drought or flooding. The fact that

OKRAM did not follow the same trend as FQI in these cases suggests that OKRAM attributes may be more accurately assessing these recently scoured sites.

OKRAM is intended to be a tool to evaluate wetland condition for remediation, mitigation, and restoration efforts statewide. In order for this to occur, it will have to be verified at wetlands statewide. This was done for depressional wetlands (Gallaway et al. 2019a), but will have to be completed for each wetland type in the state. Most of the wetlands in this study were in the eastern half of the state, primarily within the Crosstimbers Ecoregion. Oklahoma has a strong east to west precipitation gradient that roughly follows breaks in ecoregions. Gallaway et al. (2019b) found that FQI scores for depressional wetlands in Oklahoma increased from west to east along a precipitation gradient. Figure 8 shows the relationship of FQI and OKRAM scores in our study to precipitation based on site longitude. FQI shows a strong linear relationship to precipitation while the linear relationship of OKRAM scores diverges significantly from precipitation. It is important to take the precipitation gradient into account when using FQI to validate OKRAM statewide because least impacted wetlands in the western half of the state could score significantly lower FQI scores than those in the eastern half of the state. This could lead to the actual quality and value of impacted wetlands in the western half of the state being greatly underestimated (Gallaway et al. 2019b). In effect, a reference condition wetland in the western half of the state would likely have lower FQI scores than a similarly functioning wetland in the eastern half of the state. Due to the effect of the precipitation gradient, FQI score ranges used to designate least impacted and highly impacted condition may need to be determined separately for each ecosystem in Oklahoma.

The last Level 3 data we looked at was soil chemistry. Soil chemistry can be used to explain some variations between RAM scores and vegetation metrics such as when Soil phosphorus in depressional wetlands has been shown to be significantly correlated to OKRAM (Gallaway et al. 2019a) and to FQI (Lopez and Fennessy 2002). We did not find any correlation to Phosphorus for floodplain wetlands. The only soil chemistry data which showed significant correlations in our study soil nitrate. It was significantly negatively correlated to OKRAM overall and attribute scores but not to FQI. Of the four sites with the highest concentrations of nitrate, three were surrounded by agricultural land and one was in an urban watershed. The high concentrations of nitrate for these sites may be due to runoff from the surrounding landscape but I have been unable to find corroboration in the literature. Gallaway et al. (2019a) also found significant correlations between the Biotic Condition attribute and soil nitrate but not to OKRAM overall scores.

OKRAM Metrics

Looking at individual OKRAM metrics pointed out some issues that will help to inform the method going forward and help to eliminate some metric alternatives we developed for this study. Hydroperiod and Water Source correlations to LDI and Level 3 vegetation data suggest they are sufficiently capturing anthropogenic disturbance in the surrounding landscape and biological condition of our wetlands. The Water Source alternative metric with added severity multipliers was much better correlated to FQI than the original Water Source metric, which did not include severity multipliers. Since the added severity multipliers fulfilled their purpose of increasing the distribution of scores for the Water Source metric, and this led to better correlation with both LDI and FQI, the alternative metric was retained for the final OKRAM overall score. The Hydrological Connectivity metric adapted from the California Rapid Assessment Method (CRAM) (Collins et al. 2013b) was much more time intensive than its alternative and could not be measured at many sites due to deep water. Due to the inability to collect the data for the CRAM based metric at most sites, we excluded it from OKRAM calculations. The CRAM method was expected to be a better option since it is a more objective measure of condition than the alternative metric. Upon review of CRAM methodology, there was an alternative way of completing this metric based upon an estimated bankfull depth measurement in unwadeable streams. This could be accomplished by measurements from a bridge or other stable platform over the river. If you could get a depth measurement from up- and downstream of the assessment site you could use the average of the two as an estimated depth for that reach of the stream. Another option would be to use bathymetric imaging of the river bed if it is available for the stream you are assessing. Unfortunately we could not test this approach during our assessment period, but it is a potential direction to take for future studies. The alternative Hydrological Connectivity metric, using visible indicators, was easier to use but its lack of correlation to any other measure of ecological condition means it will need to be modified if it is to be used in the future. The alternative Hydrological Connectivity metric is very similar to the channel stability metric used by CRAM which suggests an alternative method of scoring this metric. Instead of scoring each type of indicator for degradation or aggradation of the channel we could use a presence or absence approach. If the channel is in equilibrium the metric would score a 1.0, if it has indicators of aggradation or degradation but none are severe, or they are not present though most of the assessed channel length, then it would score a 0.5, if the indicators are severe through most of the assessed length of the channel it would score a 0.1, and if the channel has been hardened, by artificial means such as concrete, through most of the assessed length then it would score a 0.0. Checking this alternate scoring method for the alternative Hydrological Connectivity metric will be simple given we already have the data, but it will take some time.

Due to the lack of sites with stressors for the Nutrients, Sediment, and Chemical Contaminants metrics we were unable determine any useful correlations to any other condition indicators. In future versions of OKRAM the scoring of the Water Quality attribute may need to be altered to reduce positive bias. The stressors for these metrics seem to be rare in floodplain wetlands but may have a significant effect if they are present. No stressors were present for the sediment metric in this study but at another floodplain site I surveyed, there was extreme sedimentation from a recent flood that had buried most of the understory vegetation. At that site, sedimentation was a major stressor to the wetland. There is some difficulty differentiating between anthropogenically driven sedimentation and naturally occurring sedimentation due the heavy sediment loads present in most Oklahoma streams, but that can be alleviated by training assessors in the difference between naturally occurring and anthropogenic sedimentation rates. Between the Buffer Filter metric and its alternative we found no significant difference in correlations with FQI or LDI. Other studies looking at landscape buffers around riverine wetlands have found similar correlations at multiple scales including looking at upstream buffer (Stein et al. 2009) but no studies I have found looked at buffers upslope. High resolution digital elevation models (DEMs) are difficult to find for Oklahoma and manually drawing polygons based on topographic imagery is very time consuming. Due to these difficulties and the lack of significant differences in correlation for the two metrics we decided to use the simplified buffer metric to calculate the final overall OKRAM score.

The Vegetation and both Habitat Connectivity metrics were well correlated to LDI and FQI showing they are sufficiently capturing anthropogenic disturbance in the surrounding landscape and biological condition of our wetlands. Habitat Connectivity was modified from previous studies by reducing the measured buffer size from 2000 meters to 1000 meters as suggested by Gallaway et al. (2017). In addition, an alternative metric was developed which included a temporary dispersal barrier/ marginal habitat category, instead of just connected and unconnected habitat, to attempt to obtain a greater range of scores. Temporary dispersal barriers included areas that are anthropogenically disturbed but are still used by animals such as hay meadows and frequently used bike trails. Marginal habitat includes areas of ecosystem conversion such as forest converted to rangeland and Eastern Red Cedar encroachment on native prairie. Including these temporary dispersal barriers and marginal habitat in the scoring for Habitat Connectivity increased the distribution of scores within the metrics score range. This change in scoring resulted in a distribution of scores that was less skewed than the original metric and closer to the distribution shown by FQI (Figure 7). We selected the alternative metric for inclusion into

OKRAM because it showed an increase in correlation to both LDI and FQI scores and a better distribution of scores along its range.

Stream Type and Size

In this study we did not control for stream order, only for whether the wetland was associated with the main channel of the river systems or one of their tributaries. We also divided the sites by stream type (e.g., incised or braided) of the main channel streams. That being said, all of the tributary streams which we sampled sites on were much smaller than their associated main channels and shared similarities due to their associated watersheds. We intended to determine if any clear patterns in correlations to Level 1 and Level 3 data could be determined based on the river system being studied or the size of the stream. While we had hoped to compare these findings to other studies we were unable to locate any similar studies in our research. The result of splitting the data into subsets did yield some results we felt were worth further review. Overall though, OKRAM was well correlated with LDI and FQI independent of stream size or type.

Two subsets, the North Canadian Main channel and the Deep Fork tributaries, showed no significant correlation to LDI. Of the sites which fell outside of confidence levels, one within the North Canadian Main subset had a high (0.85) OKRAM score and also had a high LDI score. LDI was scored in a 1000m buffer around the wetland and in this case it included land-use on the opposite side of the river with a high concentration of anthropogenic land-use which increased the LDI score but had little effect on the wetland. In this case, the correlation might be improved by reducing the size of buffer for LDI calculations to 100m. Other studies (Rooney et al. 2012) have shown that buffers of about 100m more accurately represent significant buffers around floodplains. Within the Deep Fork Tributary subset, the opposite was true. There were two sites which had relatively low LDI scores but also had very low OKRAM scores. These discrepancies are likely due to sample size.

FQI and OKRAM correlations were insignificant for all three of the main channel subsets. The reason for this is not obvious from the data but may be because of the 15 sites included in these three subsets, only three of the sites had low scores. This may simply be a symptom of sample size, or it may be an effect of the very large floodplain areas along the main channel of these rivers. One potential way to account for these large wetland areas is to sample multiple AAs within the wetland and average the scores to get an overall score for the entire wetland.

Condition Classes

Low mean of LDI scores suggest sites were skewed toward the least disturbed category. Since both OKRAM and FQI also showed a tendency toward lower disturbance, this may indicate that our a priori categorization of our sites was insufficient. While we chose sites based on best professional judgement, we learned more about how to recognize riverine wetlands, based on vegetation and signs of high water, as we progressed through the study. Upon reviewing our site choices we may have been able to find more highly impacted sites and better low impact sites based on our current knowledge of these systems. Better selection of sites may have yielded stronger relationships between assessment methods or helped to segregate issues within OKRAM for this wetland type. Another possibility is that wetland condition in Riverine wetlands is generally higher than in other wetland classes. Gallaway et al. (2019a) determined condition class thresholds to be at 0.84 and higher for least disturbed sites and 0.50 and lower for highly disturbed sites. Only two of our wetlands met the 0.50 threshold for highly impacted condition but 18 of our sites met the 0.84 threshold for least impacted condition. We would need a randomly selected sampling of wetlands to use the protocol by Sifneos et al. (2010) to establish condition class thresholds for Riverine wetlands. I feel that the skew in the data, since it occurs in all three methods, is likely caused by poor site selection protocols. To better choose sites at either end of the spectrum for Riverine wetlands I would choose sites based upon LDI scores within a

100m buffer around the wetland. While this would eliminate the use of LDI for the calibration of metrics, but it would likely provide a better sampling of highly impacted and least impacted sites.

CONCLUSION

OKRAM has already been proven to be an effective tool for measuring condition at depressional wetlands (Gallaway et al. 2019a). Each wetland type exhibits unique stressors (e.g., differences in water source, direction of water flow, differences in vegetation community, etc.) requiring that OKRAM be validated for each wetland type (Sutula et al. 2006, Fennessy et al. 2007, Stein et al. 2009). This study demonstrates that OKRAM can be used as an effective tool to assess floodplain wetlands rapidly and affordably though some metrics will need to be modified to improve its efficacy. Some metrics (e.g., Hydrologic Connectivity, Sediment, Nutrients, and Chemical Contaminants) will need to be further refined, scored differently, or discarded. We suggest revisiting the Hydrologic Connectivity metric from CRAM to determine if there is a safe method of taking these measurements in cases where the water is too deep to wade. In retrospect, one of the issues we see with the Hydrologic Connectivity Alternative metric is that we did not consider the stream type when we were scoring the metric. For instance, the first stressor for the metric is vertical/sheer banks (Appendix A). The Deep Fork River is an incised stream, and it could be argued that vertical or sheer banks are the natural state of the stream. In this case, we recommend a review of the metric and its stressors in relation to different types of streams. As for the Sediment, Nutrients, and Chemical Contaminants metrics, I recommend combining the metrics into a single score.

The intended outcome of this study was a fully calibrated method which could then be applied to a larger validation study across the state. I think we partially accomplished this with the alternative metrics we devised and tested. Two of those alternative metrics, Water Source and Habitat Connectivity, proved to be more effective than the original metrics. More still needs to be done to perform a proper calibration of the method as I outlined above. A large validation study will also still need to be completed using randomly selected sites. Validation will ensure that the calibrated metrics work well for Riverine Floodplain Wetlands across the state. I recommend a stratified random sampling method using Oklahoma's ecoregions (e.g., Western Tablelands, Crosstimbers, Gulf Coastal Plain) to stratify the sites. This will help to reduce bias in FQI due to the precipitation gradient and ensure that wetlands in each strata share similar vegetation communities which can also affect FQI.

Based on our results, I believe that OKRAM can differentiate between least impacted and highly impacted floodplain wetlands for the purposes of wetland management and wetland loss remediation. I recommend that the identified metrics be refined and that a statewide validation study be conducted for floodplain wetlands before OKRAM is officially used as an assessment tool for this wetland type. Continuing calibration and validation will also be needed to expand OKRAM use to other Oklahoma wetland types.

FIGURES AND TABLES

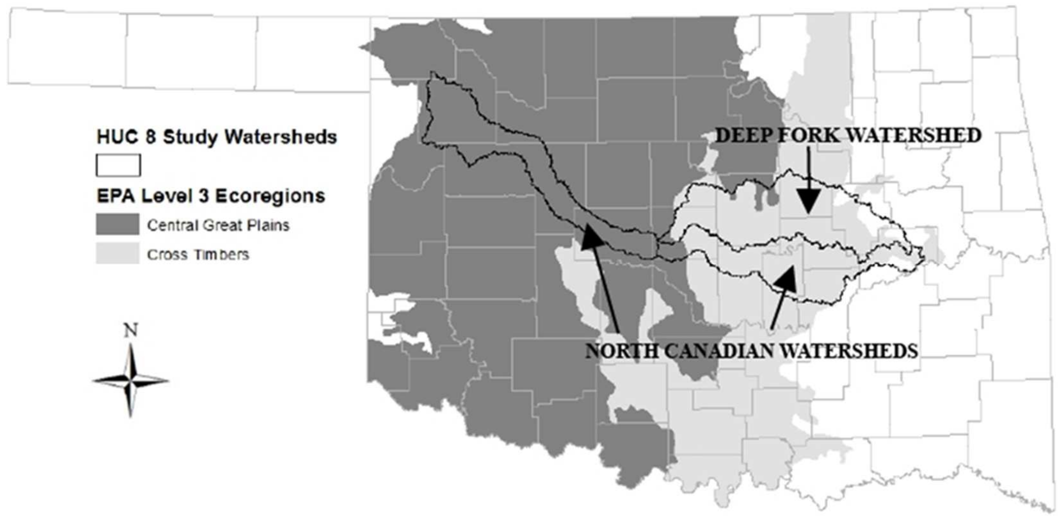

Figure 1. Map showing the Central Great Plains and Cross Timbers ecoregions in Oklahoma. The outlined areas are the HUC 8 watersheds of the Deep Fork and North Canadian Rivers. 30 sites were selected from the watersheds of the two rivers, for the calibration of the Oklahoma Rapid Assessment Method (OKRAM) for floodplain wetlands, and assessed between May and September of 2018.

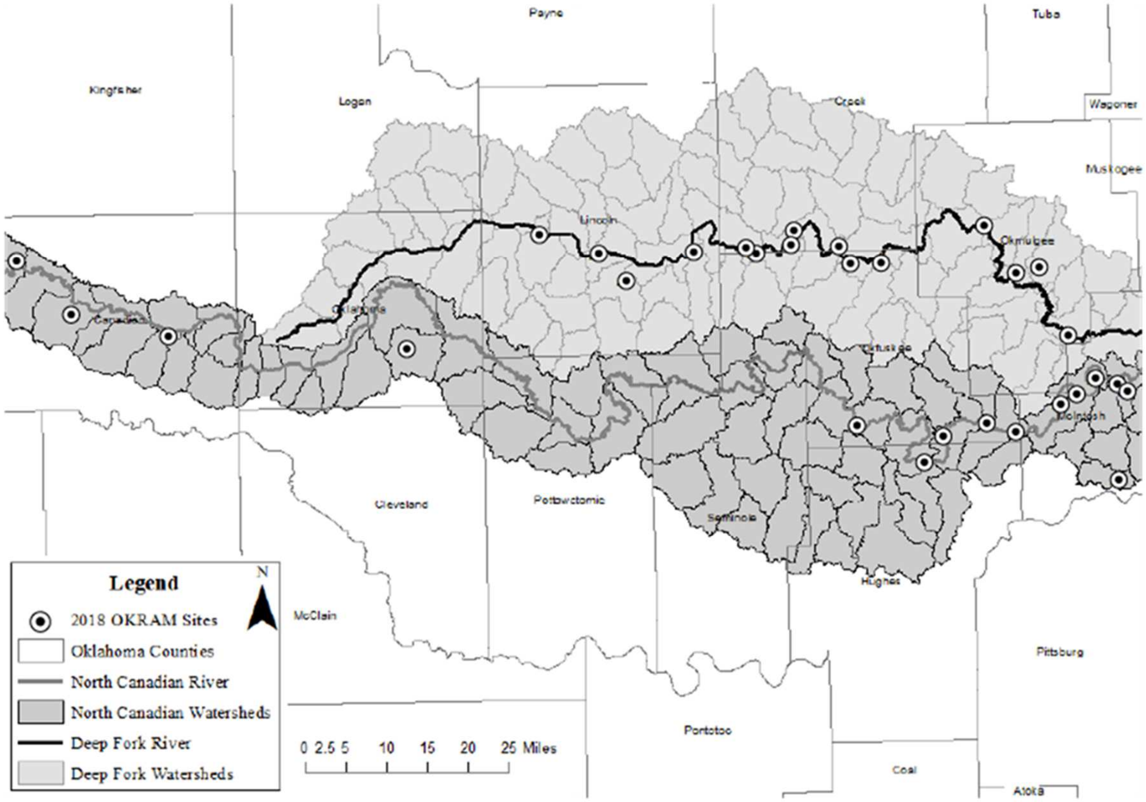

Figure 2. Map showing study sites for the calibration of OKRAM for floodplain wetlands in Oklahoma. Data for the study was collected from May to September of 2018 at 30 sites within the Deep Fork and North Canadian River watersheds. HUC 12 Watersheds are outlined in white. The thick black line outlines the watersheds for the Deep Fork River.

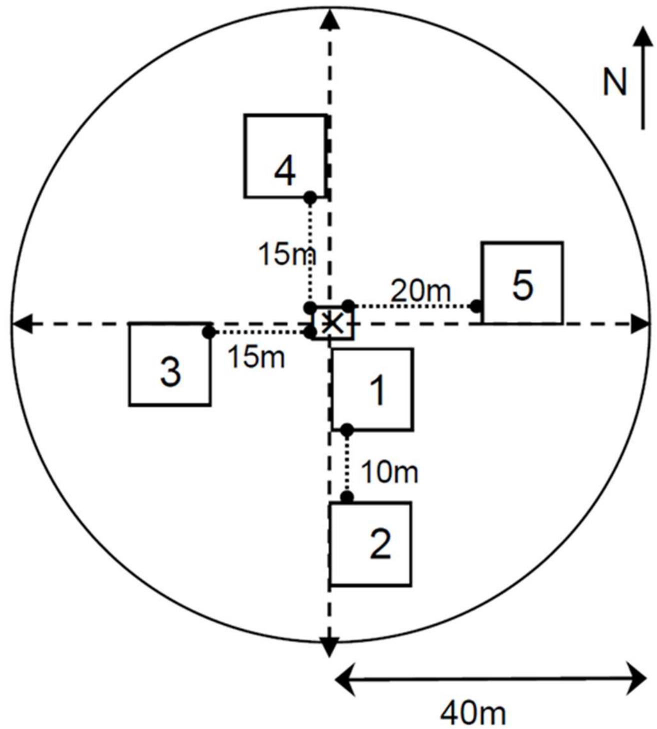

Figure 3. NWCA standard vegetation plot layout consisting of a 0.5ha circular AA and five 100m2 box plots (USEPA 2016b - Figure 5-3. Reference Card V-2, Side A).

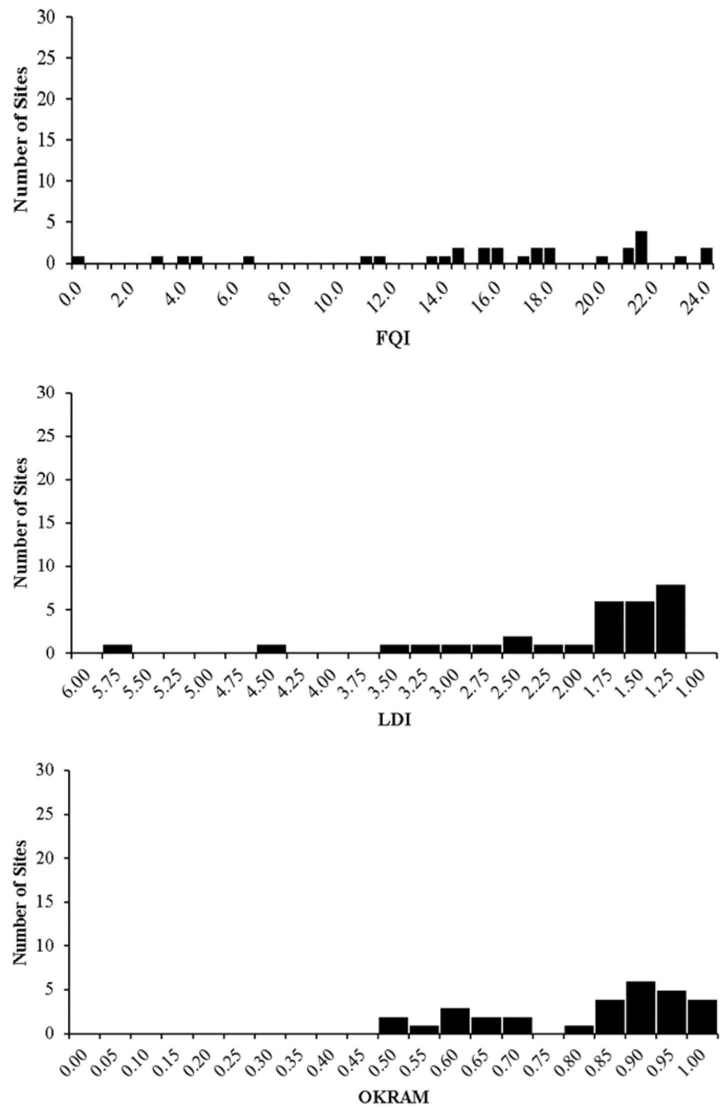

Figure 4. Histograms showing the range of FQI, LDI, and OKRAM scores from 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma. Data was collected during the months of May to September of 2018. All three show a broad spread of scores but most sites were clustered toward one end of the score range indicating a skewing of sites toward least impacted condition. OKRAM scores fell into the upper half of OKRAM's potential score range. This likely indicates that OKRAM's score threshold for least impacted and highly impacted condition will have to be adjusted for this type of wetland in this region.

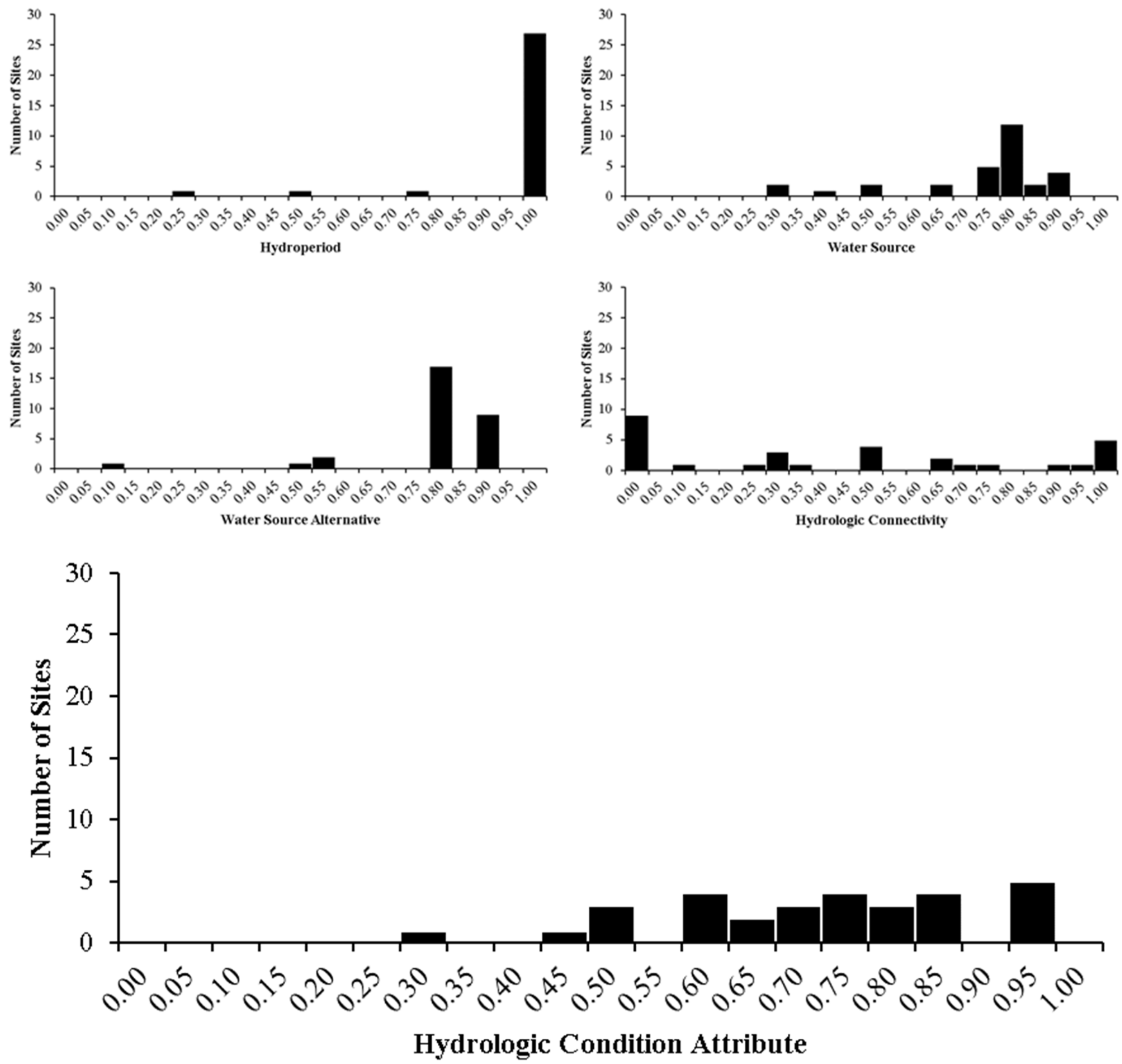

Figure 5. Histograms showing the range of scores for the OKRAM Hydrologic Condition attribute and related metrics from 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma. Data was collected during the months of May to September of 2018. The Hydroperiod, Water Source, and Hydrologic Connectivity metric scores are averaged to determine the Hydrologic Condition attribute score for each site. We expect to see scores clustering toward the higher end of the range with a few on the lower end similar to FQI.

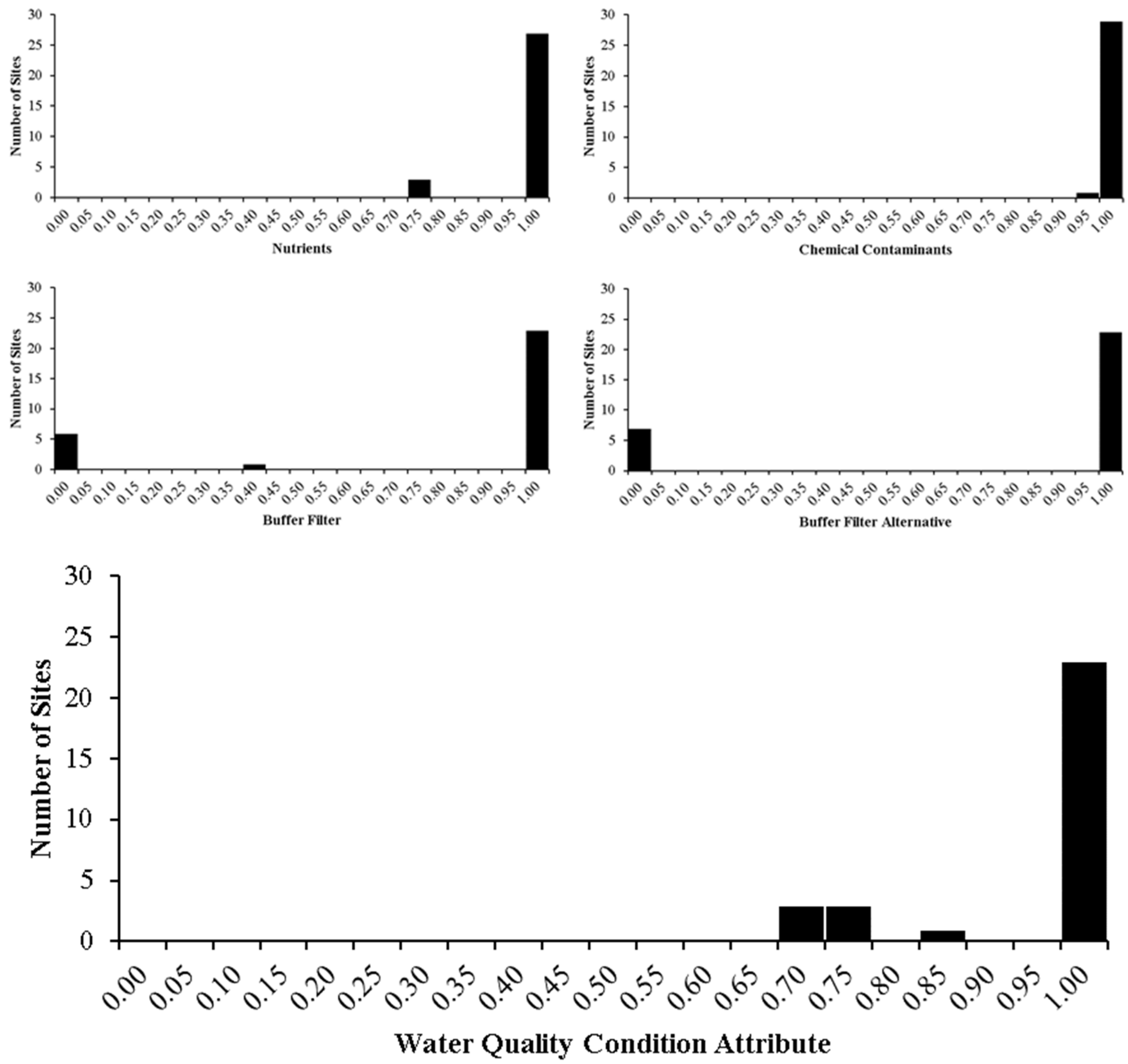

Figure 6. Histograms for OKRAM water quality attribute and related metric scores from 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma. Data was collected during the months of May to September of 2018. The Nutrients, Sediment, Chemical Contaminants, and Buffer Filter metric scores are averaged to determine the Water Quality Condition attribute score for each site. Sediment stressors were not recorded at any site, so the metric is not shown. We expect to see scores clustering toward the higher end of the range with a few on the lower end similar to FQI.

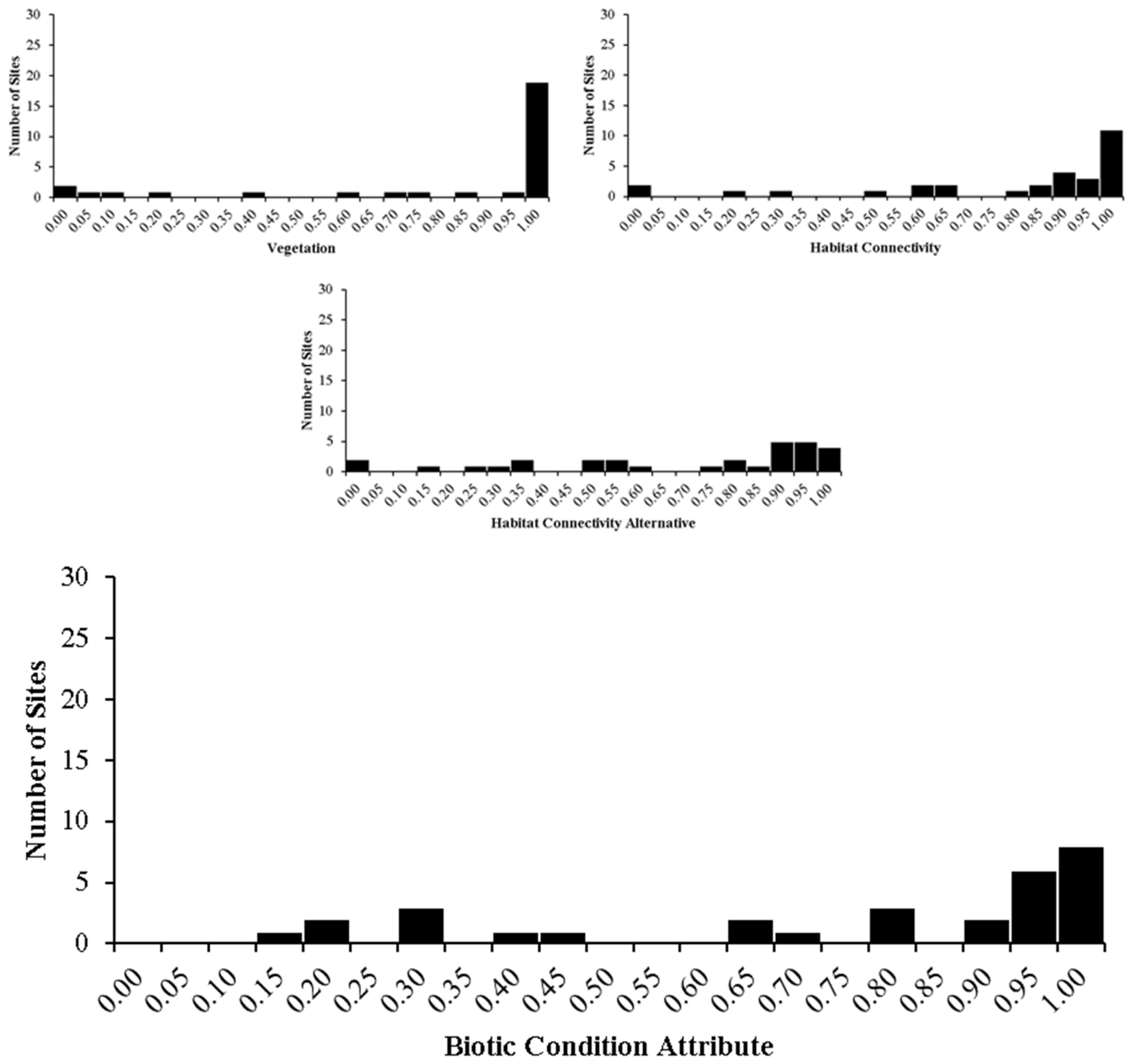

Figure 7. Histograms for OKRAM biota attribute and related metric scores from 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma. Data was collected during the months of May to September of 2018. The Vegetation and Habitat Connectivity metric scores are averaged to determine the Biotic Condition attribute score for each site. We expect to see scores clustering toward the higher end of the range with a few on the lower end similar to FQI.

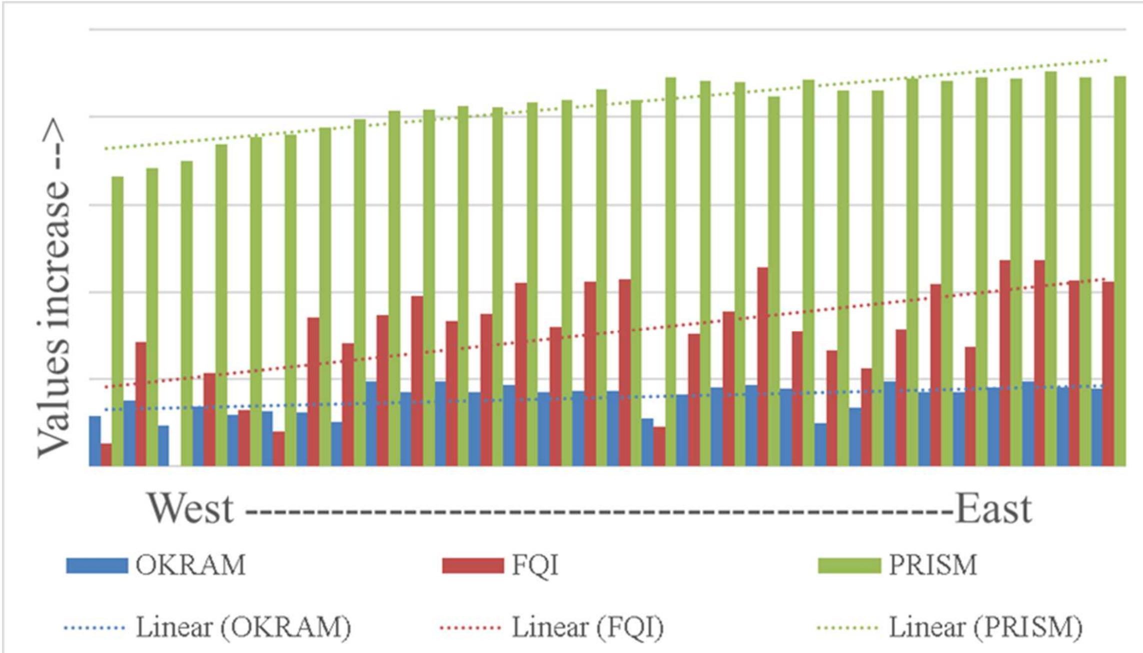

Figure 8. Bar chart showing comparison of OKRAM and FQI scores to precipitation along a West-East gradient and trend lines for each. This data was collected at 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma during the months of May to September of 2018 OKRAM scores were increased by a factor of ten so they would be visible on the chart. The numbers along the bottom axis are longitude coordinates in decimal degrees for each site with the west most site on the left side of the chart and the east most site on the right side of the chart. FQI shows a clear trend of increasing with increased precipitation. Precipitation data comes from the USDA NRCS' PRISM Climate Rasters.

Table 1. Data subsets separated by river type (the Deep Fork River system represents incised streams while the North Canadian River system represents braided/meandering streams), stream order (main channel or tributary), and a priori ecological condition. The OKRAM score range and number of sites is given for each data subset. This data was collected at 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma during the months of May to September of 2018.

River System	Main Channel/ Tributary	*A priori* condition	(N)	OKRAM score range
Deep Fork	Main Channel	High disturbance	3	0.58-0.86
Deep Fork	Main Channel	Reference	4	0.84-0.97
Deep Fork	Tributary	High disturbance	4	0.50-0.67
Deep Fork	Tributary	Reference	4	0.85-0.94
North Canadian	Main Channel	High disturbance	3	0.55-0.85
North Canadian	Main Channel	Reference	5	0.87-0.97
North Canadian	Tributary	High disturbance	4	0.46-0.76
North Canadian	Tributary	Reference	3	0.89-0.97

Table 2. National Land Cover Database (NLCD) land cover layer land-use classes and corresponding coefficients used to calculate LDI scores. This data was collected at 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma during the months of May to September of 2018.

Land Use Classification	LDI Coefficient
Natural System	1.0
Open Water	1.0
Pasture	3.41
Developed, Open Space	6.92
Cropland	7.0
Developed, Low Intensity	7.55
Barren Land	8.32
Developed, Medium Intensity	9.42
Developed, High Intensity	10.0

Table 3. OKRAM attributes and metrics with descriptions of each as used in our study. Metrics are grouped by the attribute to which they contribute.

Hydrologic Condition	
Hydroperiod	This metric evaluates indicators of inundation duration. This metric was altered from the depressional OKRAM. Indicators for up – and down-stream dams were moved to the Water Source metric.
Water Source	This metric evaluates alterations to the wetland's water source. This metric was altered from the depressional OKRAM. Indicators for up – and down-stream dams were moved from the hydroperiod metric.
Water Source Alternative	This metric is the same as the water source metric except it adds severity weights to the indicators.
Hydrologic Connectivity	This metric evaluates a wetland's connectivity to its water source. This metric is new and was adapted from the California Rapid Assessment Method. It uses quantitative channel entrenchment measurements to evaluate connectivity.
Hydrologic Connectivity Alternative	This metric evaluates a wetland's connectivity to its water source. This metric is new and was developed for OKRAM as an alternative to the CRAM method. It uses quantitative measurements of easily visible signs of degradation and aggradation to evaluate connectivity
Water Quality Condition	
Nutrients	This metric evaluates indicators of anthropogenic nutrient enrichment.
Sediment	This metric evaluates indicators of altered sedimentation.
Contaminants	This metric evaluates indicators of chemical contamination.
Buffer Filter	This metric evaluates indicators of alteration to the vegetative buffer around a wetland.
Biotic Condition	
Vegetation	This metric evaluates indicators of changes in the vegetation community.
Habitat Connectivity	This metric evaluates indicators of alteration to the contiguous habitat around a wetland
Habitat Connectivity Alternative	This metric is the same as habitat connectivity but uses a different scoring method to get a greater range of scores.

Table 4. Subsets of data showing number of sites, the standard error for final OKRAM scores, Spearman's ρ correlations of final OKRAM score, LDI, and FQI by subsets of the data. The subsets represent different combinations of stream type and order with Deep Fork River (DF) streams representing incised stream types and North Canadian River (NC) streams representing braided stream types. Main are the high order main channels of each river. Trib are the lower order tributary streams which contribute to each river system. This data was collected at 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma during the months of May to September of 2018.

			Correlation					
Subset of Data	N	SE	OKRAM/LDI		OKRAM/FQI		LDI/FQI	
			ρ	P-value	ρ	P-value	ρ	P-value
All Sites	30	0.03	-0.657	< 0.001	0.726	< 0.001	-0.558	0.001
DF Sites	15	0.04	-0.779	< 0.001	0.611	0.016	-0.446	0.095
NC Sites	15	0.04	-0.793	< 0.001	0.875	< 0.001	-0.739	0.002
Main Sites	15	0.03	-0.665	0.007	0.474	0.075	-0.386	0.156
Trib Sites	15	0.03	-0.668	0.007	0.864	< 0.001	-0.732	0.002
DF Main Sites	7	0.06	-0.857	0.014	0.393	0.383	-0.071	0.879
NC Main Sites	8	0.02	-0.619	0.102	0.690	0.058	-0.524	0.183
DF Trib Sites	8	0.06	-0.667	0.071	0.738	0.037	-0.667	0.071
NC Trib Sites	7	0.02	-0.964	< 0.001	1.000	0.000	-0.964	< 0.001

Table 5. OKRAM overall, attribute, and metric scores correlated to LDI, FQI, and Native Species Richness. Metrics are grouped with and above their associated attribute. Alternative metrics contribute to the score for alternative attributes. The sediment metric is not included in the table since no stressors for the metric were found at any of the sites. This data was collected at 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma during the months of May to September of 2018.

	LDI		FQI		Native Species Richness	
	ρ	P-value	ρ	P-value	ρ	P-value
Hydroperiod	-0.51	0.004	0.51	0.004	0.48	0.007
Water Source	-0.40	0.030	0.53	0.002	0.41	0.025
Water Source Alternative	-0.59	< 0.001	0.71	< 0.001	0.57	0.001
Hydrologic Connectivity	-0.23	0.213	0.28	0.133	0.00	0.983
Hydrologic Condition	-0.48	0.007	0.57	< 0.001	0.29	0.126
Nutrients	-0.30	0.105	0.31	0.091	0.12	0.520
Contaminants	-0.27	0.152	0.23	0.231	0.15	0.428
Buffer Filter	-0.45	0.012	0.59	< 0.001	0.35	0.056
Buffer Filter Alternative	-0.46	0.011	0.57	0.001	0.32	0.089
Water Quality Condition	-0.46	0.010	0.58	< 0.001	0.33	0.072
Vegetation	-0.53	0.003	0.59	< 0.001	0.30	0.111
Habitat Connectivity	-0.60	< 0.001	0.46	0.010	0.43	0.019
Habitat Connectivity Alternative	-0.62	< 0.001	0.54	0.002	0.42	0.020
Biotic Condition	-0.66	< 0.001	0.56	0.001	0.38	0.038
OKRAM	-0.66	< 0.001	0.73	< 0.001	0.43	0.018

Table 6. OKRAM overall, attribute, and metric scores correlated to soil nitrogen, phosphorus, ammonia, and organic matter. Metrics are grouped with and above their associated attribute. Alternative metrics contribute to the score for alternative attributes. The sediment metric is not included in the table since no stressors for the metric were found at any of the sites. This data was collected at 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma during the months of May to September of 2018.

	Nitrate (NO3)		Phosphorus (P)		Ammonia (NH4)		Organic Matter (OM)	
	ρ	P-value	ρ	P-value	ρ	P-value	ρ	P-value
Hydroperiod	-0.26	0.171	-0.06	0.761	0.12	0.527	-0.12	0.533
Water Source	-0.37	0.045	-0.60	0.000	0.43	0.019	0.03	0.891
Water Source Alternative	-0.48	0.008	-0.35	0.058	0.17	0.364	-0.13	0.489
Hydrologic Connectivity	-0.02	0.910	0.23	0.223	-0.11	0.573	-0.04	0.841
Hydrologic Condition	-0.25	0.190	0.06	0.759	-0.03	0.880	-0.15	0.442
Nutrients	0.02	0.919	0.29	0.130	-0.08	0.661	-0.10	0.613
Contaminants	-0.09	0.651	-0.10	0.612	0.25	0.189	-0.08	0.693
Buffer Filter	-0.25	0.190	0.15	0.419	-0.11	0.554	-0.14	0.458
Buffer Filter Alternative	-0.24	0.193	0.13	0.492	-0.11	0.555	-0.15	0.428
Water Quality Condition	-0.23	0.216	0.16	0.385	-0.11	0.566	-0.15	0.423
Vegetation	-0.31	0.097	-0.02	0.937	0.03	0.873	-0.20	0.302
Habitat Connectivity	-0.41	0.025	-0.26	0.171	0.06	0.736	-0.26	0.164
Habitat Connectivity Alternative	-0.49	0.007	-0.10	0.591	-0.08	0.675	-0.37	0.044
Biotic Condition	-0.45	0.013	-0.07	0.724	-0.09	0.646	-0.36	0.052
OKRAM	-0.40	0.028	-0.07	0.715	0.04	0.837	-0.24	0.193

Table 7. Correlations between all OKRAM metrics. This data was collected from 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma during the months of May to September of 2018.

OKRAM Sites										
OKRAM metrics being compared										
	Water Source	Water Source Alternative	Hydrologic Connectivity	Nutrients	Chemical Contaminants	Buffer Filter	Buffer Filter Alternative	Vegetation	Habitat Connectivity	Habitat Connectivity Alternative
Hydroperiod	ρ = 0.28 P = 0.131	ρ = 0.40 P = 0.028	ρ = 0.05 P = 0.780	ρ = 0.50 P = 0.005	ρ = 0.49 P = 0.006	ρ = 0.22 P = 0.247	ρ = 0.21 P = 0.278	ρ = 0.51 P = 0.004	ρ = 0.40 P = 0.027	ρ = 0.41 P = 0.025
Water Source			ρ = 0.17 P = 0.031	ρ = 0.14 P = 0.456	ρ = 0.20 P = 0.280	ρ = 0.53 P = 0.003	ρ = 0.52 P = 0.003	ρ = 0.48 P = 0.007	ρ = 0.59 P < 0.001	ρ = 0.57 P = 0.001
Water Source Alternative			ρ = 0.04 P = 0.843	ρ = -0.07 P = 0.711	ρ = 0.23 P = 0.231	ρ = 0.26 P = 0.165	ρ = 0.26 P = 0.163	ρ = 0.44 P = 0.016	ρ = 0.43 P = 0.017	ρ = 0.42 P = 0.020
Hydrologic Connectivity				ρ = -0.01 P = 0.973	ρ = -0.27 P = 0.145	ρ = 0.01 P = 0.942	ρ = 0.01 P = 0.951	ρ = 0.31 P = 0.094	ρ = -0.07 P = 0.702	ρ = 0.15 P = 0.427
Nutrients					ρ = 0.56 P = 0.001	ρ = 0.60 P < 0.001	ρ = 0.58 P < 0.001	ρ = 0.37 P = 0.044	ρ = 0.15 P = 0.436	ρ = 0.25 P = 0.182
Chemical Contaminants						ρ = 0.33 P = 0.072	ρ = 0.32 P = 0.084	ρ = 0.19 P = 0.328	ρ = 0.27 P = 0.151	ρ = 0.27 P = 0.152
Buffer Filter								ρ = 0.57 P = 0.001	ρ = 0.45 P = 0.012	ρ = 0.63 P < 0.001
Buffer Filter Alternative								ρ = 0.57 P < 0.001	ρ = 0.46 P = 0.011	ρ = 0.63 P < 0.001
Vegetation									ρ = 0.43 P = 0.017	ρ = 0.67 P < 0.001

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APPENDICES

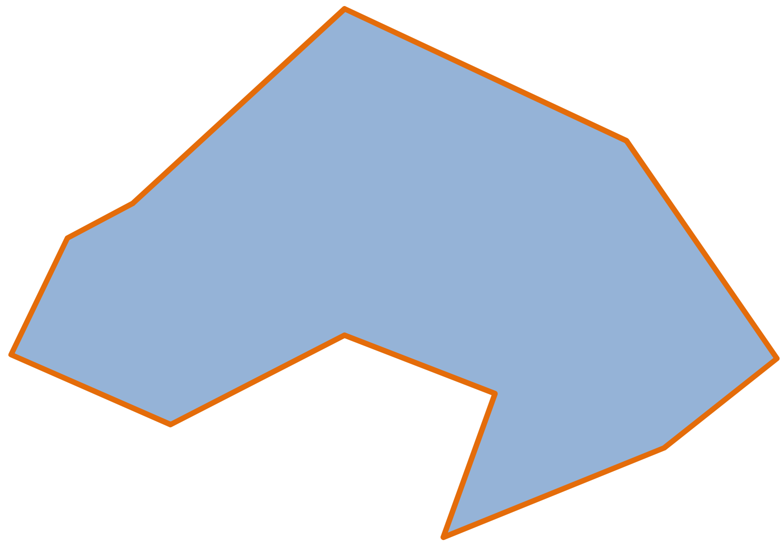
Appendix A: Oklahoma Rapid Assessment Method (OKRAM) datasheets. This assessment method was used at 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma during the months of May to September of 2018.

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 hectare 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.

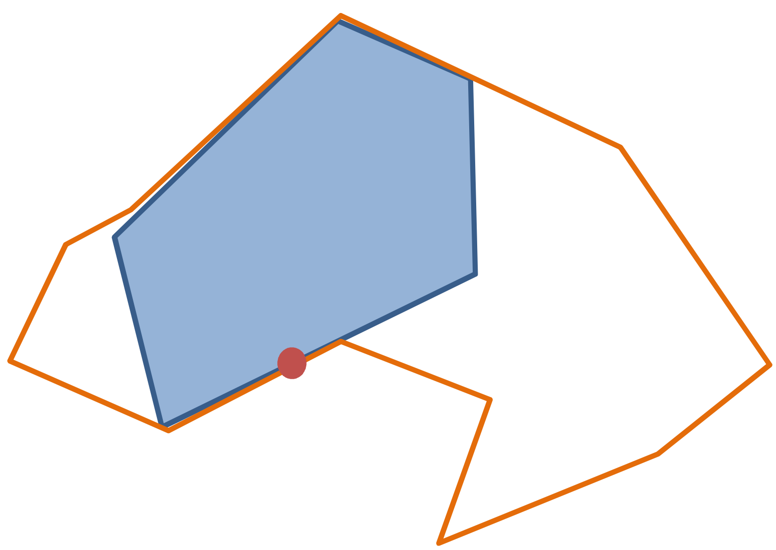
Hydrogeomorphic Wetland Subclassification Dichotomous Key	
1. Wetland is within the 5 year floodplain of a river but not fringing an impounded water body.	*Riverine*(5)
1. Wetland is associated with a topographic depression, flat or slope.	2
2. Wetland is located on a topographic slope (slight to steep) 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

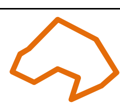
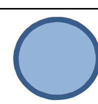
When a wetland is smaller than 1 hectare the entire wetland is the Assessment Area



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

<table>
<tr><th colspan="7">Site Description</th></tr>
<tr><td>Site Name</td><td colspan="6"></td></tr>
<tr><td>Date of Assessment</td><td colspan="6"></td></tr>
<tr><td>Assessor Name(s)</td><td colspan="6"></td></tr>
<tr><td>Assessor Affiliation(s)</td><td colspan="6"></td></tr>
<tr><td colspan="7"></td></tr>
<tr><td>Site Latitude</td><td colspan="6"></td></tr>
<tr><td>Site Longitude</td><td colspan="6"></td></tr>
<tr><td>Coordinate System</td><td colspan="6"></td></tr>
<tr><td>Ecoregion</td><td colspan="6"></td></tr>
<tr><td>Directions</td><td colspan="6"></td></tr>
<tr><td colspan="7"></td></tr>
<tr><td>Size of Wetland</td><td colspan="6"></td></tr>
<tr><td>Assessment Area size</td><td colspan="6"></td></tr>
<tr><td>Reason for Assessment</td><td colspan="6"></td></tr>
<tr><td colspan="7"></td></tr>
<tr><td>Dominant Water Source</td><td>Surface flow</td><td colspan="2">Precipitation</td><td>Groundwater</td><td colspan="2">Overbank flooding</td></tr>
<tr><td>Hydrodynamics</td><td>Unidirectional</td><td colspan="2">Bidirectional</td><td>Vertical</td><td colspan="2"></td></tr>
<tr><td>Geomorphic Setting</td><td>Depression</td><td colspan="2">Flat</td><td>Fringe</td><td colspan="2">Slope</td></tr>
<tr><td>HGM Class</td><td>Depression</td><td>Flat</td><td>Slope</td><td>Lacustrine</td><td colspan="2">Riverine</td></tr>
<tr><td rowspan="6">Regional Subclass</td><td>Closed Impounded</td><td>Hardwood</td><td>Headwater</td><td>Disconnected Oxbow</td><td colspan="2">Connected Oxbow</td></tr>
<tr><td>Open Impounded</td><td></td><td>Low-gradient</td><td>Reservoir Fringe</td><td colspan="2">Beaver Complex</td></tr>
<tr><td>Groundwater</td><td></td><td></td><td>Pond Fringe</td><td colspan="2">In-Channel</td></tr>
<tr><td>Open Surface Water</td><td></td><td></td><td></td><td colspan="2">Floodplain</td></tr>
<tr><td>Closed Surface Water</td><td></td><td></td><td></td><td colspan="2">Floodplain Depression</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2">Riparian</td></tr>
<tr><td rowspan="4">Cowardin Class (four most dominant and area as a % of AA)</td><td>Class</td><td colspan="2"></td><td>% AA</td><td colspan="2"></td></tr>
<tr><td>Class</td><td colspan="2"></td><td>% AA</td><td colspan="2"></td></tr>
<tr><td>Class</td><td colspan="2"></td><td>% AA</td><td colspan="2"></td></tr>
<tr><td>Class</td><td colspan="2"></td><td>% AA</td><td colspan="2"></td></tr>
<tr><td colspan="7"></td></tr>
<tr><td>Notes</td><td colspan="6"></td></tr>
</table>

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, cattle trails that convey storm water, 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, cattle trails that convey storm water 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 deep-water
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 deep-water

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 its 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. Delineate an area in which to calculate the cover of indicators of altered water source. Follow the river or stream, upstream for 2 km. Use the 2 km river segment to create a 2km buffer. Use a topographic map to remove the portion of the buffer downstream of the study site as well as the area upstream of the upstream edge of the 2km channel segment. Exclude any area within the 2km buffer that falls outside of the HUC 12 that contains the study site, or the HUC 12 immediately upstream of the study site. Fill in the % Cover of each of the indicators of altered water source within the created buffer. 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 than 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**	**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	**0**	
METRIC SCORE 1b	**1**	

1. Hydrologic condition **b. Water Source Alternative**			
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 its 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. Delineate an area in which to calculate the cover of indicators of altered water source. Follow the river or stream, upstream for 2 km. Use the 2 km river segment to create a 2km buffer. Use a topographic map to remove the portion of the buffer downstream of the study site as well as the area upstream of the upstream edge of the 2km channel segment. Exclude any area within the 2km buffer that falls outside of the HUC 12 that contains the study site, or the HUC 12 immediately upstream of the study site. Fill in the % Cover of each of the indicators of altered water source within the created buffer. 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 than 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. Hydrologic Connectivity - Riverine**			
Instructions: 1. If stream access is possible (landowner permission and less than 500 meters from the wetland), begin at the stream location closest to the wetland. If river access is not possible then begin at the closest bridge that crosses the source stream, and is representative of stream condition. 2. Identify bankfull indicators on both banks. Estimate bankfull width by measuring the distance between the right and left bankfull indicators. 3. Estimate maximum bankfull depth as the height of the channel from the deepest part of the channel to an imaginary line at bankfull width. 4. Estimate flood prone depth by doubling the estimate of bankfull depth. 5. Imagine a level line at a height equal to the flood prone depth. This line begins and ends where it intersects the channel banks. Measure the distance of this line 6. Calculate entrenchment ratio by dividing the flood prone width by the bankfull width 7. If stream access was possible Repeat steps 2 through 6 for three cross sections and calculate the average entrenchment ratio. If assessing connectivity from a bridge crossing, repeat steps 2 through 6 for two cross sections, one upstream and one downstream of the bridge. 8. Determine if wetland elevation is >3 times bankfull depth and is permanently disconnected from flood waters or only receives flood water in the most extreme flood events. 9. Score the metric using the scoring guidelines below based on entrenchment ratio.			
Measurement	**Cross Section**		
	1	**2**	**3**
Bankfull width			
Maximum bankfull depth			
Flood prone depth			
Flood prone width			
Entrenchment ratio	0	0	0
Average entrenchment ratio	0		
Wetland elevation is >3 times bankfull depth.		yes/no	
METRIC SCORE 1c	**1**		

Guidelines for wetlands associated with non-confined rivers	
Score	**Scoring Guidelines**
1	Entrenchment ratio is >2.2
0.75	Entrenchment ratio is 1.9 to 2.2
0.5	Entrenchment ratio is 1.5 to 1.8
0.25	Entrenchment ratio is < 1.5
0	Wetland elevation is > 3 times bankfull depth and only receives flood waters in the most extreme events.

Guidelines for wetlands associated with confined rivers	
Score	**Scoring Guidelines**
1	Entrenchment ratio is >1.8
0.75	Entrenchment ratio is 1.6 to 2.8
0.5	Entrenchment ratio is 1.2 to 1.5
0.25	Entrenchment ratio is <1.2
0	Wetland elevation is > 3 times bankfull depth and only receives flood waters in the most extreme events.

1. Hydrologic condition c. Hydrologic Connectivity - Riverine Alternative		
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, for both banks of the channel. 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, on both banks of the channel. 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 (200 m total using both banks of the channel) that has 40 meters of undercut banks and 20 meters of leaning riparian vegetation would score 1-((40+20)/200)=0.7		
Channel Length	400	
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 coalesced into one channel		
Channel has nick-points 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 pools are 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 spp. (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.)				
Storm water 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 phenomenon. 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
Storm water inputs (discharge pipes, culverts, adjacent impervious surface or railroads)	Adjacent impervious surfaces such as paved roads or railroads (within 10 meters of wetland)	Storm water 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. pump jacks, 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 motor craft uses 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 Alternative

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 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**

3. Biotic Condition

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%.

Indicators of altered vegetation community (% cover in each layer)	Vegetation Layers			
	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 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 1000m 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 1000 m buffer.	
Included in connected habitat	
open water	
other wetlands	
natural uplands	
nature or wildland parks	
bike trails	
infrequently used, at-grade 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	
raised railroads, or frequently used at-grade railroads	
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 1000 m buffer	0
METRIC SCORE 4c	1

3. Biotic Condition b. Habitat connectivity Alternative	
Instructions: 1. Land use surrounding the wetland is divided into 3 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 + 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	
infrequently used, at-grade railroads	
roads not hazardous to wildlife	
swales and ditches	
vegetated levees	
open range land	
Temporary Dispersal Barriers/ Marginal Habitat	
hay meadows	
pine plantations	
pedestrian/bike trails with near constant traffic	
forests converted to rangeland	
woody encroachment into native prairie/rangeland (e.g. Eastern Red Cedar)	
raised railroads, or frequently used at-grade railroads	
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	0
Area of Connected Habitat	0
Area within 1000 m buffer	0
METRIC SCORE 4c	1

4. OKRAM Overall Condition Score					
Metric		**Score**	**Metric**		**Score**
1	***Hydrology***				
1a.	Hydroperiod	1.00			
1b.	Water source	1.00	1b.	Water source- Alt	1.00
1c.	Hydrologic Connectivity	1.00	1c.	Hydrologic Connectivity-Alt	1.00
Hydrology Attribute		**1.00**	**Hydrology Attribute Alternative**		**1.00**
(metric 1a +metric 1b + metric 1c)/3					
2	***Water Quality***				
2a.	Nutrients	1.00			
2b.	Sediment	1.00			
2c.	Contaminants	1.00			
2d.	Buffer Filter	1.00	2d.	Buffer Filter Alternate	1.00
Water Quality Attribute		**1.00**	**Water Quality Attribute Alternative**		1.00
(metric 2a +metric 2b + metric 2c + metric 2d)/4					
3	***Biota***				
3a.	Vegetation	1.00			
3b.	Habitat Connectivity	1.00	3b.	Habitat Connectivity-Alt	1.00
Biota Attribute		**1.00**	**Biota Attribute Alternative**		**1.00**
(metric 3a + metric 3b)/2					
Overall Condition Score		**1.00**	**Overall Condition Score (Alt)**		**1.00**

5. Additional notes and suggestions to improve this assessment				
Metric	**Score**	**Was the metric scored too high or too low? Why?**	**How can the metric be improved in the future?**	**Are there additional indicators that need to be considered?**
1a. Hydroperiod				
1b. Water Source				
1c. Hydrologic Connectivity				
2a. Nutrients				
2b. Sediment				
2c. Contaminants				
2d. Buffer Filter				
3a. Vegetation				
3b. Wetland Loss				
3c. Habitat Connectivity				
Additional Notes				

Appendix B: National Wetland Condition Assessment (NWCA) Vegetation Datasheets. This assessment was used at 30 sites on the Deep Fork and North Canadian Rivers of Oklahoma during the months of May to September of 2018.

FORM V-1: NWCA 2016 VEGETATION PLOT ESTABLISHMENT (Front)

Reviewed by (initial): ____

Site ID: NWCA16-   Date: ___ / ___ / 2 0 1 6

Vegetation Plot Layout - Fill in the bubble for the Vegetation Plot Layout configuration used in this AA (see Reference Card V-2 for descriptions of plot layout configurations).

○ Standard Veg Plot Layout - 1/2 ha Circular AA (Veg Plots on 2 axes, cardinal directions from AA Center)

Alternate Veg Plot Layouts

○ Wide Polygon AA Veg Plot Layout - 1/2 ha Polygon AA with width and length >30m (Veg Plots on 2 axes)

○ Narrow Polygon AA Veg Plot Layout - 1/2-ha Polygon AA ≤ 30m wide (Veg Plots on 1 axis)

○ Wetland Boundary AA Veg Plot Layout - AA <1/2-ha polygon equal to wetland boundary (Veg Plots distributed)

For alternate or obstacle vegetation plot layouts only: Coordinates for plot corner closest to the AA center.

○ Obstacle Veg Plot Layout Used

(Fill bubble if obstacles prevent placement of plot(s) as designated by the selected Veg Plot Layout).

Obstacle Type (mark all that apply):

○ Deep Water

○ Tide Channel

○ Safety Hazard

○ Other:

Plot	Latitude North (Decimal Degrees)	Longitude West (Decimal Degrees)
Plot 1	.	– .
Plot 2	.	– .
Plot 3	.	– .
Plot 4	.	– .
Plot 5	.	– .

Add Veg Plot locations to the annotated aerial photo. Number Veg Plots 1 through 5 using guidelines on Reference Card V-2. If needed, elaborate on plot layout or make notes about unique features or gradients in the vegetation or environment in the notes section on the back of this form.

Predominant NWCA Target Wetland Type	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Definitions: **EH** - Estuarine Emergent **EW** - Estuarine Shrub/Forest **PRL-EM** - Palustrine, Riverine, and Lacustrine Emergent **PRL-SS** - Palustrine, Riverine, and Lacustrine Scrub/Shrub **PRL-FO** - Palustrine, Riverine, and Lacustrine Forested **PRL-UBAB** - Palustrine, Riverine, and Lacustrine Unconsolidated **PRL-f** - Palustrine, Riverine, and Lacustrine Farmed (not actively farmed) (See Reference Card AA-3, Side A for wetland type descriptions)	○ EH ○ EW ○ PRL-EM ○ PRL-SS ○ PRL-FO ○ PRL-UBAB ○ PRL-f	○ EH ○ EW ○ PRL-EM ○ PRL-SS ○ PRL-FO ○ PRL-UBAB ○ PRL-f	○ EH ○ EW ○ PRL-EM ○ PRL-SS ○ PRL-FO ○ PRL-UBAB ○ PRL-f	○ EH ○ EW ○ PRL-EM ○ PRL-SS ○ PRL-FO ○ PRL-UBAB ○ PRL-f	○ EH ○ EW ○ PRL-EM ○ PRL-SS ○ PRL-FO ○ PRL-UBAB ○ PRL-f

Plant Species Nomenclature: Record citations for Floras/Field Guides/Databases used for plant identification

1.

2.

3.

4.

03/24/2016 V-1 NWCA 2016 Vegetation Plot Establishment   4543346166

FORM V-1: NWCA 2016 VEGETATION PLOT ESTABLISHMENT (Back)

Reviewed by (initial): ____

Site ID: NWCA16-

Date: ___ / ___ / 2 0 1 6

NOTES: If needed, elaborate on reasons for plot layout selection and make notes about unique features or gradients in the vegetation or environment.

Veg Plot Layout:

Vegetation or Environment of AA:

Specific Notes for Individual Plots:

Plot 1:

Plot 2:

Plot 3:

Plot 4:

Plot 5:

03/24/2016 V-1 NWCA 2016 Vegetation Plot Establishment

9761346163

FORM V-2: NWCA 2016 VASCULAR SPECIES PRESENCE AND COVER (Front)

Reviewed by (initial): ______

Site ID: NWCA16-   Date: ___ / ___ / 2 0 1 6   Page 1 of ___

Instructions:

1. **General:** Print using ALL CAPITAL LETTERS. Write as neatly as possible, keeping all marks within data fields or workspace areas.
2. **Species Name:** List scientific name or pseudonym for each plant species observed in the Veg Plots (See the NWCA FOM for Pseudonym assignment rules).
3. **Presence Data:** For each species occurring in a quadrat nest (SW or NE corners of Veg Plot), **record the smallest quadrat/plot size in which it occurs by filling in the appropriate bubble (S (small) = 1-m² quadrat, M (medium) = 10-m² quadrat.) If a species does not occur in a particular nest (SW or NE), but occurs in the 100-m² Veg Plot, fill in the W (whole plot) bubble for that corner.**
4. **Predominant Height Class:** For each species observed, note its predominant height across each 100-m² Veg Plot by recording the appropriate height class code (defined below).
5. **Cover Data:** Estimate cover across each 100-m² Veg Plot (0 to 100%; See NWCA-FOM) for each species observed and record in the Cover data field. If necessary, use the gray workspace to make preliminary cover estimates for each species in each of the four quarters of the Veg Plot, and then combine preliminary estimates to obtain total cover for the species in the Veg Plot and record in the Cover data field.
6. **Collect Specimens and Assign Collection Numbers:** Follow procedures in NWCA FOM for specimen collection. Record the collection number for each specimen in the Coll # column. Label Unknown Specimens consecutively prefaced with the letter U, e.g., U1, U2, U3, etc. Label Quality Assurance (QA) Voucher Specimens consecutively prefaced with the letter Q, e.g., Q1, Q2, Q3, Q4, or Q5.

Total number of plots sampled: ___ of 5   If less than 5 plots sampled, flag here & explain in comments ___

IMPORTANT: Empty data cells or bubbles indicate absence or zero.

Complete if Collected

Height Classes (except E, which may occur in any vertical stratum):
1 = <0.5m, 2 = >0.5-2m, 3 = >2-5m, 4= >5-15m, 5 = >15-30m, 6 = >30m, and E = liana, vine or epiphyte species

		Plot 1					Plot 2					Plot 3					Plot 4					Plot 5					
Coll #	Species Name or Pseudonym	SW	NE	Ht. Class	% Cover	Work Space	SW	NE	Ht. Class	% Cover	Work Space	SW	NE	Ht. Class	% Cover	Work Space	SW	NE	Ht. Class	% Cover	Work Space	SW	NE	Ht. Class	% Cover	Work Space	Flag

Flag codes: K = No measurement made, U = Suspect measurement. F1,F2, etc. = misc. flags assigned by each field crew. Explain all flags in comment section on back side of form.

03/24/2016   V-2 NWCA 2016 Vascular Plant Species Presence & Cover (Front)   1848303096

FORM V-2: NWCA 2016 VASCULAR SPECIES PRESENCE AND COVER (Back)

Reviewed by (initial): ______

Site ID: NWCA16-

Date: ___ / ___ / 2 0 1 6

Flag	Comments	Flag	Comments

03/24/2016 V-2 NWCA 2016 Vascular Plant Species Presence and Cover (Back)

4517095056

FORM V-3: NWCA 2016 VEGETATION TYPES (Front)

Reviewed by (initial):______

Site ID: NWCA16-

Date: ___ / ___ / 2 0 1 6

Instructions:

1. Estimate the cover for each *Vascular Vegetation Stratum*.
2. Estimate cover and collect categorical data for *Non-Vascular Taxonomic Groups*.
3. Cover can range from 0 - 100% for each of the following groups: submerged aquatic vegetation, floating aquatic vegetation, lianas, vines, and epiphytes, each height class of other vascular vegetation and each Non-Vascular Group.

Total number of plots sampled: ___ of 5

If less than 5 plots sampled, flag here & explain in comments

IMPORTANT: Empty data cells or bubbles indicate absence or zero.

% Cover Vascular Vegetation Strata	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Flag
COVER OF SUBMERGED AQUATIC VEGETATION (rooted in sediment, most plant cover submerged or floating on water) (0 - 100%)						
COVER OF FLOATING AQUATIC VEGETATION (not rooted in sediment) (0 - 100%)						
COVER OF LIANAS, VINES AND EPIPHYTES IN ANY HEIGHT CLASS (0 - 100%)						
COVER FOR ALL OTHER VASCULAR VEGETATION FOR EACH OF THE FOLLOWING HEIGHT CLASSES:						
>30m tall: e.g., very tall trees (0 - 100%)						
>15 to 30m tall: e.g., tall trees (0 - 100%)						
>5 to 15m tall: e.g., very tall shrubs; short to mid-sized trees (0 - 100%)						
>2 to 5m tall: e.g., tall shrubs; tree saplings (0 - 100%)						
0.5 to 2m tall: e.g., medium height shrubs; tree seedlings and saplings; tall aquatic emergent/terrestrial herbaceous species (0 - 100%)						
< 0.5m tall: e.g., low aquatic emergent/terrestrial herbaceous species; low shrubs; tree seedlings (0 - 100%)						

% Cover and Categorical Data for Non-Vascular Taxa	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Flag
COVER OF BRYOPHYTES (mosses and liverworts) growing on ground surfaces, logs, rocks, etc.) (0 - 100%)						
Fill bubble if Bryophytes are dominated by *Sphagnum* or other peat-forming mosses	○	○	○	○	○	
COVER OF LICHENS growing on ground surfaces, logs, rocks, etc. (0 - 100%)						
ABUNDANCE OF ARBOREAL EPIPHYTIC BRYOPHYTES AND LICHENS NONE: Absent. SPARSE: Less than 1/3 of woody surface area covered. COMMON: 1/3 to 3/4 of woody surface area covered. ABUNDANT: >3/4 of woody surface area covered, epiphytes often draping or pendant.	☐ None ☐ Sparse ☐ Common ☐ Abundant	☐ None ☐ Sparse ☐ Common ☐ Abundant	☐ None ☐ Sparse ☐ Common ☐ Abundant	☐ None ☐ Sparse ☐ Common ☐ Abundant	☐ None ☐ Sparse ☐ Common ☐ Abundant	
COVER OF FILAMENTOUS OR MAT FORMING ALGAE (0 - 100%)						
COVER OF MACROALGAE (freshwater species/seaweeds, living or wrack) (0 - 100%):						

Flag	Comments	Flag	Comments

Flag codes: K = No measurement made, U = Suspect measurement, F1,F2, etc. = misc. flags assigned by each field crew. Explain all flags in comment section.

03/24/2016 V-3 NWCA 2016 Vegetation Types

1746368566

FORM V-3: NWCA 2016 GROUND SURFACE ATTRIBUTES (Back)

Reviewed by (initial):______

Site ID: NWCA16- Date: ___ / ___ / 2 0 1 6

Instructions: For each ground surface attribute **carefully record the requested data**.

1. **Water Cover** – Estimate total percent of Veg Plot area covered by water.
2. **Water Depth** – Measure water depth with marked PVC pole or ruler to represent the predominant water level across the Veg Plot.
3. **Litter** – Estimate total cover of litter. Identify the predominant type. Measure litter depth in SW and NE most corners of Veg Plot in center of 1-m^2 quadrat.
4. **Bare ground** – Estimate cover for exposed a) soil/sediment, b) gravel/cobble, c) rock. (The sum of a+b+c $\leq$100%).
5. **Dead Woody Material Cover** – Estimate cover (0 to 100%) for each category of dead woody material.

Total number of plots sampled: ___ of 5

If less than 5 plots sampled, flag here & explain in comments ___

IMPORTANT: Empty data cells or bubbles indicate absence or zero.

Water Cover	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Flag
Total Cover of Water (0-100%)						
Water Depth	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Flag**
Predominant Depth (cm)						
Time of Day (24 hour clock)						
Cover of Bare ground = a+b+c $\leq$100%	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Flag**
a) Exposed soil/sediment						
b) Exposed gravel/cobble (~2mm to 25cm)						
c) Exposed rock (>25cm)						
Vegetative Litter	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Flag**
Total Cover Vegetative Litter (0-100%)						
Predominant Litter type (Select one per plot) G = Graminoid (e.g., grasses, sedges, rushes) C= Coniferous Tree F = Forb D = Deciduous Tree R = Fern E = Broadleaf Evergreen Tree	○G ○C ○F ○D ○R ○E	○G ○C ○F ○D ○R ○E	○G ○C ○F ○D ○R ○E	○G ○C ○F ○D ○R ○E	○G ○C ○F ○D ○R ○E	
Litter Depth (cm) in center of 1-m² quadrat at SW Veg Plot corner						
Litter Depth (cm) in center of 1-m² quadrat at NE Veg Plot corner						
Cover of Downed Dead Woody Material (angle of incline <45°)	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Flag**
Cover of Downed Coarse Woody debris (>5cm diameter) (0-100%)						
Cover of Downed Fine Woody debris (<5cm diameter) (0-100%)						

Flag	Comments

Flag codes: K = No measurement made, U = Suspect measurement, F1,F2, etc. = misc. flags assigned by each field crew. Explain all flags in comment section.

9075456264

03/24/2016 V-3 NWCA 2016 Ground Surface Attributes

FORM V-4: NWCA 2016 SNAG AND TREE COUNTS AND TREE COVER

Site ID: NWCA16- Date: / / 2 0 1 6

Reviewed by (initial): ______

Page 1 of ___

Total number of plots sampled: ___ of 5. If no trees were observed in plots, this counts as sampled.

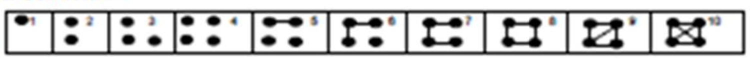
If less than 5 plots sampled, flag here & explain in comments

IMPORTANT: Empty data cells equal zero

Instructions for Recording Data:

1. **Fill out Header Information.**
2. **If either Live Trees or Snags are Present** in a Veg Plot, collect data across the entire 100-m² area of each Veg Plot.
3. **Small (<5cm DBH) Standing Dead Trees/Snags:** Rapidly estimate approximate number.
4. **Standing Dead (>5cm DBH) Trees and Snags (angle of incline > 45°):** Count snags > 5cm DBH by diameter class and record the total number of snags for each DBH class in the white data column for the appropriate Veg Plot.
5. **For Each Live Tree Species:** Use one row for each plot in which each tree species is found. Be sure to indicate the Veg Plot number in the *Plot #* column next to each species name. Record species names or pseudonyms for each tree species. Ensure pseudonyms match those used on **Form V-2**.
6. **Cover of trees in height classes:** Record the percent cover (0-100%) for each tree species for each height class. (All trees, no minimum DBH).
7. **Live Trees (>5cm DBH):** Count trees in each Veg Plot by species in DBH classes and record the total number of trees for each diameter class in the white data column.
8. **Counting Trees or Snags (>5cm DBH):** If needed, for smaller DBH classes when many trees or snags are present, a running tally* of the numbers of all snags, or for each tree species, in each DBH class can be recorded in the gray shaded workspace in the DBH columns. Once all the snags or tree species are tallied for a plot, record the total number for each species in each DBH class in the white data field for each DBH column.

*Tally format



Estimate small standing dead trees/snags (<5cm DBH)

Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
○ None	○ None	○ None	○ None	○ None
○ Few(1-10)	○ Few(1-10)	○ Few(1-10)	○ Few(1-10)	○ Few(1-10)
○ Common(11-20)	○ Common(11-20)	○ Common(11-20)	○ Common(11-20)	○ Common(11-20)
○ Many(>20)	○ Many(>20)	○ Many(>20)	○ Many(>20)	○ Many(>20)

Standing Dead Tree/Snag Counts by DBH Class
(White box = data field, Gray box = tally workspace)

Plot	5 to 10cm	11 to 25cm	26 to 50cm	51 to 75cm	76 to 100cm	101 to 200cm	Flag
1							
2							
3							
4							
5							

Tree Cover by Height Class / **Tree Counts by DBH Class**
(White box = data field, Gray box = tally workspace) (DBH = diameter breast height)

Plot #	Live Tree Species Name/Pseudonym	<0.5m	>0.5-2m	>2-5m	>5-15m	>15-30m	>30m	5 to 10cm	11 to 25cm	26 to 50cm	51 to 75cm	76 to 100cm	101 to 200cm	>200 cm	Flag
○1 ○2 ○3 ○4 ○5															
○1 ○2 ○3 ○4 ○5															
○1 ○2 ○3 ○4 ○5															
○1 ○2 ○3 ○4 ○5															
○1 ○2 ○3 ○4 ○5															
○1 ○2 ○3 ○4 ○5															

Flag codes: K = No measurement made, U = Suspect measurement, F1, F2, etc = misc.flags assigned by each field crew. Explain all flags in comment section on the continuation page.

03/24/2016 V-4 NWCA 2016 Snag & Tree Counts (Front) 2766277681

FORM V-4: NWCA 2016 SNAG AND TREE COUNTS AND TREE COVER (Continued)

Reviewed by (initial): ______

Site ID: NWCA16- ______ Date: ___ / ___ / 2 0 1 6 Page ___ of ___

Plot #	Live Tree Species Name/Pseudonym	Tree Cover by Height Class						Tree Counts by DBH Class (White box = data field, Gray box = tally workspace)											
		<0.5m	>0.5-2m	>2-5m	>5-15m	>15-30m	>30m	5 to 10cm		11 to 25cm		26 to 50cm		51 to 75cm		76 to 100cm	101 to 200cm	>200 cm	Flag
1 2 3 4 5																			
1 2 3 4 5																			
1 2 3 4 5																			
1 2 3 4 5																			
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1 2 3 4 5																			
1 2 3 4 5																			
1 2 3 4 5																			

Flag	Comment	Flag	Comment

Flag codes: K = No measurement made, U = Suspect measurement, F1, F2, etc = misc.flags assigned by each field crew. Explain all flags in comment section.

03/24/2016 V-4 NWCA 2016 Snag & Tree Counts (Continued) 8686242804

Appendix C: List of Plants Collected in 30 Floodplain Wetland sites on the Deep Fork and North Canadian Rivers of Oklahoma. Data was collected during the months of May to September of 2018.

Scientific Name	Common Name	CoC	# of Sites
Acalypha rhomboidea	common threeseed mercury	1	12
Acer negundo	boxelder	1	21
Acer saccharinum	silver maple	2	3
Ageratina altissima	white snakeroot	1	2
Allium canadense	meadow garlic	2	1
Amaranthus tuberculatus	rough amaranth	0	3
Ambrosia artemisiifolia	annual ragweed	0	2
Ambrosia psilostachya	Cuman ragweed	3	3
Ambrosia trifida	great ragweed	0	11
Amorpha fruticosa	false indigo bush	6	2
Amorpha laevigata	smooth false indigo	7	1
Ampelopsis arborea	peppervine	7	6
Ampelopsis cordata	heartleaf peppervine	2	3
Andropogon virginicus	broomsedge bluestem	0	2
Apios americana	groundnut	6	1
Arisaema dracontium	green dragon	6	1
Aristida desmantha	curly threeawn	6	2
Aristolochia tomentosa	woolly dutchman's pipe	7	4
Asclepias incarnata	swamp milkweed	5	1
Asclepias viridiflora	green comet milkweed	6	1
Asclepras viridis	green antelopehorn	1	1
Betula nigra	river birch	3	3
Boehmeria cylindrica	smallspike false nettle	6	13
Botrychium biternatum	sparselobe grapefern	10	5
Bromus racemosus	bald brome	0	1
Broussonetia papyrifera	paper mulberry	0	1
Campsis radicans	trumpet creeper	3	20
Cardiospermum halicacabum	balloon vine	0	4
Carex arkansana	Arkansas sedge	7	1
Carex bulbostylis	false hair sedge	8	1
Carex cherokeensis	Cherokee sedge	6	1
Carex crus-corvi	ravenfoot sedge	7	5
Carex debilis	white edge sedge	9	1
Carex frankii	Frank's sedge	5	1
Carex gracilescens	slender looseflower sedge	7	2

Scientific Name	Common Name	CoC	# of Sites
Carex grisea	inflated narrow-leaf sedge	3	1
Carex hyalinolepis	shoreline sedge	5	2
Carex hystericina	bottlebrush sedge	7	2
Carex leavenworthii	Leavenworth's sedge	2	1
Carex lupuliformis	false hop sedge	8	1
Carex microdonta	littletooth sedge	7	1
Carex muehlenbergii	Muhlenberg's sedge	6	1
Carex squarrosa	squarrose sedge	7	2
Carex tribuloides	blunt broom sedge	4	10
Carya cordiformis	bitternut hickory	4	3
Carya illinoinensis	pecan	6	20
Celtis laevigata	sugarberry	5	18
Celtis occidentalis	common hackberry	1	2
Celtis reticulata	netleaf hackberry	5	1
Cephalanthus occidentalis	common buttonbush	4	3
Cercis canadensis	eastern redbud	2	2
Chasmanthium latifolium	Indian woodoats	4	15
Chenopodium album	lambsquarters	0	1
Chenopodium incanum	mealy goosefoot	6	1
Chenopodium pallescens	slimleaf goosefoot	1	1
Chenopodium pratericola	desert goosefoot	3	1
Chenopodium simplex	mapleleaf goosefoot	2	1
Chenopodium standleyanum	Standley's goosefoot	3	1
Cirsium altissimum	tall thistle	2	2
Cirsium carolinianum	soft thistle	8	1
Clematis pitcheri	bluebill	4	1
Clematis reticulata	netleaf leather flower	unknown	2
Cocculus carolinus	Carolina coralbead	6	7
Coleataenia anceps	beaked panicgrass	3	1
Commelina erecta	whitemouth dayflower	4	6
Conoclinium coelestinum	blue mistflower	4	2
Convolvulus arvensis	field bindweed	0	1
Conyza canadensis	Canadian horseweed	0	8
Coreopsis tinctoria	golden tickseed	1	1
Cornus drummondii	roughleaf dogwood	1	5
Cornus florida	flowering dogwood	6	3
Crataegus viridis	green hawthorn	4	2
Croton glandulosus	vente conmigo	1	2
Croton texensis	Texas croton	1	1

Scientific Name	Common Name	CoC	# of Sites
Cryptotaenia canadensis	Canadian honewort	4	1
Cynanchum laeve	honeyvine	0	5
Cynodon dactylon	Bermudagrass	0	11
Cyperus acuminatus	tapertip flatsedge	3	1
Cyperus odoratus	fragrant flatsedge	3	4
Cyperus reflexus	bentawn flatsedge	5	1
Cyperus retrorsus	pine barren flatsedge	4	2
Desmodium paniculatum	panicledleaf ticktrefoil	4	4
Desmodium pauciflorum	fewflower ticktrefoil	8	1
Dichanthelium oligosanthes	Heller's rosette grass	4	4
Digitaria ciliaris	southern crabgrass	1	1
Digitaria sanguinalis	hairy crabgrass	0	2
Diospyros virginiana	common persimmon	2	5
Ditaxis humilis	low silverbush	8	1
Dysphania ambrosioides	Mexican tea	0	3
Echinochloa crus-galli	barnyardgrass	0	1
Echinochloa muricata	rough barnyardgrass	0	5
Eclipta prostrata	false daisy	3	1
Elephantopus carolinianus	Carolina elephantsfoot	4	8
Elymus canadensis	Canada wildrye	5	2
Elymus virginicus	Virginia wildrye	3	11
Equisetum spp.	scouring rush	3	2
Erigeron strigosus	prairie fleabane	4	1
Eriochloa contracta	prairie cupgrass	0	2
Erodium texanum	Texas stork's bill	unknown	2
Euonymus fortunei	winter creeper	0	1
Eupatorium serotinum	lateflowering thoroughwort	2	2
Euphorbia dentata	toothed spurge	0	1
Euphorbia exstipulata	squareseed spurge	unknown	1
Euphorbia hexagona	sixangle spurge	2	1
Euphorbia maculata	spotted sandmat	0	1
Euphorbia marginata	snow on the mountain	0	1
Euphorbia prostrata	prostrate sandmat	0	1
Festuca paradoxa	clustered fescue	7	2
Festuca subverticillata	nodding fescue	4	2
Festuca versuta	Texas fescue	9	1
Fleischmannia incarnata	pink thoroughwort	9	2
Forestiera acuminata	eastern swampprivet	7	8

Scientific Name	Common Name	CoC	# of Sites
Fraxinus americana	white ash	7	1
Fraxinus pennsylvanica	green ash	3	16
Galactia regularis	eastern milkpea	6	1
Gamochaeta purpurea	spoonleaf purple everlasting	4	1
Geum canadense	white avens	1	2
Gleditsia triacanthos	honeylocust	0	7
Glycine max	soybean	0	1
Gonolobus suberosus	angularfruit milkvine	7	6
Helenium amarum	sneezeweed	0	1
Helianthus petiolaris	prairie sunflower	1	1
Heliotropium indicum	Indian heliotrope	0	2
Heterotheca subaxillaris	camphorweed	2	1
Hieracium gronovii	queendevil	5	1
Ilex decidua	possumhaw	5	14
Impatiens capensis	jewelweed	5	2
Ipomoea lacunosa	whitestar	2	7
Iva angustifolia	narrowleaf marsh elder	1	1
Iva annua	annual marsh elder	0	4
Juglans nigra	black walnut	3	1
Juncus interior	inland rush	2	2
Juniperus virginiana	eastern redcedar	1	4
Koeleria macrantha	prairie Junegrass	6	1
Kummerowia stipulacea	Korean clover	0	1
Kummerowia striata	Japanese clover	0	2
Lactuca canadensis	Canada lettuce	2	1
Lactuca floridana	woodland lettuce	3	1
Lactuca serriola	prickly lettuce	0	2
Lathyrus hirsutus	Caley pea	0	1
Leersia virginica	whitegrass	4	4
Lepidium densiflorum	common pepperweed	0	2
Lepidium virginicum	Virginia pepperweed	0	1
Leptochloa panicea	mucronate sprangletop	3	1
Lespedeza cuneata	sericea lespedeza	0	5
Lespedeza repens	creeping lespedeza	5	1
Lespedeza stuevei	tall lespedeza	4	1
Leucospora multifida	narrowleaf paleseed	0	1
Ligustrum sinense	Chinese privet	0	1
Lindera benzoin	northern spicebush	7	1
Lobelia cardinalis	cardinalflower	6	1

Scientific Name	Common Name	CoC	# of Sites
Lonicera japonica	Japanese honeysuckle	0	7
Lycopus americanus	American water horehound	4	1
Maclura pomifera	Osage-orange	1	1
Melothria pendula	Guadeloupe cucumber	1	5
Mollugo verticillata	green carpetweed	0	4
Monarda punctata	spotted beebalm	7	1
Morus alba	white mulberry	0	11
Morus rubra	red mulberry	5	6
Ostrya virginiana	hophornbeam	5	1
Oxalis corniculata	creeping woodsorrel	1	8
Panicum coloratum	kleingrass	0	4
Panicum philadelphicum	Philadelphia panicgrass	4	1
Parthenocissus quinquefolia	Virginia creeper	1	14
Paspalum dilatatum	dallisgrass	0	1
Paspalum floridanum	Florida paspalum	5	2
Paspalum pubilflorum	hairyseed paspalum	4	2
Passiflora incarnata	purple passionflower	4	2
Perilla frutescens	beefsteakplant	0	3
Persicaria bicornis	pink smartweed	1	1
Persicaria hydropiperoides	swamp smartweed	4	9
Persicaria lapathifolia	curlytop knotweed	4	1
Persicaria pensylvanica	Pennsylvania smartweed	2	2
Persicaria punctata	dotted smartweed	4	13
Persicaria setacea	bog smartweed	5	1
Persicaria virginiana	jumpseed	2	5
Phyla lanceolata	lanceleaf fogfruit	3	5
Physalis longifolia	longleaf groundcherry	2	2
Physalis pubescens	husk tomato	4	3
Phytolacca americana	American pokeweed	0	2
Pilea pumila	Canadian clearweed	2	2
Platanus occidentalis	American sycamore	4	8
Pluchea odorata	sweetscent	2	1
Poa compressa	Canada bluegrass	0	1
Polygonella americana	southern jointweed	10	3
Polygonum erectum	erect knotweed	1	1
Polygonum ramosissimum	bushy knotweed	1	1
Polypremum procumbens	juniper leaf	4	1
Populus deltoides	eastern cottonwood	0	9
Portulaca oleracea	little hogweed	0	1

Scientific Name	Common Name	CoC	# of Sites
Prunus americana	American plum	3	1
Prunus angustifolia	Chickasaw plum	3	3
Prunus mexicana	Mexican plum	3	1
Pyrrhopappus carolinianus	Carolina desert-chicory	1	1
Quercus macrocarpa	bur oak	4	7
Quercus michauxii	swamp chestnut oak	9	2
Quercus muehlenbergii	chinquapin oak	5	1
Quercus nigra	water oak	5	2
Quercus palustris	pin oak	3	2
Quercus phellos	willow oak	4	1
Quercus rubra	northern red oak	6	4
Quercus shumardii	Shumard's oak	6	1
Quercus stellata	post oak	4	2
Ranunculus abortivus	littleleaf buttercup	1	1
Robinia pseudoacacia	black locust	6	1
Rotala ramosior	lowland rotala	4	1
Rumex altissimus	pale dock	0	2
Rumex crispus	curly dock	0	5
Salix nigra	black willow	2	9
Salsola tragus	prickly Russian thistle	0	1
Sanicula canadensis	Canadian blacksnakeroot	2	2
Sapindus drummondii	western soapberry	3	4
Scutellaria lateriflora	blue skullcap	5	1
Setaria faberi	Japanese bristlegrass	0	2
Setaria pumila	yellow foxtail	0	7
Sida spinosa	prickly fanpetals	1	3
Sideroxylon lanuginosum	gum bully	5	4
Smilax bona-nox	saw greenbrier	5	21
Smilax tamnoides	bristly greenbrier	2	7
Solanum carolinense	Carolina horsenettle	1	6
Solidago canadensis	Canada goldenrod	2	1
Solidago gigantea	giant goldenrod	3	2
Solidago speciosa	showy goldenrod	7	4
Sorghum halepense	Johnsongrass	0	8
Spiranthes cernua	nodding lady's tresses	5	4
Strophostyles helvola	amberique-bean	3	1
Strophostyles leiosperma	slickseed fuzzybean	3	1
Symphoricarpos orbiculatus	coralberry	1	9
Symphyotrichum drummondii	Drummond's aster	2	1

Scientific Name	Common Name	CoC	# of Sites
Symphyotrichum subulatum	eastern annual saltmarsh aster	4	4
Symplocos tinctoria	common sweetleaf	6	2
Teucrium canadense	Canada germander	3	6
Toxicodendron radicans	eastern poison ivy	0	17
Tridens flavus	purpletop tridens	1	2
Tridens strictus	longspike tridens	6	1
Tridens x oklahomensis	slim tridens	0	1
Trifolium pratense	red clover	0	1
Trifolium repens	white clover	0	2
Ulmus alata	winged elm	4	5
Ulmus americana	American elm	2	14
Ulmus rubra	slippery elm	3	15
Urtica chamaedryoides	heartleaf nettle	8	5
Verbena urticifolia	white vervain	2	2
Verbesina alternifolia	wingstem	4	1
Verbesina encelioides	golden crownbeard	1	1
Vernonia missurica	Missouri ironweed	4	1
Viburnum rufidulum	rusty blackhaw	5	2
Vicia caroliniana	Carolina vetch	6	1
Vicia sativa	garden vetch	0	1
Vitis acerifolia	mapleleaf grape	5	5
Vitis aestivalis	summer grape	5	4
Vitis cinerea	graybark grape	4	1
Vitis mustangensis	mustang grape	unknown	2
Vitis riparia	riverbank grape	2	5
Vitis vulpina	frost grape	3	6
Xanthium strumarium	rough cocklebur	0	5
Zizaniopsis miliacea	giant cutgrass	9	2

Appendix D: Metrics Calculated for 30 Floodplain Wetland sites on the Deep Fork and North Canadian Rivers of Oklahoma. Data was collected during the months of May to September of 2018.

(a) Landscape Development Intensity Index (LDI) Scores.

Site	LDI Score
1	1.42
2	1.07
3	1.26
4	1.07
5	2.38
6	5.62
7	1.24
8	1.31
9	2.05
10	1.67
11	1.17
12	1.65
13	4.26
14	1.14
15	2.76
16	3.32
17	2.42
18	1.41
19	1.69
20	1.10
21	1.66
22	1.48
23	1.20
24	1.02
25	1.63
26	2.60
27	1.54
28	1.96
29	1.32
30	3.23

(b) Plant Richness, Native Richness, and Floristic Quality Index (FQI) Scores.

Site	Species Richness	Native Species Richness	FQI
1	44	39	22.16
2	30	27	17.34
3	25	24	19.60
4	19	19	16.75
5	56	43	17.12
6	12	7	2.60
7	24	23	15.72
8	28	27	15.40
9	37	33	15.12
10	35	28	13.69
11	46	42	21.23
12	26	26	17.85
13	3	1	0.00
14	34	32	21.44
15	6	3	4.49
16	27	21	6.47
17	26	21	11.18
18	16	14	4.00
19	42	41	23.61
20	24	23	17.52
21	41	31	14.07
22	40	38	22.90
23	29	28	15.97
24	36	34	21.00
25	25	20	13.27
26	35	31	14.20
27	31	31	21.37
28	29	29	21.17
29	36	34	23.67
30	20	18	10.73

(c) Soil Chemistry Data. (P - Phosphorus, NO3 - Nitrate, NH4 - Ammonium, Na - Sodium, OM - Organic Matter, SAR - Sodium Adsorption Ratio).

Site	**P (lbs/A)**	**NO3 (lbs/A)**	**NH4 (ppm)**	**Na (ppm)**	**OM (%)**	**SAR (%)**	**pH**
1	27	3	13.4	9.8	3.24	0.30	6.2
2	47	3	14.1	13.4	1.55	0.46	7.9
3	70	2	42.4	32.6	3.41	0.75	7.6
4	48	11	22.1	71.1	4.27	1.74	6.6
5	55	10	18.7	15.8	3.85	0.34	6.0
6	68	59	21.1	30.8	2.46	0.55	7.9
7	41	7	9.9	13.3	1.33	0.34	7.9
8	37	4	5.7	9.7	0.75	0.34	8.1
9	36	3	6.2	9.3	0.60	0.30	8.0
10	20	2	3.1	6.1	0.23	0.28	8.3
11	36	10	12.7	21.0	2.29	0.47	7.9
12	44	7	10.7	17.3	1.67	0.45	8.0
13	183	62	16.0	128.0	5.51	2.28	6.6
14	30	20	12.3	47.9	4.28	1.12	6.3
15	33	20	14.1	15.4	2.02	0.40	8.2
16	42	13	8.3	22.3	3.64	0.44	6.7
17	9	6	33.9	20.3	2.61	0.68	5.7
18	35	9	11.0	5.2	1.05	0.22	7.2
19	50	15	14.3	16.3	1.15	0.48	8.3
20	39	13	31.3	34.6	5.30	0.82	6.4
21	19	9	40.6	19.5	3.74	0.63	6.4
22	43	34	72.4	17.8	8.00	0.39	6.4
23	19	1	18.7	9.8	1.30	0.41	7.3
24	24	25	39.7	18.9	5.21	0.57	6.2
25	27	19	21.0	47.0	5.04	1.93	6.0
26	142	61	35.8	246.3	8.85	3.95	6.8
27	32	2	41.1	22.4	2.48	0.82	6.6
28	20	1	21.1	16.2	3.23	0.71	5.8
29	17	1	29.2	7.9	2.27	0.39	6.0
30	20	84	54.2	32.2	6.50	0.58	7.3

VITA

Anthony Wayne Thornton

Candidate for the Degree of

Master of Science

Thesis: DEVELOPMENT OF THE OKLAHOMA RAPID ASSESSMENT METHOD FOR FLOODPLAIN WETLANDS

Major Field: Natural Resource Ecology and Management

Biographical:

Education:

Completed the requirements for the Master of Science in Natural Resource Ecology and Management at Oklahoma State University, Stillwater, Oklahoma in December 2021.

Completed the requirements for the Bachelor of Science in Natural Resource Ecology and Management at Oklahoma State University, Stillwater, Oklahoma in May 2016.

Experience:

Student Field/Lab Technician, Oklahoma State University, Stillwater, OK, August 2014 – May 2016

Graduate Research Assistant, Oklahoma State University, Stillwater, OK, September 2017 – December 2020

Professional Memberships: Society of Wetland Scientists, Association of State Wetland Managers