National Wetland Condition Assessment Intensification and Method Development Study

FY 2020 §106 I-01F83601, Project 2

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Table of Contents

INTRODUCTION

In Oklahoma development and implementation of a comprehensive wetland monitoring program is a high priority. One of the key goals of Oklahoma's Wetland Program Plan is to develop the capacity to assess the condition of wetland habitats in the state (OCC 2020a). Development of a statewide rapid wetland assessment method began in 2012 as a partnership between Oklahoma State University (OSU), Oklahoma Conservation Commission (OCC) and Oklahoma Water Resources Board (OWRB) (OWRB 2015). The Oklahoma Rapid Assessment Method (OKRAM) is a stressor based condition assessment created for management applications including identifying degraded wetlands in need of restoration and locating pristine wetlands in need of protection. An additional application of critical importance to the state is a wetland assessment tool that can be used to plan and track mitigation in the context of §404 of the Clean Water Act (CWA).

OKRAM was initially calibrated for depressional wetlands of the Central Great Plains. Initial results indicated that OKRAM condition scores correlated well with measures of vegetation community diversity and sediment chemistry. In order for OKRAM to be effective as an assessment tool, the method needs to be calibrated and validated at the numerous wetland types, and variable wetland conditions found across Oklahoma. To that end, it is critical that OKRAM continue to be trialed at additional wetland classes such as riverine and slope wetlands. For calibration and validation to be completed successfully, independent measures of ecosystem condition must be collected concurrently with RAM data (Fennessey et al. 2004). In this way, the assumptions of a rapid assessment can be tested against more intensive measures of ecosystem condition such as biotic community data.

Collecting intensive biotic data can be time-consuming and expensive when compared with the relatively low cost and time required for rapid assessments. As a result, it has proven challenging for many states to complete RAM validation (Stein et al. 2009). The National Wetland Condition Assessment (NWCA) provides a unique opportunity to collect intensive biotic, water quality and soil data (USEPA 2021a) concurrently with OKRAM data across the variable wetland conditions in Oklahoma. Oklahoma completed an NWCA intensification in 2017, following the 2016 nationwide NWCA effort. An additional 33 wetlands were assessed in the Central Great Plains and Cross Timbers ecoregions of central Oklahoma, and overall OKRAM score was found to be correlated with both the NWCA Vegetation Multi Metric Index (VMMI) and Floristic Quality Assessment Index (FQAI; OCC 2019).

At the commencement of the 2021 NWCA, over 200 wetlands had been assessed with OKRAM (approximately 250 total assessments including repeat visits), through individual studies of approximately 50 sites (OCC 2020b; OCC 2019; Gallaway et al., 2016; OWRB 2015). However, each of these studies restricted the geographic extent of method application and/or hydrogeomorphic class targeted, in order to reduce the natural variability associated with measures of biological communities used for validation. The

2021 NWCA provided an opportunity to evaluate OKRAM correlations with intensive biotic data at the statewide scale, with a relatively robust sample size of 48 wetlands. Furthermore, the assessments completed during this project (in addition to targeted OKRAM assessments completed in 2022 to fill data gaps in HGM class and disturbance category (OCC 2022)), will allow for a full statewide validation of OKRAM with a dataset of over 300 assessments completed across the diversity of wetland types and landscape conditions of Oklahoma. This full analysis is planned to be completed in 2025.

The overall goal of this project is to advance the State's ability to monitor and assess wetland condition throughout Oklahoma. It is of primary importance to Oklahoma to have a condition assessment that can be deployed for impact assessment as well as mitigation planning and tracking for CWA §404 projects. A rapid, accurate and repeatable assessment tool will help Oklahoma to maintain the quantity and quality of wetlands across the state. Furthermore, completing an intensive application of NWCA protocols provides the additional benefit of using nationally validated methods to estimate the overall health of the population of wetlands in the state of Oklahoma.

The objectives for this project are to:

1. Validate OKRAM's effectiveness at tracking wetland condition through comparison with NWCA intensive biotic.

2. Refine OKRAM metrics for application at all wetland types in Oklahoma.

3. Use the NWCA intensification data to provide a statewide assessment of the current condition of wetlands in Oklahoma.

4. Continue to build a dataset of OKRAM for calibration and validation effort planned for 2025 and provide insight into that analysis.

METHODS

Study area

The study area includes the entirety of Oklahoma (Figure 1), which includes four of the ten aggregated ecoregions used for 2021 NWCA reporting, The Great Plains (GPL), Southern Appalachian Plains (SAP), The Temperate Plains (TPL) and Coastal Plains (CPL; EPA 2021). These four ecoregions represent an update to the three aggregated ecoregions utilized for the 2016 NWCA in Oklahoma, Interior Plains (IPL), Coastal Plains (CPL) and Eastern Mountains and Upper Midwest (EMU; EPA 2023). The CPL remained the same from to 2016, the SAP was split from the EMU, but the area within Oklahoma remained the same. The 2016 IPL ecoregion was split into the GPL, which includes the majority of the area in Oklahoma, and the TPL which is a small portion of northeast Oklahoma.

Site Selection

The USEPA-ORD National Health and Environmental Effects Research Laboratory in Corvallis, Oregon produced the draw for the 33 national NWCA assessments to be completed in 2021. For the intensification, we followed EPA guidelines for site evaluation (USEPA 2020) to complete additional site assessments in 2022 from the initial, national site draw. Using the output generated by USEPA-ORD, sites were evaluated sequentially to determine landowner permission, accessibility, and site suitability for NWCA. We sampled 15 additional sites in the study area in 2022. Our goal was to assess 50 total sites. However, we completed a total of 48 site assessments due to a failure to receive sufficient access permission prior to the end of the 2022 index period. Of the 380 sites for which we requested permission via mail, access was denied on 221 sites. An additional 111 sites were deemed non-target either through desktop or field evaluations. Sampleable sites were defined as target wetlands by the 2021 NWCA protocol, as not currently in crop production, with rooted vegetation, and when present, shallow open water less than 1 meter in depth (USEPA 2021a). Sites were not assessed, if access permission was denied, the site was not safely accessible, an assessment area could not be established due to wetland size or shape, or if the site was a non-target wetland.

Field Protocols

Initial NWCA assessments (33 and 2 revisits) were completed in 2021, and intensification assessments (15) were completed in 2022 during the index period (June 1 to September 30). Data were collected within an Assessment Area (AA), ranging from 0.1 to 0.5 ha in size, and an associated 100-m surrounding buffer. During intensification assessments, we followed NWCA protocols to conduct vegetation surveys, collect water samples (standard chemistry only, no chlorophyll, dissolved organic carbon or microsystin) when sampleable water was present, and complete soil profiles. Additionally, hydrologic and buffer assessments were completed according to NWCA protocols (USEPA 2021a). For more detailed description of the field protocols followed, see USEPA (2021a).

In addition, to NWCA protocols, we completed a separate assessment of wetland condition using the Oklahoma Rapid Assessment Method (OKRAM) within each wetland AA. OKRAM aggregates 9 metrics that assess the hydrology, biogeochemistry and biotic condition into a single condition score. OKRAM was created in 2012 and has since been calibrated and validated at wetlands across Oklahoma (Gallaway et al., 2016, OWRB 2015). OKRAM application followed standard protocols developed through USEPA 104(b)(3) wetland program development grants (Gallaway et al. 2016, OWRB 2015). The most current OKRAM field datasheets can be found in Appendix A.

Laboratory Protocols

Water samples from intensification sites were analyzed at the Oklahoma Department of Agriculture Food and Forestry (ODAFF) water quality lab. The ODAFF water quality lab follows USEPA approved protocols. Quality control procedures for NWCA data are further outlined in the NWCA QAPP (USEPA 2021b).

Plants were identified to the lowest taxonomic level possible while in the field. Unknown specimens were collected and identified in the laboratory. Quality Assurance (QA) specimens were collected according to NWCA protocols (USEPA 2021b) and identified by an independent botanist.

Analysis

Inference Population Calculation and Site Weights

The target population of our assessment was the entirety of wetlands within the study area. However, the extent to which we were able to infer the condition of wetlands in the study area depended upon the outcome of site evaluation. Therefore, the first step in assessing wetland condition within the study area was to determine the inference population. The inference population was calculated according to the National Wetland Condition Assessment 2016 Technical Report (USEPA 2023a). The inference population represents the portion of the Oklahoma wetlands that are represented by these analyses.

Initially, during the GRTS selection process all sites in the sample draw are assigned a weight, which designates the portion of the target population represented. However, removing non-target sites from the study reduces the overall size of the inference population relative to the target population. After all site assessments were completed, site weights were reassigned based on the number of sites presumed to be target wetlands following site evaluation (including sites assessed, sites where access was denied, and inaccessible sites). We calculated site weights according to USEPA (2023) using the function "adjwgt" in the package "spsurvey" (Kincaid et al. 2018) in program R (R core team 2013) following additional guidance from USEPA Office of Research and Development (M. Dumelle, personal communication, Feb. 8,2024).

Site Condition Scores and Extent

Site condition scores were calculated by applying a Vegetation Multimetric Index (VMMI) following protocols outlined in the NWCA 2016 Technical Report (USEPA 2023a). The VMMI includes four metrics depending upon the vegetation community. For Inland Herbaceous (PRLH) wetlands the following metrics were included in the VMMI:

1. Percent richness of obligate (OBL) and facultative wetland (FACW) species,
2. Floristic Quality Index based on all species,
3. Relative cover of native species, and

4. Richness of tolerant species (C-value <=4).

The VMMI for Inland Woody (PRLW) wetlands included the following metrics:

1. Relative cover of native monocots
2. Mean coefficient of conservatism based on all species,
3. Relative cover of native species, and
4. Relative frequency of native species.

Each metric is rescaled to a continuous scale ranging from 0 to 10, with 10 being the best score achievable. Scores for each metric are aggregated into a VMMI and standardized on a continuous scale from 0 to 100, with higher values representing less disturbed condition. For more details on the calculation of VMMI metrics see USEPA (2016a).

Plant attributes needed to calculate metrics were downloaded from the 2016 NWCA datasets (USEPA 2023a). Plant species not found in the 2016 dataset were assigned attributes from USDA Plant Database (USDA 2023) and COCs generated for surrounding states (Oklahoma (Ewing and Hoagland 2012), Kansas and Missouri [Ladd and Thomas 2015]).

Each site was then placed in a condition category of good, fair or poor based on the VMMI score. Distinct condition score thresholds were established for PRLH and PRLW inland wetlands (which encompasses all study sites; USEPA 2023a). VMMI scores greater than or equal to the 25th percentile of least disturbed sites represented good condition, scores less than the 5th percentile of least disturbed sites represented poor condition, and scores between the 5th and 25th percentile represented fair condition. The percentage of the inference population in good, fair and poor condition can then be calculated by summing the site weights in each category. We calculated condition extent and confidence intervals for the entire inference population within Oklahoma using the function "cat_analysis" in the package "spsurvey" (Kincaid et al. 2018) in Program R (R Core team 2013). Addition analyses were completed to calculate condition extent within NWCA aggregated ecoregion, vegetation type (PRLW vs. PRLH) and private vs. public wetlands.

Stressor Calculations

At each site, we calculated eight indicators of stress, based on field data collected at NWCA site locations. The indicators utilized were those established in USEPA (2023) and include six measures of physical stress: vegetation removal (VEGREM), vegetation replacement (VEGREP), water addition/subtraction (WADSUB), flow obstruction (WOBSTR), soil hardening (SOILHD), and surface modification (SOMODF). Sites were then placed in three categories including poor, fair and good for each indicator based on thresholds established in USEPA (2023). Additionally, we calculated a measure of overall stress (Physical Alteration SUM; PALT) by summing the above six scores and applying condition categories according to USEPA (2023). Finally, a biological measure of stress, the Non-native Plant Indicator (NNPI) was calculated, which aggregates relative cover, richness and frequency of non-native species. NNPI included four condition categories including good, fair, poor and very poor (USEPA 2023a). We calculated stressor extent estimates and confidence intervals using the function "cat_analysis" in the package "spsurvey" (Kincaid et al. 2018) in Program R (R Core team 2013).

Risk Assessment

We calculated relative and attributable risk for the six physical stressor indicators, and the overall stress indicator. Relative risk is the probability of a site being in poor condition when the stressor-level is high relative to when the stressor-level is low (USEPA 2023a). Relative risk was estimated with contingency tables using two condition classes based on VMMI condition category and two stressor categories. Condition classes and stressor categories included "poor" and "not poor", the latter of which combined good and fair condition sites. Attributable risk is a measure of the proportion of the study population that would be improved if the effects of a particular stressor were restored to an unimpacted state. Relative and attributable risk calculations followed those established in USEPA (2016a), using the functions "relrisk.est" and "attrisk.est" in the package "spsurvey" (Kincaid et al. 2018) in Program R (R core team 2013).

OKRAM/NWCA Correlations.

We performed spearman rank correlations to determine how well the NWCA VMMI condition metric correlated with OKRAM site scores. We compared the overall OKRAM score with both the NWCA VMMI and FQAI. In previous studies, we have found that OKRAM scores at depressional wetlands were well correlated with FQAI (Gallaway et al., 2016). Additionally, because VMMI and FQAI are measures of the biotic community, we compared the biotic attribute component score of OKRAM with both VMMI and FQAI. Because plant community composition is impacted by wetland type and geography, we ran a linear model with ranked OKRAM scores as a response, and ranked VMMI as a predictor, with vegetation community type, eastern vs. western sites (-97 longitude cutoff) and HGM class as random effects.

We also summed the stressor score for all six physical stressors and quantified the correlation with OKRAM, FQAI and VMMI. Additionally, we evaluated the relationship between individual NWCA measures of stress with correlate OKRAM attributes (VEGREM and VEGREP with OKRAM Biota; WADSUB and WOBSTR with OKRAM Hydrology).

Finally, we utilized condition classes established for OKRAM from previous studies (Gallaway et al., 2016; OWRB 2015) to compare the agreement of the condition class designations of both methods (OKRAM and VMMI).

RESULTS

Vegetation Surveys and Water Samples

We identified a total of 449 unique plant species (Appendix B). In 2021, the field botanist agreed with the laboratory botanist on the identification of 98% of the quality assurance specimens. On the 3 specimens where field and lab botanists disagreed, specimens were identified to the same genus and the laboratory botanist's ID was used for analyses. During the 2022 intensification, the lab and field botanist agreed on the identification of all QA specimens.

Only seven of the 15 sites had water and the results are presented in Appendix C. Due to the limited water at assessment locations (only 22 of 48 assessed sites including 2021 assessments), water data was not used in analyses.

Inference Population Calculation and Site Weights

To estimate the extent of wetland acreage used in our analysis, we calculated the inference population (i.e., area of wetlands represented by our samples), from our target population (i.e., total target-wetland area in the study area). To reach our sample of 48 sites, we evaluated 380 sites from the draw. The final acreage represented by our sampled sites was 1,114,473 acres, approximately 73% of the target population (411,028 acres removed as non-target; Figure 2).

Site Condition Scores and Extent

VMMI scores for the 16 herbaceous sites ranged from 32.7 to 66.4 (1 fair condition sites and 15 poor condition sites). For the 32 wooded sites, VMMI scores ranged from 22.1 to 81.4 (11 poor condition sites, 14 fair condition sites, and 7 good condition sites; Table 1). According to VMMI scores, approximately 72.6% (809,329 acres) of the inference population wetlands are in poor condition, 17.7% (197,498 acres) are in fair condition and 9.7% (107,646 acres) are in good condition (Figure 3). According to VMMI scores herbaceous wetlands are in worse condition (98.6% and 666,155 acres in poor condition) than wooded wetlands (32.6% and 143,174 acres in poor condition; Figure 4.) Condition category percentages were similar between groups when considering ownership status (public vs. private) and ecoregion alone.

Stressor Calculations

The majority of the inference population was good to fair according to the NNPI (~70%). While approximately 30% of the inference population was rated as poor or very poor (Figure 5). Again herbaceous wetlands were indicated as being in worse condition with approximately 43% in poor or very poor condition compared to 11% for wooded wetlands (Figure 6). According to the overall stressor score (PALT) approximately 78% of the inference population was poor, this was largely driven by poor scores at 70% of the inference population for vegetation removal. Flow obstruction indicated poor conditions at 19% of wetlands, while remaining stressors had minimal (VEGREP) to no impacts (WADSUB, SOILHD, and SOMODF; Figure 7).

Risk Assessment

VEGREM, WOBSTR and VEGREP and PALT all were associated with relative risk greater than 1 (1.4, 1.5, 1.4 and 1.3 respectively; Figure 8) However the confidence interval for PALT and VEGREM intersected 1. The same stressors had positive attributable risk. However, the confidence interval for all stressors intersected 0. All stressors had attributable risk with confidence intervals that intersected zero (Figure 9). Therefore, it is difficult to predict any ecological improvement from eliminating any of the measured stressors.

OKRAM Scores

OKRAM scores at the 48 study sites ranged from 0.55 to 0.98 (Table 2). Previous studies calibrating OKRAM have placed the threshold for good condition sites at 0.85, and poor condition sites at 0.5 (Gallaway et al., 2016). According to these previously established thresholds, 34 sites were in good condition and 14 sites were in fair condition. In general there was poor agreement (27%) between the OKRAM condition designations and the VMMI (Table 3).

OKRAM/NWCA/Stressor Correlations

VMMI and FQAI were not significantly correlated with OKRAM overall (ρ=0.07; p=0.6 and ρ=0.08; p=0.6 respectively) or biotic attribute scores (ρ=0.27; p=0.06 and ρ=0.19; p=0.19 respectively). In the mixed effects model, there was no significant effect of VMMI on OKRAM score (p=0.8), when accounting for variation associated with wetland vegetation, geography or HGM class.

PALT was not significantly correlated with VMMI or FQAI (ρ=-0.14; p=0.32 and ρ=-0.11; p=0.43 respectively) but did have a weak significant correlation with OKRAM score (ρ=-0.32; p=0.03). OKRAM vegetation metric was not significantly correlated with NWCA vegetation stressors (ρ=-0.02; p=0.89) but OKRAM hydrology was moderately correlated with WADSUB AND WOBSTR (ρ=-0.53; p=0.0001).

DISCUSSION

Overall wetland condition category estimates in Oklahoma based on VMMI categories compared similarly to NWCA category estimates for 2016, when accounting for vegetation community type (woody and herbaceous) and ecoregion (USEPA 2023b). In the Interior Plains of Oklahoma in 2021 and 2022 (no other ecoregion had more than 5 sites in ecoregion by vegetation community group), percentage of herbaceous and woody wetlands in poor condition fell within the confidence intervals for the 2016 NWCA estimates in the Interior Plains. Herbaceous wetlands in our intensification study, as well as the 2016 national survey, had a higher percentage of wetlands in poor condition than woody wetlands.

Interestingly, while we found a high percentage of wetlands in poor condition according to VMMI, there was no correlation between VMMI and any of the NWCA stressor metrics. Furthermore, only VEGREP and WOBSTR had a relative risk with a confidence interval that did not cross 1. Not surprisingly then, OKRAM, a stressor based measure of condition, consistently scored wetlands into higher condition categories, and did not correlate with VMMI. Overall OKRAM score was correlated with PALT (the aggregated measure of NWCA stress), and OKRAM attribute scores were correlated with related measures of NWCA stress as well (e.g., WADSUB and WOBSTR with the OKRAM hydrology attribute).

In every previous study (including the 2016/2017 NWCA intensification) validating OKRAM scores with plant community metrics, we found moderate to strong correlations (OCC 2020b, OCC 2019, Gallaway et al. 2016, OWRB 2015). The disconnect in this study between vegetation community measures of condition and stressor based measures, may be a result of multiple factors. One possibility is that identifying legacy stressors is outside the scope of a rapid visual assessment of condition. Historic land-use changes may be imperceptible during a one day assessment but may impact plant community dynamics centuries later (Foster et al., 2003). Furthermore, vegetation community stress resulting from global change may be unaccounted for using RAMs, as species distributions shift at broad scales (Franklin et al. 2016). For example, site 10021 is on public land along the Arkansas River and is extremely difficult to access. The site was dominated by several tolerant native plant species, but currently exists in a relatively low anthropogenic stress landscape. As a result, this site scored poorly for the VMMI and well for OKRAM. It is difficult to pinpoint the environmental stressors unaccounted for by OKRAM (and NWCA stressor assessments) that are driving the plant community response. However, with over 70% of the cover dominated by box elder (*Acer negundo*) in both the overstory and herbaceous layer, it is clear that the system is responding to disturbance, either natural or anthropogenically induced.

During the 2016/2017 intensification we identified several metrics that may have contributed to inflated OKRAM scores, particularly at riverine wetlands. Attempts to create revised metrics to better capture relevant stressors, appear not to have completely resolved the issue. Several new metrics were first created following the previous NWCA intensification and deployed during a state-wide validation of OKRAM at Riverine wetlands in 2018 and 2019 (OCC 2020). These updated metrics were also utilized during this intensification project. Firstly, the "Water Source" metric deals with the quantity of water reaching a study wetland. Previously, the metric did not account for alterations to lotic systems, which would be the primary water source for riverine wetlands. The alternative "Water Source" metric was updated to account for stress from river impoundments, as well as landscape level changes that alter the movement of surface water. Secondly, the "Hydrologic Connectivity" metric in depressional systems dealt primarily with the movement of water between uplands and the wetland ecosystem. However, we wanted a method to quantify the ability of the wetlands to receive water from the river system that supplies floodwater. Anthropogenic induced entrenchment is a major problem for Oklahoma streams and can dramatically alter the frequency and intensity of flood events that are critical to functioning floodplain wetlands. We developed an alternative method of assessing "Hydrologic Connectivity", based on the "Hydrologic Connectivity" metric developed for California (California Wetlands Monitoring Group 2013) and is an estimate of the source river entrenchment (Figure 8). Finally, the "Buffer Filter" metric, a component of the water quality attribute, considers the contribution of degraded water quality to a wetland from the surrounding landscape. Previously, this metric did not consider the topography of the surrounding landscape. However, the updated metric only looks at the surrounding land, up-slope from the study wetland. During the riverine validation study and this intensification we found that only the updated "Water Source" metric improved correlation with plant community data. The 'Hydrologic Connectivity' metric was too difficult to complete because access to the river is often impossible as a result of distance or landowner permission. The buffer filter metric added very little information, with added complexity in metric calculation. As a result, moving forward we will utilize the original 'Hydrologic Connectivity' and "Buffer Filter" metric to maintain consistency in application, until improvements can be made.

Other updates to OKRAM that resulted from this project were largely for consistency in application, and to improve the distribution of scores. The most current version of OKRAM, including these updates are included in Appendix A. The 'Hydroperiod' metric was updated for clarity. The original version of OKRAM recorded 'indicators of reduced hydroperiod' and 'indicators of increased hydroperiod' separately in the worksheet, but this led to questions regarding how to record stressors when both indicators of increased and decreased hydroperiod were present at the same site. As a result, these indicators have been merged into 'indicators of altered hydroperiod'. This should have no impact on scoring but should streamline documentation and assessment. Secondly, the 'Chemical Contaminants' metric rarely deviates from a perfect score, and ultimately restricts the range of overall OKRAM scores. As a result, we have combined 'Nutrients' and 'Chemical Contaminants' into a single metric which should improve the distribution of scores. OCC staff have already revisited historic assessments and updated scores to reflect this change.

Given the relatively strong correlations found between OKRAM and plant community composition (FQAI, VMMI and diversity metrics) over the last decade (OCC 2020b, OCC 2019, Gallaway et al. 2016, OWRB 2015), it is unlikely that legacy disturbances and needed OKRAM metric adjustments are the primary drivers of the disparity. This was the first statewide attempt to validate OKRAM with plant community data. Previous validation studies employed restricted wetland types (i.e., depressional or riverine only) and/or geography (e.g. Central Great Plains Ecoregion). VMMI metrics, like FQAI are impacted by geographic distributions of plants, and the condition category thresholds utilized in this study were based on vegetation type alone (herbaceous vs.

woody) and not ecoregion or other regional subdivisions. While empirical justification for the national condition categories is well detailed in USEPA (2023a), reference condition categories more appropriate to Oklahoma may need to be established to apply the same metrics at the state scale.

In a previous study we found that the established threshold FQAI score of 20 for statewide reference wetlands (Bried et al. 2014) was too high for wetlands in the western half of the state (Gallaway et al. 2016). In the same study, of 70 statewide depressional wetlands the highest FQAI score was 24.5. To receive a perfect score for the NWCA FQAI metric (a component of the VMMI) an herbaceous wetland would need to receive a 35.77 (USEPA 2023a). Precipitation is a strong driver of the distribution of plant species, and more tolerant species are found at semi-arid western Oklahoma wetlands (Gallaway et al. 2016). These wetlands are exposed to more extreme fluctuations in water levels, and at times can be dominated by more upland adapted taxa that have lower coefficients of conservatism (Gallaway et al. 2016). While least disturbed depressional wetlands in Eastern Oklahoma (east of I-35) had an average FQAI score of 19.9, those in the western half of the state (west of I-35) had an average FQAI score of 13. Meaning, that what Gallaway et al. (2016) found to be an average least disturbed herbaceous wetland would receive an FQAI metric score of 4.8 and 2.6 in the eastern and western parts of the state, respectively (OCC 2019). East to west, climate gradients may also influence other VMMI metrics in Oklahoma, like the “percentage richness of OBL and FACW plants”. Wetlands in the Oklahoma panhandle receive 80 cm less annual precipitation than those in far Southeastern Oklahoma, and rainfall often occurs in large episodic events (Gallaway et al. 2019). As a result western wetlands are often dominated by facultative plants than can tolerate dramatic wet-dry cycles.

Furthermore, we continue to find anecdotal evidence that the VMMI metrics can be strongly influenced by natural stressors. Far western Oklahoma aquatic ecosystems can be extremely saline, as a result of natural geologic influences. Wetland 10131 along the Red River in Harmon County was dominated by salt-tolerant plants like saltgrass (*Distichilis spicata*) and groundsel-tree (*Bacharis halimifolia*), and had an FQAI of 14.8, which converted to a VMMI metric score of 3.2, despite being a score expected of a least-disturbed wetland in western Oklahoma (Gallaway et al. 2016). Furthermore, despite a relatively high percentage of cover (~50%) by facultative wetland (FACW) plants, this site scored a 0 for “percentage richness of OBL and FACW plants” because the richness of OBL and FACW was limited to a few taxa, potentially as a result of the natural stress from salt concentrations, and drier climate of western Oklahoma.

As in 2016 we found the “percentage of native monocot” metric to score wooded riverine wetlands poorly. Understory communities in these dynamic floodplain environments are often responding to frequent flood events that alter plant community composition. Six of 13 riverine wooded wetlands assessed in 2021/2022 had minimal disturbance identified during OKRAM assessments but scored 2.1 or less for the native monocot metric. Furthermore, several of the assessed riverine wooded wetlands were climax communities, dominated by stands of old growth trees with extensive canopies and limited opportunity for summer monocot growth (DeSteven et al. 2015). A further complication is that these same riverine systems are often responding to upstream and downstream hydrologic disturbances at large scales, such as changes to regional climate and impoundments. As a result, while vegetation community assessments may overestimate stress following natural disturbances, stressor assessments may omit important anthropogenic impacts occurring outside the area or timescale of observation. Disentangling these impacts is challenging and may contribute to the disparity in OKRAM and VMMI scores we found in this study.

Despite the poor correlation between VMMI and OKRAM at wetlands assessed in 2021 and 2022 for this intensification, this project has been critical to continue to build a robust database of OKRAM assessments completed in Oklahoma with concurrently collected intensive plant community data. An additional 30 wetland assessments were completed in 2023 at highly disturbed wetlands across the state. With this intensification and the 2023 assessments over 300 OKRAM assessments have been completed across the state. With the compiled dataset, we will establish Oklahoma specific vegetation metric reference conditions that account for the spatial variability in climate, vegetation community, and hydrogeomorphic class. Following establishment of refined vegetation metrics, we can re-calibrate OKRAM statewide. With the robust dataset that NWCA intensifications has allowed us to compile, we can also set-aside a large number of wetland assessments for method validation.

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USEPA (2020) National Wetland Condition Assessment 2021: Site Evaluation Guidelines. Office of Water, Washington, D.C.

TABLES AND FIGURES

Table 1. Vegetation condition and stress levels for 48 wetlands assessed for the NWCA intensification project in Oklahoma. FQAI is floristic quality assessment index ,VMMI is vegetation multi-metric index and NNPI is the non-native plant index. All metrics were calculated and organized into condition categories following NWCA guidelines. Condition levels include good, fair and poor. NNPI also includes a very poor category. Physical stress was calculated by aggregating the stress scores for Vegetation Removal (VEGREM), Vegetation Replacement (VEGREP), Water Addition/Subtraction (WADSUB), Flow Obstruction (WOBSTR) Soil Hardening (SOILHD), and Surface modification (SOMODF). All stressor metrics were also categorized into good, fair and poor.

Site ID	Vegetation	FQAI	VMMI	VMMI Condition	NNPI	VEG REM	VEG REP	WAD SUB	W OBSTR	SOIL HD	SO MODF	Physical Stress Sum
10020	Herbaceous	18.47	45.68	poor	very poor	poor	good	good	good	fair	good	poor
10021	Woody	15.27	46.17	poor	fair	poor	good	good	good	good	good	poor
10023	Herbaceous	28.19	44.98	poor	poor	poor	poor	fair	good	good	good	poor
10036	Woody	29.27	58.30	fair	fair	good	good	good	good	good	good	good
10038	Woody	17.74	43.26	poor	fair	fair	fair	good	fair	good	good	fair
10045	Woody	28.79	62.61	fair	fair	fair	good	good	good	fair	good	poor
10055	Herbaceous	22.61	32.68	poor	poor	poor	fair	good	good	fair	good	poor
10058	Woody	16.08	30.58	poor	poor	poor	fair	good	good	good	good	poor
10070	Herbaceous	12.03	42.58	poor	poor	poor	fair	good	good	fair	good	poor
10073	Woody	23.17	60.23	fair	good	poor	good	good	good	good	good	poor
10078	Woody	21.26	67.48	good	good	good	good	good	good	good	good	good
10080	Woody	21.78	48.30	poor	fair	fair	good	good	good	good	good	fair
10083	Woody	30.30	55.09	fair	fair	fair	fair	fair	fair	fair	fair	poor
10091	Woody	13.64	43.56	poor	fair	poor	good	good	good	good	good	poor
10095	Woody	16.82	55.20	fair	good	poor	good	good	good	good	good	poor
10102	Woody	6.38	22.11	poor	poor	fair	fair	good	good	good	good	fair
10109	Woody	28.01	72.25	good	good	poor	good	good	good	good	good	poor
10112	Woody	21.11	53.84	fair	good	poor	good	good	good	good	good	poor
10123	Woody	25.52	46.92	poor	poor	good	fair	good	fair	good	good	fair
10126	Woody	16.62	49.53	poor	fair	good	good	good	good	good	good	good
10127	Woody	19.14	55.93	fair	good	poor	fair	good	good	good	good	poor

Site ID	Vegetation	FQAI	VMMI	VMMI Condition	NNPI	VEG REM	VEG REP	WAD SUB	W OBSTR	SOIL HD	SO MODF	Physical Stress Sum
10130	Woody	23.88	60.17	fair	good	poor	good	good	good	good	good	poor
10131	Herbaceous	14.82	46.04	poor	fair	fair	fair	good	good	good	good	fair
10153	Woody	35.38	81.38	good	good	poor	good	good	good	good	good	poor
10156	Woody	29.86	62.91	fair	fair	fair	fair	good	good	good	good	fair
10159	Herbaceous	18.00	66.41	fair	good	poor	fair	good	fair	fair	good	poor
10168	Woody	30.01	49.79	poor	fair	poor	good	good	good	good	good	poor
10170	Herbaceous	20.28	42.36	poor	poor	poor	good	good	good	fair	good	poor
10173	Woody	21.51	77.09	good	good	fair	good	good	good	good	good	fair
10193	Woody	16.71	24.28	poor	very poor	poor	good	good	good	good	good	poor
10207	Woody	20.15	55.53	fair	good	poor	good	good	good	good	good	poor
10210	Woody	18.31	44.91	poor	fair	fair	good	good	fair	good	good	fair
10225	Herbaceous	21.49	46.58	poor	fair	poor	fair	good	fair	fair	good	poor
10244	Woody	15.33	55.33	fair	good	poor	fair	good	good	good	good	poor
10258	Herbaceous	16.15	63.45	poor	fair	good	fair	good	fair	fair	good	poor
10261	Herbaceous	5.55	53.17	poor	fair	good	good	good	good	good	good	good
10271	Woody	20.68	58.50	fair	good	poor	good	good	good	good	good	poor
10274	Woody	19.34	58.18	fair	fair	poor	good	good	good	good	good	poor
10300	Woody	21.21	53.88	fair	fair	good	good	good	good	good	good	good
10321	Herbaceous	24.20	49.75	poor	poor	poor	good	good	good	good	good	poor
10324	Herbaceous	24.41	46.50	poor	fair	fair	fair	fair	fair	good	fair	poor
10335	Woody	21.68	67.92	good	good	fair	good	good	good	good	good	fair
10344	Woody	26.67	70.80	good	fair	fair	fair	fair	fair	good	good	fair
10347	Herbaceous	11.26	49.55	poor	fair	poor	fair	good	fair	good	good	poor
10355	Herbaceous	11.55	48.54	poor	fair	poor	fair	good	poor	fair	good	poor
10368	Herbaceous	17.05	49.79	poor	fair	poor	fair	fair	fair	fair	good	poor
10371	Herbaceous	16.53	56.38	poor	fair	fair	fair	fair	poor	fair	fair	poor
10372	Woody	20.98	73.76	good	good	poor	good	good	good	fair	good	poor

Table 2. Oklahoma Rapid Assessment Method (OKRAM) metric, attribute (Hydrology, Water Quality and Biotic) and overall scores for 48 wetlands assessed for the NWCA intensification project Oklahoma. Hydrology metrics include hydroperiod, water source and hydrologic connectivity (Hydro. Con.). Water Quality metrics include nutrients, sedimentation (Sediment), contaminants (Contam) and buffer filter (Buffer). Biotic metrics include vegetation (Veg.) and habitat connectivity (Habitat Con.)

Site ID	Vegetation	Wetland Type	Hydro period	Water Source	Hydro Con.	Hydrology	Nutr.	Sed.	Contam.	Buffer	Water Quality	Veg.	Habitat Con.	Biotic	OKRAM	OKRAM Category
10020	Herbaceous	Riverine	1.00	0.78	1.00	0.93	0.75	n/a	1.00	0.75	0.83	0.46	0.59	0.53	0.76	fair
10021	Woody	Depression	1.00	0.96	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.82	0.93	0.87	0.95	good
10023	Herbaceous	Riverine	0.75	0.88	1.00	0.88	0.50	n/a	1.00	0.00	0.50	0.40	0.42	0.41	0.60	fair
10036	Woody	Depression	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.85	0.91	0.97	good
10038	Woody	Depression	1.00	0.46	1.00	0.82	1.00	1.00	1.00	1.00	1.00	0.99	0.54	0.77	0.86	good
10045	Woody	Depression	0.50	0.99	0.50	0.66	0.50	0.65	1.00	0.00	0.54	0.71	0.78	0.75	0.65	fair
10055	Herbaceous	Depression	1.00	0.93	1.00	0.98	1.00	1.00	1.00	0.00	0.75	0.13	0.48	0.30	0.68	fair
10058	Woody	Depression	1.00	0.98	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.84	0.92	0.97	good
10070	Herbaceous	Depression	1.00	0.68	1.00	0.89	0.50	1.00	1.00	0.00	0.63	0.83	0.77	0.80	0.77	fair
10073	Woody	Riverine	1.00	0.75	1.00	0.92	0.75	n/a	1.00	0.00	0.58	0.97	0.72	0.85	0.78	fair
10078	Woody	Riverine	1.00	0.85	1.00	0.95	1.00	n/a	1.00	1.00	1.00	1.00	0.91	0.95	0.97	good
10080	Woody	Depression	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.93	0.95	0.98	good
10083	Woody	Depression	0.50	1.00	0.60	0.70	1.00	1.00	1.00	1.00	1.00	0.72	0.74	0.73	0.81	fair
10091	Woody	Riverine	1.00	0.67	1.00	0.89	1.00	n/a	1.00	1.00	1.00	0.92	0.85	0.88	0.92	good
10095	Woody	Depression	0.95	0.98	1.00	0.98	0.50	0.95	1.00	0.00	0.61	0.83	0.93	0.88	0.82	fair
10102	Woody	Depression	1.00	0.93	1.00	0.98	1.00	1.00	1.00	1.00	1.00	0.72	0.91	0.82	0.93	good
10109	Woody	Riverine	1.00	0.80	1.00	0.93	0.75	n/a	1.00	1.00	0.92	0.97	0.93	0.95	0.93	good
10112	Woody	Depression	1.00	0.96	1.00	0.99	0.75	1.00	1.00	1.00	0.94	0.99	0.73	0.86	0.93	good
10123	Woody	Depression	1.00	0.88	1.00	0.96	1.00	1.00	1.00	1.00	1.00	0.85	0.93	0.89	0.95	good
10126	Woody	Depression	1.00	0.96	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.97	0.44	0.71	0.90	good
10127	Woody	Riverine	1.00	0.76	1.00	0.92	1.00	n/a	1.00	1.00	1.00	1.00	0.67	0.83	0.92	good
10130	Woody	Lacustrine	0.50	0.91	1.00	0.80	1.00	1.00	1.00	1.00	1.00	1.00	0.60	0.80	0.87	good

Site ID	Vegetation	Wetland Type	Hydro period	Water Source	Hydro Con.	Hydrology	Nutr.	Sed.	Contam.	Buffer	Water Quality	Veg.	Habitat Con.	Biotic	OKRAM	OKRAM Category
10131	Herbaceous	Riverine	1.00	0.88	1.00	0.96	0.75	n/a	1.00	1.00	0.92	0.89	0.75	0.82	0.90	good
10153	Woody	Slope	1.00	0.93	1.00	0.98	1.00	1.00	1.00	1.00	1.00	0.99	0.94	0.97	0.98	good
10156	Woody	Depression	1.00	0.98	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.98	0.89	0.94	0.98	good
10159	Herbaceous	Depression	0.50	0.95	0.50	0.65	0.93	1.00	1.00	1.00	0.98	1.00	1.00	1.00	0.88	good
10168	Woody	Riverine	1.00	0.87	1.00	0.96	1.00	n/a	1.00	1.00	1.00	1.00	0.90	0.95	0.97	good
10170	Herbaceous	Riverine	1.00	0.74	1.00	0.91	1.00	n/a	1.00	1.00	1.00	0.81	0.72	0.77	0.89	good
10173	Woody	Lacustrine	0.50	0.86	1.00	0.79	0.75	1.00	1.00	1.00	0.94	0.96	0.78	0.87	0.86	good
10193	Woody	Riverine	1.00	0.95	1.00	0.98	1.00	n/a	1.00	1.00	1.00	0.97	0.69	0.83	0.94	good
10207	Woody	Riverine	1.00	0.51	1.00	0.84	1.00	n/a	0.25	1.00	0.75	1.00	0.31	0.65	0.75	fair
10210	Woody	Lacustrine	0.50	0.95	1.00	0.82	1.00	1.00	1.00	1.00	1.00	0.99	0.85	0.92	0.91	good
10225	Herbaceous	Depression	0.25	0.92	0.00	0.39	0.75	1.00	1.00	0.00	0.69	0.91	0.23	0.57	0.55	fair
10244	Woody	Riverine	1.00	0.33	1.00	0.78	0.50	1.00	1.00	1.00	0.88	0.92	0.87	0.89	0.85	fair
10258	Herbaceous	Lacustrine	1.00	0.87	0.70	0.86	1.00	1.00	1.00	1.00	1.00	0.98	0.58	0.78	0.88	good
10261	Herbaceous	Lacustrine	1.00	1.00	0.85	0.95	1.00	1.00	1.00	1.00	1.00	0.73	0.71	0.72	0.89	good
10271	Woody	Riverine	1.00	0.58	0.00	0.53	1.00	n/a	1.00	1.00	1.00	0.98	0.63	0.81	0.78	fair
10274	Woody	Riverine	1.00	0.80	1.00	0.93	1.00	n/a	1.00	1.00	1.00	1.00	1.00	1.00	0.98	good
10300	Woody	Riverine	1.00	0.80	1.00	0.93	1.00	n/a	1.00	1.00	1.00	0.94	0.97	0.96	0.96	good
10321	Herbaceous	Riverine	1.00	0.80	1.00	0.93	1.00	n/a	1.00	1.00	1.00	0.93	1.00	0.97	0.97	good
10324	Herbaceous	Riverine	0.50	0.38	1.00	0.63	1.00	n/a	1.00	0.95	0.98	0.96	0.96	0.96	0.86	good
10335	Woody	Depression	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.77	0.88	0.96	good
10344	Woody	Depression	1.00	0.94	0.50	0.81	0.70	1.00	1.00	0.86	0.89	0.99	0.25	0.62	0.77	fair
10347	Herbaceous	Depression	1.00	0.94	0.90	0.95	0.75	1.00	1.00	0.99	0.93	0.92	0.79	0.85	0.91	good
10355	Herbaceous	Lacustrine	1.00	0.37	1.00	0.79	1.00	1.00	1.00	1.00	1.00	0.92	0.66	0.79	0.86	good
10368	Herbaceous	Riverine	1.00	0.46	1.00	0.82	1.00	n/a	1.00	0.98	0.99	0.98	0.79	0.88	0.90	good
10371	Herbaceous	Depression	1.00	0.89	0.10	0.66	1.00	1.00	1.00	1.00	1.00	0.99	0.43	0.71	0.79	fair
10372	Woody	Riverine	1.00	0.63	1.00	0.88	0.75	n/a	1.00	1.00	0.92	0.83	1.00	0.92	0.90	good

Table 3. Agreement of condition class categories using the Oklahoma Rapid Assessment Method OKRAM, and Vegetation Multimetric Index (VMMI) for 48 wetlands in Oklahoma. Areas shaded in gray were placed in the same condition class using both methods.

	OKRAM Category	
VMMI Category	fair	good
poor	6	20
fair	7	8
good	1	6

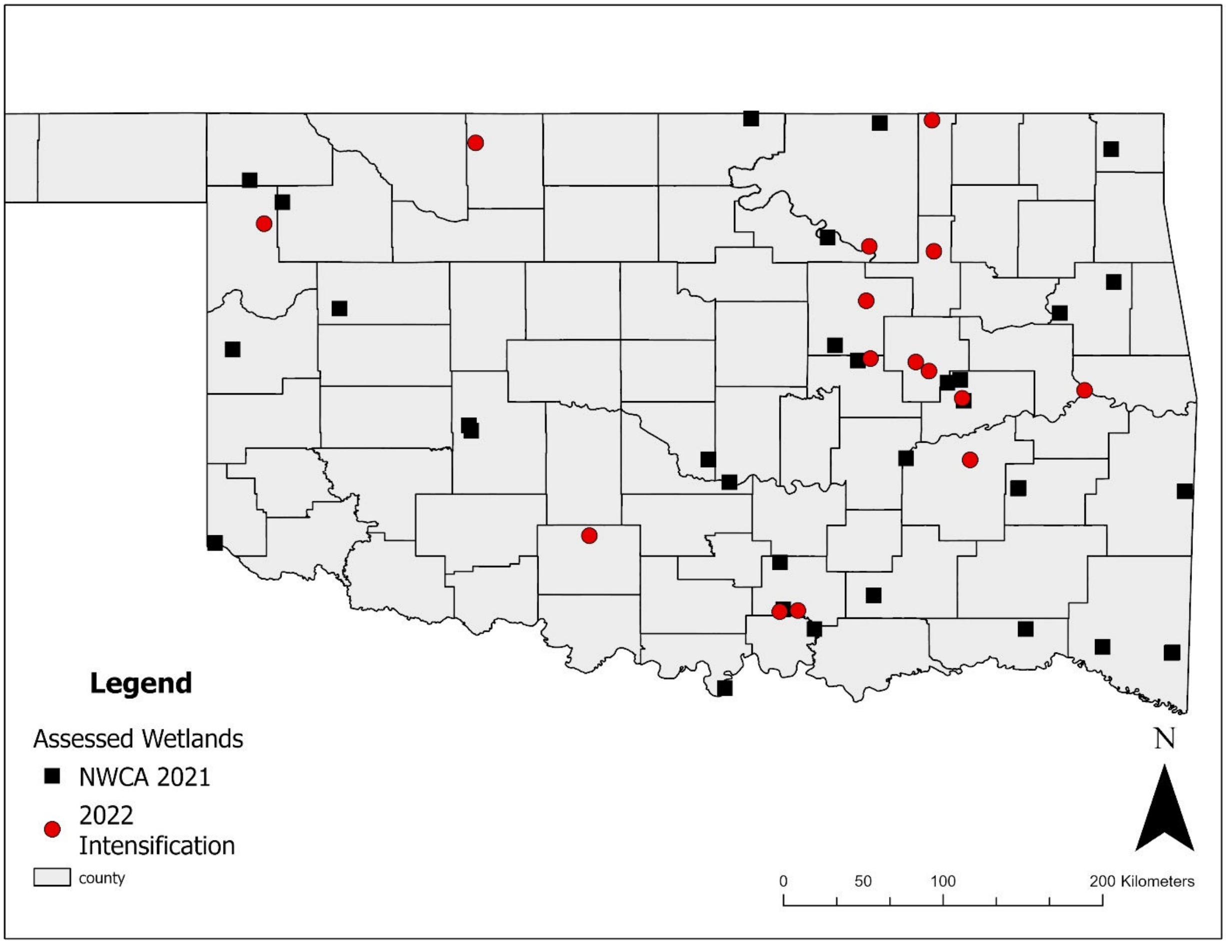


Fig 1. Study area for the application of the 2021/2022 National Wetland Condition Assessment and Intensification Study in Oklahoma and location of assessment wetlands.

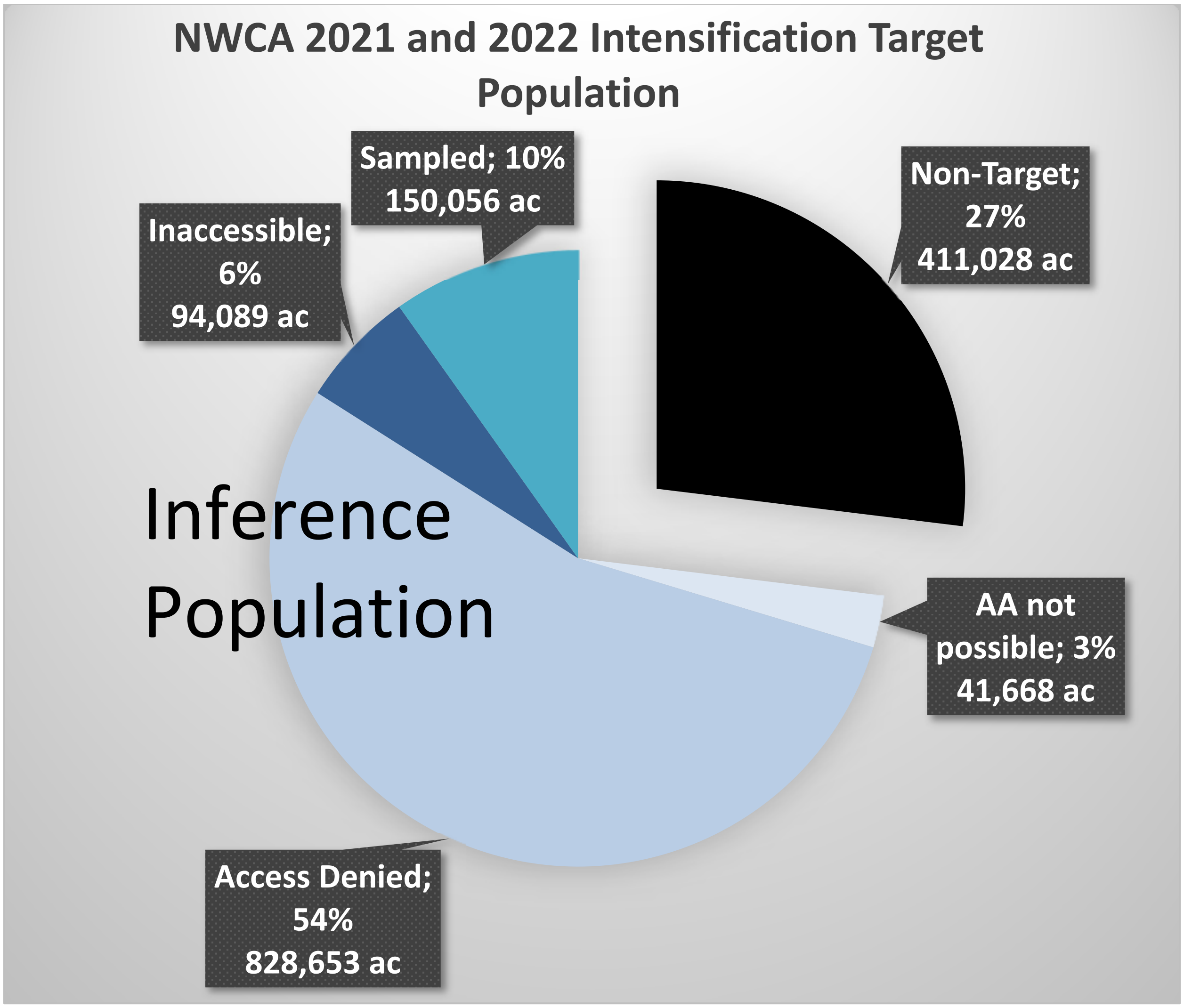
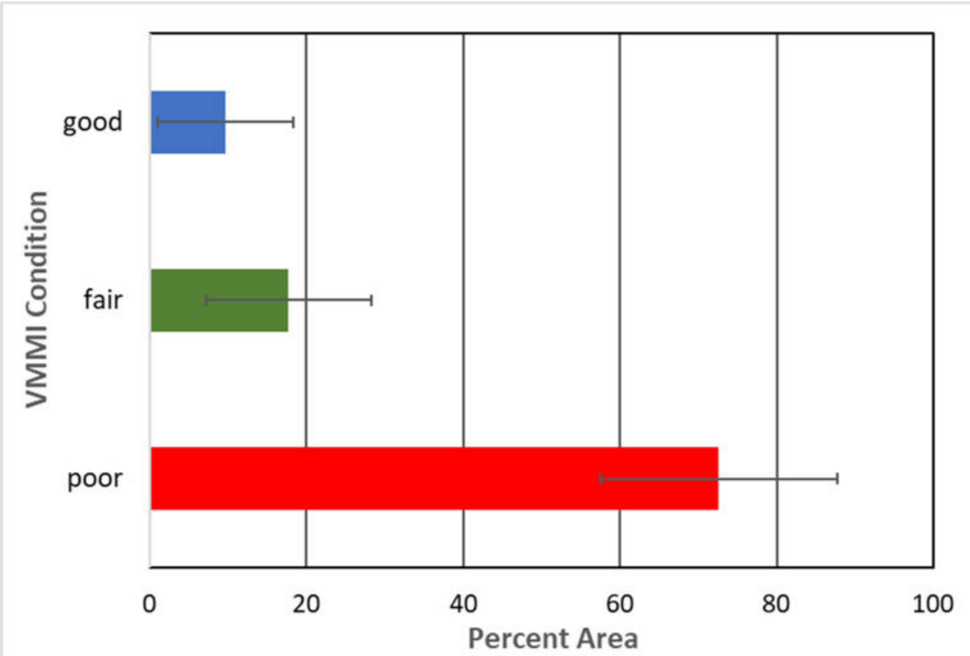
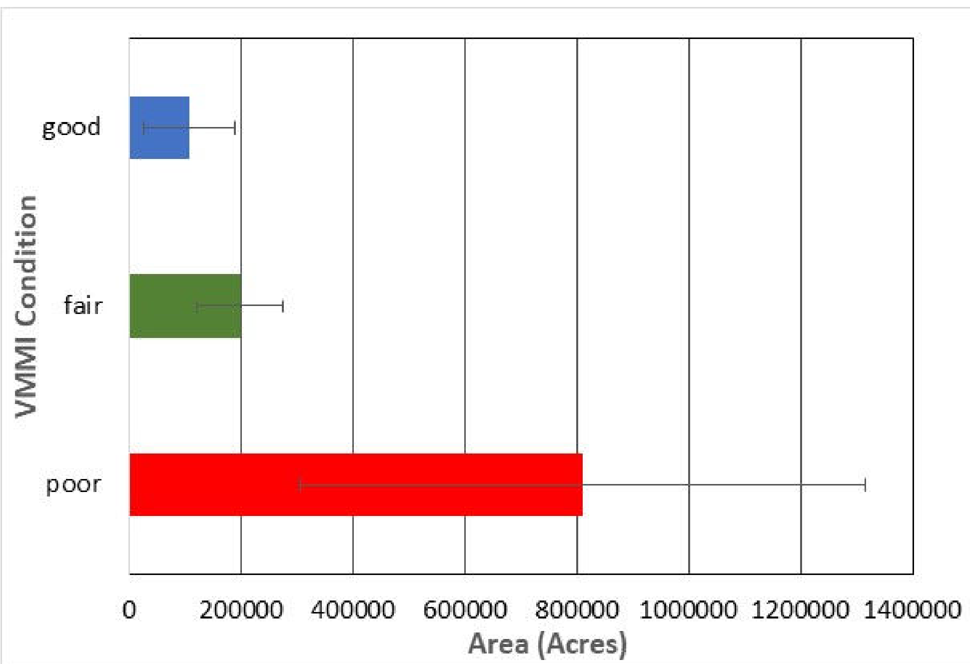


Fig 2. The 2021 NWCA and 2022 NWCA intensification "Target Population" for Oklahoma. The target population is divided into the "Inference Population", for which condition extent is estimated, and includes sampled sites, inaccessible sites, sites where an AA could not be created, and sites where permission was denied. Nontarget sites are removed from the inference population.

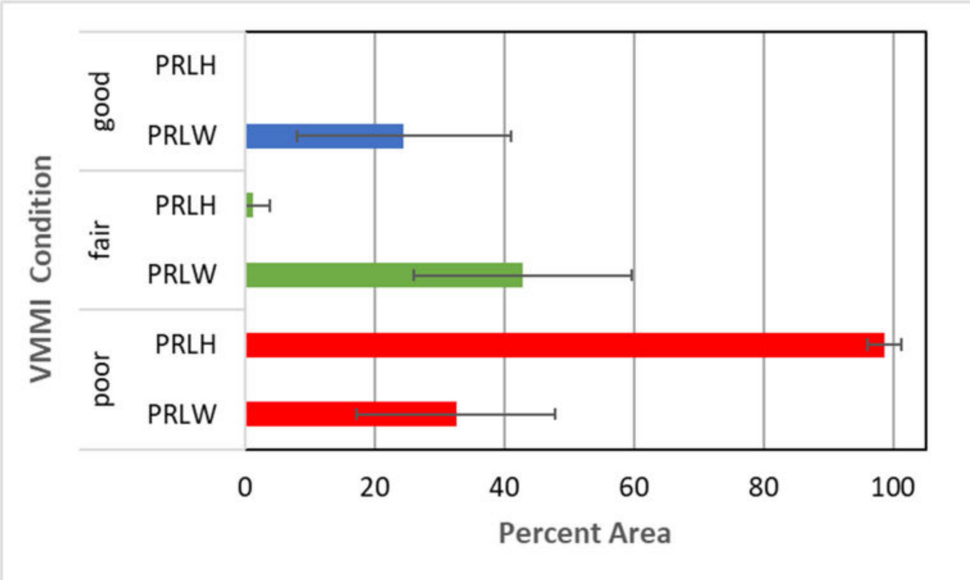


(a)



(b)

Fig. 3. Percentage (a) and area (b) of wetland sites in good, fair and poor condition based on the National Wetlands Condition Assessment (NWCA) Vegetation Multimetric Index (VMMI) in Oklahoma.



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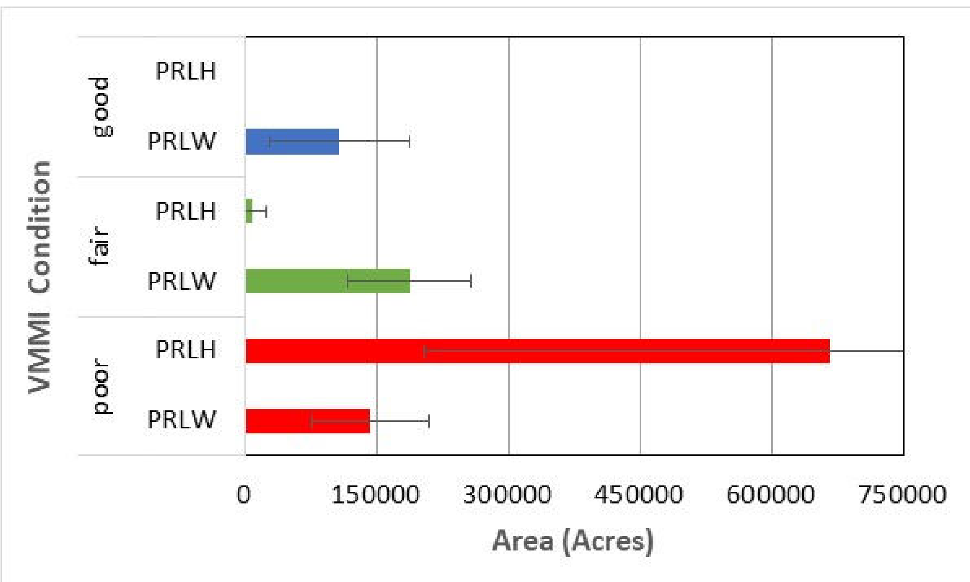
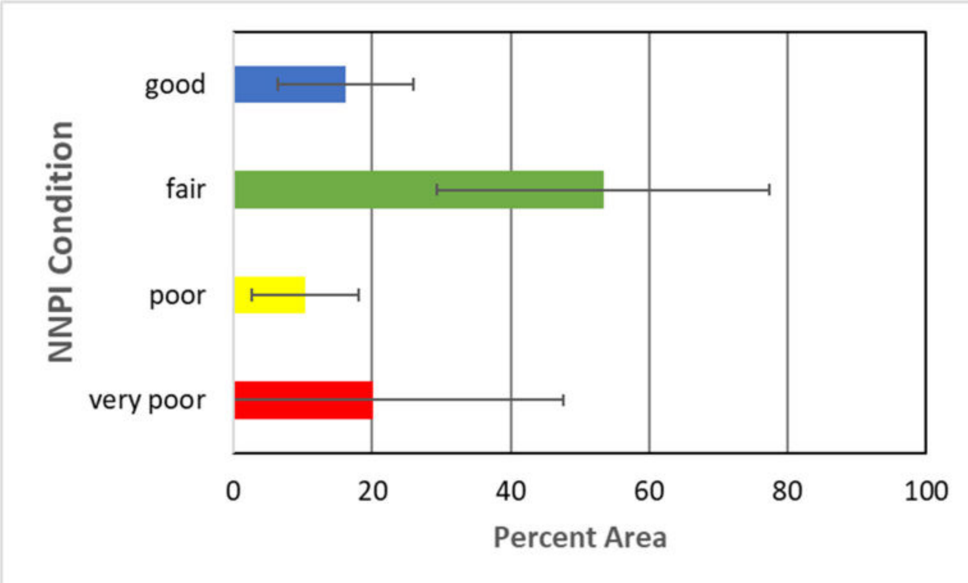
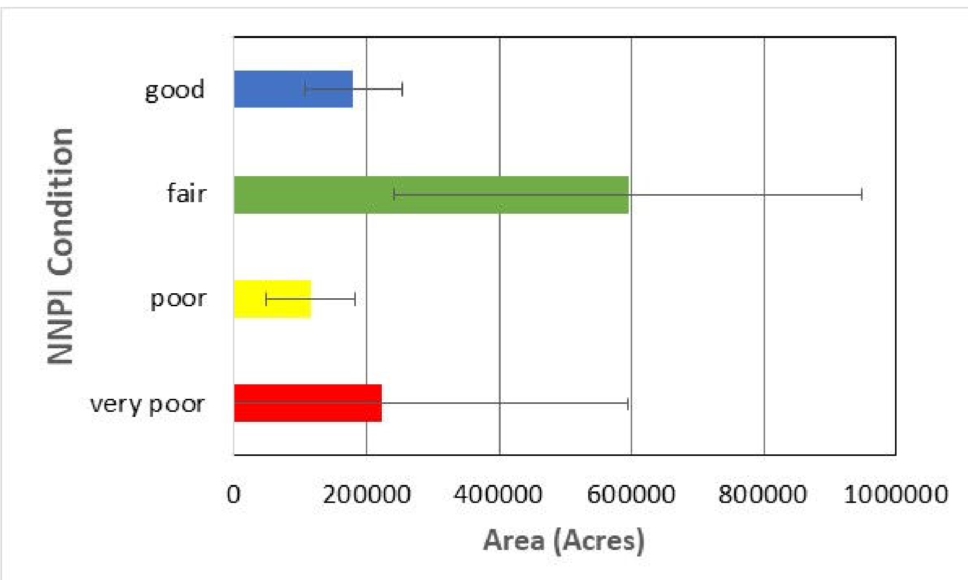


(b)

Fig. 4. Percentage (a) and area (b) of wetland sites in good, fair and poor condition based on the National Wetlands Condition Assessment (NWCA) Vegetation Multimetric Index (VMMI) in Oklahoma sorted by vegetation community (PRLH and PRLW).

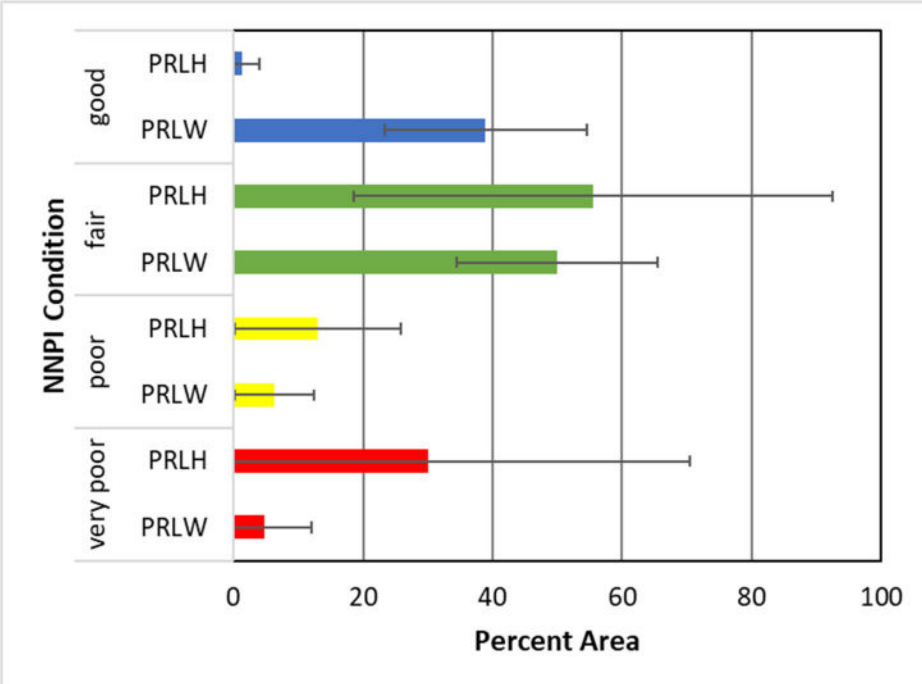


(a)

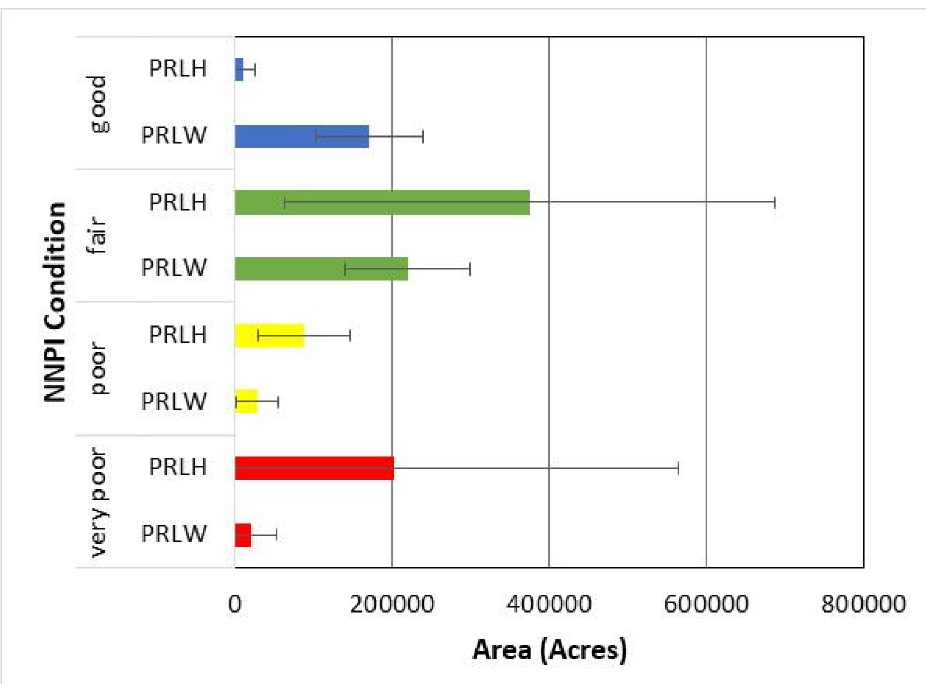


(b)

Fig 5. Percentage (a) and area (b) of wetland sites exhibiting stress in Oklahoma. Stress was determined by assessing the presence of non-native plant communities, based on the National Wetlands Condition Assessment (NWCA) Non-native Plant Indicator (NNPI).



(a)



(b)

Fig 6. Percentage (a) and area (b) of wetland sites exhibiting stress in Oklahoma. Stress was determined by assessing the presence of non-native plant communities, based on the National Wetlands Condition Assessment (NWCA) Non-native Plant Indicator (NNPI) sorted by vegetation community.

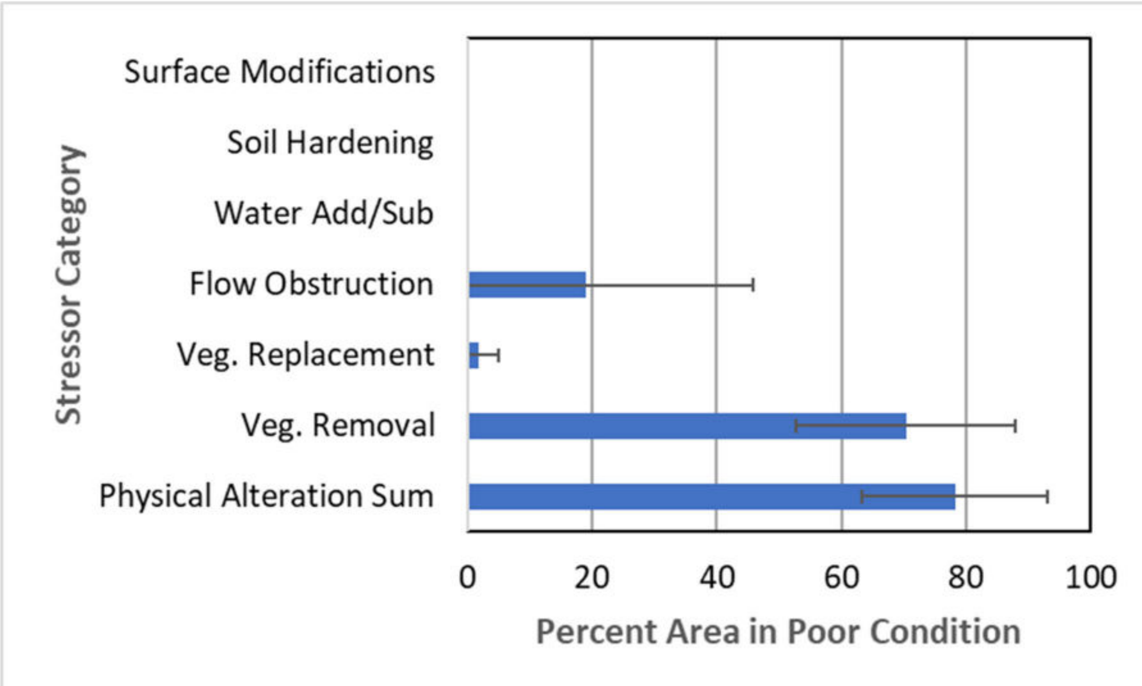
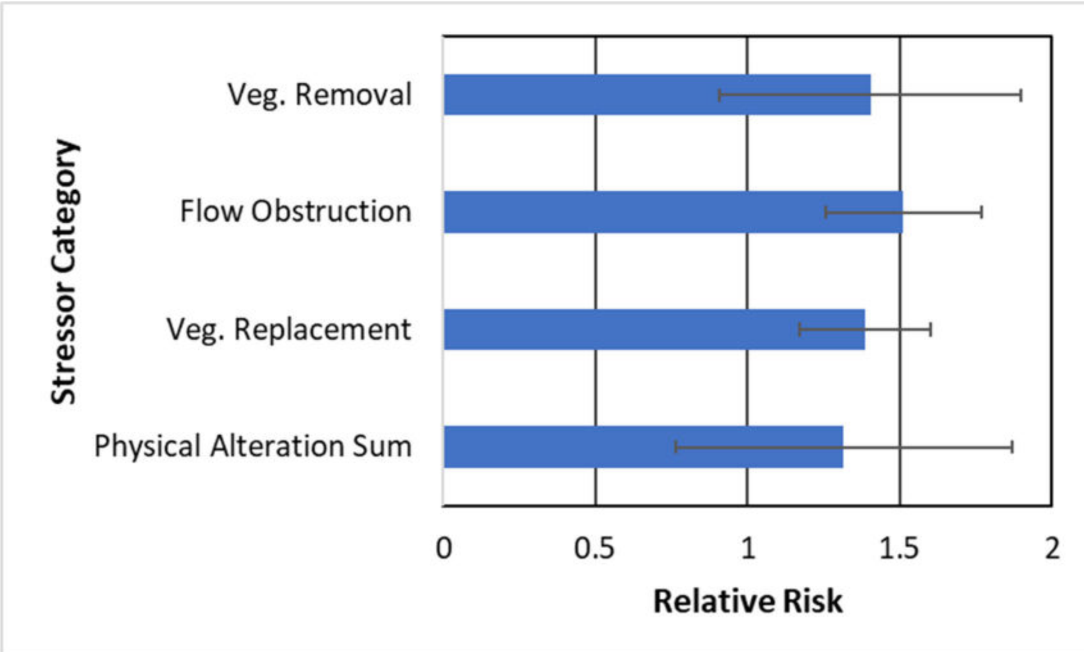
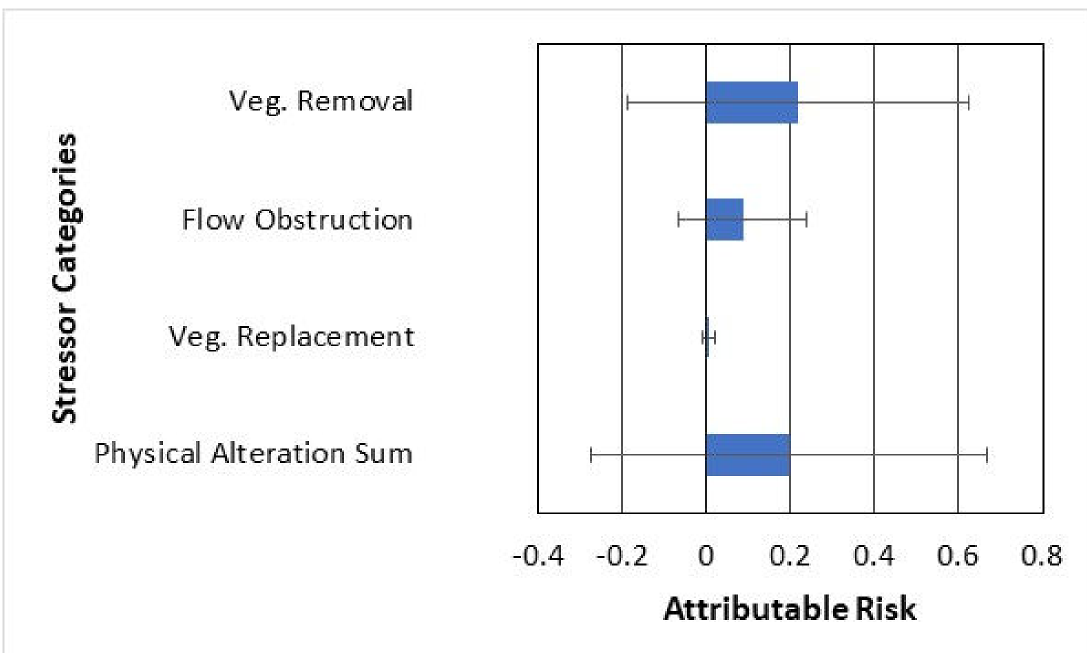


Fig 7. Percentage of wetland sites exhibiting stress in Oklahoma. Stress was determined by assessing wetlands according to the National Wetlands Condition Assessment (NWCA) protocols for six measures of physical alteration and an overall physical alteration category.



(a)



(b)

Fig 8. Relative (a) and attributable (b) risk for physical stressors at wetlands in Oklahoma. Risk was determined by assessing wetlands according to the National Wetlands Condition Assessment (NWCA) protocols.

APPENDIX A: OKRAM Worksheets

Dichotomous Key for HGM Wetland Classification in Oklahoma (DRAFT)	
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* (15)
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 and wetlands are restricted to the margin of the depression.	*Lacustrine Fringe (10)*
4. Topographic depression does not contain permanent water greater than 2 meters.	*Depression (11)*
Dichotomous Key for Riverine Wetland Subclassification in Oklahoma	
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 (includes vegetated ephemeral channels, bars and islands).	**In-channel**
7. The wetland is directly adjacent to the river channel or occurs on a topographic floodplain (may include back-channels, swales or other topographic relief).	**8**
8. Stream is intermittent or ephemeral	**Floodplain (Non-perennial)**
8. Stream is perennial	**9**
9. Stream is a 1st or 2nd order	**Floodplain (Upper Perennial)**
9. Stream is a 3rd order or higher	**Floodplain (Lower Perennial)**
Dichotomous Key for Lacustrine Wetland Subclassification in Oklahoma	
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.	**Man-made Lacustrine Fringe**
Dichotomous Key for Depressional Wetland Subclassification in Oklahoma	
11. Wetland was created by human activity.	12
11. Wetland was not created by human activity.	13
12. Wetland does not have discernible water outlets.	**Closed Impounded Depression**
12. Wetland has discernible water outlet.	**Open Impounded Depression**
13. Wetland primary water source is groundwater.	**Groundwater Depression**
13. Wetland primary water source is surface water.	14
14. Wetland does not have any discernible water outlets.	**Closed Surface Water Depression**
14. Wetland has discernible water outlets.	**Open Surface Water Depression**
Dichotomous Key for Slope Wetland Subclassification in Oklahoma	
15. Wetland is hydrologically connected to a low order (Strahler <=4), high gradient, or ephemeral stream.	**Headwater Slope**
15. 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**

Site Description (DRAFT)

Site Name	
Date of Assessment	
Assessor Name(s)	
Assessor Affiliation(s)	

Location Information

Site Latitude	
Site Longitude	
Coordinate System	
Level III Omernik Ecoregion	
Directions/Access Notes	

Assessment Area Information

Size of Wetland					
# of Assessment Areas					
Assessment Area ID		**AA Type**		**AA size**	
Reason for Assessment					

HGM Classification (circle one class and any relevant subclasses)

HGM Class	**Depression**	**Flat**	**Slope**	**Lacustrine**	**Riverine**
Regional Subclass	*Closed Impounded*	*Hardwood*	*Headwater*	*Disconnected Oxbow*	*Connected Oxbow*
	Open Impounded		*Low-gradient*	*Man-made Lacustrine*	*Beaver Complex*
	Groundwater				*In-Channel*
	Open Surface Water				*Floodplain (non-perennial)*
	Closed Surface Water				*Floodplain (upper perennial)*
					Floodplain (lower perennial)

Additional Site Characteristics (circle dominant condition)

Hydrologic Condition at time of assessment	Ponded/inundated		Saturated Soil (no surface water)			Dry
Hydroperiod	Temporary *(inundated for <1 month)*		Seasonal *(inundated for extended periods of growing season)*		Semi-permanent/ Permanent *(inundated except during drought years)*	
Dominant Vegetation	Forested	Scrub/Shrub	Emergent	Submergent/ Floating Leaved		Unvegetated
Management	Unmanaged	Agriculture	Stormwater	Water treatment	Water supply	Wildlife

Site Notes

Additional AA Description (DRAFT)

Site Name							
Date of Assessment							
Location Information							
Site Latitude							
Site Longitude							
Additional Assessment Area Information							
Assessment Area ID		**AA Type**			**AA size**		
HGM Classification (circle one class and any relevant subclasses)							
HGM Class	**Depression**		**Flat**	**Slope**	**Lacustrine**		**Riverine**
Regional Subclass	*Closed Impounded*		*Hardwood*	*Headwater*	*Disconnected Oxbow*		*Connected Oxbow*
	Open Impounded			*Low-gradient*	*Man-made Lacustrine*		*Beaver Complex*
	Groundwater						*In-Channel*
	Open Surface Water						*Floodplain (non-perennial)*
	Closed Surface Water						*Floodplain (upper perennial)*
							Floodplain (lower perennial)
Additional Site Characteristics (circle dominant condition)							
Hydrologic Condition at time of assessment	Ponded/inundated		Saturated Soil (no surface water)				Dry
Hydroperiod	Temporary *(inundated for <1 month)*		Seasonal *(inundated for extended periods of growing season)*		Semi-permanent/ Permanent *(inundated except during drought years)*		
Dominant Vegetation	Forested	Scrub/Shrub	Emergent	Submergent/ Floating Leaved			Unvegetated
Management	Unmanaged		Agriculture	Stormwater	Water treatment	Water supply	Wildlife
Additional Assessment Area Notes							

1. Hydrologic condition

a. Hydroperiod

Instructions:

1. In the office, mark potential hydroperiod stressors that occur within 500 meters of the AA on aerial imagery for further inspection in the field.
2. In the field, confirm hydroperiod stressors identified in the office, as well as any other hydroperiod stressors, matching the alteration to the indicator and the severity from the table on the following worksheet (1a- Hydroperiod Indicators). Annotate an aerial image with the aerial extent of impact from all identified indicators.
3. In the hydroperiod worksheet, record the percentage (0-100) of the AA impacted by each indicator in the appropriate severity column. Overlapping areas of indicators are only counted once for the highest severity indicator present. Therefore the total percent cover of indicators cannot exceed 100 If no hydroperiod stressors are identified, select the "No Indicators of Altered Hydroperiod Present' checkbox.

No Indicators of Altered Hydroperiod Present: ☐

Indicators of Altered Hydroperiod	Minor	Moderate	Major	Complete Loss	Indicator Description
Fill/sedimentation					
Water being pumped into or out of the wetland					
Water control structures					
Culverts, discharges, ditches or tile drains into our out of the wetland					
Beaver dam removal					
Excavation/Dredging/Mining					
TOTAL IMPACTED AREA					
SEVERITY WEIGHT	0.25	0.5	0.75	1	
SEVERITY WEIGHTED AREA					
METRIC SCORE 1A					

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 into our 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 from wetland only during high water events AND/OR Water enters wetland from culverts, diversions or ditches only during large storm events. Water is consistently discharged into wetland from agricultural irrigation.	Water is drained from wetland at all times of the year but still retains wetland hydrology AND/OR Water from culvert, diversion, irrigation or ditch is the dominant water source for the wetland.	Wetland completely dried OR Wetland completed converted to permanent deepwater
5. Beaver dam removal	n/a	n/a	Still retains wetland hydrology	Wetland completely dried
6. Excavation/ Dredging/ Mining (including center of the wetland excavated to dry remainder of the wetland)	n/a	n/a	Wetland excavated but still retains wetland hydrology. Hydroperiod substantially lengthened.	Wetland converted to permanent deepwater

1. Hydrologic condition

b. Water Source (Depression)

Instructions:

1. In the office, delineate the catchment for the entire wetland that contains the AA.
2. In the office, identify indicators of altered water source with the catchment.
3. Where possible, confirm indicators of altered water source in the field.
4. In the worksheet below, record the percent cover (0-100) of each indicator of altered water source identified within the catchment. If the catchment's water source is completely unaltered, select the box labeled, "No Indicators of Altered Water Source Present". The metric is autocalculated in the worksheet.

No Indicators of Altered Water Source Present: ☐

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			
METRIC SCORE 1b			

1. Hydrologic condition

b. Water Source (Riverine)

Instructions:

1.In the office, identify the stream or the river that serves as the primary water source for the study wetland. Follow that stream or river upstream. Continue until an impoundment is identified, or until the headwaters, or upstream end of the Hydrologic Unit Code 8 (HUC8) watershed boundary is reached. Record the stream distance (in meters) to the nearest upstream impoundment in the 'Distance' field next to 'Upstream Impoundment' in the worksheet. If no impoundment is encountered, leave this field blank.

downstream confluence (i.e., stream changes name), or the downstream edge of the HUC 8 watershed is reached. Record the stream distance (in meters) to the nearest downstream impoundment in the 'Distance' field next to 'Upstream Impoundment' in the worksheet. If no impoundment is encountered, leave this field blank.

3. In the office, delineate the catchment for the entire wetland that contains the AA.
4. In the office, identify indicators of altered water source within the catchment that are listed in the worksheet.

5. Where possible, confirm indicators of altered water source in the field.

6. In the worksheet, record the percent cover (0-100) of each indicator of altered water source identified within the catchment. If the catchment's water source is completely unaltered and there are no upstream or downstream impoundments, select the box labeled, "No Indicators of Altered Water Source Present". The metric is autocalculated in the worksheet.

No Indicators of Altered Water Source Present: ☐

HUC 8 Indicators of altered water source	Distance (m)	Score Reduction
Upstream Impoundment		0
Downstream Impoundment		0

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			
METRIC SCORE 1b Alternate			

1. Hydrologic condition

c. Hydrologic Connectivity

Instructions:

1. When in the field, outline on an aerial image (a photocopy of the assessment wetland) all areas around the boundary of the entire wetland that encompasses the AA , where hydrologic connectivity has been altered. In larger wetlands, the assessment of the connectivity metric should be restricted to the portion of the wetland within 500 meters of the AA boundary.

2. Fill in on the worksheet the percentage (0-100) of the perimeter where hydrologic connectivity is impaired. If no indicators of altered connectivity are present, select the 'No Indicators of Altered Hydrologic Connectivity Present' checkbox.

No Indicators of Altered Hydrologic Connectivity Present: ☐

Indicators of altered connectivity	Perimeter Percentage	Description
Levees, Berms, Dams, Weirs		
Road Grades		
METRIC SCORE 1C		

2. Water Quality Condition

a. Excess Nutrients and Contaminants

1. When in the field, outline on an aerial image (a photocopy of the assessment wetland), all areas within the AA where nutrient cycling has been altered, matching the alteration to the indicator and the severity on the worksheet titled '2a. Nutrient Indicators'. Complete the same assessment, marking areas where chemical contaminants have been observed, matching the alteration to the indicator and the severity on the worksheet titled '2a. Contaminant Indicators'

2. Fill in on the worksheet the percentage (0-100) of the AA impacted by each nutrient stressor indicator in the appropriate severity column. Overlapping areas of nutrient indicators are only counted once for the highest severity indicator present. Complete the same steps above for contaminant indicators. Overlapping areas of chemical contaminants are only counted once for the highest severity indicator present. However, nutrient indicators may overlap chemical contaminant indicators. If no excess nutrient or chemical contaminant stressors are observed, select the 'No Indicators of Altered Nutrients or Chemical Contaminants' Checkbox.

No Indicators of Altered Nutrients or Chemical Contaminants: ☐

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				
SEVERITY WEIGHT	**0.25**	**0.5**	**0.75**	
SEVERITY WEIGHTED AREA				

Indicators of Chemical Contaminants	Minor	Moderate	Major	Indicator Description
Point source discharge (ditch or pipes from industries, etc.)				
Stormwater inputs (ditches, discharge pipes, culverts, adjacent impervious surface or railroad tracks)				
Increased salinity (e.g., salt crust)				
Industrial spills or dumping				
Oil sheen (does not include sheen from iron precipitates)				
TOTAL IMPACTED AREA				
SEVERITY WEIGHT	**0.25**	**0.5**	**0.75**	
SEVERITY WEIGHTED AREA				
METRIC SCORE 2a				

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 wastewater/sewage treatment plant
Excessive algae or Lemna sp. (Do not count this metric if algae or *Lemna* blooms are a result of evapoconcentration of nutrients as wetland is drying.)	Sparse mats or blooms of filamentous algae, *Lemna* , or cyanobacteria. Small contiguous patches are less than 200 square meters	Mats or blooms of filamentous algae, *Lemna* , or cyanobacteria may cover large areas but will not be contiguous for more than 0.1 hectares and will contain intermittent gaps where no mats or blooms or present.	Mats or blooms of filamentous algae, *Lemna* , or cyanobacteria that are contiguous for areas larger than 0.1 hectares.

2.Water Quality

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

2. Water Quality Condition

b. Sediment (Depressional)

1. When in the field, outline on an aerial image (a photocopy of the assessment wetland) all areas within the AA where sediment loading has been altered, matching the alteration to the indicator and severity from the worksheet titled '2b. Sediment Indicators'.

2. Fill in on the worksheet, the percentage (0-100) of the AA impacted by each stressor indicator in the appropriate severity column. Overlapping areas of indicators are only counted once for the highest severity indicator present. Therefore, the total percent cover of indicators cannot exceed 100. If no sedimentation stressors are observed, select the 'No Indicators of Altered Sediment Loading' checkbox.

No Indicators of Altered Sediment Loading Present: ☐

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				
SEVERITY WEIGHT	**0.25**	**0.5**	**0.75**	
SEVERITY WEIGHTED AREA				
METRIC SCORE 2b				

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. Buffer filter

Instructions:

1. In the office, draw eight evenly spaced 250 m lines or buffer transects emanating perpendicularly from the AA perimeter starting at due north on an aerial image of the wetland. For a standard AA, buffers will emerge from the AA in a starburst pattern. If the AA is directly adjacent (i.e., sharing a boundary) to permanent open water (e.g., lake, large river, or slough) at least 30 meters wide, exclude that portion of the boundary from buffer calculations. Permanent open water not directly adjacent to the AA or less than 30 meters wide should be considered buffer.

2. In the field, annotate all human impacted land-use along each of the buffer transects on an aerial photo. Record land-use as high impact, moderate impact or low impact according to the table below

3. In the buffer worksheet, record the distance when high impact land use is encountered along each transect. If no high impact land-use is encountered within 250 meters, record 250. Next, record the distance when moderate-impact land-use is encountered. If no moderate-impact land-use is found within 100 meters of the wetland, record 100. Finally, record the distance when low-impact land-use is encountered. If no low-impact land-use is found within 30 meters of the wetland, record 30. The metric score is autocalculated in the worksheet.

Land use category	**Types of Land-use Beyond Buffer**	**Required Buffer width**
High Impact	Intensive livestock (feedlot, dairy farm, pig farm) or	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
No Impact	Natural uplands, water bodies not directly adjacent to AA, wildland parks, bike trails, foot trails, horse trails, gravel/dirt roads, railroad tracks	n/a

Buffer	Distance to High Impact	Distance to Moderate Impact	Distance to Low Impact	% Intact
1				
2				
3				
4				
5				
6				
7				
8				
Metric Score 2d				

3. Biotic Condition

a. Vegetation condition

Instructions:

1. In the field, conduct a visual assessment of the percent cover (0-100) of each vegetation layer. If vegetation removal has occurred within a layer, the percent cover for that layer should be recorded as the sum of the cover observed at the time of assessment, plus the estimated cover of removed vegetation.

2. Determine the percent cover (0-100) of all indicators of altered vegetation community for each vegetation layer in the vegetation condition worksheet.

3. Record the vegetation layer and indicator covers below. The metric score is autocalculated in the worksheet.

	Vegetation Layers			
Indicators of altered vegetation community (% cover in each layer)	**Tree**	**Shrub/sapling**	**Herbaceous/ Emergent**	**Submergent/ Floating leaved**
Vegetation removal (e.g., tree harvest, brush hogging, animal trampling or rooting) †				
Native monoculture (only emergent and submergent layers)◊				
Haying or mowing				
Invasive species and crop/pasture grasses*				
Excessive grazing (only emergent and submergent) ƚ				
Herbicide impacted area				
Mechanical disturbance from structures (e.g. rip-rap, right of ways and roads etc.)				
Upland plant encroachment and/or stunted vegetation as a result of altered hydroperiod (increased or decreased) ⋮				

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

Notes:

† 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.

◊ Native monocultures occur when more than 50% of a an assessment area is dominated 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).

* 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 Department. A species is considered invasive if it is listed as a problem in border states as well. https://www.okinvasives.org/plants-database

ƚ 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.

⋮ Only includes changes to vegetation development and/or community composition as a result of hydrologic alteration and does not include normal shifts to more upland dominated plants that may occur seasonally or during periods of drought.

3. Biotic Condition

b. Habitat connectivity

Instructions:
1.In the office before visiting the wetland, delineate a 1 km buffer around the boundary of the AA on aerial imagery.

2.In the office, assign all habitat within the 1 km buffer into three categories (natural, marginal and dispersal barrier)s using the table below. Delineate a polygon around the AA that only includes connected natural habitat. Delineate a second polygon around the AA that includes connected marginal and natural habitat.

3. Print aerial imagery with habitat types marked from Step 2. Confirm land-use within the 1 km buffer in the field for all areas that are feasibly accessed, considering access, amount of time required or other logistical constraints
4. Calculate the area within the 1 km buffer created in Step 1. Calculate the area within the natural habitat polygon and the natural/marginal habitat polygons created in Step 2 and confirmed in Step 3.
5. Fill in the buffer and connected habitat areas in the Habitat Connectivity Worksheet. The metric score is autocalculated in the worksheet.

Natural Habitat (includes linear disturbances that minimally impact wildlife movement)
open water
other wetlands
natural uplands
nature or wildland parks
railroad tracks
roads not hazardous to wildlife (e.g., unpaved or farm roads)
swales and ditches
vegetated levees
open range land
Marginal Habitat
hay meadows
pine plantations
pedestrian/bike trails with near constant traffic
forests converted to rangeland
Dispersal Barriers (not included in connected habitat)
Commercial Developments
Fences that interfere with animal movements (e.g., high fences for commercial hunting)
intensive agriculture (e.g. row crops, orchards, vineyards)
dryland farming
heavily managed pasture lands (e.g., improved bermuda grass pastures)
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 Natural and Marginal Connected Habitat	
Area of Natural Connected Habitat	
Area within 1 km buffer	
METRIC SCORE 3b	

4. OKRAM Overall Condition Score - Depressional

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

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

APPENDIX B: Plant Species

Species	# of Site Occurrences
ACALYPHA OSTRYIFOLIA	2
ACALYPHA RHOMBOIDEA	2
ACALYPHA VIRGINICA	8
ACER NEGUNDO	25
ACER RUBRUM	2
ACER SACCHARINUM	8
ACER SACCHARUM	3
ACHILLEA MILLEFOLIUM	1
AILANTHUS ALTISSIMA	1
ALBIZIA JULIBRISSIN	1
ALLIUM CANADENSE	3
ALTERNANTHERA PHILOXEROIDES	1
AMARANTHUS TUBERCULATUS	4
AMBROSIA ARTEMISIIFOLIA	8
AMBROSIA PSILOSTACHYA	6
AMBROSIA TRIFIDA	22
AMMANNIA AURICULATA	1
AMMANNIA COCCINEA	7
AMORPHA FRUTICOSA	6
AMPELOPSIS CORDATA	14
ANDROPOGON GERARDII	1
ANDROPOGON VIRGINICUS	1
APIOS AMERICANA	2
APOCYNUM CANNABINUM	7
ARISAEMA DRACONTIUM	3
ARNOGLOSSUM PLANTAGINEUM	1
ARUNDINARIA GIGANTEA	4
ASCLEPIAS VIRIDIS	1
ASIMINA TRILOBA	1
ATHYRIUM FILIX-FEMINA	1
AZOLLA FILICULOIDES	1
AZOLLA MICROPHYLLA	1
BACCHARIS HALIMIFOLIA	3
BASSIA SCOPARIA	2
BERCHEMIA SCANDENS	9
BETULA NIGRA	3
BIDENS BIPINNATA	4
BIDENS CERNUA	1

Species	# of Site Occurrences
BIDENS FRONDOSA	15
BIGNONIA CAPREOLATA	2
BOEHMERIA CYLINDRICA	30
BOTHRIOCHLOA LAGUROIDES	1
BOTRYCHIUM BITERNATUM	1
BOTRYCHIUM VIRGINIANUM	1
BROMUS PUBESCENS	1
BROMUS RACEMOSUS	4
BROUSSONETIA PAPYRIFERA	1
BRUNNICHIA OVATA	4
CALLICARPA AMERICANA	2
CALYSTEGIA SEPIUM	1
CAMPSIS RADICANS	22
CARDIOSPERMUM HALICACABUM	6
CAREX AMPHIBOLA	1
CAREX ANNECTENS	3
CAREX BLANDA	11
CAREX CHEROKEENSIS	4
CAREX CRINITA	1
CAREX CRUS-CORVI	8
CAREX DEBILIS	2
CAREX FESTUCACEA	8
CAREX FRANKII	15
CAREX HYALINOLEPIS	4
CAREX INTUMESCENS	2
CAREX LEAVENWORTHII	3
CAREX LUPULIFORMIS	1
CAREX LUPULINA	5
CAREX LURIDA	2
CAREX SCOPARIA	1
CAREX SQUARROSA	1
CAREX TRIBULOIDES	5
CAREX UMBELLATA	1
CAREX VULPINOIDEA	6
CARPINUS CAROLINIANA	4
CARYA CORDIFORMIS	4
CARYA ILLINOINENSIS	24
CARYA OVATA	3
CARYA TEXANA	1

Species	# of Site Occurrences
CATALPA SPECIOSA	2
CELTIS LAEVIGATA	26
CELTIS OCCIDENTALIS	4
CENCHRUS SPINIFEX	1
CEPHALANTHUS OCCIDENTALIS	33
CERATOPHYLLUM DEMERSUM	1
CERCIS CANADENSIS	4
CHAEROPHYLLUM PROCUMBENS	1
CHAMAECRISTA FASCICULATA	2
CHAMAESYCE MACULATA	2
CHAMAESYCE MISSURICA	1
CHAMAESYCE NUTANS	2
CHAMAESYCE PROSTRATA	3
CHAMAESYCE SERPENS	1
CHASMANTHIUM LATIFOLIUM	18
CHASMANTHIUM LAXUM	1
CHENOPODIUM ALBUM	6
CHENOPODIUM BERLANDIERI	2
CHENOPODIUM SIMPLEX	1
CHENOPODIUM STANDLEYANUM	2
CHLORIS CUCULLATA	1
CICUTA MACULATA	4
CIRSIUM ALTISSIMUM	1
COCCULUS CAROLINUS	11
COMMELINA COMMUNIS	4
COMMELINA VIRGINICA	3
CONIUM MACULATUM	2
CONOCLINIUM COELESTINUM	2
CONYZA CANADENSIS	16
CORNUS DRUMMONDII	15
CORNUS FOEMINA	1
CRATAEGUS VIRIDIS	1
CROPTILON DIVARICATUM	1
CROTON LINDHEIMERIANUS	1
CROTON MONANTHOGYNUS	1
CRYPTOTAENIA CANADENSIS	6
CUSCUTA GRONOVII	1
CUSCUTA INDECORA	2
CYCLANTHERA DISSECTA	2

Species	# of Site Occurrences
CYNANCHUM LAEVE	1
CYNODON DACTYLON	11
CYPERUS ACUMINATUS	1
CYPERUS ECHINATUS	4
CYPERUS ESCULENTUS	3
CYPERUS ODORATUS	1
CYPERUS PSEUDOVEGETUS	1
CYPERUS REFLEXUS	1
CYPERUS SQUARROSUS	2
CYPERUS STRIGOSUS	4
DESMANTHUS ILLINOENSIS	6
DESMODIUM PANICULATUM	4
DIARRHENA OBOVATA	1
DICHANTHELIUM ACICULARE	1
DICHANTHELIUM ACUMINATUM	1
DICHANTHELIUM CLANDESTINUM	2
DICHANTHELIUM DICHOTOMUM	8
DICHANTHELIUM LATIFOLIUM	2
DICHANTHELIUM LAXIFLORUM	1
DICHANTHELIUM LINEARIFOLIUM	1
DICHANTHELIUM OVALE	1
DICHANTHELIUM SCOPARIUM	3
DICHANTHELIUM SPHAEROCARPON	1
DICLIPTERA BRACHIATA	2
DIGITARIA CILIARIS	2
DIGITARIA COGNATA	1
DIMORPHOCARPA CANDICANS	1
DIODIA TERES	2
DIODIA VIRGINIANA	7
DIOSCOREA POLYSTACHYA	1
DIOSCOREA VILLOSA	2
DIOSPYROS VIRGINIANA	28
DISTICHLIS SPICATA	3
DRACOPIS AMPLEXICAULIS	2
DYSPHANIA AMBROSIOIDES	1
ECHINOCHLOA CRUS-GALLI	4
ECHINOCHLOA MURICATA	3
ECHINOCYSTIS LOBATA	1
ECHINODORUS CORDIFOLIUS	4

Species	# of Site Occurrences
ECLIPTA PROSTRATA	5
ELAEAGNUS UMBELLATA	1
ELEOCHARIS OBTUSA	5
ELEOCHARIS PALUSTRIS	7
ELEPHANTOPUS CAROLINIANUS	14
ELYMUS CANADENSIS	1
ELYMUS VIRGINICUS	31
EQUISETUM HYEMALE	4
EQUISETUM LAEVIGATUM	5
ERAGROSTIS CAPILLARIS	1
ERAGROSTIS HIRSUTA	1
ERECHTITES HIERACIIFOLIUS	1
ERIGERON STRIGOSUS	4
ERIOGONUM ANNUUM	1
ERYNGIUM PROSTRATUM	1
EUPATORIUM CAPILLIFOLIUM	1
EUPATORIUM PERFOLIATUM	2
EUPATORIUM SEROTINUM	14
EUPHORBIA HEXAGONA	1
EUPHORBIA MARGINATA	2
EUTHAMIA GYMNOSPERMOIDES	1
FIMBRISTYLIS VAHLII	4
FLEISCHMANNIA INCARNATA	1
FORESTIERA ACUMINATA	7
FRANGULA CAROLINIANA	1
FRAXINUS PENNSYLVANICA	34
FROELICHIA GRACILIS	1
FUNASTRUM CYNANCHOIDES	1
GALIUM APARINE	1
GALIUM TRIFLORUM	1
GAMOCHAETA PURPUREA	2
GEUM CANADENSE	14
GLEDITSIA TRIACANTHOS	17
GLYCERIA STRIATA	1
GYMNOCLADUS DIOICUS	2
HACKELIA VIRGINIANA	1
HELENIUM AUTUMNALE	1
HELIANTHUS ANNUUS	3
HELIOTROPIUM INDICUM	7

Species	# of Site Occurrences
HETEROTHECA SUBAXILLARIS	1
HIBISCUS LAEVIS	6
HIBISCUS MOSCHEUTOS	4
HORDEUM JUBATUM	2
HORDEUM PUSILLUM	2
HYDROCOTYLE UMBELLATA	1
HYDROLEA OVATA	2
HYMENOCALLIS LIRIOSME	1
HYPERICUM MUTILUM	3
HYPERICUM PUNCTATUM	1
ILEX DECIDUA	12
ILEX OPACA	4
IMPATIENS CAPENSIS	6
IPOMOEA LACUNOSA	4
IVA ANGUSTIFOLIA	1
IVA ANNUA	8
JUGLANS NIGRA	7
JUNCUS ACUMINATUS	5
JUNCUS CORIACEUS	3
JUNCUS EFFUSUS	9
JUNCUS MARGINATUS	6
JUNCUS TORREYI	5
JUNIPERUS VIRGINIANA	10
JUSTICIA AMERICANA	1
KICKXIA ELATINE	1
KUMMEROWIA STRIATA	4
KYLLINGA ODORATA	1
LACTUCA SERRIOLA	6
LEERSIA LENTICULARIS	3
LEERSIA ORYZOIDES	12
LEERSIA VIRGINICA	5
LEMNA MINOR	3
LEMNA MINUTA	6
LEPIDIUM VIRGINICUM	1
LEPTOCHLOA FUSCA	2
LEPTOCHLOA PANICEA	4
LEPTOCHLOA PANICOIDES	1
LESPEDEZA CUNEATA	12
LEUCOSPORA MULTIFIDA	2

Species	# of Site Occurrences
LIGUSTRUM SINENSE	10
LIMNOSCIADIUM PINNATUM	1
LINDERA BENZOIN	3
LINDERNIA DUBIA	7
LIQUIDAMBAR STYRACIFLUA	5
LOLIUM PERENNE	1
LONICERA JAPONICA	15
LUDWIGIA ALTERNIFOLIA	4
LUDWIGIA DECURRENS	6
LUDWIGIA PALUSTRIS	8
LYCOPUS AMERICANUS	18
LYTHRUM ALATUM	2
MACLURA POMIFERA	7
MARSILEA VESTITA	2
MATELEA GONOCARPOS	11
MELILOTUS OFFICINALIS	2
MELOTHRIA PENDULA	6
MICROSTEGIUM VIMINEUM	1
MIKANIA SCANDENS	6
MIMULUS ALATUS	2
MOLLUGO VERTICILLATA	6
MORUS ALBA	6
MORUS RUBRA	15
NAJAS GUADALUPENSIS	2
NEKEMIAS ARBOREA	12
NEPETA CATARIA	1
NYSSA SYLVATICA	1
OENOTHERA LACINIATA	1
OPLISMENUS HIRTELLUS	1
OXALIS CORNICULATA	10
OXALIS DILLENII	2
PANICUM DICHOTOMIFLORUM	1
PANICUM RIGIDULUM	3
PANICUM VIRGATUM	4
PARIETARIA PENSYLVANICA	3
PARTHENOCISSUS QUINQUEFOLIA	28
PASPALUM DILATATUM	2
PASPALUM DISSECTUM	2
PASPALUM FLORIDANUM	1

Species	# of Site Occurrences
PASPALUM PUBIFLORUM	3
PASSIFLORA INCARNATA	5
PENTHORUM SEDOIDES	3
PERILLA FRUTESCENS	9
PHRAGMITES AUSTRALIS	2
PHRYMA LEPTOSTACHYA	1
PHYLA LANCEOLATA	21
PHYLA NODIFLORA	1
PHYSALIS ANGULATA	4
PHYSALIS HETEROPHYLLA	4
PHYSALIS PUBESCENS	1
PHYTOLACCA AMERICANA	10
PILEA PUMILA	6
PINUS TAEDA	1
PLANERA AQUATICA	3
PLANTAGO MAJOR	2
PLATANUS OCCIDENTALIS	14
PLUCHEA CAMPHORATA	5
PLUCHEA ODORATA	8
POA ARIDA	2
PODOPHYLLUM PELTATUM	1
POLANISIA DODECANDRA	1
POLYGONUM AMPHIBIUM	3
POLYGONUM HYDROPIPER	2
POLYGONUM HYDROPIPEROIDES	15
POLYGONUM LAPATHIFOLIUM	3
POLYGONUM PENSYLVANICUM	3
POLYGONUM PERSICARIA	2
POLYGONUM PUNCTATUM	2
POLYGONUM RAMOSISSIMUM	2
POLYGONUM VIRGINIANUM	9
POLYPOGON MONSPELIENSIS	2
POLYPREMUM PROCUMBENS	1
POLYSTICHUM ACROSTICHOIDES	1
POPULUS DELTOIDES	17
PORTULACA OLERACEA	2
POTAMOGETON FOLIOSUS	1
POTAMOGETON NODOSUS	2
POTENTILLA SIMPLEX	1

Species	# of Site Occurrences
PRUNUS AMERICANA	1
PRUNUS SEROTINA	3
PTILIMNIUM NUTTALLII	2
PYRRHOPAPPUS CAROLINIANUS	2
QUERCUS ALBA	5
QUERCUS FALCATA	3
QUERCUS MACROCARPA	7
QUERCUS NIGRA	6
QUERCUS PALUSTRIS	1
QUERCUS PHELLOS	3
QUERCUS RUBRA	1
QUERCUS SHUMARDII	7
QUERCUS STELLATA	1
QUERCUS VELUTINA	1
RANUNCULUS AQUATILIS	1
RANUNCULUS SCELERATUS	4
RAYJACKSONIA ANNUA	1
RHEXIA MARIANA	1
RHUS AROMATICA	1
RHUS GLABRA	1
RHYNCHOSPORA CORNICULATA	3
RHYNCHOSPORA GLOMERATA	1
RHYNCHOSPORA RECOGNITA	1
RIBES AUREUM	1
ROBINIA PSEUDOACACIA	3
RORIPPA PALUSTRIS	4
ROSA MULTIFLORA	7
ROTALA RAMOSIOR	3
RUBUS ARGUTUS	2
RUBUS FRONDOSUS	1
RUBUS TRIVIALIS	14
RUDBECKIA HIRTA	1
RUDBECKIA LACINIATA	1
RUELLIA PEDUNCULATA	2
RUMEX ALTISSIMUS	2
RUMEX CONGLOMERATUS	1
RUMEX CRISPUS	11
RUMEX PULCHER	1
RUMEX VERTICILLATUS	5

Species	# of Site Occurrences
SACCHARUM RAVENNAE	2
SAGITTARIA LATIFOLIA	6
SALIX INTERIOR	3
SALIX NIGRA	26
SALSOLA TRAGUS	1
SALVIA LYRATA	2
SAMBUCUS NIGRA	1
SAMOLUS EBRACTEATUS	1
SAMOLUS VALERANDI	2
SANICULA CANADENSIS	1
SANICULA ODORATA	10
SAPINDUS SAPONARIA	9
SASSAFRAS ALBIDUM	1
SAURURUS CERNUUS	4
SCHEDONORUS ARUNDINACEUS	3
SCHIZACHYRIUM SCOPARIUM	2
SCHOENOPLECTUS PUNGENS	4
SCHOENOPLECTUS TABERNAEMONTANI	1
SCIRPUS ATROVIRENS	1
SCIRPUS CYPERINUS	1
SCIRPUS PENDULUS	1
SCUTELLARIA LATERIFLORA	7
SENNA MARILANDICA	1
SESBANIA HERBACEA	6
SETARIA FABERI	1
SETARIA PARVIFLORA	6
SETARIA VIRIDIS	1
SIDA SPINOSA	4
SIDEROXYLON LANUGINOSUM	15
SILPHIUM PERFOLIATUM	1
SMILAX BONA-NOX	27
SMILAX ROTUNDIFOLIA	15
SMILAX TAMNOIDES	7
SOLANUM CAROLINENSE	7
SOLANUM ELAEAGNIFOLIUM	1
SOLANUM PHYSALIFOLIUM	1
SOLANUM PTYCANTHUM	1
SOLANUM ROSTRATUM	1
SOLIDAGO CANADENSIS	2

Species	# of Site Occurrences
SOLIDAGO GIGANTEA	4
SONCHUS ASPER	1
SORGHASTRUM NUTANS	1
SORGHUM HALEPENSE	11
SPERMACOCE GLABRA	3
SPHENOPHOLIS INTERMEDIA	1
SPIRODELA POLYRRHIZA	3
SPOROBOLUS TEXANUS	3
STACHYS TENUIFOLIA	2
STEINCHISMA HIANS	1
STELLARIA MEDIA	1
SYMPHORICARPOS ORBICULATUS	15
SYMPHYOTRICHUM DIVARICATUM	1
SYMPHYOTRICHUM SUBULATUM	4
TAMARIX CHINENSIS	5
TAXODIUM DISTICHUM	2
TEUCRIUM CANADENSE	23
TORILIS ARVENSIS	3
TOXICODENDRON RADICANS	26
TRACHELOSPERMUM DIFFORME	3
TRAGIA BETONICIFOLIA	1
TRAGOPOGON PRATENSIS	1
TREPOCARPUS AETHUSAE	2
TRIDENS STRICTUS	2
TRIFOLIUM CAMPESTRE	1
TRIFOLIUM PRATENSE	2
TRIFOLIUM REPENS	2
TRIODANIS PERFOLIATA	1
TYPHA ANGUSTIFOLIA	2
TYPHA DOMINGENSIS	4
TYPHA LATIFOLIA	1
ULMUS ALATA	7
ULMUS AMERICANA	35
ULMUS CRASSIFOLIA	1
ULMUS PUMILA	2
ULMUS RUBRA	5
URTICA DIOICA	5
VACCINIUM ARBOREUM	1
VERBENA BRACTEATA	1

Species	# of Site Occurrences
VERBENA BRASILIENSIS	1
VERBENA URTICIFOLIA	8
VERBENA XUTHA	1
VERBESINA ALTERNIFOLIA	7
VERBESINA VIRGINICA	3
VERNONIA BALDWINII	2
VERONICA ANAGALLIS-AQUATICA	3
VERONICA PEREGRINA	1
VIBURNUM RUFIDULUM	1
VIOLA PUBESCENS	1
VIOLA SORORIA	10
VITIS CINEREA	10
VITIS MUSTANGENSIS	1
VITIS PALMATA	1
VITIS RIPARIA	9
VITIS ROTUNDIFOLIA	2
VITIS RUPESTRIS	1
VITIS VULPINA	12
WOODWARDIA AREOLATA	1
XANTHIUM STRUMARIUM	13
ZIZANIOPSIS MILIACEA	4

APPENDIX C: Water Data

Site ID	Date	Conductivity (µS/cm)	pH	Ammonia (mg/L)	TP (mg/L)	TKN (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Sulfate (mg/L)
NWCAOK-10234	6/16/2022	668.00	7.75	0.94	0.06	1.58	22.90	0.10	0.41	4.93
NWCAOK-10258	7/20/2022	176.00	7.93	<0.015	0.06	0.61	11.00	<0.02	<0.02	17.70
NWCAOK-10335	6/29/2022	513.00	7.83	0.02	0.10	0.90	22.00	<0.02	<0.02	20.20
NWCAOK-10344	6/9/2022	81.00	6.94	0.24	0.18	1.49	<0.5	0.02	<0.02	<0.02
NWCAOK-10355	8/1/2022	823.00	7.92	0.06	0.24	1.23	113.00	<0.02	<0.02	42.90
NWCAOK-10368	7/13/2022	1520.00	8.13	0.02	0.05	0.43	234.00	0.34	<0.04	215.00
NWCAOK-10371	8/22/2022	1060.00	8.10	<0.015	0.11	0.88	163.00	<0.02	<0.02	86.20