Method Development to Incorporate Wetland Resources in Watershed Planning Efforts in Oklahoma: Final Report

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1. INTRODUCTION

In the 1980's it was estimated that 67% of the pre-colonial wetlands in Oklahoma were lost to human activities (Dahl 1990). As a result, wetland restoration is a crucial component in the state's wetland program, to reestablish the important hydrologic, biogeochemical and biotic functions that wetlands provide. Developing a systematic method to identify and prioritize potential restoration sites is advantageous because wetland restoration is conducted through multiple programs, managed by multiple agencies. Maintaining a publicly available dataset of potentially restorable sites, based on such a method should improve coordination among agencies and aid in the selection of restoration sites that can restore multiple functions to the landscape. For example, in a 303(d) listed impaired watershed, wetland mitigation required under section 404 of the Clean Water Act can be targeted to meet the needs of the permittee, with the added benefit of improving the water quality of the downstream receiving water.

This document, presents an assessment protocol for identifying and prioritizing potential wetland restoration sites, as well as the results from the initial application of the protocol in three watersheds in Oklahoma. The Restorable Wetland Identification Protocol (RWIP) consists of three components:

1. identification of potential historic wetland areas,
2. organization of sites based on likelihood of restoration success, and
3. prioritization of restoration sites for improvement of downstream receiving water quality.

Several other states have developed protocols that served as the groundwork for this effort in Oklahoma (Donnelly 2001, Hatch and Bernthal 2008, Robertson 2012). The identification of restorable wetlands in Wyoming, Wisconsin and Minnesota has been based on the assumption that areas designated as hydric in the Natural Resource Conservation Service (NRCS) web soil survey but unmapped by the National Wetlands Inventory (NWI) represent the most likely areas where wetlands have been lost (Donnelly 2001, Hatch and Bernthal 2008, Robertson 2012). We used the same approach for Oklahoma. The potential historic wetland area was further organized by topography (Robertson 2012), land-use (Hatch and Bernthal 2008) and hydrology to identify those locations where restoration is more likely to be successful.

The identification of potential historic wetland areas, and further organization of sites based on likelihood of restoration success provides a dataset of restoration sites that is useable for multiple restoration mechanisms and programs. To promote nexus of wetland resource management with water quality programs, these sites were further prioritized based on their ability to improve the water quality of downstream receiving water bodies based on basin size, watershed size and surrounding land-use. Traditionally, in Oklahoma, wetland restoration has been treated separately from the management of lakes and river systems. However, inclusion of wetland restoration in an integrated watershed based approach promotes a more holistic surface-water management model, while increasing the potential to reduce non-point source pollution and improve water quality in 303(d) listed waterbodies.

2. METHODS

2.1 Project background

Identification and prioritization of potentially restorable wetlands was conducted in geographic information systems (GIS) through spatial and attribute queries of pre-existing datasets. The first step was to identify locations where wetlands have likely been lost. The potential historic extent of wetlands in the state was determined by selecting the poorly drained soils from the NRCS Soil Survey Geographic Database (SSURGO). The current extent of wetlands is represented by the National Wetlands Inventory (NWI). NWI represents the most complete and recent mapping effort for wetlands in Oklahoma. NWI maps for Oklahoma were completed in the 1980's and subsequently digitized. Areas where poorly drained are mapped and no NWI polygons are mapped were included in the list of potentially restorable wetlands. Mapped poorly drained soils that intersect NWI polygons represent current wetlands and were not added to the list of restorable wetlands. The exception is that poorly drained soils that intersect NWI polygons with a farmed or "f" designation were included in the list of potentially restorable wetlands, because they represent historic wetland area that has been lost to, or impacted by farming. Poorly drained soils that intersect Wetland Reserve Program (WRP) polygons were also removed from the list of potentially restorable wetlands. These WRP wetlands have been restored after the creation of NWI.

All potential historic wetlands were further filtered with topographic land-use, and hydrologic information. Only poorly drained soils occurring in basins were considered potentially restorable (Robertson 2012). Digital elevation models (DEMs) with a 10 meter resolution were used to identify basins using the “fill sink” tool in ARC GIS (ESRI, 380 New York St., Redlands, CA 92373). Additionally, poorly drained soils that now occur in high intensity or mid intensity urban areas, water, or barren land-cover were deemed non-restorable (Hatch and Bernthal 2008). Restoration of historic wetlands now covered with impervious surface or deep water was considered infeasible and cost-prohibitive. Poorly drained soils intersecting urban land-use with low development intensity and developed open spaces were retained in the restorable wetland dataset, flagged and visually inspected to determine feasibility of restoration. Developed open space and low intensity land-uses are areas with less than 50% impervious surfaces. Land-use/land-cover data was obtained from the 2006 US Geologic Survey (USGS) National Land Cover Dataset (NLCD). Furthermore, because wetland restoration sites require a water source, we filtered the list of potential restoration locations to ensure that sufficient flow was available to restore wetland hydrology. This was accomplished by creating a flow accumulation layer from DEMs. The degree of flow required was manually determined for each watershed based on best professional judgement of regional climate and drainage patterns. GIS layers used for this study are presented in Table 1.

Finally, the completed potential restorable wetlands layer (i.e. poorly drained soil layer filtered with NWI, topography, land-use and flow data) was attributed based on the potential for a site to improve the water quality of downstream receiving waters. Each potentially restorable polygon was attributed with (1) wetland size, (2) watershed to wetland ratio, and (3) percent crop and urban land-use within the restorable wetland watershed. These attributes provide information on the degree to which a restored wetland can improve water quality to downstream receiving waterbodies. Larger sites can capture and treat more runoff than smaller sites. Furthermore, sites that are relatively large compared to their watersheds have a greater probability of receiving and treating runoff prior to outflow. Sites surrounded by human-altered land-uses are more likely to receive runoff in need of treatment (e.g. high quantities of nutrients and sediment). Each attribute (e.g. wetland size) is scored 1 to 4. Scores for all three attributes are summed to provide a total possible score ranging from 3 (least likely to improve water quality) to 12 (most likely to improve water quality). For each attribute the scores (i.e. 1 through 4) are determined based on the quartiles for all the potentially restorable sites within the study watershed. For example the largest 25% of sites within a specific watershed are given a score of 4 for the wetland size attribute, while the smallest 25% receive a score of 1. For each potentially restorable wetland all attributes are also scored on a statewide scale with pre-determined thresholds set for the entirety of Oklahoma. Calculating the attribute on watershed and statewide scales allows for the comparison of sites to determine optimal restoration locations both within a watershed and for all of Oklahoma. The attributed dataset is stored as a GIS shapefile and will be made publicly available through the Wetland Program website. A list of restorable wetlands, including their location, will be added to the Watershed Based Plans for which the RWIP was applied. A more detailed description of the data processing steps to identify and attribute potentially restorable wetlands can be found in the next section "GIS Processing Steps".

This protocol is designed to be applied within watershed boundaries. The pilot application of the RWIP was conducted in three priority watersheds, Horse Creek, Lake Thunderbird, and North Canadian River between Canton and Bethany. See figure 1.

2.2 GIS processing steps

Identify Restorable Wetlands

1. Create a poorly drained soils layer representing the potential historic extent of wetlands in the study area
    a. **Query** dominant drainage class (extremely poorly drained, poorly drained, somewhat poorly drained)
    b. **Export** to a new shapefile
    c. **Clip** to study area
2. Create National Wetlands Inventory layer representing the current extent of wetlands in the study area
    a. **Clip** to study area
3. Create basins layer
    a. **Fill sinks** on DEM
    b. **Convert** filled DEMs to slope.
    c. **Reclassify** the slope maps to separate 0 values from all other slope values
    d. **Vectorize** reclassed slope maps
    e. **Delete** non-zero slope polygons
    f. **Clip** to watershed

    g. **Dissolve** adjacent polygons

4. Create urban land-use layer
    a. **Reclassify** NLCD
        i. 1: Barren, water, developed medium intensity, developed high intensity
        ii. 2: All other cover
    b. Vectorize
    c. **Clip** to area
    d. **Delete** all polygons with a reclassified land-use class of "2"
5. **Union** NWI (layer 2) and poorly drained soils (layer 1)
    a. **Remove** polygons where NWI wetlands currently exist
6. **Union** poorly drained soils with no NWI wetlands (layer 5) with basins (layer 3)
    a. **Remove** basins not on poorly drained soils
    b. **Remove** poorly drained soils not in basins
7. **Union** poorly drained basins (layer 6) with developed land-use (layer 4)
    a. **Remove** developed land
8. Clean up poorly drained basins not developed (layer 7)
    a. **Dissolve** adjacent polygons
    b. **Multipart to singlepart** polygons
    c. Calculate area
    d. **Remove** polygons <0.5 acres
9. Limit polygons by flow
    a. **Fill Sinks** on DEM
    b. **Create flow direction** raster from filled DEM
    c. **Create flow accumulation** raster from flow direction (layer 9b)
    d. Manually determine flow threshold based on climate and drainage patterns (for North Canadian 500 pixel flow or >12.7 acres drainage area was used)
    e. Using **map algebra** on flow accumulation raster (layer 9c) [con(layer>=threshold,1)] create a raster of only pixels above determined threshold
    f. Use **stream to feature** with processed flow accumulation raster (layer 9e) and flow direction raster (layer 9b)
    g. **Select** poorly drained basins (layer 8d) that intersect stream feature (layer 9f)
    h. **Export** selected features to new shapefile called restorable wetlands

<u>Prioritize Restorable Wetlands</u>

10. **Create** Watershed layer
    a. **Create** new point shapefile called pourpoints
    b. **Create** pourpoints at downstream intersection of restorable wetlands layer (layer 9h) and the flow accumulation raster (layer 9c)

c. **Split** pourpoint layer by attributes to create a new shapefile for pourpoints at each restorable basin
d. **Snap** pour point layers (layers 10c) to flow accumulation raster (layer 9c)
e. Use **watershed tool** on snapped pour points (layer 10d) and flow direction layer (layer 9b)
f. **Vectorize** watershed rasters (layer 10e)
g. **Merge** watershed vectors (layer 10f)
h. **Dissolve** merged layer by ID
i. **Calculate area** for each watershed

11. **Create** crop and urban land-use layer
    a. **Reclassify** NLCD into two classes
        i. 1: All crops and urban land covers
        ii. 2: All others
    b. In Geospatial modeling run **isectpolyrst** and determine percent urban/crop in each watershed
    c. **Join** watershed to restorable basins (layer 9h) by attribute ID
    d. **Export** layer to new shapefile called prioritized restorable wetlands
12. **Calculate** attributes for prioritized restorable wetlands
    a. **Calculate** watershed ratio by creating new field called "wat_rat" and using field calculator (watershed area/restorable basin area)
    b. **Calculate** scores using standard statewide scoring applied for all watersheds in Oklahoma
        i. **Create** four new fields for restorable basin size score (bas_sc), watershed ratio score (rat_sc), land-use score (lu_score) and site score (site_sc)
        ii. Restorable basin score is calculated as follows:
            1. 1: <2.5 acres
            2. 2: 2.5-4.99 acres
            3. 3: 5.0-9.99 acres
            4. 4: >=10.0 acres
        iii. Watershed Ratio score is calculated as follows
            1. 1: >50:1
            2. 2: 50:1-20.01:1
            3. 3: 20:1-10.01:1
            4. 4: <=10:1
        iv. Land-use score is calculated as follows
            1. 1: <25% urban and crop
            2. 2: 25%-49.99% urban and crop
            3. 3: 50-74.99% urban and crop
            4. 4: >=75% urban and crop

   v. **Sum** restorable basin (bas_sc), watershed ratio (rat_sc) and land-use scores (lu_sc) in the site score (site_sc) field
c. **Calculate** scores specific for each watershed
   i. **Create** four new fields for watershed specific restorable basin size score (ws_bas_sc), watershed specific watershed ratio score (ws_rat_sc), watershed specific land-use score (ws_lu_sc) and watershed specific site score (ws_site_sc)
   ii. "Ws_bas_sc", "ws_rat_sc" and "ws_lu_sc" are calculated using quartiles.
      1. First quartile =1
      2. Second quartile=2
      3. Third quartile=3
      4. Fourth quartile=4
   iii. **Sum** "ws_bas_sc", "ws_rat_sc" and "ws_lu_sc" in the watershed specific site score (ws_site_sc) field.

Note: Many of the steps outlined above can be accomplished in batch processor and/or model builder to expedite data processing.

2.3 Field verification

Field verification was conducted in the North Canadian River watershed to assess the accuracy of the RWIP. Sites for verification were prioritized based on their potential to improve water quality (scoring methods outlined in Section 2.2), with the highest scoring sites visited first. An attempt was made to secure landowner permission to visit the highest ranking 20 sites. Permission was secured and we field verified 16 of the 20 sites. Field verification consisted of an assessment of the sites' current condition as well as the potential to restore wetland hydrology and biota. The field form completed at each site can be found in Appendix A. Sites were considered candidates for restoration if (1) they were not currently wetlands or if they exhibited wetland characteristics degraded through human alteration and (2) wetland hydrology could be restored through restoration either through remediation of previous impact or modification of current conditions.

3. RESULTS

The RWIP identified 232 potential wetland restoration sites in the North Canadian River Watershed from Canton to Bethany. Of those sites, 44 received scores of 10 or above for potential to improve water quality within the watershed (Table 2). Figure 2 displays one of the highest rated potential restoration sites identified through the RWIP with obvious signs of hydrological alteration from ditching. Sites with scores of 10 or above were selected for field verification. Of the 16 sites visited, 5 individual sites were deemed potential restoration candidates and 2 sites were joined as one potential restoration site. Figure 3 includes photographs of a potential restoration candidate site. The remainder of the sites that were field verified were deemed unsuitable for restoration due to one or combinations of three reasons; (1)

absence of suitable soils or topography capabable of ponding water, (2) current presence of a wetland and/or (3) inability to restore wetland hydrology due to insufficient local water source. In the Lake Thunderbird and Horse Creek Watersheds the RWIP identified 28 and 26 sites respectively.

4. DISCUSSION AND CONCLUSIONS

The RWIP correctly identified about 38-43% of the field verified sites as potential locations for restoration. While overall accuracy is low, as a screening-level tool, the protocol is extremely useful for identifying those locations most likely to provide successful restoration opportunities. Furthermore, the incorrectly identified sites in this study were primarily a result of the accuracy limitations and age of the GIS layers utilized to identify restoration locations. We are currently evaluating potential changes to the protocol that may improve accuracy. In a concurrent project, we are mapping historic wetlands in two watersheds in Oklahoma. Having a dataset of historic wetland locations will provide an additional dataset for validation of RWIP output. Further analysis of those historic datasets may yield insights into adjustments to the spatial and attribute queries used to identify potential restoration locations.

Now that a protocol for identifying potential restoration locations has been established, RWIP can be relatively rapidly applied to additional watersheds across the state. The goal is to apply the protocol throughout the state and have a complete list of potentially restorable wetlands across all of Oklahoma. Ultimately, all locations with restoration potential and landowner interest can be listed through the Wetland Registry and made available on the Wetland Program Website at www.ok.gov/wetlands. The Wetland Registry is a searchable database of restoration opportunities throughout the state. Combining statewide RWIP application with the Wetland Registry will help streamline wetland restoration in the state by identifying potential restoration locations, prioritizing those locations based on the level of functions restored (e.g. water quality improvement) and providing those locations to the public in an easily searchable format.

5. FIGURES AND TABLES

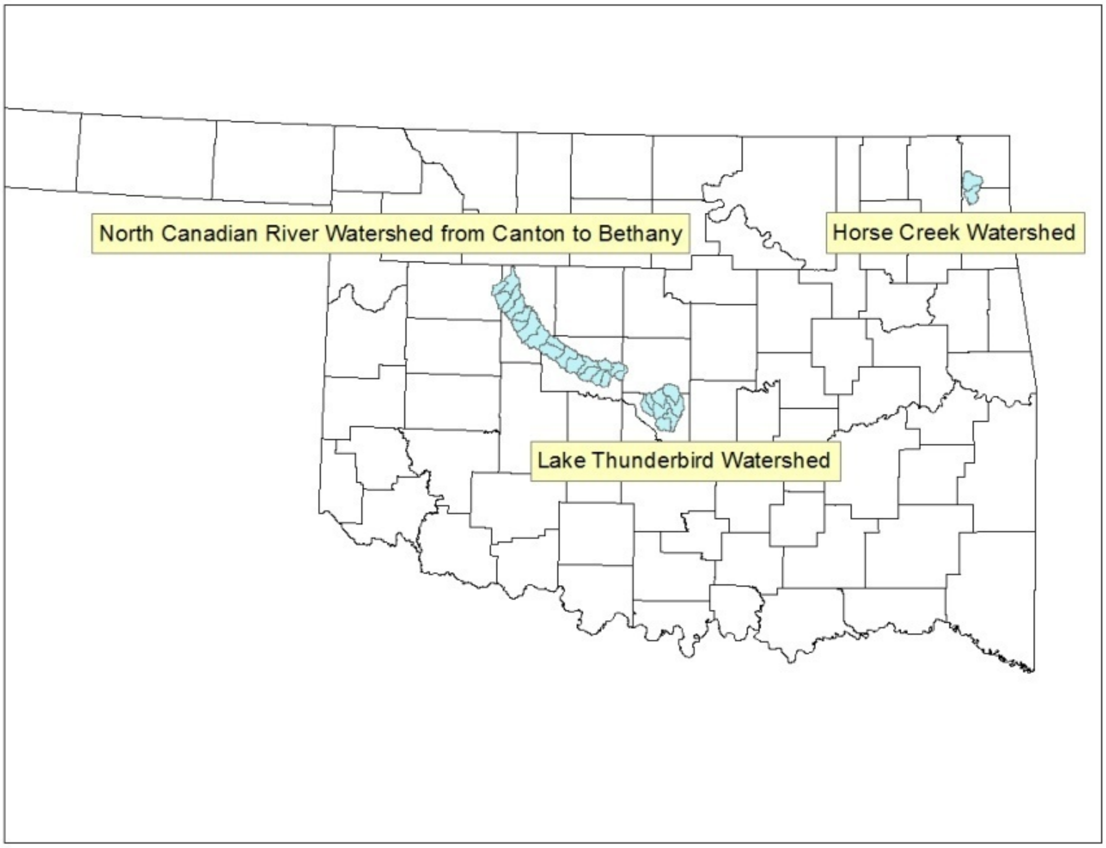

Figure 1: Priority watersheds for application of Restorable Wetland Identification Protocol

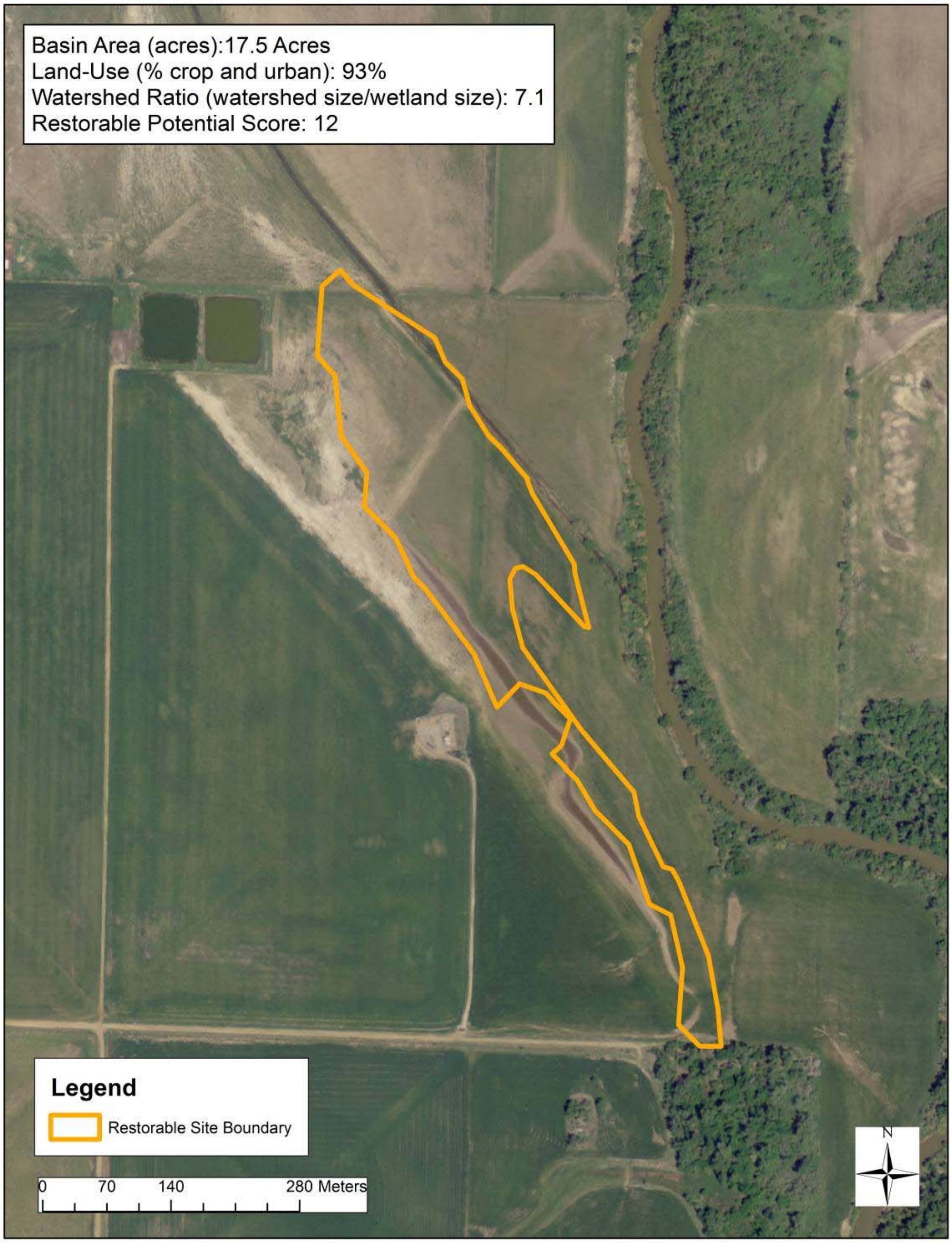

Figure 2: Potential restorable site identified through the Restorable Wetland Identification Protocol with evidence of hydrologic alteration

(a)

(b)

Figure 3: Field verified potential restoration site in the North Canadian Watershed. (a) Drainage that removes water from floodplain (b) Floodplain currently in agricultural production

Table 1. GIS layers used in Restorable Wetland Identification Protocol

Layer	Agency	Data Type	Minimum Mapping Unit (vector) or Pixel size (raster)	Accuracy
Soil Survey Geographic Database (SSURGO)	NRCS	Vector	0.4 to 4 hectares	Meets United States National Map Accuracy Standards
National Agricultural Imagery Program (NAIP).	USDA	Raster	1 meter	Horizontal accuracy within 6 meters of photo-identifiable ground control points.
National Wetlands Inventory (NWI)	USFWS	Vector	0.2 hectares	Feature accuracy of 98% and attribute accuracy of 85%.
Digital Elevation Models (DEM)	USGS	Raster	10 meters	Accuracy of vertical elevation data has a root mean squared error of 2.44 meters.
Topographic maps	USGS	Raster	2.44 meters	Meets United States National Map Accuracy Standards.
National Land Cover Dataset (NLCD) 2006	USGS	Raster	30 meters	NLCD 2001 has a Level 1 class accuracy of 85.3% and a Level 2 class accuracy of 78.7%
Hydrologic Unit layer(HUC)	USGS	Vector	12-digit hydrologic units	12.2 meter horizontal accuracy from a well defined point at a scale of 1:24,000

Table 2: Potentially restorable wetlands by watershed

		Potential to Improve Water Quality Score		
Watershed	Restorable Sites	12 through 10	9 through 7	6 through 3
North Canadian	232	44	108	80
Thunderbird	28	6	10	12
Horse Creek	26	6	10	10

6. LITERATURE CITED

Dahl, T.E. 1990. Wetlands Losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C.

Donnelly, C. 2001. Evaluating the Potential of Using a GIS for a Drained Wetlands Inventory: 7-County Metropolitan Area, Minnesota.Minnesota Board of Water and Soil Resources.

Hatch, B and Bernthal T. 2008.Mapping Potentially Restorable Wetlands in the Rock River Basin. Final Report to the US Environmental Protection Agency, Region V. Wetland Grant #CD 96544501-0.

Robertson, A. 2012.Mapping Potentially Restorable Wetlands in Wyoming.Presentation at the Association of State Wetland Managers State/Tribal/Federal Coordination Meeting.

Appendix A: Field Verification Form

Restorable Wetland Identification Protocol Field Form

OFFICE DATA

Site ID: ________________ County:_______________ Watershed:______________________

Lat/Long :_______________________ Datum: __________________________________

Recorder(s): __________________________________ Date: ________________________

Access Notes: ____

Landowner Name:____

Basin Size Score: ____

Watershed Ratio Score: ____

Land-use Score: ____

Overall Score: ____

FIELD DATA

Hydrology

Water Depth at the time of field visit: ________________

Indicators

Standing water___ Water Marks ___

Buttressed Trunks ___ Water Stained Leaves___

Water Carried Debris ___ Saturated Soils ___

Floating Mat ___ Shallow Roots ___

Bare Areas ___ Oxidized Rhizospheres ___

Other Indicators of Hydrology____

Water Source(s):____

Hydrodynamics:____

Landscape Position:____

Hydrogeomorphic Classification:____

Surrounding Land Use: ____

Plant Community

Tree % cover: _________ Shrub % cover: _________ Herb % cover: _________

Floating % cover: _________ Submergent % cover: _________

Common Plant *Spp.*: ____
____

Less Common Plant *Spp.*: ____
____

Rare or Unique Plant *Spp.*: ____
____

Soils/Substrate

Soil Map Unit Name: ____

Taxonomy: ____

Drainage Class: _________________________ Hydric List (National)_____ Other_____

Soil Survey Publication Date: ______________

Munsell: hue value chroma

_______________________depth________ Texture _______________

_______________________depth________ Texture _______________

_______________________depth________ Texture _______________

_______________________depth________ Texture _______________

Hydric Soil Indicators

Histosol_____ Concretions_______ Histic Epipedon _______

High Organic Content____ Sulfuric Odor_____ Organic Streaking______

Aquic Moisture Regime___ Reducing Conditions___ Gleyed_____

Other Remarks____

____

Disturbance

Hydrological Alterations (e.g. fill, drainage, ditches, channels, impoundment, dredging, roads): ____

Substrate Disturbance (e.g. farming, tilling, sedimentation, excavation, filling, development): ____

Vegetation Disturbance (e.g. farming, tilling, sedimentation, removal, tree harvest, fire): ____

Other: ____

SITE EVALUATION

Site is currently a wetland?

Hydrology:____

Soils: ____

Biota: ____

Other Notes: ____

Site has potential to be restored or improved?

Source of degradation can be remedied: ______________________________

Soils have potential to hold water: ______________________________

Site can receive sufficient water: ______________________________

Potential to restore plant community:______________________________

Landowner is interested in restoration: ____________________________