Montana Wetland Ecological and Vulnerability Prioritization

Prepared for:
Montana Department of Environmental Quality

Prepared by:
Jamul Hahn, Claudine Tobalske, Melissa Hart and Linda Vance

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Any errors or omissions in the report are entirely the responsibility of the authors.

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INTRODUCTION

Wetlands provide multiple biological and economic benefits such as plant and wildlife habitat, flood attenuation, groundwater recharge, and improvements to water quality. Despite these benefits, wetlands continue to experience pressures from multiple uses including urban, exurban, and agricultural development, as well as resource extraction. This project is intended to further our understanding of where these pressures are greatest in Montana and how that relates to opportunities for conservation from an ecological perspective.

Toward that end, we developed a Wetland Prioritization Database (an ArcGIS geodatabase) for the state of Montana. We collated and created relevant spatial and tabular data to build the geodatabase; carried out analyses to support ecological prioritization and risk/vulnerability assessments, and worked with collaborators to determine a "roll-up" method to serve as the basis for final statewide prioritization and vulnerability mapping.

Final products include:

1) The ***mt_wetrip_prioritization_2016*** geodatabase, which has a) a feature class identifying all prioritized areas; b) a feature class of wetlands and riparian areas with high risk and vulnerability; c) all feature classes used in the analysis; and d) metadata, including a data dictionary (Appendix A).
2) This report, which details methods used in data creation, collation, and analysis.

The project is divided into four tasks:

1) Create and collate relevant spatial and tabular data to support the ecological prioritization analysis.
2) Complete analyses to support ecological prioritization.
3) Complete analyses to support risk and vulnerability assessment.
4) Integrate analyses into final statewide prioritization and vulnerability assessments.

All tasks were completed using ArcGIS software (versions 10.2.2-10.3.1; ESRI 2014). We discuss each task below.

TASK 1, CREATING AND COLLATING SUPPORTING DATA

For Task 1, we collated and created relevant spatial and tabular data to build an ArcGIS geodatabase to support the ecological prioritization and risk/vulnerability assessments.

The geodatabase consists of three main feature datasets, "Ancillary" "Analysis" and "Wetlands." The "Ancillary" feature dataset contains the most current ancillary datasets including land ownership and administration, land cover and land use, hydrologic units, and ecoregions. The "Analysis" feature dataset includes all of the layers used for the various analyses. The "Wetlands" feature dataset includes the feature class *mt_wetrip2016* which is the core feature dataset of wetlands and riparian areas to be used as the basis of the analysis.

The *mt_wetrip2016* feature class represents the extent, type, and approximate location of wetlands, riparian areas, and deep-water habitats in Montana. Data sources for this dataset include all MTNHP-mapped wetlands. These data delineate the areal extent of wetlands and deep-water habitats as defined by Cowardin et al. (2013) and riparian areas as defined by the U.S. Fish and Wildlife Service (2009) and the Montana Natural Heritage Program. These data were manually digitized at a scale of 1:4,500 or 1:5,000 from orthorectified digital color-infrared aerial imagery collected during the summers of 2005, 2006, 2009, 2011, and 2013 by the National Agricultural Imagery Program (NAIP). These data have undergone three rounds of internal quality assurance/quality control procedures performed by the MTNHP. For areas not yet mapped by the MTNHP, data sources include historic mapping from the National Wetlands Inventory (NWI); riparian ecological systems and riparian forests/woodlands from the MSDI Land cover 2015 dataset; and National Hydrography Dataset (NHD) swamp and marsh features.

The tabular data contained in the geodatabase include several Cowardin and NWI tables that have definitions and descriptions for the wetland and riparian types, NWI and Cowardin codes, water regimes and special modifiers. Tables were also created for the county codes, conservation easement holders, public land owners, Indian reservations, ecoregions (levels 1-4) and hydrologic units (levels 4-6).

Appendix A provides a data dictionary for this and all other tasks.

TASK 2, ECOLOGICAL PRIORITIZATION

For Task 2, we next performed spatial analyses and scoring for each wetland in the Wetland Prioritization Database (ArcGIS geodatabase). Here, we summarize the work completed, the rationale behind the different components of the analyses, and our recommendations for use in prioritization.

As described for Task 1, the *Wetlands* feature dataset includes the feature class *mt_wetrip201*6 which is the core feature dataset of wetlands and riparian areas to be used as the basis of the analysis. The *Layers* feature dataset, also a product of Task 1, contains the most current ancillary datasets including land ownership and administration, land cover and land use, hydrologic units, and ecoregions.

Task 2 involved six separate analyses, described below.

Task 2a – Rarity Scores

Task definition: "Rarity, based on whether the wetland is a type (e.g., PFDB) that is uncommon (<5% of all wetlands) statewide or within its Level 3 ecoregion (<2% of all wetlands). Scores will range from 1 to 5, with 1 representing the most common wetlands and 5 representing wetlands that are rare on a statewide scale."

- **Rationale**: The less widespread a community is, the more likely it is to be lost. Also, an uncommon wetland provides uncommon habitat, and therefore may have unique biodiversity significance.
- **Metrics**:
    - <100 examples statewide.
    - <2% in HUC or Level 4 ecoregion.
    - <2% statewide numbers or acres.
    - In 90th percentile of size.
- **Scoring**: 0 to 5 (5=most rare).

In conservation planning, the rarity of a species or a community is a key determinant of its conservation status (Rodrigues et al. 2006). The less widespread a species or community is, the more likely it is to be lost. In Task 2a, we begin with the assumption that an uncommon wetland provides uncommon habitat, and therefore may have unique biodiversity significance. In this we follow the InVEST model (Tallis et al. 2011), a decision support tool for evaluating natural capital and environmental services. Like the InVEST model, we propose that rarer habitats be given higher priority, because conservation opportunities are limited, and because the rarity poses the threat that unique species and processes associated with these rare habitats may be lost if the habitats themselves are lost.

The challenge posed by evaluating rarity in a GIS is that the apparent rarity of a mapped habitat may be an artifact of the mapping itself. To avoid this, we first analyzed the existing wetland mapping to find unique attributes and modifiers. Some of these were the result of typos (e.g., an inadvertent lower case attribute modifier); some were coding conventions that carried over from the early NWI but are no longer in use; some were combinations of attributes (e.g., "PEM/PAB") that appear to have signaled extreme variability in a given wetland or difficulty in visual interpretation, again in the early NWI. All attributes that resulted from typos, differences in mapping conventions or uncertainty were recoded before beginning the analysis.

The final Rarity scores are stored in the feature class *wetrip2016_prioritization* in the *Wetlands* feature dataset, the *rarity_cp_wetrip_2016* feature class in the *Analysis* feature dataset and the *rarity_2016* database table. The feature class *rare_scores* in the Analysis feature dataset has all of the calculation scores found in Table 1.

We trimmed the database further to exclude all features with special modifiers that indicated human alteration: d (partially drained/ditched), f (farmed), h (diked/impounded), and x (excavated). This left us with a set of 1,183,155 features. To assess rarity within the remaining wetland and riparian polygons, a series of calculations was then made using the ArcGIS summary statistics tool to determine mean, minimum, maximum, and total acres for each wetland type (as defined in the ATTRIBUTE field) across the state and by 4th code hydrologic unit (HUC4) and Level 4 ecoregion. (Calculations by Level 3 ecoregion also were initially made, but proved less useful than the Level 4 calculations and thus weren't pursued.) From these numbers, we calculated the percentage of the state/HUC4/Level 4 ecoregion occupied by each type twice: once based on number of features, and once based on acreage of features. All of these calculations were repeated for each of the four wetland systems (lacustrine, palustrine, riverine, riparian), as defined by the SYSTEM field. Because there is a well-established species-area relationship for bats, herptiles, birds, invertebrates and non-flying mammals (Watling and Donnelly 2006), and because Montana wetlands are often small, we also identified uncommonly large wetlands as part of the rarity calculations, using R to capture the 90th percentile of acreages for each wetland type.

These percentages were then used to assign a series of rarity scores to each wetland/riparian feature:

1) 5 points for wetland types with <100 occurrences statewide. These wetland types were then removed from subsequent analysis (i.e., none of these wetlands were scored on any additional metrics);
2) 1 point for wetland types representing <2% of the statewide total, based on number of features;
3) 1 point for wetland types representing <2% of the statewide total, based on acreage;
4) 1 point for features with acreages $\geq$ 90th percentile for their wetland type;
5) 1 point for wetland types representing <2% of the total wetlands in a HUC4, based on number of features;
6) 1 point for wetland types representing <2% of the total wetlands in a Level 4 ecoregion, based on number of features.

From these scores, a composite score (RARESCORE2) was calculated. Wetland/riparian features with <100 occurrences statewide immediately received the maximum score of 5; even though they may also have qualified for some or all of the 1-point scores, their score was held at 5. For all other features, the other 5 scores were added together to derive RARESCORE2.

In all, 201,614 wetland/riparian features mapped by MTNHP or historic NWI were assigned overall rarity scores (RARESCORE2 $\geq$ 1). Additional wetland/riparian features extracted from the NHD or 2015 Montana land cover datasets also were assigned rarity scores on an intermediate basis, but are not included in final analyses.

Table 1. Fields created during the assignment of rarity scores. Note that all of these numeric attributes have been assigned 0s instead of NULL values (e.g., for RARELT100, features that did not receive a score of 5 instead were scored as 0). Final rarity scores are stored in RARESCORE2, but should be used only if INCL_RARITY_RANK = 1.

RARELT100	Assigned 5 for wetland types with less than 100 occurrences statewide (n = 1039).
RARELT2NUM	Assigned 1 for wetland types with <2% by number statewide, as calculated by system (lacustrine, palustrine, riverine, riparian).
RARELT2AC	Assigned 1 for wetland types with <2% by acreage statewide, as calculated by system.
RARE90PCTL	Assigned 1 for individual wetlands with acreage greater than or equal to the 90th percentile calculated for their type.
RARELT2HUC	Assigned 1 for wetland types with <2% by number by 4th code HUC, as calculated by system.
RARELT2L4	Assigned 1 for wetland types with <2% by number by Level 4 Ecoregion, as calculated by system.
RARESCORE	RARELT100 + RARELT2NUM + RARELT2AC + RARE90PCTL + RARELT2HUC + RARELT2L4 (range 0-10).
RARESCORE2	Calculated by selecting for RARELT100 = 5 and then calculating RARESCORE2 = 5, switching the selected set, and calculating RARESCORE2 = RARESCORE. This second attribute was necessary to zero out the scores for the other attributes for those wetlands that had already scored 5 based on their fewer than 100 occurrences statewide.
ATTRIBHUC8	Concatenation of the ATTRIBUTE and HUC8 fields, used as a unique identifier to populate the RARELT2HUC field.
ATTRIBL4ECO	Concatenation of the ATTRIBUTE and L4_Ecoreg fields, used as a unique identifier to populate the RARELT2L4 field.
RARELT2NUMALL	Assigned 1 for wetland types with <2% by number statewide, calculated for all systems together.
RARELT2ACALL	Assigned 1 for wetland types with <2% by acreage statewide, calculated for all systems together.
VAL90PCTL	Cutoff value for the 90th percentile for each wetland type.
INCL_RARITY_RANK	Assigned 1 if wetland is to be included in rarity ranking calculations, 0 if not. Note: values were calculated for other attributes even if INCL_RARITY_RANK = 0, so those are available for use if desired.
INCL_RARITY_PCT	Assigned 1 if wetland was used to calculate percentages determining rarity (features with special modifiers d, f, h, and x were excluded from that analysis)

Task 2b – Landscape Complex

Task definition: "Part of a landscape complex determined using the wetland density mapping and kernel sampling methods described in Copeland et al 2009 ("A geospatial assessment of the distribution, condition and vulnerability of Wyoming's wetlands"), modified to include riparian corridors and riverine wetlands. Wetlands that are not part of a landscape complex will receive a score of 0, while wetlands that are part of a landscape complex will be given a score of 5."

- **Rationale**: Wetland "hotspots" constitute a unique habitat type for birds and amphibians.
- **Ecological function**: Complexes provide habitat for a diversity of wildlife species
- **Metric**: >5 wetlands per hectare (ha).
- **Scoring**: 0 if <5 wetlands/ha; 3 if 5-9 wetlands/ha; 5 if >10 wetlands/ha.

Wetland complexes can be defined in two ways: first, clusters of wetlands with diverse permanence and varying areal extent embedded within a vegetated upland habitat (Naugle et al. 2001, Johnson et al. 2010), or second, multiple wetland types, contiguous to each other or to a river/stream feature, forming a single, diverse and connected habitat area (Rucker and Schrauzer 2010). Because these two types of complexes are hydrologically distinct and offer different habitat types, in the execution of this task, we separated them, identified the first type of complex as a Landscape Complex, and the second type as a Wetland Mosaic. Some wetlands met the criteria for both Landscape Complex and Wetland Mosaic.

The scores for the landscape complexes are stored in the feature class *ldnscp_cmplx_cp_wetrip_2016* in the *Analysis* feature dataset and the *ldnscp_cmplx_2016* database table. The final landscape complex score is stored in the *wetrip2016_prioritization* feature class in the *Wetlands* feature dataset.

To identify landscape complexes, the wetland polygons were first converted to points (*ldnscp_cmplx_cp_wetrip_2016*). Then, all lacustrine, intermittent riverine and riparian features were excluded from the dataset. This left us with 973,471 features. To perform the density analysis, we used the ArcGIS kernel density tool that is part of the Spatial Analyst/Density toolset found in ArcToolbox. The following parameters were used: Input layer mt_wetrip2016_centerpoints; Population Field none; Output Cell Size 1 hectare; Area Units square kilometers; and a Search Radius of 5km (Copeland, 2010). The resulting output float raster was then converted to integer raster using the 3D Analyst Tools/Raster Math/Float tool found in ArcToolbox (Copeland, 2010). The complexes were scored in two ways. The highest density areas (wetland densities greater than 10/hectare) were given a score of 5. The next highest density areas (wetland densities with 5-9/hectare) were given a score of 3. All other wetlands received a score of 0.

- ***LndscpCmplxScore:*** scored 0, 3 or 5. If the wetland/riparian feature was part of a landscape complex with greater than 10 features/hectare, it received a score of 5. If the wetland/riparian feature was part of a landscape complex with 5-9 features/hectare, it received a score of 3. If the wetland/riparian feature was not part of a landscape complex, it received a score of 0.

Task 2c – Wetland Mosaics

Task Definition: "Part of a wetland mosaic where 5 or more individual wetland/riparian areas intermingled as indicated by sharing a boundary line. Wetlands that are not part of a wetland mosaic will receive a score of 0, while wetlands that are part of a wetland mosaic will be given a score of 1 to 5, reflecting the diversity and physical extent of the mosaic."

- **Rationale**: Contiguous wetlands with varying vegetation and water regimes provide multilayered habitat options.
- **Metric**: Number and types of wetlands in a mosaic.
- **Scoring**: 0-15 depending on size of mosaic, count of types, and diversity of types.

The scores for the wetland mosaics are stored in the feature class *wetlnd_mosaics_cp_wetrip_2016* in the *Analysis* feature dataset and the *wetlnd_mosaics_2016 database table.* The final wetland mosaic score is stored in the *wetrip2016_prioritization* feature class in the *Wetlands* feature dataset.

To identify the wetland mosaics, we first used the ArcGIS buffer tool to buffer the mt_wetrip2016 feature class boundaries by 10 meters. We chose 10 meters as the buffer distance to ensure features such as roads didn't limit the complexes. Next we made several attempts to aggregate the buffered features (as a complete dataset then by County) with the ArcGIS dissolve tool, but the lack of physical memory available would not allow it to completely process as the dataset is simply too large. To work around this limitation, we then used ArcGIS Model Builder to: select the features by 4^{th} code HUC basins; buffer each feature by 10 m; and aggregate the features with the ArcGIS Dissolve tool. After completing this process for all 101 basins, the features were loaded into a single feature class called *mosaics*. We then attempted to aggregate the *mosaics* feature class with the ArcGIS dissolve tool, but again, the lack of physical memory available would not allow it. To work around this limitation, we then simplified the polygons to reduce the vertex count for each polygon using the ArcGIS simplify tool. The following parameters were used: Point Remove simplification algorithm; 10 m maximum allowable offset; No Check handling topological errors. The simplified polygons were then successfully aggregated using the Dissolve tool to create the *mosaics* feature class (*WetlandMosaics* feature dataset).

In an effort to produce more consistent classifications of functionally interconnected mosaics, several post processing tasks were executed. We started by creating three different levels for the mosaics: terrene, riverine, and floodplain. Terrene mosaics were determined to be clusters of wetlands not joined by any lower or upper perennial riverine features (R2AB; R2UB; R3AB; R3UB) or large reservoir features. Riverine mosaics occur on or around lower or upper perennial riverine features. Floodplain mosaics occur on the floodplains of large rivers. To determine the three levels, we started by removing the larger river features (R2AB; R2UB; R3AB; R3UB) and large reservoir features (L1 - Canyon Ferry reservoir; Flathead Lake; Fort Peck reservoir; Lake Koocanusa; Hungry Horse reservoir; Holter Lake) from the mosaics using the ArcGIS erase tool. To determine the floodplain mosaics, we buffered the *Large_River* feature class by 500 meters and selected all mosaics with their centroid inside the buffer. The riverine mosaics were determined by selecting all mosaics intersecting larger river features (R2AB; R2UB; R3AB; R3UB) with their centroids outside of the 500m *Large_River* feature class buffer.

The terrene mosaics were the remaining mosaics. Some manual selection and editing was necessary to separate several riverine mosaics from adjacent floodplain mosaics.

All *mosaics* with less than 5 wetland/riparian features were selected and these immediately received a final *WetlndMosaic_Score* of 0. For the remaining wetland/riparian features, we scored the *mosaics* based on three criteria: the size of the wetland mosaic; the number of wetlands intersecting the mosaic; and the diversity of the wetland mosaic.

To store results, four fields were added to the *wetlnd_mosaic_cp_wetrip_2016* feature class:

- ***WMSizeScore:*** (*Tables 2, 5 & 8*) scored from 1 to 5 and was determined using the *wetland_complex* ACRES field. Natural breaks were used to determine the classifications.
- ***WMCntScore***:(*Tables 3, 6 & 9*) scored from 1 to 5 and was determined by performing a spatial join using the *mosaic* and the *wetlnd_mosaics_cp_wetrip_2016* feature classes and creating a COUNT field to get the number of wetlands intersecting each wetland mosaic. Natural breaks were used to determine the classifications.
- ***WMDiversScore***: (*Tables 4, 7 & 10*) scored from 1 to 5 and was calculated using the ArcGIS summary statistics tool to determine the number of different types of wetlands in the wetland mosaic. We used the COUNT and ATTRIBUTE fields as the summary fields. Natural breaks were used to determine the classifications.
- ***WMFnlScore:*** the final score from 1 to 15 and was determined by adding the *WM_SizeScore, WM_CountScore,* and *WM_DiversityScore* fields.

Table 2. Terrene mosaic sizes by score.

Terrene_Mosaic_Size_Score	**Size of mosaic in acres**
1	0.7-210.5
2	210.6-666.0
3	666.1-1525.3
4	1525.4-2759.9
5	2759.9-14712

Table 3. Number of wetlands in terrene mosaics by score.

Terrene_Mosaic_Count_Score	**Number of wetlands in mosaic**
1	5-82
2	83-269
3	270-590
4	591-1083
5	1084-1515

Table 4. Wetland diversity for terrene mosaics by score.

Terrene_Mosaic_Diversity_Score	**Wetland Diversity**
1	1-5
2	6-9
3	10-14
4	15-21
5	22-32

Table 5. Riverine mosaic sizes by score.

Riverine_Mosaic_Size_Score	Size of mosaic in acres
1	0.9-895
2	895.5-2555
3	2555.1-6555.5
4	6555.6-14091.7
5	14091.8-23387.9

Table 6. Number of wetlands in riverine mosaics by score.

Riverine_Mosaic_Count_Score	Number of wetlands in mosaic
1	5-183
2	184-515
3	516-1010
4	1011-1656
5	1657-3458

Table 7. Wetland diversity for riverine mosaics by score.

Riverine_Mosaic_Diversity_Score	Wetland Diversity
1	1-5
2	6-9
3	10-14
4	15-21
5	22-32

Table 8. Floodplain mosaic sizes by score.

Floodplain_Mosaic_Size_Score	Size of mosaic in acres
1	0.83-776.6
2	776.7-2495.6
3	2495.7-6976.6
4	6976.7-14947.8
5	1497.9-23387.9

Table 9. Number of wetlands in floodplain mosaics by score.

Floodplain_Mosaic_Count_Score	Number of wetlands in mosaic
1	5-106
2	107-275
3	276-563
4	564-1043
5	1044-2170

Table 10. Wetland diversity for floodplain mosaics by score.

Floodplain_ Mosaic_Diversity_Score	Number of wetlands in mosaic
1	1-7
2	8-12
3	13-18
4	19-28
5	29-41

Task 2d – Habitat Significance

Task Definition: "Habitat significance, evaluated by intersecting buffered wetlands with BIRDPOD and SOC records and models created by the Prairie Potholes Joint Venture and other groups identified by the collaborators. As possible and available, we will include predictive models for SOC distribution based on an intersection between point observations and wetland characteristics. Scores will range from to 10 with 1 representing the lowest habitat significance and 10 representing the highest habitat significance, as indicated by the number and diversity of species using the habitat."

- **Rationale**: Other indicators are surrogates for habitat; this is a direct measure of observations
- **Metrics**: Number of species observations within the wetland buffer (100 or 400 meters) over 25 years.
- **Scoring**: 0-7. The metric is worth 0-5 based on natural breaks in data. Additional points were given for direct (2 points) and indirect (1 point) evidence of breeding. Final score is additive.

The challenges of evaluating habitat significance based on opportunistic observations have been extensively documented and discussed (e.g., Harvey 2009, Franklin 2010, Porzig et al. 2014 and sources cited therein). MTNHP has the advantage of data compiled over a long time frame from both structured surveys and opportunistic observations; indeed, we have over 1.5 million animal observations in our databases. Furthermore, within Montana, wetlands themselves have been singled out as potential sites for both targeted and probabilistic surveys. However, because of access limitations, most surveyed wetlands fall on public lands, meaning that species observations will tend to be concentrated by ownership. Consequently, while the results of this task yield a certain amount of information about habitat suitability, the use of other indicators (e.g., habitat complexity, landscape integrity) as surrogates for biodiversity may be preferred over direct observation records. We were unable to make meaningful links between predictive models built on ecological system mapping at 1:100,000 and individual wetland polygons. First, ecological systems do not crosswalk easily to NWI attributes; in almost all cases, the relationship is both one-to-many and many-to-one, and varies by geography. Second, because the classification of wetland ecological systems is generally less accurate than the classification of upland systems due to the small size of wetlands, predictive distribution models for wetland-dependent species are themselves subject to inaccuracy. While it would be possible to link specific species to specific NWI classifications within their range based on observation data, doing so is beyond the scope of this task. Consequently, all we were able to do here was intersect and assess observation data from our databases.

The scores for the habitat significance are stored in the feature class *hab_sig_wetrip_2016* in the *Analysis* feature dataset and the *hab_sig_2016* database table. The final habitat significance scores are stored in the *wetrip2016_prioritization* feature class in the *Wetlands* feature dataset.

First we broke the wetland and riparian features into three classes:

- Class 1: non-riverine wetlands smaller or equal to 2 acres (N = 1,092,362 or 78.29% of total)
- Class 2: non-riverine wetlands larger than 2 acres (N = 229,192 or 16.36% of total)
- Class 3: riverine wetlands (N = 74,627 or 5.35% of total).

Classes 2 and 3 were processed together since it was the same method (buffer polygons by 100m). The ArcGIS buffer tool was used to create the buffers. We used 400 meter centroid buffers on Class 1 wetlands because many bird monitoring efforts detect birds out to 400 meters from the observer and some wetland birds may be defending territories a short way out from the wetland. We used 100 meter buffers on Class 2 and 3 wetlands because observers are likely to be traveling to larger water bodies specifically to detect birds on those larger water bodies.

Next we queried and created a selection for all of the wetland associated species of concern and plant species of concern (SOC/PSOC) with a temporal filter of 25 years and a location certainty of less than 400 meters from the BIRDBOD/SOC database (13,219 species observation records; 187 species). The 25-year temporal filter was chosen to adequately capture most species that may be present only under certain conditions. Observations beyond 400 meters were decided to be unsuitable for determining wetland habitat significance. We then intersected the SOC/PSOC records with the three buffered wetland and riparian feature classes using the ArcGIS intersect and summary statistics tools to determine the number and diversity of species using the habitat. The wetlands were then parsed into three categories for separate scoring: Lacustrine, Palustrine and Riparian, and Riverine. Points were also given to the wetland if the SOC database records indicated direct or indirect evidence of breeding.

To store results, three fields were added to the *hab_sig_wetrip_2016* feature class:
- ***HabSigCnt_Score***: (*Tables 5, 6 & 7*): total number of observation records from BIRDBOD/SOC database within buffer, scored 1 to 5. Natural breaks were used to determine the classifications.
- ***DrctBreed*** and ***IndrctBreed***: direct evidence of breeding (2 points) or indirect evidence (1 point).
- ***HabSigFnl_Score***: is the final habitat significance score determined by adding the *HabSigCnt_Score* and *DrctBreed* and *IndrctBreed* fields to get a score from 1 to 7.

Table 11. Number of species observations within buffers for lacustrine wetlands by score.

Lacustrine_HabSig_CountScore	**Number of observations within buffer**
1	1-5
2	6-13
3	14-25
4	26-38
5	39-59

Table 12. Number of species observations within buffers for palustrine and riparian wetlands by score.

Palustrine_Rp_HabSig_CountScore	Number of observations within buffer
1	1-2
2	3-4
3	5-8
4	9-12
5	13-19

Table 13. Number of species observations within buffers for riverine wetlands by score.

Riverine_HabSig_CountScore	Number of observations within buffer
1	1-14
2	15-38
3	39-67
4	68-157
5	158-221

Task 2e – Headwater Status

Task Definition: "Headwater status, using methods developed by Vance and Tobalske 2015. Wetland in headwater areas will be given a score of 5, while wetlands outside those areas will be given a score of 0."

- **Rationale**: Headwater wetlands provide unique and critical water supply functions in an arid state.
- **Metric**: Wetland is in a headwater area OR a headwater position.
- **Scoring**: Binary, 0 or 1.

The headwater status scores are stored in the feature class *hdwtr_status_cp_wetrip_2016* in the *Analysis* feature dataset and the *hdwtr_status_2016* database table. The final headwater status scores are stored in the *wetrip2016_prioritization* feature class in the *Wetlands* feature dataset.

Headwater status was determined using methods developed by Vance et al. (2015) for the Missouri Headwaters basin (3rd code HUC) to the other fifteen 3rd code HUC basins of Montana (Figure 1). Wetlands in headwater areas were given a score of 5, while wetlands outside those areas were given a score of 0. We extended the analysis into adjacent states or Canada if the 3rd code HUC overlapped their boundaries.

Within each 3rd code HUC we worked at the 5th code HUC watershed level, except for portions of Canada where 5th code HUC boundaries were not available; there we used 4th code HUCs instead (Figure 1).

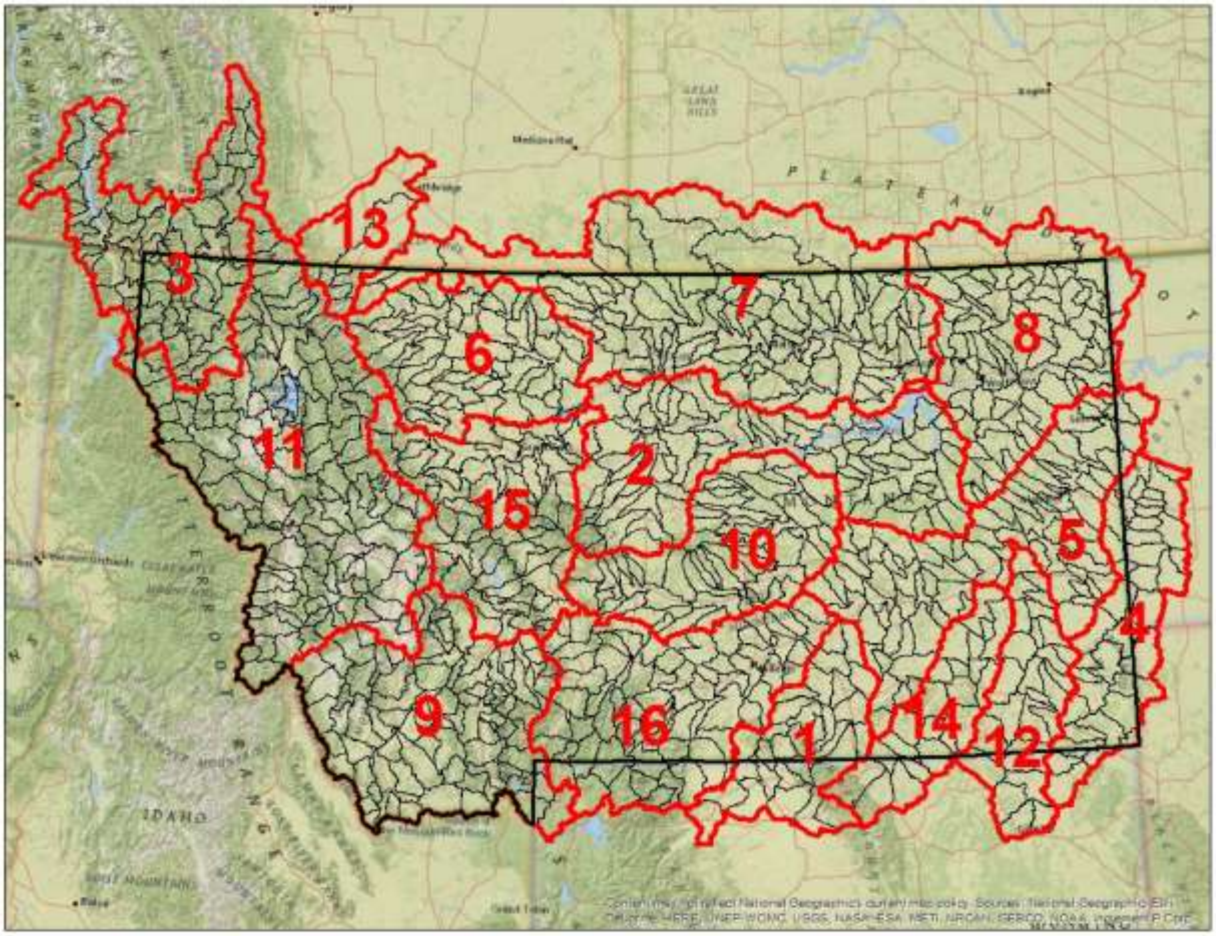

Figure 1. The sixteen third code HUC basins of Montana: 1) Big Horn, 2) Fort Peck Lake, 3) Kootenai, 4) Little Missouri, 5) Lower Yellowstone, 6) Marias, 7) Milk, 8) Missouri-Poplar, 9) Missouri Headwaters, 10) Musselshell, 11) Pend'Oreille, 12) Powder, 13) Saskatchewan, 14) Tongue, 15) Upper Missouri, and 16) Upper Yellowstone. The fourth and fifth code HUC watersheds are shown in black.

For each 5^{th} (or 4^{th}) code watershed we calculated a Topographic Position Index (TPI) from the 30m NED Digital Elevation Model (DEM) using Jenness' Land Facet Corridor Designer Revision 1.2.884 (Jenness 2013). We used the following parameters: Standardized Elevation; Circle Neighborhood Shape; and a radius of 100 cells (3000m). In addition, we generated a 10-class landform model based on the parameters defined by Manis (2002), originally programmed as an Arc/Info aml script by John Lowry, and converted to an ArcGIS script in ModelBuilder. We also computed a slope layer in degrees from the DEM.

The continuous TPI output was converted to a categorical output as follows:

a. If TPI < 1 and slope < 12 degrees, classify pixel as Gentle Slopes;
b. If TPI < 1 and slope >= 12 degrees, classify pixel as Steep slopes;
c. If TPI >= 1, classify pixel as Mountaintops and Ridges;
d. If Landform = "Valley flats, Toe slopes, bottoms and swales" or "Nearly level plateaus and terraces", reclassify Gentle Slopes to Valley bottoms/Plateaus.

We chose 12 degrees, or 21.3 %, as the cutoff for "steep" based on an examination of slope values for Palustrine Wetlands in the Missouri Headwaters basin. Although Palustrine Wetlands are sometimes found in steeply sloping valleys, they are more characteristic of toe slopes, flats and gentle slopes. The value of 12 degrees represents the mean slope value plus two standard deviations for all Palustrine Wetlands in the Missouri Headwater's basin; examination of slope values for Palustrine Wetlands in other 3rd code HUCs did not show a significant divergence from this value so it was applied statewide. After building individual rasters for each 5th code HUC in the 3rd HUC basin, we mosaicked them into a single raster (Figure 2).

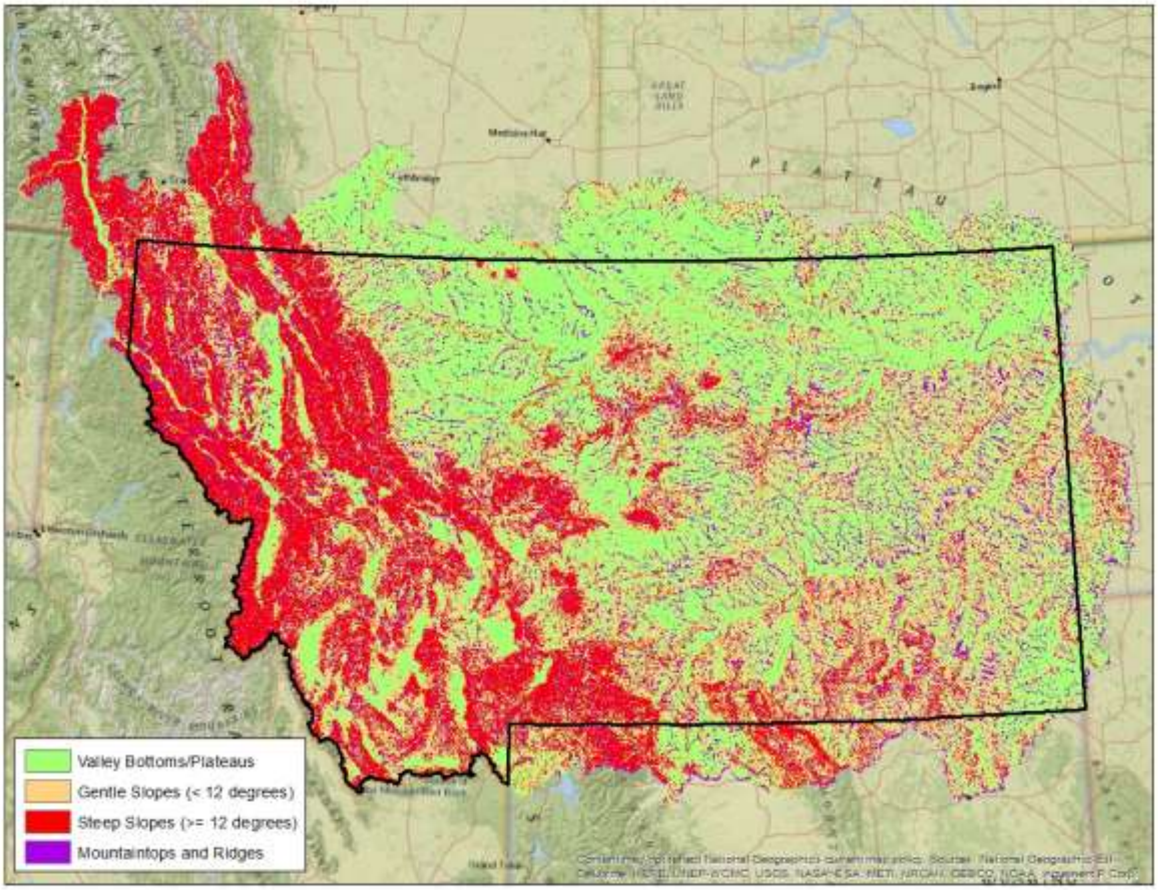

Figure 2. Modified Topographic Position Index.

For each 3rd code HUC, we also developed a cumulative elevation over area curve. Similar to the hypsometric curve used in hydrology (Vivoni et al. 2008), a graphical depiction of the distribution of elevation "bins" helps identify the landscape profile of a basin. We used Spatial Analyst in ArcGIS to reclassify the 30m DEM into 100 equal elevation bins. The attribute table, containing a Value field (1-100) for each bin, and a Count field indicating the number of pixels in that bin, was exported to Excel. We calculated cumulative area by adding each cell to the sum of previous cells, and identified the elevation bin that split the dataset in half (Table 14). Based on this elevation we created a mask: all portions of 5th code HUCs above the elevation cutoff and all portions lying below.

The status of Headwater Wetland was assigned to all wetlands whose centroid fell in the upper elevation half of a 5th code HUC (*Headwater1* field), as well as to those wetlands whose centroid fell in the lower elevation half AND were located on Steep Slopes or Mountaintops and Ridges (*Headwater2* field) (Figure 3).

Table 14. Elevation cutoff values used to split each 3rd HUC watershed into upper and lower portions.

Third code HUC watershed	**Elevation cutoff (m)**
Big Horn	1305
Fort Peck Lake	943
Kootenai	1433
Little Missouri	962
Lower Yellowstone	860
Marias	1117
Milk	883
Missouri-Poplar	738
Missouri Headwaters	2070
Musselshell	1136
Pend’Oreille	1565
Powder	1036
Saskatchewan	1203
Tongue	1142
Upper Missouri	1453
Upper Yellowstone	1555

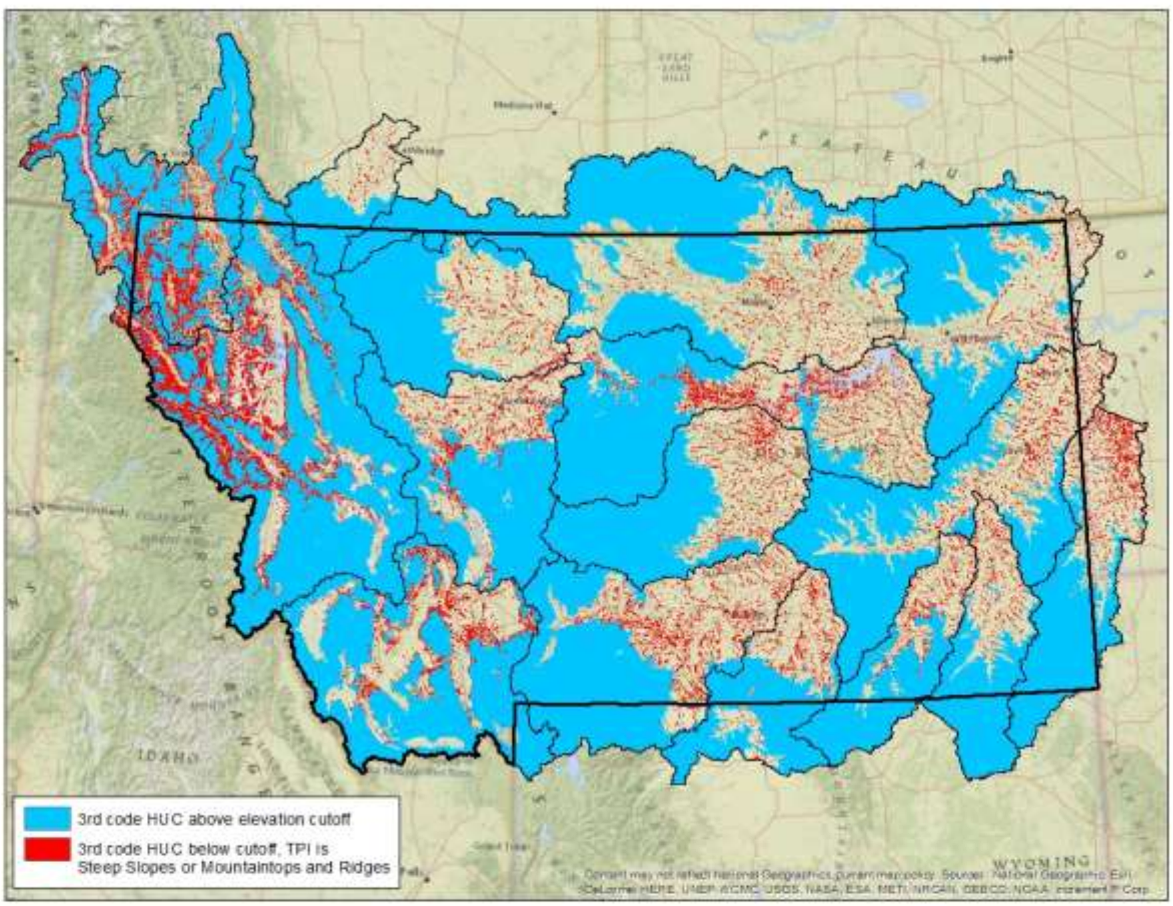

Figure 3. Headwater Wetland status was assigned to all wetlands whose centroid fell in the blue or red areas.

Task 2f – Landscape Context

Task definition: "Landscape context, using the Human Disturbance Index developed by the MTNHP. Wetland and riparian polygons will be buffered by 300 m and their HDI values calculated. Wetlands and riparian areas whose values fall within the lowest 5% of all HDI scores will be given a score of 5."

- **Definition**: Wetlands in the least disturbed landscapes statewide.
- **Rationale**: Wetlands in least disturbed habitat are more likely to approach baseline or reference condition.
- **Metric**: Value for MT Human Disturbance Index.
- **Scoring**: Binary, 1 for HDI<200, 0 for HDI 200-4,114.

While disturbance is a structuring factor in community composition and resilience, as such may promote greater biodiversity in an ecosystem (Supp and Ernest 2014), unfragmented landscapes where disturbances are primarily caused by natural forces (e.g., wind, floods, fire, etc.) are generally seen as conservation targets (Bennett and Sanders 2010). Furthermore, wetlands in relatively undisturbed landscapes are generally thought to reflect the processes and community dynamics that are "typical" of wetlands of their type, and as such be useful as reference standard or sentinel sites (Batzer and Sharitz 2014). This metric selects wetlands occurring in landscapes which appear to be the least disturbed by human activities in the 2014 Montana Landcover Land Use dataset, as interpreted by the Montana Human Disturbance Index (HDI) tool (MTNHP 2014; Figure 4). In the threat section, we use the HDI to assign risk based on human disturbance. In that case, assigned scores represent the degree of threat, from very small to very large. Here, the metric has simple binary scoring, with a score of 1 assigned to wetlands in these relatively undisturbed landscapes, and no score assigned to all others.

Landscape context was evaluated using the statewide Human Disturbance Index (HDI) developed by the MTNHP (2014). First, all 1,395,294 wetland and riparian polygons were buffered by 300 m. Next, the HDI raster was resampled from 30 m to 10 m; although the true data resolution remains at 30 m, resampling to 10 m allows HDI values to be calculated for many very small wetland/riparian polygons that would be lost at a 30 m cell size. The HDI raster also was converted from ArcGIS to ERDAS IMAGINE format to facilitate use of Geospatial Modeling Environment (GME; Beyer 2012) in calculating means. Mean HDI values for each buffered wetland/riparian polygon were then calculated using the *isectpolyrst* command in GME. Command parameters were set to specify the HDI raster as continuous (rather than thematic) data and to allow calculation of means for features along the state border that overlap only partially with HDI data.

The landscape context scores are stored in the *ldnscp_cntxt_cp_wetrip_2016* feature class in the *Analysis* feature dataset and the *ldnscp_cntxt_2016* database table. Final scores are stored in the *wetrip2016_prioritization* feature class in the *Wetlands* feature dataset.

- ***HDIMN***: mean HDI values for the 300 m buffer around each wetland/riparian feature. (If the mean is negative, the feature is completely outside the state HDI raster.)
- ***HDI_SCORE/ LndscpCntxtScore****:* 1/0. Scored 1 for wetlands with HDI means of 0 (200,003 features) and for the next 5% of scores greater than 0 (58,596 features). The 5% cutoff value for HDI means was 1.7746. Note that we originally intended to assign

scores of 5 to these wetlands, but switched to scores of 1 to allow for weighting in later steps.

Future users should note that the ArcGIS *Zonal Statistics as Table* tool, which would seem ideally suited for a calculation of this sort, will not work, at least as of ArcGIS 10.2. *Zonal Statistics as Table* does not handle overlapping polygons, and many of the 300 m buffers on wetland/riparian polygons do overlap. A supplemental tool, *Zonal Statistics as Table 2*, was released by ESRI to circumvent this problem, but we were unable to get it to work on our dataset. These tools seem to be programmed in such a way that they process data more slowly with each iteration; they never came close to processing the million-plus wetland/riparian polygons. GME offers a much better alternative at this time.

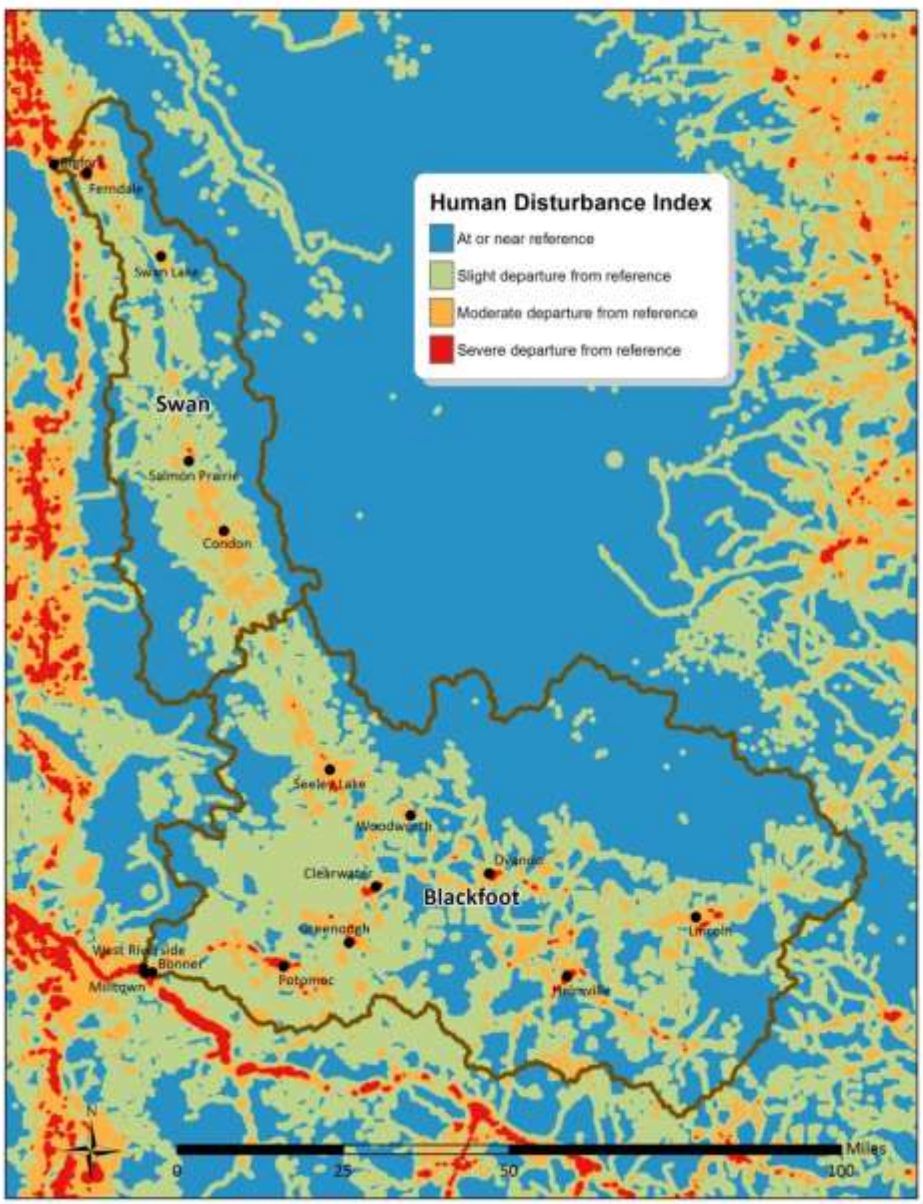

Figure 4. An example of the human disturbance index (HDI) data mapped for the Blackfoot and Swan basins.

TASK 3, RISK AND VULNERABILITY ASSESSMENT

We analyzed six measures of risk and vulnerability, assigning each wetland a score of 1 to 5 (1 = lowest and 5 = highest vulnerability) for each measure. These measures of risk are:

1. Urban development using methods following Theobald 2005 ("Landscape patterns of exurban growth in the USA from 1980 to 2020");
2. Rural land use/land cover change based on models in Sleeter et al. 2012 ("Scenarios of land use and land cover change in the conterminous United States");
3. Oil and gas potential using methods described in Copeland et al. 2009 ("Mapping oil and gas development in the US Intermountain West and estimating impact to species"), supplemented by data available from MTFWP;
4. Level 1 condition, based on the Human Disturbance Index score (MTNHP 2014) at the centroid of the polygon and across the 300m buffer;
5. Climate change, modifying the approach by Byrd et al. 2015 ("Quantifying climate change mitigation potential in the United States Great Plains wetlands for three greenhouse gas emission scenarios") to highlight wetland complexes with high vulnerability;
6. Cropland conversion risk, using the model developed by the Montana Field Office of The Nature Conservancy.

Exurban development

For this measure of risk, we originally proposed to identify areas of potential exurban growth using the methods presented in Theobald (2005), where exurban growth is defined as "low-density residential development scattered outside of suburbs and cities, and as commercial strip development along roads outside cities" (Daniels 1999). In their 2010 assessment on the distribution, condition and vulnerability of Wyoming's wetlands, Copeland et al. also identified exurban subdivision as a potential threat to wetlands. They estimated vulnerability to rural residential development using Theobald's model forecasting development potential in the United States for 2030 and calculated the percent of exurban development cells within in wetland complex.

We contacted both Dr. Theobald and Ms. Copeland and were directed to the projected housing density data from ICLUS/SERGoM model, downloadable from the EPA website: http://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryID=205305

Metadata are available here:
https://edg.epa.gov/metadata/rest/document?id=%7B2E953B8B-08A1-42FB-BAAB-1D5C246BC7D0%7D&xsl=metadata_to_html_full

"The Integrated Climate and Land-Use Scenarios (ICLUS) project developed land-use outputs that are based on a downscaled version of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) social, economic, and demographic storylines. ICLUS outputs are derived from a pair of models. A demographic model generates county-level population estimates that are distributed by a spatial allocation model (SERGoM v3) as housing density across the landscape."

The data available to download consist of five population scenarios by county for the conterminous United States and are available in 5-year increments from 2000 to 2100. The population projections for each U.S. county drive the production of new housing units, which are allocated in response to the spatial pattern of previous growth (e.g., 1990 to 2000), transportation infrastructure, and other basic assumptions. The housing allocation model recomputes housing density in 5-year time steps at the resolution of 1 hectare.

These five scenarios are (EPA 2009):

- A1 represents a world of fast economic development, low population growth and high global integration;
- B1 represents a globally-integrated world similar to A1, but with greater emphasis on environmentally sustainable economic growth;
- A2 represents a world of continued economic development, yet with a more regional focus and slower convergence between regions;
- B2 represents a regionally-oriented world of moderate population growth and local solutions to environmental and economic problems;
- BC represents a "base case" (baseline).

Human development is presented in five classes, four of which are defined based on parcel unit size: Urban (< 0.25 acres/unit), Suburban (0.25 – 2 acres/unit), exurban (2-40 acres/unit), and rural (>= 40 acres/unit). Commercial/Industrial is not related to parcel unit size.

We downloaded these five raster layers for 2010 and 2030 and clipped them to the extent of Montana, which resulted in the following changes among classes (Table 15):

Table 15. Land-use conversion from 2010 to 2030 in Montana resulting from five population growth scenarios; values in hectares.

Scenario	**Rural to exurban**	**Exurban to Suburban**	**Suburban to Urban**	**Total change**
A1	7,544	263	9	7,816
B1	12,816	632	79	13,718
BC (baseline)	12,020	512	21	14,041
A2	11,907	482	31	16,326
B2	20,140	839	83	23,842

Even looking at the furthest projection year, 2100, the data show little conversion in Montana, mostly around current population centers. It may be that the models used are more appropriate for other parts of the country, such as the east coast or the Midwest. To develop a measure of risk, we combined the five scenarios and used only pixels converted from rural to exurban (Figure 5). We reasoned that rural-to-exurban development presented the greatest threat to wetlands that are currently in relatively undisturbed settings, as opposed to wetlands already influenced by human land use. This resulted in a total of 24,780 ha, because converted pixels could overlap among scenarios, i.e., most pixels converted from rural to exurban under scenario

A1 would also be included in the count for scenario B1, etc. The resulting file was intersected with the wetland polygon layer and each wetland was assigned a binary score, 0 for wetlands that do not overlap a potential converted pixel, 5 for wetlands that do (Figure 6).

For all risk factors used in this analysis, the scoring of wetlands classified by type using the Cowardin wetland classification system (http://www.fws.gov/wetlands/Data/Wetland-Codes.html) is presented in a series of tables in Appendix B.

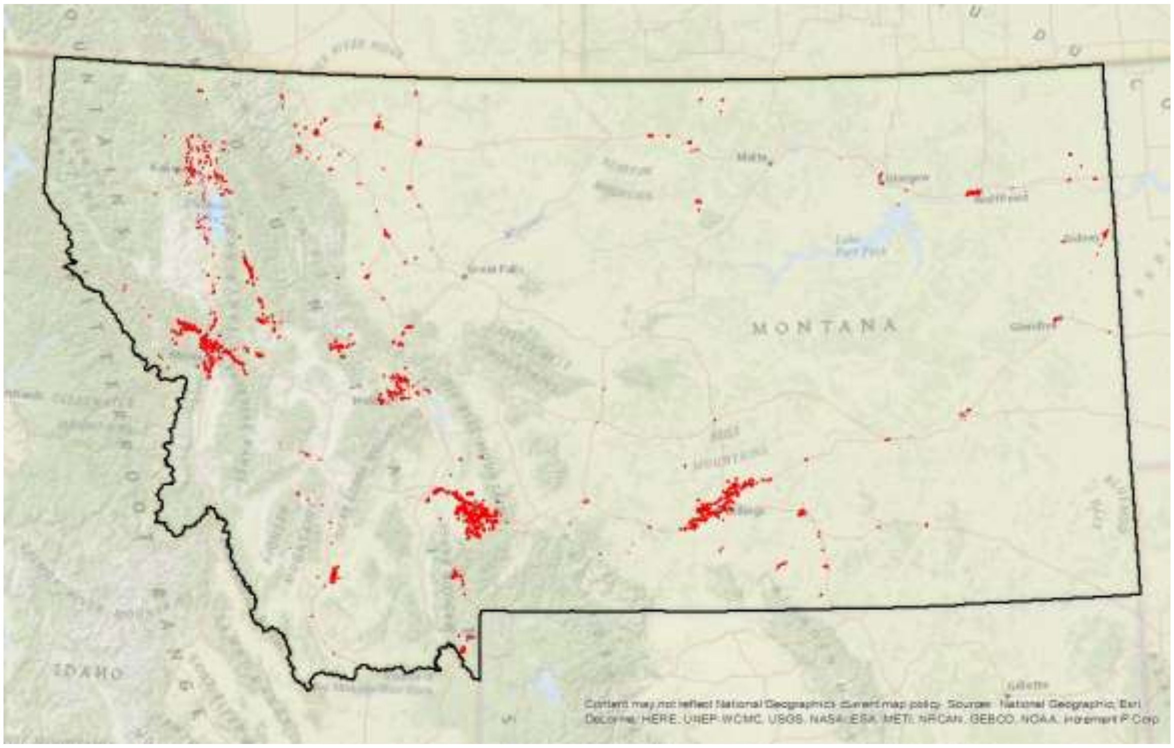

Figure 5. Potential rural-to-exurban conversion between 2010 and 2030 based on five ICLUS scenarios.

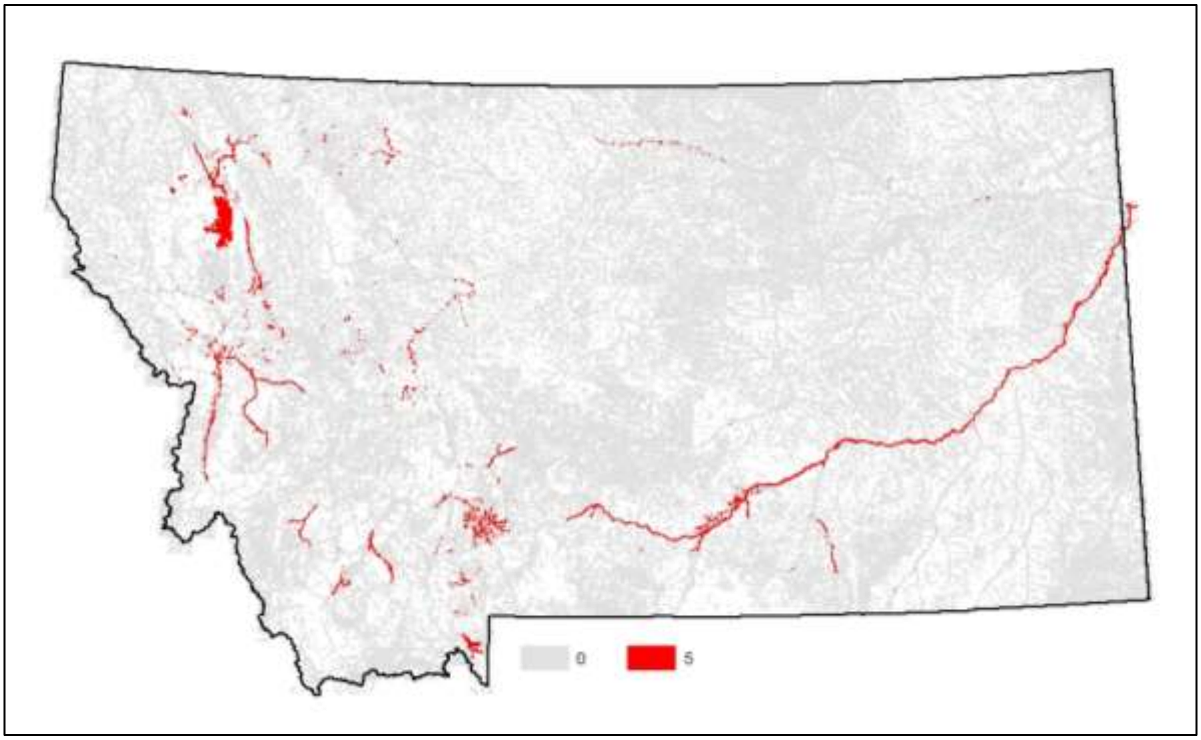

Figure 6. Wetland score, rural to exurban conversion.

Rural land use/land cover change

For this measure of risk, we used data presented in a study looking at opportunities for avoided loss of wetland carbon stocks in the Great Plains in the context of future agricultural expansion through analysis of land use-land cover change scenarios (Byrd et al. 2013). Rather than focusing on the expansion of the human footprint in the form of homes, roads and the like, this metric assesses the loss of "natural" land cover such as forests, shrubland, grassland, etc. It expands the scope of the threat captured by Metric 1. Upon contacting the lead author, we were directed to the USGS LandCarbon website: http://landcarbon.org/categories/land-use/download/

"The projected period uses future storylines from the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) in conjunction with a spatial modeling method to produce LULC maps from 2006 to 2050."

Projections were run for three scenarios using 250m pixels. We downloaded data for 2015 and 2030 for these three available scenarios:

- A1B: moderate population growth, high economic growth, rapid technological innovations, balanced energy use.
- A2: medium-high emissions scenario. Continuous population growth, uneven economic and technology growth, heat-trapping emissions increase, atmospheric CO2 concentrations triples by 2100 relative to pre-industrial levels.
- B1: lower emissions scenario. High economic growth, global population peaks by mid-century then decreases, rapid shift towards less fossil fuel intensive industries, introduction of clean and resource-efficient technologies; heat-trapping emissions peak

by mid-century then decrease. Atmospheric CO_2 concentrations double by 2100 relative to pre-industrial levels.

After extracting data for Montana, 2015 to 2030 conversion from "natural" land cover types (Grassland, Shrubland, Deciduous Forest, Mixed Forest, Evergreen Forest, Herbaceous Wetland, Woody Wetland, Open Water, and Ice/Snow) to human land use differed among scenarios (Table 16):

Table 16. Land use-land cover changes for Montana based on three different scenarios; values in hectares.

Conversion from Natural to:	**A1B**	**A2**	**B1**
Barren	324	541	31
Mechanically Disturbed	709,569	592,636	517,840
Agriculture/Hay/Pasture	954,078	1,081,549	668,034
Mining	1,344	1,591	494
Developed	27,279	26,008	13,452

To develop a measure of risk, we used data from scenario A1B only, which seems to be the most appropriate scenario for a non-manufacturing state like Montana. We note that this scenario does capture impacts from logging, although it may not fully account for logging in beetle-killed forests (Figure 7). Pixels predicted to change from natural land cover to human land use between 2015 and 2030 were extracted for each wetland, which was assigned a binary 0 or 5 score, with 5 given to any wetland overlapping a converted pixel (Figure 8).

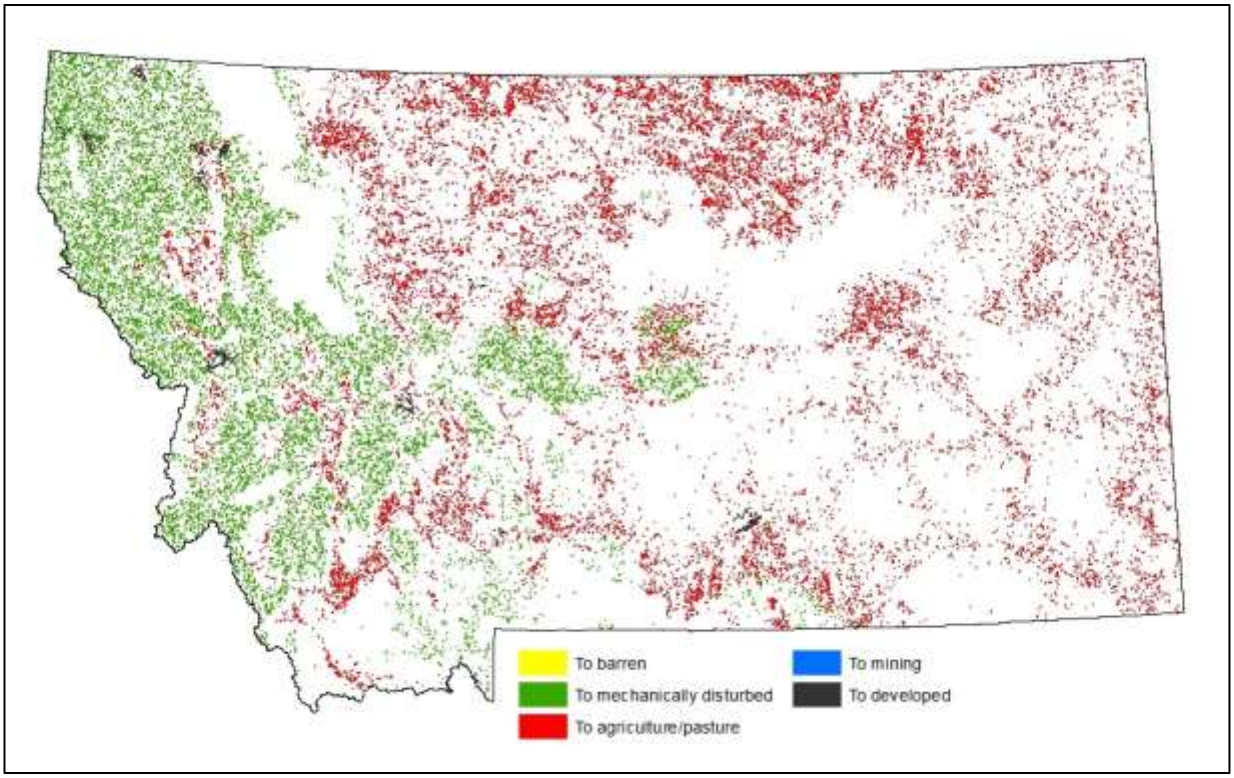

Figure 7. Conversion from natural land cover to human land use between 2015 and 2030 based on IPCC scenario A1B.

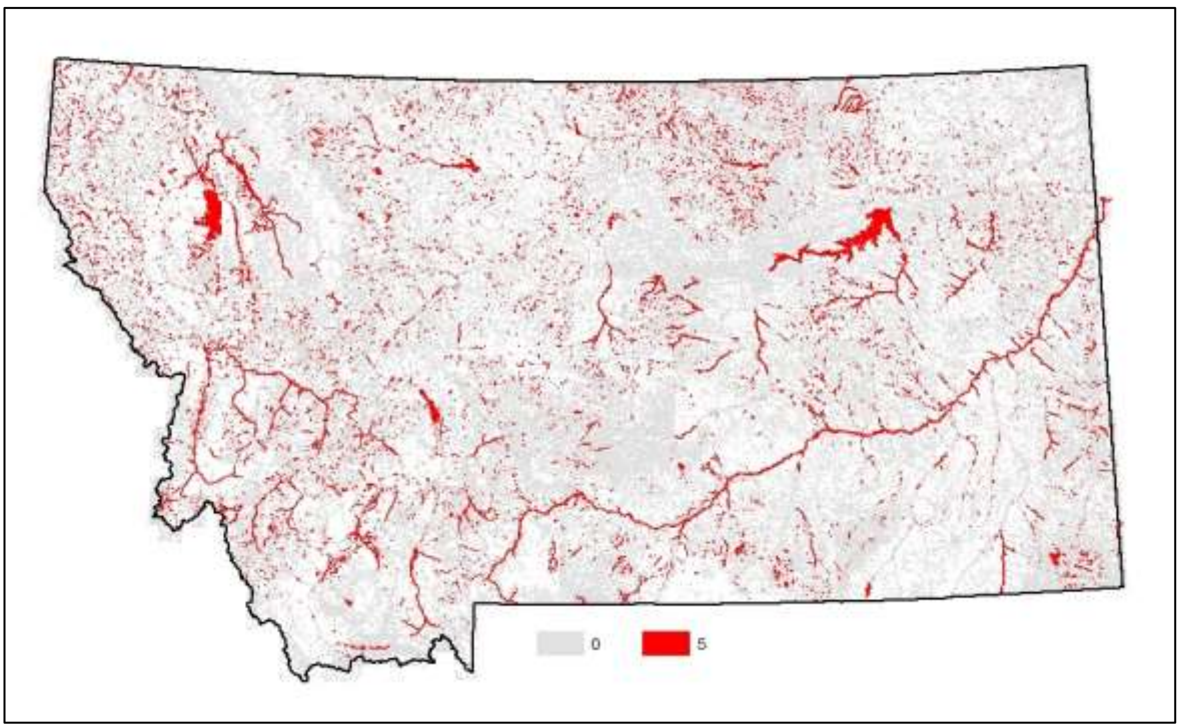

Figure 8. Wetland score, rural land use/land cover change.

Oil and gas potential

For this measure of risk, we replicated the methods described in Copeland et al. (2009). We used RandomForest in R to develop a model of oil and gas potential from seven predictive variables and Montana Fish, Wildlife and Parks data on producing and non-producing wells. The predictive variables we used were:

- Elevation (from NED 30m DEM);
- Slope (derived from DEM);
- Geology (1:500,000 Montana geology) downloaded from: https://mrdata.usgs.gov/geology/state/state.php?state=MT;
- Depth to Bedrock from the USDA STATSGO Depth to Lythic Bedrock attribute: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053629
- Magnetic Anomaly grid, Bouguer Gravity Anomaly grid, and Isostatic Residual Gravity Anomaly grid, all with 1000m pixels and downloaded from the USGS Mineral Resource Online Spatial Data: http://mrdata.usgs.gov/ (Geophysics tab)

All variables were resampled to 1000m. The Montana Board of Oil and Gas Wellsurface shapefile layer from 01/22/2013 was the source of presence and absence points required by RandomForest. For presence, we used wells with Status = "Producing", not including water wells; for absence, we used wells with Type = "Dry hole". Points were converted to pixels; if both producing and non-producing wells occurred in a 1000m pixel, that pixel was classified as producing. This resulted in N = 5,462 producing (presence) and N = 11,152 non-producing (absence) wells. We randomly selected 80% of well data for model development, setting aside 20% for independent validation.

User's accuracies from the independent validation dataset were 78.5% for producing wells and 85.2% for non-producing wells; overall accuracy was 83.3% and Cohen's Kappa was 0.61. These values are similar to those obtained by Copeland et al. A final model was developed using 100% of the data (Figure 9) and used to generate the measure of risk, by performing a spatial intersection between the model and the wetland layer. Each wetland was assigned a binary 0 or 5 score, with 5 given to any wetland overlapping a predicted oil and gas pixel (Figure 10). We did not remove Riverine wetlands from this step; however, we suggest that this might be appropriate before using the dataset for planning purposes.

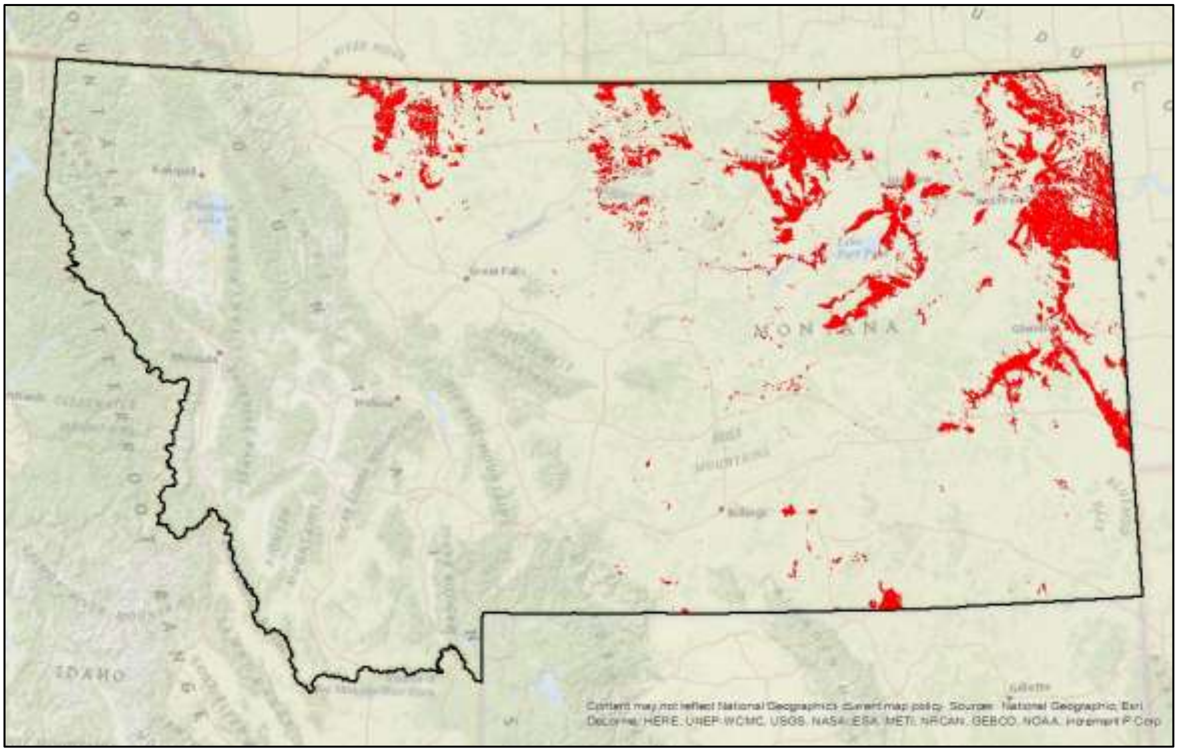

Figure 9. Oil and gas potential predictive model.

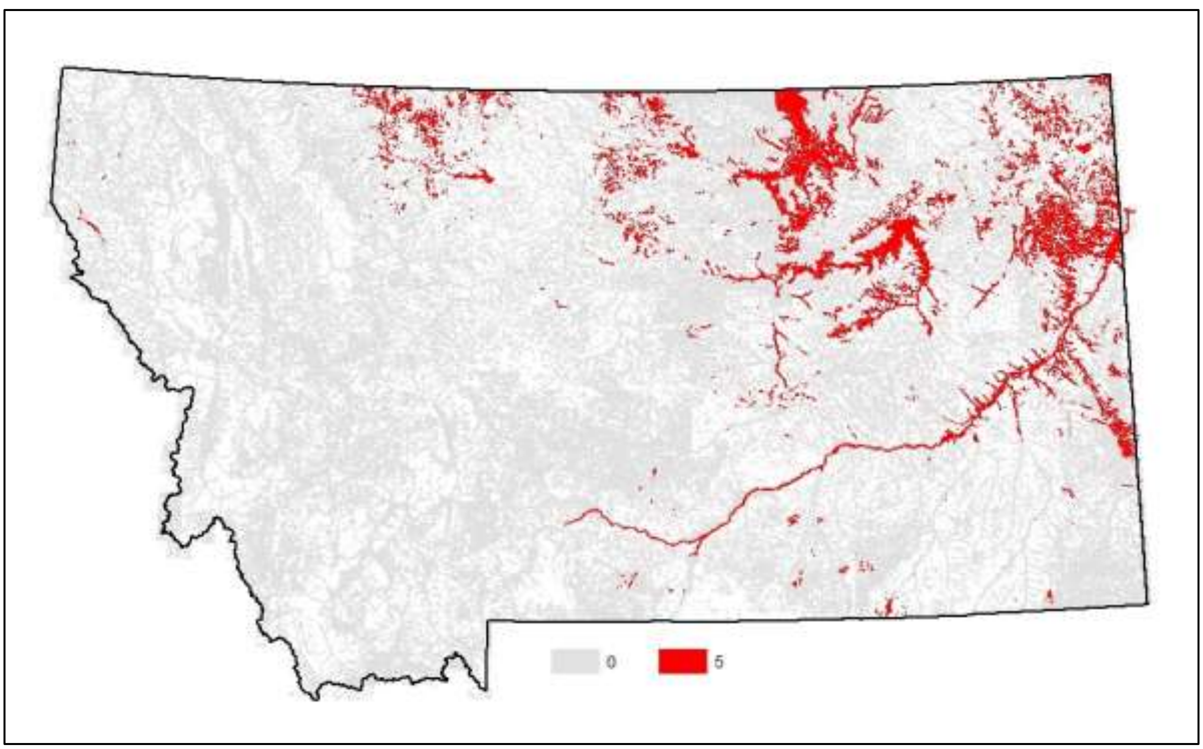

Figure 10. Wetland score, oil and gas potential.

Level 1 condition

This measure of risk is based on the Montana Human Disturbance Index (HDI; Figure 11), a Montana Natural Heritage Program product representing six disturbance categories: Development, Transportation, Agriculture, Resource Extraction/Energy Development, Introduced Vegetation, and Forestry Practices. Disturbances used in the dataset were based on the Montana Spatial Data Infrastructure 2015 Land Cover Land Use dataset, which is available on request.

Detailed metadata can be found at:
http://mslapps.mt.gov/Geographic_Information/Data/DataList/datalist_MetadataDetail?did=%7B639e7c86-8224-11e4-b116-123b93f75cba%7D

Landscape context was evaluated by buffering each wetland and riparian polygon by 300m and calculating mean HDI value for each resulting buffer. Values range from 0 to 4098; to convert this continuum to a 0 to 5 score, we used the cutoff values provided by the ArcGIS "Natural Breaks" classification scheme (Figure 12). We calculated natural breaks for both the entire dataset, and also after removing large waterbodies and rivers (N = 9,708), and found no significant difference (Table 17).

*Table 17. Comparison of Natural Break values and resulting percent polygon by break class, using all wetland/riparian polygons and after removing large waterbodies and rivers. *0 values were excluded from the Natural Break classification.*

All wetland/riparian polygons		Remove large waterbodies/rivers	
Natural break value	Percent polygons	Natural break value	Percent polygons
0*	16.01	0*	15.96
> 0 and < 368.92	24.77	>0 and < 368.81	24.79
368.92 – 834.15	21.32	368.81 – 834.21	21.33
834.15 – 1311.15	19.69	834.21 – 1311.34	19.71
1311.15 – 1894.45	13.15	1311.34 – 1894.92	13.15
>= 1894.45	5.06	>= 1894.92	5.06

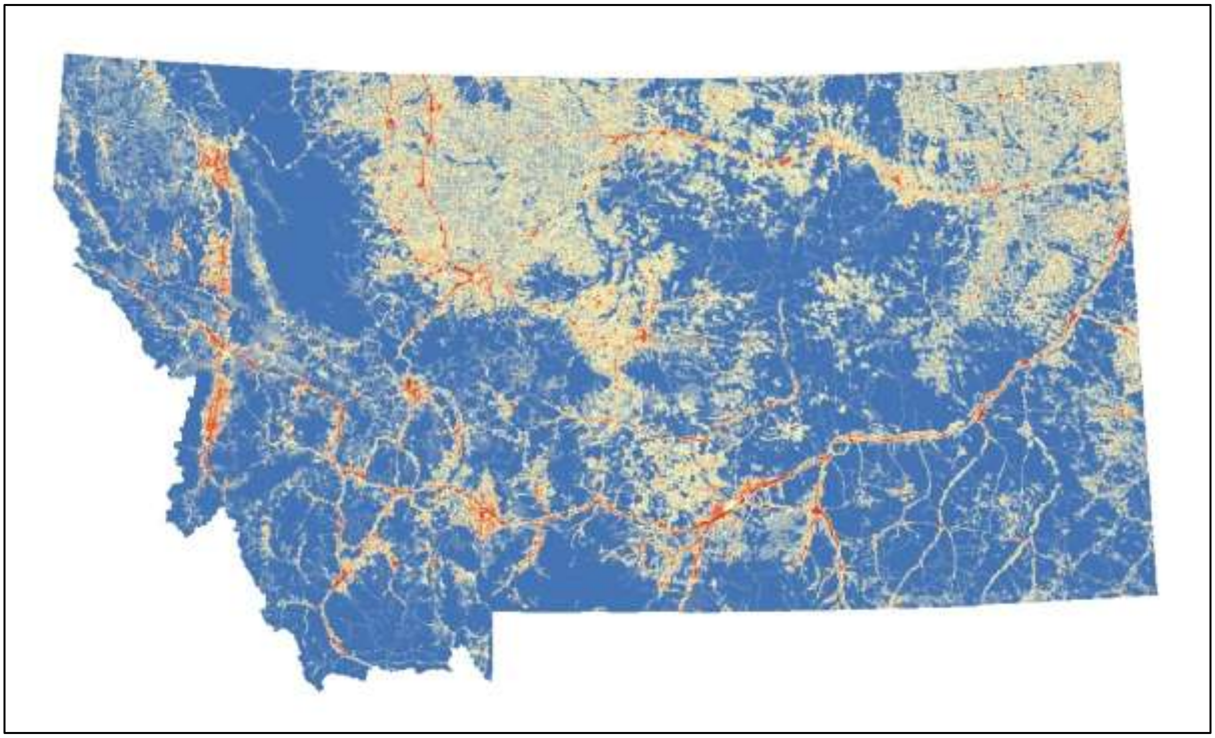

Figure 11. The Montana Human Disturbance Index. Unitless values range from 0 (no human disturbance, blue) to 4,314 (highest human disturbance, red).

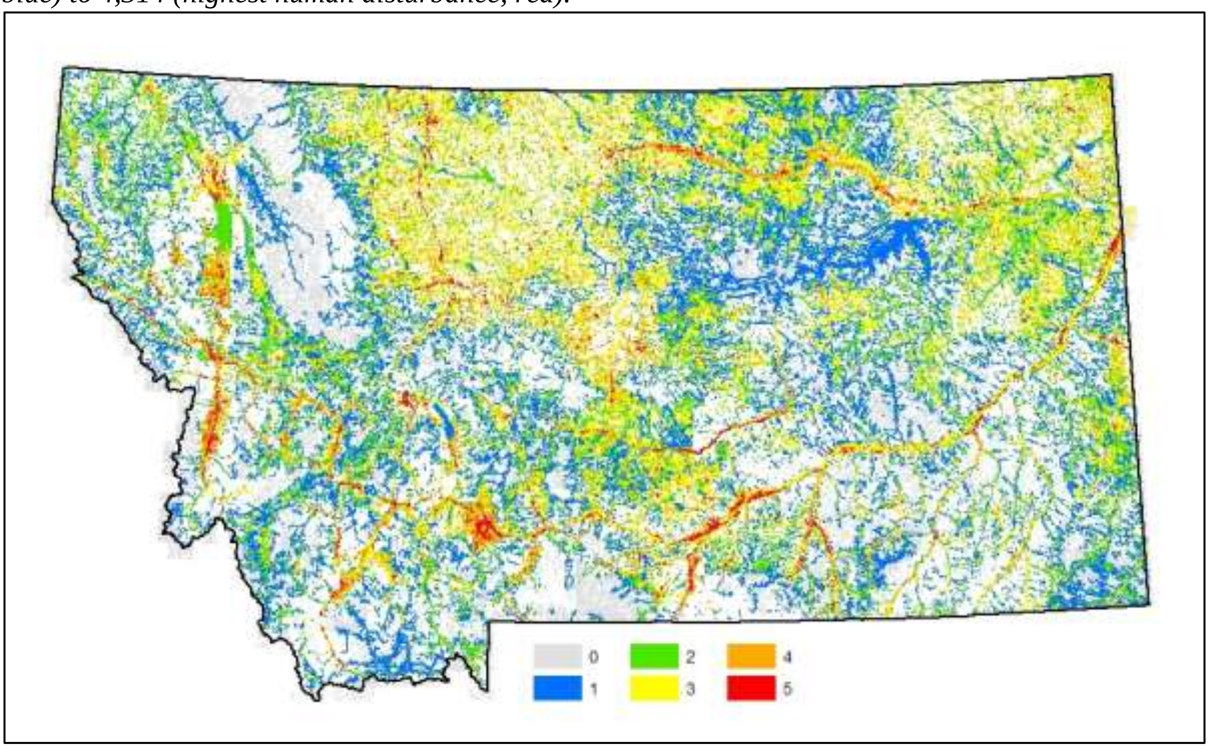

Figure 12. Wetland score, Human Disturbance Index.

Climate change

We based this section on methods presented in Copeland et al. (2010), who adapted methods from Enquist et al. (2008). We replicated Copeland et al.'s method to calculate a "water balance deficit" metric after downloading Montana TopoWx 800m monthly mean temperature data (ftp://mco.cfc.umt.edu/tmean/monthly/Esri/) and Montana Daymet 1000m monthly mean precipitation data (ftp://mco.cfc.umt.edu/prcp/Daymet/monthly/Esri/).

A water balance deficit (referred to as a "climate water deficit" in Enquist et. al 2008) occurs when potential evapotranspiration (PET) is greater than actual evapotranspiration (AET). PET is the maximum amount of water that would be evapotranspired if enough water were available (from precipitation and soil moisture). By contrast, AET will be limited by the amount of available water. Therefore, AET will always be less than, or equal to, PET. When more water is available than can be evapotranspired, no deficit will occur. Because of this, precipitation (PPT) can be used as a surrogate for AET when PPT<=PET, and indeed is used this way in the well-known Palmer Drought Severity Index (Dai 2015). This approach generally assumes an arid or semi-arid environment, where soil moisture is a direct response to rainfall. In mountainous areas, where precipitation is held in the snow pack for long periods, and soil moisture content rises long after the precipitation event, water deficits are not generally seen. Other methods may need to be explored to predict potential climate change impacts on high-elevation wetlands.

We calculated potential evapotranspiration using the Hanon equation: PET = 13.97dD2Wt where d is the number of days in a month, D is the mean monthly hours of daylight (in units of 12 h), and Wt is a saturated water vapor density term calculated by: Wt = 4.95e0.062T/100, where T is the monthly mean temperature in degree Celsius. We then calculated a Water Balance Deficit metric WBD = PET – PPT (for PPT < PET, otherwise WBD = 0), where PPT is the total monthly precipitation (mm). Water Balance Deficits were summed over all months for four years: 1981, 1991, 2001, and 2011. We identified pixels (1000m) with a positive trend (increasing water deficit over 30 years) as being impacted by climate change (Figure 13). Because of the coarseness of the climate data, WBD pixels were first buffered by 800m, then each wetland was assigned a binary 0-5 score: any wetland with more than 20% of its area falling in a WBD buffered pixel received a score of 5, all other wetlands getting a score of 0 (Figure 14).

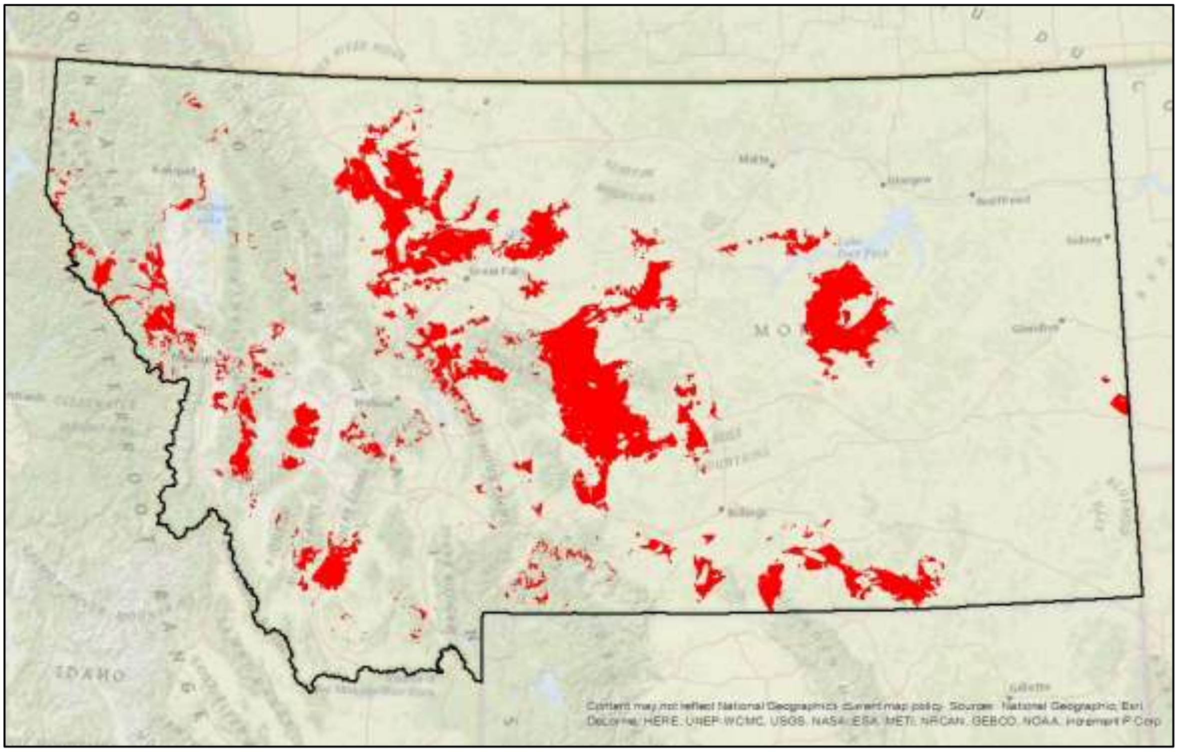

Figure 13. Water Balance Deficit, areas exhibiting a positive trend between 1981 and 2011.

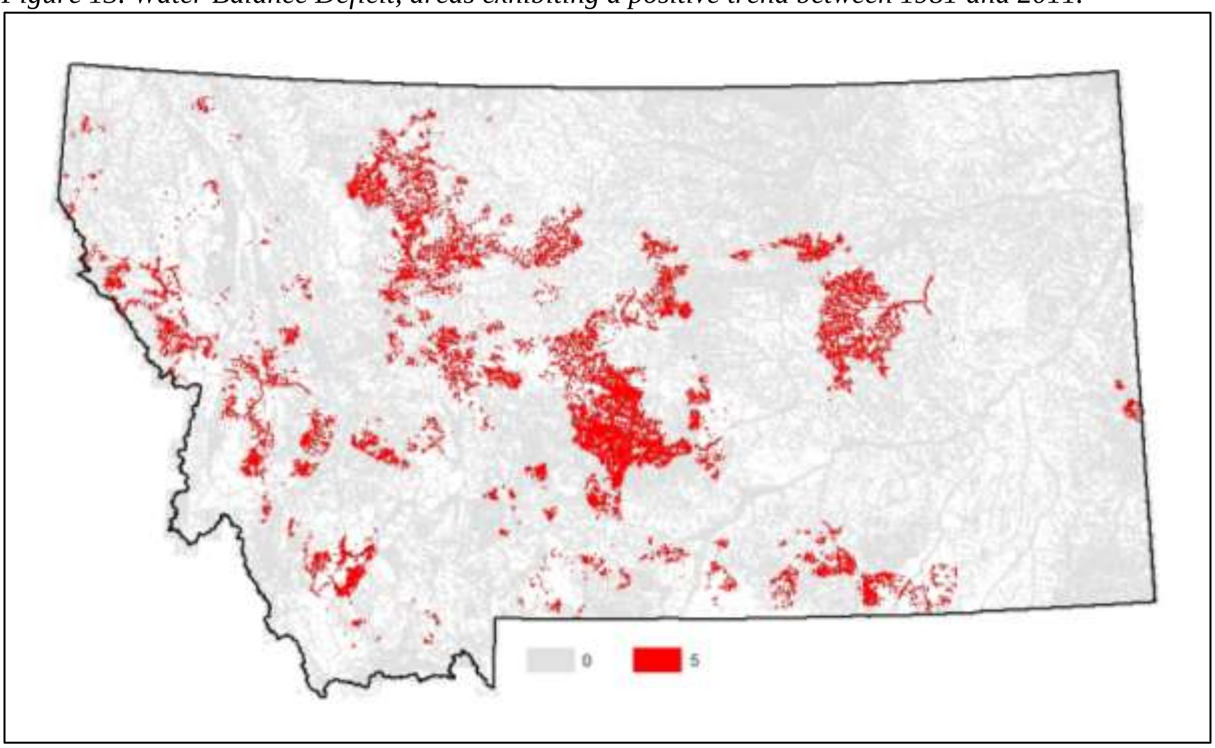

Figure 14. Wetland score, Water Balance Deficit.

Cropland conversion risk

For this risk factor, we replicated Amy Pearson's county-level methods (pers. comm., there is no existing report or specific written documentation) at the statewide level. The model combines key factors of soil cropping capability, proximity to existing cropland, and distance from roads, three parameters that have been identified as important in similar modeling exercises (Pearson, pers. comm.).

For soil cropping capability, we obtained the most recent SSURGO geodatabase and ran an online query (http://sdmdataaccess.nrcs.usda.gov/) to obtain a statewide map of the Non-Irrigated Capability Class (Figure 15): "Land capability classification shows, in a general way, the suitability of soils for most kinds of field crops. Crops that require special management are excluded. The soils are grouped according to their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management" (NRCS online documentation, http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_027925.pdf; no definition or list was given specifying which crops are excluded). Every soil component in the United States may be classified under one of the following land capability class categories:

1) Soils have slight limitations that restrict their use.
2) Soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
3) Soils have severe limitations that reduce the choice of plants or require special conservation practices, or both.
4) Soils have very severe limitations that restrict the choice of plants or require very careful management, or both.
5) Soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
6) Soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
7) Soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.
8) Soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for aesthetic purposes.

We used soil polygons with values ranging from 3 to 6 (values 1 and 2 are not found in Montana, and values 7 and 8 are unsuitable for agriculture).

We clipped the resulting layer to State, Tribal, and Private lands and removed protected areas, which focused the analysis on lands most likely to be converted to agriculture, while having the additional advantage of removing all missing data from SSURGO. Although the management of some federal lands such as wildlife refuges may involve plantations (such as wheat in the case of wildlife refuges), this sort of cropping tends to be limited in scope and therefore these federal lands were not included in the analysis.

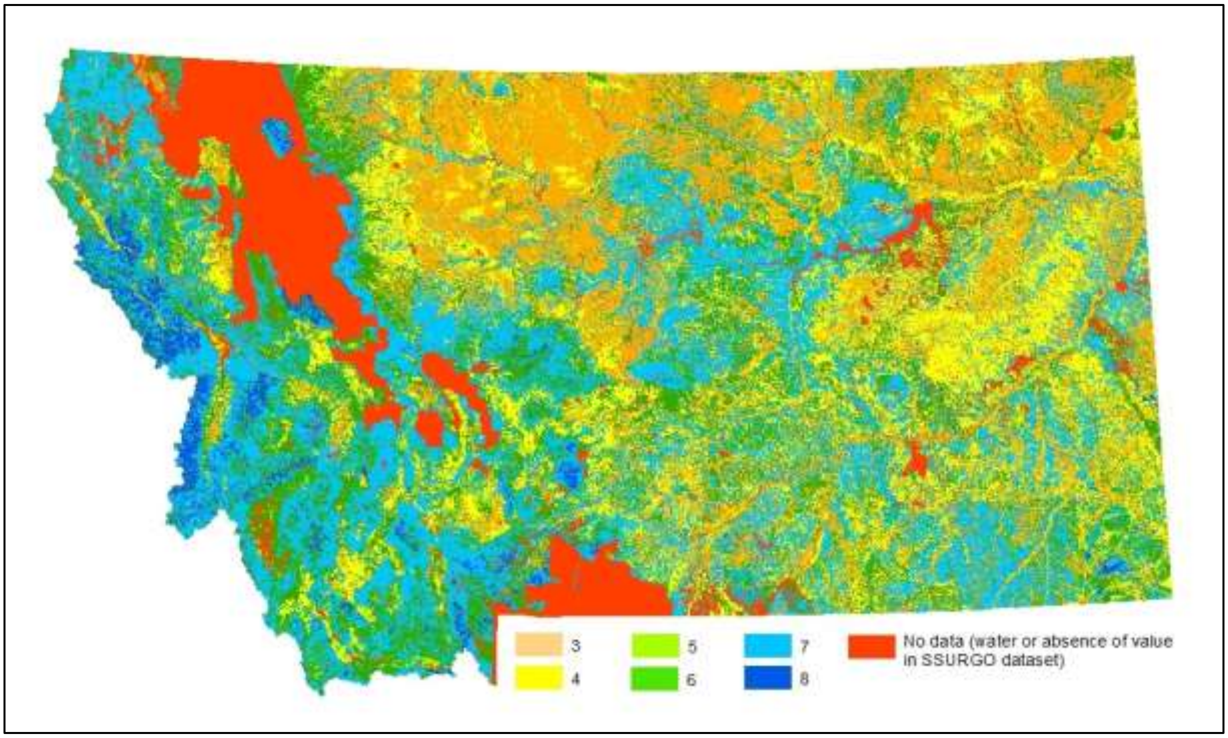

Figure 15. Soil Non-Irrigated Capability Class, from SSURGO data.

For each remaining soil polygon, we applied a series of modifiers:

- Cropland modifier: subtracting 1 if a soil polygon fell within a 2-mile buffer of existing cropland based on the most recent Department of Revenue's FLU data (Department of Revenue 2015); cropland, in this case, consisted of polygons coded as C (Continuously cropped), I (Irrigated Land), F (Summer fallow farmland), or H (non-irrigated hay land).
- Access modifier: subtracting 1 if soil polygon fell within a 2-mile buffer around all named roads, from the most recent transportation framework geodatabase;
- Precipitation modifier: subtracting 2 if the soil polygon fell within a 14-inch or higher precipitation zone, based on Montana REAP grid (http://mslapps.mt.gov/Geographic_Information/Data/nrcs/reap/); or, subtracting 1 if the soil polygon fell within an 11-14 inch precipitation zone.

The resulting "Risk Score" (Figure 16) ranged from -1 (high risk of conversion to crops: NICC value = 3, polygon within 2 miles of existing cropland and roads, polygon in 14in. or higher precipitation zone) to 6 (low risk of conversion to crops: NICC value = 6, polygon further than 2 miles of existing cropland and roads, precipitation less than 11in.). To generate a wetland score, we recoded these from 1 (original score 6, lowest risk) to 8 (original score -1, highest risk), got the average score for each wetland, and rescaled them to range from 0 to 5, to match the scores of the other measures of risk (Figure 17).

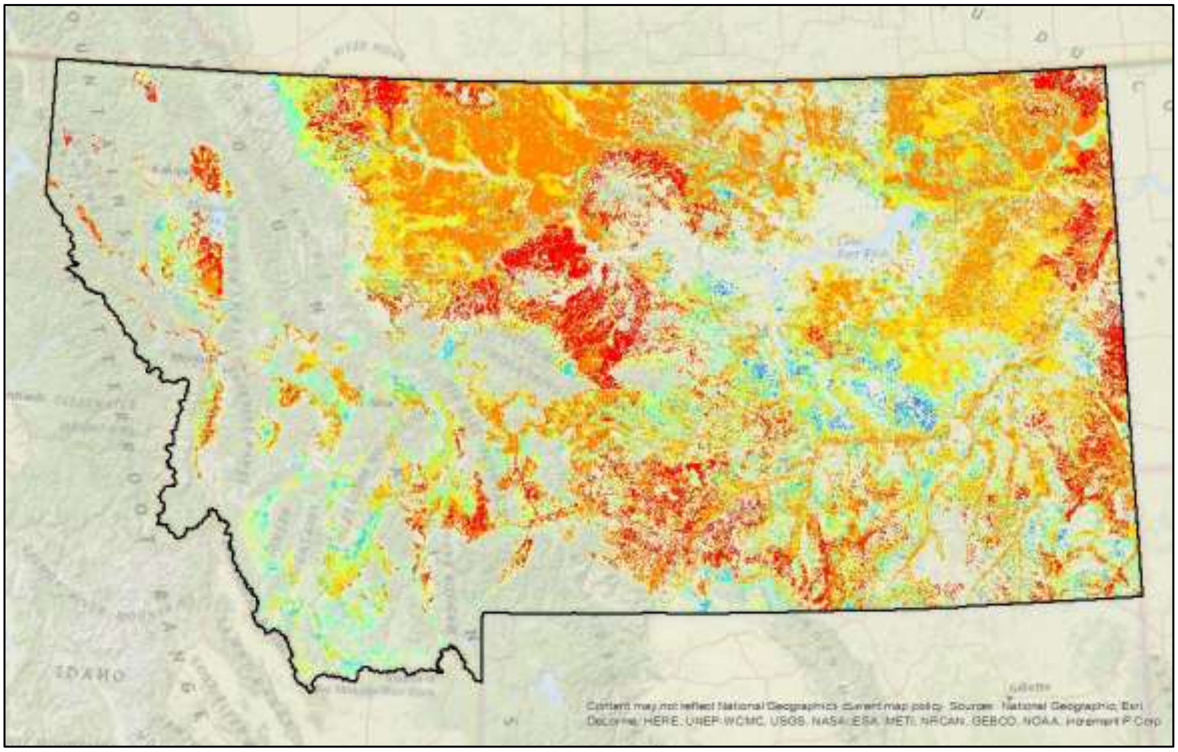

Figure 16. Cropland conversion risk (from lowest, blue, to highest, red).

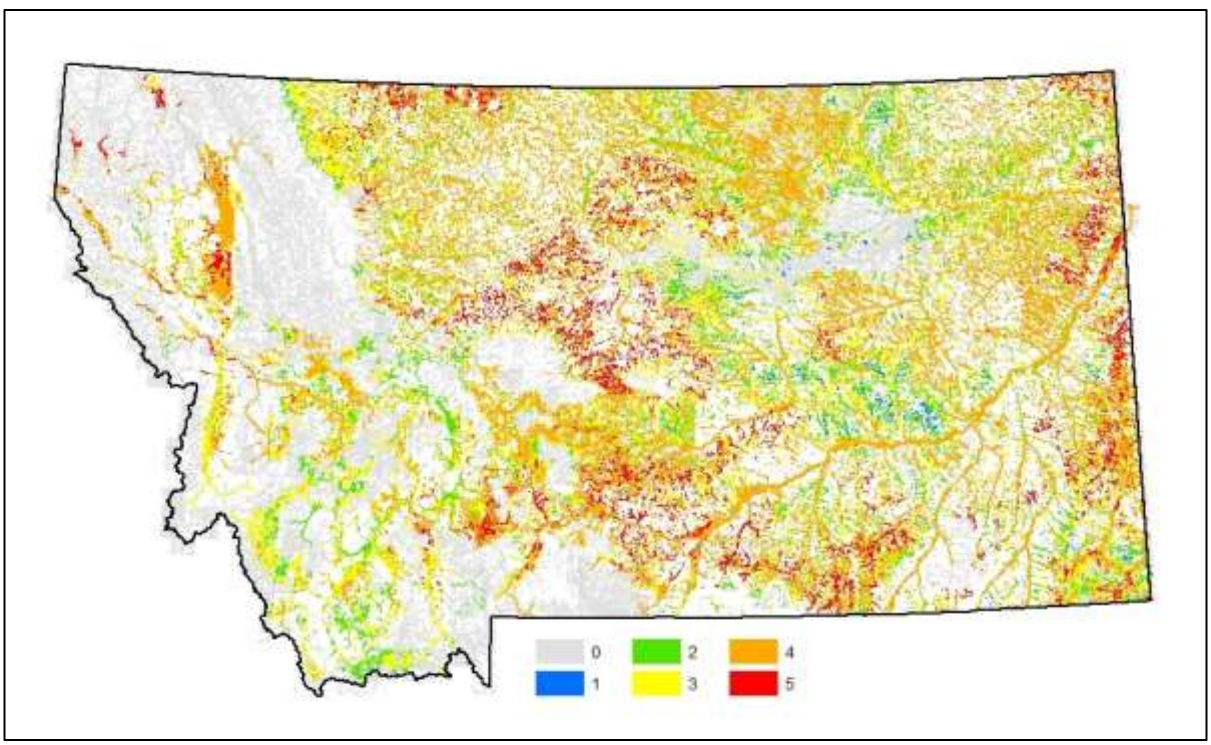

Figure 17. Wetland score, cropland conversion risk.

TASK 4, STATEWIDE PRIORITIZATION AND VULNERABILITY ASSESSMENTS

The objective of Task 4 was to test functionality of the statewide wetland prioritization database by creating maps for four pilot areas, then integrating the results of the pilot into final statewide prioritization and vulnerability assessments.

Methods

We worked in four pilot areas: Northern Blaine and Phillips County, the Centennial Valley, the Mission Valley, and the Musselshell flood plain. We used ArcGIS Hot Spot Analysis, a tool which identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). This tool creates a new Output Feature Class with a z-score, p-value and confidence level bin (Gi_Bin) for each feature in the Input Feature Class (in this study, each wetland polygon). The Gi_Bin field identifies statistically significant hot and cold spots, and can be corrected for multiple testing and spatial dependence using the False Discovery Rate (FDR) correction method. Features in the +/-3 bins (features with a Gi_Bin value of either +3 or -3) are statistically significant at the 99 percent confidence level; features in the +/-2 bins reflect a 95 percent confidence level; features in the +/-1 bins reflect a 90 percent confidence level; and the clustering for features with 0 for the Gi_Bin field is not statistically significant. Because the underlying Getis-Ord Gi* statistic used by this tool is asymptotically normal, results are reliable even if the Analysis Field (in this study, unweighted summed prioritization scores and unweighted summed vulnerability scores) contains skewed data.

After generating a series of outputs using both the regular and Optimized Hot Spot analysis tools at the local and statewide level, we opted to only retain the statewide hot spot analysis. Running this type of analysis locally, even with fixed parameters, results in different outputs from a statewide run because P-values and Z-scores (on which the Gi_Bin assignment is based) are population-dependent. For example, performing the analysis for northern Phillips and Blaine Counties will identify as hot spots those wetlands that form the hottest spots in this area, which is itself a general hotspot in a statewide analysis: as a result, the significance of this area at the statewide level would be muted.

A global prioritization score was computed for each wetland through simple addition of the six scores computed in Task 2: Rarity, Landscape Complex, Wetland Mosaic, Habitat Significance, Headwater, and Landscape Context. Statewide, it ranges from 0 to a maximum value of 17.

A global vulnerability score was computed for each wetland through simple addition of the six scores computed in Task 3: Exurban, Land Use Land Cover, Oil and Gas, Water Balance Deficit, Cropland, and Human Disturbance Index. Statewide, it ranges from 0 to a maximum value of 27.

We ran the regular Hot Spot Analysis on each global score with the following options: Conceptualization of Distance Relationships: FIXED_DISTANCE_BAND; Distance Method: EUCLIDEAN_DISTANCE; Distance band or Threshold Distance: 1000m. Based on the Optimized Hot Spot analysis runs in several subset areas, the average distance between a wetland

and its 30 nearest neighbors is roughly 1000m (Centennial Valley 952m, Blaine-Phillips 962m, Mission Valley 681m, Musselshell 1126m). Finally, we checked the Apply False Discovery Rate (FDR) Correction box.

We ran a sensitivity analysis by removing in turn each component of the global prioritization score and global vulnerability score, running the hot spot analysis and comparing each output to the full one.

Results

There are currently 1,395,290 mapped wetlands and riparian areas in the mt_wetrip2016 dataset, which forms the spatial basis for this study. The histogram of unweighted, global prioritization scores shows a gradual diminution of number of wetlands as score increases (Figure 18), whereas that of global vulnerability scores is bimodal, with one peak at 1 and another around 5-6-7 (Figure 19). Acreages for cold, not significant, and hot spots (at the 90% confidence level) is presented in Table 18, with their statewide distribution presented in Figures 20 and 21.

Table 18. Acreages of cold, not significant, and hot spots (90% confidence level) for wetland prioritization and vulnerability analyses in Montana.

	Prioritization	Vulnerability
Cold Spot (90%)	959,733	1,137,883
Not Significant	1,416,233	1,284,752
Hot Spot (90%)	1,078,818	1,037,094

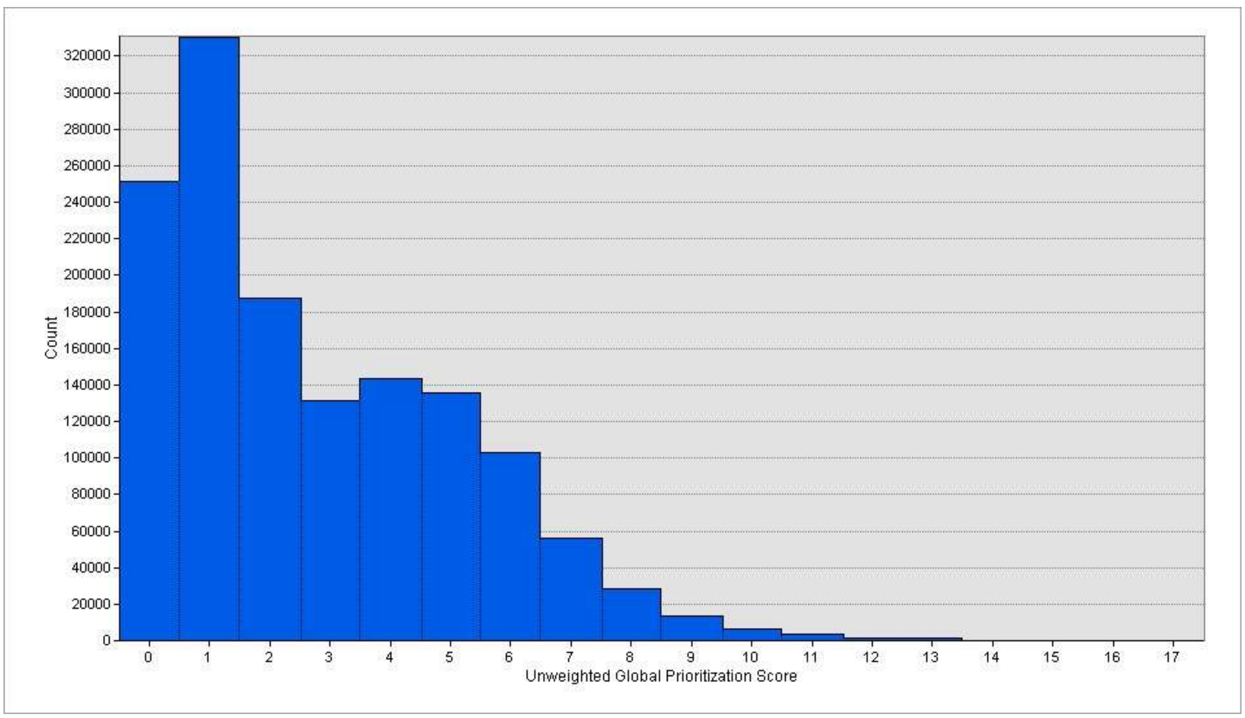

Figure 18. Histogram distribution of unweighted, summed prioritization scores for Montana wetlands.

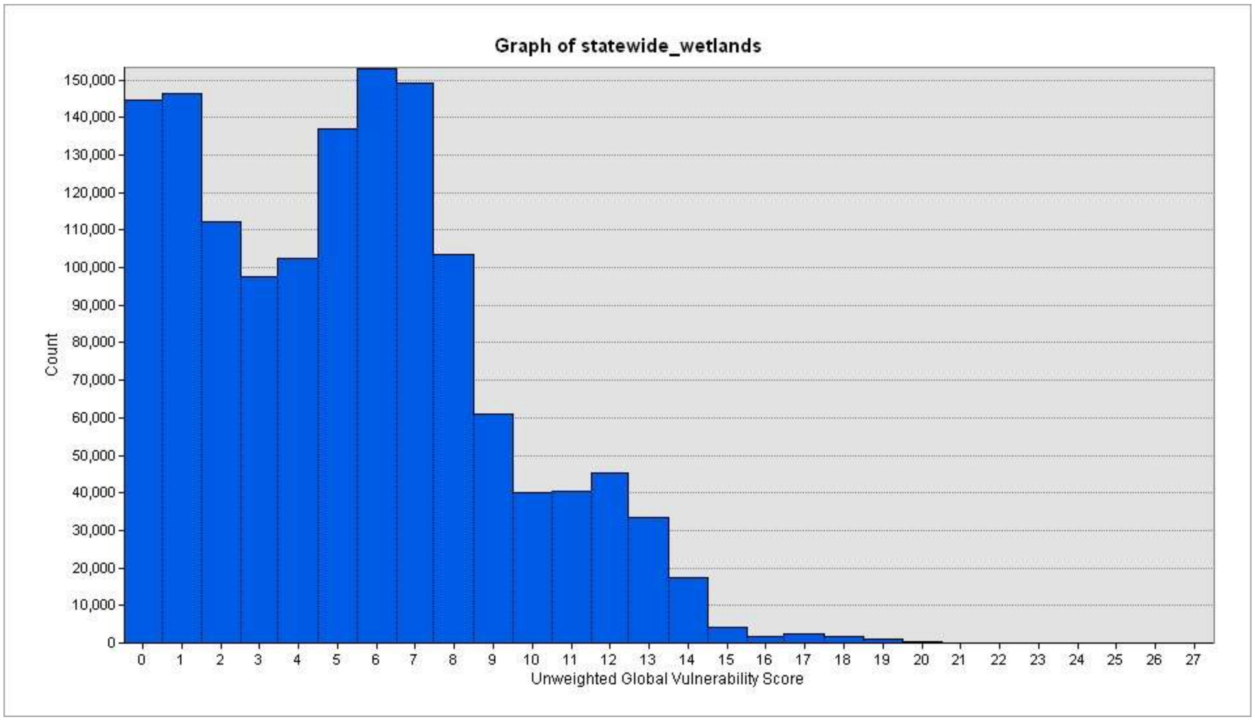

Figure 19. Histogram distribution of unweighted, summed vulnerability scores for Montana wetlands.

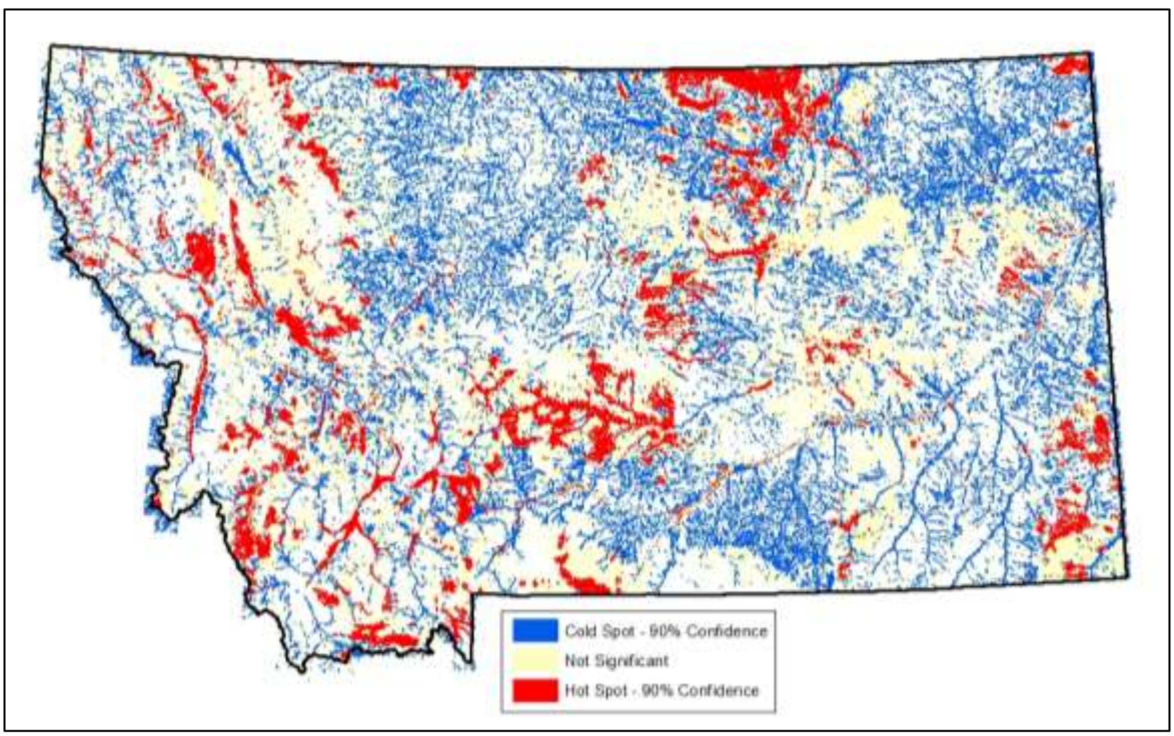

Figure 20. Distribution of cold, not significant, and hot spots (90% confidence level) for wetland prioritization analysis in Montana.

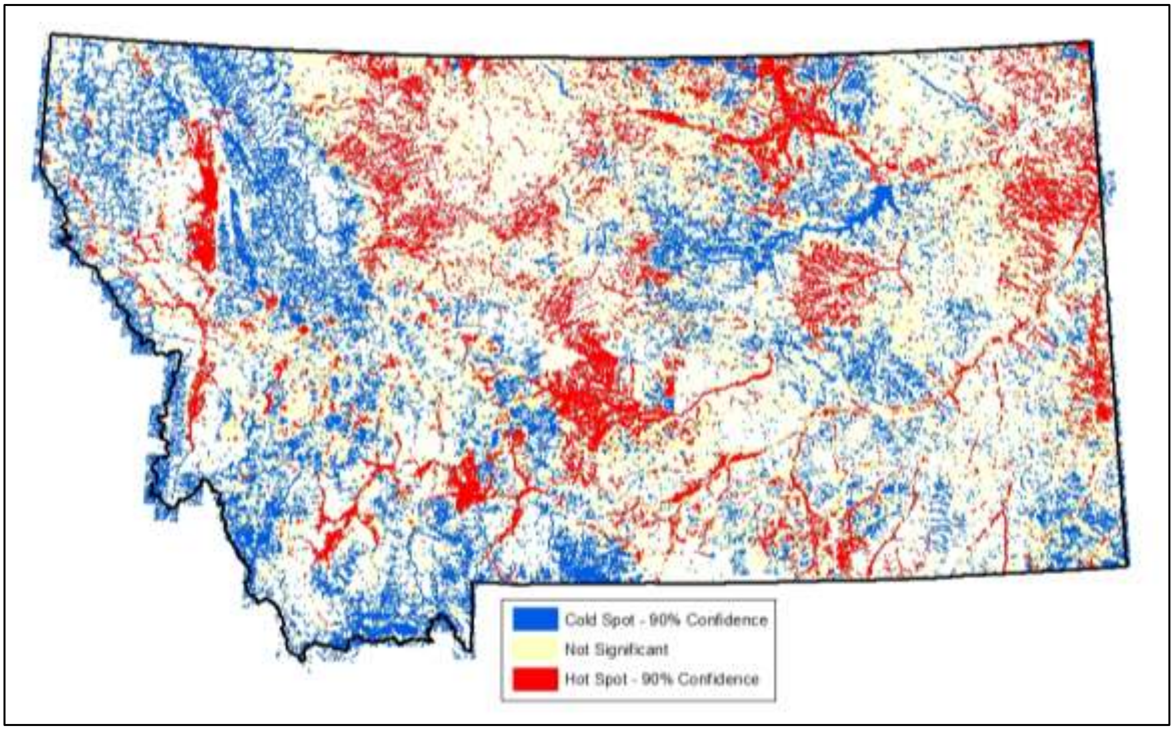

Figure 21. Distribution of cold, not significant, and hot spots (90% confidence level) for wetland vulnerability analysis in Montana.

A sensitivity analysis was conducted by removing in turn each component from the global prioritization and vulnerability scores. Global prioritization hot spot acreage is most sensitive to Habitat Significance followed by Wetland Mosaic and Rarity (Figure 22). Headwater has the least effect on acreage of prioritization cold spots, while Landscape Complex, Habitat Significance and Landscape Context have the greatest influence (Figure 23).

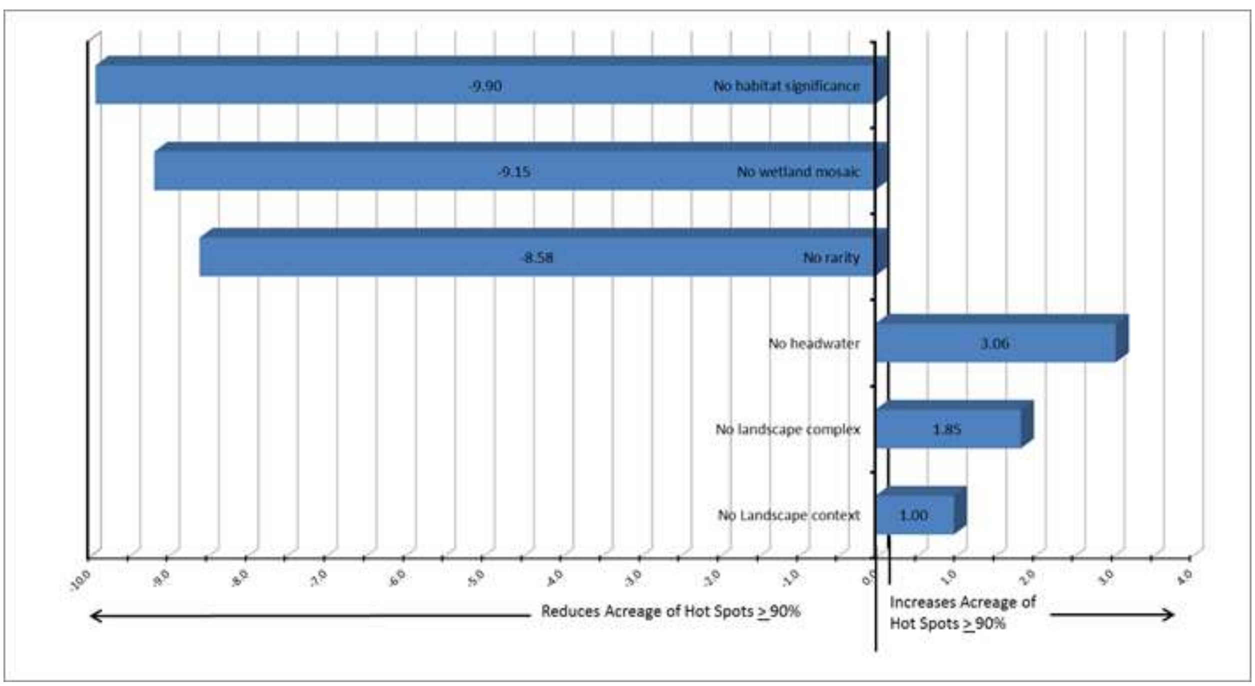

Figure 22. Prioritization sensitivity analysis, hot spots (90% significance).

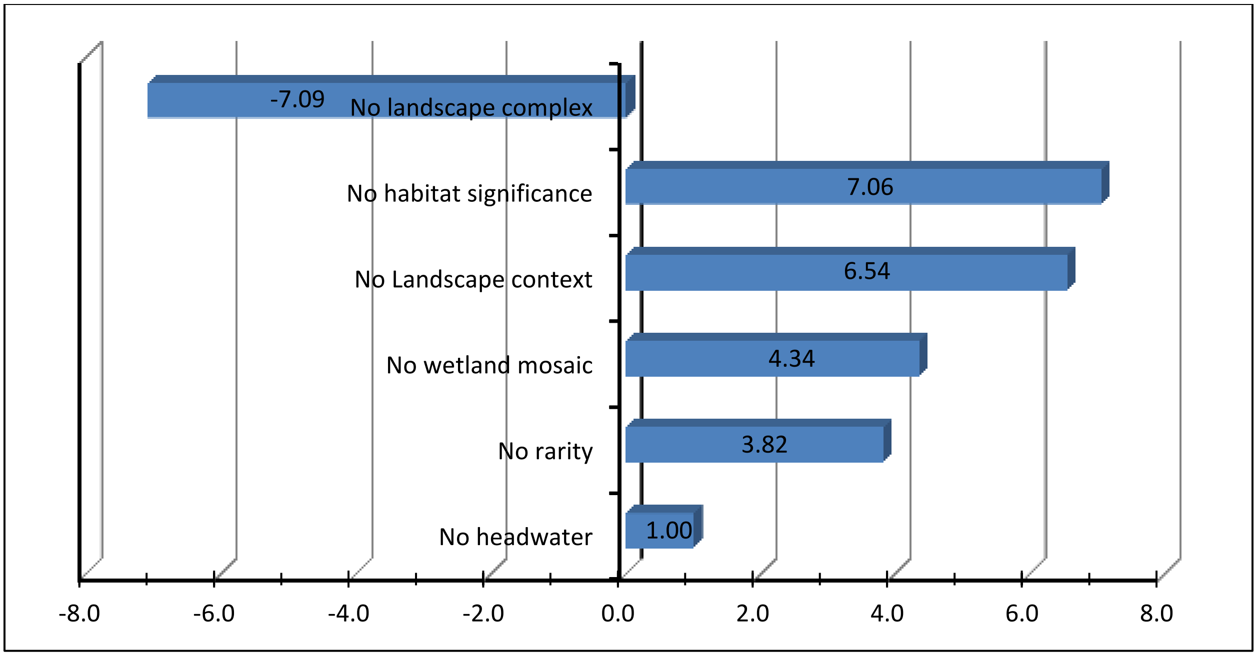

Figure 23. Prioritization sensitivity analysis, cold spots (90% significance).

Vulnerability hot spots were most sensitive to HDI, LULC, Exurban, and WBD (Figure 24); cold spots to HDI and Cropland (Figure 25).

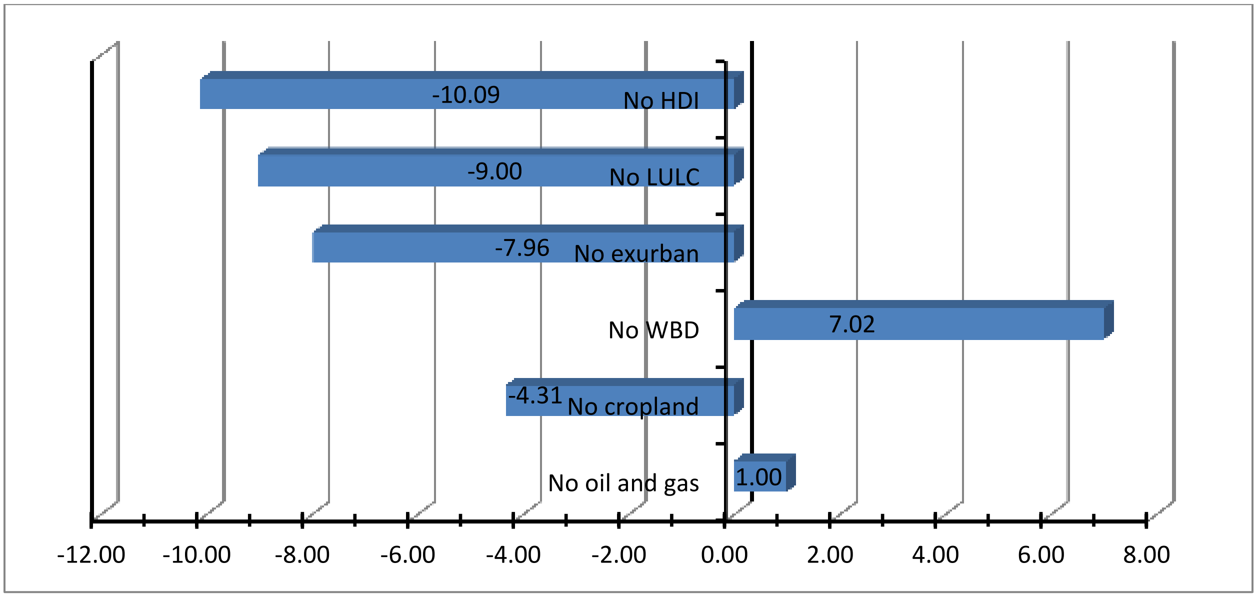

Figure 24. Vulnerability sensitivity analysis, hot spots (90% significance).

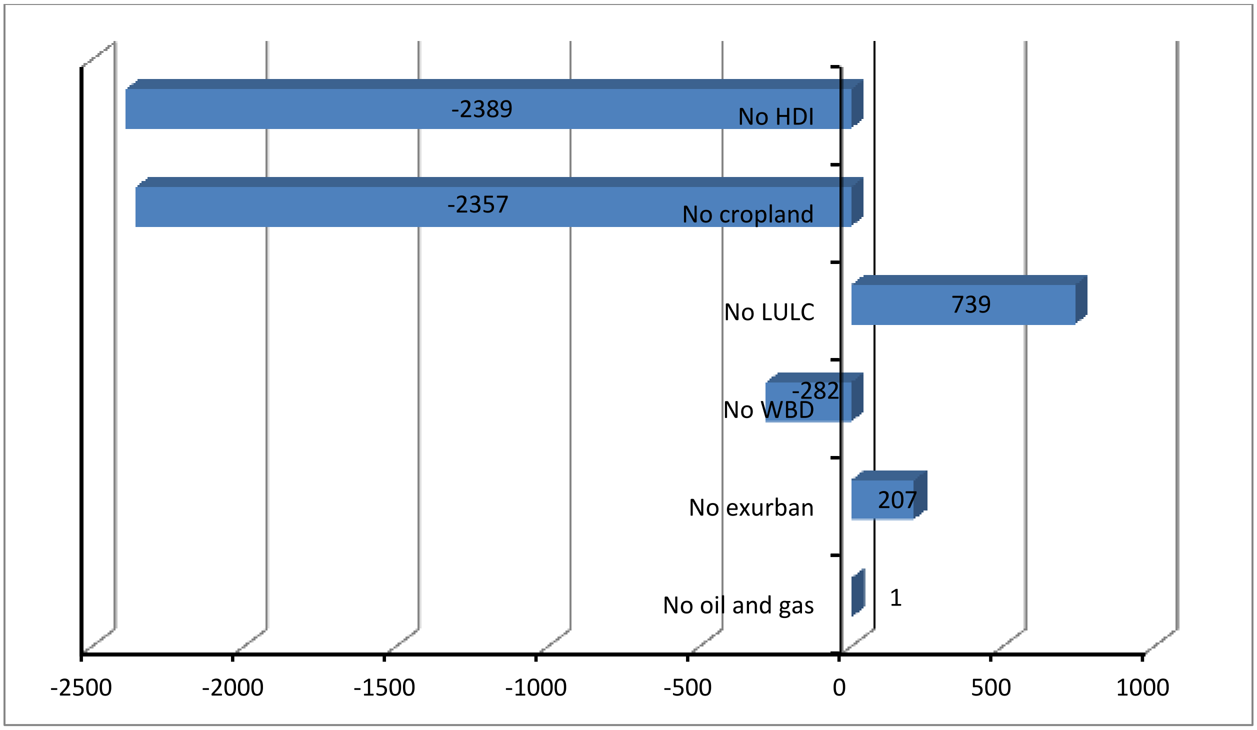

Figure 25. Vulnerability sensitivity analysis, hot spots (90% significance).

CONCLUSION

In many ways, this project is a culmination of the mapping efforts begun by MTNHP with support from MTDEQ almost a decade ago. While current statewide mapping is not complete, we have reached a point in the process where detailed analyses, like this one, can be carried out with confidence that the final product can provide guidance to land managers, restoration practitioners, and watershed planners.

In terms of next steps, we recommend the addition of Landscape Position, Landform, Water Path and Water Flow (LLWW) descriptors (after Tiner 2003), which would allow users to extend the analysis to include wetland functions. We were also limited by time and funding to a small handful of threats, and a limited set of data inputs with which to assess them. We feel that this is an area that could be expanded more fully.

Finally, we encourage users to work with this database to explore questions of their own choosing. While the intent was to create a product that would facilitate identification of potential protection and/or restoration targets, this data-rich resource can be used to answer myriad other questions, such as the distribution and role of beaver on the landscape, the location of potential reference standard wetlands, clusters of sites that might support concentrations of wetland-dependent species and the like. We also encourage users to "complete the loop" by submitting any such analyses back to us, so that we can continue to update the geodatabase.

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APPENDIX A. Data dictionary.

Task 1

mt_wetrip_prioritization_2016 Geodatabase		
DATA	**TYPE**	**DESCRIPTION**
Layers	feature dataset	
ConEasements	poly	Montana lands with conservation easements. This layer shows private lands parcels on which a public agency or qualified Land Trust has placed a Conservation Easement in cooperation with the land owner. http://geoinfo.msl.mt.gov/home/msdi/cadastral
County	poly	Database of Montana Counties created to be coincident with the Montana Cadastral Parcel Boundaries. http://geoinfo.msl.mt.gov/home/msdi/cadastral
MT_L3_Ecoregions	poly	Ecoregions by state were extracted from the seamless national shapefile. Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. http://archive.epa.gov/wed/ecoregions/web/html/mt_eco.html
MT_L4_Ecoregions	poly	Ecoregions by state were extracted from the seamless national shapefile. Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. http://archive.epa.gov/wed/ecoregions/web/html/mt_eco.html
OwnerParcel	poly	The Montana Cadastral Database is comprised of taxable parcels (fee land) and public land (exempt property). http://geoinfo.msl.mt.gov/home/msdi/cadastral
PLSSFirstDivision	poly	The PLSS First Division is commonly the section. This is the first set of divisions for a PLSS Township. http://geoinfo.msl.mt.gov/home/msdi/cadastral
PLSSTownship	poly	In the Public Land Survey System, a Township refers to a unit of land that is nominally six miles on a side, usually containing 36 sections. http://geoinfo.msl.mt.gov/home/msdi/cadastral
PublicLands	poly	The Montana Public Lands data contains public administered lands that are recorded in the Montana Department of Revenue's tax appraisal database. Each public land polygon is attributed with the name of the public agency that owns it. The data are derived from the

		statewide Montana Cadastral Parcel layer. http://geoinfo.msl.mt.gov/home/msdi/cadastral
Reservations	poly	Montana Indian Reservation Boundaries were digitized from the U.S. Geological Survey (USGS) 1:250,000 scale maps adjusted to be coincident with the Bureau of Land Management's Geographic Coordinate Database (GCDB) or the USGS 1:24,000 scale Digital Raster Graphics (DRGs). http://geoinfo.msl.mt.gov/home/msdi/cadastral
WBDHU10_MT	poly	This data set is a complete digital hydrologic unit boundary layer of the Watershed (10-digit) 5th level for Montana. http://geoinfo.msl.mt.gov/Home/msdi/hydrologic_units
WBDHU12_MT	poly	This data set is a complete digital hydrologic unit boundary layer of the Subwatershed (12-digit) 6th level for Montana. http://geoinfo.msl.mt.gov/Home/msdi/hydrologic_units
WBDHU8_MT	poly	This data set is a complete digital hydrologic unit boundary layer of the Subbasin (8-digit) 4th level for Montana. http://geoinfo.msl.mt.gov/Home/msdi/hydrologic_units
Wetlands	feature dataset	
mt_wetrip2016	poly	The mt_wetrip2016 feature class represents the extent, type, and approximate location of wetlands, riparian areas, and deepwater habitats in Montana. These data were included from the following sources: the Montana Natural Heritage Program (MTNHP); Historic mapping from the NWI; the Landcover 2015 dataset (wetland and riparian features); and the National Hydrography Dataset (waterbodies, swamps and marshes).
mt_wetrip_quadstatus2016	poly	All USGS quadrangles in Montana and their wetland mapping status, project name, project funder, etc.
Tables		
ConservationEasementHolder	table	Montana lands with conservation easements. This table lists private lands parcels on which a public agency or qualified Land Trust has placed a Conservation Easement in cooperation with the land owner. This table contains the conservation easement holder code (number) and the conservation easement holder name. This table shares a relationship class with the feature class *mt_wetrip2016* titled *mt_wetrip_conease*. This table was exported from the *ConEasements*feature class.

CountyCode	table	This table is a complete list of the codes, names and name abbreviations for all counties in Montana. This table shares a relationship class with the feature class mt_wetrip2016 titled mt_wetrip_conease. This table was exported from the ConEasementsfeature class.
CowardinSpecialModifiers	table	This table contains codes, names and definitions for the Cowardin wetland classification special modifiers. This table shares a relationship class with the feature class *mt_wetrip2016* titled *mt_wetrip_modifier.* This table was created by the MTNHP.
CowardinWaterRegime	table	This table contains codes and definitions for the Cowardin wetland classification water regimes. This table shares a relationship class with the feature class *mt_wetrip2016* titled *mt_wetrip_regime*. This table was created by the MTNHP.
HUC10	table	This table is a complete list of the hydrologic unit boundaries of the Watershed (10-digit) 5th level for Montana. This table was exported from the *WBDHU10_MT* feature class.
HUC12	table	This table is a complete list of the hydrologic unit boundaries of the Watershed (12-digit) 6th level for Montana. This table was exported from the *WBDHU12_MT* feature class.
HUC8	table	This table is a complete list of the hydrologic unit boundaries of the Watershed (8-digit) 4th level for Montana. This table shares a relationship class with the feature class *mt_wetrip2016* titled *mt_wetrip_huc8*. This table was exported from the *WBDHU8_MT* feature class
L1_EcoRegions	table	This table is a complete list of the Level 1 ecoregions in Montana. This table was exported from the *MT_L4_Ecoregions* feature class.
L2_EcoRegions	table	This table is a complete list of the Level 2 ecoregions in Montana. This table was exported from the *MT_L4_Ecoregions* feature class.
L3_EcoRegions	table	This table is a complete list of the Level 3 ecoregions in Montana. This table was exported from the *MT_L4_Ecoregions* feature class.
L4_EcoRegions	table	This table is a complete list of the Level 4 ecoregions in Montana. This table shares a relationship class with the feature class *mt_wetrip2016* titled *mt_wetrip_huc8*. This table was exported from the *MT_L4_Ecoregions*feature class.
NWICode	table	This table contains the National Wetland Inventory (NWI) codes and descriptions for the wetland types, systems, subsystems and classes. This table shares a relationship class with the feature class *mt_wetrip2016*

		titled *mt_wetrip_nwi* linked by the NWI_Code fields. This table was created by the MTNHP.
PublicLandOwnership	table	The Montana Public Lands table contains public administered lands that are recorded in the Montana Department of Revenue's tax appraisal database. This table contains the owner code (number) and the name of the public land owner. Each public land polygon is attributed with the name of the public agency that owns it. The data are derived from the statewide Montana Cadastral Parcel layer. This table shares a relationship class with the feature class *mt_wetrip2016* titled *mt_wetrip_publandowner*.
QuadCode	table	This table is a complete list of the codes and names for the USGS quadrangles in Montana. This table was exported from the *mt_wetrip_quadstatus2016* feature class.
QuadStatusCode	table	This table is a complete list of the mapping status codes and definitions for the USGS quads. This table was created by the MTNHP.
ReservationsCode	table	This table is a complete list of the codes and names of the Indian reservations in Montana. This table was exported from the *Reservations* feature class. This table shares a relationship class with the *mt_wetrip2016* feature class title *mt_wetrip_reservation*.
Raster		
landcover_2015	raster	The Land Cover/Land Use (LCLU) database records all Montana natural vegetation, land cover and land use, classified from satellite and aerial imagery, mapped at a scale of 1:100000, and interpreted with supporting ground-level data. http://geoinfo.msl.mt.gov/Home/msdi/land_use_land_cover
mtreap	raster	Relative Effective Annual Precipitation data for Montana. The data was created by the Montana Natural Resources Conservation Service. REAP is an indicator of the amount of moisture available at a location, taking into account precipitation, slope and aspect, and soil properties. http://mslapps.mt.gov/Geographic_Information/Data/nrcs/reap/

*The attribute table for feature class **mt_wetrip2016** summarizes the information collected in Task 1. Fields in this attribute table are described below.*

UNIQUE_ID: persistent unique identifying code given to each feature.

SOURCE: wetland or riparian mapping data source. Sources include MTNHP modern/current mapping (1); MTNHP historic/outdated mapping (2); select MTNHP Landcover wetland and riparian features (3); and features from the National Hydrography Dataset (NHD) including swamps/marshes and waterbodies (4).

ATTRIBUTE: wetland and riparian habitat type classification codes, based on the Cowardin classification system: https://www.fws.gov/wetlands/Documents/NWI_Wetlands_and_Deepwater_Map_Code_Diagram.pdf

WETLAND_TYPE: type of wetland habitat as defined by the ATTRIBUTE code. The definitions and codes can be found in the geodatabase table *NWICode.*

WATER_REGIME: Cowardin code for water regime definition. Definitions for each water regime are listed in the *CowardinWaterRegime* geodatabase table.

SYSTEM: Cowardin classification code for major wetland systems. The definitions and codes can be found in the geodatabase table *NWICode.*

SUBSYTEM: Cowardin classification code for Lacustrine, Riverine and Riparian subsystems. The definitions and codes can be found in the geodatabase table *NWICode.*

CLASS: Cowardin classification code for major wetland class. The definitions and codes can be found in the geodatabase table *NWICode.*

MAJOR_CLASS: Cowardin classification code for major wetland class.

SPECIAL_MODIFIER: Cowardin classification code for wetland special modifiers. Definitions for each water regime are listed in the *CowardinSpecialModifiers* geodatabase table.

ACRES: feature's area in acres. This field was calculated using GIS.

HECTARES: feature's area in hectares. This field was calculated using GIS.

L1_ECOREG: code for the feature's Level 1 ecoregion. The names and codes can be found in the geodatabase table *L1_EcoRegions*. This field was calculated via intersect.

L2_ECOREG: code for the feature's Level 2 ecoregion. The names and codes can be found in the geodatabase table *L2_EcoRegions*. This field was calculated via intersect.

L3_ECOREG: code for the feature's Level 3 ecoregion. The names and codes can be found in the geodatabase table *L3_EcoRegions*. This field was calculated via intersect.

L4_ECOREG: code for the feature's Level 4 ecoregion. The names and codes can be found in the geodatabase table *L4_EcoRegions*. This field was calculated via intersect.

HUC8: code for the feature's sub-basin hydrologic unit. The sub-basin names and codes can be found in the geodatabase table *HUC8*. This field was calculated via intersect.

HUC10: code for the feature's watershed hydrologic unit. The watershed names and codes can be found in the geodatabase table *HUC10*. This field was calculated via intersect.

HUC12: code for the feature's sub-watershed hydrologic unit. The sub-watershed names and codes can be found in the geodatabase table *HUC12*. This field was calculated via intersect.

COUNTY_CODE: code for the feature's county. The county names and codes can be found in the geodatabase table *CountyCode*. This field was calculated via intersect.

RESERVATION_CODE: code for the Indian Reservation the feature falls within. The reservation names and codes can be found in the geodatabase table *ReservationsCode*. This field was calculated via intersect.

QUAD_CODE: code for the feature's USGS quadrangle (Quad). The quad names and codes can be found in the geodatabase table *QuadCode*. This field was calculated via intersect.

TOWNSHIP: code for the Public Land Survey System (PLSS) Township the feature falls within. This field was calculated via intersect.

RANGE: code for the PLSS Range the feature falls within. This field was calculated via intersect.

SECTION: code for the PLSS Section the feature falls within. This field was calculated via intersect.

PUBLICLANDOWNER: name of the public land owner the feature falls within. The owner names and codes can be found in the geodatabase table *PublicLandOwnership*. This field was calculated via intersect.

CONSERVATIONEASEMENTHOLDER: holder of the conservation easement the feature falls within. The holder names and codes can be found in the geodatabase table *ConservationEasementHolder*. This field was calculated via intersect.

STATE: name of the state the feature falls within. This field was calculated via intersect.

NWI_CODE: this code includes the Cowardin codes for System, Subsystem and Class. The names, definitions and codes can be found in the geodatabase table *NWICode.*

Task 2

*The attribute table for feature class **mt_wetrip2016_prioritization** summarizes the information collected in Task 2. Fields in this attribute table are described below. (For ease of use, they are also stored in **mt_wetrip2016_risk_vulnerability**.)*

RarityScore*:* scored from 0 to 5 (5= most rare). A composite score was calculated from the following: 5 points for wetland types with <100 occurrences statewide. These wetland types were then removed from subsequent analysis (i.e., none of these wetlands were scored on any additional metrics); 1 point for wetland types representing <2% of the statewide total, based on number of features; 1 point for wetland types representing <2% of the statewide total, based on acreage; 1 point for features with acreages ≥ 90^{th} percentile for their wetland type; 1 point for wetland types representing <2% of the total wetlands in a HUC4, based on number of features; 1 point for wetland types representing <2% of the total wetlands in a Level 4 ecoregion, based on number of features.

LndscpCmplxScore*:* scored 0, 3 or 5. 0 if <5 wetlands/ha; 3 if 5-9 wetlands/ha; 5 if >10 wetlands/ha.

HabSigScore: scored from 0 to 8. Scores were determined by adding the *HabSigCnt_Score* (total number of observation records from BIRDPOD/SOC database within buffer and were scored 1 to 5. Additional points were given for direct (2 points) and indirect (1 point) evidence of breeding. Final score is additive.

Headwater1: scored 0 or 1. Value of 1 assigned to wetlands which have their centroids in headwater areas.

Headwater2*:* scored 0 or 1. Value of 1 to wetlands which do not have their centroids in headwater areas, but are located either on steep slopes (>12 degrees) or on mountaintop and ridges.

LndscpCntxtScore: scored 0 or 1. Scored 1 for wetlands with HDI means of 0 and for the next 5% of scores greater than 0. The 5% cutoff value for HDI means was 1.7746.

WetMosScaled: scored 0 to 5. 0 if < than 5 features in mosaic. If > than 5 features, scores were determined by the size of the wetland mosaic (0-5 using natural breaks), the number of wetlands intersecting the mosaic (0-5 using natural breaks); and the diversity of the mosaic (0-5 using natural breaks). The scores were finally scaled by dividing the total by 3.

Task 3

*The attribute table for feature class **mt_wetrip2016_risk_vulnerability** summarizes the information collected in Task 3. Fields in this attribute table related to Task 3 are described below.*

pct_exurban: percent of wetland that would get converted to exurban development by 2030, based on the EPA Integrated Climate and Land-Use Scenarios.

exurban: exurban development class, derived from pct_exurban as follows: 0% of wetland converted = 0, 1-20% = 1, 21-40% = 2, 41-60% = 3, 61-80% = 4, 81-100% = 5.

pct_lulc: percent of wetland that would get converted to human land use (Mechanically Disturbed, Agriculture/Hay/Pasture, Mining, Developed) or to barren by 2030, based on the Intergovernmental Panel on Climate Change Special Report on Emission scenario A1B (moderate population growth, high economic growth, rapid technological innovations, balanced energy use).

lulc: land use land cover class, derived from pct_lulc as follows: 0% of wetland converted = 0, 1-20% = 1, 21-40% = 2, 41-60% = 3, 61-80% = 4, 81-100% = 5.

pct_oilgas: percent of wetland with high oil and gas development potential, based on a model developed from seven predictive variables and USFWP data on producing and non-producing wells.

oilgas: oil and gas development potential class, derived from pct_oilgas as follows: 0% of wetland overlapping the oil and gas model = 0, 1-20% = 1, 21-40% = 2, 41-60% = 3, 61-80% = 4, 81-100% = 5.

pct_wbd: percent of wetland with a positive Water Balance Deficit defined as a linear increase in water deficit over 30 years and calculated as the difference between Potential Evapo-Transpiration and Precipitation averaged for 12 months for four years (1981, 1991, 2001, 2011).

WBD: Water Balance Deficit class, derived from pct_wbd as follows: 0% of wetland with a positive WBD = 0, 1-20% = 1, 21-40% = 2, 41-60% = 3, 61-80% = 4, 81-100% = 5.

avg_crop: average cropland conversion risk score, ranging from 1 (lowest) to 8 (highest), based on the NRCS SSURGO's Non-Irrigated Capability Class and several modifiers (proximity to existing cropland, proximity to roads, precipitation zone).

Cropland: cropland conversion risk class derived from avg_score by rescaling 1-8 values to 0-5, to match the other measures of risk.

HDImn: Human Disturbance Index score extracted for each wetland buffered by 300m.

HDI: Human Disturbance Index class, derived from HDImn using cutoff values provided by the ArcGIS “Natural Breaks” classification scheme: HDImn 0 = 0, 1 – 368 = 1, 369 – 833 = 2, 834 – 1310 = 3, 1311 – 1893 = 4, >= 1894 = 5.

ATTRIBUTE: wetland type, based on the Cowardin classification system: http://www.fws.gov/wetlands/Data/Wetland-Codes.html

Task 4

*The attribute table for feature class **mt_wetrip2016_risk_vulnerability** summarizes the information collected in Task 4. Fields in this attribute table related to Task 4 are described below.*

Sum_prioritization: A global prioritization score computed for each wetland through simple addition of the six scores: Rarity, Landscape Complex, Wetland Mosaic, Habitat Significance, Headwater, and Landscape Context. Statewide, it ranges from 0 to a maximum value of 27.

Sum_vulnerability: A global vulnerability score computed for each wetland through simple addition of six scores: Exurban, Land Use Land Cover, Oil and Gas, Water Balance Deficit, Cropland, and Human Disturbance Index. Statewide, it ranges from 0 to a maximum value of 27.

GiZScore Fixed <#>: Z-score for each wetland

GiPValue Fixed <#>: P-value for each wetland

Gi_Bin_Fixed <#>_FDR: this field identifies statistically significant hot and cold spots, corrected for multiple testing and spatial dependence using the False Discovery Rate (FDR) correction method.

refers to a numeric value that is a function of the area processed.

APPENDIX B. Tables with distribution of wetland types for six measures of risk/vulnerability (Task 3).

Table A1. Distribution of wetland types among 2 classes of potential exurban development between 2010 and 2030. 0 = none, 5 >= 1% of wetland polygon in class. Values presented as number of wetlands instead of percent because all values in class 5 would be less than 1%.

		Exurban class	
Wetland	*N total*	0	5
L1ABH	3	3	
L1UBC	2	2	
L1UBF	23	23	
L1UBG	6	6	
L1UBH	838	830	8
L2ABF	97	97	
L2ABG	318	315	3
L2ABH	50	49	1
L2EMA	29	29	
L2EMC	10	10	
L2EMF	37	37	
L2EMH	7	7	
L2UBF	15	15	
L2UBG	17	17	
L2UBH	88	88	
L2USA	336	335	1
L2USC	415	415	
L2USG	1	1	
PABC	473	473	
PABF	63573	63446	127
PABFb	8894	8881	13
PABG	3716	3713	3
PABGb	6546	6528	18
PABH	1467	1463	4
PABHb	99	99	
PABK	2	2	
PEMA	317229	316307	922
PEMAb	72	72	
PEMB	13892	13875	17
PEMBb	48	48	
PEMC	131799	131434	365
PEMCb	1292	1292	
PEME	381	381	
PEMF	12778	12726	52
PEMFb	360	359	1
PEMG	1	1	
PEMGb	2	2	
PEMH	8	8	
PEMJ	7261	7261	
PEMK	2	2	
PFOA	15586	15485	101
PFOAb	11	11	
PFOB	362	362	

PFOC	560	557	3
PFOCb	13	13	
PFOF	1	1	
PFOGb	2	2	
PSSA	81201	80650	551
PSSAb	215	215	
PSSB	1778	1767	11
PSSBb	135	135	
PSSC	15482	15378	104
PSSCb	847	844	3
PSSF	517	516	1
PSSFb	94	94	
PSSG	2	2	
PSSGb	1	1	
PSSJ	996	996	
PUBF	2522	2521	1
PUBFb	7	7	
PUBG	458	458	
PUBH	1046	1038	8
PUBHb	8	8	
PUSA	12194	12191	3
PUSAb	3	3	
PUSB	90	90	
PUSC	7957	7947	10
PUSCb	218	218	
PUSJ	785	785	
Sum	715278	712947	2331

Table A2. Distribution of wetland types among 2 classes of land use/land cover conversion between 2015 and 2030. 0 = none, 5 >= 1% of wetland polygon in class. Values presented as number of wetlands with percent for class 5 in parentheses.

		Land use/land cover Class	
Wetland	*N total*	0	5
L1ABH	3	3	
L1UBC	2	1	1 (50)
L1UBF	23	23	
L1UBG	6	6	
L1UBH	838	791	47 (5.61)
L2ABF	97	85	12 (12.37)
L2ABG	318	298	20 (6.29)
L2ABH	50	42	8 (16)
L2EMA	29	27	2 (6.90)
L2EMC	10	9	1 (10)
L2EMF	37	34	3 (8.11)
L2EMH	7	7	
L2UBF	15	14	1 (6.67)
L2UBG	17	16	1 (5.88)
L2UBH	88	86	2 (2.27)
L2USA	336	305	31 (9.23)
L2USC	415	395	20 (4.82)
L2USG	1	1	
PABC	473	462	11 (2.33)

PABF	63573	62132	1441 (2.27)
PABFb	8894	8716	178 (2)
PABG	3716	3641	75 (2.02)
PABGb	6546	6421	125 (1.91)
PABH	1467	1443	24 (1.64)
PABHb	99	96	3 (3.03)
PABK	2	2	
PEMA	317229	304377	12852 (4.05)
PEMAb	72	71	1 (1.39)
PEMB	13892	13382	510 (3.67)
PEMBb	48	47	1 (2.08)
PEMC	131799	126353	5446 (4.13)
PEMCb	1292	1251	41 (3.17)
PEME	381	373	8 (2.10)
PEMF	12778	12283	495 (3.87)
PEMFb	360	344	16 (4.44)
PEMG	1	1	
PEMGb	2	2	
PEMH	8	8	
PEMJ	7261	6529	732 (10.08)
PEMK	2	2	
PFOA	15586	14802	784 (5.03)
PFOAb	11	11	
PFOB	362	348	14 (3.87)
PFOC	560	534	26 (4.64)
PFOCb	13	11	2 (15.38)
PFOF	1	1	
PFOGb	2	2	
PSSA	81201	78351	2850 (3.51)
PSSAb	215	209	6 (2.79)
PSSB	1778	1730	48 (2.70)
PSSBb	135	132	3 (2.22)
PSSC	15482	14938	544 (3.51)
PSSCb	847	813	34 (4.01)
PSSF	517	501	16 (3.09)
PSSFb	94	91	3 (3.19)
PSSG	2	2	
PSSGb	1	1	
PSSJ	996	983	13 (1.31)
PUBF	2522	2492	30 (1.19)
PUBFb	7	7	
PUBG	458	457	1 (0.22)
PUBH	1046	1015	31 (2.96)
PUBHb	8	7	1 (12.50)
PUSA	12194	11708	486 (3.99)
PUSAb	3	3	
PUSB	90	89	1 (1.11)
PUSC	7957	7738	219 (2.75)
PUSCb	218	207	11 (5.05)
PUSJ	785	751	34 (4.33)
Sum	715278	688013	27265 (3.81)

Table A3. Distribution of wetland types among 2 classes of oil and gas potential development. 0 = none, 5 >= 1% of wetland polygon in class. Values presented as number of wetlands with percent for class 5 in parentheses.

		Oil and gas class	
Wetland	*N total*	0	5
L1ABH	3	3	
L1UBC	2	2	
L1UBF	23	22	1 (4.35)
L1UBG	6	6	
L1UBH	838	838	
L2ABF	97	83	14 (14.43)
L2ABG	318	278	40 (12.58)
L2ABH	50	50	
L2EMA	29	24	5 (17.24)
L2EMC	10	7	3 (30)
L2EMF	37	28	9 (24.32)
L2EMH	7	7	
L2UBF	15	15	
L2UBG	17	15	2 (11.76)
L2UBH	88	88	
L2USA	336	248	88 (26.19)
L2USC	415	332	83 (20)
L2USG	1	1	
PABC	473	473	
PABF	63573	60078	3495 (5.50)
PABFb	8894	8434	460 (5.17)
PABG	3716	3689	27 (0.73)
PABGb	6546	6467	79 (1.21)
PABH	1467	1462	5 (0.34)
PABHb	99	99	
PABK	2	2	
PEMA	317229	292291	24938 (7.86)
PEMAb	72	71	1 (1.39)
PEMB	13892	13663	229 (1.65)
PEMBb	48	48	
PEMC	131799	120082	11717 (8.89)
PEMCb	1292	1100	192 (14.86)
PEME	381	381	
PEMF	12778	11929	849 (6.64)
PEMFb	360	353	7 (1.94)
PEMG	1	1	
PEMGb	2	2	
PEMH	8	8	
PEMJ	7261	4977	2284 (31.46)
PEMK	2	2	
PFOA	15586	15557	29 (0.19)
PFOAb	11	11	
PFOB	362	362	
PFOC	560	557	3 (0.54)
PFOCb	13	13	
PFOF	1	1	
PFOGb	2	2	
PSSA	81201	80456	745 (0.92)

PSSAb	215	193	22 (10.23)
PSSB	1778	1777	1 (0.06)
PSSBb	135	135	
PSSC	15482	15308	174 (1.12)
PSSCb	847	810	37 (4.37)
PSSF	517	507	10 (1.93)
PSSFb	94	91	3 (3.19)
PSSG	2		2 (100)
PSSGb	1	1	
PSSJ	996	863	133 (13.35)
PUBF	2522	2502	20 (0.79)
PUBFb	7	7	
PUBG	458	458	
PUBH	1046	1046	
PUBHb	8	8	
PUSA	12194	11008	1186 (9.73)
PUSAb	3	3	
PUSB	90	90	
PUSC	7957	7285	672 (8.45)
PUSCb	218	216	2 (0.92)
PUSJ	785	588	197 (25.10)
Sum	715278	667514	47764 (6.68)

Table A4a. Distribution of wetland types among 6 classes of Human Disturbance Index. 0 = none, 1 = 1-20%, 2 = 20-40%, 3 = 40-60%, 4 = 60-80%, 5 >= 80% of wetland polygon in class. Values presented as number of wetlands.

		Human disturbance index class					
Wetland	*N total*	0	1	2	3	4	5
L1ABH	3	1	1		1		
L1UBC	2	1		1			
L1UBF	23	4	1	3	6	5	4
L1UBG	6	3		2	1		
L1UBH	838	606	132	59	34	5	2
L2ABF	97	7	25	28	23	13	1
L2ABG	318	60	41	109	75	28	5
L2ABH	50	5	4	21	16	4	
L2EMA	29	3	10	9	5	2	
L2EMC	10		5	3	2		
L2EMF	37	1	8	19	9		
L2EMH	7	4	1	2			
L2UBF	15	3	3	5	4		
L2UBG	17	7	3	4	1	2	
L2UBH	88	67	5	6	8	2	
L2USA	336	72	74	101	63	18	8
L2USC	415	109	115	115	53	17	6
L2USG	1			1			
PABC	473	172	184	50	41	18	8
PABF	63573	11508	14907	13020	11525	8827	3786
PABFb	8894	972	3270	2367	1490	665	130
PABG	3716	2416	789	240	139	102	30
PABGb	6546	1337	3026	1248	593	314	28

PABH	1467	75	96	157	364	584	191
PABHb	99	50	36	12		1	
PABK	2						2
PEMA	317229	56333	85200	67966	61849	34811	11070
PEMAb	72	3	27	18	15	8	1
PEMB	13892	3500	3775	2939	2372	1169	137
PEMBb	48	10	16	14	7		1
PEMC	131799	25151	32696	27262	25535	15766	5389
PEMCb	1292	83	462	356	249	131	11
PEME	381	20	5	29	69	173	85
PEMF	12778	1675	2554	2420	2540	2474	1115
PEMFb	360	36	94	114	71	27	18
PEMG	1			1			
PEMGb	2						2
PEMH	8	1	1	3	3		
PEMJ	7261	697	3395	1954	1032	175	8
PEMK	2				1	1	
PFOA	15586	4080	3580	3679	2020	1520	707
PFOAb	11	1	1	8		1	
PFOB	362	40	101	119	48	39	15
PFOC	560	143	200	88	50	58	21
PFOCb	13	1	1	6		5	
PFOF	1						1
PFOGb	2			2			
PSSA	81201	13658	20444	18635	13251	10737	4476
PSSAb	215	17	78	50	41	26	3
PSSB	1778	398	671	452	148	67	42
PSSBb	135	25	91	11	5	3	
PSSC	15482	2879	4411	3443	2243	1849	657
PSSCb	847	60	281	265	153	77	11
PSSF	517	85	134	106	88	86	18
PSSFb	94	14	26	30	15	9	
PSSG	2					1	1
PSSGb	1		1				
PSSJ	996	49	470	312	142	23	
PUBF	2522	1464	184	296	361	181	36
PUBFb	7			1	1	5	
PUBG	458	421	31	6			
PUBH	1046	388	259	82	92	163	62
PUBHb	8	2	4	2			
PUSA	12194	1863	3614	2728	2519	1118	352
PUSAb	3		2		1		
PUSB	90	1	6	12	49	19	3
PUSC	7957	1553	2467	1717	1295	695	230
PUSCb	218	6	59	48	59	44	2
PUSJ	785	59	284	274	149	18	1
Sum	715278	132199	188361	153030	130926	82086	28676

Table A4b. Distribution of wetland types among 6 classes of Human Disturbance Index. 0 = none, 1 = 1-20%, 2 = 20-40%, 3 = 40-60%, 4 = 60-80%, 5 >= 80% of wetland polygon in class. Values presented as percent.

		Human disturbance index class					
Wetland	*N total*	0	1	2	3	4	5
L1ABH	3	33.33	33.33		33.33		
L1UBC	2	50.00		50.00			
L1UBF	23	17.39	4.35	13.04	26.09	21.74	17.39
L1UBG	6	50.00		33.33	16.67		
L1UBH	838	72.32	15.75	7.04	4.06	0.60	0.24
L2ABF	97	7.22	25.77	28.87	23.71	13.40	1.03
L2ABG	318	18.87	12.89	34.28	23.58	8.81	1.57
L2ABH	50	10.00	8.00	42.00	32.00	8.00	
L2EMA	29	10.34	34.48	31.03	17.24	6.90	
L2EMC	10		50.00	30.00	20.00		
L2EMF	37	2.70	21.62	51.35	24.32		
L2EMH	7	57.14	14.29	28.57			
L2UBF	15	20.00	20.00	33.33	26.67		
L2UBG	17	41.18	17.65	23.53	5.88	11.76	
L2UBH	88	76.14	5.68	6.82	9.09	2.27	
L2USA	336	21.43	22.02	30.06	18.75	5.36	2.38
L2USC	415	26.27	27.71	27.71	12.77	4.10	1.45
L2USG	1			100.00			
PABC	473	36.36	38.90	10.57	8.67	3.81	1.69
PABF	63573	18.10	23.45	20.48	18.13	13.88	5.96
PABFb	8894	10.93	36.77	26.61	16.75	7.48	1.46
PABG	3716	65.02	21.23	6.46	3.74	2.74	0.81
PABGb	6546	20.42	46.23	19.07	9.06	4.80	0.43
PABH	1467	5.11	6.54	10.70	24.81	39.81	13.02
PABHb	99	50.51	36.36	12.12		1.01	
PABK	2						100.00
PEMA	317229	17.76	26.86	21.42	19.50	10.97	3.49
PEMAb	72	4.17	37.50	25.00	20.83	11.11	1.39
PEMB	13892	25.19	27.17	21.16	17.07	8.41	0.99
PEMBb	48	20.83	33.33	29.17	14.58		2.08
PEMC	131799	19.08	24.81	20.68	19.37	11.96	4.09
PEMCb	1292	6.42	35.76	27.55	19.27	10.14	0.85
PEME	381	5.25	1.31	7.61	18.11	45.41	22.31
PEMF	12778	13.11	19.99	18.94	19.88	19.36	8.73
PEMFb	360	10.00	26.11	31.67	19.72	7.50	5.00
PEMG	1			100.00			
PEMGb	2						100.00
PEMH	8	12.50	12.50	37.50	37.50		
PEMJ	7261	9.60	46.76	26.91	14.21	2.41	0.11
PEMK	2				50.00	50.00	
PFOA	15586	26.18	22.97	23.60	12.96	9.75	4.54
PFOAb	11	9.09	9.09	72.73		9.09	
PFOB	362	11.05	27.90	32.87	13.26	10.77	4.14
PFOC	560	25.54	35.71	15.71	8.93	10.36	3.75
PFOCb	13	7.69	7.69	46.15	0.00	38.46	
PFOF	1						100.00
PFOGb	2			100.00			
PSSA	81201	16.82	25.18	22.95	16.32	13.22	5.51

PSSAb	215	7.91	36.28	23.26	19.07	12.09	1.40
PSSB	1778	22.38	37.74	25.42	8.32	3.77	2.36
PSSBb	135	18.52	67.41	8.15	3.70	2.22	
PSSC	15482	18.60	28.49	22.24	14.49	11.94	4.24
PSSCb	847	7.08	33.18	31.29	18.06	9.09	1.30
PSSF	517	16.44	25.92	20.50	17.02	16.63	3.48
PSSFb	94	14.89	27.66	31.91	15.96	9.57	
PSSG	2					50.00	50.00
PSSGb	1		100.00				
PSSJ	996	4.92	47.19	31.33	14.26	2.31	
PUBF	2522	58.05	7.30	11.74	14.31	7.18	1.43
PUBFb	7			14.29	14.29	71.43	
PUBG	458	91.92	6.77	1.31			
PUBH	1046	37.09	24.76	7.84	8.80	15.58	5.93
PUBHb	8	25.00	50.00	25.00			
PUSA	12194	15.28	29.64	22.37	20.66	9.17	2.89
PUSAb	3		66.67		33.33		
PUSB	90	1.11	6.67	13.33	54.44	21.11	3.33
PUSC	7957	19.52	31.00	21.58	16.27	8.73	2.89
PUSCb	218	2.75	27.06	22.02	27.06	20.18	0.92
PUSJ	785	7.52	36.18	34.90	18.98	2.29	0.13
Sum	715278	18.48	26.33	21.39	18.30	11.48	4.01

Table A5. Distribution of wetland types among 2 classes of Water Balance Deficit between 1981 and 2011. 0 <20%, 5 >= 20% of wetland polygon in class. Values presented as number of wetlands with percent for class 5 in parentheses.

		Water balance deficit class		
Wetland	*N total*	0	5	
L1ABH	3	3		
L1UBC	2	2		
L1UBF	23	19	4	(17.39)
L1UBG	6	5	1	(16.67)
L1UBH	838	794	44	(5.25)
L2ABF	97	81	16	(16.49)
L2ABG	318	315	3	(0.94)
L2ABH	50	49	1	(2.00)
L2EMA	29	22	7	(24.14)
L2EMC	10	7	3	(30.00)
L2EMF	37	36	1	(2.70)
L2EMH	7	5	2	(28.57)
L2UBF	15	8	7	(46.67)
L2UBG	17	17		
L2UBH	88	88		
L2USA	336	298	38	(11.31)
L2USC	415	387	28	(6.75)
L2USG	1	1		
PABC	473	436	37	(7.82)
PABF	63573	55503	8070	(12.69)
PABFb	8894	8078	816	(9.17)
PABG	3716	3528	188	(5.06)

PABGb	6546	6051	495	(7.56)
PABH	1467	1403	64	(4.36)
PABHb	99	86	13	(13.13)
PABK	2	2		
PEMA	317229	283050	34179	(10.77)
PEMAb	72	52	20	(27.78)
PEMB	13892	11349	2543	(18.31)
PEMBb	48	34	14	(29.17)
PEMC	131799	119951	11848	(8.99)
PEMCb	1292	1247	45	(3.48)
PEME	381	379	2	(0.52)
PEMF	12778	11241	1357	(10.62)
PEMFb	360	327	33	(9.17)
PEMG	1	1		
PEMGb	2	2		
PEMH	8	8		
PEMJ	7261	6774	487	(6.71)
PEMK	2	2		
PFOA	15586	13911	1675	(10.75)
PFOAb	11	10	1	(9.09)
PFOB	362	346	16	(4.42)
PFOC	560	540	20	(3.57)
PFOCb	13	13		
PFOF	1	1		
PFOGb	2	2		
PSSA	81201	73032	8169	(10.06)
PSSAb	215	203	12	(5.58)
PSSB	1778	1619	159	(8.94)
PSSBb	135	105	30	(22.22)
PSSC	15482	14348	1134	(7.32)
PSSCb	847	771	76	(8.97)
PSSF	517	472	45	(8.70)
PSSFb	94	93	1	(1.06)
PSSG	2	2		
PSSGb	1	1		
PSSJ	996	727	269	(27.01)
PUBF	2522	2403	119	(4.72)
PUBFb	7	3	4	(57.14)
PUBG	458	452	6	(1.31)
PUBH	1046	1022	24	(2.29)
PUBHb	8	8		
PUSA	12194	10415	1779	(14.59)
PUSAb	3	2	1	(33.33)
PUSB	90	27	63	(70.00)
PUSC	7957	7030	927	(11.65)
PUSCb	218	188	30	(13.76)
PUSJ	785	711	74	(9.43)
Sum	715278	640098	75180	(10.51)

Table A6a. Distribution of wetland types among 6 classes of Cropland. 0 = none, 1 = 1-20%, 2 = 20-40%, 3 = 40-60%, 4 = 60-80%, 5 >= 80% of wetland polygon in class. Values presented as number of wetlands.

		Cropland class					
Wetland	*N total*	0	1	2	3	4	5
L1ABH	3	2				1	
L1UBC	2					2	
L1UBF	23	8			1	14	
L1UBG	6	3			1	1	1
L1UBH	838	757		19	34	21	7
L2ABF	97	38		7	18	26	8
L2ABG	318	137		24	66	70	21
L2ABH	50	31		9	2	7	1
L2EMA	29	13		1	1	12	2
L2EMC	10	3		4		3	
L2EMF	37	30			1	5	1
L2EMH	7	7					
L2UBF	15	13		1	1		
L2UBG	17	11		1	2	2	1
L2UBH	88	81		1	2	4	
L2USA	336	208		39	33	51	5
L2USC	415	260	1	43	49	49	13
L2USG	1	1					
PABC	473	295		28	50	71	29
PABF	63573	28751	217	7809	7097	15892	3807
PABFb	8894	4505		705	1557	1653	474
PABG	3716	3105	1	315	174	108	13
PABGb	6546	2373	4	1084	1770	770	545
PABH	1467	238		6	108	973	142
PABHb	99	93		2	3	1	
PABK	2					2	
PEMA	317229	125818	1332	33166	36275	100324	20314
PEMAb	72	28		4	14	24	2
PEMB	13892	7941	15	1049	1613	2459	815
PEMBb	48	24		7	8	8	1
PEMC	131799	55950	259	13704	16916	35076	9894
PEMCb	1292	566		39	234	285	168
PEME	381	33		63	98	111	76
PEMF	12778	5265	10	1120	1595	3874	914
PEMFb	360	177		6	27	92	58
PEMG	1	1					
PEMGb	2	2					
PEMH	8	1					7
PEMJ	7261	3214	5	576	653	2749	64
PEMK	2					1	1
PFOA	15586	11968		490	1106	1557	465
PFOAb	11	6					5
PFOB	362	235		9	48	56	14
PFOC	560	412		28	40	68	12
PFOCb	13	2			2	1	8
PFOF	1				1		
PFOGb	2						2
PSSA	81201	46748	6	7218	9533	14429	3267

PSSAb	215	98		11	40	41	25
PSSB	1778	1230		86	223	188	51
PSSBb	135	59		27	26	13	10
PSSC	15482	9567	1	1289	1752	2401	472
PSSCb	847	443		54	104	115	131
PSSF	517	310		31	50	97	29
PSSFb	94	56		4	18	12	4
PSSG	2					2	
PSSGb	1	1					
PSSJ	996	181	11	257	287	232	28
PUBF	2522	1962		26	42	433	59
PUBFb	7				4		3
PUBG	458	453		1		4	
PUBH	1046	688		29	58	235	36
PUBHb	8	8					
PUSA	12194	3741	78	1806	1518	4501	550
PUSAb	3	1		1			1
PUSB	90	19		8	8	43	12
PUSC	7957	2901	77	1028	1012	2464	475
PUSCb	218	128		5	11	60	14
PUSJ	785	239	2	258	146	133	7
Sum	715278	321439	2019	72498	84432	191826	43064

Table A6b. Distribution of wetland types among 6 classes of Cropland. 0 = none, 1 = 1-20%, 2 = 20-40%, 3 = 40-60%, 4 = 60-80%, 5 >= 80% of wetland polygon in class. Values presented as percent.

		Cropland class					
Wetland	*N total*	0	1	2	3	4	5
L1ABH	3	66.67	0.00	0.00	0.00	33.33	0.00
L1UBC	2	0.00	0.00	0.00	0.00	100.00	0.00
L1UBF	23	34.78	0.00	0.00	4.35	60.87	0.00
L1UBG	6	50.00	0.00	0.00	16.67	16.67	16.67
L1UBH	838	90.33	0.00	2.27	4.06	2.51	0.84
L2ABF	97	39.18	0.00	7.22	18.56	26.80	8.25
L2ABG	318	43.08	0.00	7.55	20.75	22.01	6.60
L2ABH	50	62.00	0.00	18.00	4.00	14.00	2.00
L2EMA	29	44.83	0.00	3.45	3.45	41.38	6.90
L2EMC	10	30.00	0.00	40.00	0.00	30.00	0.00
L2EMF	37	81.08	0.00	0.00	2.70	13.51	2.70
L2EMH	7	100.00	0.00	0.00	0.00	0.00	0.00
L2UBF	15	86.67	0.00	6.67	6.67	0.00	0.00
L2UBG	17	64.71	0.00	5.88	11.76	11.76	5.88
L2UBH	88	92.05	0.00	1.14	2.27	4.55	0.00
L2USA	336	61.90	0.00	11.61	9.82	15.18	1.49
L2USC	415	62.65	0.24	10.36	11.81	11.81	3.13
L2USG	1	100.00	0.00	0.00	0.00	0.00	0.00
PABC	473	62.37	0.00	5.92	10.57	15.01	6.13
PABF	63573	45.23	0.34	12.28	11.16	25.00	5.99
PABFb	8894	50.65	0.00	7.93	17.51	18.59	5.33
PABG	3716	83.56	0.03	8.48	4.68	2.91	0.35
PABGb	6546	36.25	0.06	16.56	27.04	11.76	8.33
PABH	1467	16.22	0.00	0.41	7.36	66.33	9.68

PABHb	99	93.94	0.00	2.02	3.03	1.01	0.00
PABK	2	0.00	0.00	0.00	0.00	100.00	0.00
PEMA	317229	39.66	0.42	10.45	11.43	31.63	6.40
PEMAb	72	38.89	0.00	5.56	19.44	33.33	2.78
PEMB	13892	57.16	0.11	7.55	11.61	17.70	5.87
PEMBb	48	50.00	0.00	14.58	16.67	16.67	2.08
PEMC	131799	42.45	0.20	10.40	12.83	26.61	7.51
PEMCb	1292	43.81	0.00	3.02	18.11	22.06	13.00
PEME	381	8.66	0.00	16.54	25.72	29.13	19.95
PEMF	12778	41.20	0.08	8.77	12.48	30.32	7.15
PEMFb	360	49.17	0.00	1.67	7.50	25.56	16.11
PEMG	1	100.00	0.00	0.00	0.00	0.00	0.00
PEMGb	2	100.00	0.00	0.00	0.00	0.00	0.00
PEMH	8	12.50	0.00	0.00	0.00	0.00	87.50
PEMJ	7261	44.26	0.07	7.93	8.99	37.86	0.88
PEMK	2	0.00	0.00	0.00	0.00	50.00	50.00
PFOA	15586	76.79	0.00	3.14	7.10	9.99	2.98
PFOAb	11	54.55	0.00	0.00	0.00	0.00	45.45
PFOB	362	64.92	0.00	2.49	13.26	15.47	3.87
PFOC	560	73.57	0.00	5.00	7.14	12.14	2.14
PFOCb	13	15.38	0.00	0.00	15.38	7.69	61.54
PFOF	1	0.00	0.00	0.00	100.00	0.00	0.00
PFOGb	2	0.00	0.00	0.00	0.00	0.00	100.00
PSSA	81201	57.57	0.01	8.89	11.74	17.77	4.02
PSSAb	215	45.58	0.00	5.12	18.60	19.07	11.63
PSSB	1778	69.18	0.00	4.84	12.54	10.57	2.87
PSSBb	135	43.70	0.00	20.00	19.26	9.63	7.41
PSSC	15482	61.79	0.01	8.33	11.32	15.51	3.05
PSSCb	847	52.30	0.00	6.38	12.28	13.58	15.47
PSSF	517	59.96	0.00	6.00	9.67	18.76	5.61
PSSFb	94	59.57	0.00	4.26	19.15	12.77	4.26
PSSG	2	0.00	0.00	0.00	0.00	100.00	0.00
PSSGb	1	100.00	0.00	0.00	0.00	0.00	0.00
PSSJ	996	18.17	1.10	25.80	28.82	23.29	2.81
PUBF	2522	77.80	0.00	1.03	1.67	17.17	2.34
PUBFb	7	0.00	0.00	0.00	57.14	0.00	42.86
PUBG	458	98.91	0.00	0.22	0.00	0.87	0.00
PUBH	1046	65.77	0.00	2.77	5.54	22.47	3.44
PUBHb	8	100.00	0.00	0.00	0.00	0.00	0.00
PUSA	12194	30.68	0.64	14.81	12.45	36.91	4.51
PUSAb	3	33.33	0.00	33.33	0.00	0.00	33.33
PUSB	90	21.11	0.00	8.89	8.89	47.78	13.33
PUSC	7957	36.46	0.97	12.92	12.72	30.97	5.97
PUSCb	218	58.72	0.00	2.29	5.05	27.52	6.42
PUSJ	785	30.45	0.25	32.87	18.60	16.94	0.89
Sum	715278	44.94	0.28	10.14	11.80	26.82	6.02