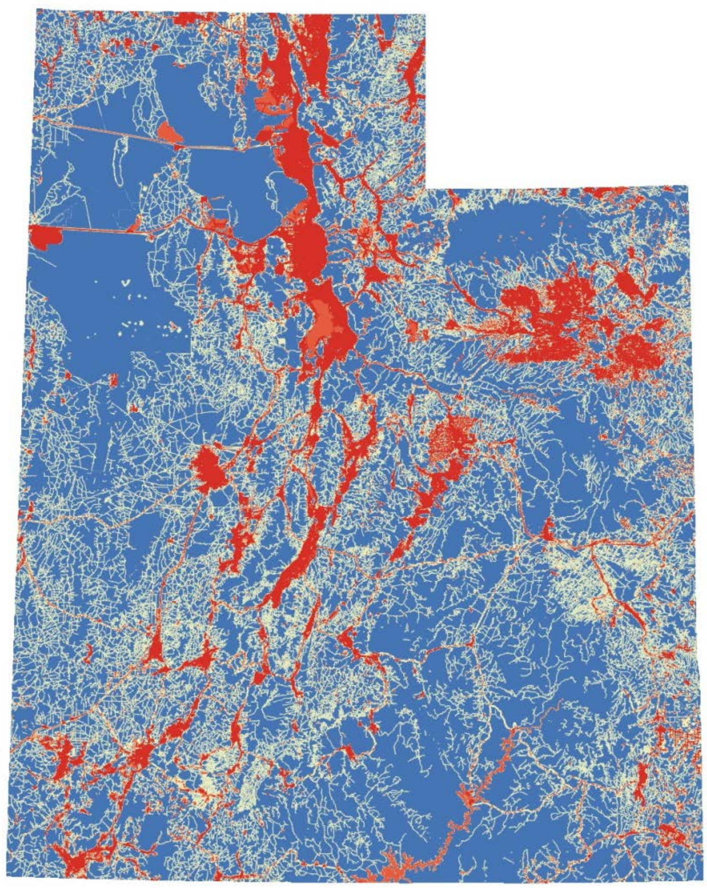
Landscape Integrity Model for Utah's Wetlands



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Cover:
Landscape stress model for the state of Utah. Red represents areas of high stress and blue represents areas of low stress.

Disclaimer

Executive Summary

Though wetland and aquatic resources constitute a minor component of the landscape in Utah, they provide diverse ecosystem services including water-quality enhancement, sediment storage, and nutrient cycling, as well as critical habitat for wildlife and other biota. Spatial data for these unique and valuable systems are limited in scope and insufficient at detailing system location, area, use, and condition. The aim of this project was to create a spatial dataset showing the distribution and intensity of stressors on wetland and aquatic resources in Utah. The project includes a literature review of studies that model aggregated aquatic stressors, a compilation of spatial stressor data, the development of a landscape integrity model, and the application of the landscape model to a target wildlife species and to wetlands and aquatic habitats. The landscape integrity model is a step towards the development of a comprehensive monitoring and assessment program in the state and can provide managers with a valuable decision-making tool.

We reviewed over 30 relevant scientific articles and reports, creating narrative and spreadsheet-based summaries of each. Results of the review include a list of variables used in each study and the source of the variable data. Land cover and road data were the most commonly used variables in the reviewed literature, followed by resource extraction, water quality, and hydrologic modification. Many studies used whole-watershed variables in their models, particularly for hydrologic variables such as the total upstream water withdrawal or upstream miles of canals per miles of natural stream. Unfortunately, calculation of these types of variables was beyond the scope of this project. We combined Utah geospatial data with obtainable data from the reviewed literature to create a relevant geospatial dataset for this project. We then explored the utility of data sources by evaluating accuracy compared to aerial imagery and comparing similar data layers to determine the most appropriate data for use. We created a document that lists the data used in our model, the strengths and weaknesses of the data, and the recommended processing steps. We also documented data that was considered for use, but ultimately excluded from analysis as well as data that was unavailable.

Our model focuses on local stressors to aquatic resources rather than watershed-based stressors for two main reasons. First, we did not have variables available at the scale of the whole upstream watershed and did not have time and funding to compute such variables. Second, based on our literature review, many wetlands are most affected by stressors within a few hundred to one thousand meters, except wetlands directly connected to stream flows. We assigned a weight to stressors based on their probable severity and different decay functions based on the distance at which the stressor was assumed to no longer impact a site. Our model is most appropriate for use with more isolated aquatic systems and much less appropriate for estimating in-stream conditions. We created a 30-m resolution final landscape stress model as an ArcGIS raster as well as 30-m resolution rasters for the modeled stress effect of each individual stressor.

We applied the landscape model to key aquatic habitats used in the Utah Department of Wildlife Resource’s Wildlife Action Plan. The key aquatic habitats in the Wildlife Action Plan include emergent, scrub-shrub, and forested wetlands, riverine wetlands, and open water. We divided the open water wetlands into limnetic (deepwater), littoral (shallow lake), and palustrine (pond) categories to distinguish between different types of open water habitat. We found that forested wetlands are the least common aquatic habitat by area and experience the highest levels of landscape stress. The model showed that limnetic and littoral open water systems have the lowest levels of stress by area, but total stress may

underestimated if many of these lakes are connected to larger rivers and streams. We present our landscape model results in a series of tables summarized by key aquatic habitat and Level III Omernik Ecoregion and in maps showing data summarized by key aquatic habitat and stress level per HUC8. We also include summarized geospatial data for each wetland polygon in the state that can be used to create customized data viewing.

We applied the landscape model to Western toad (*Anaxyrus boreas*). We attempted to use data from the Utah Diversion of Wildlife Resource's Ecological Integrity Tables to better understand wetland types and landscape features suitable for this species. However, most of the values in the tables either did not correspond with actual Western toad locations in the state or could not be used with the available geospatial data. We focused on Western toad habitat within the Wasatch and Uinta Mountains Level 3 Ecoregion and used elevation and summer temperature thresholds to assign the landscape to most suitable, moderately suitable, and least suitable categories. Most wetland area in the study is in least or moderately suitable categories based on elevation and temperature class; less than a third of all wetland area is in the most suitable habitat category. Of the most suitable habitat, however, little area is in poor condition based on the landscape stress data, whereas about 13% is modeled as very good. Results of the Western toad analysis are presented in tables and figures in this report and are also available as geospatial data for custom viewing.

Our model is statewide and can be applied to individual wetlands to determine landscape stress. However, it is important to note some key limitations of this work. First, actual stress levels at individual wetlands will vary depending on the accuracy of input data, the effectiveness of buffers near sites, whether sites are being improved through management, and whether unmeasured stressors are acting on a site. One important stressor that is not included in the model is livestock grazing. We were not able to use this variable in our models because of the lack of consistently available data on the presence and intensity of livestock grazing across the state. We recommend combining the landscape stressor results with the results of other studies, such as the rapid assessments being conducted by the Utah Geological Survey (UGS), to determine actual levels of stress on the landscape. For example, UGS found that 43% of Wasatch and Uinta Mountains Level III Ecoregion sites had evidence of livestock grazing during surveys of the Weber River HUC6 Watershed, and 40% of those sites had moderate to severe impacts. An additional limitation of our model is that it should only be applied to more isolated features. We recommend calculating full upstream watershed stressor values for certain stressors and applying them to flow-connected aquatic systems to obtain better measures of in-stream condition. Third, the results of our work are only as valid as the input data. We vetted all potential input variables to select only those most appropriate for use in our models. However, there was only one available dataset showing the distribution of key aquatic habitats, derived from the U.S. Fish and Wildlife Service's National Wetlands Inventory data (NWI). We recommend continued support of new wetland mapping projects, especially in areas of importance for sensitive species, to make up-to-date estimates about habitat availability. We also recommend using the results of the Utah State University-led riparian mapping project to help expand our definition of key aquatic habitats to included potential or actual riparian area in addition to the wetland features captured by NWI. Last, we recommend continuing to improve the Ecological Integrity Tables for key aquatic species to better define habitat suitability. Thresholds in the tables may be improved by using existing species data or through additional literature review.

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Introduction

Utah is estimated to have lost approximately 30% of its wetland and aquatic habitat acreage prior to the 1980s and many of the remaining resources are at risk of loss and degradation due to anthropogenic disturbances (Dahl, 1990). With growing urbanization, changes to climate, and ongoing resource development across the state, stresses to wetland resources are increasing and unpredictable. These stressors can cause degradation of habitat, reduction in water quality, and non-native species invasion among other declines in quality and function. Distinct stressors differ in scope and severity across the landscape and when combined with other stressors may inconsistently impact the integrity of wetland and aquatic resources. Though direct activities such as dredge and fill, draining, and tilling have been the principal cause for loss and degradation in these habitats, indirect influence from surrounding land use causes impacts that are often more difficult to quantify. Knowing the distribution and intensity of these stressors on wetland and aquatic resources can inform both use and conservation needs.

Managing species and habitats at the state scale requires an understanding of the possible stresses on target resources. Assessment tools for local and landscape scales are a vital component of understanding status and trends in valuable resources and support more focused conservation efforts by land managers. The principal goal of this project is to model aggregated stressors that impact wetland and aquatic resources at the landscape scale in Utah. The landscape integrity model assesses stressors most associated with degradation in target resources and provides a tool for evaluating broad-scale impacts.

Literature Review

Compilation Methods

We compiled literature on approaches used to examine potential environmental stress in the landscape, with a particular emphasis on studies focused on wetlands and other aquatic systems. We did not aim to achieve a comprehensive review of the literature due to time limitations, but rather a broad review of common variables and common approaches used in landscape models. First, we examined literature that had been previously collected by the Utah Geological Survey (UGS) to determine relevance to the study. Second, we examined Wetland Program Plans (http://water.epa.gov/type/wetlands/wpp.cfm) and, in some cases, websites for individual states' wetland programs, for EPA Region 8 states as well as California, Nevada, Oregon, and Washington to determine whether states within the region had developed wetland landscape models. Third, we conducted a literature review in Thomson Reuters Web of Science using the following search terms: 1) wetland* +"level I", 2) wetland* + "level 1", 3) wetland* + risk + landscape (results filtered by Science and Technology), 4) wetland* + integrity+ landscape, 5) wetland* + vulnerability + landscape, 6) wetland* + "landscape model", 7) wetland* + stress* + landscape, 8) wetland* + "condition assessment" + landscape, 9) wetland* + intact* + model, 10) review + aquatic + landscape +model, 11) review +buffer size, 12) aquatic + "landscape model." Titles, and occasionally abstracts, were read to determine suitability of search results for inclusion in the review.

Study location, study methods, and validation results, if validated, were summarized in a text document. Major study traits were summarized in a spreadsheet to make it easier to locate studies with particular features. Landscape stressors included in analysis for many of the studies were catalogued in a spreadsheet.

Literature Reviewed

We reviewed a total of 32 studies, including both peer-reviewed scientific literature and grey literature such as reports and technical documents. Over half (66%) of the studies were wetland-specific and another 19% focused on non-wetland aquatic systems. The remaining five studies merited inclusion either due to their unique approach to landscape analysis or thorough review of expected impacts of a broad range of landscape stressors. Compiled literature included subject area reviews (n=4), models developed primarily through best professional judgment and literature review (n=10), and regression analyses between field measured site conditions and landscape characteristics (n=8). Six studies used the Landscape Development Intensity index (LDI) in analysis, which assigns coefficients to different land use classes based on their energy use per unit area (Brown and Vivas, 2005). A final LDI value is assigned to each location based on the weighed sum of all land use classes surrounding the location.

Variables Used

We compiled information on variables used in 22 of the reviewed studies, including 13 wetland-specific studies and 5 other aquatic studies. We only included three of the six LDI studies in the variable review since these studies used variables similar to one another. We organized the variables into six major categories: biological stress, hydrologic modification, land cover, resource extraction, roads, and water quality. Agriculture land cover was considered in the land cover category, whereas variables associated with agriculture, such as fertilizer and pesticide use or potential nitrogen export, were considered in the water quality category. Land cover data were used in all of the models examined and road data were used in all but three. Variables related to resource extraction (59%), water quality (50%), and hydrologic modification (46%) were included in about half of all models whereas biological stress (measured as presence of introduced or invasive species) was only used in 18% of models. Agriculture, development, and roads were the three most commonly included variables, and no other variables were used in more than half of the studies. Other variables used in at least 20% of studies included mines (50%), artificial flow (e.g., pipelines, canals, 36%), housing or population density (36%), oil and gas wells (36%), natural land cover (32%), dams (23%), surface water use (23%), impervious surface cover (23%), point source dischargers (23%), and other agricultural stressors (e.g., fertilizer, manure, nutrients, 23%).

There were many different ways in which studies processed and calculated variable data to create input datasets. Studies differed in how they took subsets of variables, such as whether they looked at all pesticide use (Bryce and others, 2012) versus use of specific pesticide compounds (Falcone and others, 2010) or all mines (Comer and Hak, 2012) versus particular types of mines (Brown and Froemke, 2012). Hydrologic features such as dams, water withdrawal, and artificial flow were sometimes included as raw point features (e.g., Copeland and others, 2010; Bryce and others, 2012) and other times relativized based on flow, storage capacity, or stream length (e.g., Liu and others, 2006; Lemly and others, 2011).

Studies differed in the degree to which they provided justification for inclusion of particular variables in landscape models. For regression studies that used landscape variables to create models of measured field conditions, final variable inclusion could be justified based on model results. In other studies, variable inclusion was often based on a combination of best professional judgement and literature review. Rather than recompile literature reviews that summarize relationships between stressors and condition, we highlight two reviews that were particularly thorough. Perkl (2013) provides a detailed justification for variable inclusion and variable processing decisions in Section 1.4 of his report for the terrestrial landscape integrity model for Arizona, and Comer and others (2013) provide similar information in Table 3-3 in their report on the rapid ecoregional assessment for the central basin and range region of Nevada and western Utah. The review by Comer and others (2013) includes variables specific to aquatic systems, and they also, in Table 4-5, indicate the aquatic systems most relevant to each variable.

Scales Used in Models

The overall footprint of each stressor, or the spatial area that they are modeled to affect, was calculated in different ways. Three studies summarized all stressors within HUC10 watersheds (e.g., Brown and Froemke, 2012; Bryce and others, 2012; Comer and others, 2013). These watersheds are the second smallest of the six nested levels of watersheds found in the U.S. Geological Survey's (USGS) Watershed Boundary Dataset (http://nhd.usgs.gov/wbd.html). Eight of the studies used literature review or best professional judgment to assign an overall distance of impact to each stressor. For example, in Lemly and others (2011), active surface mines are modeled to have an effect up to 500 m from each feature whereas other mines types are modeled to have an impact up to 300 m. Most of these studies incorporated a decay function or other device to make overall impact from a stressor highest immediately adjacent to the source of stress and lower until it ultimately reaches no impact at a set distance from the stressor. Sixteen studies calculated stressor values for each wetland rather than creating a continuous surface across the study area. Copeland and others (2010) calculated the mean distance between wetlands and stressors and then normalized values between 0 and 1. The remaining fifteen studies calculated stressor data within predefined distances from focal wetlands. For example, Hychka and others (2007) calculated stressor variables at five scales: 250 m, 1000 m, wetland watershed, and the intersection of the 250 m and 1000 m buffers with the watershed. Calculating stressors in buffers or landscape units of a set distance from wetlands is similar to declaring that stressors only impact wetlands if they are within that set distance from the wetland. Six wetland-specific studies used only one buffer size, including 100 m (Reis and Brown, 2007), 300 m (Mita and others, 2007), 1000 m (Brooks and others, 2004; Mack, 2006, 2007), and wetland watershed (Danz and others, 2007). Nine studies tested multiple distances; results of seven of those studies are summarized in table 1. There was no consistent distance that worked best across all studies. Study results may be dependent on the types of wetlands studied and the particular response variables evaluated. In particular, wetland water source probably plays a large role in determining how the landscape affects wetland condition, with wetlands connected to streams and rivers probably affected by a larger area than more isolated wetlands.

Model Construction

We reviewed details of how nine of the non-regression based models were constructed (table 2). In all but two studies, weights were assigned to each stressor variable based on either principal components analysis (two studies) or literature review and best professional judgment of stressor impact compared to impact of other stressors (five studies). In five of the nine studies, stressor variables were evaluated within categories before being combined with all other stressors. For example, Lemly and others (2011) calculated the maximum score for all surface hydrologic alteration variables and then added that score to other stressors. Bryce and others (2012) used the mean of road density and road stream intersections and then added that score to other stressors. In all but two cases, final stressors or categories of stressors were added together to obtain a final value. Bryce and others (2012) used the minimum value (representing the least intact or more disturbed) of three categories, hydrologic alteration, land and water quality, and road impacts, as their final value. Comer and others (2013) did not combine stressors together because they state it can be more helpful to assess impacts independently.

Literature Review Conclusions

Based on our literature review, different wetland types are most affected by the landscape at different scales. The quality of wetland habitat is always influenced by local conditions within a few hundred meters of sites, including presence of non-native species surrounding sites, connectivity to other habitats, and runoff that may reach sites. Aquatic habitats that receive substantial input of water from streams or lakes are often affected by the entire watershed that contributes to the lake or stream, while wetlands such as isolated depressions and slope wetlands often have much smaller and/or harder to define watersheds.

Table 1. Summary of studies that tested the relationship between wetland condition and stressors within certain distances to the wetland.

Study	Wetland Types	Response Variable	Distances Tested (m)	Best Distance(s) (m)	Notes
Liu and others, 2006	Various	No independent validation	1000, 500, 200, 100 vs. 500, 200, 100, 0	Not important	Compared *sets* of widths in sensitivity analysis; found only small effect
Brown and Vivas, 2005[4]	Depressional herbaceous	Rapid assessment scores	100, 200, 500	100	200 m was similar to 100 m
Margriter and others, 2014[4]	Coastal tidal, depressional, riverine	Three rapid assessment methods	100, 1000, watershed	watershed, 1000 generally best	
Menuz and others, 2014	Emergent wetlands	Three rapid assessment methods, floristic measures	1000, 3000, 5000 (higher elevation, full)	1000 full (agriculture), 3000 higher (roads)	Both 360 degree and higher elevation buffers created for sites
Weller and others, 2007	Freshwater flat and riverine	HGM field assessment	100, 1000, dist.[3]	100, dist. (flat), 100, 1000 (riverine)	
Hychka and others, 2007	Slope	Floristic measures	250[1], 1000[1], watershed	1000	1000 m best based on strength and number of correlations
Rooney and others, 2012	Marsh	Bird and plant indices	100, 300, 500, 1000, 1500, 2000, 3000	100 (plants), 500 (birds)	

[1]looked at both 360 degree buffer and buffer that intersected with watershed
[2]360 degree buffer, not intersected buffer
[3]distance to nearest feature
[4]calculated Landscape Development Intensity index

We found a wide variety of variables used in landscape models. Variable choice can be dependent on the scale at which stress is modeled. Poorly georeferenced data can be used when data are summarized to larger spatial aggregations, and more precise data are required to model fine resolution conditions. Many variables used in the reviewed studies were only available at the county or HUC8 scale, the third smallest of the USGS's watershed boundaries. Some studies adjusted hydrologic variables to account for differences in total flow or upstream stream length. These adjustments allow for better differentiation between, for example, the impacts that a set amount of surface water diversion would have on a low-flowing stream versus a stream with higher flow levels. Unfortunately, this type of data are not widely available.

Table 2. Summary of model construction techniques. BPJ listed under Weights indicates that Best Professional Judgement was used to determine how different stressors were weighted in models.

Paper	Model of…	Weights	Combination	Combination Categories
Brown and Vivas, 2005 (and five other papers)	Generally wetlands	Based on energy use	Summation of layers	
Brown and Froemke 2012	Sediments, toxics, nutrients	principle components analysis-derived	Summation of layers	Developed three separate models for each response
Bryce and others, 2012	Aquatic intactness	None	Minimum value (least intact) of three categories, different combinations *within* categories	Hydrologic alteration, land and water quality, road impacts
Comer and Hak 2012	Terrestrial landscape	BPJ	Summation of layers	
Comer and others, 2013	Aquatic landscape (various features)	BPJ	Not combined	
Copeland and others, 2010	Wetlands	None	Summation of layers	
Danz and others, 2007	Wetlands	principle components analysis-derived	First axis of PCA for each category	Agriculture, deposition, population, land cover, point source pollution
Lemly and others, 2011	Wetlands	BPJ	Maximum values for listed categories added to all other stressors	Development and roads, wells, mines, surface hydrologic alteration
Perkl, 2013	Terrestrial landscape	BPJ	Combined categories within feature (i.e. airport type or land cover type) and then added to other features	Many categories
Vance, 2009	Wetlands	BPJ	Weights assigned to features within categories and then between categories, summed together	Roads, land cover, hydrology, resource extraction

Data Compilation

We searched many sources for appropriate data to use in the landscape integrity model for Utah's aquatic resources. A list of potential data sources was previously compiled by UGS and to this we added data from the U.S. Forest Service's (USFS) Intermountain Region GIS Data Library (http://www.fs.usda.gov/main/r4/landmanagement/gis), the U.S. Bureau of Land Management (BLM, http://www.blm.gov/ut/st/en/prog/more/geographic_information.html), the Utah Mapping Portal (AGRC, http://gis.utah.gov) and associated Spatial Database Engine (SDE), and the Utah Division of Water Rights GIS webpage (UDWRi, http://www.waterrights.utah.gov/gisinfo/wrcover.asp). We also looked at data sources cited in the reviewed literature to determine their availability for our study region. We participated in meetings held by the Conservation Biology Institute (CBI) while they worked on an Aquatic Intactness model for Utah associated with a broader Rapid Ecoregional Assessment for the state. CBI shared their spreadsheet of potential data sources with us as they updated it throughout the project. Last, we emailed individuals and organizations to obtain updated data or inquire about data availability.

We explored each dataset to better understand strengths and limitations. We first identified fields useful for subdividing or excluding features. For example, road data from AGRC includes information on the road type (e.g., interstate, state highway, local road), and oil and gas well data from Utah Division of Oil, Gas and Mining has fields that specify the activity level of the well (e.g., not yet built, currently operating, plugged and abandoned) and the well type (e.g., service well versus drilling well). Most datasets included metadata that described the uses and limitations of the data and the fields. In some cases, we contacted the originators of the data to clarify field attributes that we did not completely understand.

Next we examined datasets to determine the relative degree of spatial accuracy, and, when more than one dataset captured similar information, we compared datasets to determine completeness and accuracy. We examined spatial accuracy in ArcGIS, using 2011 aerial imagery and occasionally more recent imagery. Sometimes we examined spatial accuracy by class to determine whether, for example, large dams were more likely to be correctly located than smaller dams. To compare datasets, we symbolized each dataset with a different color and looked for areas where only one dataset was located. For example, when comparing the AGRC road data with data from the USFS, we placed both features in the ArcGIS Table of Contents and symbolized the AGRC as black and the USFS roads as bright pink. We then zoomed in to National Forest areas and noted whether there were many evident areas with bright pink, indicating the presence of roads in the USFS data that were not in the AGRC data. Last, we zoomed in closer to areas with bright pink to determine whether there was indeed a road at the indicated location based on examination of the aerial imagery.

Data considered for inclusion with some notes about usability can be found in appendix A. Detailed information about variables used in the final model, including important data attributes and results of data examination, can be found in the final package of deliverables for this project.

Model Development

Scale of Modeling Effort

We first determined the appropriate scale for the modeling. Based on the reviewed literature in table 1, many wetlands are most affected by stressors within their immediate vicinity (between 100 and 1000 m from the wetland), though non-isolated wetlands receiving substantial water from rivers and streams (e.g., riverine wetlands in Hawaii, emergent Great Salt Lake wetlands fed primarily by canals off major rivers) sometimes did better with stressor data from larger scales (whole-watershed, 3000 m). Wetland water quality and hydroperiod are likely to be affected by stressors within the entire wetland watershed (which may be quite small for isolated wetlands), though for groundwater-fed wetlands, these watersheds are actually an underground aquifer that is very difficult to delineate. Other aspects of wetland condition, such as plant community composition and suitability of habitat for wildlife species, are strongly dependent on more local conditions such as the intactness of the surrounding landscape and whether roads, agricultural fields, or other nearby disturbances facilitate invasion by non-native species. Many stressors, such as livestock grazing, ditching, grading, or filling, also occur directly within wetlands.

Delineating a watershed for every wetland in the state of Utah is not feasible, so we explored other spatial scale options. One option is to use local catchment features delineated for other projects, such as the USGS's hydrologic units. The finest scale USGS units are referred to as HUC12s and are typically between 10,000 and 40,000 acres (40.5 and 162 km^2) (USGS and USDA, 2013). Information resulting from data summarized within a HUC12 would be most relevant to wetlands along the mainstem stream or river that drains the HUC12 and much less relevant to isolated wetlands or wetlands along headwater streams (figure 1). Furthermore, summarizing data within a HUC12 ignores stressors to streams and rivers that are outside of the immediate HUC12. A second option is to use a set distance to determine the impact of various stressors to wetlands (with the options of having the stressor impact decay with distance and/or using different distances with different stressors). This approach does a much better job of capturing many stressors to individual wetlands (i.e., fragmented landscapes, likely sources of non-native plant propagules), but does not distinguish between up gradient and down gradient hydrologic stressors. In other words, a wetland with up gradient water quality stressors would potentially receive the same score as a wetland with down gradient water quality stressors, even though the up gradient stressors are likely to have a higher impact on the wetland.

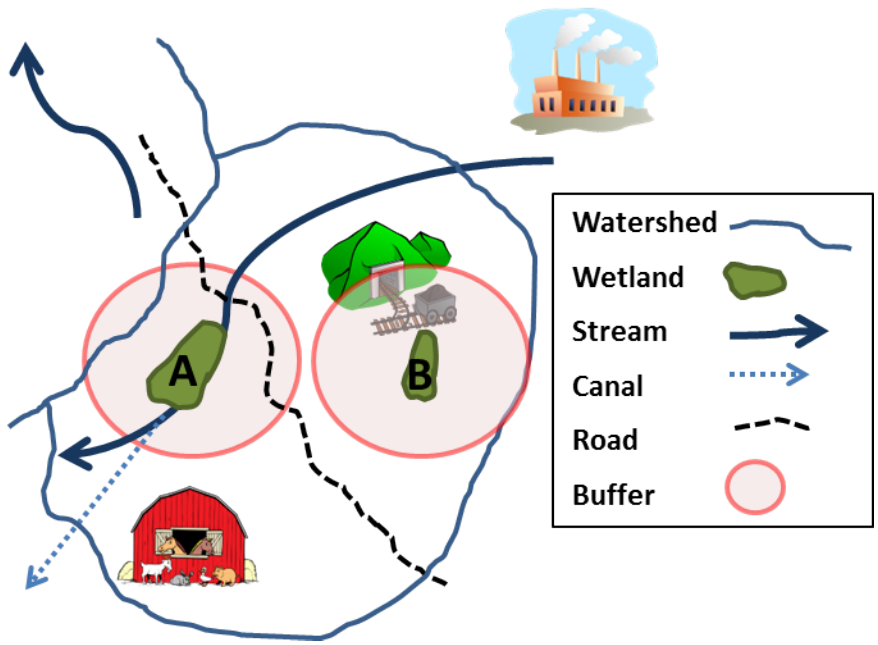

Figure 1. Effect of scale on wetland stress calculations. Using a whole-catchment approach for analysis of stressors to wetland A will correctly capture road and mining stressors, but inappropriately capture downstream farm and canal stressors that likely have a much smaller or negligible impact. The buffer approach correctly captures the road and not the farm, but incorrectly captures the canal and misses the mining. Neither approach captures the industrial plant discharging into the stream upstream from the catchment. The buffer approach more appropriately captures stressors to wetland B than the catchment approach because most of the catchment stressors are distant and downstream from wetland B.

We decided that for this modeling effort, it was most appropriate to consider stressors directly adjacent to or within the near vicinity to wetlands rather than summarizing information in larger watersheds. Nearby stressors are likely to have some degree of impact on wetlands whether or not they are flow-connected, whereas using watersheds still may ignore some important stressors while at the same time being overly inclusive of some distant stressors (figure 1). This model will not be effective for estimating in-stream conditions, since they are likely to be much more strongly controlled by watershed-scale rather than local processes. The model will still be relevant to wetlands and riparian areas adjacent to streams, particularly those that receive a substantial portion of their flow from springs and local run-off. The model will also be highly relevant to isolated wetlands and wetlands with small watersheds.

Model Construction

We considered three major factors to construct the model. First, different stressors may have different weights applied to them based on the severity with which they are expected to impact wetlands. For example, sprinkler irrigated crops may have less water run-off, and thus less impact, than flood irrigated crops and small roads may have less impact than state highways. Second, we had to decide the spatial extent that would be impacted by each stressor. Stressors could impact all area within a set distance equally or be modeled to have lessening impact with increasing distance from the stressor. Last, we had to decide the best way to combine stressors into a final model.

We adjusted all three factors through a combination of best professional judgement, reference to similar models, and calibration with field data on wetland condition. To set initial stressor weights, we considered weights used by Lemly and others (2011), weights used in the landscape development index developed by Brown and Vivas (2005), and our own best professional judgement. Weights were then adjusted throughout the model development process based on preliminary findings from the calibration data; see discussion below.

We tested two major methods for determining spatial extent of impacts, each with a somewhat unique method of stressor combination. The first method, the neighborhood method, assumed that each stressor would impact the area within 1000 m with no decline with distance. The distance of 1000 m was selected based on the literature review. For the neighborhood method, we first created a presence/absence raster with each stressor, where presence of the stressor was equal to the stressor weight and absence was equal to zero (figure 2). Next, we calculated the maximum value across all stressors, so that each 30 x 30-m raster cell was equal to the weight of the worst stressor. We used the maximum value per cell rather than the summation of all stressors within a cell because we assumed that one stressor would be dominant within each cell and that most stressors would not be additive. For example, the weight of a highly urbanized area was not added to the weight of the roads passing through the urbanized area; rather, we only captured the most intense stressor. Last, we used Focal Statistics in ArcGIS to calculate the mean of the maximum values in a 34 x 34-cell neighborhood surrounding each cell, which is equivalent to an area 1020 x 1020 m.

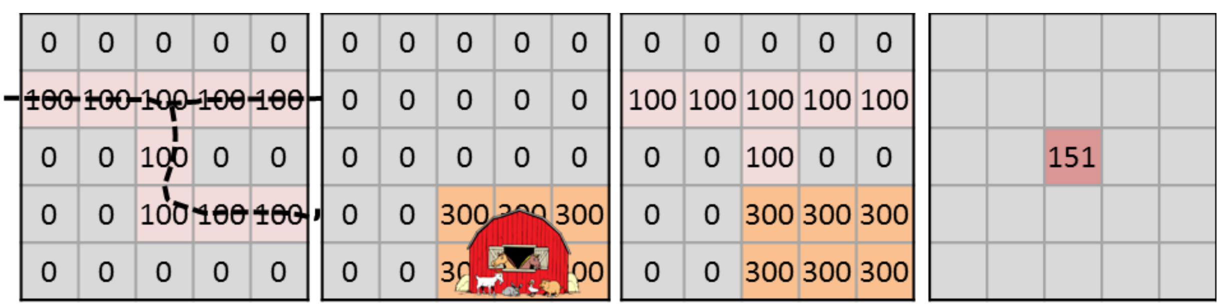

Figure 2. Example of calculating stressors based on a set neighborhood. First, the road and agriculture stressors are converted into rasters of the stressor weight (100 and 300, respectively for the road and agriculture) and zero where the stressor is absent. Then, in the third panel, the maximum stressor value in each cell is determined. Last, the mean value across all of the stressors in the neighborhood is calculated using, in this example, a 2x2-cell neighborhood. Only the central value is shown in the fourth panel because the rest of the values would depend on an area larger than that shown.

The second method we tested, the decay method, used decay functions to make the relative impact of each stressor decline with increasing distance from each stressor. We used decay curves developed by Lemly and others (2011). Using these curves, stressor impact was the maximum weight at the location of the stressor and then declined until it reached a value of zero a set distance (250, 600, or 1250 m, depending on the curve used) from the stressor (figure 3). We selected initial decay curves based on best professional judgement and curves used by Lemly and others (2011) and then adjusted curve selection as needed throughout the calibration process. We then combined variable values together within categories (e.g., hydrologic modification or urban development), either using the maximum or the summed value of all potential input values. Last, we summed the categorical variables together to create a final value. During model calibration, we determined that we needed to cap the maximum value that a stressor category could reach. For example, there may be a maximum level of stress created by development captured by an urbanization stressor. Additional stress from a nearby road would not necessarily increase the overall stress of the highly urbanized area.

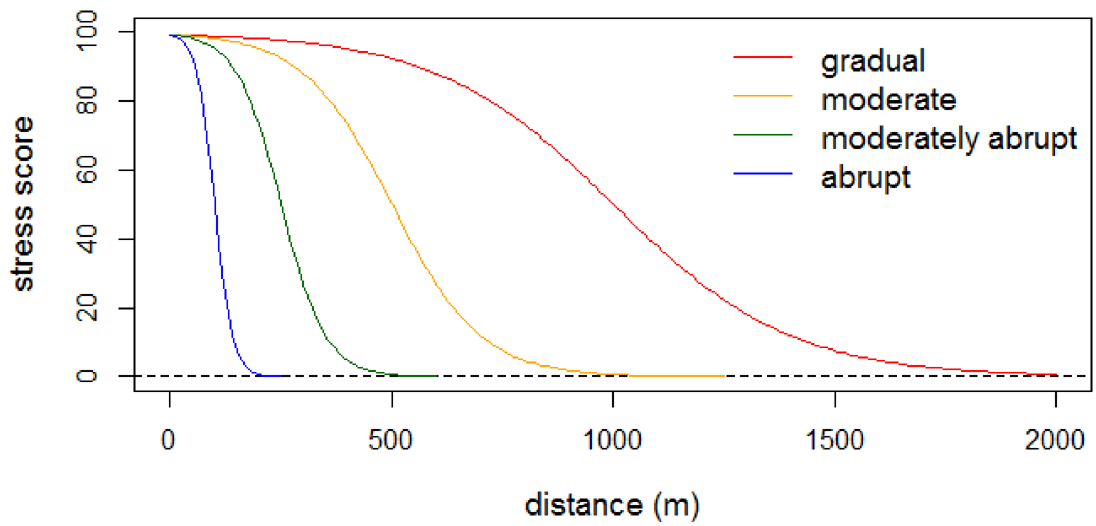

Figure 3. Relative stress level based on distance from a stressor, using four different decay curves. Stress levels can also be affected by multiplying the stress score by a weight so that two stressors with the same decay curve have different stress values.

Model Calibration

We used data from the UGS wetland assessment program to calibrate the landscape model. We expected landscape model scores to be correlated with measures collected at sites in the field. We also knew that site conditions would frequently differ from expectations due to the presence of stressors not included in the models (e.g., intense livestock grazing, invasive species establishment, unmapped ditching and other hydrologic modifications) and due to positive factors such as effective buffers around sites and effective land management. We used two metrics collected by the UGS for model calibration. The first metric was the overall site score from the Utah Rapid Assessment Procedure (URAP). URAP measures easily observed features of wetland condition, such as alterations to hydroperiod, soil disturbance, and presence of non-native species, and summarizes the results into a score between 1 (severely degraded) and 5 (near reference condition). The second metric is a measure of plant community composition. Plant community composition data are used to assess the severity of recent and ongoing stress to a wetland because plant species are relatively easy to observe in the field during a single site visit (compared to animal species) and because composition is likely due to a combination of recent past and current condition. Plant data can reflect information not easily observed during a site visit, such as recent history of intensive livestock grazing and water quality issues. We used Mean C, the mean coefficient of conservatism value (C-value) across all plant species at each site, as our measure of plant community composition. C-values are assigned to species based on best professional judgment, literature review, and/or field observations (Rocchio 2007; Rocchio and Crawford, 2013). Values are assigned based on species association with disturbance; near 1 indicates almost always at disturbed sites, near 10 indicates almost always at pristine sites, and 5 indicates equally at either. The value of 0 is reserved for non-native species. Since Utah does not have a state-specific list of C-values, we used a compiled list of values from Colorado (Rocchio, 2007), Montana (Jones, 2005), and Idaho (C-values used by the state of Idaho are from values developed for eastern Washington's Columbia Basin region [Rocchio and Crawford, 2013]). We used URAP site scores from 100 sites in the Weber watershed and the north slope of the Uinta Mountains. We used Mean C values from those same sites as well as 58 additional sites in Snake Valley and the north and east shores of Great Salt Lake.

We tested correlations between different methods of calculating a final landscape model score and the Mean C and URAP scores. We examined correlations with all of the sites and within specific Ecological Systems that had enough sites to reasonably test the strength of correlations. Ecological Systems, developed by NatureServe, are "groups of plant communities that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients" (http://explorer.natureserve.org/classeco.htm). We considered the following systems: Rocky Mountain Alpine-Montane Wet Meadow, North American Arid West Emergent Marsh, and Inter-Mountain Basins Alkaline Closed Depression. We considered using Rocky Mountain Subalpine-Montane Riparian Shrubland, but we only had a few sites outside of the north slope of the Uinta Mountains and thus did not have a representative breadth of landscape conditions to use for calibration. For models constructed using the neighborhood method, we calculated a neighborhood value in ArcGIS, extracted the output values to a shapefile of survey locations, and tested correlations using R version 3.2.0 (R Core Team 2015). For models constructed using the decay method, we extracted the values for each individual variable to the survey locations and used calculations in R to test various methods for combining variables into categorical scores and then into a final model. We tested logical groupings, such as all hydrologic stressors, stressors related to agriculture, and urbanization stressors. We also tested adding all stressors together without the use of categories.

We evaluated different model combinations based on the overall logic of variable combination rules and the strength of correlations between the model and the calibration metrics. We also examined the data associated with outliers in correlations to determine whether the anomalies were caused by incorrect data inputs, factors not included in the landscape model, or model construction factors that we could change. Some models performed well with the overall data but did not perform well within particular Ecological Systems. For example, Alkaline Depressions almost always had lower scores than Montane Wet Meadows, and certain stressors were associated with the former Ecological System and not the latter. We were interested in finding model combinations that could distinguish within and between Ecological Systems. We found that Emergent Marsh Mean C values were never correlated with the landscape model and that their URAP score was frequently positively correlated with the landscape model.

None of the sites surveyed by the UGS had stressor values for urban parks, hydrologic pipelines, oil and gas wells, and mines, so these features could not be calibrated in the final model.

Final Model Construction

The final model was constructed with five core categories: development, agriculture, hydrologic stressors, mines, and oil and gas wells. A regional model around Great Salt Lake also includes cover of *Phragmites australis*. For both models, the final score was tabulated as the sum of each of the categorical values. Table 3 summarizes the variables used and their assigned weights, decay functions, and groups.

Table 3. Stressors with weights and decay functions.

Stressor	Group 1	Group 2	Decay	Weight
Crop		Agriculture	Moderately abrupt	300
Hay		Agriculture	Moderately abrupt	200
Canal, ditch		Hydrologic	Abrupt	100
Sprinkler irrigated	Irrigation	Hydrologic	Moderately abrupt	200
Flood irrigated	Irrigation	Hydrologic	Moderately abrupt	300
Impoundments		Hydrologic	Moderately abrupt	400
Urban	Urban	Development	Moderate	200
Impervious		Development	[1]See note	400
Urban parks	Urban	Development	Abrupt	100
Interstate, state highways	Linear disturbance	Development	Moderate	250
Railroads	Linear disturbance	Development	Moderate	250
Other roads	Linear disturbance	Development	Moderately abrupt	200
Oil and gas pipelines	Linear disturbance	Development	Abrupt	100
Hydrologic pipelines	Linear disturbance	Development	Abrupt	100
Oil/gas wells		Wells	Moderately abrupt	400
Large mines		Mines	Moderately abrupt	400
Phragmites		Phragmites	[2]See note	400

[1]Mean percent impervious surface was first calculated in a 1020-m x 1020-m neighborhood around each raster cell. Values were then converted to a final score using the following equation: 400*(% impervious – 1)/59, with values greater than 60 converted to 400 and values below 1 converted to 0.
[2]Percent of 30-m x 30-m raster cell modeled to be *Phragmites*.

The following steps were taken to obtain values in each category:

1. Development, maximum 1000
   a. Linear disturbance: Sum the values in the linear disturbance group. Set all values equal to or greater than 400 to 400.
   b. Urban: Use the maximum value of the features in the urban group.
   c. Development: Sum urban, linear disturbance, and impervious together.
2. Agriculture, maximum 300
   a. Agriculture: Use the maximum value of crop and hay.
3. Hydrologic stressors, maximum 400
   a. Irrigation: Use the maximum value of flood and sprinkler irrigation.
   b. Sum irrigation, impoundments, and canals. Set all values greater than 400 to 400.
4. Mines, maximum 400
5. Oil and gas wells, maximum 400
6. *Phragmites*, maximum 400 (only in regional Great Salt Lake model)

Variable weights and model construction were dependent on the particularities of the input data and assumptions about the interactions between variables. Many mines and oil and gas wells are also mapped as urban areas and would get a total weight of 600 instead of 400. Both small houses and large cities are mapped as urban, but only the large cities have high impervious surface values. Dryland agriculture is assumed to have a smaller impact than irrigated areas. Dryland areas could have some pesticide or herbicide run-off during storms and may lead to introduction of non-native species and fragmented habitat, whereas irrigated agriculture is much more likely to impact the hydrology and water quality of surrounding wetlands.

One variable not used in the final model was surface water and groundwater withdrawal. Including these variables lowered model correlation with the field metrics since data on water withdrawal do not distinguish between diversions by the BLM or other agencies specifically for the management of wildlife. Furthermore, water diversions act in a cumulative manner within drainage areas or groundwater aquifers rather than just locally. This is particularly evident around Locomotive Springs Waterfowl Management Area where many springs have dried up due to groundwater withdrawal in the aquifer far to the north of the site (Hurlow and Burk, 2008). Data there would not be captured in a local model of water withdrawal.

Model Validation

We determined correlations between field observations of aquatic condition and the landscape model. We first looked at correlations between the UGS field data used for model calibration (table 4). While this is not an independent test of model predictive ability, we did want to present the final results of this calibration. We calculated correlations for all wetlands as well as wetlands within certain Ecological Systems and Level III Ecoregions (generally those with an adequate sample size). We also examined wetlands sampled as part of the 2014 Weber watershed sampling project and wetlands that overlapped the regional Great Salt Lake model. Almost all correlations tested showed a significant ($p<0.10$) negative correlation with the landscape model, except most correlations that involved North American Arid West Emergent Marsh sites. Results show that the landscape model is helpful for differentiating between sites in general, sites within a watershed, and montane meadow and alkaline depression sites, but not for emergent marsh sites. Most of the marsh sites with available UGS data are located around Great Salt Lake, where there are very large wetland complexes within highly managed impoundments. The landscape model may fail to capture a condition gradient at these sites for two reasons. First, many of these wetlands are in Waterfowl Management Areas or managed by privately owned duck clubs. Management activities may have a stronger effect on wetland condition than landscape stressors. Heavily managed areas, which frequently have impounded waters and relatively more roads and dikes, may be in better condition than more isolated, but less managed, areas. Second, the most important stressors to these sites may not be captured in the models. Stressors related to water quality issues from source water may be an important source of differentiation between sites, but is not captured in the landscape model, which focuses more on local conditions. Additional work should be conducted to better understand landscape drivers of wetland condition around Great Salt Lake.

We used two other datasets to evaluate the relationship between field measures of aquatic condition and landscape model scores. We examined data related to in-stream invertebrate composition, based on calculated scores of observed invertebrates versus expected invertebrates, from Scott Miller at the BLM /Utah State University (USU) National Aquatic Monitoring Center. Response data were available either as a ratio of observed to expected invertebrates (O/E scores) or as good, fair, and poor categories. Sites that were visited multiple times were frequently scored in different categories between visits. We examined the correlation between the mean O/E scores and site landscape model score. We also selected sites with consistent scores (e.g., sites that were visited more than once and were scored in the same category on each visit). We used a t-test to look for differences between consistent good versus poor sites and consistent poor versus not-poor sites. We did not find any significant relationships between O/E scores and landscape stressor values. This result was not surprising since in-stream condition is expected to be much more strongly affected by watershed features than by local effects.

Table 4. Correlations between UGS field measures of wetland condition and landscape model values. Higher values of Mean C and URAP scores are associated with better condition, whereas higher values in the landscape model are associated with more landscape stress. Insignificant p-values ($p<0.10$) are shown in grey.

Analysis Group	# Sites	Response	Correlation Coefficient	p-value
All surveyed sites	158	Mean C	-0.53	<0.001
Inter-Mountain Basins Alkaline Closed Depression sites[1]	33	Mean C	-0.30	0.09
Rocky Mountain Alpine-Montane Wet Meadow sites	43	Mean C	-0.60	0.001
North American Arid West Emergent Marsh sites[1]	46	Mean C	-0.19	0.20
Closed Depression and Emergent Marsh sites[1]	79	Mean C	-0.26	0.02
Weber watershed study sites	72	Mean C	-0.45	<0.001
Weber watershed study sites	72	URAP Score	-0.43	<0.001
Weber watershed study Wet Meadow sites	37	Mean C	-0.55	<0.001
Weber watershed study Wet Meadow sites	37	URAP Score	-0.49	<0.01
Weber watershed study Closed Depression and Emergent Marsh sites[1]	21	Mean C	-0.21	0.37
Weber watershed study Closed Depression and Emergent Marsh sites[1]	21	URAP Score	-0.34	0.13
Sites overlapping Great Salt Lake regional model[2]	63	Mean C	-0.25	0.04
Sites overlapping Great Salt Lake regional model[2]	22	URAP Score	-0.46	0.03
Emergent Marsh sites overlapping Great Salt Lake regional model[2]	39	Mean C	-0.02	0.92
Closed Depression sites overlapping Great Salt Lake regional model[2]	22	Mean C	-0.37	0.09

[1]Only including those sites in the Central Basin and Range ecoregion
[2]Correlations with Great Salt Lake regional model instead of statewide model

The last dataset we used for evaluation was wetland data collected by PhD student Rebekah Downard (R. Downard, Utah State University, written communication, 2015). She has collected data on wetland condition at 50 emergent wetland sites around Great Salt Lake. Her work is still under development and revision, but she shared preliminary site data, including a vegetation condition and disturbance score for each site and data on Mean C and relative cover of non-native plant species. We used vegetation condition and disturbance index scores from 2013. The vegetation condition score is a measure of species richness, native cover, vegetation structure, perennial plant cover, and obligate wetland species cover. The disturbance index is a combination of the following factors: presence of roads and headgates within 100 m, soil ammonium, salinity (more disturbance with levels higher or lower than expected), grazing, presence of pasture land within 500 m, and measures of water regime stability. The landscape stress model was negatively correlated with relative cover of native species and the disturbance index and was not correlated with the two other measures of condition (table 5). The negative correlations are in opposition to the expected relationship because these correlations indicate that as landscape stress increases, sites tend to have less non-native cover and/or less disturbance. As discussed above, it appears that the landscape stress model does not adequately capture disturbances within Great Salt Lake marshes, potentially due to lack of inclusion of upstream stressors and/or failure to capture positive effects of management.

Table 5. Correlations between landscape measures of wetland stress and field-measured response variables, from 50 Great Salt Lake wetlands studied by Downard (unpublished data). Insignificant p-values (p<0.10) are shown in grey.

Response	Correlation Coefficient	p-value
Condition Score	0.06	0.67
Mean C	0.84	0.56
Relative Cover Non Native Species	-0.32	0.02
Disturbance	-0.30	0.03

Model Application

Summary by Wetland Type

We calculated the amount of wetland area in each stressor class, as well as the mean and standard deviation of stressor values, for wetlands in the state of Utah. We used wetland spatial data available on the UGS SDE entitled WetlandUtah_2014 and henceforth referred to as UGS wetland data. This wetland layer was modified from the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) Program data, which is mapped using Cowardin classification (Cowardin, 1979). Major modifications included replacement of some NWI data with more recently mapped data by the U.S. Forest Service and removal of many intermittent stream features. The UGS wetland data also includes wetland types as classified by Emerson (2014, table 6), which are the types used to define key aquatic habitats in the Wildlife Action Plan (UDWR, 2015), though we used a more up-to-date version of the wetland spatial data than that used in the Wildlife Action Plan. We further divided the "open water" class into lacustrine limnetic (deepwater areas, water >2.5 m deep), lacustrine littoral (≤2.5 m) and palustrine. Palustrine wetlands are less than 8 ha in area, do not have bedrock shoreline, and are <2.5 m deep at low water, whereas lacustrine wetlands have one or more of these features. The maximum model value is 2300, or 2700 in the Great Salt Lake regional model. We defined the following stress categories for the sake of analysis: Very Good: 0, Good: >0 to 200, Fair: >200 to 800, and Poor: >800.

Table 6. Description of wetland classes, taken from Emerson (2014). Features in italics are not key aquatic habitats and are not included in the summary statistics.

Class	Description
Aquatic - Forested	Characterized by woody vegetation greater than 6 meters in height, commonly found around the margins of rivers, montane lakes, or springs (Emerson 2014). Can include both intermittent and perennially flooded areas.
Aquatic - Scrub/Shrub	Characterized by woody vegetation less than 6 meters tall, and can include those areas adjacent to lotic (flowing-water) systems dominated by woody vegetation. Includea both intermittent and perennially flooded areas.
Riverine	Perennial streams, constrained to a channel (includes canals and ditches).
Emergent	Palustrine (marsh-like) wetlands with emergent vegetation, often associated with groundwater discharge or shallow surface flow.
Open water: limnetic	Perennial bodies of standing water, including natural lakes, reservoirs, and ponds. Limnetic open water is considered deepwater habitat with water over 2.5 m in depth.
Open water: littoral	Perennial bodies of standing water, including natural lakes, reservoirs, and ponds. Littoral open water is generally found along the shores of lakes and reservoirs where water is less than 2.5 m deep.
Open water: palustrine	Perennial bodies of standing water, including natural lakes, reservoirs, and ponds. Palustrine open water is found in ponds that are less than 8 ha in area and less than 2.5 m in depth.
Fringe Mudflat	*Mostly non-vegetated wetlands near the shoreline of lakes and reservoirs where water availability is controlled by lake levels and where the primary movement of water is sheet flow; often expansive mudflats or barren ground during low water-level periods around the fringe of reservoirs and endorheic lakes.*
Playa	*Ephemeral ponds, depressional features, or expansive mineral flats where evapotranspiration exceeds water supply or through-flow; a mineral soil must be present.*
Waterpocket	*Bedrock pothole where little to no soil is present and water is supplied only by precipitation.*

To calculate wetland statistics, we divided wetland polygons into shapefiles with small (<0.28 ha) and large areas. We used Geospatial Modelling Environment (Spatial Ecology LLC, 2015) to calculate the minimum, maximum, and mean landscape stressor values for each large-area polygon. Data were not calculated for seven large-area polygons. We appended these seven polygons to the shapefile of smaller wetlands. We converted the smaller wetlands to points and extracted the landscape model values to the points. We then updated the smaller wetland shapefile with the extracted values and merged the large and small wetland shapefiles together. Last, we used spatial join to join the wetland data to Level III Ecoregions, counties, and HUC6 and HUC8 watersheds.

We assigned each wetland polygon the mean stress value per wetland, though other approaches could be used. For small wetland polygons, the mean stress value is almost always going to be very similar to other potential methods of summarizing values, such as the minimum, maximum, and median values. For larger wetlands, mean values may under represent wetland stress because internal wetland areas are further from stress than the wetland edge and edge stress likely decreases the intactness of the internal wetland area. On the other hand, large wetlands may have some internal buffering from stressors, so mean values may be appropriate. We compared stress classification using mean versus maximum stress values for the wetlands over 0.28 ha in size. Wetland polygons classified as good using the mean value were changed to fair and poor 12.3% and 0.3% of the time, respectively, using the maximum value, whereas 13.7% of the wetlands classified as fair were changed to poor. The median size of wetlands that changed stress categories was 3.9 ha, whereas the median size of those that did not change was 0.85 ha.

About 60% of key aquatic habitat by area and 57% by number of polygons is in very good or good condition based on the landscape model and 5% by area and 15% by number of polygons are in poor condition (tables 7 and 8). Forested wetlands, the least common aquatic habitat, are subject to the most stress, based on both the percent of wetland polygons and the amount of area in poor condition. Over half of the area of forested wetlands, emergent wetlands, and palustrine wetlands are in fair or poor condition. Level III Ecoregions vary in the typical amount of landscape stress found by wetland type (table 8). Emergent wetlands experience the most landscape stress in the Colorado Plateau, followed by the Wyoming Basin, whereas the Wasatch and Uinta Mountains have the highest percent of wetland area in the very good category and also a high percent in fair and poor. Forested wetlands have the highest level of stress in the Central Basin and Range and much less stress on the Colorado Plateau. This type of information helps determine potential regional problems and associated species that might be affected.

Table 7. Percent of total wetlands in each stress category and total number of wetland polygons, by wetland class.

Wetland Class	**Percent of Wetland Polygons in Stress Categories and Total Number of Wetland Polygons**					**Mean Stress Value**	**Stress Standard Deviation**
	Very Good	**Good**	**Fair**	**Poor**	**Total #**		
Emergent	25%	30%	28%	17%	6,7451	344	378
Forest	5%	23%	40%	32%	975	564	386
Open Water: Limnetic	27%	9%	51%	13%	1,216	375	322
Open Water: Littoral	67%	8%	24%	1%	1,027	138	243
Open Water: Palustrine	24%	40%	24%	13%	39,173	293	351
Riverine	17%	33%	38%	11%	9,347	327	325
Scrub/Shrub	24%	36%	30%	10%	14,155	281	320
Total	**24%**	**33%**	**28%**	**15%**	**133,344**		

Table 8. Percent of wetland area in each stress category and total area of wetlands, by wetland class and Level III Ecoregions. Ecoregions are not listed under an aquatic habitat type if they have no area in that class type.

Level III Ecoregion	Very Good	Good	Fair	Poor	Total (ha)
All Emergent	***7.7%***	***25.7%***	***51.2%***	***15.3%***	***167,744.5***
Central Basin and Range	4.3%	35.1%	51.9%	8.7%	90,956.8
Colorado Plateaus	2.1%	11.7%	48.1%	38.1%	20,925.2
Northern Basin and Range	1.8%	20.0%	74.9%	3.3%	871.3
Southern Rockies	7.5%	78.9%	13.6%	0.0%	229.9
Wasatch and Uinta Mountains	23.6%	21.1%	41.9%	13.4%	35,967.2
Wyoming Basin	0.2%	4.5%	68.7%	26.5%	18,794.2
All Forested	***2.7%***	***21.3%***	***47.9%***	***28.0%***	***1,777.1***
Central Basin and Range	0.3%	1.8%	37.2%	60.7%	375.0
Colorado Plateaus	3.6%	44.6%	44.9%	7.0%	579.6
Northern Basin and Range	0.0%	100.0%	0.0%	0.0%	0.3
Southern Rockies	6.6%	52.7%	40.7%	0.0%	10.4
Wasatch and Uinta Mountains	3.4%	13.6%	52.8%	30.3%	733.9
Wyoming Basin	1.7%	10.8%	77.2%	10.3%	77.9
All Open Water: Limnetic	***0.8%***	***71.8%***	***23.7%***	***3.6%***	***164,623.4***
Central Basin and Range	0.8%	75.6%	20.2%	3.5%	155,885.8
Colorado Plateaus	0.0%	21.1%	77.4%	1.6%	1,252.8
Mojave Basin and Range	0.0%	0.0%	100.0%	0.0%	740.6
Northern Basin and Range	0.0%	0.0%	100.0%	0.0%	35.2
Wasatch and Uinta Mountains	3.1%	2.0%	86.0%	8.8%	5,329.3
Wyoming Basin	0.0%	6.0%	93.7%	0.3%	1,379.8
All Open Water: Littoral	***0.5%***	***67.3%***	***32.1%***	***0.1%***	***382,344.9***
Central Basin and Range	0.0%	86.4%	13.5%	0.1%	266,731.7
Colorado Plateaus	0.1%	0.0%	99.6%	0.3%	59,922.9
Wasatch and Uinta Mountains	14.4%	1.9%	83.5%	0.2%	11,767.0
Wyoming Basin	0.0%	60.8%	39.2%	0.0%	43,923.2
All Open Water: Palustrine	***13.5%***	***23.1%***	***42.0%***	***21.4%***	***10,771.7***
Central Basin and Range	2.3%	11.4%	56.6%	29.6%	3,820.0
Colorado Plateaus	2.6%	14.1%	47.9%	35.4%	2,180.5
Mojave Basin and Range	0.3%	6.3%	58.6%	34.8%	112.2
Northern Basin and Range	6.2%	31.3%	35.0%	27.5%	26.2
Southern Rockies	18.8%	49.2%	30.5%	1.4%	71.7
Wasatch and Uinta Mountains	29.3%	37.8%	26.0%	6.9%	4,368.2
Wyoming Basin	5.3%	20.2%	46.8%	27.8%	192.8
All Riverine	***4.7%***	***48.0%***	***40.6%***	***6.6%***	***31,000.1***
Central Basin and Range	0.7%	9.9%	60.1%	29.3%	4,469.3
Colorado Plateaus	5.7%	56.0%	36.5%	1.9%	22,894.7
Mojave Basin and Range	1.1%	10.0%	65.0%	23.8%	70.0
Southern Rockies	0.0%	100.0%	0.0%	0.0%	0.03
Wasatch and Uinta Mountains	5.5%	36.1%	45.7%	12.7%	2,195.6
Wyoming Basin	1.0%	60.7%	36.8%	1.6%	1,370.5
All Scrub-Shrub	***19.7%***	***39.1%***	***33.2%***	***8.0%***	***22,017.0***
Central Basin and Range	4.2%	36.1%	37.5%	22.2%	2,198.3
Colorado Plateaus	17.4%	41.7%	33.6%	7.4%	10,302.0
Northern Basin and Range	12.7%	52.7%	25.4%	9.1%	35.1
Southern Rockies	27.8%	57.8%	14.4%	0.0%	66.7
Wasatch and Uinta Mountains	29.9%	39.8%	26.6%	3.8%	8,127.3
Wyoming Basin	0.7%	18.2%	66.2%	14.9%	1,287.7
All Key Habitat Area	***3.0%***	***57.0%***	***35.0%***	***5.0%***	***780,278.6***

We mapped wetland stress levels across the landscape by displaying the proportion of wetland area per landscape stress class in each HUC6 watershed as a pie chart (figures 4-6). These maps can be used to determine which aquatic habitat types are rare and which are threatened within each watershed, which can be tied to species' requirements and distributions to help determine threats to species. For example, the Duchesne HUC8 has a large number of emergent, palustrine open water, and shrub-scrub wetlands. The emergent wetlands experience the highest amount of landscape stress whereas in the Lower Sevier HUC8 emergent and scrub-shrub wetlands are in good to very good condition and palustrine open water wetlands experience much greater levels of stress, potentially because many of the palustrine wetlands may be constructed. Data on wetland area by wetland class in each landscape stress category is available by HUC8 and county in appendix B, which can be used to produce additional maps.

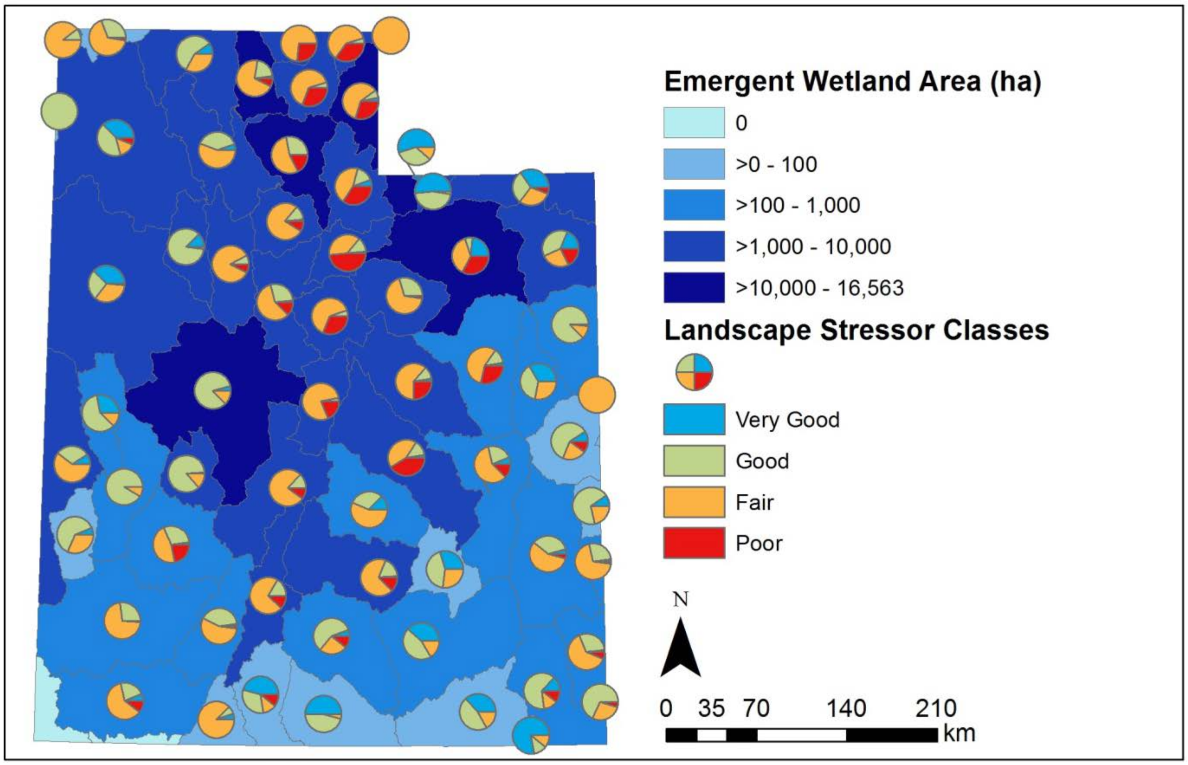

Figure 4. Emergent wetland area by HUC8 and landscape stressor class.

Focal Species Example

We applied the landscape integrity model to Western toad (*Anaxyrus boreas*), a species under review for federal threatened and endangered listing, to demonstrate the utility of the model for species of conservation interest. We developed the Western toad model for areas within the Wasatch and Uinta Mountains Omernik Level 3 ecoregion (Omernik 1987). We initially wanted to use data from the Western Toad Ecological Integrity Table (Oliver, 2006) to help categorize Western toad habitat. The Integrity Table summarizes information from existing scientific literature to determine thresholds to divide indicators into very good, good, fair, and poor categories. For example, daytime summer air temperatures above 25C° is considered very good and below 7C° considered poor in the Western toad Integrity Table.

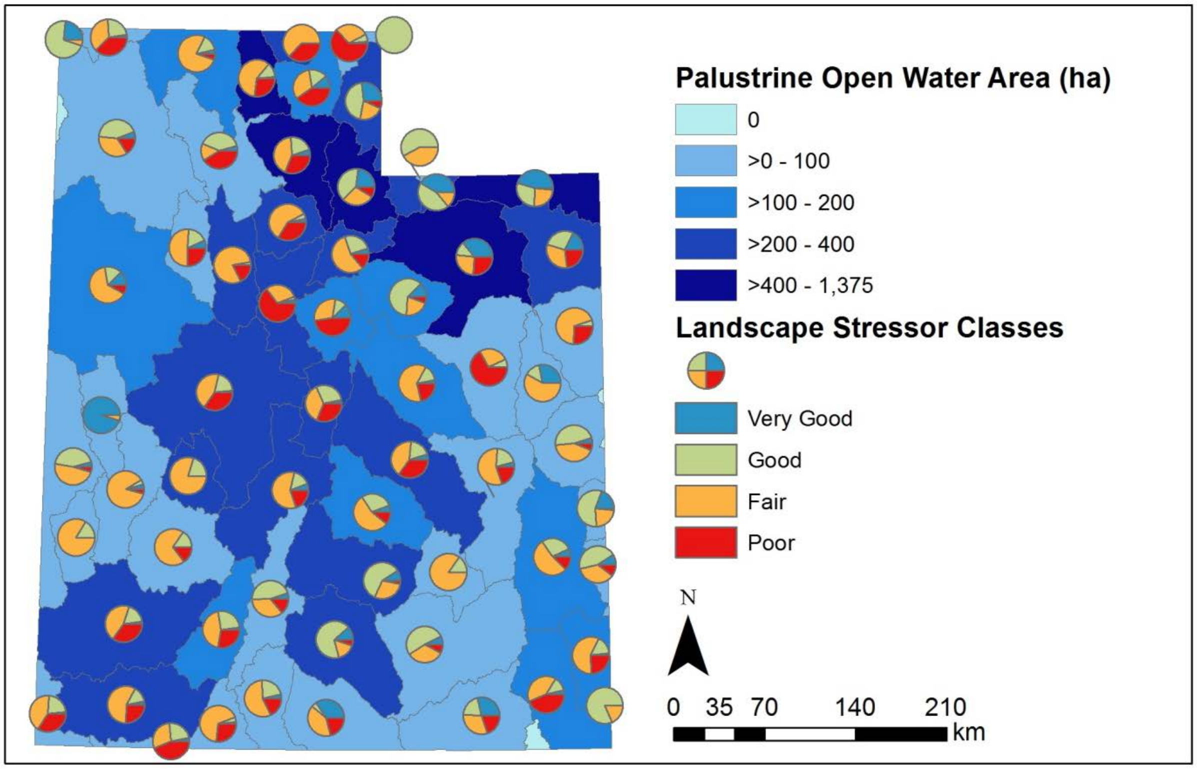

Figure 5. Palustrine open water area by HUC8 and landscape stressor class.

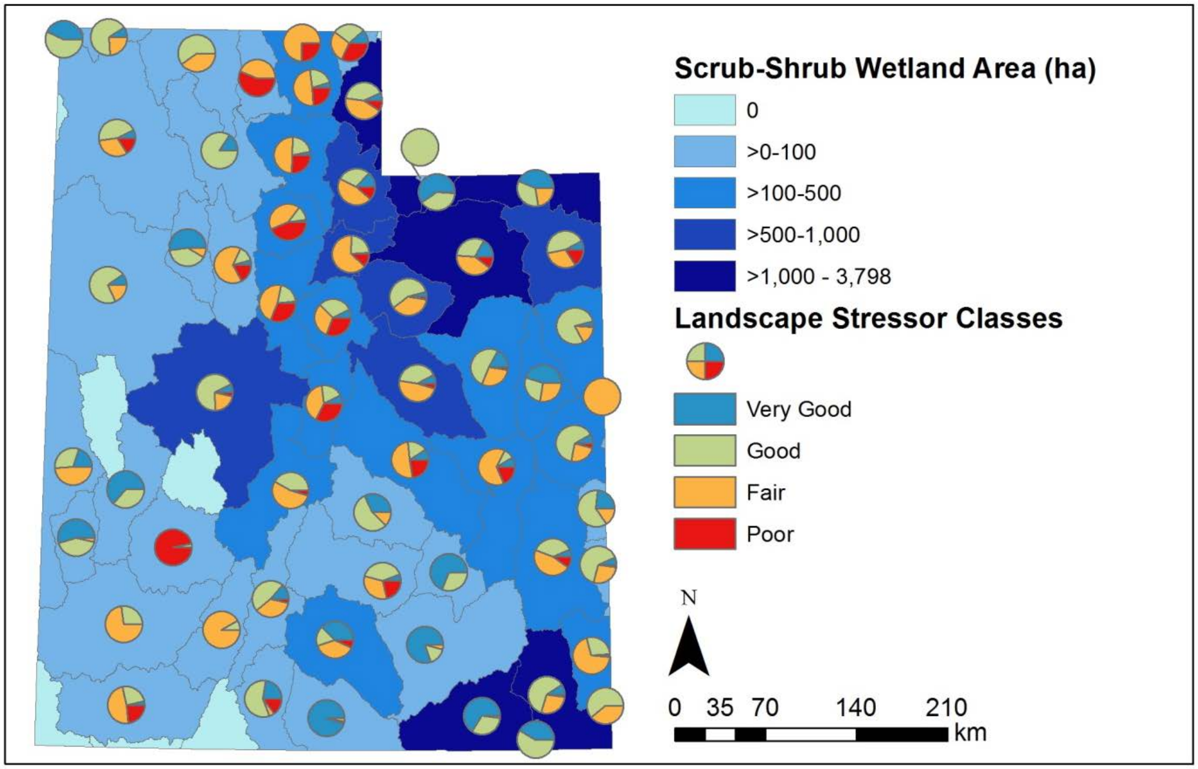

Figure 6. Scrub-shrub wetland area by HUC8 and landscape stressor class.

We examined thresholds in the Integrity Table to determine suitability of use with this project. The daytime summer air temperature thresholds were from Western toad growth experiments with sub-adult toads in three different growth regimes (constant 7C°, constant 25C°, and 12 hour fluctuating 7 and 25C°). Toads at 7C° lost weight, whereas the other two groups gained weight. With only three tested temperature regimes, it is impossible to know the range of temperatures that allow for toad growth. To assess the applicability of these temperature thresholds, we compared the percent of area in ten temperature classes for all land in the study area and all recent (post-1990) Western toad occurrences. We used mean June through September mean maximum and minimum monthly temperatures to calculate temperature classes (see discussion below). Twice as many Western toads as expected, based on land cover area, were found in areas with mean maximum temperatures between 18.5 and 20.9C°. Few occurrences were in areas above 25.6C° or below 16.1C°, though these areas had 20.5% and 3.3% of all land area, respectively. Western toads were over two and a half times more likely than expected to be found in areas with mean minimum temperatures between 3.6 and 5.6C° and were infrequently found at locations with mean minimum temperatures above 7.7C°, despite 37.5% of the total land area falling into that temperature regime. In a similar "quick and dirty" analysis, we found that Western toad occurrences were not frequently found near areas that appeared to have high shrub cover in ArcGIS, despite an association between shrub cover and good Western toad habitat listed in the Integrity Tables. We consider these analyzes "quick and dirty" because they ignore other factors that may also co-vary with temperature, such as land cover, and because many Western toad locations are clustered, meaning that data from large clusters of occurrences may overly influence the analysis. Nonetheless, this analysis plus the uncertainties in the original data source suggests that the best Western toad habitat is unlikely to be above 25°C.

Because of the great uncertainties in the Integrity Table, we used the following three variables to define Western toad habitat (table 9). First, we used mean maximum and mean minimum temperatures using 800 m resolution PRISM 30 year monthly mean data for the months of June, July, August, and September (http://www.prism.oregonstate.edu/normals). We assumed most tadpole development would occur during these four months, though tadpole development may occur as early as May in montane areas, particularly in mild winters. Eggs take between just a few days to around 12 days to hatch, and tadpoles take one to three months to undergo metamorphosis. Faster hatching and development occur in warmer temperatures. (http://explorer.natureserve.org/servlet/NatureServe?searchName=Bufo+boreas). We used thresholds from the "quick and dirty" analysis discussed above, despite shortcomings. Last, we used the elevation ranges from the Ecological Integrity Table because these ranges appeared to be roughly accurate. We used a 30-m statewide digital elevation model to classify the landscape as good, fair, and poor.

Table 9. Habitat indicators, thresholds, and data sources used for focal species model.

Indicator	Good	Fair	Poor
Mean Maximum Temperature, June-September	18.5 to 20.9°C	16.1 to 18.5°C, 20.9 to 25.6°C	All other temperatures
Mean Minimum Temperature, June-September	3.6 to 5.6°C	1.5 to 3.6°C, 5.6 to 7.7°C	All other temperatures
Elevation	2133 to 3048 m	1570 m to <2133 m, 3048 m to 3220 m	<1570 m and > 3220 m

We considering using information from the Ecological Integrity Table to determine which wetland polygons represented appropriate habitat. The Integrity Table indicates that the best breeding habitat is ponds and lake edges deep enough not to dry up and not to freeze at night, with shallow edges where eggs could be laid and warmed by the sun during the day. Low velocity, low-gradient streams are considered fair habitat, and faster streams and small, shallow temporary pools are considered poor habitat. Using the UGS wetland data, we attempted to select suitable features based on water regime and Cowardin class. We found very little correspondence between selected suitable features and known Western toad locations because toads did not seem associated with the selected wetland types and because not all wetlands were mapped in the UGS wetland data. We therefore considered all wetlands with water regimes of seasonally flooded, semi-permanently flooded, intermittently exposed, and permanently flooded (Cowardin modifiers C, F, G, and H) as potentially suitable wetlands. We also excluded area mapped as limnetic open water because we assumed that deepwater areas were not highly suitable habitat for Western toad. Including limnetic open water would likely overestimate available habitat because a few large lakes account for a large amount of total wetland area while only providing suitable habitat along the lake edge.

We converted temperature and elevation rasters into good, fair, and poor rasters using the thresholds from table 9 and using the values of 1 to 3, respectively, to represent the ratings. We also converted the landscape stress model to very good, good, fair, and poor, using the following thresholds: Very Good: 0, Good: >0 to 200, Fair: >200 to 800, and Poor: >800. We then converted all of the rasters to polygons and intersected the rasters with the selected wetlands to assign each wetland to a landscape suitability class. We used two different methods to determine landscape suitability. For the first method, we used the mean suitability value across the three measures (elevation and two temperatures). We converted values less than 1.5 to good, between 1.5 and 2.5 to fair, and all others to poor. We then summarized wetland area by landscape suitability class, landscape stress class, and wetland type. We used a second method to visualize wetland availability spatially at the HUC12 scale. For map-making purposes, we assumed that wetlands may be suitable as long as two of the three habitat elements were in the fair or good category. We then added all of the wetland area in suitable landscape locations per HUC12 and displayed this information in separate maps for different landscape stress categories.

Most wetland area in the study area is in least or moderately suitable based on elevation and temperature class, with just under a third of all wetland area in the most suitable habitat (table 10). Only 2% of the most suitably located wetland area is in the poor landscape stress class, whereas about 13% is in the very good class. Almost all of the most suitable littoral open water is in fair landscape stress condition, whereas the most suitable palustrine open water is almost all very good or good landscape stress class. This difference is likely due to the fact that littoral open water is more frequently associated with impoundments, which are considered stressors in our landscape model. Water impoundment affects many important processes in aquatic systems, including flow regimes, water temperature, and water quality. However, there are large populations of Western toad at the impounded Strawberry Reservoir, indicating that this stressor may not critically affect the species.

Areas with the most suitable wetland area in low landscape stress categories were located in several headwater streams leading to the Weber River, in headwater tributaries to Strawberry Reservoir and to Currant Creek, and on the northwest slope of the Uinta Mountains (figure 7). In southern Utah, areas with the most low-stress wetlands are found around Boulder Mountain, Big Swale, Jacobs Valley, and Riddle Flat. HUC12s with a lot of suitable wetland area in low-stress condition may be ideal locations to look for new populations of Western toad. Areas with a lot of wetland area in fair landscape stress condition include many areas lower in the Weber River watershed, watersheds directly adjacent to Strawberry Reservoir, and several watersheds near Scofield. HUC12s with a lot of suitable wetland area in moderate stress condition may be ideal locations to conduct restoration activities and to ensure that wetlands have intact buffers from nearby stressors. Of the 14,391 total hectares of wetland where at least two of the three measures of suitability were scored as good or fair, 12% was considered very good, 29% good, 45% fair, and 14% poor, based on landscape stress.

Table 10. Area of "wet" aquatic habitat (water regimes C, F, G, and H) by landscape suitability class (based on elevation and temperature) and landscape stress class. Landscape suitability is based on the mean suitability value across the three measures of landscape suitability.

Key Aquatic Habitat By Landscape Suitability	Landscape Stress Class				Total Area (ha)
	Very Good	Good	Fair	Poor	
Most suitable elevation and temperature					
Emergent	7.7%	34.4%	54.3%	3.6%	2,237
Woody	15.8%	42.1%	40.1%	1.9%	1,117
Riverine	27.2%	51.6%	18.8%	2.4%	240
Open water: littoral	1.8%	6.9%	90.9%	0.4%	966
Open water: palustrine	25.3%	52.2%	21.6%	0.9%	1,381
Total	**13.2%**	**36.2%**	**48.5%**	**2.1%**	**5,941**
Moderately suitable elevation and temperature					
Emergent	5.5%	13.4%	45.2%	35.8%	3,519
Woody	3.4%	0.1%	71.6%	24.9%	1,020
Riverine	30.1%	38.5%	26.9%	4.6%	1,903
Open water: littoral	12.2%	38.4%	31.8%	17.6%	883
Open water: palustrine	8.3%	36.7%	44.0%	11.0%	1,152
Total	**11.9%**	**23.2%**	**42.7%**	**22.2%**	**8,477**
Least suitable elevation and temperature					
Emergent	0.8%	4.5%	42.3%	52.4%	2,043
Woody	12.7%	0.1%	60.8%	26.4%	1,049
Riverine	54.0%	9.7%	17.5%	18.9%	658
Open water: littoral	8.9%	18.8%	47.5%	24.9%	526
Open water: palustrine	2.9%	12.1%	49.9%	35.1%	345
Total	**12.1%**	**6.4%**	**44.1%**	**37.3%**	**4,621**
Total All Habitat Types	**12.34%**	**23.19%**	**44.88%**	**19.59%**	**19,039**

We compared the distribution of land versus the distribution of recent Western toad locations in areas with zero, one, two, or three landscape suitability measures in the good or fair range. Just over half of the study area was suitable in all three measures and almost all of the Western toad locations were in these areas (table 11). Western toad was underrepresented in less suitable areas. We used Western toad location data to help establish our temperature thresholds, so it is not surprising to see such a strong correspondence between two of our measures of suitability and Western toad locations. However, this comparison does show that the elevation data also appears appropriate and further confirms our use of the "quick and dirty" temperature thresholds.

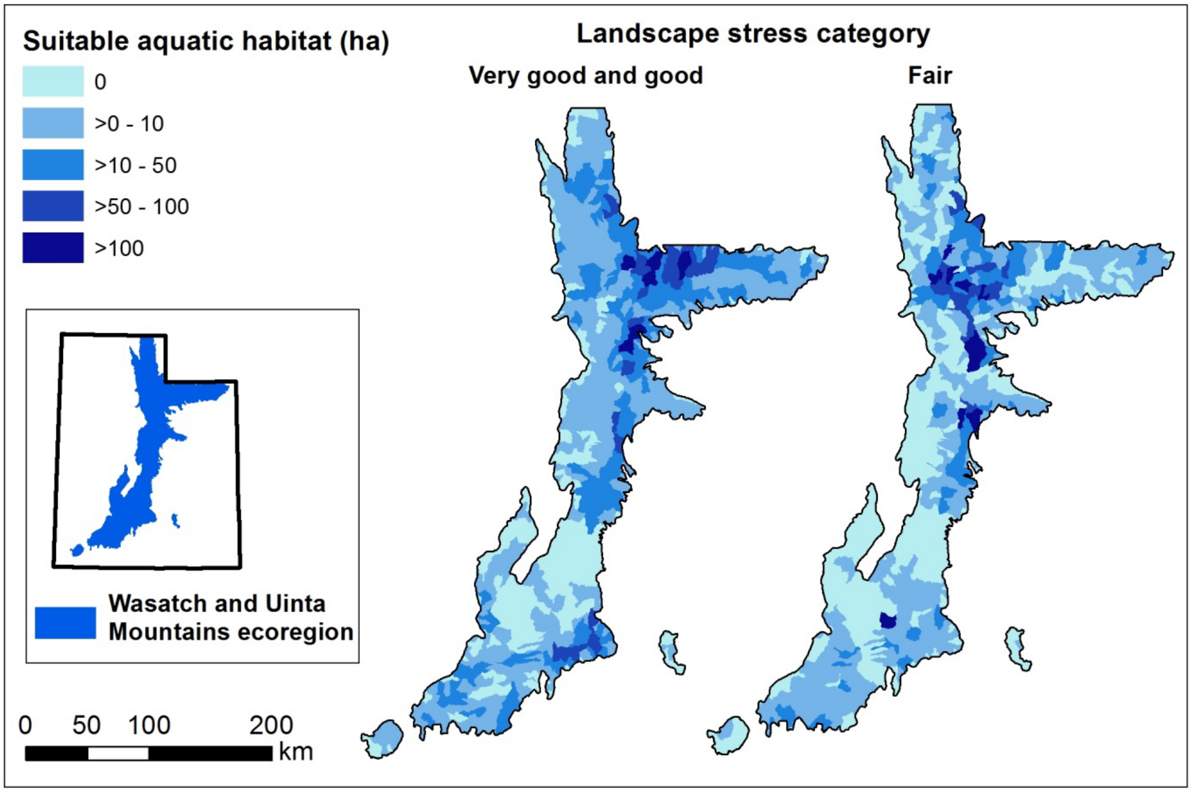

Figure 7. Area of wetlands within the Wasatch and Uinta Mountains ecoregion mapped as seasonally flooded or wetter per HUC12, for those wetlands in the very good and good or fair landscape stress categories. Only wetlands with at least two out of the three Western toad habitat elements (elevation and temperature) in the fair or good range area included in the map.

Table 11. Percent of the study total area and percent of all toad locations found in areas with between zero and 3 suitable landscape characteristics. Landscape suitability is based on one elevation and two temperature measures and includes all values designated as good or fair.

Landscape Suitability	% of Study Area	% of Toad Locations
No suitable landscape measures	2.9%	0.0%
1 suitable landscape measure	15.7%	0.6%
2 suitable landscape measure	29.4%	7.2%
3 suitable landscape measure	52.0%	92.2%
Total Area/Total Toad Records	**43,428 km^2**	**638 locations**

Conclusions

We produced detailed documentation on the types of geospatial data frequently used in aquatic resource landscape studies as well as their availability and utility for use in Utah. This documentation should increase efficiencies for any future efforts using the data, whether it is producing landscape models for individual species or creating models at different scales than our model. The documentation provides guidance for interpreting the often opaque data fields and recommendations for improving data layers through efforts such as improving spatial accuracy or turning point features into polygons.

The landscape model revealed clear differences in landscape stress levels among different aquatic habitat types as well as spatially, whether considering catchments or ecoregions. Forested, emergent, and palustrine open water experience the highest levels of landscape stress, and lacustrine limnetic and littoral open water were modeled as having the least. No ecoregion experiences the highest or lowest stress levels across all aquatic habitat types, though the Southern Rockies and Northern Basin and Range (two ecoregions with little area in Utah) had consistently low levels of stress and the Central Basin and Range had among the highest level of stress for most aquatic habitats. Because landscape stress levels are assigned to individual wetland polygons, our results can be summarized by any geographic unit with available spatial data, including cities, counties, Level IV ecoregions, and hydrologic basins of any scale.

Our model of stressors to aquatic habitats assumed that wetlands were affected only by stressors within 1000 m of sites, or even smaller distance for some stressors. The full extent of stress to aquatic habitats that receive substantial inputs of water from large watersheds, such as many riverine and lacustrine systems, is not fully captured by our landscape model. Limitations in our model are evident from the lack of correspondence with both instream invertebrate community integrity data and wetland condition scores from around Great Salt Lake. Instream conditions are likely heavily influenced by stressors to water quality that occur further than 1000 m from sites. Similarly, sites around Great Salt Lake, including sites visited by USU researcher Downard and Emergent Marsh sites visited by UGS, receive inputs of water from canals connected to major rivers in the region. Furthermore, water moves through Great Salt Lake sites through a series of impoundments, further complicating the hydrologic story of the region. Major hydrologic stressors are shared by all aquatic habitat in the region; *differences* in condition between sites may be more dependent on factors such as management decisions and local site conditions not captured in the landscape model, as well as difference in water quality between source water and water as it moves through impoundments.

Model application to Western toad habitat showed that wetland habitat most suitable based on elevation and temperature ranges also had the lowest levels of landscape stress. Just under 50% of all palustrine open water habitat was located in the most suitable elevation and temperature area, with over 75% of that habitat modeled as having very good or good levels of landscape stress. Littoral sites had much higher landscape stress values because many lakes are created by artificial impoundment. Impoundment is considered a stressor in the model even though Western toad populations have been found in some cases to thrive in and near impoundments. Our aquatic stress model is a general depiction of landscape stress; individual stressors will have higher or lower levels of impact to specific species than modeled depending on specific species tolerances.

Our model of landscape stress is more likely to accurately depict level of stress within regions or by type of aquatic habitat rather than at individual wetlands. This lack of direct applicability to individual sites is partially due to the inherent inaccuracies in geospatial data, but is also strongly influenced by factors that could not be included in the model due to lack of available data. Stressors such as adjacent or within-site livestock grazing, small unmapped diversions of water, and established non-native plant species can lead to lower site condition than modeled. On the other hand, proactive management and the presence of intact buffers can play an important role in producing better condition at sites than expected based on the landscape model.

Recommendations

Our model currently is applicable to isolated wetlands and wetlands with small watersheds. It would be useful to create a second model with watershed-based stressor values to more accurately capture in-stream conditions and condition of riverine and lacustrine aquatic habitat. Many hydrologic variables, such as amount of diverted water and length of ditching, should be corrected based on total upstream features to produce variables such as diverted water per unit stream flow or length of upstream ditches per length of all streams in the watershed. An even more complex model of in-stream condition could be developed by tracing stressors along stream networks to find, for example, the distance downstream between a dam and the next major tributary or the distance between a point source discharger and an impoundment along Great Salt Lake. We have received more Endangered Species Mitigation Fund funding for fiscal year 2016 to calculate watershed-based stressor values for a study region within the state. In addition, the Environmental Protection Agency Office of Research and Development in Corvallis, Oregon, is working on developing some watershed-based metrics for the entire nation. We plan to refine our existing model with these new metrics to make it more applicable to instream condition. This work will result in the creation of two separate models, one for more isolated features and one for features that are located along major stream networks

As discussed above, many potential influences on site condition were not included in the landscape model. We can improve landscape model results by combining them with the results of other studies, such as the rapid assessments being conducted by the UGS to determine actual levels of stress on the landscape. For example, we found relatively low levels of stress in palustrine open water sites that were suitable for Western toad habitat. However, field surveys conducted by the UGS showed that 43% of Wasatch and Uinta Mountains sites had evidence of livestock grazing during surveys of the Weber River HUC6 Watershed, and 40% of those sites showed moderate to severe impacts. The landscape stress model in combination with the field survey data provides a more accurate indication of Western toad habitat condition. UGS survey results can also be used to determine whether sites are in better than expected condition by determining the percent of sites in each study area with intact buffers.

To increase applicability of the landscape model to individual species, we recommend either improving some thresholds in the Ecological Integrity Tables or using available species occurrence data to create robust models of habitat suitability for focal wildlife species. Efforts to create such models may be hampered by the nature of the currently available species data, which is frequently focused on monitoring sites with known populations and may be clustered in certain elevation and temperature zones. Nonetheless, it is important to be able to overlay habitat suitability information with information on suitable wetlands and landscape stress to understand the nature and distribution of threats to species.

The results of our work are only as valid as the data available for inputs. We vetted all potential input variables to select the most appropriate for our models, but found that some key variables were poorly georeferenced. We recommend improving spatial accuracy of datasets whenever possible, collaborating with data producers whenever possible to permanently improve data rather than making changes to UGS versions only. Inaccuracies in the U.S. Fish and Wildlife Service's NWI data are also an important limitation of our work. This data are the only statewide dataset showing the distributing of key aquatic habitats, but is often out-of-date and inconsistently mapped between regions. We recommend continuing to support new wetland mapping projects, especially in areas of importance for sensitive species, so we can make up-to-date estimates about habitat availability. We also recommend using the results of the Utah State University-led riparian mapping project to help expand our definition of key aquatic habitats to included potential or actual riparian area in addition to the wetland features captured by NWI.

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Richard Emerson at Utah Geological Survey began the collaboration between the wetland program and the Utah Division of Wildlife Resources (UDWR) that made this project possible. He worked with UDWR to develop the aquatic habitat classifications used in this study. Individuals at UDWR have also provided important support and encouragement for our continual efforts to characterize aquatic habitat. Jennifer Jones, formerly with Utah Geological Survey, supported development of this project and, along with Ryhan Sempler and this study's author, developed the Utah Rapid Assessment Procedure which was used to calibrate model results. Jennifer, Ryhan, Diane, and two summer interns, Maddy Merrill and Pete Goodwin, collected field data that supported calibration. Becka Downard at Utah State University and Scott Miller at the U.S. Bureau of Land Management/Utah State University National Aquatic Monitoring Center provided data for use in model validation. Numerous people contributed data for this project and answered inquires to better explain metadata, including individuals at the Utah Division of Water Rights, Utah Division of Water Quality, Utah Division of Water Resources, Utah Division of Oil, Gas, and Mining, U.S. Natural Resources Conservation Service, Utah Natural Heritage Program, and Utah Department of Agriculture and Food. This work benefited greatly from participation in meetings and data collaboration with individuals involved in the development of a Rapid Ecoregional Assessment Aquatic Intactness model for Utah, led by the Conservation Biology Institute and funded by the U.S. Bureau of Land Management. This project would not have been possible without funding and support from Chris Keleher and the Endangered Species Mitigation Fund.

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Appendix A

Table of Variables Considered for Model

Table A-1. Data for stressor variables considered for landscape integrity model. Variables used in final model are in bold.

Category	Variable	Source	Notes	Link to Data
Biological Stress	Noxious weeds	Utah Department of Agriculture and Food	Maintain some data on locations of noxious weeds in the state; data is not complete; emailed Rich Riding about location of dataset 12/15/2014.	
Biological Stress	Tamarisk distribution	Utah Natural Heritage Program	GIS Analyst Gary Ogden had been looking for statewide data on tamarisk distribution but said he was not able to put together a usable statewide dataset as of December 2014.	
Biological Stress	Tamarisk and Russian olive distribution	Catherine Jarvenich, USGS Fort Collins Science Center	Catherine Jarvenich has created habitat suitability models for tamarisk and Russian olive for the western United States. The model for tamarisk is at about 1 km resolution.	
Biological Stress	**Phragmites distribution**	**Lexine Long, former USU graduate student**	**Created a map of *Phragmites* around Great Salt Lake and may be working on a habitat suitability model for the species as well (emailed 12/18/2014 to ask about data).**	
Biological Stress	BLM National Invasive Species Information Management System	BLM		http://www.blm.gov/wo/st/en/prog/more/weeds/nisims.html
Biological Stress	Forest Service Current Invasive Plants Inventory	U.S. Forest Service		http://data.fs.usda.gov/geodata/edw/datasets.php?dsetCategory=biota
Biological Stress	Existing vegetation, including introduced species' classes	USGS Landfire	Data on existing vegetation on landscape, which includes some classes of introduced species. Most recent version of data is from 2012 imagery.	http://www.landfire.gov
Biological Stress	Noxious weeds	AGRC SDE	Most up-to-date record from 2006; not comprehensive coverage.	SGID10.BIOSCIENCE.NoxiousWeed_Point (or Polygon or Line)
Hydrologic Modification	**Statewide artificial flow (canals, ditches)**	**USGS National Hydrography Dataset (NHD)**	**Data needs to be selected both from NHDFlowline and from NHDArea. Segments called artificial flow can be from 2D canals, streams, or lakes/reservoirs. See http://nationalmap.gov/standards/pdf/NHDH0799.PDF for feature definitions.**	**http://nhd.usgs.gov/data.html**
Hydrologic Modification	**GSL artificial flow (canals, ditches)**	**UGS SDE**	**Lines are more accurate than NHD lines for area where they were digitized. Lines were digitized using 2011 aerial imagery and LiDAR data during the winter of 2013-2014. Contact Rich Emerson or Diane Menuz at UGS for more information.**	**UGGP.UGGPADMIN.GreatSaltLake\UGGP.UGGPADMIN.GSL_LiDAR_FlowPath**
Hydrologic Modification	**Utah Division of Water Rights Dams**	**Utah Division of Water Rights WRDAMS**	**Based on analysis in Weber Watershed, dam file includes all NHD dams, but location of smaller dams often seem incorrect.**	**http://www.waterrights.utah.gov/gisinfo/wrcover.asp**
Hydrologic Modification	U.S.Army Corps Dams	U.S. Army Corps National Inventory of Dams (NID)	NID data cannot be directly downloaded from the listed site. NID data includes dams with a high or significant hazard classification, exceed 15 acre-feet of storage and over 25 ft tall, or exceed 50 acre-feet of storage and over 6 feet tall. Researcher Holly Strand at USU stated that NID is larger than USGS dams, but locations are somewhat off.	http://geo.usace.army.mil/pgis/f?p=397:1:0

Hydrologic Modification	**NHD dams**	**USGS National Hydrography Dataset (NHD)**	**NHDPointEventFC has data on dams, mostly taken from NID. The file has a unique identifier that links these dams to dams in the Utah Division of Water Rights dam ID number. NHD has less dams than WRDAMS, but generally NHD dam locations are more precise (and snapped to NHDFlowlines) than WRDAMS.**	**http://nhd.usgs.gov/data.html**
Hydrologic Modification	**NHD Waterbodies (including reservoirs)**	**USGS National Hydrography Dataset (NHD)**	**In NHD, features of FTYPE Reservoir are constructed basins whereas LakePond can be either dammed or natural features with natural (unconstructed) shorelines.**	**http://nhd.usgs.gov/data.html**
Hydrologic Modification	**Water Related Land Use Reservoirs**	**Utah Division of Water Resources**	**Reservoirs were no longer mapped starting in around 2014 because it was difficult to be consistent in their designations. Features designated as reservoirs are artificially impounded waterbodies. UDWRe also has a separate file of reservoirs that have been connected with dam points that is available via email.**	**http://gis.utah.gov/data/planning/water-related-land; UDNR.WRE.UtahCurrentLandUse; http://www.water.utah.gov/Landuse/Default.htm**
Hydrologic Modification	**Impoundments**	**Utah Division of Water Quality, Toby Hooker**	**Impounded wetlands and other ponds around Great Salt Lake digitized by Toby. Toby said: "Some of those ponds are most likely shallow depressions / mudflat rather than IWs for waterfowl, but I included them with an eye toward shorebird habitat in the future."**	
Hydrologic Modification	Stream alteration	Utah Division of Water Rights WRSTRALT	Locations of stream alteration permits, updated daily. The permit program was implemented in 1972, though data mainly exists for 2004 and later.	http://www.waterrights.utah.gov/gisinfo/wrcover.asp
Hydrologic Modification	Points of diversion (WRPOD)	Utah Division of Water Rights WRPOD	Updated regularly; includes data on surface and groundwater extraction, points where water is returned to the system, permits for areas along streams where stock drink, etc. See associated metadata.	http://www.waterrights.utah.gov/gisinfo/wrcover.asp
Linear Landscape Disturbance	**Gas Pipelines**	**Shawn Servoss at BLM; forwarded to UGS via Conservation Biology Institute**	**This dataset represents the natural gas distribution facilities for portions of Davis, Salt Lake, and Utah Counties. These data were digitized as part of the State of Utah Comprehensive Emergency Management Earthquake Preparedness Program, 1986-1989.**	
Linear Landscape Disturbance	**Kern River Pipeline**	**Shawn Servoss at BLM; forwarded to UGS via Conservation Biology Institute**		
Linear Landscape Disturbance	**Topographic Pipelines**	**Shawn Servoss at BLM; forwarded to UGS via Conservation Biology Institute**	**This data set represents the oil and gas transmission pipelines in Utah and portions of Arizona, Colorado, Idaho, Nevada and New Mexico that appear on the 1:100,000 scale topographical map series from the U. S. Geological Survey (USGS).**	
Linear Landscape Disturbance	**Oil and Gas Pipelines (BLM)**	**Shawn Servoss at BLM; forwarded to UGS via Conservation Biology Institute**	**This data set represents the oil and gas transmission pipelines in Utah. The data were compiled from DLG and CFF data collected from the U. S. Forest Service and the U. S. Geological Survey. The most current data available was used.**	

Linear Landscape Disturbance	**Ruby Pipeline**	**Shawn Servoss at BLM; forwarded to UGS via Conservation Biology Institute**	**The approximate Utah portion of the Ruby pipeline corridor was digitized at 1:24,000 scale using aerial imagery. The pipeline path is less accurate in agricultural, urban, and other areas where it was not as visible.**	
Linear Landscape Disturbance	**Oil and Gas Pipelines (UGS)**	**Rebekah Wood at UGS**	**Oil and gas pipeline data compiled by UGS as part of production of map of oil and gas resources in the state. Data for compilation is from a variety of sources and differs in resolution.**	
Boundary	Level III and IV Ecoregions	US EPA Western Ecology Division		http://www.epa.gov/wed/pages/ecoregions.htm
Demography	Populated Block Areas 2010 Approximation	U.S. Census Bureau 2010, available on AGRC online and SDE	This dataset was created by AGRC using the original 2010 census blocks. The blocks were cut when necessary to only cover residential areas. This was done using mainly aerial imagery and is just an approximation.	SGID10.DEMOGRAPHIC.PopBlockAreas2010_Approx; http://gis.utah.gov/data/demographic/2010-census-data, SGID10.DEMOGRAPHIC.PopBlockAreas2010_Approx
Demography	Populated Place Points 2010 Approximation	U.S. Census Bureau 2010, available on AGRC online and SDE	Point locations of populated places in Utah with their approximated populations in 2010. Incorporated municipality populations were determined by the U.S. Census Bureau. The population of unincorporated places were approximated by AGRC using a given place's surrounding census blocks and their 2010 census population counts.	SGID10.DEMOGRAPHIC.PopPlacePts2010_Approx; http://gis.utah.gov/data/demographic/2010-census-data, SGID10.DEMOGRAPHIC.PopPlacePts2010_Approx
Regulated Dischargers	EPA National Facility Registry Service (FRS) facilities	EPA Envirofacts Geospatial Data Download Service	Includes data on superfund sites, toxic release sites, hazardous waste, point source dischargers, etc. However, at least some of the spatial info on the points appears incorrect (i.e. several major point source dischargers) and point source dischargers are not categorized by types (CAFO, industrial stormwater, etc.). NAICIS codes and SIC codes can be helpful for distinguishing between different types of UPDES permits; for example, sewerage systems are likely to be MS4s and general contractors are likely to be construction. Can subset out FRS features with Clean Water Act components.	http://www.epa.gov/enviro/geo_data.html
Regulated Dischargers	UPDES Permit Holders by Permit Type	EPA OTIS webpage and AGRC's SDE	Data compiled from the EPA's OTIS system in 2013, which is no longer in use, with spatial data from either OTIS or Utah's SDE. Multiple queries had to be made to OTIS in order to determine permit types, which includes biosolid, CAFO, sewer overflow, POTW, industrial and construction stormwater, and MS4s.	OTIS has been replaced by ECHO (http://echo.epa.gov); SGID10.ENVIRONMENT.UPDESSites
Regulated Dischargers	UDEQ Land-Related Contaminant and Cleanup Data	AGRC and UDEQ	Sites are probably the same as those in the EPA FRS, though the coordinates may differ in some cases. Files are older than the EPA list; updated through 2007 when I looked at it in 2014. From AGRC description:US EPA and State designated hazardous materials storage sites and contamination clean up program sites including CERLA, National Priority List, Underground Storage Tanks (UST), Brownfields, Voluntary Cleanup (VCP), Tier 2, Toxic Release Inventory (TRI), User Oil Permitted Facilities, Formerly Used Defense (FUD), RCRA Large & Small Quantity Hazardous Waste Generators, Solid Waste Facilities, and Enforceable Written Assurance sites.	http://gis.utah.gov/data/environment/deq-land-related-contaminant-cleanup-sites/

Energy and Extraction	**Oil and gas wells**	**SDE**	**Oil and gas well information is updated nightly on SDE. Many different well types exist; see metadata spreadsheet, including service wells, dry holes, injection wells and extraction wells. Also must distinguish between wells in use and wells that are plugged and abandoned and/or permitted but not yet built**	**http://gis.utah.gov/data/energy/oil-gas, SGID10.ENERGY.DNROilGasWells**
Energy and Extraction	Power Plants	AGRC	Dated from 2008.	http://gis.utah.gov/data/energy/energy-generation/
Energy and Extraction	Permitted Uranium Mines	AGRC/SDE	Most of these mines also appear to be available in the Mine data received from DOGM	http://gis.utah.gov/data/energy/uranium, SGID10.ENERGY.PermittedUraniumMines
Energy and Extraction	**DOGM Permitted Mineral Mines**	**Utah DOGM (via email)**	**Point data of locations of permitted mines, taken from DOGM's mineral database. Some mines included in the dataset may be not approved or are retired or do not require a permit.**	
Energy and Extraction	**DOGM Permitted Mineral Mines Area Features**	**Utah DOGM (via email)**	**Feature is for internal use only. Polygon features showing area of mine impacts, area of reseeding efforts and/or other features. Not complete for all permitted mines and not up-to-date, though features include the year of the digitization**	
Energy and Extraction	DOGM Coal Permit Areas	Utah DOGM (via email)	Permit boundaries for coal permits. All mining activity would occur within the permitted area, but not necessarily all of the permitted area will ever be mined	
Energy and Extraction	DOGM Abandoned Mine Reclamation Program mines	Utah DOGM (via email)	Feature is for internal use only. Point data of abandoned mines that have been located and may or may not have been reclaimed by DOGM. Includes mines that were in existence before the mine permitting system was begun.	
Energy and Extraction	USGS Active Mines and Mineral Plants as of 2003	USGS	Probably not best source of data b/c metadata says that is includes those active in 2003 and surveyed by USGS, probably a more limited dataset than what we can get internally.	http://mrdata.usgs.gov/mineplant/
Energy and Extraction	DNR SDE Mine layer	Utah DOGM on DNR SDE	Has less features than data directly from DOGM, as of 2013 when this was investigated; no associated metadata.	UDNR.OGM.MineralMineArea, UDNR.OGM.MineralMineArea, UDNR.OGM.MineDist
Energy and Extraction	USGS Mineral Resources Data System (MRDS)	USGS	System stopped being updated in 2011; new database in development. Contains information on past and present mineral producers, areas with deposits, etc. Contains some duplicate records.	http://mrdata.usgs.gov/mrds/
Fire	Federal Wildland Fire Occurrence Data		Data from 1980 to 2013 for fires on federal land, including BIA, BLM, BOR, USFS, FWS, NPS.	http://wildfire.cr.usgs.gov/firehistory/data.html
Fire	2014 Fire History	BLM	Metadata states that data is through the 2010 fire season.	http://www.blm.gov/ut/st/en/prog/more/geographic_information/gis_data_and_maps.html
Fire	Monitoring Trends in Fire Severity		Data on the burn severity and fire perimters across the entire US from 1984 to the present day.	http://www.mtbs.gov/
Hydrologic Modification	Ground Water Permits	UDWQ on AGRC SDE	No metadata is associated with this file, but features are most likely permits for groundwater discharge permits. According to UDEQ, potential permittees include anyone likely to discharge pollutants to groundwater, though facilities with permits through other agencies (e.g., mines, etc.) *may* not have to get a separate permit through UDEQ.	SGID10.ENVIRONMENT.DWQGroundWaterPermits

Hydrologic Modification	USGS Water Data for the Nation	USGS	Site specific information on surface water, groundwater, water quality and water use data. Water use data is only available by county.	http://waterdata.usgs.gov/nwis
Land Cover, Land Use	Landfire Existing Vegetation	LANDFIRE	Data from 2012. Also includes information on existing vegetation cover and height. Vegetation is generally mapped using Ecological Systems.	http://www.landfire.gov/refresh_overview.php
Land Cover, Land Use	NLCD Land Cover	Multi-Resolution Land Characteristics Consortium	Most recent available data is from 2011. Roads frequently show up as development, but not consistently enough to be considered an accurate depiction of roads.	http://www.mrlc.gov/index.php
Land Cover, Land Use	**NLCD impervious surface**	**Multi-Resolution Land Characteristics Consortium**	**Most recent data is from 2011. Raster shows percent of each grid that is composed of impervious surface.**	**http://www.mrlc.gov/index.php**
Land Cover, Land Use	USFS Recreation Sites	USFS Region 4 GIS Data Library		http://www.fs.usda.gov/main/r4/landmanagement/gis
Land Cover, Land Use	Military Bases	USDOT		http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_atlas_database/2013/polygon.html
Land Cover, Land Use	**Water Related Land Use**	**Utah Division of Water Resources**	**Separate files for each major basin and each year that it was inventoried are available on the UDNR SDE. This information can potentially be broken into different categories, such as all irrigated lands, all row crops, all (irrigated) pasture, etc. Also has urban areas mapped which may in some cases be more accurate than NLCD since it was mapped based on imagery and doesn't confuse roads with urban. Mapping techniques and attributions are not necessarily 100% consistent between years. Metadata is available online at http://www.water.utah.gov/Landuse/gisdata.htm.**	**http://gis.utah.gov/data/planning/water-related-land; UDNR.WRE.UtahCurrentLandUse; http://www.water.utah.gov/Landuse/Default.htm**
Land Cover, Land Use	Grazing Allotment	AGRC/SDE	Dated from 2009 on AGRC, seems to have both BLM, SITLA, and USFS allotments.	http://gis.utah.gov/data/farming/grazing-allotments, SGID10.FARMING.GrazingAllotments
Land Cover, Land Use	BLM Grazing Allotment	BLM	Contains only info on BLM and SITLA grazing allottments but may be more up-to-date then grazing allotment info in the AGRC file.	http://www.blm.gov/ut/st/en/prog/more/geographic_information/gis_data_and_maps.html
Land Cover, Land Use	Golf Courses	ARCG/SDE, Utah Golf Association		http://gis.utah.gov/data/recreation/golf-courses, SGID10.RECREATION.GolfCourses
Transportation	**Transportation Road Core FS**	**USFS**	**Road data for USFS Region 4. As of 2015, the file was dated on website from 2013. Road data can also be downloaded by individual forest. Comparison with AGRC road data shows high correspondence, but AGRC is missing some roads.**	**http://www.fs.usda.gov/main/r4/landmanagement/gis**
Transportation	**Road Centerlines**	**AGRC**		**http://gis.utah.gov/data/sgid-transportation/roads-system/**
Transportation	**Railroads**	**AGRC/SDE**	**Can look at by TYPE- heavy, scenic, light or null.**	**http://gis.utah.gov/data/sgid-transportation/railroads, SGID10.TRANSPORTATION.Railroads**
Transportation	UWCNF Trails	Uinta-Wasatch-Cache National Forest	Other National Forests probably also have individual road information.	http://www.fs.usda.gov/detail/uwcnf/landmanagement/gis/?cid=stelprdb5434510
Transportation	Trails	AGRC	Data from AGRC is slowly being updated but not currently complete. Trails are coded as hiking, singletrack bicycle, paved, and road/trail.	http://gis.utah.gov/data/recreation/trails/

Energy and Extraction	Wind Turbines	USGS Onshore Industrial Wind Turbine Locations	Only a few locations with mapped wind turbines in Utah. Data through 2013.	http://pubs.usgs.gov/ds/817/
Hydrologic Modification	Groundwater Conditions in Utah Spring 2013	USGS Cooperative Investigations Report No. 54	Report that includes information on groundwater development and delineates areas with significant and lesser development, data not spatial but could be digitized.	http://ut.water.usgs.gov/publications/GW2013.pdf
Water Quality	Impaired Lakes and Streams	UDWQ	The latest Integrated Water Quality report from UDWQ is from 2012-2014, but was still in draft form as of April 2015. Water quality is assessed at designated lakes and along perennial stream stretches of within Assessment Units. Data from one or more sampling locations within an AU are summarized to determine impairment status. the latest draft information is available through email request only.	http://www.waterquality.utah.gov/WQAssess/currentIR.htm
Land Cover, Land Use	North Slope Uinta Grazing Allotments	USFS	Current grazing allotment units on the north slopes of the Uinta Mountains. Does not say what type of livestock.	
Land Cover, Land Use	USFS Timber Harvest	USFS	Depicts the area planned and accomplished acres treated as a part of the timber harvest program of work, funded through the budget allocation process and reported through the FACTS database. Activities are self-reported by Forest Service Units. Probable missing data.	http://data.fs.usda.gov/geodata/edw/datasets.php

Appendix B

Summarized Landscape Stressor Data

Table B-1. Hectares of emergent wetland in each landscape stress class by HUC8 membership.

HUC8	Very Good	Good	Fair	Poor	Total Area
14010005	0.00	0.00	1.36	0.00	1.36
14030001	2.51	16.57	5.69	2.78	27.54
14030002	5.35	60.01	157.01	4.95	227.32
14030004	9.02	64.54	19.94	0.00	93.50
14030005	13.86	122.79	196.76	14.17	347.58
14040106	1,601.99	1,384.01	1,395.16	256.92	4,638.08
14040107	1,457.86	1,323.28	65.26	0.00	2,846.40
14040108	59.06	35.83	12.54	0.00	107.43
14050007	1.16	150.37	19.54	2.44	173.50
14060003	3,664.47	1,053.17	5,857.31	5,096.46	15,671.41
14060004	10.58	402.02	901.35	38.41	1,352.36
14060005	15.77	96.21	399.01	206.22	717.20
14060006	139.33	158.93	117.81	0.00	416.07
14060007	50.41	228.11	1,257.44	505.76	2,041.72
14060008	7.51	25.77	69.56	14.31	117.14
14060009	72.26	359.42	1,188.13	1,129.23	2,749.05
14060010	888.21	1,807.49	1,216.36	825.00	4,737.07
14070001	47.12	55.70	20.07	0.00	122.88
14070002	16.84	40.41	74.18	0.00	131.43
14070003	24.37	348.94	1,319.17	255.01	1,947.49
14070004	6.96	10.23	6.28	0.00	23.47
14070005	30.87	321.80	141.00	59.85	553.51
14070006	35.10	31.95	2.92	0.00	69.97
14070007	17.42	12.26	4.56	4.00	38.25
14080201	20.93	100.13	19.54	16.13	156.73
14080202	0.00	5.48	2.23	0.37	8.08
14080203	2.27	42.88	89.05	8.91	143.11
14080204	3.44	0.49	0.47	0.00	4.39
14080205	1.75	2.23	0.81	0.00	4.78
15010003	0.29	0.36	4.64	0.00	5.29
15010008	30.73	106.10	291.26	48.43	476.52
15010009	0.00	0.00	0.00	0.00	0.00
15010010	0.00	0.00	0.00	0.00	0.00
16010101	460.20	1,026.61	9,108.75	4,452.79	15,048.35
16010102	0.00	1.37	1,973.36	0.00	1,974.73
16010201	11.59	76.58	1,049.06	602.55	1,739.79
16010202	0.05	18.66	1,412.81	513.24	1,944.76
16010203	4.49	131.06	1,730.30	839.41	2,705.26
16010204	383.23	3,332.73	11,595.58	1,252.11	16,563.65
16020101	159.25	419.16	1,204.18	936.62	2,719.22
16020102	67.34	3,435.80	6,631.13	2,169.02	12,303.30
16020201	131.89	2,650.22	5,695.01	1,181.86	9,658.98
16020202	16.69	182.38	2,174.73	1,079.56	3,453.37
16020203	29.17	236.46	712.80	907.87	1,886.30
16020204	100.92	626.38	3,915.36	466.29	5,108.95
16020301	139.98	440.75	887.40	4.16	1,472.29
16020302	1.73	17.37	8.96	0.00	28.06
16020303	32.33	67.88	13.59	0.00	113.79
16020304	20.41	415.52	4,601.19	412.48	5,449.61
16020305	573.81	3,871.08	101.30	22.04	4,568.23
16020306	632.47	450.08	569.66	21.61	1,673.81
16020307	0.00	0.17	0.00	0.00	0.17
16020308	680.85	777.56	273.50	112.81	1,844.72
16020309	425.14	2,533.33	1,466.47	25.87	4,450.81
16020310	313.83	2,403.61	3,469.67	7.57	6,194.68
16030001	6.74	133.95	182.83	7.22	330.74
16030002	9.01	190.96	839.67	140.81	1,180.46
16030003	16.29	261.79	1,573.58	198.95	2,050.60
16030004	17.76	293.16	7,515.03	1,748.61	9,574.56
16030005	444.19	8,989.97	1,400.17	107.27	10,941.60
16030006	0.65	33.99	88.98	1.65	125.27
16030007	1.89	31.51	48.87	23.05	105.32
16030008	18.48	1,539.75	242.09	2.73	1,803.05
16030009	0.15	126.88	12.16	0.22	139.42
17040210	0.16	16.84	36.85	1.31	55.16
17040211	0.40	62.40	531.92	0.00	594.71

Table B-2. Hectares of forested wetland in each landscape stress class, by HUC8 membership.

HUC8	Very Good	Good	Fair	Poor	Total Area
14010005	0.00	0.00	0.00	0.00	0.00
14030001	0.00	1.60	0.00	0.00	1.60
14030002	0.00	2.37	3.06	0.00	5.43
14030004	0.00	0.00	0.00	0.00	0.00
14030005	0.69	2.02	0.86	0.00	3.57
14040106	6.06	3.07	2.36	0.00	11.49
14040107	0.26	0.73	0.00	0.00	0.98
14040108	0.00	0.00	0.00	0.00	0.00
14050007	0.00	0.81	0.79	0.00	1.59
14060003	12.90	97.93	158.83	21.43	291.09
14060004	0.41	0.00	1.38	0.00	1.80
14060005	0.00	23.97	6.65	0.00	30.63
14060006	0.00	0.00	3.42	0.00	3.42
14060007	4.61	0.00	0.26	0.00	4.87
14060008	0.00	0.00	0.00	0.82	0.82
14060009	0.00	4.71	0.40	0.00	5.11
14060010	2.56	121.76	119.74	13.67	257.73
14070001	0.00	0.00	0.00	0.00	0.00
14070002	0.00	0.00	0.65	0.00	0.65
14070003	0.04	0.36	0.16	0.00	0.56
14070004	0.00	0.00	0.00	0.00	0.00
14070005	0.00	0.72	0.00	0.00	0.72
14070006	0.00	0.00	0.00	0.00	0.00
14070007	0.00	0.00	0.00	0.00	0.00
14080201	9.70	42.85	21.71	0.39	74.65
14080202	0.00	0.00	0.00	0.00	0.00
14080203	0.00	1.09	5.43	0.00	6.52
14080204	2.73	0.70	0.00	0.00	3.42
14080205	0.00	0.00	0.00	0.00	0.00
15010003	0.00	0.00	0.00	0.00	0.00
15010008	0.00	1.04	3.88	4.96	9.87
15010009	0.00	12.23	3.83	0.00	16.05
15010010	0.00	0.00	0.00	0.00	0.00
16010101	3.97	11.37	56.85	7.70	79.88
16010102	0.00	0.00	0.00	0.00	0.00
16010201	1.33	9.05	5.30	0.63	16.30
16010202	0.00	0.00	15.75	9.15	24.90
16010203	0.56	2.34	87.78	77.57	168.24
16010204	0.00	2.38	11.21	17.68	31.27
16020101	0.97	3.09	98.55	66.97	169.58
16020102	0.00	12.62	52.41	144.41	209.44
16020201	0.00	0.00	7.85	19.50	27.34
16020202	1.11	3.77	19.14	45.98	70.00
16020203	0.00	0.00	138.09	56.03	194.12
16020204	0.00	4.12	5.86	7.25	17.23
16020301	0.00	1.03	2.04	0.09	3.16
16020302	0.00	0.45	0.00	0.00	0.45
16020303	0.00	0.00	0.00	0.00	0.00
16020304	0.00	3.06	6.22	1.47	10.75
16020305	0.00	0.53	0.43	0.80	1.76
16020306	0.68	0.00	0.00	0.13	0.81
16020307	0.00	0.00	0.00	0.00	0.00
16020308	0.00	0.28	0.70	0.00	0.98
16020309	0.00	0.00	0.00	0.00	0.00
16020310	0.00	0.00	0.00	0.00	0.00
16030001	0.00	0.85	1.47	0.00	2.32
16030002	0.00	1.28	0.00	0.00	1.28
16030003	0.00	4.40	7.38	0.00	11.78
16030004	0.00	0.43	0.00	1.70	2.13
16030005	0.00	0.00	0.52	0.00	0.52
16030006	0.00	0.00	0.17	0.00	0.17
16030007	0.00	0.00	0.00	0.04	0.04
16030008	0.00	0.00	0.00	0.00	0.00
16030009	0.00	0.00	0.00	0.00	0.00
17040210	0.00	0.00	0.00	0.00	0.00
17040211	0.00	0.00	0.00	0.00	0.00

Table B-3. Hectares of limnetic open water wetland in each landscape stress class by HUC8 membership.

HUC8	Very Good	Good	Fair	Poor	Total Area
14010005	0.00	0.00	0.00	0.00	0.00
14030001	0.00	0.00	0.00	0.00	0.00
14030002	0.00	0.00	0.00	0.00	0.00
14030004	0.00	0.00	23.60	0.00	23.60
14030005	0.00	81.56	0.00	0.00	81.56
14040106	7.79	0.32	47.38	0.00	55.50
14040107	91.35	0.15	0.00	0.00	91.50
14040108	0.00	0.00	0.00	0.00	0.00
14050007	0.00	0.00	0.00	0.00	0.00
14060003	65.08	2.61	66.28	9.00	142.98
14060004	0.00	0.00	744.82	0.00	744.82
14060005	0.00	0.00	66.24	0.00	66.24
14060006	0.00	0.00	2.92	0.00	2.92
14060007	0.00	0.00	169.32	1.05	170.37
14060008	0.00	0.00	11.23	0.00	11.23
14060009	0.00	0.00	5.12	1.79	6.91
14060010	0.68	174.42	653.43	0.00	828.53
14070001	0.00	0.00	0.00	0.00	0.00
14070002	0.00	8.10	66.87	10.52	85.49
14070003	0.00	3.81	1,473.68	0.00	1,477.50
14070004	0.00	0.00	0.00	0.00	0.00
14070005	0.00	34.60	11.87	0.00	46.47
14070006	0.00	0.00	0.00	0.00	0.00
14070007	0.00	0.00	37.06	0.00	37.06
14080201	0.00	0.00	0.00	0.00	0.00
14080202	0.00	0.00	0.00	0.00	0.00
14080203	0.00	0.00	4.65	0.00	4.65
14080204	0.00	0.00	0.00	0.00	0.00
14080205	0.00	0.00	0.00	0.00	0.00
15010003	0.00	0.00	23.75	0.00	23.75
15010008	0.00	0.00	858.85	18.59	877.44
15010009	0.00	0.00	0.00	0.00	0.00
15010010	0.00	0.00	0.00	0.00	0.00
16010101	2.47	82.92	216.57	4.50	306.46
16010102	0.00	0.00	0.00	0.00	0.00
16010201	0.00	0.00	1,045.77	0.00	1,045.77
16010202	0.00	0.00	167.42	23.09	190.51
16010203	0.00	0.31	1,061.94	95.89	1,158.14
16010204	0.00	60.15	6,901.99	39.36	7,001.50
16020101	0.39	0.00	460.28	316.96	777.63
16020102	0.00	99.27	3,193.41	2,890.32	6,182.99
16020201	0.00	0.00	4,861.44	36.62	4,898.06
16020202	0.00	0.00	4,456.79	0.00	4,456.79
16020203	0.00	0.78	216.89	1.58	219.25
16020204	0.00	8.66	2,223.32	36.64	2,268.62
16020301	0.00	15.22	0.33	0.00	15.54
16020302	0.00	0.00	0.00	0.00	0.00
16020303	0.00	0.00	0.00	0.00	0.00
16020304	0.00	15.88	993.99	65.47	1,075.34
16020305	0.00	0.00	0.00	0.00	0.00
16020306	0.40	49.83	547.66	1.45	599.33
16020307	0.00	0.00	0.00	0.00	0.00
16020308	0.00	0.00	19.18	233.36	252.54
16020309	7.34	14.43	319.09	20.29	361.15
16020310	1,142.19	77,279.92	6,615.00	2,043.32	87,080.42
16030001	0.00	22.27	434.19	0.00	456.46
16030002	0.00	43.68	343.80	0.00	387.47
16030003	0.00	0.00	219.89	101.16	321.05
16030004	0.00	0.00	89.55	6.61	96.16
16030005	50.72	82.51	115.57	0.00	248.80
16030006	0.00	637.68	271.83	0.00	909.51
16030007	0.00	0.00	0.00	0.00	0.00
16030008	0.00	0.00	0.00	0.00	0.00
16030009	0.00	39,519.42	0.00	0.00	39,519.42
17040210	0.00	0.00	15.98	0.00	15.98
17040211	0.00	0.00	0.00	0.00	0.00

Table B-4. Hectares of littoral open water wetland in each landscape stress class by HUC8 membership.

HUC8	Very Good	Good	Fair	Poor	Total Area
14010005	0.00	0.00	0.00	0.00	0.00
14030001	0.00	0.00	0.00	0.00	0.00
14030002	0.00	0.00	50.48	0.00	50.48
14030004	0.00	0.00	0.00	0.00	0.00
14030005	0.00	0.00	69.20	14.91	84.11
14040106	250.78	19.58	554.35	0.00	824.71
14040107	74.12	6.46	17,058.45	0.00	17,139.03
14040108	0.00	0.00	0.00	0.00	0.00
14050007	0.00	0.00	0.00	0.00	0.00
14060003	1,166.64	142.04	1,498.66	34.63	2,841.98
14060004	0.00	0.00	4,096.71	0.00	4,096.71
14060005	0.00	0.00	0.00	0.00	0.00
14060006	0.00	0.00	32.06	0.00	32.06
14060007	0.00	0.00	1,115.14	0.00	1,115.14
14060008	0.00	0.00	0.00	0.00	0.00
14060009	0.00	0.00	1,023.19	101.62	1,124.81
14060010	88.76	3.87	721.31	0.00	813.95
14070001	0.00	0.00	0.00	0.00	0.00
14070002	0.00	0.00	18.39	0.00	18.39
14070003	22.19	7.19	93.20	0.00	122.58
14070004	0.00	0.00	0.00	0.00	0.00
14070005	0.00	29.87	176.51	16.97	223.34
14070006	0.00	0.00	56,726.15	0.00	56,726.15
14070007	0.00	0.00	0.00	0.00	0.00
14080201	0.00	0.00	46.19	0.00	46.19
14080202	0.00	0.00	0.00	0.00	0.00
14080203	0.00	0.00	5.43	0.00	5.43
14080204	0.00	0.00	0.00	0.00	0.00
14080205	57.97	0.00	0.00	0.00	57.97
15010003	0.00	0.00	0.00	0.00	0.00
15010008	0.00	0.00	85.04	0.00	85.04
15010009	0.00	0.00	0.00	0.00	0.00
15010010	0.00	0.00	0.00	0.00	0.00
16010101	87.05	11.82	351.84	0.00	450.71
16010102	0.00	0.00	0.00	0.00	0.00
16010201	0.00	26,714.64	0.00	0.00	26,714.64
16010202	0.00	0.00	359.51	0.00	359.51
16010203	0.00	0.00	169.91	4.36	174.27
16010204	0.00	0.00	12.40	5.88	18.28
16020101	6.44	5.58	471.65	0.00	483.67
16020102	0.00	0.00	864.95	28.34	893.29
16020201	0.00	0.00	26,137.40	0.00	26,137.40
16020202	0.00	0.00	19.76	6.41	26.18
16020203	0.00	0.00	782.27	10.94	793.21
16020204	0.00	0.00	45.26	0.00	45.26
16020301	0.00	0.00	116.15	0.00	116.15
16020302	0.00	0.00	0.00	0.00	0.00
16020303	0.00	0.00	0.00	0.00	0.00
16020304	0.00	0.00	821.28	0.00	821.28
16020305	0.00	0.00	0.00	0.00	0.00
16020306	0.00	0.00	0.00	10.59	10.59
16020307	0.00	0.00	0.00	0.00	0.00
16020308	0.00	0.00	0.00	0.00	0.00
16020309	0.00	0.00	0.00	0.00	0.00
16020310	0.00	230,342.07	4,063.57	0.00	234,405.63
16030001	0.00	0.00	170.42	0.00	170.42
16030002	0.00	0.00	555.24	0.00	555.24
16030003	0.00	2.41	3,221.65	0.00	3,224.06
16030004	0.00	0.00	548.47	0.00	548.47
16030005	0.00	0.00	830.86	203.97	1,034.83
16030006	0.00	0.00	4.18	0.00	4.18
16030007	0.00	0.00	0.00	0.00	0.00
16030008	0.00	0.00	0.00	0.00	0.00
16030009	0.00	0.00	0.00	0.00	0.00
17040210	0.00	0.00	0.00	0.00	0.00
17040211	0.00	0.00	0.00	0.00	0.00

Table B-5. Hectares of palustrine open water wetland in each landscape stress class by HUC8 membership.

HUC8	Very Good	Good	Fair	Poor	Total Area
14010005	0.00	0.00	0.00	0.00	0.00
14030001	0.99	10.17	9.14	1.31	21.61
14030002	4.35	22.01	17.26	5.11	48.73
14030004	8.80	25.01	10.23	0.69	44.74
14030005	7.13	28.13	54.39	12.84	102.50
14040106	226.24	142.72	119.38	8.22	496.56
14040107	112.70	119.64	38.27	0.00	270.61
14040108	0.07	4.30	3.11	0.00	7.48
14050007	0.05	1.92	24.59	9.09	35.65
14060003	490.06	177.89	349.72	357.68	1,375.35
14060004	19.55	94.66	31.68	8.73	154.62
14060005	0.51	4.62	16.93	42.87	64.93
14060006	6.09	3.00	12.55	0.13	21.76
14060007	5.77	25.72	113.99	40.04	185.52
14060008	1.70	8.36	23.63	8.30	41.99
14060009	11.50	44.14	96.34	82.10	234.08
14060010	40.96	64.97	73.69	53.45	233.07
14070001	2.42	17.17	10.75	2.56	32.89
14070002	8.61	42.14	81.67	15.86	148.27
14070003	28.20	189.10	91.06	9.57	317.93
14070004	0.00	0.52	2.93	0.00	3.45
14070005	28.61	172.91	40.28	13.29	255.09
14070006	3.44	0.52	4.02	2.10	10.08
14070007	1.64	10.55	27.27	8.43	47.90
14080201	3.93	13.08	41.37	45.65	104.04
14080202	0.00	1.33	0.30	0.00	1.63
14080203	1.99	18.04	65.91	27.86	113.79
14080204	0.00	0.00	0.00	0.00	0.00
14080205	7.19	5.21	7.70	4.96	25.06
15010003	1.24	3.80	61.66	24.28	90.98
15010008	9.21	41.02	171.50	75.37	297.10
15010009	0.32	2.78	3.44	5.05	11.59
15010010	0.15	2.09	4.00	3.23	9.46
16010101	102.40	172.99	82.76	25.42	383.57
16010102	0.00	3.38	0.00	0.00	3.38
16010201	0.58	3.25	14.18	30.65	48.66
16010202	0.30	0.27	180.10	104.90	285.57
16010203	19.11	28.59	57.51	69.95	175.17
16010204	6.05	64.40	306.28	139.78	516.50
16020101	121.61	204.74	153.08	47.43	526.85
16020102	35.23	140.42	282.78	210.92	669.34
16020201	8.16	7.24	75.60	166.95	257.95
16020202	12.64	10.94	32.32	50.00	105.90
16020203	14.07	71.32	159.57	37.82	282.78
16020204	9.99	13.85	182.94	105.12	311.90
16020301	2.33	24.55	27.01	2.80	56.69
16020302	0.00	0.85	4.25	0.00	5.11
16020303	24.67	0.19	1.23	0.00	26.09
16020304	1.36	6.54	208.63	44.88	261.41
16020305	0.76	1.95	5.68	2.78	11.17
16020306	14.22	17.80	74.28	9.31	115.60
16020307	0.00	0.00	0.00	0.00	0.00
16020308	3.21	25.56	20.94	9.32	59.03
16020309	6.05	27.45	144.89	10.41	188.79
16020310	0.25	2.41	0.92	2.48	6.06
16030001	2.16	30.78	52.76	33.05	118.75
16030002	3.68	33.59	25.87	10.34	73.48
16030003	15.39	42.02	159.55	52.75	269.71
16030004	7.40	65.44	85.79	72.61	231.25
16030005	3.76	51.52	114.71	90.68	260.68
16030006	4.94	49.49	124.12	96.81	275.35
16030007	0.15	3.57	16.38	3.41	23.51
16030008	0.00	77.65	298.85	0.80	377.30
16030009	1.04	1.14	22.45	0.97	25.60
17040210	0.24	2.28	3.53	3.61	9.66
17040211	0.96	2.90	0.21	0.00	4.07

Table B-6. Hectares of riverine wetland in each landscape stress class by HUC8 membership.

HUC8	Very Good	Good	Fair	Poor	Total Area
14010005	0.00	1,236.75	18.64	0.43	1,255.82
14030001	1.01	52.05	59.69	2.78	115.53
14030002	1.58	35.07	0.00	0.00	36.65
14030004	4.95	33.63	11.62	0.88	51.09
14030005	115.17	192.56	178.22	7.68	493.64
14040106	15.23	820.47	27.77	1.18	864.65
14040107	2.86	38.48	2.80	0.00	44.14
14040108	0.00	0.00	0.00	0.00	0.00
14050007	36.34	125.70	144.78	6.86	313.68
14060003	53.00	205.02	429.09	164.24	851.35
14060004	8.55	10.42	37.89	11.47	68.32
14060005	124.19	290.27	4,359.13	0.74	4,774.33
14060006	4.30	13.54	12.12	0.00	29.97
14060007	51.54	277.21	83.69	33.99	446.44
14060008	18.12	4,504.27	1,220.86	6.29	5,749.54
14060009	123.96	1,522.99	55.23	41.59	1,743.78
14060010	82.64	205.54	423.35	63.74	775.27
14070001	104.42	43.61	25.23	0.00	173.25
14070002	36.44	307.00	54.48	0.85	398.77
14070003	16.49	111.41	195.60	34.12	357.62
14070004	130.71	391.54	58.93	2.81	583.99
14070005	95.06	79.50	73.58	20.12	268.26
14070006	0.41	42.70	1.07	0.00	44.18
14070007	94.71	234.49	264.72	0.36	594.28
14080201	62.53	409.27	318.72	0.00	790.51
14080202	0.56	2,333.34	8.94	0.00	2,342.84
14080203	5.86	49.06	82.41	0.36	137.70
14080204	8.28	47.83	0.00	0.00	56.10
14080205	168.28	89.54	20.30	0.00	278.13
15010003	1.69	27.13	94.16	2.19	125.16
15010008	26.02	142.31	428.28	43.80	640.41
15010009	0.00	37.31	1.41	8.93	47.65
15010010	0.79	6.17	5.54	0.00	12.50
16010101	3.50	8.17	235.29	1.35	248.30
16010102	0.00	0.00	249.29	0.00	249.29
16010201	4.48	27.58	18.27	21.69	72.03
16010202	0.00	2.73	172.05	1.97	176.75
16010203	0.00	0.00	2.57	2.74	5.32
16010204	20.46	33.42	688.11	530.26	1,272.25
16020101	0.00	1.33	6.94	57.22	65.50
16020102	1.00	21.27	256.54	326.33	605.15
16020201	0.00	5.39	12.45	16.80	34.64
16020202	1.29	17.12	53.54	10.13	82.08
16020203	0.00	0.00	122.20	21.87	144.07
16020204	0.00	0.00	66.25	205.49	271.74
16020301	0.00	0.63	13.37	0.96	14.96
16020302	0.00	0.00	0.00	0.00	0.00
16020303	0.00	0.00	0.00	0.00	0.00
16020304	0.00	0.00	98.24	24.17	122.41
16020305	0.00	0.00	0.00	0.00	0.00
16020306	0.53	1.87	15.82	96.55	114.77
16020307	0.00	0.00	0.00	0.00	0.00
16020308	0.00	0.00	73.54	0.00	73.54
16020309	7.42	0.45	7.20	0.00	15.07
16020310	0.00	0.00	28.53	0.00	28.53
16030001	1.64	139.75	263.88	22.58	427.85
16030002	16.99	229.85	46.31	9.02	302.16
16030003	1.54	128.33	530.90	59.99	720.76
16030004	0.00	13.28	83.96	75.25	172.49
16030005	0.34	154.44	506.86	41.84	703.48
16030006	3.30	93.42	200.54	19.93	317.19
16030007	7.07	89.80	144.81	52.55	294.24
16030008	0.00	0.00	0.00	0.00	0.00
16030009	0.00	0.00	0.00	0.00	0.00
17040210	0.00	0.00	0.00	0.00	0.00
17040211	0.00	0.00	0.00	0.00	0.00

Table B-7. Hectares of scrub-shrub wetland in each landscape stress class by HUC8 membership.

HUC8	Very Good	Good	Fair	Poor	Total Area
14010005	0.00	0.00	9.90	0.00	9.90
14030001	8.46	70.33	25.95	4.52	109.26
14030002	1.44	14.12	5.92	0.50	21.98
14030004	13.84	35.52	9.05	0.00	58.41
14030005	12.83	72.01	88.24	18.60	191.68
14040106	708.88	550.52	363.28	3.89	1,626.58
14040107	696.64	455.75	12.87	0.00	1,165.26
14040108	0.00	1.55	0.00	0.00	1.55
14050007	8.68	165.81	34.47	2.13	211.09
14060003	638.41	1,224.60	1,542.58	392.26	3,797.85
14060004	32.43	414.11	279.38	15.95	741.87
14060005	62.92	185.70	103.45	9.54	361.62
14060006	163.51	98.80	101.03	0.29	363.63
14060007	39.03	203.67	243.86	24.23	510.79
14060008	11.07	11.11	82.13	23.64	127.95
14060009	38.34	72.58	208.37	92.57	411.87
14060010	44.09	263.40	181.34	90.82	579.65
14070001	28.61	5.67	1.45	0.00	35.73
14070002	4.76	8.30	1.81	0.00	14.88
14070003	4.91	33.54	27.38	17.59	83.42
14070004	0.11	0.05	0.00	0.00	0.15
14070005	66.69	31.94	65.75	12.89	177.27
14070006	10.97	0.21	0.34	0.00	11.52
14070007	0.20	0.51	0.04	0.13	0.87
14080201	221.89	1,467.58	662.88	43.00	2,395.35
14080202	0.00	120.14	78.13	0.33	198.60
14080203	4.80	108.77	271.48	4.97	390.03
14080204	186.63	261.35	0.56	0.00	448.55
14080205	912.40	448.53	23.35	5.07	1,389.35
15010003	0.00	0.00	0.00	0.00	0.00
15010008	2.89	19.90	39.17	18.93	80.90
15010009	0.00	0.00	0.00	0.00	0.00
15010010	0.00	0.00	0.00	0.00	0.00
16010101	150.29	823.50	888.15	185.75	2,047.70
16010102	0.00	0.00	0.00	0.00	0.00
16010201	11.27	27.60	26.81	31.26	96.93
16010202	0.00	0.00	144.97	48.99	193.96
16010203	17.69	88.25	194.85	94.20	394.99
16010204	0.00	0.17	27.18	34.83	62.19
16020101	82.65	184.53	283.36	71.93	622.47
16020102	11.26	75.10	174.69	90.15	351.20
16020201	7.35	79.84	186.48	124.32	397.99
16020202	15.05	63.56	66.65	64.17	209.44
16020203	6.30	125.42	343.09	63.86	538.68
16020204	2.34	13.47	45.87	47.65	109.33
16020301	3.59	5.44	8.65	0.05	17.73
16020302	7.09	5.38	0.52	0.00	12.99
16020303	0.00	0.00	0.00	0.00	0.00
16020304	3.16	10.88	50.92	13.20	78.15
16020305	6.30	4.70	1.08	0.00	12.08
16020306	1.17	8.60	2.19	0.00	11.96
16020307	0.00	0.00	0.00	0.00	0.00
16020308	3.96	24.41	17.43	8.53	54.33
16020309	0.00	1.98	1.31	0.00	3.29
16020310	0.44	2.36	0.00	0.00	2.80
16030001	0.00	3.67	41.67	0.00	45.34
16030002	3.91	13.62	10.16	1.08	28.77
16030003	0.49	54.54	70.02	6.19	131.24
16030004	12.18	31.84	65.37	52.62	162.00
16030005	68.53	605.61	183.64	33.18	890.96
16030006	0.00	2.79	7.42	0.00	10.21
16030007	0.00	0.07	0.00	2.42	2.49
16030008	0.00	0.00	0.00	0.00	0.00
16030009	1.32	0.76	0.00	0.00	2.08
17040210	0.63	4.82	1.70	0.00	7.16
17040211	0.45	0.59	0.00	0.00	1.04

Table B-8. Forested wetland area in hectares by county and landscape stress category.

County	Very Good	Good	Fair	Poor	Total Area
BEAVER	0.0	0.4	0.0	0.0	0.5
BOX ELDER	0.0	2.7	11.9	18.9	33.4
CACHE	0.6	2.3	103.5	86.7	193.1
CARBON	4.6	2.1	0.0	0.0	6.7
DAGGETT	0.0	0.0	2.0	0.0	2.0
DAVIS	0.0	0.0	2.2	8.4	10.6
DUCHESNE	11.0	73.1	154.1	5.7	244.0
EMERY	0.0	2.4	0.7	0.8	3.9
GARFIELD	0.0	0.7	0.0	0.0	0.7
GRAND	0.0	1.6	0.0	0.0	1.6
IRON	0.0	0.8	0.2	0.0	1.0
JUAB	0.0	0.1	1.1	0.3	1.5
KANE	0.0	0.1	5.1	5.0	10.1
MILLARD	0.0	1.0	1.4	0.1	2.5
MORGAN	0.0	12.6	28.6	88.4	129.6
PIUTE	0.0	0.0	0.0	0.0	0.0
RICH	1.3	18.2	5.3	0.6	25.5
SALT LAKE	0.0	4.1	5.9	6.4	16.4
SAN JUAN	13.1	49.0	31.1	0.4	93.6
SANPETE	0.0	2.7	0.7	1.7	5.1
SEVIER	0.0	5.7	7.4	0.0	13.1
SUMMIT	11.3	9.1	215.8	81.4	317.6
TOOELE	0.7	3.6	6.7	2.3	13.2
UINTAH	4.4	169.2	135.3	29.4	338.4
UTAH	1.1	3.8	39.7	65.3	109.8
WASATCH	0.4	0.0	61.0	38.3	99.7
WASHINGTON	0.0	8.1	4.1	0.0	12.2
WAYNE	0.0	0.4	0.2	0.0	0.6
WEBER	0.0	0.0	27.3	58.2	85.5

Table B-9. Limnetic open water wetland area in hectares by county and landscape stress category.

County	Very Good	Good	Fair	Poor	Total Area
BEAVER	0.0	0.0	0.0	0.0	0.0
BOX ELDER	482.8	42,372.8	14,128.7	2,537.2	59,521.5
CACHE	0.0	0.3	1,229.4	119.0	1,348.7
CARBON	0.0	0.0	65.9	0.0	65.9
DAGGETT	0.9	0.0	27.0	0.0	27.9
DAVIS	20.0	12,495.6	1,674.6	64.5	14,254.7
DUCHESNE	62.0	2.3	66.3	0.9	131.5
EMERY	0.0	8.1	102.6	10.5	121.2
GARFIELD	0.0	82.1	542.7	0.0	624.8
GRAND	0.0	0.0	23.6	0.0	23.6
IRON	0.0	648.0	197.7	0.0	845.7
JUAB	10.4	64.9	559.8	0.0	635.1
KANE	0.0	11.9	69.4	0.0	81.4
MILLARD	40.7	39,602.1	103.7	0.0	39,746.5
MORGAN	0.0	0.0	291.2	0.0	291.2
PIUTE	0.0	0.0	120.9	0.0	120.9
RICH	0.0	82.9	1,262.2	4.5	1,349.6
SALT LAKE	105.3	8.7	2,148.4	36.6	2,299.0
SAN JUAN	0.0	81.6	4.7	0.0	86.2
SANPETE	0.0	0.0	127.0	8.4	135.4
SEVIER	0.0	0.0	1,857.8	101.2	1,958.9
SUMMIT	101.1	0.7	406.5	317.0	825.3
TOOELE	234.8	18,507.3	994.0	300.3	20,036.4
UINTAH	0.8	174.7	722.6	8.1	906.2
UTAH	0.0	0.0	9,318.2	37.7	9,355.9
WASATCH	3.1	0.6	939.4	1.6	944.6
WASHINGTON	0.0	0.0	933.0	18.6	951.5
WAYNE	0.0	0.0	0.0	0.0	0.0
WEBER	306.6	4,094.0	1,141.7	2,391.5	7,933.8

Table B-10. Littoral open water wetland area in hectares by county and landscape stress category.

County	Very Good	Good	Fair	Poor	Total Area
BEAVER	0.0	0.0	0.0	0.0	0.0
BOX ELDER	0.0	81,818.7	4,076.0	0.0	85,894.7
CACHE	0.0	0.0	529.4	10.2	539.7
CARBON	0.0	0.0	1,029.3	0.0	1,029.3
DAGGETT	76.7	1.6	17,097.2	0.0	17,175.4
DAVIS	0.0	0.0	0.0	0.0	0.0
DUCHESNE	1,136.7	115.5	2,351.2	0.0	3,603.5
EMERY	0.0	0.0	878.1	101.6	979.7
GARFIELD	0.0	37.1	265.0	17.0	319.0
GRAND	0.0	0.0	26.0	0.0	26.0
IRON	0.0	0.0	4.2	0.0	4.2
JUAB	0.0	0.0	788.9	0.0	788.9
KANE	0.0	0.0	56,896.6	0.0	56,896.6
MILLARD	0.0	0.0	768.3	204.0	972.3
MORGAN	0.0	0.0	123.9	9.2	133.1
PIUTE	0.0	0.0	525.2	0.0	525.2
RICH	0.0	26,714.6	277.1	0.0	26,991.8
SALT LAKE	0.0	0.0	45.3	0.0	45.3
SAN JUAN	58.0	0.0	104.9	14.9	177.7
SANPETE	0.0	2.4	4,009.3	0.0	4,011.7
SEVIER	0.0	0.0	10.2	0.0	10.2
SUMMIT	341.7	41.9	982.2	10.9	1,376.7
TOOELE	0.0	148,523.3	821.3	10.6	149,355.2
UINTAH	115.2	18.0	1,269.8	34.6	1,437.6
UTAH	0.0	0.0	25,547.0	6.4	25,553.4
WASATCH	3.5	12.3	3,536.8	0.0	3,552.7
WASHINGTON	0.0	0.0	85.0	0.0	85.0
WAYNE	22.2	0.0	34.8	0.0	57.0
WEBER	0.0	0.0	784.1	19.1	803.2

Table B-11. Palustrine open water wetland area in hectares by county and landscape stress category.

County	Very Good	Good	Fair	Poor	Total Area
BEAVER	0.3	2.4	20.3	2.3	25.4
BOX ELDER	15.7	121.9	477.0	166.9	781.4
CACHE	19.4	28.9	237.6	174.8	460.7
CARBON	1.3	16.0	67.8	20.2	105.3
DAGGETT	76.9	37.4	34.8	7.9	157.0
DAVIS	6.4	21.4	100.9	60.2	188.9
DUCHESNE	475.3	146.1	234.1	307.4	1,162.9
EMERY	8.0	42.0	179.8	112.4	342.1
GARFIELD	39.7	289.3	114.9	47.9	491.8
GRAND	6.4	37.9	41.5	14.0	99.8
IRON	7.5	62.4	122.5	92.2	284.5
JUAB	9.6	39.3	97.3	38.3	184.5
KANE	3.3	23.8	125.4	53.5	206.1
MILLARD	28.0	127.1	437.6	88.7	681.5
MORGAN	24.3	78.1	28.9	23.4	154.7
PIUTE	0.3	1.4	9.0	6.4	17.1
RICH	9.9	24.4	58.1	49.6	142.0
SALT LAKE	10.0	13.3	163.4	102.7	289.3
SAN JUAN	31.8	102.2	170.1	86.3	390.3
SANPETE	20.5	109.0	183.4	86.4	399.2
SEVIER	25.5	71.7	154.3	53.9	305.4
SUMMIT	464.5	575.0	377.0	66.9	1,483.3
TOOELE	11.6	21.6	237.5	57.7	328.4
UINTAH	59.9	88.0	292.0	162.5	602.3
UTAH	23.2	18.0	93.7	189.2	324.1
WASATCH	29.9	155.2	94.6	26.9	306.6
WASHINGTON	9.0	39.9	157.5	73.1	279.4
WAYNE	16.0	108.7	60.4	9.6	194.6
WEBER	19.1	81.6	156.6	123.7	381.0

Table B-12. Riverine wetland area in hectares by county and landscape stress category.

County	Very Good	Good	Fair	Poor	Total Area
BEAVER	7.1	87.4	144.8	52.6	291.8
BOX ELDER	28.9	40.9	740.2	574.6	1,384.6
CACHE	0.0	2.7	174.6	4.7	182.1
CARBON	62.4	36.4	5,562.9	32.9	5,694.7
DAGGETT	14.6	810.5	26.9	1.2	853.1
DAVIS	0.0	0.0	0.2	0.0	0.2
DUCHESNE	62.0	156.9	238.8	160.6	618.3
EMERY	192.5	810.0	119.0	44.0	1,165.7
GARFIELD	121.9	697.3	300.7	47.5	1,167.3
GRAND	31.4	7,076.5	278.1	16.5	7,402.5
IRON	4.3	113.4	159.5	19.8	297.1
JUAB	0.9	11.4	208.2	2.7	223.2
KANE	173.7	336.7	463.7	9.9	984.0
MILLARD	0.0	153.4	340.3	41.9	535.5
MORGAN	0.0	0.0	39.8	79.8	119.6
PIUTE	1.0	8.1	0.2	0.0	9.3
RICH	4.5	33.4	487.1	21.7	546.7
SALT LAKE	0.0	0.0	66.3	123.3	189.6
SAN JUAN	365.5	3,155.5	438.6	0.4	3,959.9
SANPETE	0.0	69.7	256.6	76.9	403.2
SEVIER	8.3	217.4	417.9	62.9	706.5
SUMMIT	7.0	52.1	59.3	133.2	251.6
TOOELE	0.0	0.0	181.7	120.7	302.4
UINTAH	182.3	591.2	833.4	84.9	1,691.9
UTAH	1.3	17.1	72.2	108.8	199.4
WASATCH	0.7	9.6	97.1	5.0	112.5
WASHINGTON	26.6	157.3	446.7	45.2	675.8
WAYNE	168.3	225.7	250.7	36.9	681.6
WEBER	0.0	14.3	190.3	145.4	350.0

Table B-13. Scrub-shrub wetland area in hectares by county and landscape stress category.

County	**Very Good**	**Good**	**Fair**	**Poor**	**Total Area**
BEAVER	8.1	6.3	0.5	0.0	15.0
BOX ELDER	5.0	32.0	47.8	44.0	128.8
CACHE	17.7	88.2	339.8	143.2	588.9
CARBON	22.5	56.7	110.7	23.4	213.3
DAGGETT	49.6	199.3	84.1	3.9	336.8
DAVIS	0.9	13.8	0.0	3.0	17.7
DUCHESNE	624.2	818.0	880.1	314.7	2,637.0
EMERY	53.1	105.4	233.9	105.0	497.5
GARFIELD	68.7	62.0	87.2	14.1	232.0
GRAND	141.4	156.2	166.8	31.0	495.4
IRON	1.5	10.2	48.2	0.0	60.0
JUAB	0.9	27.4	36.9	7.3	72.5
KANE	18.9	10.0	28.5	6.1	63.5
MILLARD	71.4	590.8	160.1	34.9	857.1
MORGAN	5.0	58.1	96.7	42.5	202.3
PIUTE	0.2	2.5	4.3	0.0	7.1
RICH	21.7	75.1	356.2	154.9	607.9
SALT LAKE	2.3	13.5	45.9	47.4	109.1
SAN JUAN	1,384.9	2,496.5	1,054.1	56.0	4,991.5
SANPETE	33.7	134.7	203.9	60.0	432.2
SEVIER	0.5	3.2	19.9	0.6	24.2
SUMMIT	1,571.9	1,752.9	1,298.3	150.8	4,773.9
TOOELE	10.8	26.1	54.1	13.2	104.2
UINTAH	131.7	991.7	1,177.7	192.1	2,493.3
UTAH	30.4	141.9	332.5	187.5	692.2
WASATCH	48.4	682.4	364.9	40.7	1,136.3
WASHINGTON	1.0	6.9	11.8	12.9	32.6
WAYNE	7.0	19.6	13.2	17.6	57.5
WEBER	9.2	28.3	50.2	49.5	137.2

Table B-14. Emergent wetland area in hectares by county and landscape stress category.

County	Very Good	Good	Fair	Poor	Total Area
BEAVER	2.2	52.7	82.1	8.9	145.9
BOX ELDER	1,753.9	7,908.7	15,376.4	1,438.8	26,477.8
CACHE	4.5	149.7	3,143.1	1,352.7	4,650.0
CARBON	5.4	101.0	398.3	97.5	602.2
DAGGETT	391.2	709.8	522.0	254.8	1,877.9
DAVIS	36.7	2,131.7	4,161.8	805.9	7,136.1
DUCHESNE	3,485.7	812.7	3,620.1	4,501.5	12,419.9
EMERY	27.9	221.4	1,723.5	1,504.5	3,477.3
GARFIELD	70.2	608.4	225.9	114.0	1,018.5
GRAND	113.7	216.7	193.5	15.5	539.3
IRON	10.9	173.8	180.2	28.2	393.2
JUAB	171.0	901.7	1,670.0	187.9	2,930.7
KANE	41.8	129.7	297.4	27.4	496.3
MILLARD	488.6	10,557.3	1,990.3	118.4	13,154.7
MORGAN	10.9	89.2	54.7	155.2	309.9
PIUTE	0.5	38.8	802.8	97.6	939.7
RICH	39.8	422.9	11,686.1	4,997.3	17,146.1
SALT LAKE	100.9	638.1	3,968.1	383.4	5,090.5
SAN JUAN	94.7	359.2	391.6	36.5	882.1
SANPETE	114.2	777.3	8,934.8	2,053.7	11,880.0
SEVIER	17.9	219.1	683.2	124.6	1,044.7
SUMMIT	3,274.5	2,896.0	2,797.0	1,082.7	10,050.2
TOOELE	1,228.7	4,603.8	5,174.6	510.1	11,517.2
UINTAH	1,168.5	2,634.0	4,314.4	1,660.6	9,777.4
UTAH	150.3	2,691.3	6,854.2	1,915.3	11,611.0
WASATCH	27.5	574.7	1,342.1	805.8	2,750.1
WASHINGTON	26.6	19.3	86.5	2.9	135.1
WAYNE	27.1	77.2	1,163.4	246.9	1,514.6
WEBER	50.3	2,444.8	4,080.3	1,200.6	7,776.0