A Method for Siting a Wetland Mitigation Bank in the Gallatin Valley

Montana State University LRES Capstone, Spring 2024

Authors: Pamela Adams, Lucas Colvile, Robert Crawford, Brennan Gaffney, Anna Galipeau, Logan Jenkins, Kennedy Kane, Maya Kemp, Sarah Kincy, Wyatt Kray, Weston Littman Roeder, Kalei Maunder, Anne Miller, Grace Miller, Grant Minkoff, Tucker Mueller, Collette Noël, Savanah Olson, Paige Perry, Jonathan Ritterson, Tristan Roemmich, Angelee Rose, Jordyn Solliday, Davis Taylor, William Zaiger, Jadyn Bellander (Editor)

Under the Supervision of Dr. William Kleindl

Executive Summary

Bozeman City Commission is in the process of adopting enhanced regulatory measures for wetland and stream protection and mitigation to improve water quality, climate adaptation, and habitat resiliency. Prioritization of mitigation solutions will be given such that future wetland and stream impacts will be mitigated through a series of options focusing on improvements within the watershed where the impact occurs. To that end, one mitigation option will be using a local (watershed) wetland bank instead of the existing regional bank. The Sacajawea Audubon Society is working to establish the first bank within the East Gallatin watershed, with a projected credit capacity of four years, given the recent impact rate. This timeline requires the city and partners to quickly move towards establishing additional local wetland and stream bank capacity so that the local bank option remains viable once the bank's currently underdeveloped is full.

In the Spring of 2024, the City of Bozeman requested assistance in the form of high-level planning of future local wetland bank options. Following this request, the SP-24 Capstone Class chose to identify undeveloped land within the lower Gallatin that may be suitable for use as a wetland and stream bank. The Compensatory Mitigation Rule requires that wetland mitigation use a watershed approach when locating a potential wetland mitigation site. The scope of the watershed defines the service area of the potential wetland bank. The City of Bozeman is interested in having a service area that ideally is within the City of Bozeman's urban growth boundary. Secondarily, in the lower Gallatin Valley.

The class developed a GIS-based prioritization tool combining surface water, hydric soil, land use, and land cover layers to accomplish this task. These layers were converted to raster layers made up of gridded cells. These cells were scored from 1-10 based on the contribution of the landscape to maximize the lift of ecological functions through restoration. The values of the cells in the overlaying layers were then averaged, and the cell scores of the resulting map indicated the best locations to site a wetland bank (see Figure 13 below). Areas with the highest score imply the site that would have the highest potential for lift of ecological functions through restoration. The difference between before and after restoration, the lift, leads to the potential mitigation credits available on a bank's site.

This product can help Bozeman and Gallatin County decision-makers prioritize efforts in developing public-private partnerships, full public ownership, or private management of future bank sites. As a result, the document below is the first in several steps needed to site, permit, and develop wetland and stream banks for our rapidly growing home.

Table of Contents

Introduction

The City of Bozeman has grown rapidly in the last ten years. In 2010, the population of Bozeman was approximately 36,000 people, and in 2022, the population was approximately 53,000 (US Census Bureau, 2020). Bozeman has nearly doubled in population, with a more than 40% growth rate in the last ten years (US Census Bureau, 2020). With this influx to the city, the development to accommodate individuals transforms undisturbed natural areas into housing developments. The 2020 Bozeman Community Plan addresses concerns about the growth and accommodation of new city residents. One of the main themes within the Community Plan is “A City Influenced by Our Natural Environment, Parks, and Open Lands” (City of Bozeman, 2022), details the goals of ensuring the development of Bozeman is “responsive to natural features” (City of Bozeman, Montana, 2022). According to the city’s plan, this means prioritizing the acquisition of parks to provide various recreational opportunities throughout the city and promoting the uses of the natural environment that maintain and improve habitat, water quantity, and water quality.

Developmental projects in Bozeman have and will continue to impact wetlands and streams. Within the designated Bozeman growth boundary are an estimated 1,628 acres of wetlands and 254 miles of waterways that may be affected by urban development (Kleindl, 2024). To mitigate these potential impacts, developers must adhere to regulations such as Section 404 of the Clean Water Act. Section 404 of the Clean Water Act requires authorization from the US Army Corps of Engineers (USACE) to discharge dredged or fill material into all waters of the United States, including wetlands (Clean Water Act, 1972). Stipulations of these permits typically require a permittee to compensate for all unavoidable impacts by producing wetlands of equal or greater value (compensatory mitigation: (US Army Corps of Engineers et al., 2015)). Wetland mitigation banks or in-lieu-fee programs are the preferred venues for compensatory mitigation. Wetland and stream impacts can be quantified, and banks may purchase mitigation credits to compensate for their loss. The nearest wetland and stream mitigation bank to Bozeman is in Twin Bridges, Montana. This bank is 64 miles west of Bozeman. Credits from the Twin Bridges bank can be purchased to mitigate the effects of impacts in Bozeman. While the Twin Bridges mitigation bank meets the requirements of a watershed approach under the Clean Water Act, it does not effectively contribute to the “no net loss” of ecosystem function and services within the impacted area of Bozeman and the lower Gallatin Valley.

The Sacajawea Audubon Society recently purchased a 33-acre parcel of land. It established the Indreland Audubon Wetland Preserve (IAWP) to use this area as a wetland mitigation bank to serve the City of Bozeman and nearby areas (Sacajawea Audubon Society, 2021). Although this wetland mitigation bank will provide a local approach to mitigation, Sacajawea Audubon Society estimates that about four years' worth of credits will be available in the IAWP at Bozeman’s current rate of growth and development. Therefore, we are proposing methods and techniques to select sites for additional wetland mitigation bank sites in the lower

Gallatin Valley to aid in preserving the natural environment and ecosystem function and services in the wake of further development. Maintaining larger protected areas in mitigation banks or in-lieu fee sites can be more attractive than many small, unconnected projects.

As with any project, there are challenges associated with compensatory mitigation. The goal of compensatory mitigation is to have "no net loss" of ecosystem function and services (GPO, 2008), which means completing restoration equal or greater in ecosystem service and function when impacting an ecosystem. A memorandum from the director of the United States Fish and Wildlife Service states, "Conservation banking reduces the piecemeal approach to conservation efforts that can result from individual projects by establishing larger reserves and enhancing habitat connectivity" (Leibowitz, 2003). However, establishing newly constructed wetlands or restoring degraded wetlands does not result in the same function and services as an ancient established wetland. This leads to the question: How should an ideal site be selected for wetland establishment or restoration, and how is it ensured that the project remains successful over time?

The compensatory mitigation rule was established in 2008 and was designed to improve our ability to create no net loss of wetlands and aquatic resources (GPO, 2008). To offset the wetlands lost due to the creation of new infrastructure in Bozeman, the compensatory mitigation rule must be followed, and strategies from the rule must be implemented. The compensatory mitigation rule provides guidance to offset impacts, be practicable with resource management, and be environmentally preferable (GPO, 2008). These ideas are accomplished by prioritizing preservation, enhancement, restoration, and establishment (GPO, 2008).

The three main mechanisms that can accomplish the stated outcomes from the compensatory mitigation rule are mitigation banks, in-lieu fee, and permittee-responsible mitigation (US Army Corps of Engineers, 2004). Historically, the most common type of mitigation was onsite mitigation, permittee-responsible mitigation. Permittee-responsible mitigation occurs when the party responsible for the negative impacts on a wetland must create a mitigation plan to offset the associated damage to the original location. This strategy includes a largely private process and is usually not monitored by a third party to check if the required amount of mitigation offset is created. Additionally, this type of compensatory mitigation can occur on or off-site (US Army Corps of Engineers, 2004). Due to a historic lack of reliability, permittee-responsible mitigation is less preferred.

Mitigation banks and in lieu fee sites tend to be better alternatives to permittee-driven mitigation projects because the required restoration is overseen by qualified individuals with experience creating or restoring successful wetland sites. This also allows the permittee to purchase credits and pass the burden of maintenance and success to a third party.

Wetland banking takes a market-driven approach and has emerged as a viable solution for compensating losses in wetland functionality. This approach operates similarly to currency, creating a 'debits' and 'credits' system to regulate the exchange of wetland ecosystem services as commodities (Lave & Doyle, 2020). The value of a credit is represented by Functional Capacity Units (FCUs), which quantify the capacity of a wetland to perform core ecological functions, such as flood control, maintaining water quality, and providing habitat across the area. These metrics ensure that wetland compensation requirements accurately reflect the loss of ecological functions to anthropogenic growth. When a wetland is modified in some way, the estimated loss of functions creates debits (Hruby et al., 2012). When a degraded wetland site is improved through mitigation, the gain in functions generates credits (Hruby et al., 2012). The way the debits within a site are quantified is the same method used to determine the number of marketable credits within a mitigation bank site (Lave & Doyle, 2020). This ensures that a standardized and equitable approach is taken toward wetland mitigation. In adherence to current regulations, which mandate "no net loss" of wetlands, any adverse impacts on wetland sites necessitate mitigation measures to offset the incurred debts. To compensate for these deficits, an equivalent number of 'credits' must be purchased to counteract the loss of function. This balance of debit and credits satisfies the no net loss of wetlands. The third in-lieu fee type of compensatory mitigation, in-lieu fee, is similar to mitigation banking, but payment is required before any mitigation.

The compensatory mitigation rule directly promotes mitigation banking over the other two strategies because it is easily verifiable and performance-based, so there will likely be better uplift of wetlands to offset impacts than in-lieu fee (US Army Corps of Engineers, 2004). Mitigation banks also utilize multiple agencies to create the best outcome for the wetland that they are restoring (US Army Corps of Engineers, 2004).

Compensatory mitigation also includes the watershed plan/approach. The watershed plan/approach is created to ensure that the mitigation site is chosen to be suitable for a wetland mitigation project (US Army Corps of Engineers, 2004). More specifically, the watershed approach is necessary to ensure the wetland bank and various mechanisms for mitigation are kept within a logical and feasible location. When creating a watershed approach, many factors should be considered, such as hydrology, land use, sediment source for streams, and whether or not the mitigation site is in the same watershed as the impacted site (Kleindl, 2024). These factors are incorporated into the watershed plan when thinking about site selection. The mitigation site should be as close to the impacted site as possible, but it is often hard to do with a limited wetland area. For example, the distance between Bozeman and Twin Bridges mitigation bank is not ideal when considering the amount of mitigation necessary because of Bozeman's infrastructure growth.

Consider a situation where a corporation plans to develop a new apartment complex, requiring filling a wetland and resulting in the loss of five FCU credits. To offset this loss and proceed with the project, the developer must purchase five equivalent FCU credits from the local wetland mitigation bank. Using these funds, the loss of function within the developed wetland will then be recreated in a nearby wetland. These credits represent an investment into preserving, restoring, or creating wetlands elsewhere, maintaining the overall integrity of wetland ecosystems within the watershed.

Marketed credits must also be durable, protecting them from future activities that could negate their ecological benefits (Lave & Doyle, 2020). For example, precautions must be taken to prevent contamination via runoff from nearby construction projects. Safeguards must also be put into place to ensure the banking site will never face filling or other forms of development. This can be accomplished through permanent regulations, such as establishing a conservation easement. In addition to ensuring credit durability, understanding the intricacies of calculating Functional Capacity Units is essential for understanding the complexities of wetland mitigation banking and its role in maintaining ecological integrity. The amount of credits designated to a wetland mitigation bank is determined by the positive change in ecosystem function, or functional lift, from the degraded site to the restored wetland bank (Hauer et al., 2002). Ecosystem functions are an environment's biological and physical processes, including energy flow, nutrient cycling, and biogeochemical cycling (de Groot et al., 2002).

Calculating Debits and Credits

Functional lift can be quantified by measuring different parameters of a wetland. Two main assessment methods used in Montana to determine functional lift in wetlands are the Montana Wetland Assessment Method (MWAM: (J. Berglund and R. McEldowney, 2008)) and the Hydrogeomorphic method (HGM). The HGM, which the U.S. Army Corps of Engineers is moving towards standardizing for determining wetland credits in Montana, utilizes eight different wetland functions. These include surface-groundwater storage and flow, nutrient cycling, retention of organic and inorganic particles, generation and export of organic carbon, characteristic plant community, characteristic aquatic invertebrate food webs, characteristic vertebrate habitats, and floodplain interspersion and connectivity (Hauer et al., 2002). The wetland functions used for the HGM assessment often comprise several smaller, quantifiable parameters.

Using the HGM approach as an example, surface-groundwater storage and flow are found by first finding the frequency of surface flooding ($V_{SURFREQ}$), frequency of subsurface flooding ($V_{SUBFREQ}$), macrotopographic complexity (V_{MACRO}), and geomorphic modification (V_{GEOMOD}). All these variables are measured from 0 to 1, with 0 being no function present and 1 being the reference standard. The functional capacity index (FCI), which is an index of a wetland’s capacity to perform a function relative to other wetlands within the regional subclass, for surface-groundwater storage and flow is (Hauer et al., 2002):

$$FCI = [(\frac{V_{SURFREQ}+V_{SUBFREQ}+V_{MACRO}}{3}) \times V_{GEOMOD}]^{½} \qquad \text{(Equation 1)}$$

Functional capacity index scores can be converted to functional capacity units, or FCUs, which are then used to inform how many credits are designated to a mitigation bank. To change an FCI to an FCU, first, the FCI lift must be found by taking the FCI score from before the restoration of the wetland and subtracting it from the FCI score from after the restoration:

$$FCI_{lift} = FCI_{post\text{-}restoration} - FCI_{pre\text{-}restoration} \qquad \text{(Equation 2)}$$

Next, the FCI lift is multiplied by the acreage of the mitigation bank, which gives the FCUs of the bank:

$$\text{FCU} = \text{FCI}_{\text{lift}} \times \text{acreage} \qquad \text{(Equation 3)}$$

Below, Table 1 and Table 2 depict an example of how credits are determined for the HGM function of surface-groundwater storage and flow (Kleindl, 2024).

Table 1: *Calculation of FCI pre- and post-restoration of a non-existing site using Equation 1.*

Wetland Site Conditions	Vsurfreq	Vsubfreq	Vmacro	Vgeomod	FCI Score
Pre-Restoration	0.20	0.20	0.10	0.25	0.20
Post-Restoration	0.80	0.90	1.00	0.80	0.85

Using Equation 2, the FCI lift for this function is 0.65, found by subtracting 0.20 from 0.85. Below, Table 2 shows how FCI lift is converted to FCUs, which are directly related to a mitigation bank's number of credits.

Table 2: *Calculation of FCU - The total credits available at the bank - at a non-existing site using Equation 3.*

Wetland	FCI	Area (acres)	FCU	Total Bank Credits
Final Bank	0.65	75	48.75	48.75

The HGM assessment method does not specify how to find one credit number derived from the eight functions listed in the HGM rather than eight individual credit values. However, this could be done by taking the average FCI values from all eight HGM functions (Kleindl, 2024). Wetland credits can also be determined using the MWAM. In this case, functional lift from a wetland restoration is quantified by summing the functional points and expressing this as a percentage of the total (J. Berglund and R. McEldowney, 2008). FCU and wetland credits can then be derived from these.

Methods

Study Area

The Compensatory Mitigation Rule requires that wetland mitigation use a watershed approach when locating a potential wetland mitigation site (Hruby et al., 2012). The scope of the watershed defines the service area of the Wetland Bank. The City of Bozeman is interested in having a service area that ideally is within the City of Bozeman's urban growth boundary. Secondarily, in the lower Gallatin Valley.

For this study, we created three priority zones (Zone 1, Zone 2, and Zone 3) for site selection based on proximity to Bozeman (Figure 1). Zone 1 focused on the projected Bozeman growth boundary from the City of Bozeman (City of Bozeman, Montana 2022). Zone 2 encompasses Zone 1 with the addition of the land between the East Gallatin and Gallatin River riparian areas extending to the base of the Gallatin Mountain Range. Zone 3 includes Zone 2, with the addition of the Bridger Foothills and land owned by Turner Enterprises. All zones were created by using the "Create Polygon" tool in ArcGIS Pro. When creating the polygons for the zones, geologic features were incorporated using the topography basemap and the projected growth boundary. From our investigation, Zone 1 was given the highest priority. This is because the most ideal location for a proposed wetland mitigation site is within the growth boundary outlined by the City of Bozeman, which is where the most function is projected to be lost. The priority zones can be seen in Figure 1.

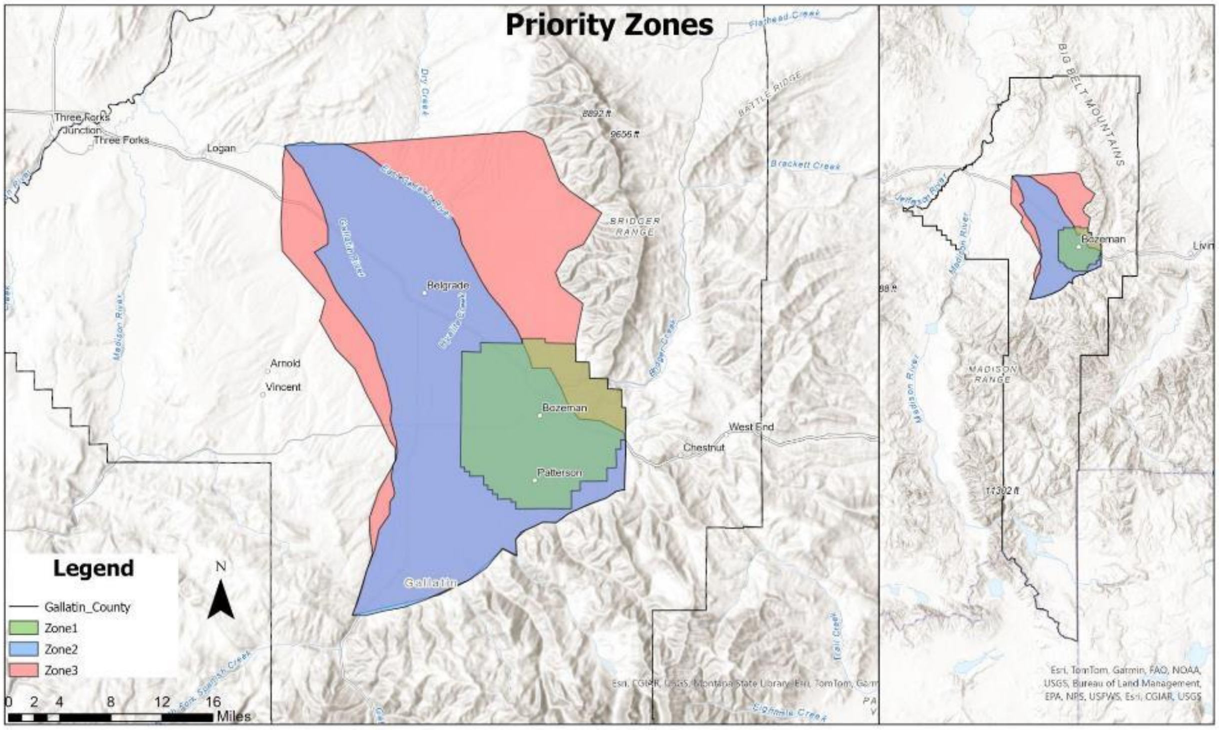


Figure 1: Reference map of Gallatin County, including priority zones.

Prioritizing sites within a watershed can be complicated. Most commonly, this is achieved using a Geographic Information System (GIS). Prioritization tools, such as suitability modelers, can assist with this effort (Hunter et al., 2012; Lee et al., 2015; Van Lonkhuyzen et al., 2004).

Figure 2 shows our workflow using the suitability modeler tool in ArcGIS Pro. Our goal was to locate multiple sites for a wetland mitigation bank in Bozeman. Our base criteria, as referenced later in the paper, were water, soil, and land. The data layers that we incorporated into the modeler for water were waterways, wetlands (acreage), and depth to groundwater (feet). The only data layer that we used for soil was hydric soils. Finally, the data layers that we incorporated into the modeler for land were land cover (vegetation class), land use, and riparian areas (acreage). All these data layers were converted to raster layers before they were run through the modeler.

Each data layer was then transformed in the suitability modeler to have the same scale so that they could be overlain in the model (Figure 2). These transformed data layers were then weighted and combined into a single raster layer, showing the most suitable areas for a wetland bank based on all criteria. Weighting and combining raster layer values and overlaying them allowed site locations to be chosen. Pixels with the highest mean of overlain values were the most suitable sites for a wetland mitigation bank.

In our study, all data and layer analysis were completed using ArcGIS Pro 3.2.2 (Esri, 2024b).

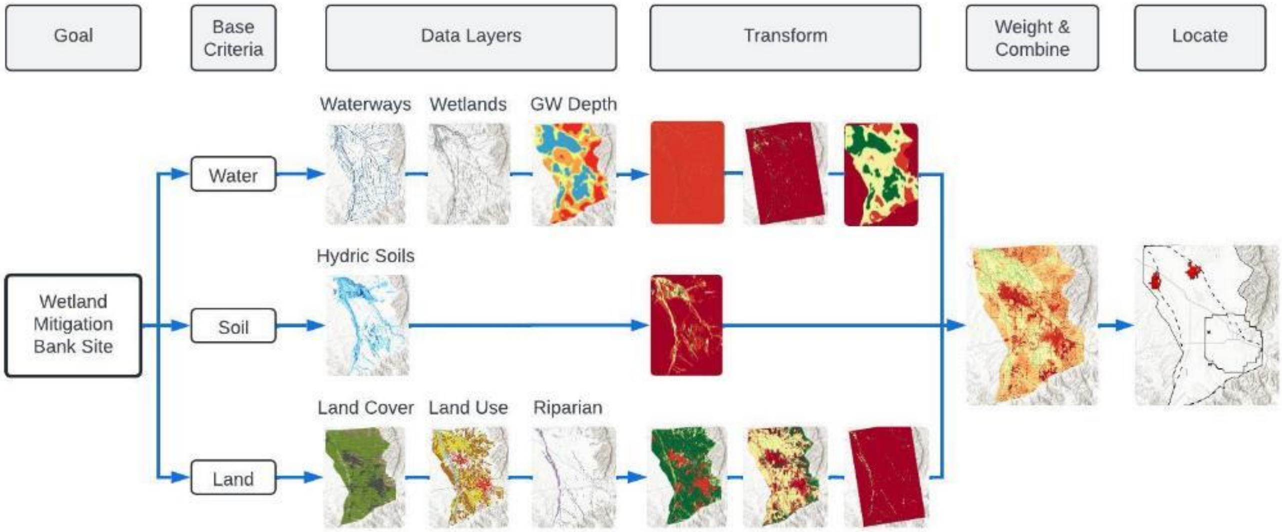


Figure 2: Suitability modeler workflow chart.

The data layers shown in Figure 2 included water data, soil data, and land data. These data types were ranked (from 1-10 where 1 was the worst and 10 was the best based on how well they would contribute to the success of a wetland mitigation bank (Table 8).

Gallatin Valley Groundwater

Groundwater resources are crucial to the success of a newly constructed wetland project. Shallow groundwater acts to maintain hydric soil conditions and standing water availability for wetlands year-round. First, establishing a basic understanding of Gallatin Valley's hydrogeomorphic conditions will help to narrow the search criteria for potential wetland mitigation sites. Hydrogeomorphological surveys (Hackett et al., 1960) lay the foundations of water flow paths within the valley (Hunter et al., 2012; Lee et al., 2015; Van Lonkhuyzen et al., 2004). Groundwater and surface water enter from the Gallatin range primarily via surface flow and then recharge groundwater in an unconsolidated tertiary aquifer, which is an aquifer made up of alluvial material like gravel and rocks from the tertiary period. Groundwater in the aquifer then comes back to the surface on the south side of the East Gallatin River due to the Central Park fault near Manhattan (Figure 3).

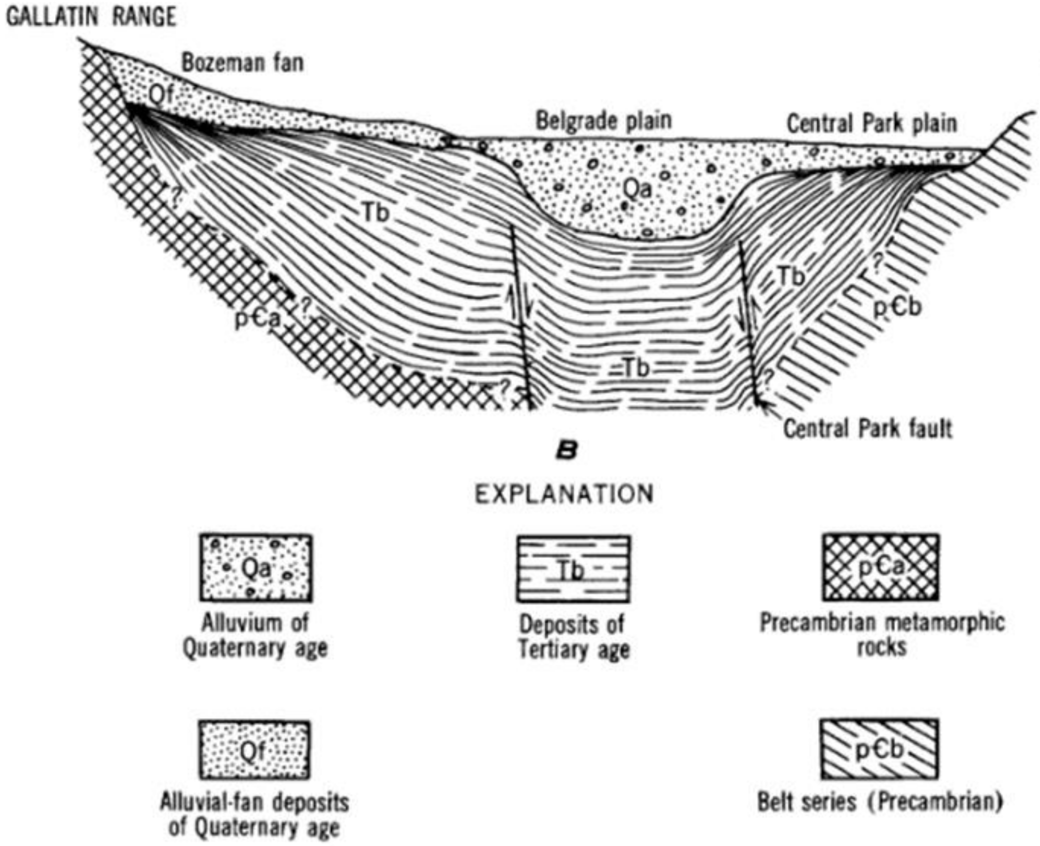


Figure 3: . Side-view drawing of the Gallatin Valley basin (Hackett et al., 1960).

Combined with the gradient of the valley floor flattening, which produces areas with shallow depth to groundwater. This informs which areas are most likely sufficient for siting a new wetland mitigation bank. We know that most of the basin's shallow groundwater resources exist in the northeastern portion of the Gallatin Valley.

To confirm this, a depth-to-groundwater layer was created to provide information on the availability of water for the suitability model. Data regarding depth to groundwater was collected from Montana's Ground Water Information Center(Montana Bureau of Mines and Geology, 2024). The depth to groundwater data was made up of point data from wells within Gallatin County. Well and borehole data was filtered to only include static groundwater values. A spatial interpolation method called kriging was used to extrapolate the values of depth to groundwater across the valley. The depth to groundwater data in feet was then classified into five classes ranging from 3.5 feet to 240.7 feet. Depth to groundwater was weighed heavily in the final suitability model.

Figure 4 shows the interpolated groundwater layer. Red values were the least suitable and showed the deepest groundwater levels, 55-240 feet. Yellow values were indicative of middle depth, 12-19 feet deep. Blue/green values were the most suitable, 3-10 feet deep. Shallower groundwater was the most suitable based on the information presented above. Table 3 shows the ranking parameters for this GIS layer.

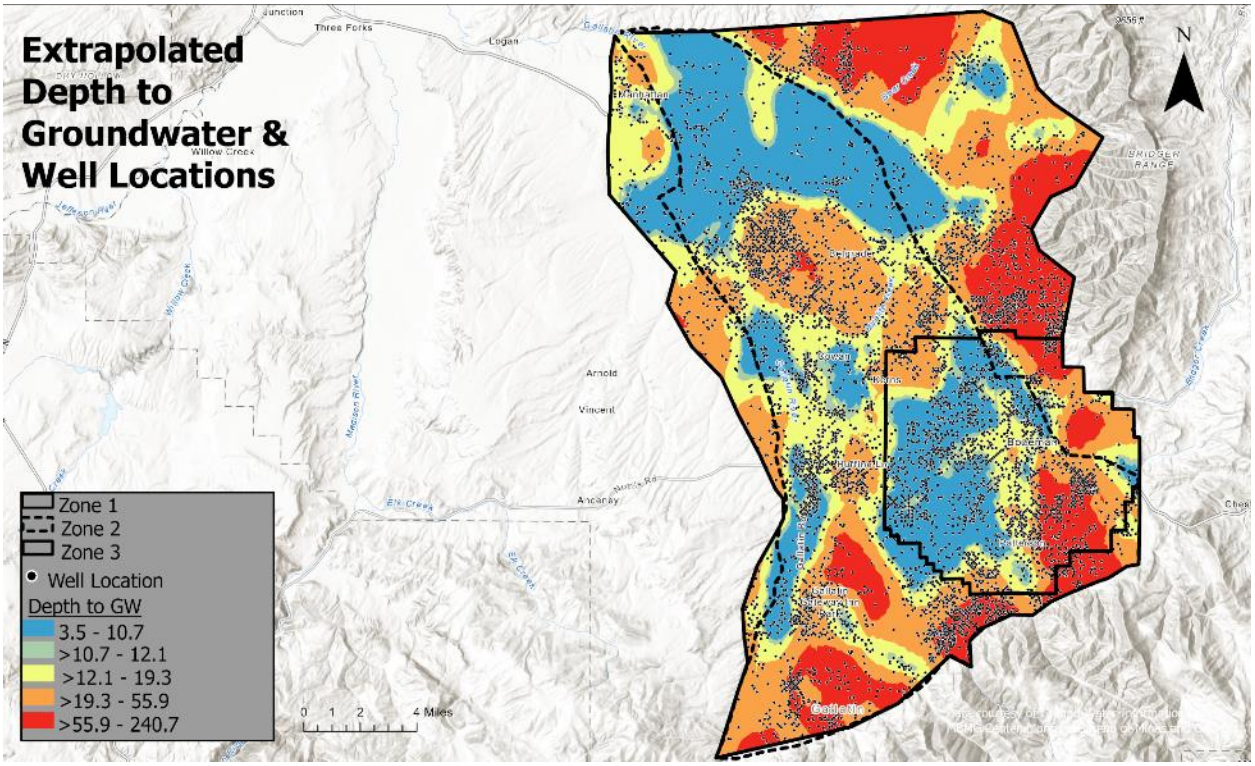
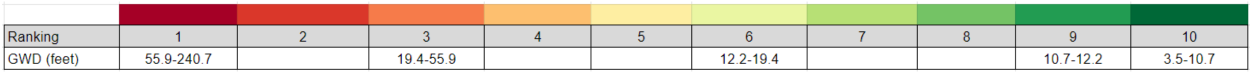


Figure 4: Interpolated & ranked depth to groundwater values

Table 3: Ranking parameters for groundwater layer.



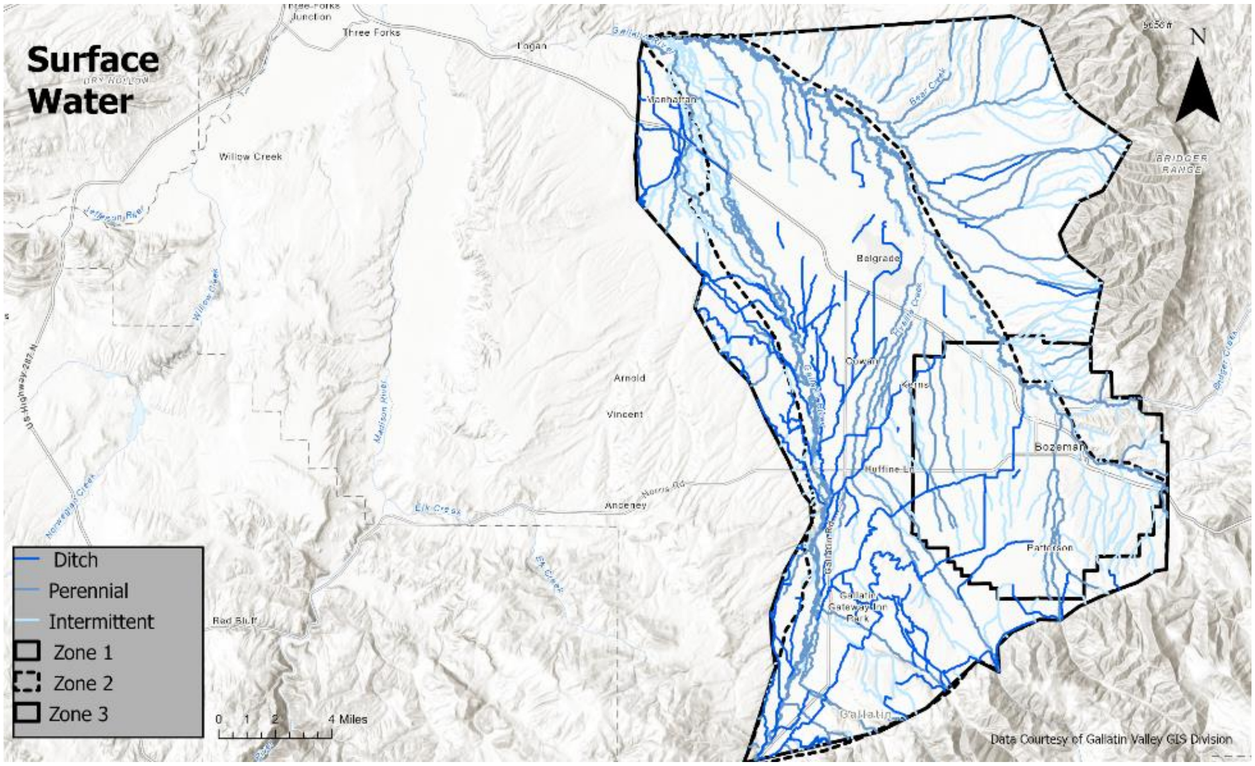
Ranking	1	2	3	4	5	6	7	8	9	10
GWD (feet)	55.9-240.7		19.4-55.9			12.2-19.4			10.7-12.2	3.5-10.7

Gallatin Valley Waterways

Surface water interacts with soil composition by influencing its characteristics and nutrient content. In wetland environments, the presence of surface water creates distinct hydrological regimes, promoting unique soil conditions such as hydric soils, which are characterized by prolonged saturation or inundation. These soil types are vital for supporting wetland vegetation and facilitating various ecological processes such as nutrient cycling and carbon sequestration. Additionally, surface water influences soil erosion and sedimentation patterns, which shape landscape features and affect habitat suitability for a wide array of organisms.

Integrating surface water resources into GIS analyses can provide valuable insights and enhance decision-making processes. In our GIS analysis, we are incorporating existing wetlands, perennial streams, and irrigation ditch data for the county to identify areas that have hydrological functions which is complementary to wetlands. This information will provide areas where surface water resources may exist for new wetlands, which are crucial for sustaining the wetland's ecological functions, services, and connection with the broader ecosystem.

For our GIS analysis, we classify surface water resources based on their general function. The data used for waterways was collected from the Gallatin County GIS Department website (Gallatin County Montana, 2024). The waterway data included line data of eight different classes of waterway: Aqueduct, Ditch, Intermittent, N/A, No Waterway, Perennial, TBD, and Unclear. The data was filtered to only include streams classified as ditch, perennial, intermittent, and no waterway. Areas that have no surface water receive a 1, intermittent streams receive a low-medium score, perennial streams receive a medium-high score, and ditches receive a maximum of 10, as seen in Table 4. Ditches scoring the highest are due to ditches having water available and the possibility of functional lift due to their channelized, somewhat degraded nature. This provides the greatest value for functional lift by reintroducing sinuosity and natural streambed characteristics. Figure 5 shows this layer, and Table 4 the related scoring metric.



Data Courtesy of Gallatin Valley GIS Division

Figure 5: GIS Layer for Waterway Suitability

Table 4: Ranking parameters for existing wetlands layer.

	🟥	🟥	🟧	🟧	🟨	🟨	🟩	🟩	🟩	🟩
Ranking	1	2	3	4	5	6	7	8	9	10
Flowing Water	No water			Intermittent				Perennial		Ditch

Gallatin Valley Wetlands

Wetlands and streams are fundamental components of freshwater ecosystems and serve as essential criteria for selecting mitigation bank sites. The National Wetlands Inventory (NWI) provides valuable data on existing wetlands across the study area (USFWS, 2023). Wetlands identified are ranked one through ten based on their ecological significance. Higher rankings are assigned to pristine or minimally impacted wetlands (ranked as 10) and lower rankings are assigned to wetlands with significant human impacts (ranked as 1). Larger wetlands were ranked lower than smaller wetlands due to their being limited functional lift. Additionally, data on impacted wetlands, such as those affected by urbanization or agriculture, are incorporated into the analysis, which can be seen in Figure 6. These wetlands are also ranked based on the extent of their impact, with heavily impacted wetlands receiving lower rankings.

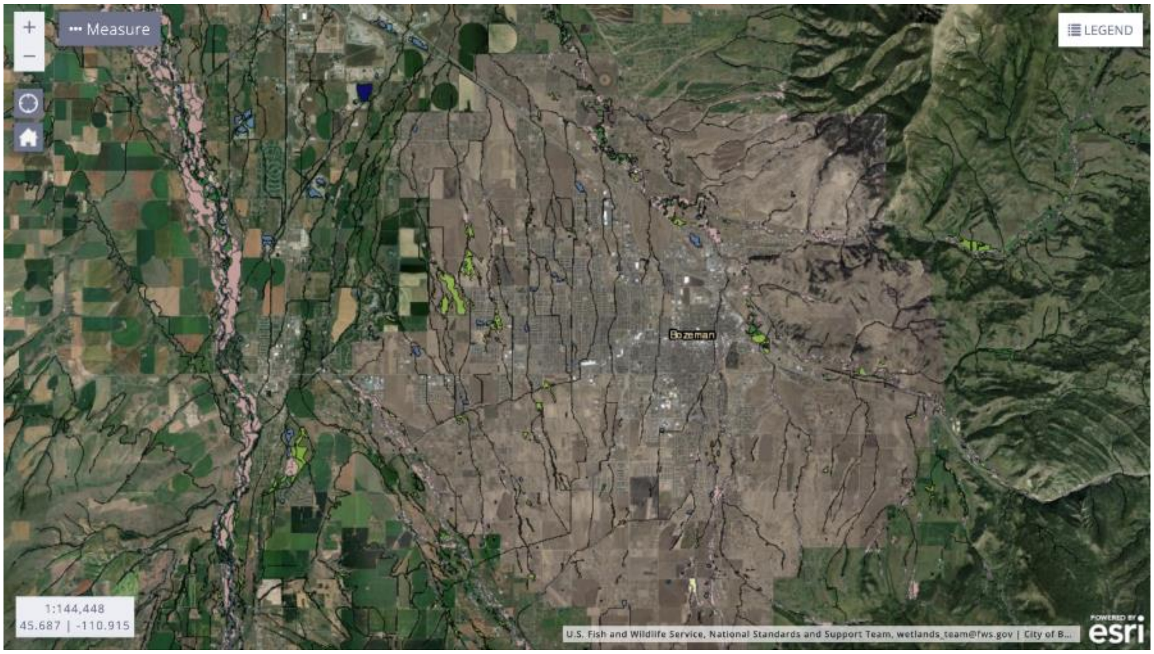


Figure 6: Pre-existing wetlands in Bozeman, MT signified by the light green patches. Riparian areas are represented by the pink patches. Satellite imagery updated in 2021.

Based on the NWI provided information on the classification codes, most of the pre-existing wetlands in the study area fall under the classification code PEM1C or PEM1A. These wetlands are freshwater palustrine systems (P) composed of emergent (EM) plant communities that are persistent (1) and are seasonally (C) or temporarily (A) flooded. These wetlands are valuable for their ecological functions, including flood control, water filtration, and habitat provision.

These wetlands may exhibit static, neutral, or dynamic behavior (Jadhav & Buchberger, 1995). Wetlands exhibit static behavior when they behave like stagnant bodies of water with minimal flow dynamics. This often occurs in wetlands with limited surface water inputs and outputs, such as isolated depressional wetlands. In such cases, water movement and nutrient cycling within the wetland is relatively slow, leading to less efficient pollutant removal and nutrient cycling processes. Neutral behavior is exhibited when there is a balance between inputs and outputs of water and nutrients. In these wetlands, vegetation moderates flow dynamics, promoting nutrient cycling and pollutant removal. The water retention time within the wetland is neither significantly increased nor decreased, resulting in relatively stable hydrological conditions. Lastly, dynamic behavior is exhibited when wetlands experience large changes in water flow and nutrient cycling processes. This often occurs in wetlands with high vegetation density and continuous surface water inputs, such as riverine or floodplain wetlands. In dynamic wetlands, the presence of dense vegetation can induce stem drag, slowing water flow and increasing retention time. This classification underscores the variability in how vegetation influences surface water flow and retention time across different wetland settings. When evaluating potential sites for wetland mitigation banks, understanding the interplay between surface water dynamics, soil, and vegetation characteristics is important for assessing credit capacity and long-term viability.

We prioritized wetlands within the Gallatin Valley based on their ability to provide functional lift on a property. Thus, we recommend looking at sites that have been anthropogenically impacted and degraded. Typically, there are two types of impacted historic wetlands: those that have been developed upon or around, and those that are within or near agricultural systems. The former is unfeasible when considering restoration practices and functional lift, so we are only interested in historic wetlands impacted by agriculture.

Identifying and prioritizing these wetlands for preservation and restoration can enhance the effectiveness of wetland mitigation efforts. Incorporating information on wetland classification codes into land use planning processes allows the city to consider wetland conservation and restoration goals in development decisions. By recognizing areas with high-quality wetlands and prioritizing their protection, the city can promote sustainable land use practices that balance environmental conservation with economic development.

Gallatin Valley Hydric Soils

Identifying specifically hydric soils in the context of wetland mitigation is crucial to execute and understand because it illustrates the interface of plant communities and aquatic health. Evidence of this in a mitigation bank environment–where the goal is to restore a self-sustaining ecosystem–is seen with soil aspects such as water availability (usually depicted by texture and color) vital to the plant community's survival (Harris & Van Bavel, 1957).

According to Berkowitz et al., hydric soils are defined as “soils formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part”(Berkowitz et al., 2021). The periodic to continuous saturation of these soils drives several aerobic and anaerobic microbial processes that provide critical ecosystem functions and services. When working with wetlands, an in-depth understanding of these soils is required to facilitate a healthy and balanced ecosystem. Hydric soils are identified in the field by examining morphological characteristics, including organic matter accumulation and redoximorphic features that form in response to prolonged periods of saturation and anaerobic conditions. Included in these characteristics is the presence of hydrogen sulfide odor (smell of rotten eggs), layers resulting from repeated sediment deposition events induced by flooding, accumulation of organic material near the soil surface, and a variety of morphological features related to dissolution, translocation, and re-precipitation of iron/manganese oxides (Berkowitz et al., 2021).

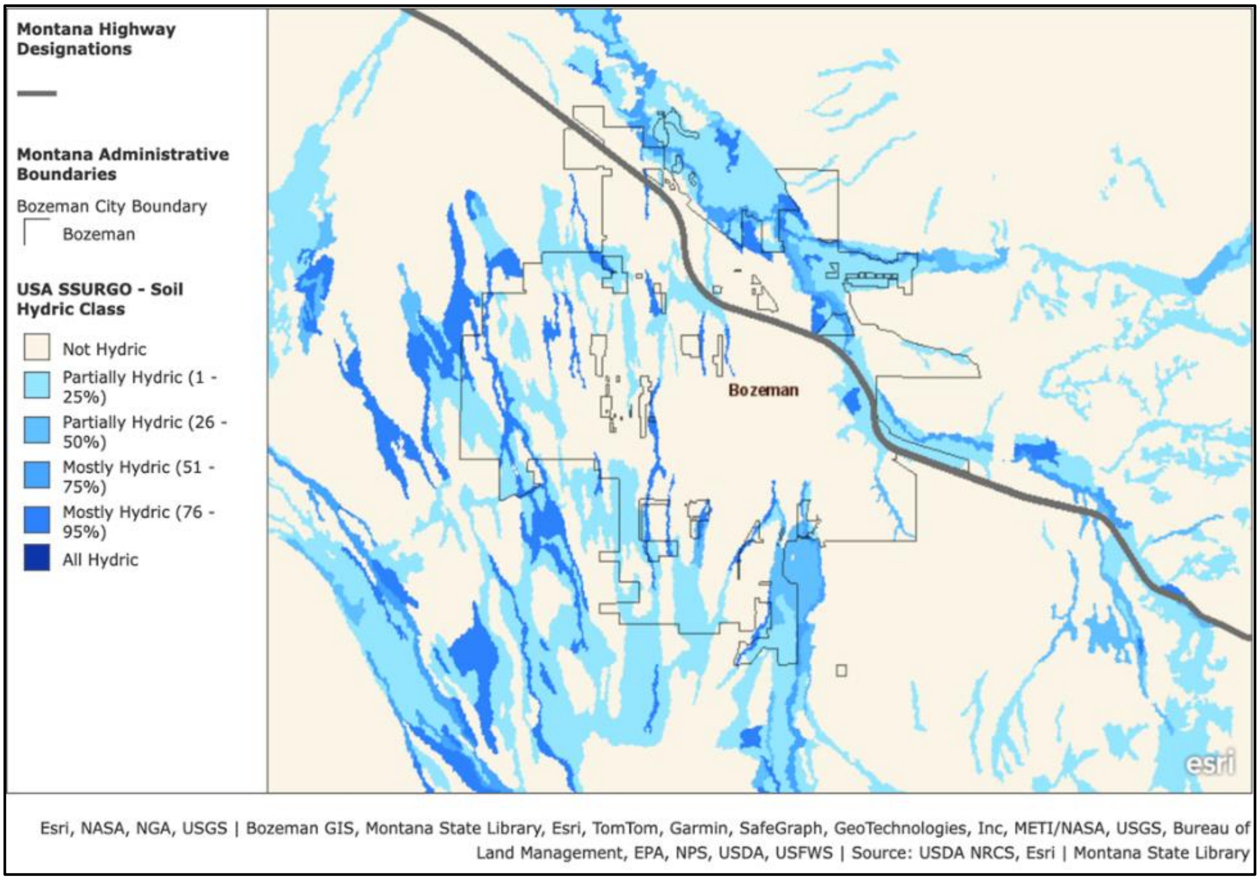
The National List of Hydric Soils utilizes four specific criteria to evaluate soil map unit components for classification in the NRCS database. These criteria encompass a range of soil types and environmental conditions, ensuring a comprehensive approach to identifying hydric soils. These components must either exhibit a range of characteristics for the soil series that partly satisfy one or more Field Indicators of Hydric Soils in the United States or demonstrate evidence aligning with the definition of hydric soils (Vasilas et al. 2016). Furthermore, components of map units experiencing frequent and prolonged ponding during the growing season are evaluated based on their characteristics or evidence indicating conformity with the definition of hydric soils. Similarly, components of map units frequently subjected to prolonged flooding during the growing season are assessed based on their characteristics or evidence meeting the definition of hydric soils. By employing these criteria, the National List of Hydric Soils ensures a standardized and thorough assessment process, enabling accurate classification of soil map unit components as hydric soils and facilitating effective wetland management and conservation efforts.

The process of delineating potential sites using hydric soils can be conducted before visiting the site physically and involves utilizing various resources and tools provided by the Natural Resources Conservation Service (NRCS), particularly the Web Soil Survey (WSS). The WSS platform contains detailed information on soil characteristics, including the likelihood of the presence of hydric soils. Utilizing soil property data from the NRCS database, WSS generates lists of hydric soils and interpretive maps, which help pinpoint areas likely to contain hydric soils.

To use the Web Soil Survey (WSS) to obtain a map of hydric rating by map unit, first access the WSS website and navigate to the "Area of Interest" (AOI) tab. Here, an AOI can be selected using various options such as address, coordinates, or drawing on the map. Once an area is defined, click on the "Soil Map" tab to view the soil map of the chosen area. Next, select the "Soil Data Explorer" tab and click on the "Land Classifications" tab. Next, click the “Hydric Rating by Map Unit” dropdown menu and click “View Rating.” This will display a list of soil map units for the designated AOI. Within the soil data, you should find the hydric rating for that map unit, which indicates the soil's presence and degree of wetness or hydrologic characteristics. The "Print" or "Download" options can also export the map and data for your reference or use in spatial analysis.

The Hydric Rating by Map Unit feature within WSS categorizes map units based on the percentage of the unit considered hydric, providing valuable insights into the distribution of hydric soils across the landscape. This rating quantifies the proportion of map units meeting the criteria for hydric soils, which are essential for wetland delineation. Map units comprise various components or soil types, each assessed as hydric or non-hydric. Map units primarily composed of hydric soils may contain minor non-hydric components in elevated areas. In contrast, those dominated by non-hydric soils may have minor hydric components in lower elevations. Ratings are determined based on the composition of each map unit's components and their respective percentages. The thematic map utilizes a color-coded scheme reflecting the composition of hydric components. These color classes range from 100 percent hydric components to less than one percent hydric components, aiding in visualizing the soil composition of the landscape. Within the Web Soil Survey, the Summary by Map Unit table presents a 'Rating' column, displaying the percentage of each map unit classified as hydric, as seen in Figure 7. By leveraging these resources and tools, areas containing hydric soils can be effectively identified and prioritized, facilitating wetland establishment and restoration efforts per regulatory standards and guidelines.

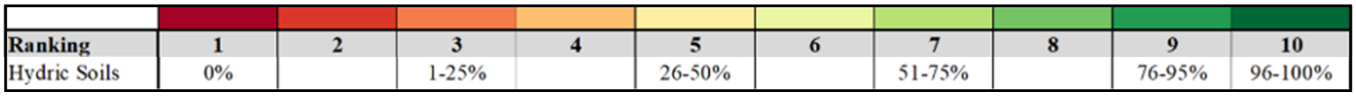
Another way to delineate hydric soils is by simplifying the criteria to only consider the percent hydric soil. For this report, a data layer from the NRCS separates the hydric soil categories into 5 sections. Specifically, soils were ranked 1-10 scale based on how hydric the soil is. A rating of 1 would be non-hydric soils, 2-2.9 being slightly hydric (0-25%), 4-4.9 being partially hydric (25-50%), 6-6.9 being moderately hydric (51-75%), 8-8.9 being mostly hydric (76-95%), 10 being hydric (96-100%) (Table 5).



Esri, NASA, NGA, USGS | Bozeman GIS, Montana State Library, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS | Source: USDA NRCS, Esri | Montana State Library

Figure 7:A map of the hydric soils in Bozeman, MT as of 2022.

Table 5: Ranking information for soils layer



Ranking	1	2	3	4	5	6	7	8	9	10
Hydric Soils	0%		1-25%		26-50%		51-75%		76-95%	96-100%

Soil Hydric Class data from the Natural Resources Conservation Service served as the primary data source for the soil analysis(Esri, 2024a; Soil Survey Staff et al., 2024). This data has 6 classes that are identified as non-hydric (0%), slightly hydric (1-25%), partially hydric (25-

50%), moderately hydric (51-75%), mostly hydric (76-95%), and fully hydric (96-100%). These classes were used to determine how suitable the soil is for a wetland–the more hydric the soil, the better that location is suited for a wetland mitigation site. Hydric soils were weighted heavily in the depth to groundwater suitability model.

Gallatin Valley Land Use and Land Cover

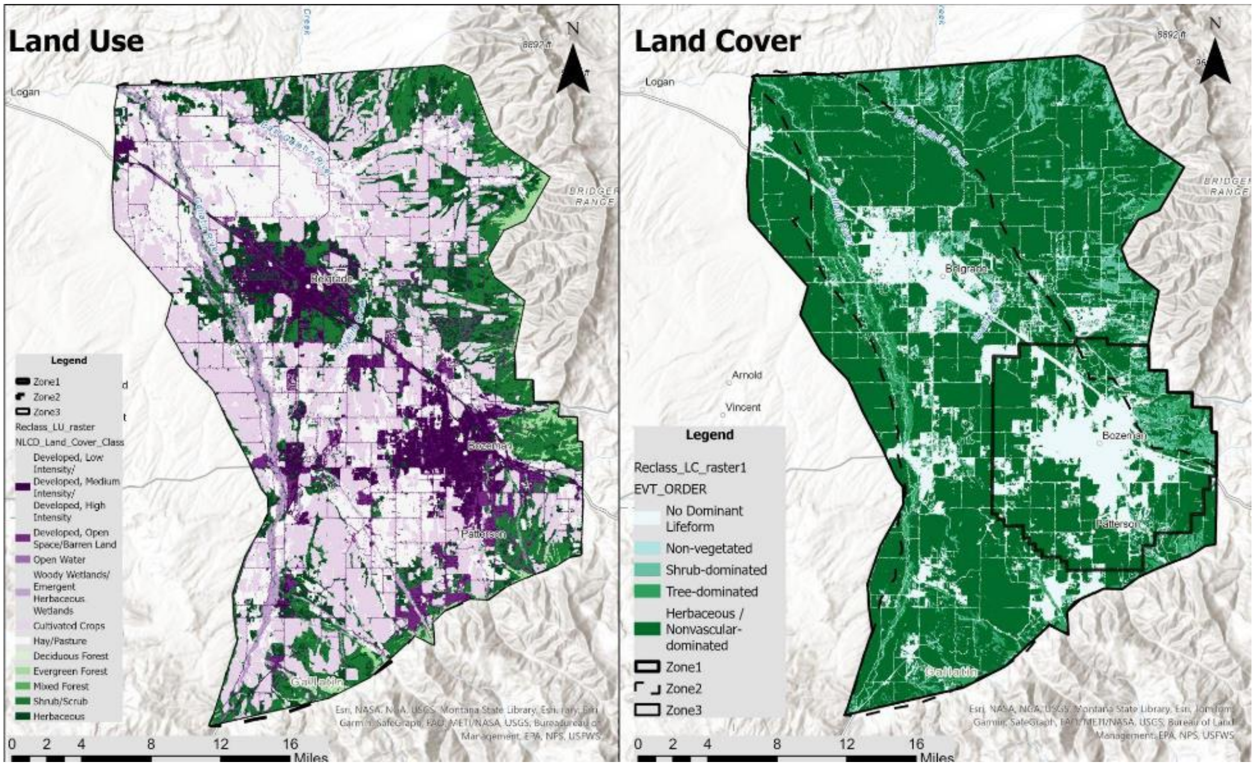


Figure 8: Land use and cover suitability map.

Land use and land cover data from the Montana Land Cover Framework (Mitchell, 2023) was used to create a data layer for the suitability index regarding vegetation, as seen in Figure 8. Using the vegetation data, a raster layer was created that contained data on the land cover that outlined areas of high suitability for a mitigation bank (i.e. areas that require functional lift). In doing so, we were able to highlight areas that have suitable vegetation compared to those without. The land cover data was weighted heavily in the land cover suitability model.

Along with vegetation, categories of land use were included for analysis. This data was retrieved from the Multi-Resolution Land Characteristics Consortium (MRLC (Multi-Resolution Land Characteristics Consortium), 2020). We narrowed the land use types down to development levels (high, medium, low, and open), open water, wetlands, and agriculture. From there, we ranked land use types from developed (high, 1) to agricultural (hay/pasture, 10). In the interest of finding a location where a wetland mitigation bank would provide functional lift, we decided to rank more highly developed and disturbed areas higher than ecosystems that already provide wetland functions. Land use data was weighted heavily in the land cover suitability model.

Disturbance

Disturbance is a physical abiotic or biotic agent that causes stress to an ecosystem. A disturbance regime is defined by time, intensity, magnitude, frequency, and duration. Time is how long since the last disturbance event. Intensity is the degree of strength of a disturbance. Magnitude is referencing the size of a disturbance. How often a disturbance event happens is frequency, and how long the event lasts is duration. Understanding these five factors is important to understanding the severity of a disturbance.

Not all disturbances are bad. Disturbance offers the local environment a chance for change and functional lift. New species have a chance to establish and thrive. Succession patterns follow a strict order of pioneers to colonizers. Plant succession refers to the dynamic process where the distribution of vegetation in a system changes over time. Succession allows for a natural functional lift.

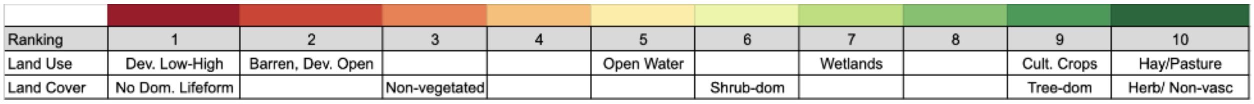
Increases in frequency and intensity of disturbances have increased by invasive plant species. Invasive plant species can do both good and bad things for a wetland. Invasive species still provide habitat for wildlife and perform some nutrient cycling functions. However, invasives negatively impact a wetland ecosystem more than improve it. Invasives commonly form mono stands that reduce plant diversity and generally provide poorer habitat quality for wildlife than native plant species. They also outcompete native species and stop the progression of plant succession. Resulting in not contributing to the functional lift of a wetland.

Sites under continuous anthropogenic disturbance, such as intensive agricultural operations, will remain in a state of pioneer species composition, many of which are considered invasive or noxious. Using the functional lift framework, removing ongoing disturbance will allow early post-disturbance pioneers to establish, if a disturbance hasn’t occurred in a long time those pioneers will slowly be outcompeted by colonizer species. These species are better at establishing and competing for required resources. Colonizer species can’t be established without the change in the environment that early seral species provide. However, anthropogenic disturbance is removed during wetland restoration, and native plant pallets are planted to establish a mature and healthy plant community.

To further identify possible wetland mitigation banks on the map, different scales involving vegetation must be added. Using vegetation, or lack thereof, as a reference point, we can rank both land use and land cover on a scale of 1-10. The highest numbers will go toward agricultural fields, such as hay/pasture (10) and cultivated crops (9). These types of fields were ranked the highest because they should be selected for restoring wetlands, as dormant agricultural fields provide space for them. Wetlands were ranked at a 7; this is because while enhancing already existing wetlands is an option, our goal here is to find sites for creating or restoring wetlands. The next lowest ranking at 5 is open water; some places with open water would be easier to make into wetlands by adding vegetation, mostly dependent on size. A pond would be easier to restore into a wetland than a lake. Barren, developed open (2), and low-high development (1) were ranked the lowest as these areas are often very dry from the development along with a lack of vegetation. Furthermore, soils are often too compacted for plants to take root.

As for land cover, tree-dominated (9) and herbaceous/non-vascular plants were ranked the highest. Trees provide an important function of soil stability. When creating or restoring a wetland, the soil on the banks must be stabilized because if they were not, the erosion control function of a wetland would be lost. Tree species should be considered, however, as many conifers such as Douglas firs are not flood tolerant while willow trees are. Herbaceous and nonvascular plants were ranked the highest because they require the most water to survive, especially with non-vascular plants such as mosses and algae. Wetlands would be where these types of plants thrive. Shrub-dominated is at a 6, the reason being that they do provide soil stability but not as much as trees do. The lowest rankings were non-vegetated (3) and no dominant lifeform (1) because they are unsuitable for plants to live. The ranking information for land use and cover in the suitability modeler can be found in Table 6.

Table 6: Ranking information for land use and land cover layers.



	🟥	🟥	🟧	🟧	🟨	🟨	🟩	🟩	🟩	🟩
Ranking	1	2	3	4	5	6	7	8	9	10
Land Use	Dev. Low-High	Barren, Dev. Open			Open Water		Wetlands		Cult. Crops	Hay/Pasture
Land Cover	No Dom. Lifeform		Non-vegetated			Shrub-dom			Tree-dom	Herb/ Non-vasc

Prioritize sites.

The “Suitability Modeler” tool was used to combine and weigh various raster data layers to develop a single raster layer that displayed suitable locations relating to wetland success. The data layers within the suitability modeler included riparian acreage, wetland acreage, waterways, hydric soils, land use, land cover, and depth to groundwater. Details regarding the specific layers can be found above in their respective sections. A summary of each layer ranking can be found below in Table 7.

Table 7: Ranking information for all layers in the suitability model.

	🟥	🟥	🟧	🟧	🟨	🟨	🟩	🟩	🟩	🟩
Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Riparian (acres)	0		52-105		25-52		11-25		3-11	>0-3
Wetland (acres)	0		254-713		103-254		28-103		6-28	>0-6
Hydric Soils	0%		1-25%		26-50%		51-75%		76-95%	96-100%
GWD (feet)	56-241		19-56			12-19			11-12	4-11
Flowing Water	No water			Intermittent				Perennial		Ditch
Land Use	Dev. Low-High	Barren, Dev. Open			Open Water		Wetlands		Cult. Crops	Hay/Pasture
Land Cover	No Dom. Lifeform		Non-vegetated			Shrub-dom			Tree-dom	Herb/ Non-vasc

Rasterizing and Suitability Modeling

After we collected, filtered, and scored the data layers, all of the data was transformed into a raster format using the “Convert To Raster” tool. Six steps were used to convert all the layers into rasters, allowed for an appropriate representation of the data layers, as each cell in a raster grid contains a single value:

1. A cell size of 10 with a 16-bit unsigned cell type was used for all data layers to maintain a level of consistency between layers.
2. The raster data layers were clipped to the desired extent using the “Clip Raster” tool.
3. The various data layers were loaded into the suitability modeler.
4. A common suitability scale was generated for all the layers based on the type of data (categorical or continuous).
5. We created several outputs where layers were weighted based on which variable was most important for citing potential wetlands. Throughout this process, variables that we wanted to weigh more heavily had a weight of 1.5 as opposed to a weight of 1:
    a. An output where all variables were weighted equally.
    b. An output where hydrology (waterways, wetlands, and riparian areas) was weighted more heavily than the other variables.
    c. An output where land use and land cover were weighted more heavily as well.
    d. Finally, an output where depth to groundwater and hydric soils were weighted for more heavily than the other variables.
6. The model produced a suitability map that included areas most suitable for wetland banking (10) and least suitable for wetland banking (1).

In the future, a seventh step can provide additional data by using the locate tab in the suitability model pane. This pane is for specifying the total area, number of regions, and shape characteristics of suitable areas.

Suggested Sites

Potential sites for the wetland mitigation bank were selected based on the suitability modeler on ArcGIS Pro. We ran the model four times, depicting different scenarios. All variables were weighted equally in the first scenario. In the second scenario, hydrological factors such as riparian, wetland, and surface water in acreage were weighted at 1.5. The third scenario weighted land factors such as cover and use at 1.5. Lastly, the fourth scenario weighed hydric soils and depth to groundwater at 1.5. When running the model on attempts 2-4, all other variables, except those otherwise specified, remained equally weighted at 1. Each map from the suitability modeler can be seen in Figures 9-13.

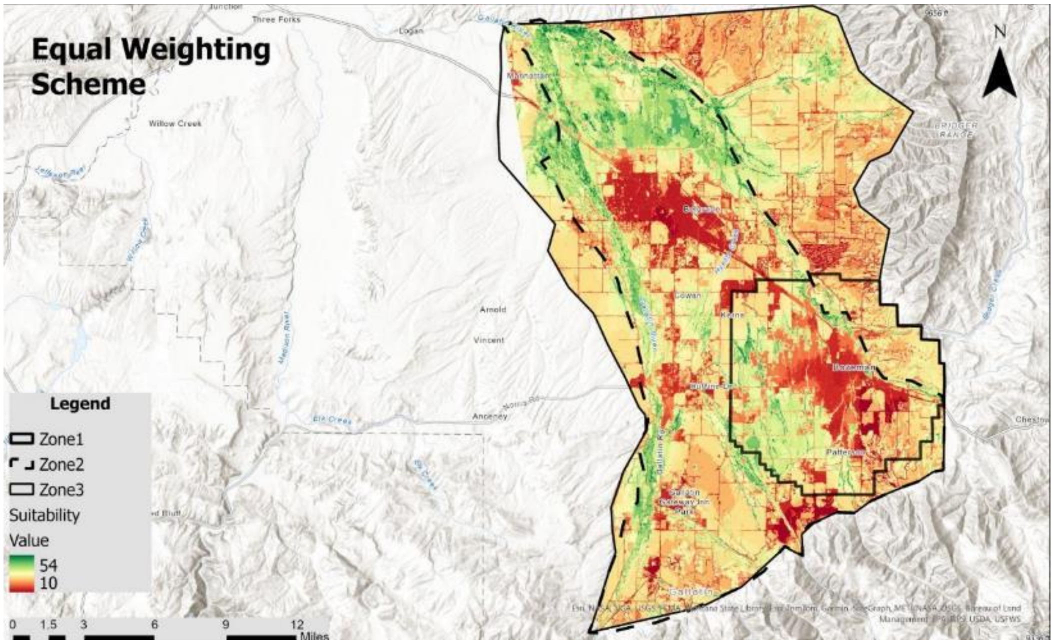


Figure 9:Equally weighted suitability map of the Gallatin Valley.

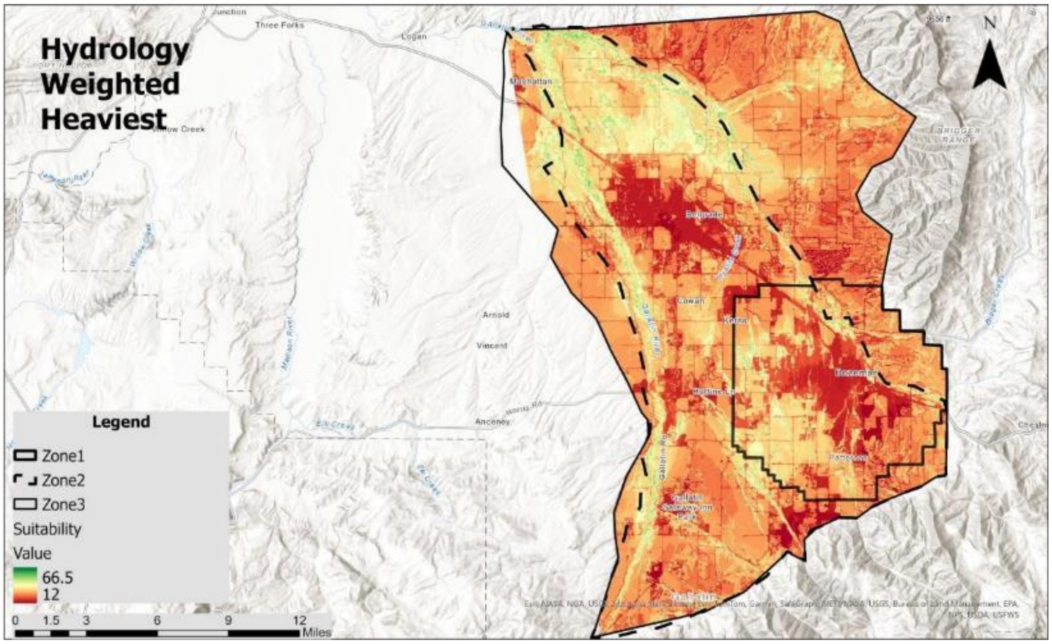


Figure 10: Suitability map of the Gallatin Valley with waterways, riparian, and wetlands weighted heaviest.

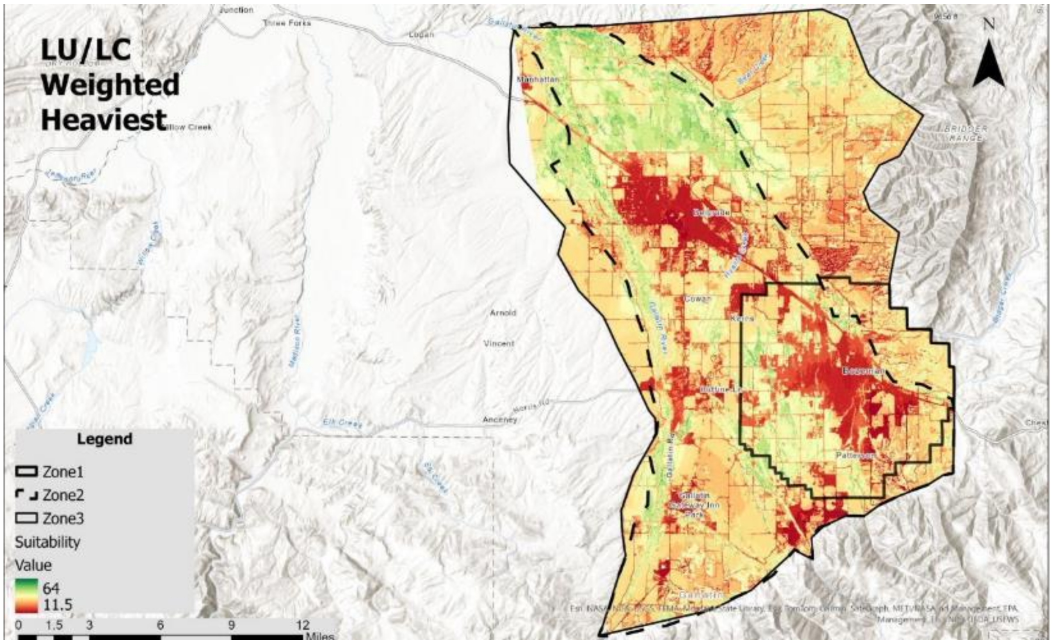


Figure 11: Suitability map of the Gallatin Valley with land use and land cover weighted heaviest.

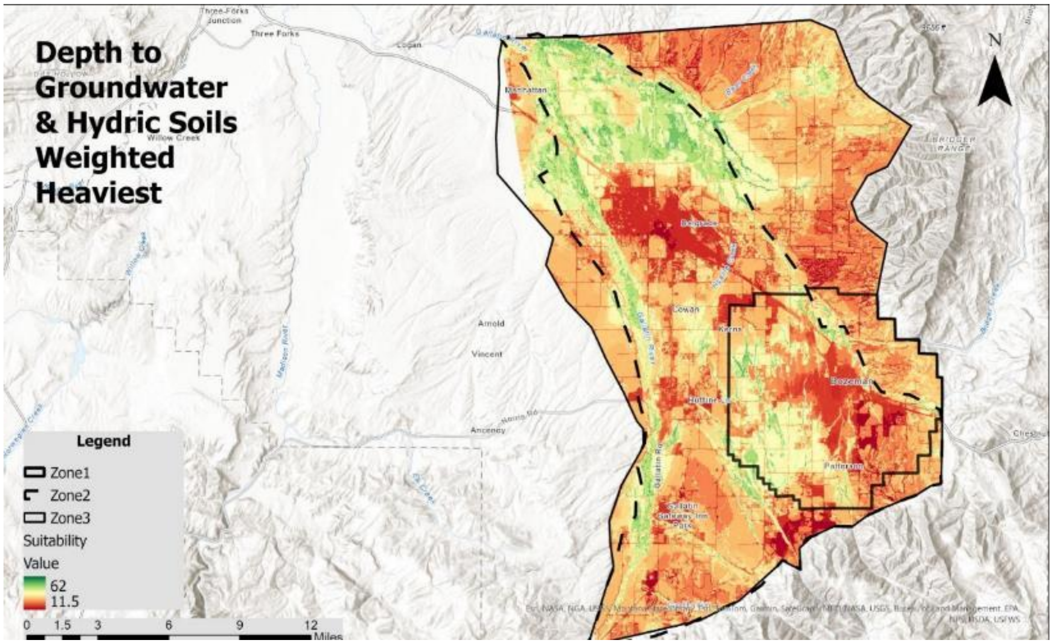


Figure 12: Suitability map of the Gallatin Valley with depth to groundwater and hydric soils weighted heaviest.

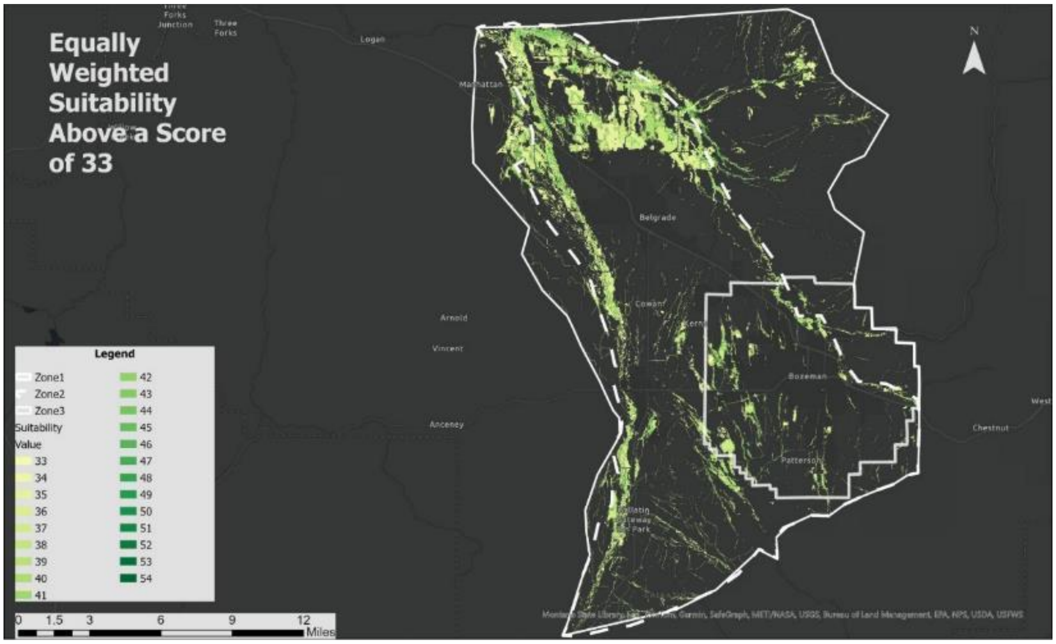


Figure 13: Equally weighted suitability map of the Gallatin Valley only including suitable areas (above a suitability score of 33).

Examples of Potential Sites

The following four sites were selected using the “equal weight” model. Potential site locations were selected aiming to have at least one site per priority zone, one landowner per site, a site size of at least 50 acres, and most of the site reading as green on the suitability map. To rank each site, each variable’s ranking was comprehensively estimated to encompass all values displayed throughout the site. Each layer received a ranking of 1-10 on a suitability scale where 1 is the worst and 10 is the best regarding a wetland mitigation bank site. The ranking information for each potential site can be found in Table 8. Then, the average was taken by adding all the layer rankings together. This provided an average ranking for each site based on the model.

Table 8. The individual layer rankings according to the "equal weight" suitability modeler for each identified potential wetland mitigation site.

Attribute	**Site 1**	**Site 2**	**Site 3**	**Site 4**
Riparian	1	8	2	6
Wetland	8	8	7	9
Hydric Soils	7	6	10	5
Land Use	6	5	6	5
Land Cover	10	10	10	10
Flowing Water	7	8	8	6
GWD	10	10	10	10
Average	7.0	7.9	7.6	7.3

Each of the four sites ranked between seven and eight, indicating similar environments. All the sites also received scores of 10 for both groundwater and land cover, making those layers the highest-ranking variables for each site.

Suggested Site 1 is located within priority zone 1 (Figure 14). This site is privately owned and is a size of 141.23 acres. The individual layer rankings for this site averaged a 7.0 on the "equal weight" suitability model. Wetlands ranked the highest among the layers for Site 1 (See Table 8).

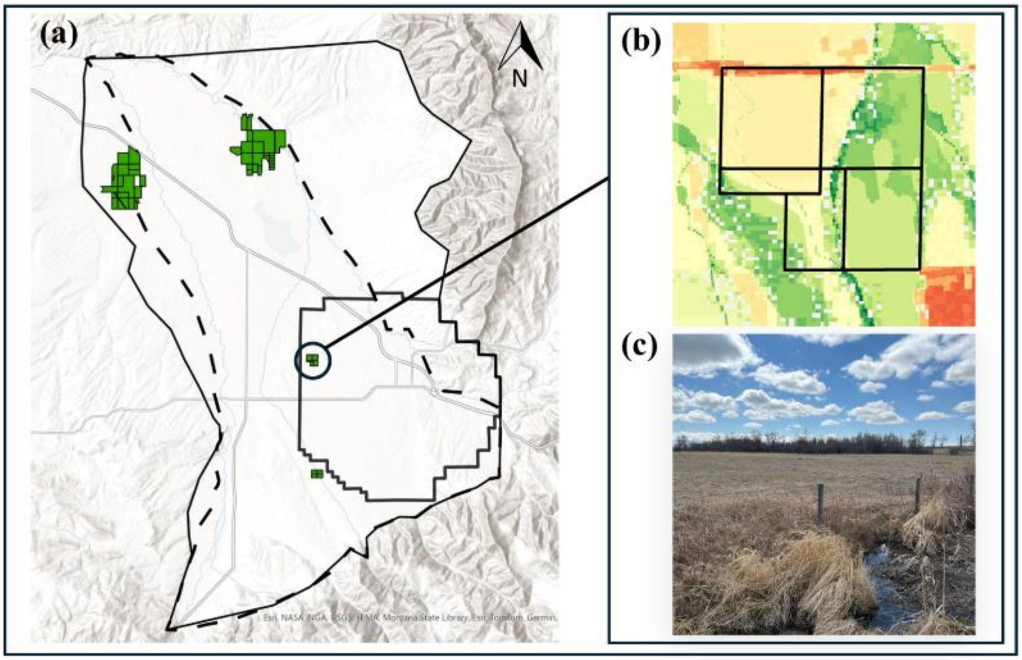


Figure 14: a) shows Site 1 in reference to the three zones b) shows the "equal weight" suitability map of Site 1 c) shows a photo taken of Site 1.

Suggested Site 2 is in priority zone 2 (Figure 15). Site 2 is currently privately owned and is 109.48 acres in size. This site had a particularly high ranking for surface water and soil. The individual layer rankings for this site averaged 7.9 on the "equal weight" suitability mode. Wetlands, flowing water, and riparian were all tied for the highest-ranking layers for Site 2 (see Table 8).

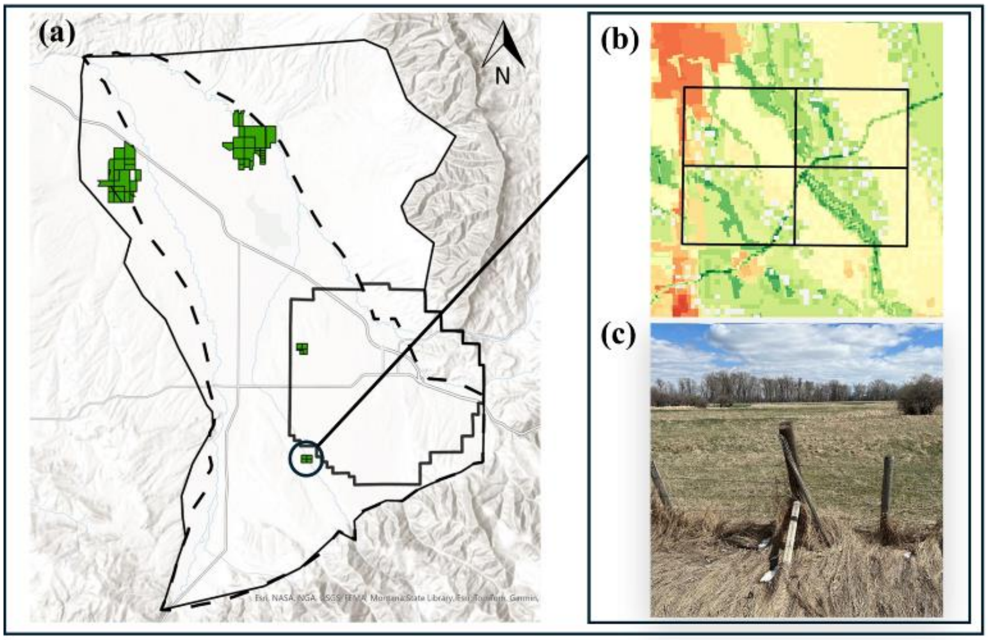


Figure 15: a) shows Site 2 in reference to the three zones b) shows the equal weight suitability map of Site 2 c) shows a photo taken of Site 2.

Suggested Site 3 is also located within the second priority zone (Figure 16). Site 3 is currently owned by an LLC and the plot is 2100.95 total acres in size. The individual layer rankings for this site averaged 7.6 on the “equal weight” suitability model. Hydric soils ranked the highest for Site 3 (see Table 8).

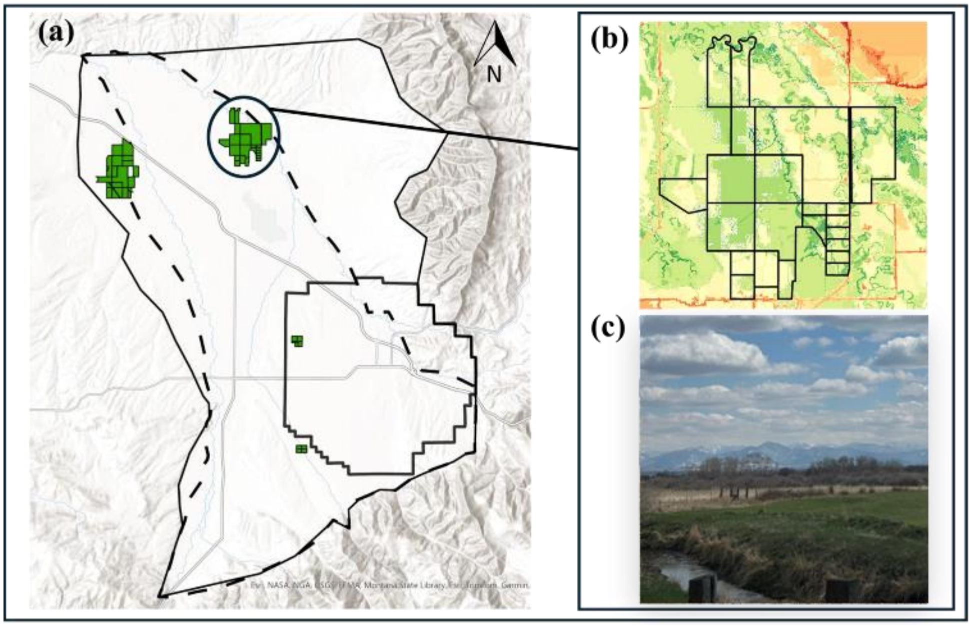


Figure 16: a) shows Site 3 in reference to the three zones b) shows the equal weight suitability map of Site 3 c) shows a photo taken of Site 3.

Suggested Site 4 is located within the third priority zone (Figure 17). Site 4 is currently owned by an LLC, and the site is 2027.34 total acres in size. The individual layer rankings for this site averaged 7.3 on the “equal weight” suitability model. Wetlands ranked the highest out of the layers for Site 4 (see Table 8).

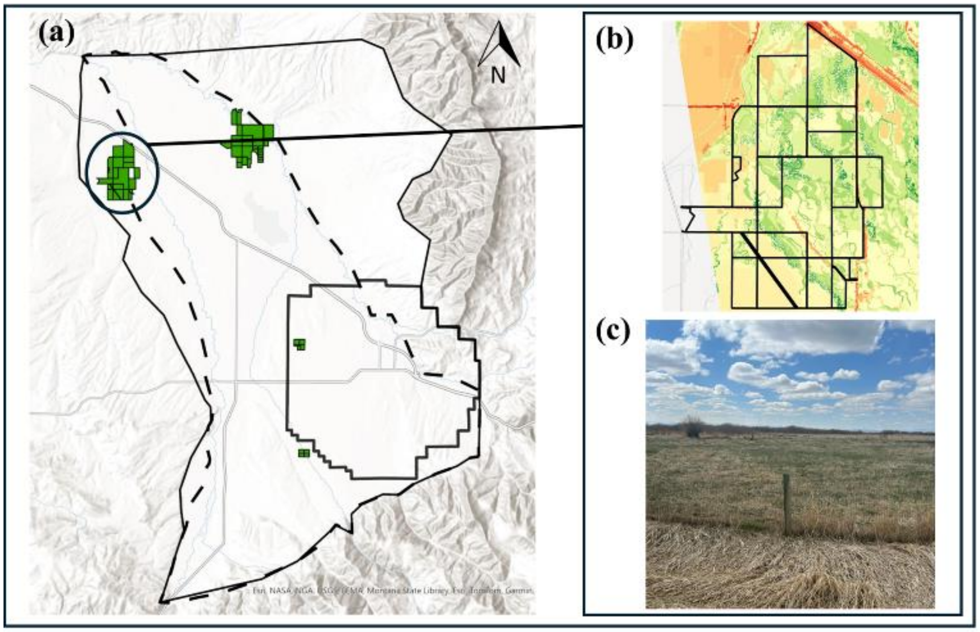


Figure 17: a) shows Site 4 in reference to the three zones b) shows the equal weight suitability map of Site 4 c) shows a photo taken of Site 4.

Project Limitations

Where General Results May Stray

The main limitations of this plan are the lack of time, inevitable discrepancies between actual site conditions and the framework, and the lack of expertise of the numerous writers. Discussing the lack of time, the capstone class in charge of writing this report was given a semester to learn about, form an idea, and write a report for the framework to select potential wetland bank sites. Another disadvantage of the plan regards the matter in which the framework was created. The GIS team developed potential site maps considering soil, plant, and water conditions. However, a major limitation is that the physical state of the site may differ from what is mapped. Old data and seasonal variation can lead to different conditions than those that are mapped. Lastly and possibly most importantly, the writers want to acknowledge that there were a total of 25 people writing this paper, and it was a bit difficult to effectively coordinate and communicate changing guidelines to each person.

Further examining the discrepancies between the mapped layer and the actual site conditions, the class has determined the biggest gaps for each wetland site criteria concerning the soil aspect of proposed wetland bank sites, the most substantial impediment is the uncertainty regarding the area of hydric soil present versus mapped. In the matter of plant communities, a lack of up-to-date species list or out-of-date abundance data could lead to a misinterpretation of ecological processes by restoration teams. Finally, regarding hydrological conditions, water flow in Montana differs greatly seasonally, and therefore, the time of year that sampling takes place could significantly influence the results or success of credit restoration. The photos were taken in the spring of 2024, so hydrological conditions may be a bit more saturated than average levels.

Groundwater and Data Filtering Results May Stray

It is also important to specifically consider groundwater and data limitations. Groundwater monitoring wells provide valuable insights into successful wetland development/restoration and are a good proxy for specific depth-to-groundwater data. We used this approach in the tool, and it does an adequate job of showing where groundwater will likely be shallow. However, this should be paired with ground-referenced data from updated surveys. The interpolation of groundwater from well data is imperfect and should not be the only tool used when sitting in a mitigation bank.

One other consideration which we did not account for in this tool due to time limitations, is groundwater fluxes due to well density and drawdown as well as annual changes. It would be important to assess this aspect in tandem with mapping the depth of groundwater to ensure that those resources are available for the bank throughout its lifespan and that groundwater is conserved.

Soil Results May Stray

Results for findings of hydric soils and the effectiveness of potential wetland sites depend highly on accurate and current data. As stated above, many sites would need to be visited to determine the viability of the project. Data for carbon stocks within soils is also highly variable and often inaccurately measured, which may affect the functional lift ability of the chosen site if the provided data is unreliable (Bridgham et al., 2006).

Mitigating Limitations

While the limitations listed above are substantial, the capstone class has taken measures to account for them accordingly. Most notably, one member has taken photos of the proposed site areas to better assess the physical conditions and ensure gaps between the map and actual sites are minimal. Additionally, every team (soils, plants, and hydrology) has reflected and pulled from four years of Montana-specific ecological knowledge to give the most accurate and encompassing recommendations possible. Likewise, even though there was a time constraint put on plan creation, the site proposals were produced by college students who are familiar with and well-suited to producing detail-oriented products on a short timeline. Given these limitations, the capstone class believes all limitations have been accounted for as best as possible.

Conclusion

The suggestions we have detailed throughout this paper are a methodology for siting a wetland mitigation bank given the known hydrology, vegetative community, and soils of Gallatin

Valley. The data and recommendations for a specific wetland mitigation bank have the potential for more detail, but this is the baseline procedure for finding a prospective mitigation bank site. Given the methodology we have laid out, we recommend utilizing a GIS suitability model that displays the best possible locations for a wetland mitigation bank in Gallatin Valley. The suitability model considers wetland acreage, waterways, hydric soils, land use, vegetative cover, and depth to groundwater. Additionally, it is crucial to recognize that potential functional lift within a wetland site results from ecological restoration. Specifically, restoration enhances a wetland's functional capacity through lift, generating more functional capacity units and sellable credits for the mitigation bank.

Moving forward, it is imperative to utilize a regional approach for wetland mitigation. This method is intended to emphasize the establishment of larger, interconnected reserves. By designating such areas as regional parks, we can ensure the perpetuity of ecosystem services while preserving recreational opportunities for residents. The success of the Story Mill Wetland serves as a testament to the effectiveness of this approach, highlighting the potential for mitigating the impacts of urban development while fostering environmental stewardship and community engagement.

Considering these considerations, we recommend using a comprehensive watershed approach to prioritize the expansion of wetland mitigation banking efforts in the Gallatin Valley. By embracing the principles of preservation, enhancement, restoration, and establishment outlined in the compensatory mitigation rule, we can strive towards achieving a balance between urban development and environmental conservation for the benefit of current and future generations.

Acknowledgments

We would like to thank the guest lecturers who helped guide our efforts: Nick Ross from the City of Bozeman, Rich McEldowney from Confluence Consulting, Leah Schwartz from Montana Freshwater Partners, and Nathan Green from the US Army Corps of Engineers.

References

Berkowitz, J. F., Vepraskas, M. J., Vaughan, K. L., & Vasilas, L. M. (2021). Development and application of the Hydric Soil Technical Standard. *Soil Science Society of America Journal*, *85*(3), Article 3. https://doi.org/10.1002/saj2.20202

Bridgham, S. D., Megonigal, J. P., Keller, J. K., Bliss, N. B., & Trettin, C. (2006). The carbon balance of North American wetlands. *Wetlands*, *26*(4), Article 4. https://doi.org/10.1672/0277-5212(2006)26[889:TCBONA]2.0.CO;2

City of Bozeman. (2022, July 1). *A City Influenced by Our Natural Environment, Parks and, Open Lands*. Bozeman MT. https://bozeman-community-plan-1-bozeman.hub.arcgis.com/pages/f33ec690155446fba7b860bfab70eecc

City of Bozeman, Montana. (2022). *Bozeman Community Plan Future Land Use* [GIS Feature Service Feature Class]. https://www.arcgis.com/home/item.html?id=71611e1633664faebf90ddfcd0611fbb

Clean Water Act, 33 U.S.C § 404 (1972).

de Groot, R. S., Wilson, M. A., & Boumans, R. M. J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, *41*(3), Article 3. https://doi.org/10.1016/S0921-8009(02)00089-7

Esri. (2024a). *USA SSURGO - Soil Hydric Class* [GIS Imagery Layer]. https://www.arcgis.com/home/item.html?id=2be45af986af4624839cedae883faf47

Esri, (Environmental Systems Research Institute). (2024b). *ArcGIS Pro* (3.2.2) [Computer software].

Gallatin County Montana. (2024). *Waterways* [GIS Shapefile]. https://www.gallatinmt.gov/geographic-information-systems/pages/data-download

GPO. (2008). *Compensatory Mitigation for Losses of Aquatic Resources 33 CFR.*

Hackett, O. M., Vishner, F. N., McMurtrey, R. G., & Steinhilber, W. L. (1960). *Geology and ground-water resources of the Gallatin Valley, Gallatin County, Montana* (p. 288) [Book]. USDI. https://doi.org/10.3133/wsp1482

Harris, D. G., & Van Bavel, C. H. M. (1957). Root Respiration of Tobacco, Corn, and Cotton Plants [1]. *Agronomy Journal*, *49*(4), Article 4. https://doi.org/10.2134/agronj1957.00021962004900040004x

Hauer, R., Cook, B. J., Gilbert, M. C., Clairain, E. J., & Smith, D. (2002). *A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Intermontane Prairie Pothole Wetlands in the Northern Rocky Mountains*. U.S. Army Engineer Research and Development Center, Vicksburg, MS. https://wetlands.el.erdc.dren.mil/pdfs/trel02-7.pdf

Hruby, T., Richter, K., Fuerstenberg, B., Murphy, M., & King County Department of Natural Resources and Parks. (2012). *Calculating Credits and Debits for Compensatory Mitigation in Wetlands of Western Washington*. Washington State Department of Ecology. https://apps.ecology.wa.gov/publications/documents/1006011.pdf

Hunter, E., Raney, P., Gibbs, J., & Leopold, D. (2012). Improving Wetland Mitigation Site Identification Through Community Distribution Modeling and a Patch-Based Ranking Scheme. *Wetlands*, *32*, 841–850. https://doi.org/10.1007/s13157-012-0315-7

J. Berglund and R. McEldowney. (2008). *MDT: Montana Wetland Assessment Method* (p. 69). Montana Department of Transportation.

mdt.mt.gov/other/webdata/external/planning/wetlands/2008_wetland_assessment/2008_mwam_manual.pdf

Jadhav, R. S., & Buchberger, S. G. (1995). Effects of vegetation on flow through free water surface wetlands. *Ecological Engineering*, *5*(4), Article 4. https://doi.org/10.1016/0925-8574(95)00039-9

Kleindl, W. (2024). *Personal Commuication*.

Lave, R., & Doyle, M. (2020). *Streams of revenue: The restoration economy and the ecosystems it creates*. The MIT Press.

Lee, J., Ellis, C., Choi, Y. E., You, S., & Chon, J. (2015). An Integrated Approach to Mitigation Wetland Site Selection: A Case Study in Gwacheon, Korea. *Sustainability*, *7*(3), Article 3. https://doi.org/10.3390/su7033386

Leibowitz, S. G. (2003). Isolated wetlands and their functions: An ecological perspective. *Wetlands*, *23*(3), Article 3. https://doi.org/10.1672/0277-5212(2003)023[0517:IWATFA]2.0.CO;2

Mitchell, J. (2023). *MSDI Montana Land Use/Land Cover* [Geodatabase]. https://msl.mt.gov/geoinfo/msdi/land_use_land_cover/

Montana Bureau of Mines and Geology. (2024, April 15). *Groundwater Information Center* [Education]. https://mbmggwic.mtech.edu/

MRLC (Multi-Resolution Land Characteristics Consortium). (2020). *National Land Cover Database*. National Land Cover Database (NLCD). http://www.mrlc.gov/index.php

Sacajawea Audubon Society. (2021, May 1). Indreland Audubon Wetland Preserve. *INDRELAND AUDUBON WETLAND PRESERVE*. https://sacajaweaaudubon.org/indreland-audubon-wetland-preserve/

Soil Survey Staff, Natural Resources Conservation Service, & United States Department of Agriculture. (2024). *Soil Survey Geographic Database (SSURGO)* [ArcGIS Map Service]. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

US Army Corps of Engineers. (2004). *Mitigation Question & Answer*. US Army Corps of Engineers. https://www.nap.usace.army.mil/Portals/39/docs/regulatory/Mitigation/mitigation-qa.pdf

US Army Corps of Engineers, United States Environmental Protection Agency, & Institute for Water Resources. (2015). *The Mitigation Rule Retrospective: A Review of the 2008 Regulations Governing Compensatory Mitigation for Losses of Aquatic Resources*. United States Environmental Protection Agency. https://www.iwr.usace.army.mil/Portals/70/docs/regulatory/2015-R-03_Factsheet.pdf

US Census Bureau. (2020). [Government Website]. Bozeman City, Montana- United State Census Bureau. https://data.census.gov/table/ACSST5Y2022.S0101?g=160XX00US3008950

USFWS, (United States Fish and Wildlife Service). (2023). *National Wetlands Inventory (NWI)* [Geodatabase]. https://www.fws.gov/program/national-wetlands-inventory/download-state-wetlands-data

Van Lonkhuyzen, R., LaGory, K., & Kuiper, J. (2004). Modeling the Suitability of Potential Wetland Mitigation Sites with a Geographic Information System. *Environmental Management*, *33*, 368–375. https://doi.org/10.1007/s00267-003-3017-3

Appendix A: Public Presentation

A Method for Siting a Wetland Mitigation Bank In Gallatin Valley

By: ENSC 499 Capstone Class

LRES Capstone
Who We Are

We are a team of 26 students in our final or penultimate semester at Montana State University.

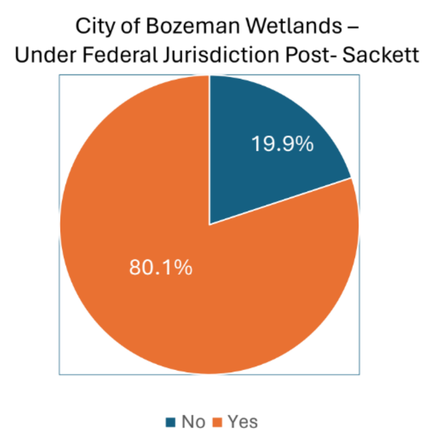
We address a scientific issue that is strongly relevant to the local Bozeman community.

Strong educational background in plant, water, soil, and geospatial sciences.

Need for Project

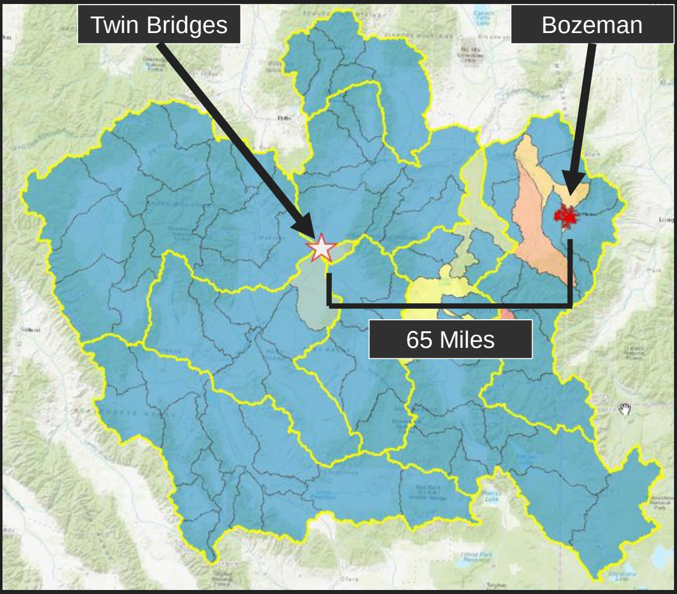
- The City of Bozeman has experienced rapid growth.
    - 40% growth rate in the last 10 years,
    - Bozeman has nearly doubled in size.
    - The 2020 Bozeman Community Plan

- Development projects in Bozeman will continue to impact wetlands and streams.
    - Within Bozeman growth boundary estimated 1,628 acres of wetlands and 254 miles of waterways



Current Mitigation Banks

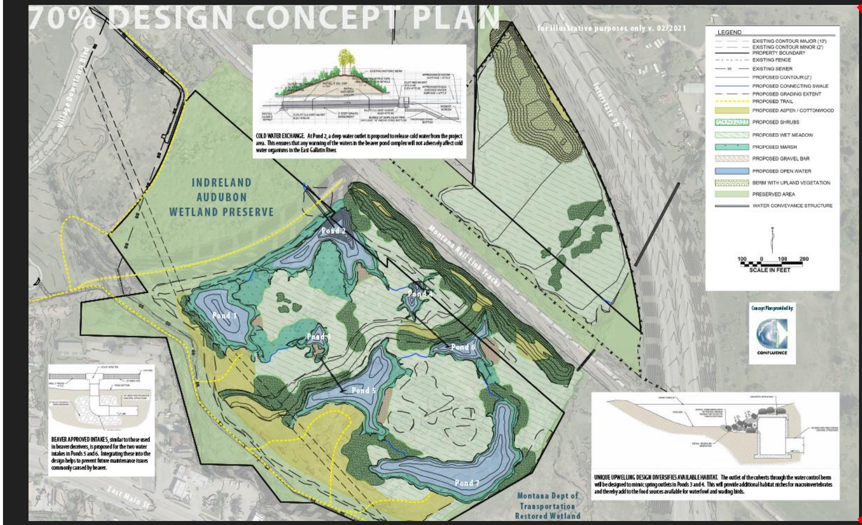
- Twin Bridges, MT Mitigation Bank
    - 65 miles west of Bozeman
    - Credits from Twin Bridges can be purchased to mitigate impacts in Bozeman



Current Mitigation Banks

- Indreland Audubon Wetland Preserve (IAWP)
  - A 33-acre parcel of land purchased by the Sacajawea Audubon Society
  - Intent to use this land as a wetland mitigation bank to serve the Gallatin Valley

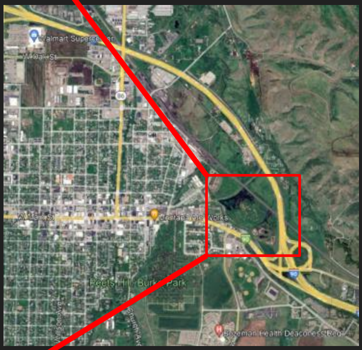
Current Mitigation Banks

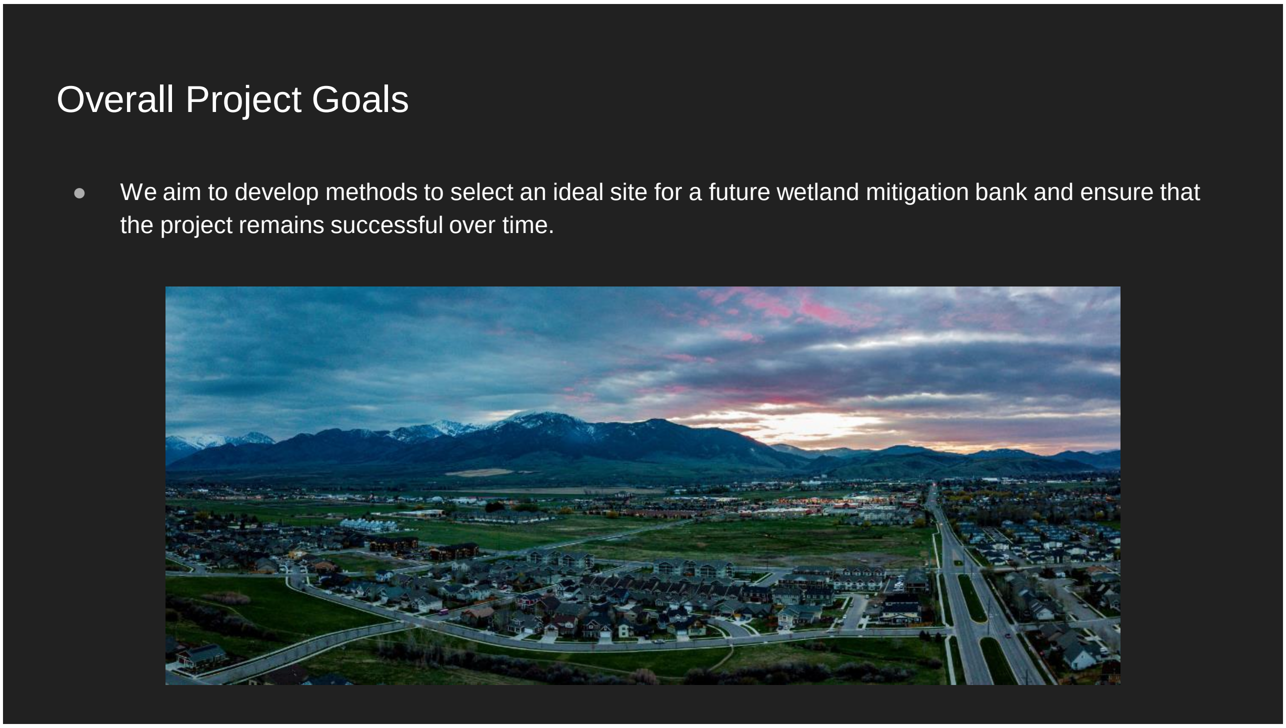


COLD WATER EXCHANGE. At Pond 2, a deep water outlet is proposed to release cold water from the project area. This ensures that any warming of the waters in the beaver pond complex will not adversely affect cold water organisms in the East Gallatin River.

BEAVER APPROVED INTAKES, similar to those used in beaver deceivers, is proposed for the two water intakes in Ponds 5 and 6. Integrating these into the design helps to prevent future maintenance issues commonly caused by beaver.

UNIQUE UPWELLING DESIGN DIVERSIFIES AVAILABLE HABITAT. The outlet of the culverts through the water control berm will be designed to mimic spring outlets in Ponds 3 and 4. This will provide additional habitat niches for macroinvertebrates and thereby add to the food sources available for waterfowl and wading birds.





Overall Project Goals

- We aim to develop methods to select an ideal site for a future wetland mitigation bank and ensure that the project remains successful over time.

History of Wetland Mitigation Banking

- In 1977 federal law stated that steps needed to be taken to avoid impacts on wetlands.
  - EPA “Protection of wetlands (Executive order 11990).
- In 2008 the Compensatory Mitigation rule established the standards for wetland mitigation.

History of Wetland Mitigation Banking

- Compensatory mitigation rule (2008) aims to achieve no net loss of wetlands in the United States.

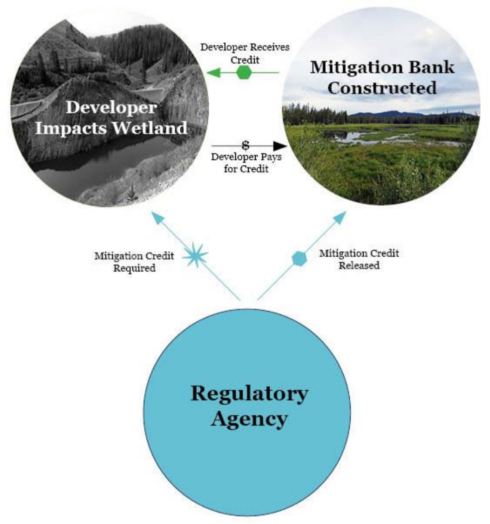
- Ideally, no net loss of wetlands is achieved through:
    - Mitigation banking
    - In-lieu fee mitigation
    - Permittee-responsible mitigation

History of Wetland Mitigation Banking

- Historically permittee-responsible mitigation was most common but has a high rate of failure.

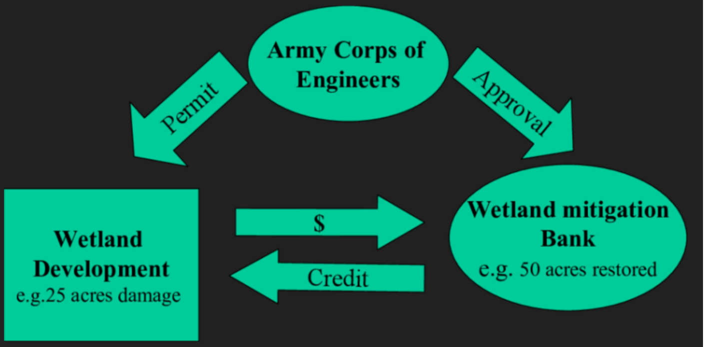
- Mitigation banking and in-lieu fee are more common now due to a higher level of qualified oversight.

- Mitigation banking is generally considered the best due to restoration occurring before any credits are sold.
    - There are high levels of qualified personal
    - Multiple companies, and
    - Agencies creating mitigation banks.



Debits and Credits

- Market-driven approach
  - Operate as a currency system
  - Credits bought/sold as commodities
- **Credits**: quantified “lift” of wetland ecosystem function
- **Debits**: quantified “loss” of wetland ecosystem function
- Equal number of credits purchased to offset debits created through wetland impacts
- Must be durable



Army Corps of Engineers

Permit

Approval

Wetland Development
e.g.25 acres damage

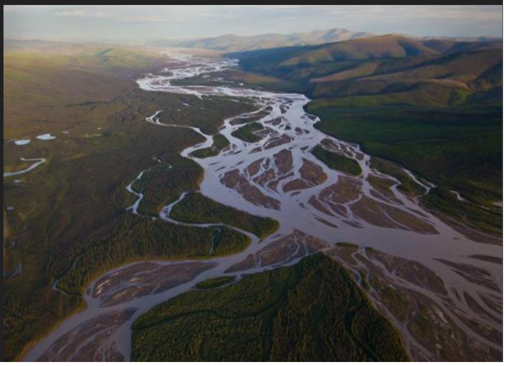
$

Credit

Wetland mitigation Bank
e.g. 50 acres restored

Rapid Assessment of Functional Capacity

- Credits Designated: functional lift of restored site
  - Positive change in ecosystem function
- Quantification of Functional Lift:
  - Montana Wetland Assessment Method (MWAM)
  - Hydrogeomorphic Assessment Method (HGM)
- HGM: Measures the capacity of a wetland to provide functions:
  - surface-groundwater storage and flow
  - nutrient cycling
  - retention of organic and inorganic particles
  - generation and export of organic carbon
  - characteristic plant community
  - characteristic aquatic invertebrate food webs
  - characteristic vertebrate habitats
  - floodplain interspersion and connectivity



Functional Capacity Units

HGM functions quantified by the Functional Capacity Index

- FCI: index of wetland's capacity to perform a function relative to other wetlands in regional subclass

- Made up of several smaller variables

Example: Surface-groundwater storage and flow

$$FCI = [(\frac{V_{surfreq} + V_{subfreq} + V_{macro}}{3}) \times V_{geomod}]^{\frac{1}{2}}$$

Convert FCI to FCU

$$FCI_{lift} = FCI_{post-restoration} - FCI_{pre-restoration}$$

$$FCU = FCI_{lift} \times acreage$$

FCU = Wetland Credits

GIS Methods

Suitability Zones of Study Area:

Zone 1: Green

Bozeman Growth Boundary (2020)

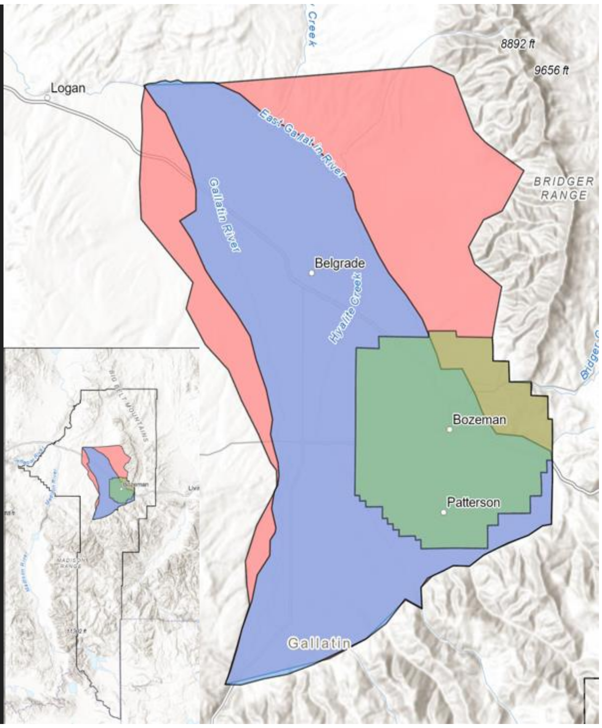
Zone 2: Blue

Bounded by Gallatin Rivers

Zone 3: Red

Bounded by Mountains

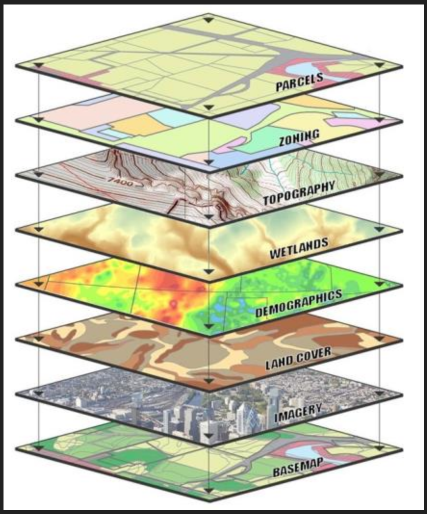
* Zone 1 is the priority zone since the city would like to prioritize a wetland bank within the Bozeman Growth Boundary



Our Goal is to find the best sites suitable for a wetland bank

Data Layers Used

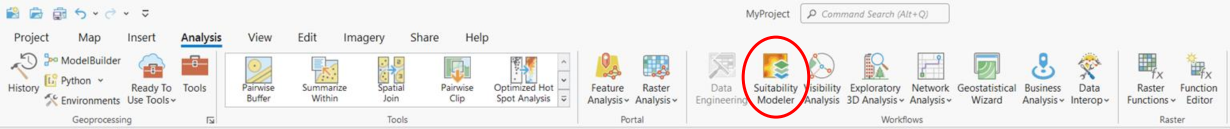
- Hydric soils
- Waterways
  - Wetland acreage
  - Surface water
- Riparian acreage
- Land Cover
  - Vegetation classes
- Land Use
- Depth to Groundwater (ft)



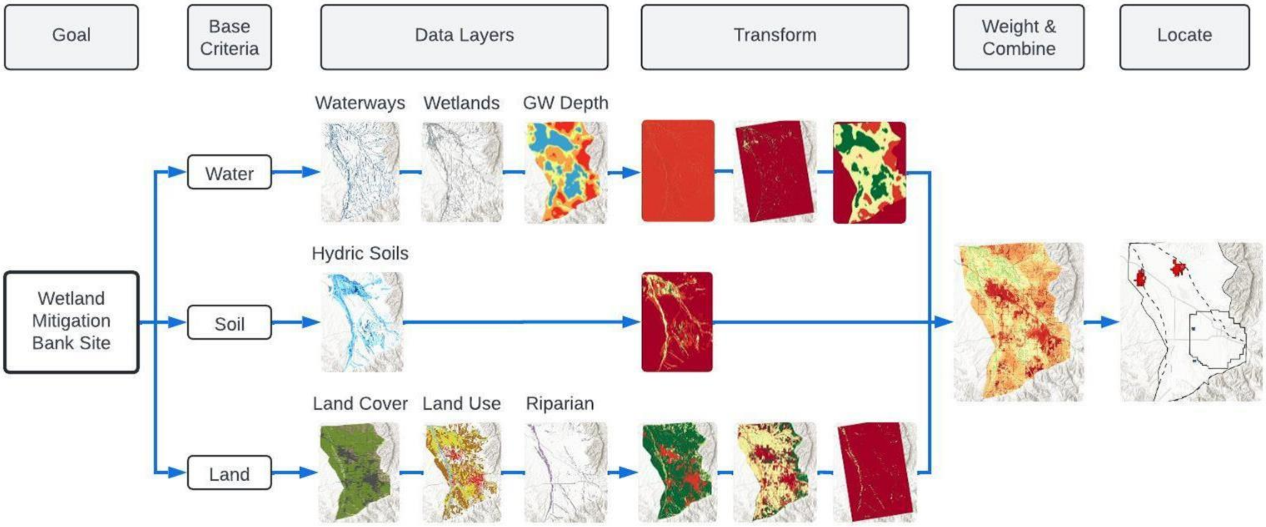
Suitability Modeler in ArcGIS Pro

Used for selecting sites by weighting raster layer values and overlaying them

Pixels with the highest mean of overlain values is the most suitable site



Suitability Modeler Flow Chart


Goal

Base Criteria

Data Layers

Transform

Weight & Combine

Locate

Wetland Mitigation Bank Site

Water

Waterways

Wetlands

GW Depth

Soil

Hydric Soils

Land

Land Cover

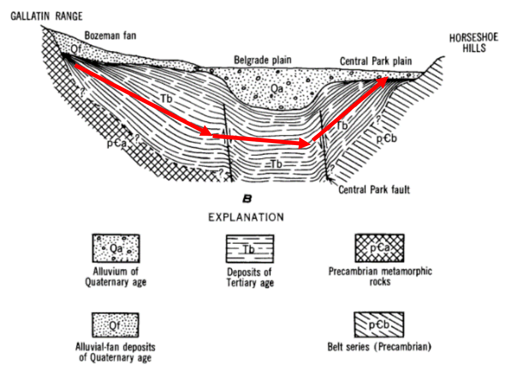
Land Use

Riparian

So, how do we scale the data layers?

Hydrogeomorphology of Gallatin Valley

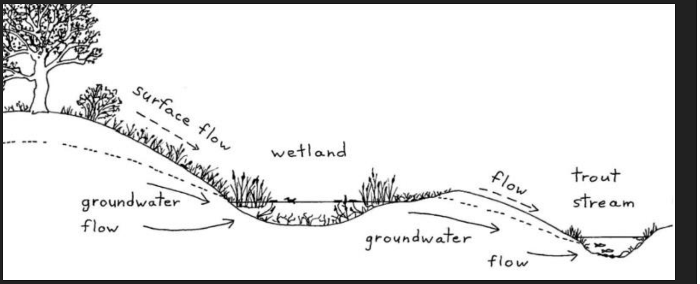
- Surface and groundwater resources are critical for mitigation bank success.
- Groundwater resources are most available in the north-western end of the valley.
- Shallow depth-to-groundwater and high availability of surface water connections.



Hackett 1960, Gallatin Valley Basin Geology

Role of Surface Water in Wetland Mitigation

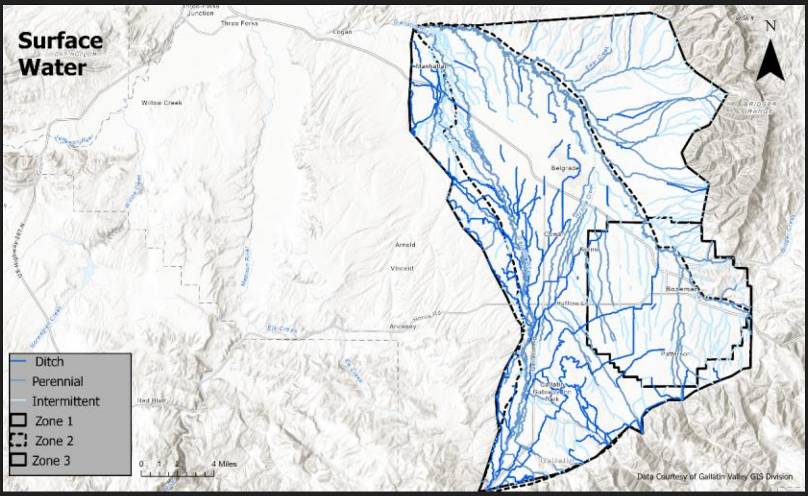
- Surface water creates hydrological regimes promoting hydric soils.
- Surface water quality influenced by sedimentation, plant uptake, litter decomposition, and microbial processes.
- Vegetation can impact retention time.



Wisconsin Wetland Association

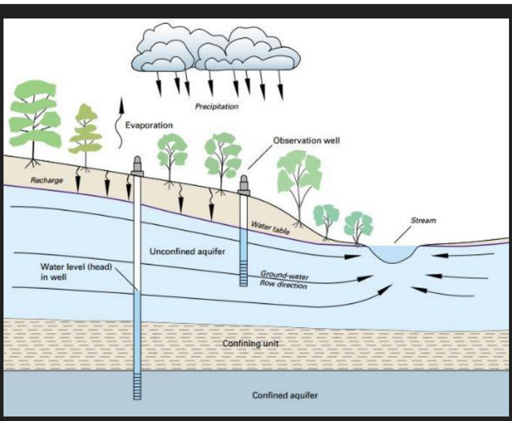
Surface Water Integration with GIS Tool

- Used waterways dataset from Gallatin Valley GIS clearing house.
- Rated on a 1-10 scale for suitability.
- Suitability is ranked by both functional lift and water availability.
- Ditches highest.
- No water lowest.



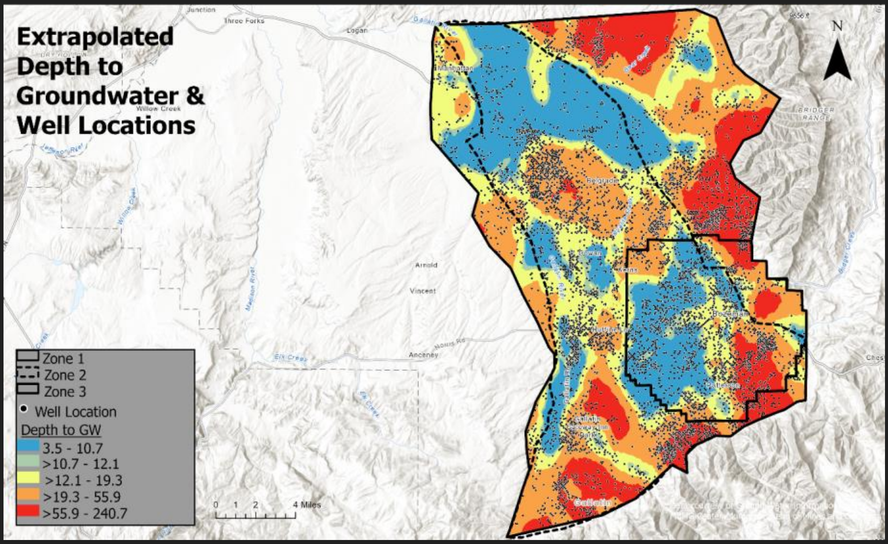
Groundwater Connections

- Crucial for wetland health/restoration
- Ground water information center (GWIC)
  - Public Data is limited in Gallatin Valley
  - Well data as a proxy.
    - Used static water levels from active wells/boreholes to determine depth-to-groundwater
    - Shallow Groundwater prime for development/restoration efforts (especially sites that otherwise lack surface flows)
    - Deep static water levels considered poor sites due to lack of water connectivity.



• Groundwater Integration with GIS Tool

- Interpolated using GWIC well data.
- Rated on a 1-10 scale for suitability.
- Blue zones indicate shallowest groundwater. 9-10 suitability score.
- Red zones indicate deepest groundwater. 1-2 suitability score.



Integration with GIS analysis.

- Wetlands identified through NWI are ranked one through ten based on their ecological significance.
- Higher rankings are assigned to pristine or minimally impacted wetlands.
- Lower rankings assigned to wetlands with significant human impacts.
- Data on land use, such as affects from urbanization or agriculture, are incorporated into the analysis.

National Wetlands Inventory (NWI)

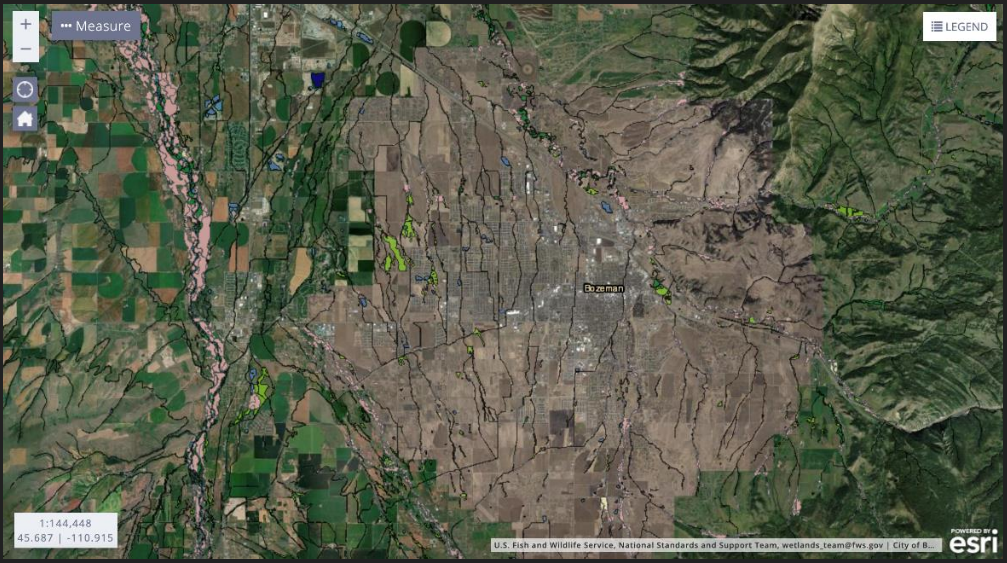


Figure 1: Pre-Existing wetlands in Bozeman MT signified by the light green patches. Riparian areas are represented by the pink patches. Satellite imagery updated in 2021.

Figure 2: Historic wetlands in Bozeman impacted by agricultural practice near Stucky Road and Cottonwood Road.

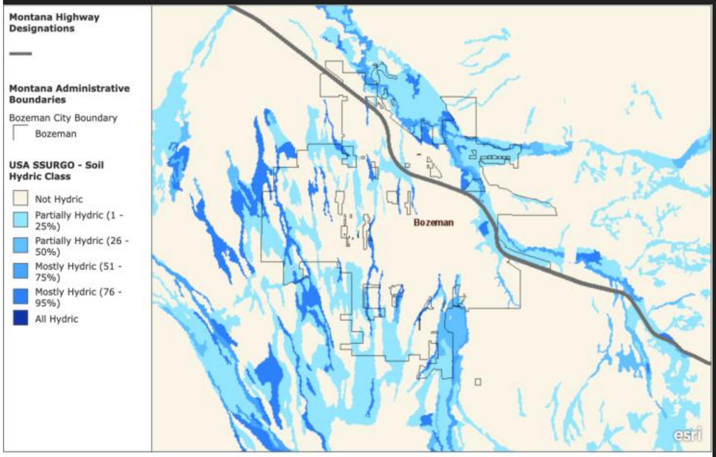
Ranking	Riparian Acres	Wetland Acres
1	0	0
2		
3	52 to 105	254 to 713
4		
5	25 to 52	103 to 254
6		
7	11 to 25	28 to 103
8		
9	3 to 11	6 to 28
10	>0 to 3	>0 to 6

Soils Methods Context

- Legal definition of hydric soils
  - Soils saturated long enough to create anaerobic conditions
- Soil properties directly relate to wetland function and structure
  - Framework developed around hydric soil presence

https://www.crops.org/news/science-news/story-behind-uniquely-dark-wetland-soil/

Soils Methods



Esri, NASA, NGA, USGS | Bozeman GIS, Montana State Library, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS | Source: USDA NRCS, Esri | Montana State Library

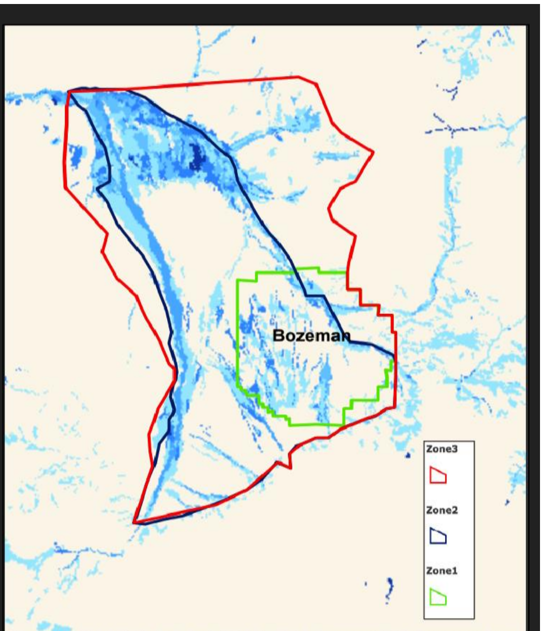
Soils: 1 - 10 scale, ranked by how hydric the soil is

A rating of:
  1 → non-hydric soils
  3→ slightly hydric (1-25%)
  5→ partially hydric (26-50%)
  7 → moderate hydric (51-75%)
  9 → mostly hydric (76-95%)
  10 → hydric (96-100%)

For additional methods
  NRCS (Web Soil Survey)
    ■ Hydric Rating by Map Unit

Soils Possible Results

- What you should expect:
  - Hydric soil values are from the gSSURGO
  - Hydric classification scores weighted with other factors into suitability score
- Where results may stray
  - Highly dependent on accurate and current data
  - On-site analysis needed



Source: USDA NRCS, Esri, Esri, CGIAR, USGS, Bozeman GIS, Montana State Library, Esri, TomTom, Garmin, SafeGraph, FAO, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USFWS

Species Composition

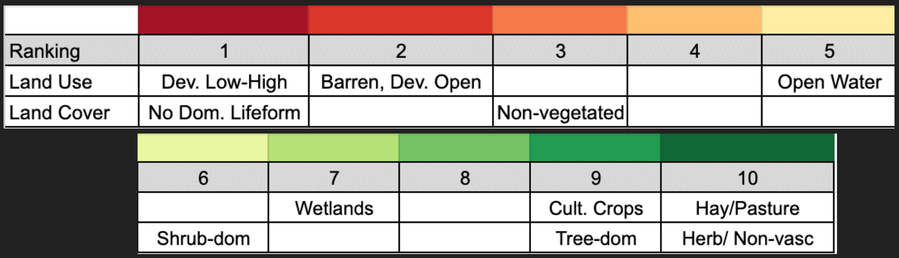
- Different types of plants to consider
  - free floating vs rooted
  - shrub vs tree
  - sedge vs willow
- Each plant has own role in ecosystem
  - Willow - stabilization
  - Sedge - nutrient cycling
- Pioneer plants
  - Set stage for immigrating species

Disturbance

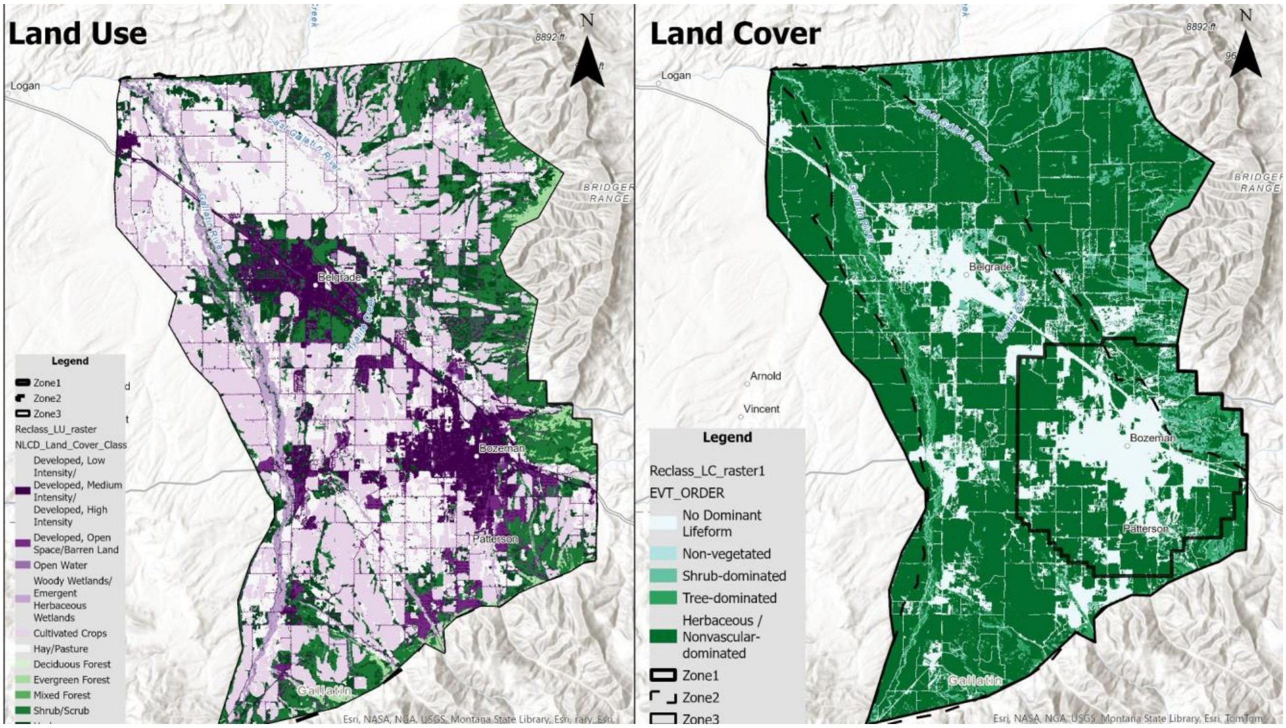
- An abiotic or biotic factor that causes stress
- Defined by
  - Time
  - Intensity
  - Magnitude
  - Frequency
  - Duration

Invasive Plant Species

- Negatively impact wetland
  - Outcompete native vegetation
  - Provide poor habitat
  - Reduce plant diversity
- Hinder functional lift

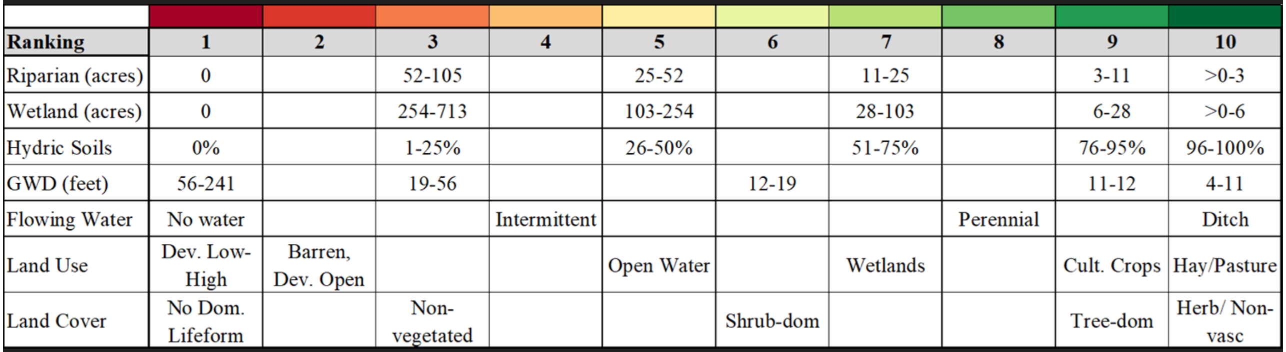


	🟥	🟥	🟧	🟧	🟨	🟨	🟩	🟩	🟩	🟩
Ranking	1	2	3	4	5	6	7	8	9	10
Land Use	Dev. Low-High	Barren, Dev. Open			Open Water		Wetlands		Cult. Crops	Hay/Pasture
Land Cover	No Dom. Lifeform		Non-vegetated			Shrub-dom			Tree-dom	Herb/ Non-vasc


Land Use
N
8892 ft
Logan
East Gallatin River
Gallatin River
BRIDGER RANGE
Belgrade
Bozeman
Patterson
Gallatin
Legend
▬ Zone1
Zone2
▭ Zone3
Reclass_LU_raster
NLCD_Land_Cover_Class
Developed, Low Intensity/ Developed, Medium Intensity/ Developed, High Intensity
Developed, Open Space/Barren Land
Open Water
Woody Wetlands/ Emergent Herbaceous Wetlands
Cultivated Crops
Hay/Pasture
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Esri, NASA, NGA, USGS, Montana State Library, Esri
Land Cover
N
8892 ft
Logan
East Gallatin River
Gallatin River
BRIDGER RANGE
Belgrade
Bozeman
Patterson
Gallatin
Arnold
Vincent
Legend
Reclass_LC_raster1
EVT_ORDER
No Dominant Lifeform
Non-vegetated
Shrub-dominated
Tree-dominated
Herbaceous / Nonvascular-dominated
Zone1
Zone2
Zone3
Esri, NASA, NGA, USGS, Montana State Library, Esri, TomTom

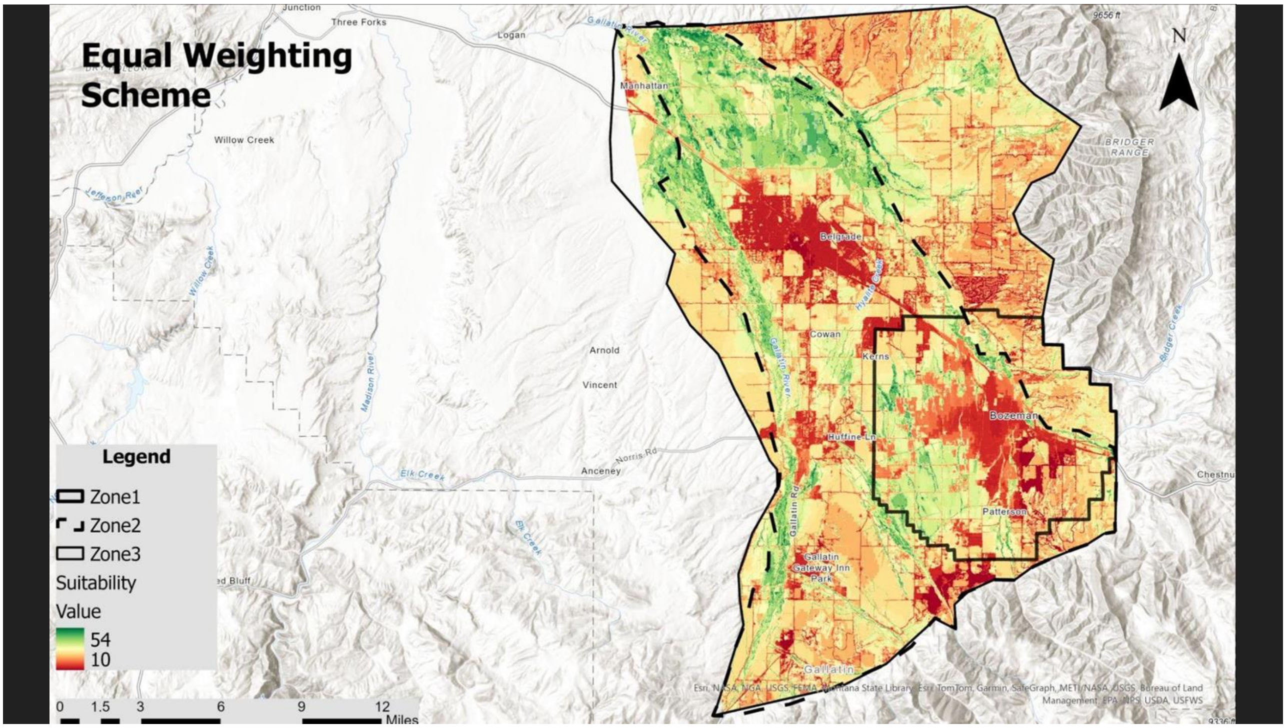
Results

Ranking System

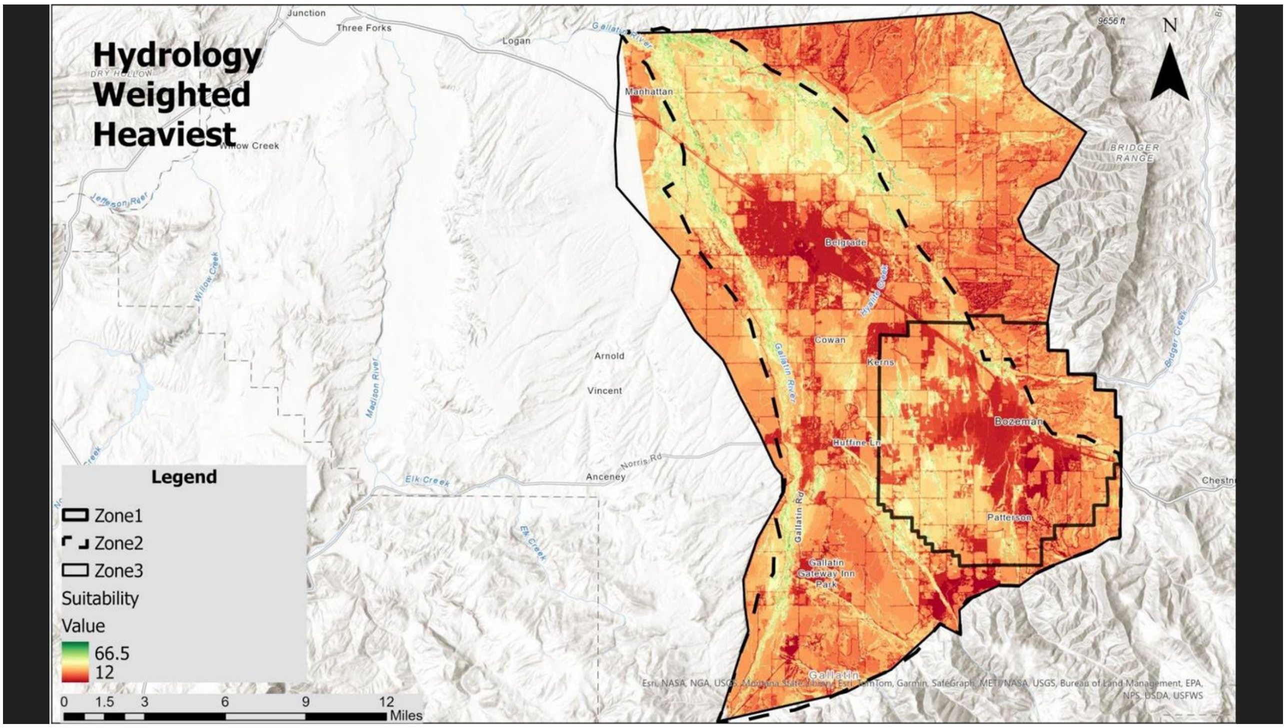


	🟥	🟥	🟧	🟧	🟨	🟨	🟩	🟩	🟩	🟩
Ranking	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Riparian (acres)	0		52-105		25-52		11-25		3-11	>0-3
Wetland (acres)	0		254-713		103-254		28-103		6-28	>0-6
Hydric Soils	0%		1-25%		26-50%		51-75%		76-95%	96-100%
GWD (feet)	56-241		19-56			12-19			11-12	4-11
Flowing Water	No water			Intermittent				Perennial		Ditch
Land Use	Dev. Low-High	Barren, Dev. Open			Open Water		Wetlands		Cult. Crops	Hay/Pasture
Land Cover	No Dom. Lifeform		Non-vegetated			Shrub-dom			Tree-dom	Herb/ Non-vasc

Equal Weighting Scheme

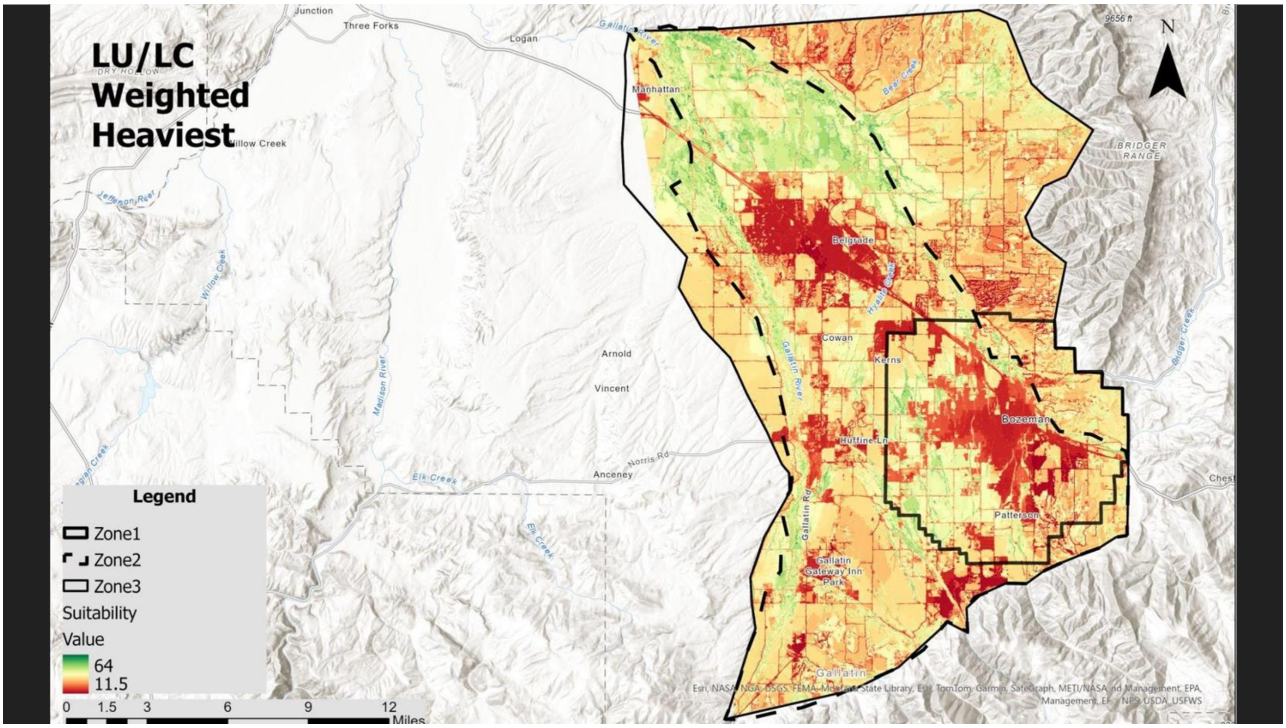


Esri, NASA, NGA, USGS, FEMA, Montana State Library, Esri, TomTom, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS



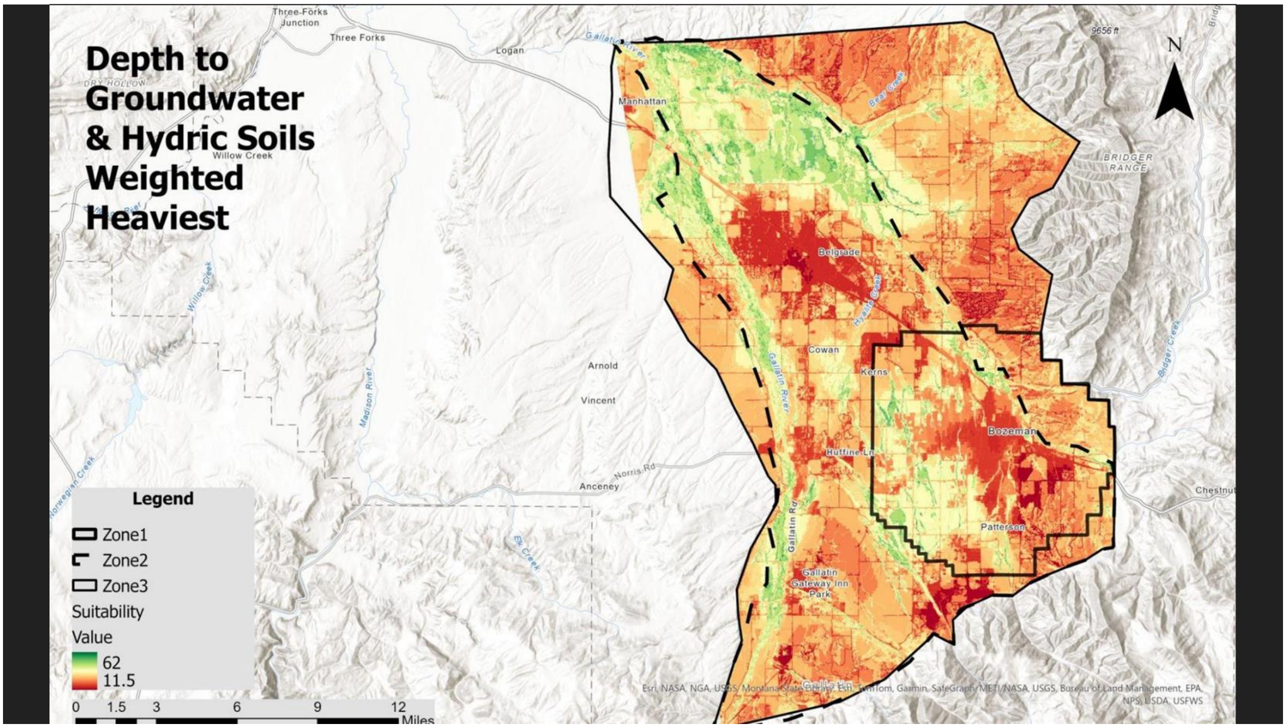
Hydrology Weighted Heaviest

39



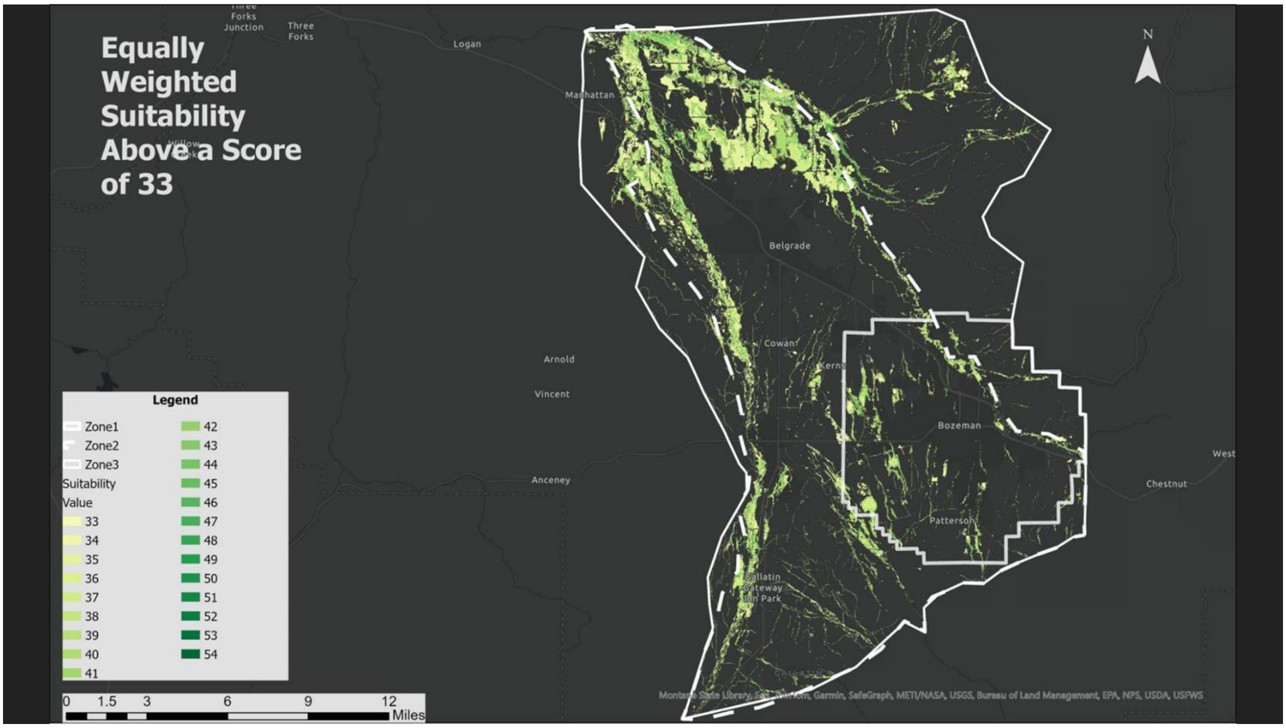
LU/LC Weighted Heaviest

40



Depth to Groundwater & Hydric Soils Weighted Heaviest

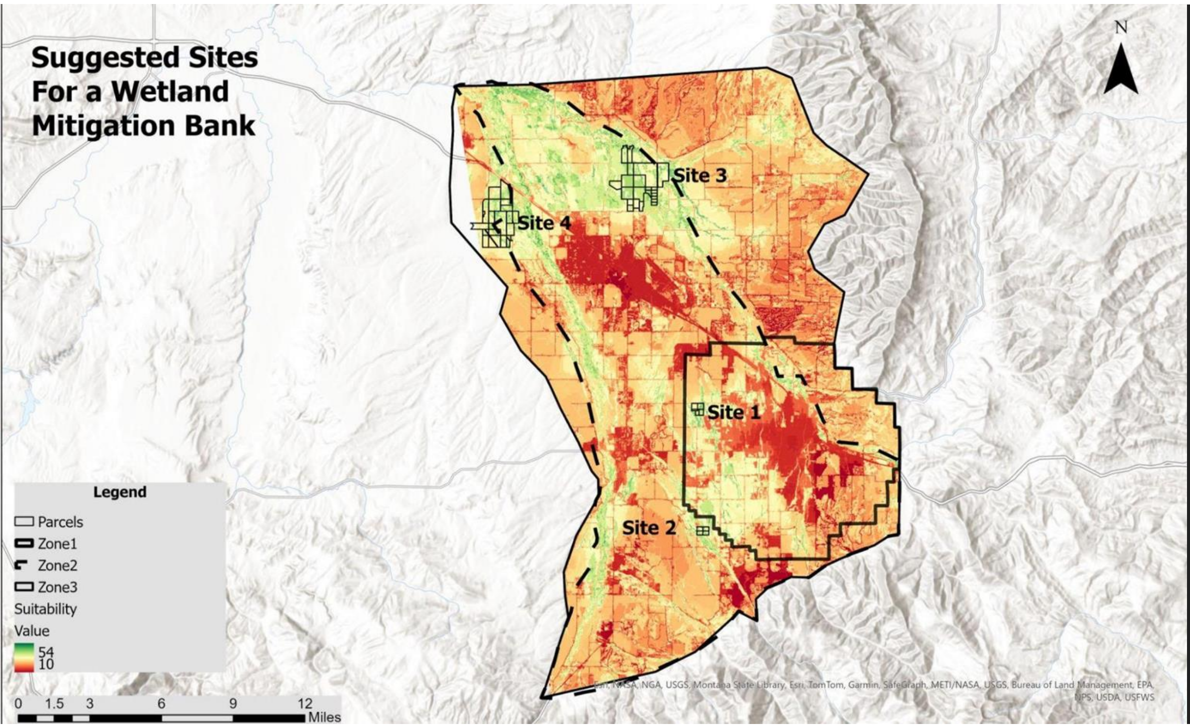
41



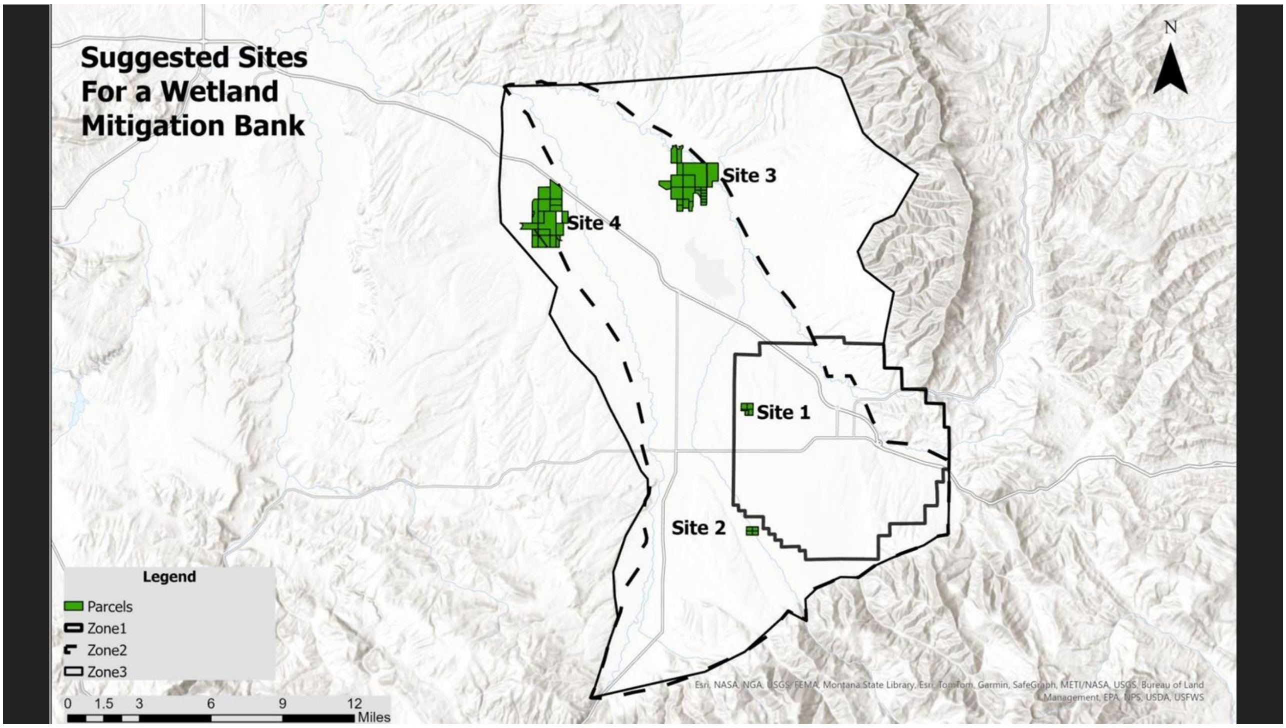
Equally Weighted Suitability Above a Score of 33

42

Suggested Sites

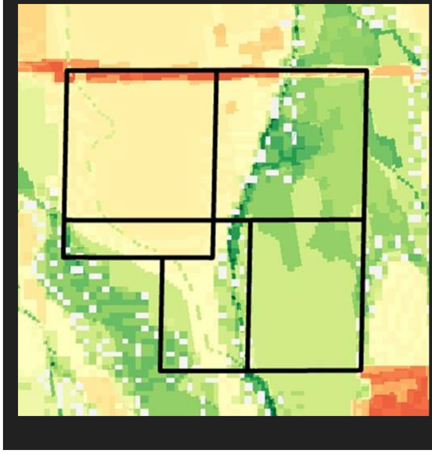


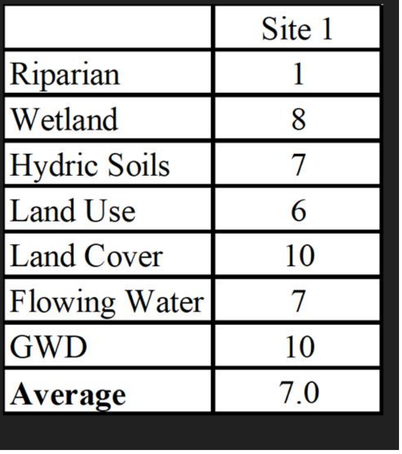
Esri, NASA, NGA, USGS, Montana State Library, Esri, TomTom, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS



Esri, NASA, NGA, USGS, FEMA, Montana State Library, Esri, TomTom, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS

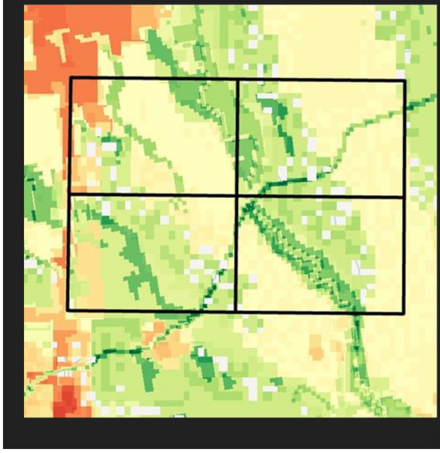
Site 1
Total Acres: 141
Owner: ------

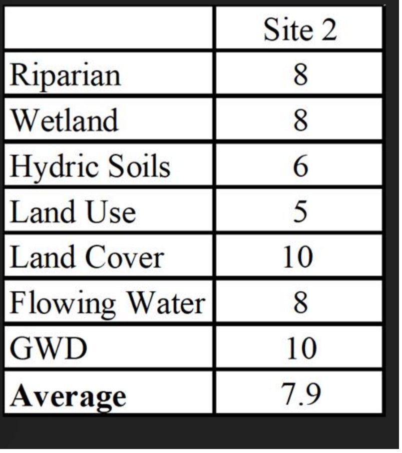




	Site 1
Riparian	1
Wetland	8
Hydric Soils	7
Land Use	6
Land Cover	10
Flowing Water	7
GWD	10
Average	7.0

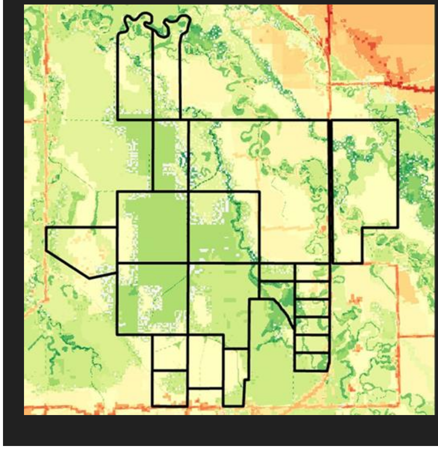
Site 2
Total Acres: 110
Owner: ------

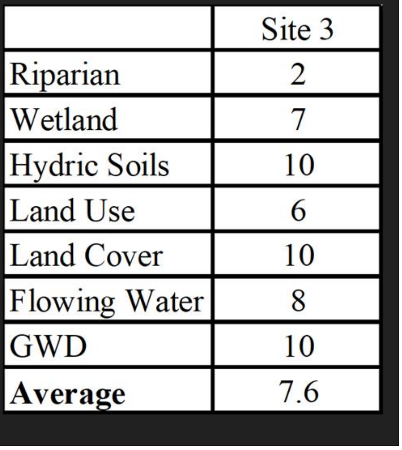




	Site 2
Riparian	8
Wetland	8
Hydric Soils	6
Land Use	5
Land Cover	10
Flowing Water	8
GWD	10
Average	7.9

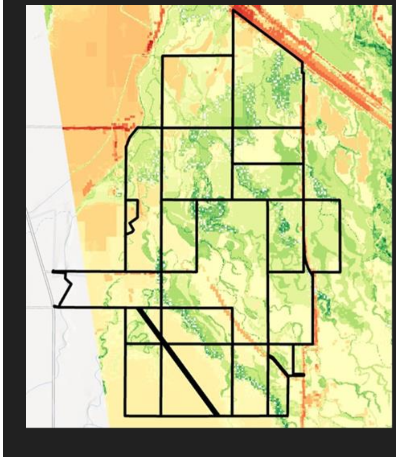
Site 3
Total Acres: 2100
Owner: ------

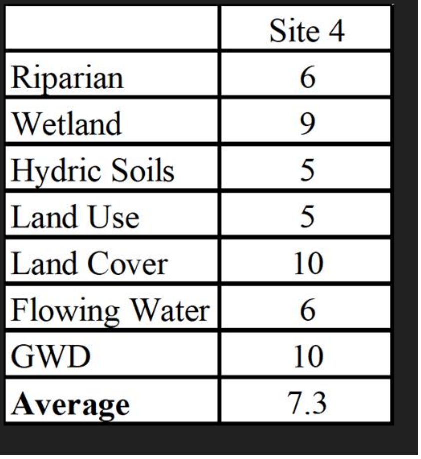




	Site 3
Riparian	2
Wetland	7
Hydric Soils	10
Land Use	6
Land Cover	10
Flowing Water	8
GWD	10
Average	7.6

Site 4
Total Acres: 2027
Owner: ------





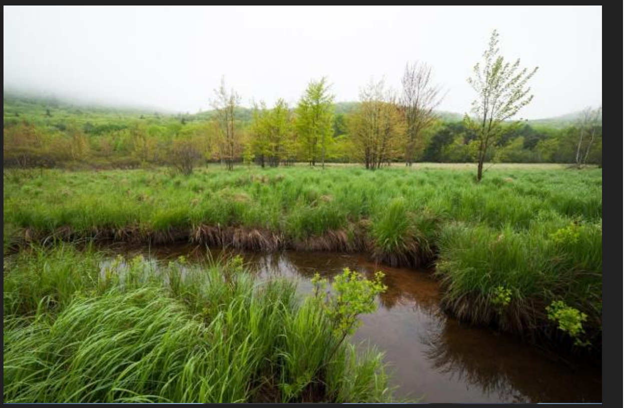
	Site 4
Riparian	6
Wetland	9
Hydric Soils	5
Land Use	5
Land Cover	10
Flowing Water	6
GWD	10
Average	7.3

Data Layer Information

- **Hydric soils:** USA SSURGO - Soil Hydric Class
- **Waterways**
    - **Wetland acreage:** USFWS Wetlands & Riparian
    - **Surface water:** Gallatin County Waterways
- **Riparian acreage:** USFWS Wetlands & Riparian
- **Land Cover:** Montana.gov Land Use/Land Cover
- **Land Use:** Montana.gov Land Use/Land Cover
- **Depth to Groundwater:** Montana Bureau of Mines and Geology Ground Water Information Center

Limitations

Limitations



Site Limitations

- Discrepancies (physical vs mapped)
- Potential Sources of Error
  - Data filtering(other water)
  - Cones of depression
  - Land-use/water rights

Limitations

Data/Budget Limitations
- Limited/outdated data
- Total maximum daily loads missing
- Cost considerations
  - Property cost
  - Restoration cost

General Limitations
- We're just doing initial siting
  - Must have willing partners
- Societal issues not considered

Overcoming Limitations

Solutions
- We have locations of potential sites
- Site visits by restoration team appointed (specific information not provided)
- We have Montana-specific ecological training
  - And great enthusiasm
- We will provide PDF and GIS layers for further advancement

Conclusions

Conclusions

- We recommend utilizing a regional wetland mitigation approach,
- Emphasize larger, interconnected reserves like the Story Mill Wetlands.
- Designate regional wetland parks, to ensure the perpetuity of ecosystem services while also providing recreational opportunities for residents.

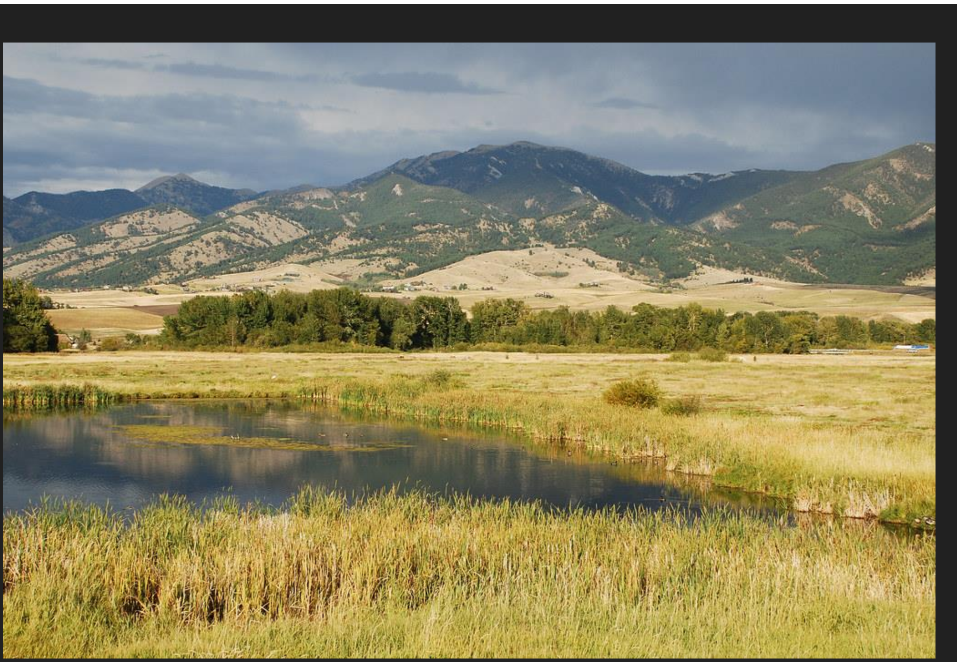
http://www.environmentportal.in/

Conclusions

We hope that these methods will assist you in the selection of an ideal site for a future wetland mitigation bank and ensure that the project remains successful over time.

https://allevents.in/

Questions?



Flicker.com