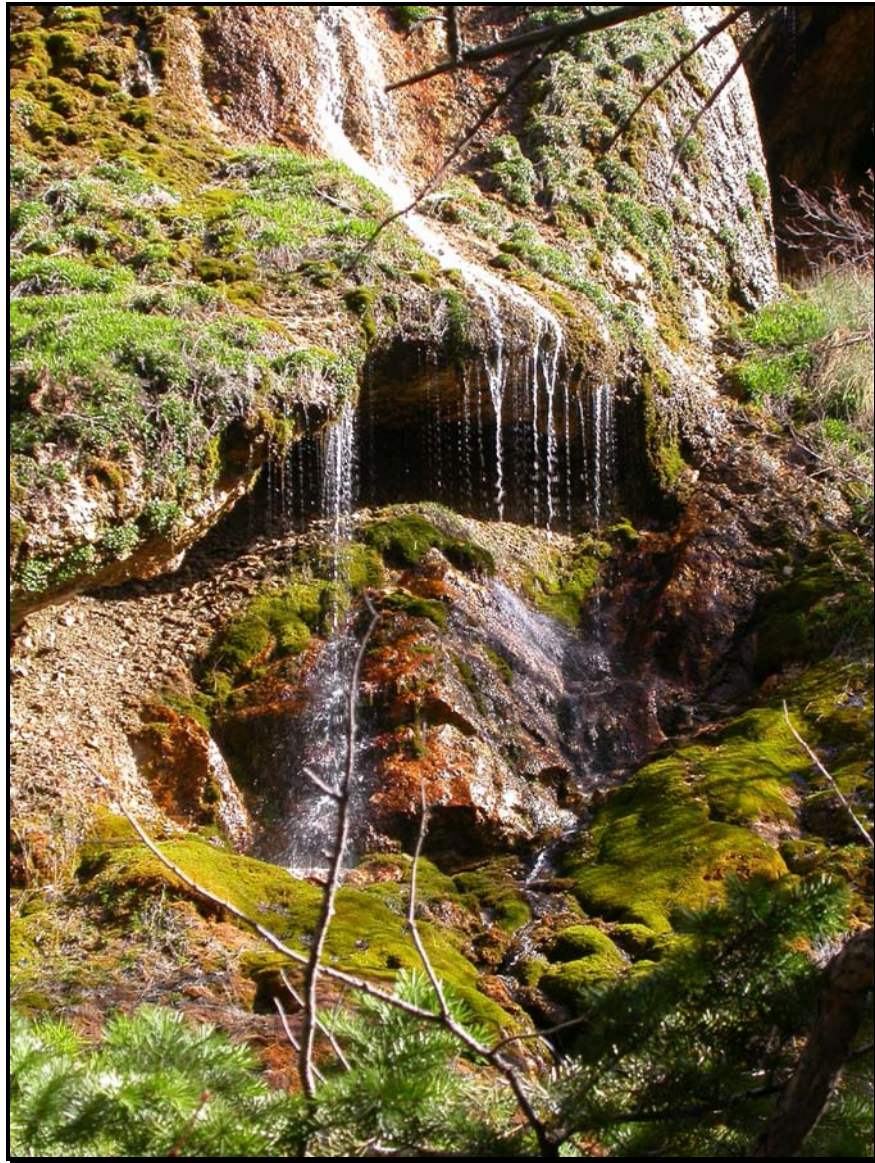


## Bighorn Canyon NRA Spring Vegetation Characterization



*Palustriella commutate* at Layout spring

Prepared for the  
Western National Parks Association and the  
Greater Yellowstone Network Inventory and Monitoring Program

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**Suzanne Morstad descending Layout Creek trail**

*All photos were taken by the author unless otherwise noted.*

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## Introduction

Plant and insect populations thrive in spring ecosystems (Perla and Stevens 2003). Springs directly or indirectly provide the majority of surface water to upland, riparian, and lotic ecosystems in Bighorn Canyon National Recreation Area (BICA). Yet, they encompass less than 1% of the land area. By providing seasonal and perennial water supplies, springs support a variety of riparian and wetland environments. Hershler and Sada (2002) found Great Basin springs to have a high potential to support endemic flora and fauna due to site isolation, stable environmental conditions or relict conditions. For example, Heidel (2004) described *Sullivantia hapemanii* var. *hapemanii* (Hapeman's coolwort), a rare plant in that occurs in five BICA springs. The Greater Yellowstone Network Inventory and Monitoring program (GRYN) is finalizing a monitoring protocol for spring water quality, but has no vegetation monitoring protocol to date. In light of these regional findings, we pursued a pilot vegetation characterization to promote a deeper understanding of BICA spring vegetation.

Cantonati and others (2006) found that the mosaic of microhabitats supported by environmental factors at a spring site account for much of the biodiversity and endemism found in spring ecosystems. In Colorado Plateau springs, Stevens and others (2004) described vegetation community associations within each microhabitat as a product of the substrate, geomorphic surface type, and hydrologic regime. Bernaldez and Rey Benayas (1992) found water chemistry (e.g. salinity and alkalinity) to indirectly affect zonation of spring plant communities through its effect on soil characteristics. Following these conclusions in aridland springs, we expected the relationships between BICA spring microhabitat composition and geology and spring water quality to inform the characterization.

Prior to this project, we observed that spring vegetation remained a gap in understanding the ecological character of BICA springs. Schmitz (2006) described the physical and chemical parameters of water resources. Through 2007 WNPA funding, Stagliano (2008) of the Montana Natural Heritage Program characterized aquatic macroinvertebrate communities in and assessed the condition of 20 BICA springs. Additionally, several authors have surveyed vascular plants in BICA (Despain 1973; Lichvar, Collins et al. 1985; Knight, Jones et al. 1987; Heidel and Fertig 2002), but no one has described nonvascular plants (Heidel and Fertig 2002). Because nonvascular plants have the potential to serve as indicators of plant associations and BICA springs support large nonvascular plant populations, we included nonvascular species to aid the development of spring microhabitat descriptions and expand the BICA plant species list. In this project, we created a spring vegetation characterization that incorporates existing geologic and water chemistry data to serve as a reference point for change detection and to provide recommendations for monitoring spring vegetation in BICA.



Figure 1. Hillsboro Main Spring.

## Objectives

We will characterize BICA spring vegetation. To that end, we will describe spring vegetation with enough detail to recommend permanent vegetation monitoring sites. Also, we will create a pilot classification. We intend association descriptions to facilitate the development of a spring vegetation monitoring protocol and to be a resource to the BICA staff regarding the quality and sensitivity of spring vegetation until a full vegetation survey can be completed. We aim to meet the following objectives:

1. Map microhabitats in 10 BICA springs.
2. Identify plant associations at 10 BICA springs.
3. Describe spring microhabitats in terms of plant associations, geomorphology, and hydrology at 10 BICA springs.
4. Recommend to GRYN locations for permanent plots for spring vegetation monitoring.

## Site description

BICA straddles the Montana and Wyoming border and follows the Bighorn River for about 71 miles. The south district of Bighorn Canyon National Recreation Area (BICA) is a dry landscape at the foot of the Pryor Mountain's scarp face (Figure 2). Vegetation communities in the park include desert shrubland, juniper woodland, mountain mahogany woodland, sagebrush steppe, basin grassland, riparian, and coniferous woodland. Springs flow from groundwater aquifers that emerge from geologic contacts or bedrock fractures and directly or indirectly provide the majority of surface water to this part of the park.

We surveyed ten springs that emerge from four geologic strata in the southern district. The Bighorn Dolomite-Madison Limestone is roughly 200 feet thick and composed of dolomite and dolomitic limestone. It influences habitat in Layout Spring and Headgate Seep. The Chugwater Siltstone ranges upwards of 300 feet thick and is a mixed bed of gypsiferous siltstone, sandstone, and limestone. Rick's, South Lockhart, and Cat Track Springs as well as Pickett's Wall Seep emerge from this stratum. The Tensleep Sandstone unit is approximately 100 feet thick and comprised of calcareous sandstone, chert, and dolomite. Springs arising from the Tensleep Sandstone unit include Hillsboro Main, Hillsboro Side, and Finley. Mason-Lovell South (ML South) emerges from Alluvium over Mowry Shale. The Mowry Shale is roughly 350 feet thick with Clay Spur

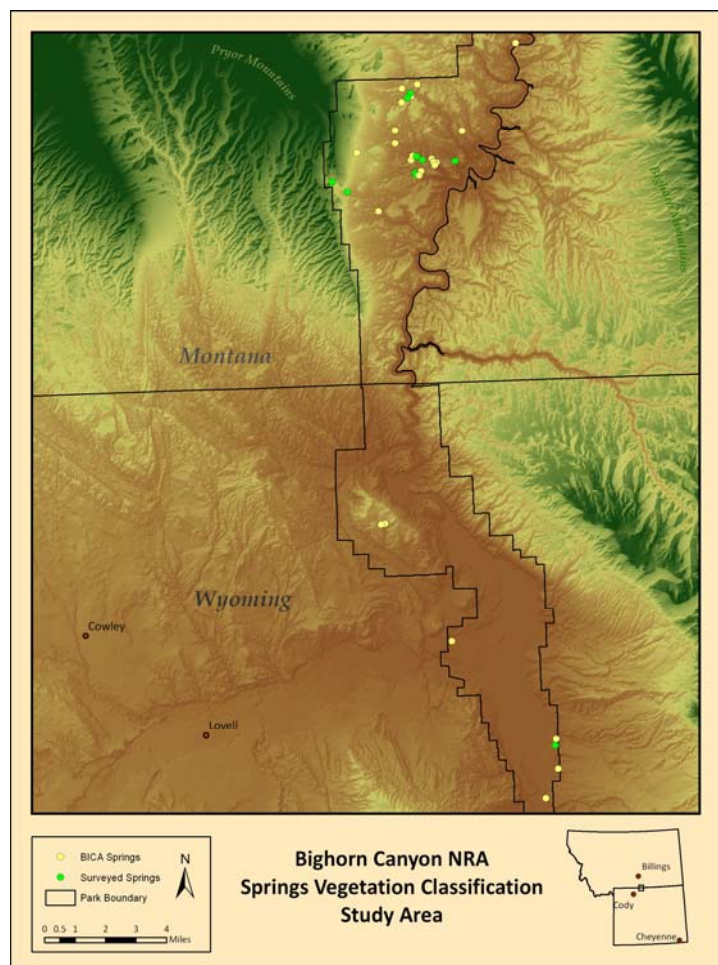


**Figure 2. Springs in the south district of Bighorn Canyon NRA occur in a variety of environmental settings. (Detailed maps in Appendix C.**

bentonite bed at the top (Richards 1955). Schmitz (2006) collected the water chemistry data that was used in this analysis between 2004 and 2007 Appendix A.

## Methods

### Study design

With input from the BICA director of natural resources, we selected a suite of ten springs that included a variety of species, microhabitats, geomorphic settings, and geologic substrates (Table 1). In the field, we drew site maps of each spring site, which illustrated the microhabitats and relevant geomorphic features. Within each microhabitat, we recorded present vascular and nonvascular plant species as frequency data for analysis. Using summary statistics and cluster analysis, we determined species associations and their relationships to environmental data (spring water quality and geology). We used this pilot data to develop a vegetation characterization and to make recommendations for developing a spring vegetation monitoring protocol.

**Table 1. We surveyed ten springs for a pilot vegetation characterization.**

| Site                     | Geology                            | Elevation |
|--------------------------|------------------------------------|-----------|
| Rick's Spring            | Chugwater Siltstone                | 1326 m    |
| S Lockhart Spring        | Chugwater Siltstone                | 1324 m    |
| Cat Track Spring         | Chugwater Siltstone                | 1204 m    |
| Finley Spring            | Tensleep Sandstone                 | 1131 m    |
| Hillsboro Main Spring    | Tensleep Sandstone                 | 1218 m    |
| Hillsboro Side #2 Spring | Tensleep Sandstone                 | 1204 m    |
| Pickett's Wall Seep      | Chugwater Siltstone                | 1184 m    |
| Layout Spring            | Bighorn Dolomite-Madison Limestone | 1697 m    |
| Headgate Seep            | Bighorn Dolomite-Madison Limestone | 1517 m    |
| ML South                 | Alluvium over Mowry Shale          | 1129 m    |

### Microhabitats and Plant Composition

We identified microhabitats as those geomorphic features that supported distinct plant communities. For the purposes of this project, we defined a plant community as a site-specific organization of plant species observable by standing at one point and viewing the surrounding vegetation layers (Hunter and Paysen 1986). We identified species in each microhabitat in the field, when possible. For others, we collected vouchers for identification in the lab. We applied the nomenclature of Dorn (2001) to be consistent with park resources. At the request of the park, we submitted vouchers to park for final processing before archiving. All nonvascular species were collected and sent to bryologist Dr. Judith Harpel for identification. We used the microhabitat species lists to create a frequency data set for analysis and classification.

### Environmental Variables

We used water chemistry data from the spring sources to help identify drivers of species assemblages. The water chemistry variables with adequate distribution among the surveyed springs and low correlation with each other were specific conductivity, nitrate, sulfate, calcium: magnesium, bicarbonate, and pH. See Appendix A for a correlation table. Note: because there was no water chemistry data for ML South spring we based species associations solely on floristic data. We used geology of the spring source as a categorical variable.

## Analysis

We conducted exploratory analysis to describe and organize the floristic and environmental data for in depth analysis. We used ordination techniques, generalized linear model regression, and cluster analysis to detect statistically significant microhabitats based on composition. Lastly, we detected potential indicator species based on the Shannon-Weiner index.

## **Results and Discussion**

### Data structure

We surveyed the ten springs shown in Table 1. We observed two to five microhabitats in each spring resulting in a total of 26. We identified 102 species present at the time of the survey including vascular and nonvascular species. See Appendix B for a complete species, as well as species lists for surveyed sites.

### Objective 1 – Map microhabitats in ten BICA springs.

We delineated each spring into microhabitats based on hydrology, geomorphic surface, and vegetation composition. We created hand drawn maps of each spring before collecting vegetation data (Appendix C).

### Objective 2 – Identify plant associations in ten BICA springs.

To characterize BICA spring vegetation, we described the vascular and nonvascular plant composition in each microhabitat, explored the relationships between species and available environmental data, and created a pilot classification from this data. We determined plant associations from presence/absence data. Prior visits to the springs for other projects indicated that, though most species bloomed in late spring, there was wide seasonality of spring vegetation. This made abundance data more variable than reliable classification could afford.

### Species Composition

We surveyed ten of the 31 known springs in BICA for this project. Of the 26 microhabitats we surveyed, nine supported eight or fewer species while 11 supported 15 or more species. Of the 102 species observed, 75 were found in less than 11% (3) of the microhabitats surveyed. Thus, most species found in BICA springs were rare relative to other species present.

We commonly observed the following wetland species (# microhabitats): *Equisetum laevigatum* (6), *Viola adunca* (5), *Carex aureum* (5), *Carex pellita* (5), and *Luzula parviflora* (5). We documented generalist riparian species most often, which included *Maianthemum stellatum* (13), *Rhus trilobata* (9), *Rosa sayi* (8), *Symphoricarpos occidentalis* (6), *Clematis ligusticifolia* (6), *Ribes aureum* (5), and *Mentha arvensis* (5). These species are ubiquitous in mesic settings and convey very little information by their presence. Other species we commonly encountered were introduced species such as *Cirsium arvense* (12), *Bromus tectorum* (5), *Poa pratensis* (11), *Festuca arundinacea* (7), and *Nasturtium officinale* (7). See Appendix B for a species list.

### Plant Species-Environment Relationships

#### **Geology**

BICA geology strongly influences spring source water chemistry (Schmitz, McGlynn et al. 2007). In turn, the chemical make-up (major cations and anions) of spring water influences spring biota (Bradley 1970; Sada and Herbst 2001; Cantonati, Gereck et al. 2006). The water chemistry associated with

geologic strata (Table 2) indicated that water flowing out of the Chugwater Siltstone has high specific conductivity, calcium: magnesium, bicarbonate, and sulfate. Water discharging from the Bighorn Dolomite-Madison Limestone was indicated by low specific conductivity, bicarbonate, and sulfate, but wide ranging calcium: magnesium. Water emerging from the Tensleep Sandstone does not show indicative values, but appears to mix with water in the Bighorn Dolomite in some cases and that from the Chugwater Siltstone in others (Schmitz 2006). We have no water quality data for the Alluvium over Mowry Shale.

Many of the springs on the Mowry Shale, Chugwater Siltstone, and Tensleep Sandstone were influenced by historic ranches and have been disturbed to varying degrees. The prevalence of several introduced species such as *Cirsium arvense*, *Bromus tectorum*, and *Nasturtium officinale* is attributed to this historical influence and convey little floristic information about the spring environment. Obligate wetland species such as *Berula erecta* are also highly tolerant of disturbance, but indicate spring microhabitats that maintain anaerobic conditions during reproductive periods. Wetland species such as *Carex pellita* and *Luzula parviflora* are common in wetlands, along streams and ditches, and in wet meadows. They are colonizing species and tolerant of disturbance. Thus, these species are indicative of moist and disturbed areas.

**Table 2. Water chemistry of spring source water shows some differences among associations. Average values for chemical parameters are shown with ranges noted in parentheses. Number of microhabitats for each geologic stratum is shown in parentheses following each stratum.**

|                       | Group 1          | Group 2   | Group 3                        | Group 4                                        | Group 5                       | Group 6 |
|-----------------------|------------------|-----------|--------------------------------|------------------------------------------------|-------------------------------|---------|
| # Microhabitats       | 5                | 2         | 6                              | 5                                              | 5                             | 3       |
| Calcium               | 9.9 (7.9-16.3)   | 7.9 (NA)  | 7.0 (2.8-13.4)                 | 4.1 (1.9-6.6)                                  | 4.5 (2.0-16.3)                | NA      |
| pH                    | 7.5 (7.4-7.6)    | 7.4 (NA)  | 7.4 (7.0-7.6)                  | 7.4 (6.9-7.9)                                  | 7.4 (7.3-7.6)                 | NA      |
| Nitrate               | 0.52 (0.28-0.62) | 0.62 (NA) | 0.23 (0.14-0.31)               | 0.14 (0.13-0.16)                               | 0.24 (0.18-0.48)              | NA      |
| Calcium:<br>Magnesium | 1.63 (1.50-1.93) | 1.57 (NA) | 1.44 (1.24-1.68)               | 1.59 (1.36-1.79)                               | 1.16 (0.95-1.93)              | NA      |
| Sulfate               | 655 (519-1082)   | 519 (NA)  | 422 (47-969)                   | 165 (7-345)                                    | 210 (32-1082)                 | NA      |
| SpEC                  | 1371 (1184-1916) | 1184 (NA) | 1006 (447-1867)                | 551 (266-875)                                  | 631 (356-1916)                | NA      |
| Bicarbonate           | 3.64 (3.37-3.91) | 3.64 (NA) | 3.48 (3.00-3.90)               | 2.97 (2.67-3.27)                               | 3.35 (3.30-3.52)              | NA      |
| Geology               | Siltstone        | Siltstone | Sandstone (4)<br>Siltstone (2) | Dolomite (2)<br>Sandstone (1)<br>Siltstone (2) | Dolomite (4)<br>Siltstone (1) | Shale   |

### Spring Source Water Chemistry

Relationships between species frequency and spring source water chemistry were not significant.

### Species Assemblages

We detected six groups of spring microhabitats using cluster analysis with complete linkage. The microhabitats (as we labeled them in the field) associated with each cluster appear in Table 3. The indicator species selected for each cluster have discriminating abilities greater than 0.75 (1.0 is maximum) based on the Shannon-Weiner index. This index assumes that all species from the community were surveyed. Because we visited the sites once and the phenological stages of some species made them undetectable or unidentifiable, a more thorough survey will be necessary to refine the classification in future work. We illustrated the species data in Appendix D. The environmental data for each group appear in Table 2.

**Table 3. Microhabitats represented in groups detected from cluster analysis with complete linkage.**

| Group 1            | Group 2           | Group 3               | Group 4                    | Group 5         | Group 6                |
|--------------------|-------------------|-----------------------|----------------------------|-----------------|------------------------|
| Rick's-Maianthemum | Rick's-Carex      | S Lockhart-Nasturtium | Picketts-Carex             | Cat Track-Carex | ML South-Glycyrrhiza   |
| Rick's-Rhus        | Rick's-Nasturtium | S Lockhart-Typha      | Picketts-Moss              | Headgate Moss   | ML South-Chrysothamnus |
| Rick's-Bromus      |                   | Finley-Carex          | Hillsboro Main-Sullivantia | Headgate-Carex  | ML South-Phragmites    |
| S Lockhart-Salix   |                   | Hillsboro Main-Luzula | Layout-Sullivantia         | Headgate-Luzula |                        |
| Cat Track-Juncus   |                   | Hillsboro Main-Berula | Layout-Moss                | Headgate-Juncus |                        |
|                    |                   | Hillsboro Side-Berula |                            |                 |                        |

### *Plant Association Descriptions*

#### Group 1 – *Symphoricarpos occidentalis/ Maianthemum stellatum*

We detected this association in three springs that emerge from the Chugwater Siltstone. We observed it in three microhabitats in Rick's spring, and one microhabitat in both South Lockhart and Cat Track springs. Site maps appear in Appendix C. *Symphoricarpos occidentalis/ Maianthemum stellatum* is a multilayered community (Figure 3). Tree and shrub species include *Populus angustifolia*, *Symphoricarpos occidentalis*, *Rhus trilobata*, *Rosa sayi*, and *Salix exigua*. The understory was dominated by *Maianthemum stellatum*, *Bromus inermis*, and *Juncus balticus*. Additional common understory wetland species included *Equisetum laevigatum*, and *Mentha arvensis*. These species are common riparian colonizers. We observed this association with four different codominants including *Juncus balticus*, *Rhus trilobata*, *Bromus inermis*, and *Salix exigua*. We have noted codominants with the genus in parentheses (ex. *Symphoricarpos occidentalis/ Maianthemum stellatum* (*Juncus*)) and symbolized them in the site maps accordingly.

The indicator species were upland, weedy, introduced, and often found in overgrazed pastures (Appendix D, Table 18). The upland nature of these species suggests that they opportunistically inhabit the area due to adequate water and nutrients, and impart little ecological information.

The water chemistry of springs associated with *Symphoricarpos occidentalis/ Maianthemum stellatum* have high calcium, nitrate, and sulfate concentrations relative to BICA springs (Table 2). Calcium and nitrate do not exceed EPA or state water quality standards. Sulfate levels were determined to be naturally elevated (Schmitz 2006).

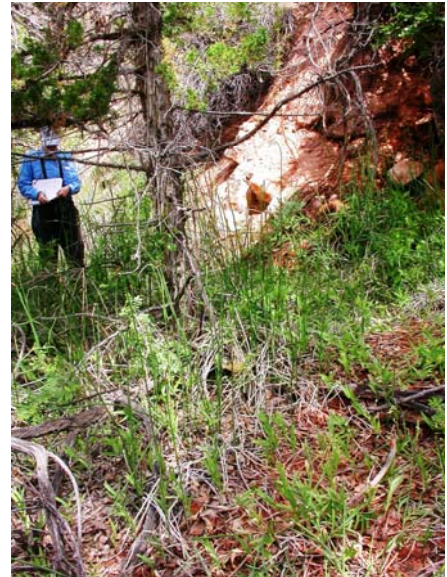


**Figure 3. *Symphoricarpos occidentalis/ Maianthemum stellatum* plant association**

### Group 2 – *Juncus parryi*/ *Carex atrata*

This association was found in two microhabitats at Rick's spring, which emerges from the Chugwater Siltstone (Appendix C). We observed these microhabitats in and adjacent to the channel and in a moist depression. *Juncus parryi*/ *Carex atrata* is a single layered herbaceous community (Figure 4). Dominant terrestrial species include *Juncus parryi* and *Carex atrata*, which are facultative wetland species. *Nasturtium officinale* was a codominant aquatic species found near the spring source. We have noted this part of the microhabitat in the site map as follows *Juncus parryi*/ *Carex atrata* (*Nasturtium*). Of note, *Najas guadalupensis* was present with *N. officinale*. It is a globally abundant (G5) aquatic species, but listed as a species of concern (S1) with the Montana Heritage Program and Wyoming Natural Diversity Database.

Indicator species were consistent with the terrestrial dominants (*Juncus parryi* and *Carex atrata*), yet included *Najas guadalupensis* (Appendix D, Table 19). *Juncus parryi* and *Carex atrata* are commonly found in non-wetland and wetland environments alike. However, *Najas guadalupensis* is an obligate wetland species and locally rare. It is common in ponds, lakes, and slow moving waterways in other states.

Associated water chemistry for the *Juncus parryi*/ *Carex atrata* association was found to be high in calcium and nitrate, although these levels are within EPA and state water quality standards (Table 2).



**Figure 4. *Juncus parryi*/ *Carex atrata* plant association. Photo by David Stagliano.**

### Group 3 – *Typha latifolia*/ *Berula erecta*

This association is found in six microhabitats at four springs which emerge from the Chugwater Siltstone and Tensleep Sandstone strata or their contact zone. Two microhabitats were found in South Lockhart Spring, one in Finley Spring, two in Hillsboro Main Spring, and one in Hillsboro Side Spring #2. We observed *Typha latifolia*/ *Berula erecta* along and within channels (Figure 5). It is composed of a variety of obligate and facultative wetland species, bryophytes, and disturbance dependant species (Appendix D, Table 20). In South Lockhart Spring, in one of the two occurrences of this association *Nasturtium officinale* was a codominant. In Finley spring, *Carex aurea* was codominant. In Hillsboro Main Spring, one of the two occurrences of this association supported *Luzula parviflora* was a codominant. We have noted codominants with the genus in parentheses (ex. *Typha latifolia*/ *Berula erecta* (*Nasturtium*)) and symbolized them in the site maps accordingly.



**Figure 5. *Typha latifolia*/ *Berula erecta* plant association. Photo by David Stagliano.**

We detected several indicator species using species discrimination. We chose to use those species with constancy above 0.30. *Typha latifolia* is an obligate wetland species commonly found in marshes. While it occurs along the Shoshone and Bighorn Rivers as well as in other springs, it was only found in two of the microhabitats surveyed for this pilot study, both of which support this association. *Berula erecta* is a common aquatic dicot found in slow moving waters. Other potential indicator species include *Funaria hygrometrica* and *Galium boreale*, both of which are considered weedy species. We

observed several codominant species such as *Carex aurea*, *Nasturtium officinale*, and *Luzula parviflora*. None of these species met the criteria for this study to be considered indicator species. However, a full botanical survey of BICA springs may find these species to be more important.

Associated water chemistry for the *Typha latifolia*/ *Berula erecta* association was found to be low in sulfate due to the influence of subsurface geology (Table 2).

#### Group 4 *Sullivantia hapemannii*

*Sullivantia hapemannii* association was found in five microhabitats at three springs. Pickett's Wall Seep supported two microhabitats, Hillsboro Main Spring one, and Layout Spring two. These springs emerge from different geologic formations, all of which have a high limestone composition and rock wall geomorphology (Figure 6). We illustrated species traits in Table 21 (Appendix D).

Heidel (Heidel 2004) described *Sullivantia hapemannii* var. *hapemannii* as endemic to calcareous springs and streams of the Bighorn Basin with additional disjunct populations. In BICA, the *Sullivantia hapemannii* association was found with several codominants. In one microhabitat of Pickett's Wall Seep, we observed significant cover of the nonvascular species *Didymodon tophaceus* and *Gymnostomum aeruginosum*. *Didymodon tophaceus* is found on moist limestone outcrops (Little 1937). *Gymnostomum aeruginosum* is found in moist conditions (e.g. Fritz, Glime et al. 2009). In the second microhabitat of Pickett's Wall Seep we observed *Carex scopulorum* as a codominant. *C. scopulorum* is a common wetland species in the region. In Layout Spring, we observed *Palustriella commutate* as a codominant. *Palustriella commutate* has been found to withstand high flow environments similar to that of Layout Spring (e.g. Pentecost and Zhaohui 2006) and is considered an indicator of calcareous environments. We have noted codominants with the genus in parentheses (ex. *Sullivantia hapemannii* (*Gymnostomum*/ *Didymodon*)) and symbolized them in the site maps accordingly.

Associated water chemistry for the *Sullivantia hapemannii* association was found to be low in soluble calcium, nitrate, sulfate and bicarbonate despite calcareous geology (Table 2).

#### Group 5 *Carex pellita*/ *Luzula parviflora*

We observed this association in five microhabitats at two springs. We surveyed four microhabitats at Headgate Seep, all of which we classified with the *Carex pellita*/ *Luzula parviflora* association. Cat Track Spring supported this association in one microhabitat. We mapped Headgate Seep as a long linear wetland that originates from several locations at the upslope end (Figure 7). In 2004, Schmitz (2006) observed a perched, 100+ meter long wetland on a steep slope that is supported by a clay layer about 18 inches below the surface while monitoring ground water levels.



Figure 6. *Sullivantia hapemannii* plant association.



Figure 7. *Carex pellita*/ *Luzula parviflora* plant association.

*Carex pellita* is a common species in somewhat disturbed wetlands, stream banks, and marshes with calcareous soils. It was found in four of the five microhabitats classified with this association. *Luzula parviflora* is a subalpine species common in wet forest and meadow settings. Codominants include *Palustriella commutate*, *Carex interior* and *Juncus mertensianus*. *Palustriella commutate*, a bryophyte, was found near the largest spring origin, which experiences the highest flows. *Carex interior* was a codominant in two microhabitats at Headgate Seep. It is commonly found in wet meadows, coniferous springs, and fens. *Juncus mertensianus* was a codominant at one Headgate Seep microhabitat. It is commonly found in wetlands of coniferous settings. We noted codominants with the genus in parentheses (ex. *Carex pellita*/*Luzula parviflora* (*Palustriella*)) and symbolized them in the site maps accordingly. We illustrated species traits in Table 22 (Appendix D).

Associated water chemistry for the *Carex pellita*/*Luzula parviflora* association was found to be low in soluble calcium despite calcareous geology (Table 2).

#### Group 6 *Salix amygdaloides*/*Phragmites australis*

*Salix amygdaloides*/*Phragmites australis* was found in three microhabitats of ML South Spring. This spring is just south the historic Mason-Lovell Ranch, where historic buildings and water developments remain as a cultural resource for the park. Figure 8 illustrates this association.

*Salix amygdaloides* is a common overstory species in riparian areas of the arid west. *Phragmites australis* is a rhizomatous grass often forming monocultures along streams and in marshes. It is listed as a noxious weed in several states. In this instance of *Salix amygdaloides*/*Phragmites australis*, we observed several upland and introduced species encroaching on the spring area. We observed codominants, *Ericameria nauseosa* and *Glycyrrhiza lepidota*, in two of the three surveyed microhabitats. We have noted codominants with the genus in parentheses (ex. *Salix amygdaloides*/*Phragmites australis* (*Ericameria*)) and symbolized them in the site maps accordingly. We detected dense patches of *Cardaria pubescens* and robust *Elaeagnus angustifolia*, which are common throughout the Yellowtail Wildlife Habitat area of the park.

We had no water chemistry data at this site.



**Figure 8. *Salix amygdaloides*/*Phragmites australis* plant association.**

#### *Other Vegetation Classifications*

We compared our results with other regional classifications from NatureServe, Montana (Hansen, Pfister et al. 1995), Wyoming (Walford, Jones et al. 2001), and Idaho (Youngblood, Padgett et al. 1985). We did not find enough similarity between our associations and published associations to confidently apply management implications, environmental concerns, or successional dynamics.

#### Objective 3 – Describe spring microhabitats

From prior work on BICA springs, we knew that existing spring and wetland classifications did not adequately describe these systems. Nevertheless, we applied the Cowardin wetland classification system (Cowardin, Carter et al. 1979) to relate our observations to a national system. We classified all surveyed springs as Palustrine systems based on the presence of emergent vegetation and shallow water depths. Generally, we placed BICA spring microhabitats into the emergent wetland class. Although, we identified two microhabitats at Rick's spring as scrub shrub-broadleaf deciduous

wetlands and one microhabitat at South Lockhart spring as a forested-broadleaf deciduous wetland. These classifications serve to broadly describe BICA spring microhabitats; however we pursued a classification to specifically describe the character of the microhabitats at each spring.

While Schmitz (2006) identified the geomorphic surfaces of 27 spring sites based on protocols developed for springs in the Colorado Plateau (Stevens et al. 2004), they found that the microhabitats of BICA springs did not conform to these classifications. Thus, we described the geomorphology of microhabitats in the field (Table 4) and illustrated them in the site maps (Appendix C). While folding and faulting as well as rockfall contribute to the large scale setting of BICA spring systems, we saw that fluvial processes were the primary drivers of plant associations and microhabitat form. Floodplains, defined channels, and gentle slopes were the most common landforms upon which we observed microhabitats. We applied the term “riparian” to these microhabitats. Pickett’s Wall Seep, Hillsboro Main Spring, and Layout Spring were the only sites we surveyed that emerged from wall formations. We labeled these microhabitats “wall”. Further, we added the influence of hydrology to the microhabitat class.

Following Cowardin for hydrology, we observed water regimes ranging from semipermanently flooded to intermittently flooded (Table 4). We used water chemistry data from the orifice to describe the salinity and pH of each microhabitat. We recommend that future investigators sample water chemistry at each microhabitat for improved accuracy. We applied the terms “wetland” or “wet” to microhabitats we classified as saturated, seasonally flooded, or semipermanently flooded. For microhabitats that were drier, we used the label “meadow”. Thus, we placed the 26 microhabitats into three different classes, wet wall, riparian wetland, and riparian meadow.

**Table 4. Microhabitats were described based on geomorphology, hydrology, and plant associations.**

| Association                                               | Microhabitat                | Geomorphology                                  | Hydrology <sup>a</sup>                                                                                                                                                                                                                                                                   | Sites                                                                                                                                      |
|-----------------------------------------------------------|-----------------------------|------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Symphoricarpos occidentalis/ Maianthemum stellatum</i> | Riparian meadow             | Floodplains<br>Slope <30°                      | -Intermittently Flooded, Oligosaline, Circumneutral<br>-Intermittently Flooded, Oligosaline, Circumneutral<br>-Intermittently Flooded, Oligosaline, Circumneutral<br>-Seasonally Flooded, Oligosaline, Alkaline<br>-Seasonally Flooded, Oligosaline, Alkaline                            | -Rick’s-Maianthemum<br>-Rick’s-Rhus<br>-Rick’s-Bromus<br>-S Lockhart-Salix<br>-Cat Track-Juncus                                            |
| <i>Juncus parryi/ Carex atrata</i>                        | Riparian wetland            | Channel margins<br>Slope <30°                  | -Seasonally Flooded, Oligosaline, Circumneutral<br>-Semipermanently Flooded, Oligosaline, Circumneutral                                                                                                                                                                                  | -Rick’s-Carex<br>-Rick’s-Nasturtium                                                                                                        |
| <i>Typha latifolia/ Berula erecta</i>                     | Riparian wetland            | Slope <30°<br>Channel margins<br>Depressions   | -Semipermanently Flooded, Oligosaline, Alkaline<br>-Saturated, Oligosaline, Alkaline<br>-Seasonally Flooded, Oligosaline, Circumneutral<br>-Semipermanently Flooded, Fresh, Circumneutral<br>-Semipermanently Flooded, Fresh, Circumneutral<br>-Semipermanently Flooded, Fresh, Alkaline | -S Lockhart-Nasturtium<br>-S Lockhart-Typha<br>-Finley-Carex<br>-Hillsboro Main-Luzula<br>-Hillsboro Main-Berula<br>-Hillsboro Side-Berula |
| <i>Sullivantia hapemannii</i>                             | Wet wall                    | Slope >30°<br>Weeping walls<br>Channel margins | -Semipermanently Flooded, Oligosaline, Circumneutral<br>-Semipermanently Flooded, Oligosaline, Circumneutral<br>-Seasonally Flooded, Fresh, Circumneutral<br>-Semipermanently Flooded, Fresh, Alkaline<br>-Semipermanently Flooded, Fresh, Alkaline                                      | -Picketts-Carex<br>-Picketts-Moss<br>-Hillsboro Main-Sullivantia<br>-Layout-Sullivantia<br>-Layout-Moss                                    |
| <i>Carex pellita/ Luzula parviflora</i>                   | Riparian wetland            | Channel margins<br>Slope <30°                  | -Seasonally Flooded, Oligosaline, Alkaline<br>-Semipermanently Flooded, Fresh, Circumneutral<br>-Seasonally Flooded, Fresh, Circumneutral<br>-Seasonally Flooded, Fresh, Circumneutral<br>-Saturated, Fresh, Circumneutral                                                               | -Cat Track-Carex<br>-Headgate Moss<br>-Headgate-Carex<br>-Headgate-Luzula<br>-Headgate-Juncus                                              |
| <i>Salix amygdaloides/ Phragmites australis</i>           | Riparian wetland/<br>meadow | Channel margins<br>Floodplains<br>Depressions  | -Temporarily Flooded<br>-Intermittently Flooded<br>-Semipermanently Flooded                                                                                                                                                                                                              | -ML South-Glycyrrhiza<br>-ML South-Chrysothamnus<br>-ML South-Phragmites                                                                   |

<sup>a</sup>Hydrology descriptors follow the Cowardin wetland classification system water regime and chemistry modifiers (Cowardin, Carter et al. 1979)

#### Objective 4 – Recommendations for spring vegetation monitoring

Given the high variability in our vegetation data set, we cannot recommend permanent plots for monitoring spring vegetation. However, we identified those factors that prevented us from fully meeting this objective and pose the following recommendations. First, we found that field work in mid-June was not appropriate to capture vegetation at phenological stages necessary for identification. We recommend sampling between late-June and mid-July. Second, we found the water chemistry of the spring source did adequately reflect the microhabitat chemical environment. We recommend that future efforts in spring vegetation monitoring include water chemistry of each microhabitat as part of the vegetation classification. We recommend that future investigators collect water samples between late May and early June. Last, we recommend surveying the entire population of known BICA springs (31 at present). We sampled one third of BICA springs and detected three microhabitats from our pilot characterization of spring vegetation. Based on our observations and those documented by Schmitz (2006), we expect additional microhabitats and species detectable at unsurveyed springs will inform the development of a monitoring program. We see the potential to develop an inferential sample design stratified by microhabitat should future investigators use this approach on a larger population of sites.

#### **Conclusions**

We produced a vegetation characterization for ten springs in BICA. In the process, we classified six plant associations and three microhabitat types from 26 surveyed microhabitats. We observed 102 species. Thirteen of these species were nonvascular species and will be added to the park plant list. *Najas guadalupensis* is also a new species not previously documented in the park. Based on this pilot project, we expect that a full vegetation survey of BICA springs will result in further addition to the park species list, a complete spring vegetation classification, guide the development of a spring vegetation monitoring protocol.

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## Appendix A. Water Chemistry Data

**Table 5. Water chemistry data for the 10 springs in the vegetation characterization.**

| Site                     | Geology                            | Elevation | Temp | pH   | SpEC | Ca   | Ca:Mg | NO3  | SO4  | HCO3 |
|--------------------------|------------------------------------|-----------|------|------|------|------|-------|------|------|------|
| Rick's Spring            | Chugwater Siltstone                | 1326      | 11.4 | 7.38 | 1184 | 7.9  | 1.57  | 0.62 | 519  | 3.64 |
| S Lockhart Spring        | Chugwater Siltstone                | 1324      | 10.5 | 7.56 | 1388 | 9.5  | 1.50  | 0.28 | 636  | 3.91 |
| Cat Track Spring         | Chugwater Siltstone                | 1204      | 11.3 | 7.61 | 1916 | 16.3 | 1.93  | 0.48 | 1082 | 3.37 |
| Finley Spring            | Tensleep Sandstone                 | 1131      | 10.8 | 6.97 | 1867 | 13.4 | 1.68  | 0.31 | 969  | 3.00 |
| Hillsboro Main Spring    | Tensleep Sandstone                 | 1218      | 10.1 | 7.35 | 473  | 3.4  | 1.36  | 0.14 | 122  | 3.27 |
| Hillsboro Side #2 Spring | Tensleep Sandstone                 | 1204      | 10.0 | 7.54 | 447  | 2.8  | 1.24  | 0.23 | 47   | 3.52 |
| Pickett's Wall Seep      | Chugwater Siltstone                | 1184      | 8.7  | 6.89 | 875  | 6.6  | 1.79  | 0.16 | 345  | 2.67 |
| Layout Spring            | Bighorn Dolomite-Madison Limestone | 1697      | 5.5  | 7.91 | 266  | 1.9  | 1.51  | 0.13 | 7    | 3.12 |
| Headgate Seep            | Bighorn Dolomite-Madison Limestone | 1517      | 12.0 | 7.29 | 356  | 2.0  | 0.95  | 0.18 | 32   | 3.30 |
| ML South                 | Alluvium over Mowry Shale          | 1129      | NA   | NA   | NA   | NA   | NA    | NA   | NA   | NA   |

**Table 6. Correlation table of environmental variables used in the analysis.**

|                  | SO <sub>4</sub> | Ca    | Mg    | SpEC  | Ca:Mg | HCO <sub>3</sub> | NO <sub>3</sub> | PO <sub>4</sub> | Na    | K     |
|------------------|-----------------|-------|-------|-------|-------|------------------|-----------------|-----------------|-------|-------|
| SO <sub>4</sub>  | 1.00            | 1.00  | 0.99  | 0.99  | 0.85  | 0.25             | 0.55            | -0.74           | 0.85  | 0.85  |
| NO <sub>3</sub>  | 0.55            | 0.52  | 0.54  | 0.59  | 0.52  | 0.43             | 1.00            | -0.74           | 0.79  | 0.78  |
| PO <sub>4</sub>  | -0.74           | -0.71 | -0.78 | -0.80 | -0.45 | -0.64            | -0.74           | 1.00            | -0.89 | -0.87 |
| Ca               | 1.00            | 1.00  | 0.98  | 0.98  | 0.86  | 0.21             | 0.52            | -0.71           | 0.81  | 0.81  |
| Mg               | 0.99            | 0.98  | 1.00  | 1.00  | 0.78  | 0.34             | 0.54            | -0.78           | 0.88  | 0.87  |
| Na               | 0.85            | 0.81  | 0.88  | 0.89  | 0.60  | 0.63             | 0.79            | -0.89           | 1.00  | 0.99  |
| K                | 0.85            | 0.81  | 0.88  | 0.90  | 0.64  | 0.59             | 0.78            | -0.87           | 0.99  | 1.00  |
| Ca:Mg            | 0.85            | 0.86  | 0.78  | 0.80  | 1.00  | -0.07            | 0.52            | -0.45           | 0.60  | 0.64  |
| HCO <sub>3</sub> | 0.25            | 0.21  | 0.34  | 0.33  | -0.07 | 1.00             | 0.43            | -0.64           | 0.63  | 0.58  |
| SpEC             | 0.99            | 0.98  | 1.00  | 1.00  | 0.80  | 0.33             | 0.59            | -0.80           | 0.89  | 0.89  |

## Appendix B. Species List

**Table 7. Vascular and non-vascular plant species observed in spring microhabitats.**

| Species                                                                | Acronym | Species                                                              | Acronym |
|------------------------------------------------------------------------|---------|----------------------------------------------------------------------|---------|
| <i>Achillea millefolium</i> L. var. <i>lanulosa</i>                    | ACHMIL  | <i>Maianthemum stellatum</i> (L.) Link                               | MAISTE  |
| <i>Alyssum alyssoides</i> (L.) L.                                      | ALYALY  | <i>Marchantia polymorpha</i> L.                                      | MARPOL  |
| <i>Arctium minus</i> Bernh.                                            | ARCMIN  | <i>Medicago sativa</i> L. var. <i>sativa</i>                         | MEDSAT  |
| <i>Artemisia cana</i> Pursh.                                           | ARTCAN  | <i>Mentha arvensis</i> L. var. <i>canadensis</i> (L.) Kuntze         | MENARV  |
| <i>Asclepias speciosa</i> Torrey                                       | ASCSPE  | <i>Najas guadalupensis</i> (Spreng.) Morong                          | NAJGUA  |
| <i>Bassia sieversiana</i> (Pallas) Weber                               | BASSIE  | <i>Nasturtium officinale</i> R. Br.                                  | NASOFF  |
| <i>Berula erecta</i> (Huds.) Cov.                                      | BERERE  | <i>Palustriella commutata</i> (Brid.) Ochyra                         | PALCOM  |
| <i>Betula occidentalis</i> Hook.                                       | BETOCC  | <i>Phragmites australis</i> (Cav.) Trin. Ex Steudel                  | PHRAUS  |
| <i>Bromus inermis</i> Leyss.                                           | BROINE  | <i>Plantanthera</i> sp                                               | PLASPP  |
| <i>Bromus tectorum</i> L.                                              | BROTEC  | <i>Poa pratensis</i> L.                                              | POAPRA  |
| <i>Bryum gemmiparum</i> De Not. cf                                     | BRYGEM  | <i>Populus acuminata</i> Rydb.                                       | POPACU  |
| <i>Bryum pseudotriquetrum</i> (Hedw.) Garetn. et al.                   | BRYPSE  | <i>Populus angustifolia</i> James                                    | POPANG  |
| <i>Camelina microcarpa</i> Andr. ex DC.                                | CARMIC  | <i>Populus deltoides</i> Bartr. Ex Marsh.                            | POPDEL  |
| <i>Cardaria pubescens</i> (Meyer) Jarmol.                              | CARPUB  | <i>Prunus virginiana</i> L. var. <i>melanocarpa</i> (A. Nels.) Sarg. | PRUVIR  |
| <i>Carex atrata</i> L.                                                 | CARATR  | <i>Pseudoleskeella tectorum</i> (Brid.) Broth.                       | PSETEC  |
| <i>Carex aurea</i> Nutt.                                               | CARAUR  | <i>Ribes aureum</i> Pursh                                            | RIBAUT  |
| <i>Carex interior</i> Bailey                                           | CARINT  | <i>Ribes oxycanthoides</i> L. var. <i>setosum</i> (Lindl.) Dorn      | RIBOXY  |
| <i>Carex nebrascensis</i> Dewey                                        | CARNEB  | <i>Rosa sayi</i> Schwein.                                            | ROSSAY  |
| <i>Carex pellita</i> Muhl. ex. Willd.                                  | CARPEL  | <i>Rosa woodsii</i> Lindl.                                           | ROSWOO  |
| <i>Carex scopulorum</i> Holm                                           | CARSCO  | <i>Rumex salicifolius</i> Weinm.                                     | RUMSAL  |
| <i>Centaurea repens</i> L.                                             | CENREP  | <i>Salix amygdaloides</i> Anderss.                                   | SALAMY  |
| <i>Chenopodium</i> spp.                                                | CHENOP  | <i>Salix exigua</i> Nutt.                                            | SALEXI  |
| <i>Cicuta bulbifera</i> L.                                             | CICBUL  | <i>Sarcobatus vermiculatus</i> (Hook.) Torrey                        | SARVER  |
| <i>Cirsium arvense</i> (L.) Scop.                                      | CIRARV  | <i>Senecio sphaerocephalus</i> Greene                                | SENSPH  |
| <i>Cirsium vulgare</i> (Savi) Tenore                                   | CIRVUL  | <i>Shepherdia argentea</i> (Pursh) Nutt.                             | SHEARG  |
| <i>Clematis ligusticifolia</i> Nutt.                                   | CLELIG  | <i>Sisyrinchium idahoense</i> E.P. Bicknell                          | SISIDA  |
| <i>Conardia compacta</i> (C.M.) Robins.                                | CONCOM  | <i>Solidago missouriensis</i> Nutt.                                  | SOLMIS  |
| <i>Cornus sericea</i> L.                                               | CORSER  | <i>Solidago</i> spp.                                                 | SOLSPP  |
| <i>Cratoneuron filicinum</i> (Hedw.) Spruce                            | CRAFIL  | <i>Sonchus</i> spp.                                                  | SONSPP  |
| <i>Descurainia pinnata</i> (Walt.) Britt.                              | DESPIN  | <i>Sporobolus airoides</i> (Torrey) Torrey                           | SPOAIR  |
| <i>Didymodon tophaceus</i> (Brid.) Lisa.                               | DIDTOP  | <i>Sullivantia hapemannii</i> (Coul. & Fish.) Coul.                  | SULHAP  |
| <i>Distichium inclinatum</i> (Hedw.) Brid.                             | DISINC  | <i>Symphoricarpos occidentalis</i> Hook.                             | SYMOC   |
| <i>Elaeagnus angustifolia</i> L.                                       | ELEANG  | <i>Syntrichia ruralis</i> (Hedw.) Web. & Mohr.                       | SYNRUR  |
| <i>Eleocharis palustris</i> (L.) R. & S.                               | ELEPAL  | <i>Tamarix chinensis</i> Loureiro                                    | TAMCHI  |
| <i>Elymus spicatus</i> (Pursh) Gould (syn. <i>Agropyron spicatum</i> ) | ELYSPI  | <i>Taraxacum officinale</i> Weber                                    | TAROFF  |
| <i>Equisetum laevigatum</i> A. Br.                                     | EQUALAE | <i>Toxicodendron rydbergii</i> (Small ex Rydb.) Greene               | TOXRyd  |
| <i>Ericameria nauseosa</i> (Pall. ex Pursh) G.L. Nesom & Baird         | ERINAU  | <i>Typha latifolia</i> L.                                            | TYPLAT  |
| <i>Festuca arundinacea</i> Schreb.                                     | FESARU  | <i>Urtica dioica</i> L.                                              | URTDIO  |
| <i>Fissidens grandifrons</i> Brid.                                     | FISGRA  | <i>Veronica americana</i> Schwein. Ex Benth.                         | VERAME  |
| <i>Funaria hygrometrica</i> Hedw.                                      | FUNHYG  | <i>Veronica anagallis-aquatica</i> L.                                | VERANA  |
| <i>Galium boreale</i> L.                                               | GALBOR  | <i>Viola adunca</i> Smith                                            | VIOADU  |
| <i>Gaura coccinea</i> Nutt. ex Pursh                                   | GAUCOC  |                                                                      |         |
| <i>Glyceria striata</i> (Lam.) Hitchc.                                 | GLYSTR  |                                                                      |         |
| <i>Glycyrrhiza lepidota</i> Pursh                                      | GLYLEP  |                                                                      |         |
| <i>Grindelia squarrosa</i> (Pursh) Dunal                               | GRISQU  |                                                                      |         |
| <i>Gutierrezia sarothrae</i> (Pursh) Britt. & Rusby                    | GUTSAR  |                                                                      |         |
| <i>Gymnostomum aeruginosum</i> Sm.                                     | GYMAER  |                                                                      |         |
| <i>Heterotheca villosa</i> (Pursh) Shinnars                            | HETVIL  |                                                                      |         |
| <i>Hypnum revolutum</i> (Brid.) Ochyra                                 | HYPREV  |                                                                      |         |
| <i>Iris missouriensis</i> Nutt.                                        | IRIMIS  |                                                                      |         |
| <i>Iva axillaris</i> Pursh                                             | IVAAXI  |                                                                      |         |
| <i>Juncus balticus</i> Willd.                                          | JUNBAL  |                                                                      |         |
| <i>Juncus confusus</i> Cov.                                            | JUNCON  |                                                                      |         |
| <i>Juncus ensifolius</i> var. <i>montanus</i> (Engelm. Hitchc.)        | JUNENS  |                                                                      |         |
| <i>Juncus mertensianus</i> Bong.                                       | JUNMER  |                                                                      |         |
| <i>Juncus parryi</i> Engelm.                                           | JUNPAR  |                                                                      |         |
| <i>Juniperus osteosperma</i> (Torrey) Little                           | JUNOST  |                                                                      |         |
| <i>Juniperus scopulorum</i> Sarg.                                      | JUNSCO  |                                                                      |         |
| <i>Luzula parviflora</i> (Ehrh.) Desv.                                 | LUZPAR  |                                                                      |         |

**Table 8. Species observed at Rick's Spring.**

**Rick's-Maianthemum**

*Alyssum alyssoides* (L.) L.  
*Bromus inermis* Leyss.  
*Camelina microcarpa* Andr. ex DC.  
*Glycyrrhiza lepidota* Pursh  
*Gutierrezia sarothrae* (Pursh) Britt. & Rusby  
*Juniperus osteosperma* (Torrey) Little  
*Maianthemum stellatum* (L.) Link  
*Mentha arvensis* L. var. *canadensis* (L.) Kuntze  
*Poa pratensis* L.  
*Rosa sayi* Schwein.  
*Symphoricarpos occidentalis* Hook.  
*Taraxacum officinale* Weber

**Rick's-Rhus**

*Alyssum alyssoides* (L.) L.  
*Artemisia cana* Pursh.  
*Camelina microcarpa* Andr. ex DC.  
*Cirsium arvense* (L.) Scop.  
*Clematis ligusticifolia* Nutt.  
*Eleocharis palustris* (L.) R. & S.  
*Grindelia squarrosa* (Pursh) Dunal  
*Gutierrezia sarothrae* (Pursh) Britt. & Rusby  
*Heterotheca villosa* (Pursh) Shinnars  
*Juniperus scopulorum* Sarg.  
*Maianthemum stellatum* (L.) Link  
*Poa pratensis* L.  
*Populus angustifolia* James  
*Sonchus* spp.  
*Symphoricarpos occidentalis* Hook.  
*Viola adunca* Smith

**Rick'-Bromus**

*Bromus inermis* Leyss.  
*Eleocharis palustris* (L.) R. & S.  
*Gutierrezia sarothrae* (Pursh) Britt. & Rusby  
*Juniperus scopulorum* Sarg.  
*Maianthemum stellatum* (L.) Link  
*Poa pratensis* L.  
*Symphoricarpos occidentalis* Hook.

**Rick's-Carex**

*Achillea millefolium* L. var. *lanulosa*  
*Carex atrata* L.  
*Carex aurea* Nutt.  
*Festuca arundinacea* Schreb.  
*Juncus parryi* Engelm.  
*Maianthemum stellatum* (L.) Link  
*Mentha arvensis* L. var. *canadensis* (L.) Kuntze  
*Symphoricarpos occidentalis* Hook.  
*Viola adunca* Smith

**Rick's-Nasturtium**

*Carex aurea* Nutt.  
*Conardia compacta* (C.M.) Robins.  
*Cratoneuron filicinum* (Hedw.) Spruce  
*Eleocharis palustris* (L.) R. & S.  
*Festuca arundinacea* Schreb.  
*Iris missouriensis* Nutt.  
*Juncus parryi* Engelm.  
*Najas guadalupensis* (Spreng.) Morong  
*Nasturtium officinale* R. Br.

**Table 9. Species observed at South Lockhart Spring.**

**S Lockhart-Nasturtium**

*Cirsium arvense* (L.) Scop.  
*Clematis ligusticifolia* Nutt.  
*Eleocharis palustris* (L.) R. & S.  
*Nasturtium officinale* R. Br.  
*Prunus virginiana* L. var. *melanocarpa* (A. Nels.) Sarg.  
*Ribes aureum* Pursh  
*Ribes oxycanthoides* L. var. *setosum* (Lindl.) Dorn  
*Shepherdia argentea* (Pursh) Nutt.

**S Lockhart-Salix**

*Cirsium arvense* (L.) Scop.  
*Clematis ligusticifolia* Nutt.  
*Cornus sericea* L.  
*Juncus balticus* Willd.  
*Maianthemum stellatum* (L.) Link  
*Poa pratensis* L.  
*Populus angustifolia* James  
*Rosa sayi* Schwein.  
*Salix exigua* Nutt.  
*Solidago* spp.  
*Symphoricarpos occidentalis* Hook.

**S Lockhart-Typha**

*Cicuta bulbifera* L.  
*Cirsium arvense* (L.) Scop.  
*Eleocharis palustris* (L.) R. & S.  
*Galium boreale* L.  
*Juncus balticus* Willd.  
*Mentha arvensis* L. var. *canadensis* (L.) Kuntze  
*Nasturtium officinale* R. Br.  
*Poa pratensis* L.  
*Populus angustifolia* James  
*Salix exigua* Nutt.  
*Typha latifolia* L.  
*Veronica americana* Schwein. Ex Benth.

**Table 10. Species observed at Pickett's Wall Seep.**

**Pickett's-Carex**

*Betula occidentalis* Hook.  
*Carex aurea* Nutt.  
*Carex scopulorum* Holm  
*Cirsium arvense* (L.) Scop.  
*Cornus sericea* L.  
*Iris missouriensis* Nutt.  
*Juniperus scopulorum* Sarg.  
*Maianthemum stellatum* (L.) Link  
*Poa pratensis* L.  
*Sonchus* spp.  
*Sullivantia hapemannii* (Coult. & Fish.) Coult.  
*Veronica americana* Schwein. Ex Benth.

**Pickett's-Moss**

*Betula occidentalis* Hook.  
*Bryum pseudotriquetrum* (Hedw.) Garetn. et al.  
*Carex scopulorum* Holm  
*Cratoneuron filicinum* (Hedw.) Spruce  
*Didymodon tophaceus* (Brid.) Lisa.  
*Didymodon tophaceus* (Brid.) Lisa.  
*Distichium inclinatum* (Hedw.) Brid.  
*Equisetum laevigatum* A. Br.  
*Palustriella commutate* (Brid.) Ochyra  
*Sullivantia hapemannii* (Coult. & Fish.) Coult.  
*Veronica americana* Schwein. Ex Benth.

**Table 11. Species observed at Cat Track Spring.****Cat Track-Juncus**

*Cirsium arvense* (L.) Scop.  
*Clematis ligusticifolia* Nutt.  
*Eleocharis palustris* (L.) R. & S.  
*Equisetum laevigatum* A. Br.  
*Equisetum laevigatum* A. Br.  
*Festuca arundinacea* Schreb.  
*Glycyrrhiza lepidota* Pursh  
*Juncus balticus* Willd.  
*Maianthemum stellatum* (L.) Link  
*Nasturtium officinale* R. Br.  
*Poa pratensis* L.  
*Populus acuminata* Rydb.  
*Rosa sayi* Schwein.

**Cat Track-Carex**

*Betula occidentalis* Hook.  
*Carex pellita* Muhl. ex. Willd.  
*Cirsium arvense* (L.) Scop.  
*Eleocharis palustris* (L.) R. & S.  
*Equisetum laevigatum* A. Br.  
*Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & Baird  
*Festuca arundinacea* Schreb.  
*Juniperus scopulorum* Sarg.  
*Maianthemum stellatum* (L.) Link  
*Medicago sativa* L. var. *sativa*  
*Populus acuminata* Rydb.  
*Ribes aureum* Pursh

**Table 12. Species observed at Mason-Lovell South Spring.****ML South-Glycyrrhiza**

*Bassia sieversiana* (Pallas) Weber  
*Bromus tectorum* L.  
*Cardaria pubescens* (Meyer) Jarmol.  
*Chenopodium* spp.  
*Descurainia pinnata* (Walt.) Britt.  
*Eleocharis palustris* (L.) R. & S.  
*Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & Baird  
*Glycyrrhiza lepidota* Pursh  
*Rosa sayi* Schwein.  
*Salix amygdaloides* Anderss.  
*Sarcobatus vermiculatus* (Hook.) Torrey  
*Sporobolus airoides* (Torrey) Torrey

**ML South-Chrysothamnus**

*Asclepias speciosa* Torrey  
*Bromus tectorum* L.  
*Cardaria pubescens* (Meyer) Jarmol.  
*Chenopodium* spp.  
*Cirsium arvense* (L.) Scop.  
*Elaeagnus angustifolia* L.  
*Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & Baird

**ML South-Phragmites**

*Bassia sieversiana* (Pallas) Weber  
*Centaurea repens* L.  
*Ericameria nauseosa* (Pall. ex Pursh) G.L. Nesom & Baird  
*Iva axillaris* Pursh  
*Phragmites australis* (Cav.) Trin. ex. Steudel  
*Symphoricarpos occidentalis* Hook.

**Table 13. Species observed at Finley Spring.****Finley-Carex**

*Arctium minus* Bernh.  
*Bromus tectorum* L.  
*Bryum gemmiparum* De Not. cf  
*Carex aurea* Nutt.  
*Cirsium arvense* (L.) Scop.  
*Cirsium vulgare* (Savi) Tenore  
*Descurainia pinnata* (Walt.) Britt.  
*Eleocharis palustris* (L.) R. & S.  
*Eleocharis palustris* (L.) R. & S.  
*Eleocharis palustris* (L.) R. & S.  
*Funaria hygrometrica* Hedw.  
*Galium boreale* L.  
*Juncus ensifolius* var. *montanus* (Englem. Hitchc.)  
*Juncus parryi* Engelm.  
*Juniperus osteosperma* (Torrey) Little  
*Marchantia polymorpha* L.  
*Poa pratensis* L.  
*Populus deltoides* Bartr. Ex Marsh.  
*Ribes aureum* Pursh  
*Rosa sayi* Schwein.  
*Rosa woodsii* Lindl.  
*Veronica americana* Schwein. Ex Benth.  
*Veronica americana* Schwein. Ex Benth.  
*Veronica anagallis-aquatica* L.

**Table 14. Species observed at Layout Spring.****Layout-Sullivantia**

*Bryum pseudotriquetrum* (Hedw.) Garetn. et al.  
*Cratoneuron filicinum* (Hedw.) Spruce  
*Plantanthera* sp  
*Sullivantia hapemannii* (Coul. & Fish.) Coul.  
*Urtica dioica* L.

**Layout-Moss**

*Palustriella commutate* (Brid.) Ochyra  
*Palustriella commutate* (Brid.) Ochyra  
*Sullivantia hapemannii* (Coul. & Fish.) Coul.

**Table 15. Species observed at Hillsboro Side Spring #2.****Hillsboro Side-Berula**

*Berula erecta* (Huds.) Cov.  
*Cirsium arvense* (L.) Scop.  
*Conardia compacta* (C.M.) Robins.  
*Eleocharis palustris* (L.) R. & S.  
*Hypnum revolutum* (Brid.) Ochyra  
*Maianthemum stellatum* (L.) Link  
*Nasturtium officinale* R. Br.  
*Pseudoleskeella tectorum* (Brid.) Broth.  
*Rosa sayi* Schwein.  
*Rosa woodsii* Lindl.  
*Syntrichia ruralis* (Hedw.) Web. & Mohr.

**Table 16. Species observed at Hillsboro Main Spring.****Hillsboro Main-Sullivantia**

*Cratoneuron filicinum* (Hedw.) Spruce  
*Gymnostomum aeruginosum* Sm.  
*Prunus virginiana* L. var. *melanocarpa* (A. Nels.) Sarg.  
*Rosa woodsii* Lindl.  
*Solidago missouriensis* Nutt.  
*Sonchus* spp.  
*Sullivantia hapemannii* (Coult. & Fish.) Coult.  
*Toxicodendron rydbergii* (Small ex Rydb.) Greene

**Hillsboro Main-Luzula**

*Berula erecta* (Huds.) Cov.  
*Bromus tectorum* L.  
*Carex pellita* Muhl. ex. Willd.  
*Cirsium arvense* (L.) Scop.  
*Eleocharis palustris* (L.) R. & S.  
*Elymus spicatus* (Pursh) Gould (syn. *Agropyron spicatum*)  
*Funaria hygrometrica* Hedw.  
*Gaura coccinea* Nutt. ex Pursh  
*Glyceria striata* (Lam.) Hitchc.  
*Luzula parviflora* (Ehrh.) Desv.  
*Mentha arvensis* L. var. *canadensis* (L.) Kuntze  
*Nasturtium officinale* R. Br.  
*Poa pratensis* L.  
*Populus deltoides* Bartr. Ex Marsh.  
*Prunus virginiana* L. var. *melanocarpa* (A. Nels.) Sarg.  
*Rosa woodsii* Lindl.  
*Salix exigua* Nutt.  
*Senecio sphaerocephalus* Greene  
*Tamarix chinensis* Loureiro  
*Typha latifolia* L.

**Hillsboro Main-Berula**

*Berula erecta* (Huds.) Cov.  
*Bromus tectorum* L.  
*Cirsium arvense* (L.) Scop.  
*Conardia compacta* (C.M.) Robins.  
*Fissidens grandifrons* Brid.  
*Fissidens grandifrons* Brid.  
*Marchantia polymorpha* L.  
*Nasturtium officinale* R. Br.  
*Solidago* spp.  
*Sonchus* spp.  
*Sullivantia hapemannii* (Coult. & Fish.) Coult.

**Table 17. Species observed at Headgate Seep.****Headgate Seep (Headgate.Moss)**

*Carex interior* Bailey  
*Carex nebrascensis* Dewey  
*Equisetum laevigatum* A. Br.  
*Luzula parviflora* (Ehrh.) Desv.  
*Maianthemum stellatum* (L.) Link  
*Palustriella commutata* (Brid.) Ochyra  
*Sisyrinchium idahoense* E.P. Bicknell  
*Viola adunca* Smith

**Headgate Seep (Headgate.Sedge1)**

*Carex pellita* Muhl. ex. Willd.  
*Cirsium vulgare* (Savi) Tenore  
*Eleocharis palustris* (L.) R. & S.  
*Festuca arundinacea* Schreb.  
*Luzula parviflora* (Ehrh.) Desv.  
*Maianthemum stellatum* (L.) Link  
*Rosa sayi* Schwein.

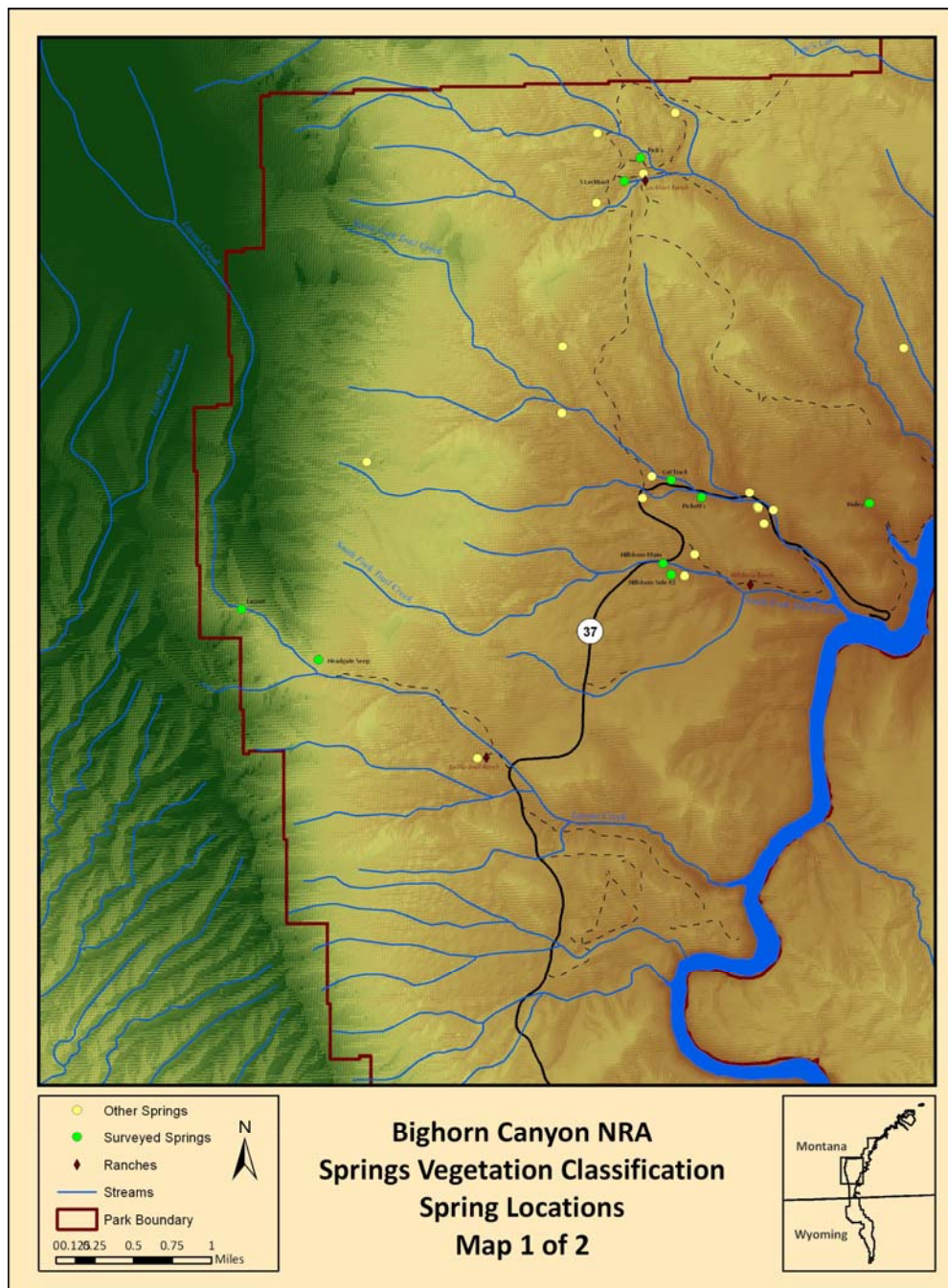
**Headgate Seep (Headgate.Sedge2)**

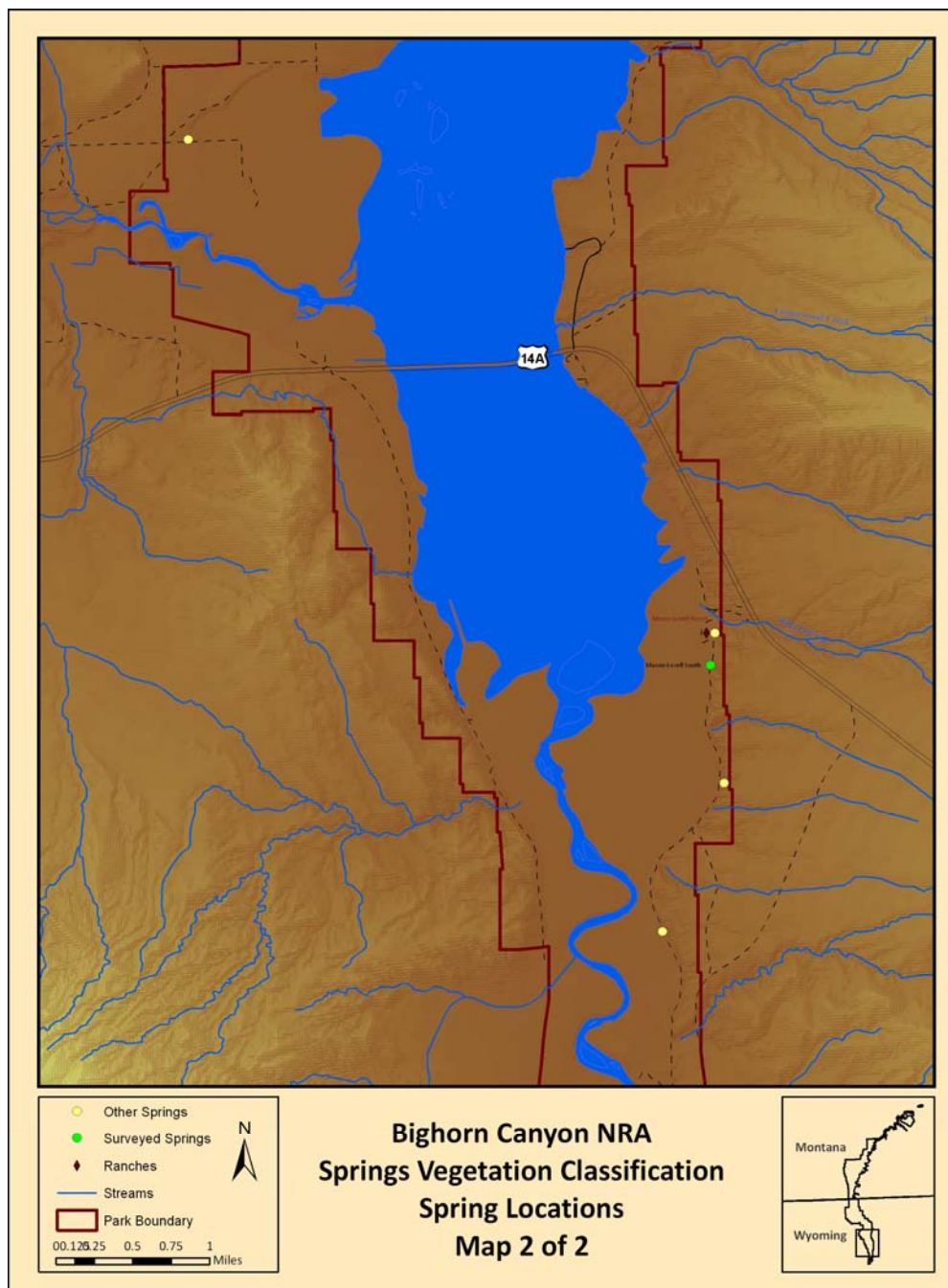
*Bryum pseudotriquetrum* (Hedw.) Garetn. et al.  
*Carex aurea* Nutt.  
*Carex pellita* Muhl. ex. Willd.  
*Cirsium vulgare* (Savi) Tenore  
*Clematis ligusticifolia* Nutt.  
*Equisetum laevigatum* A. Br.  
*Festuca arundinacea* Schreb.  
*Juncus confusus* Cov.  
*Juncus mertensianus* Bong.  
*Juniperus osteosperma* (Torrey) Little  
*Luzula parviflora* (Ehrh.) Desv.  
*Maianthemum stellatum* (L.) Link  
*Mentha arvensis* L. var. *canadensis* (L.) Kuntze  
*Poa pratensis* L.  
*Ribes aureum* Pursh  
*Rosa sayi* Schwein.  
*Rumex salicifolius* Weinm.  
*Sisyrinchium idahoense* E.P. Bicknell  
*Viola adunca* Smith

**Headgate Seep (Headgate.Juncus)**

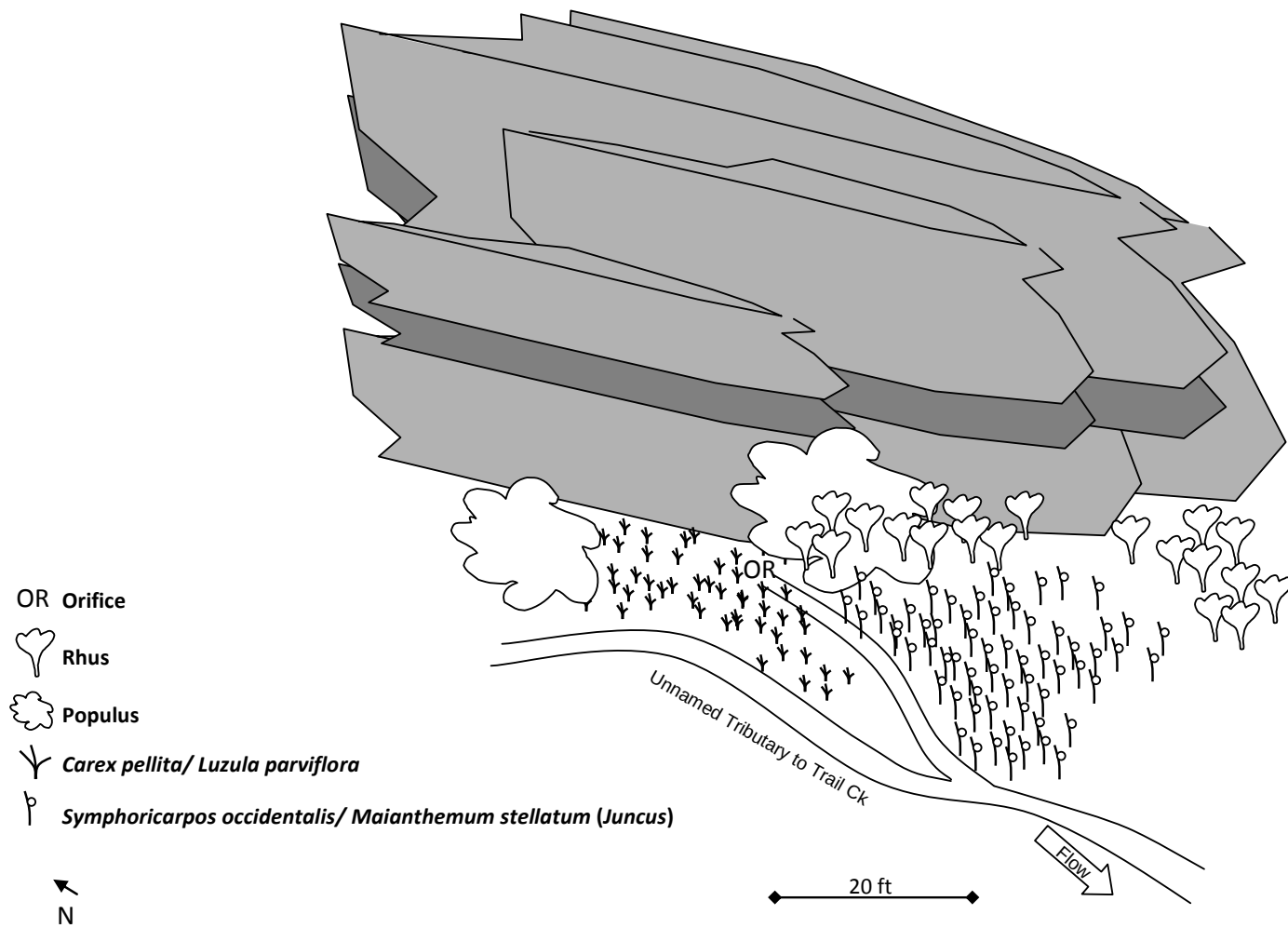
*Bryum pseudotriquetrum* (Hedw.) Garetn. et al.  
*Carex nebrascensis* Dewey  
*Carex pellita* Muhl. ex. Willd.  
*Clematis ligusticifolia* Nutt.  
*Equisetum laevigatum* A. Br.  
*Festuca arundinacea* Schreb.  
*Juncus balticus* Willd.  
*Juncus mertensianus* Bong.  
*Luzula parviflora* (Ehrh.) Desv.  
*Maianthemum stellatum* (L.) Link  
*Poa pratensis* L.  
*Ribes aureum* Pursh  
*Sisyrinchium idahoense* E.P. Bicknell  
*Syntrichia ruralis* (Hedw.) Web. & Mohr.  
*Viola adunca* Smith

## Appendix C. Area and Spring Microhabitat Maps





# Cat Track Spring



# Finley Spring

OR Orifice



Rhus



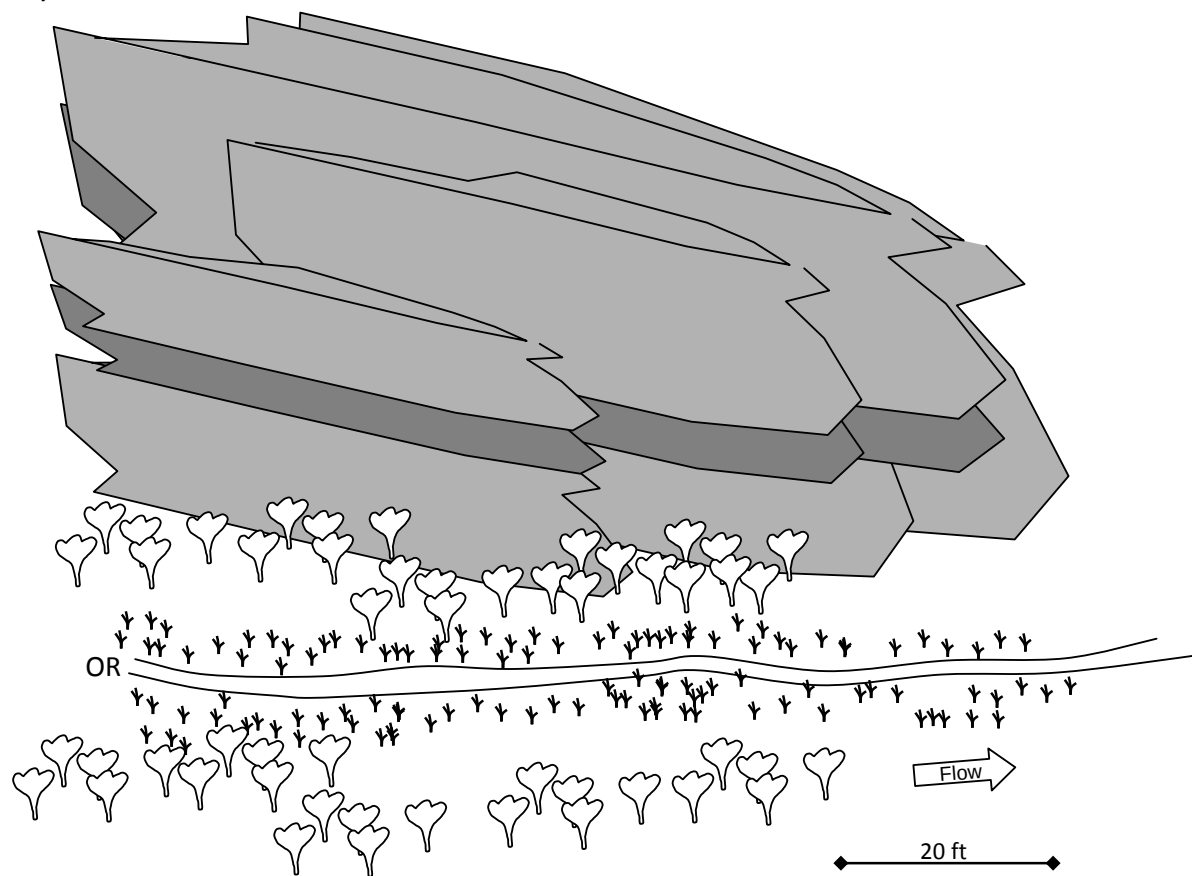
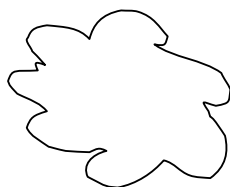
Populus



*Typha latifolia/ Berula erecta (Carex)*



N



# Headgate Seep

OR Orifice

GW Monitoring Well

☼ Juniperus

☿ Elymus

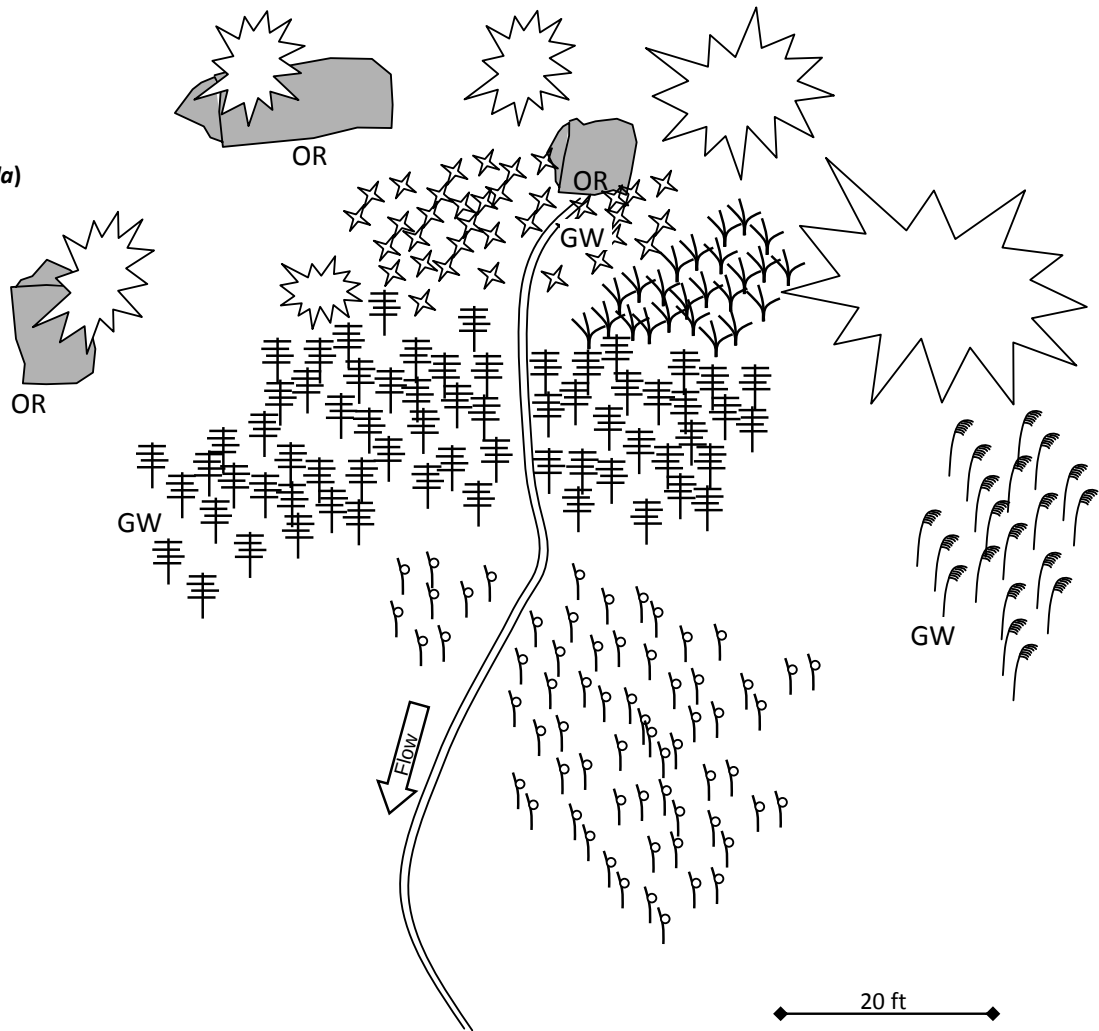
☆ *Carex pellita/ Luzula parviflora (Palustriella)*

✎ *Carex pellita/ Luzula parviflora (Carex)*

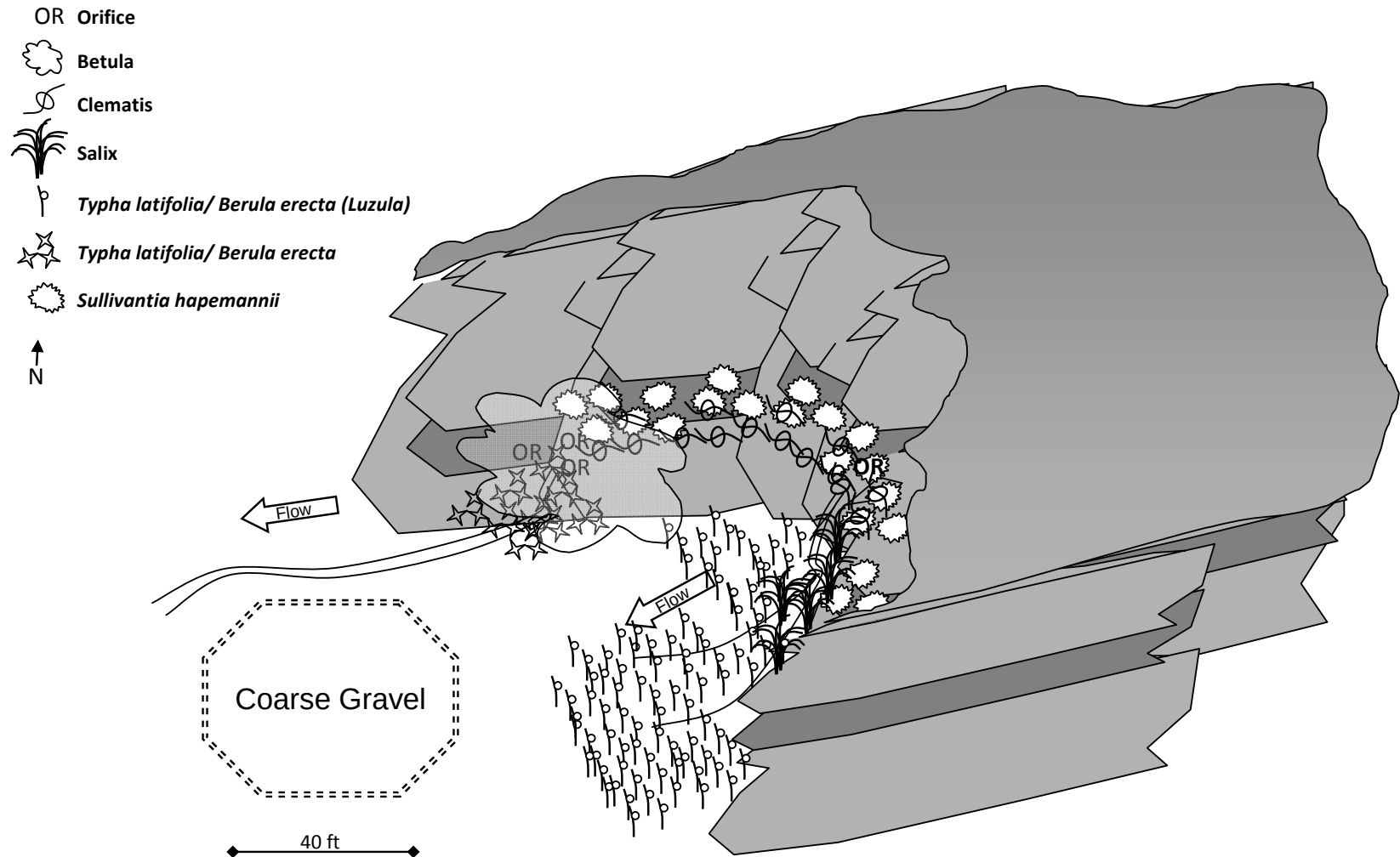
≡ *Carex pellita/ Luzula parviflora (Carex)*

⌒ *Carex pellita/ Luzula parviflora (Juncus)*

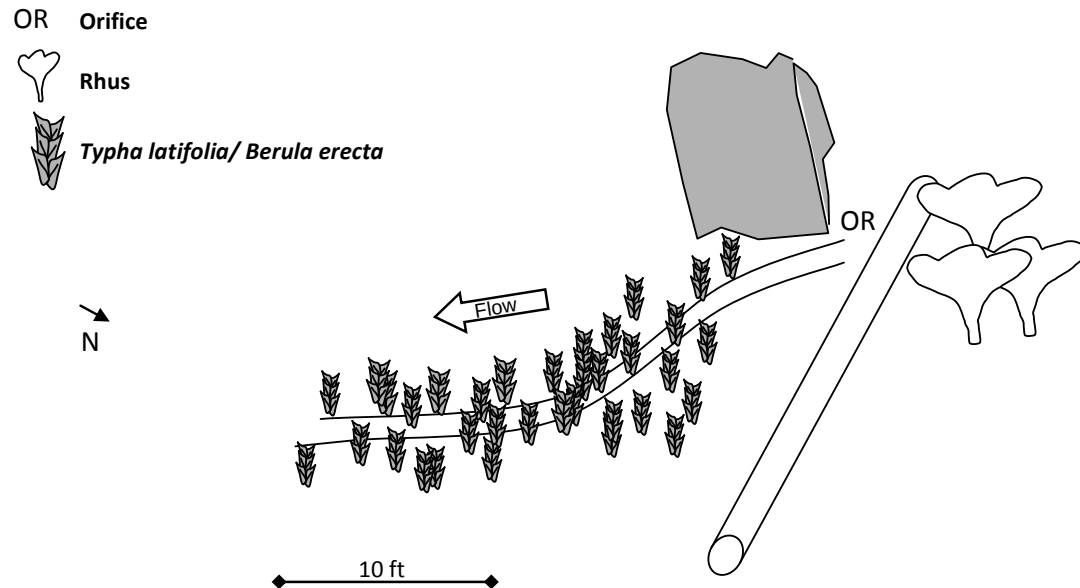
↑  
N



# Hillsboro Main Spring



## Hillsboro Side Spring #2

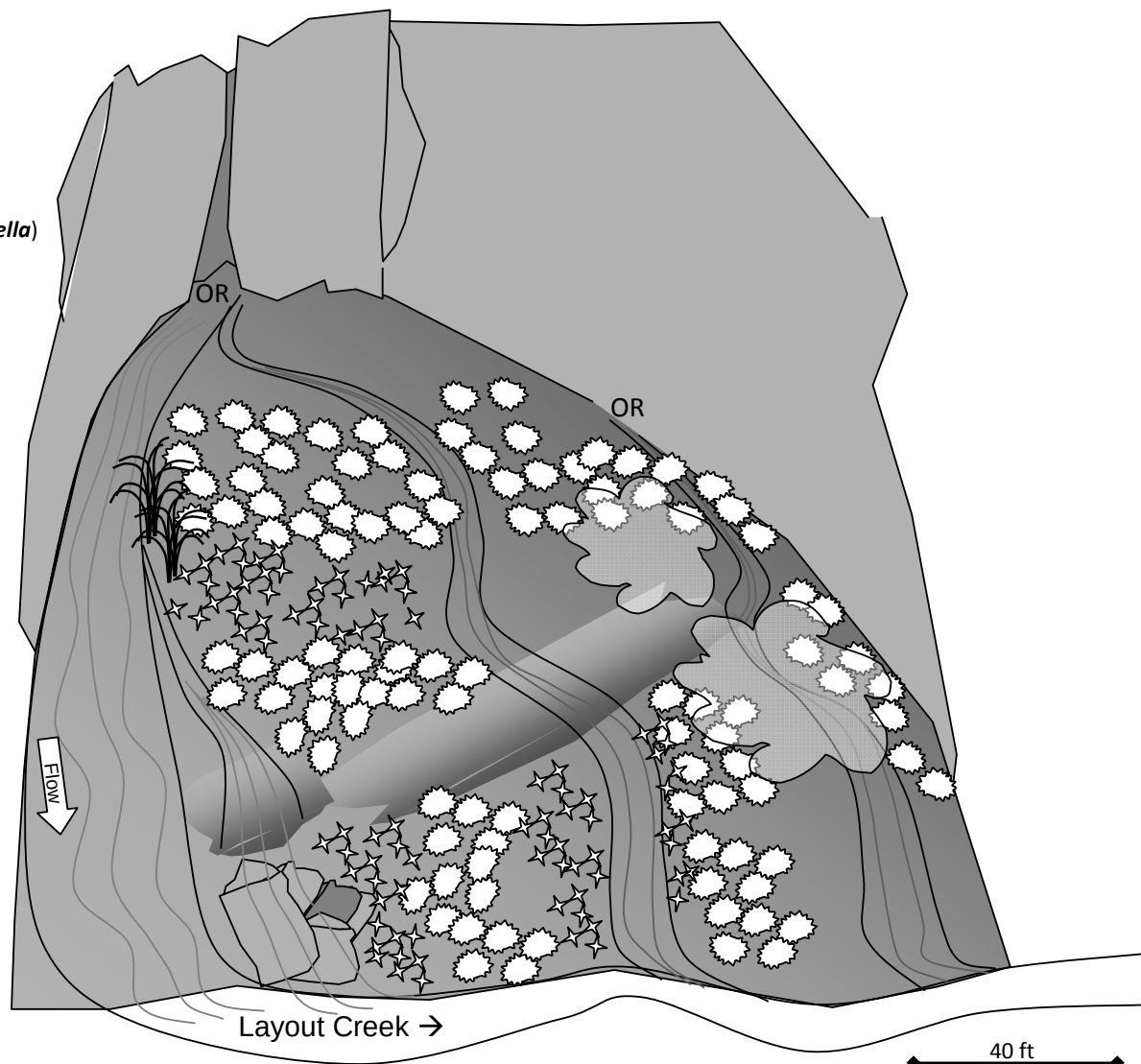


# Layout Spring

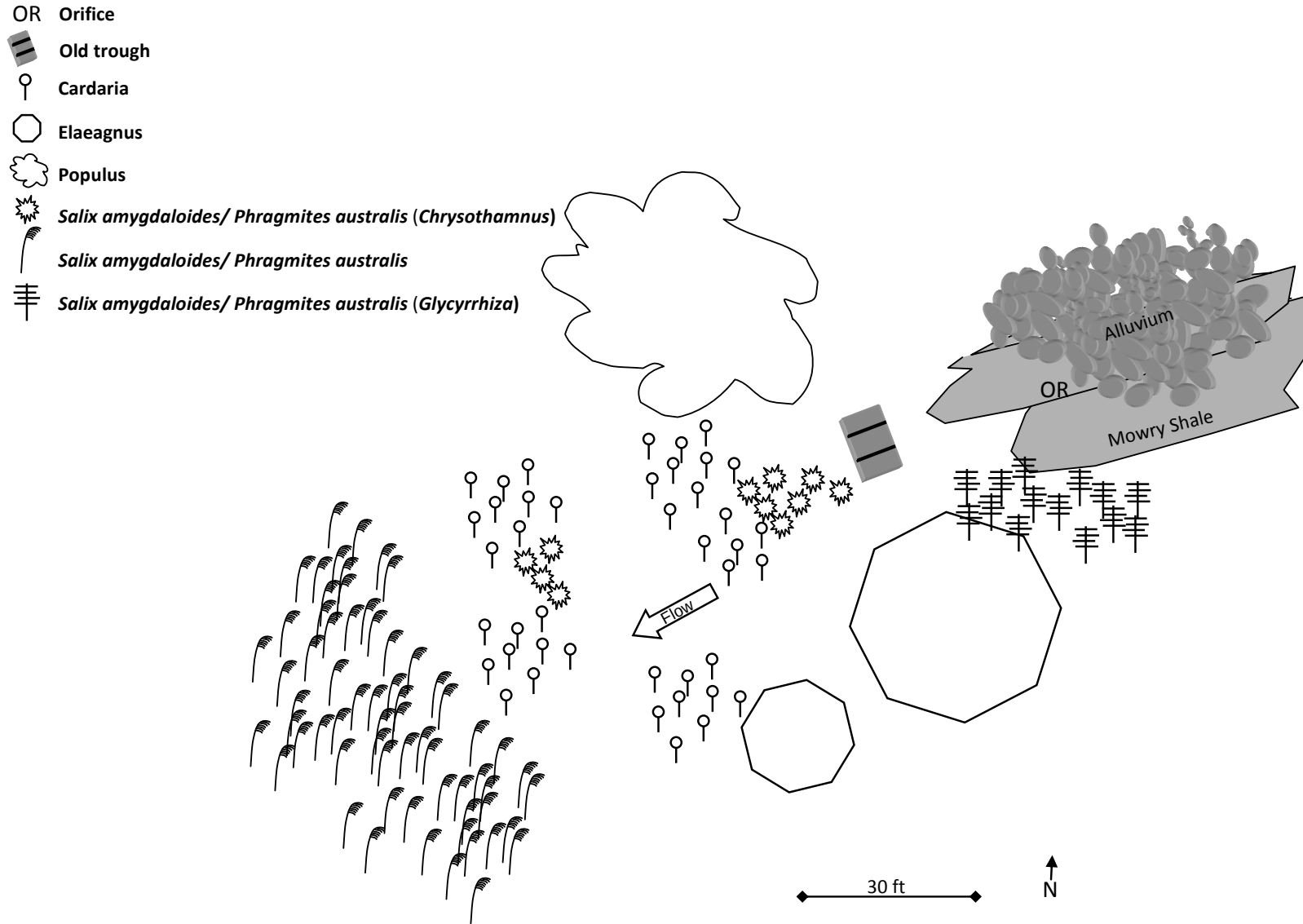
- OR Orifice
-  Betula
-  Salix
-  *Sullivantia hapemannii*
-  *Sullivantia hapemannii* (*Palustriella*)

N ↑

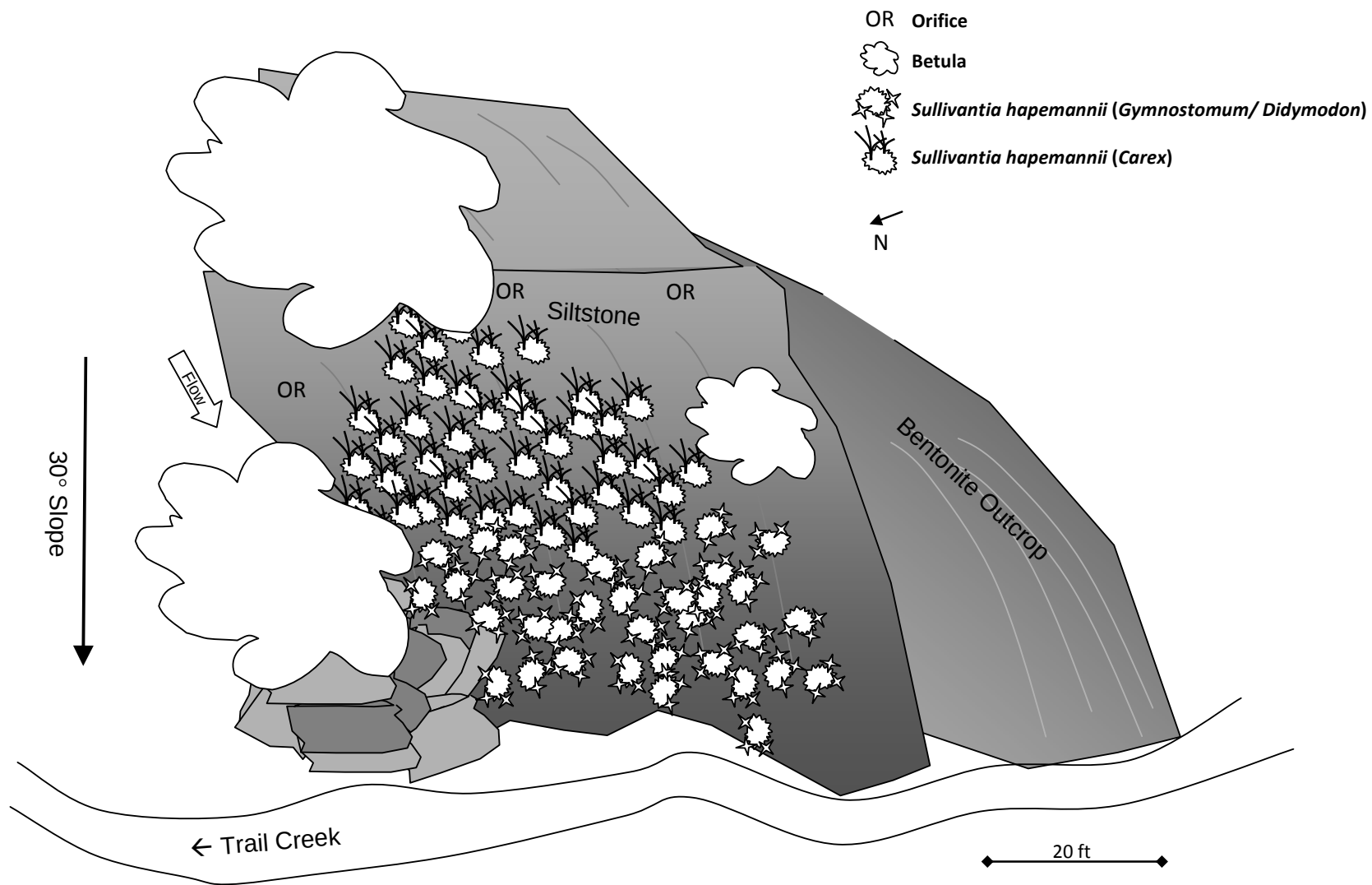
45° Slope ↑



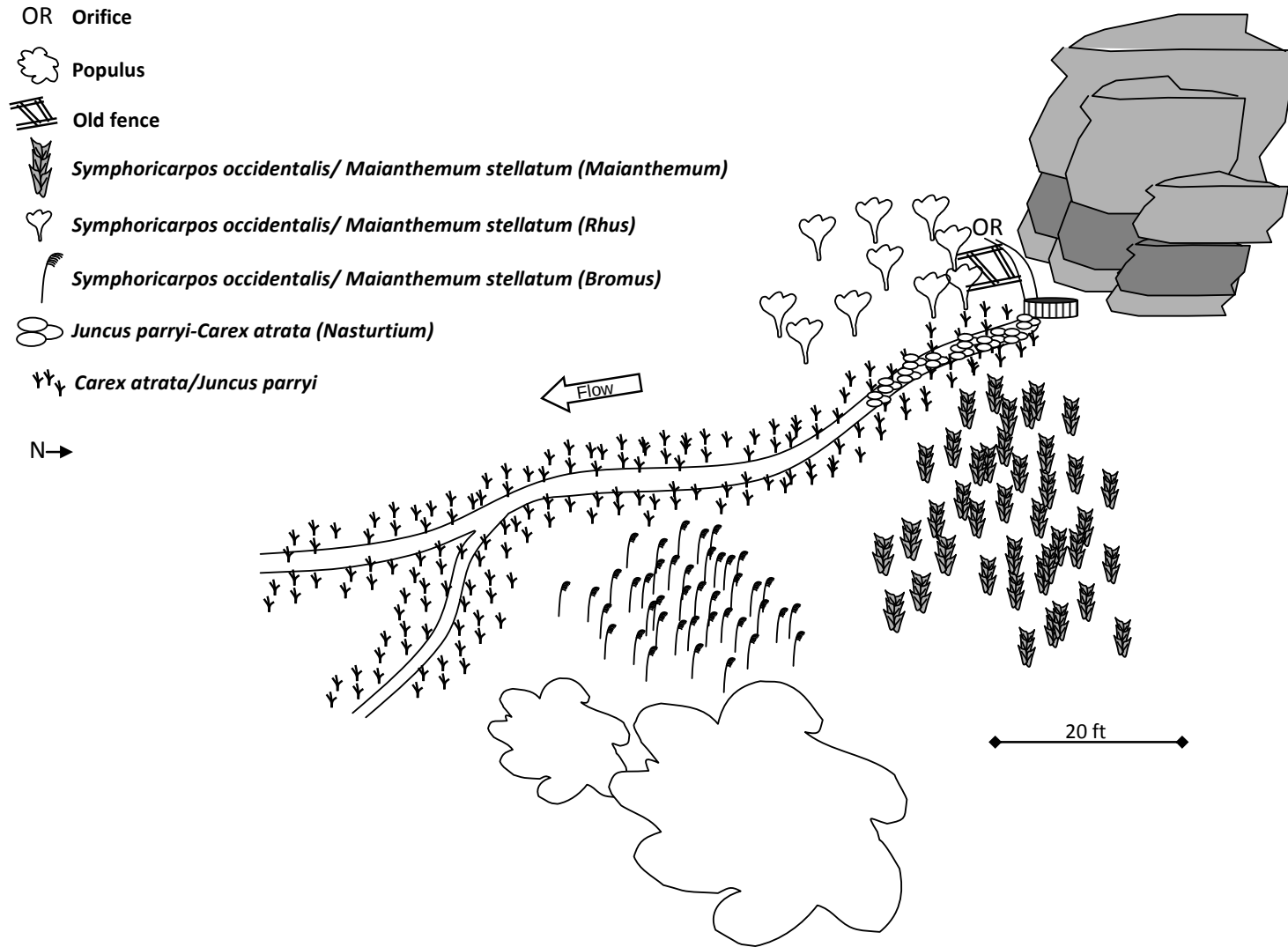
# Mason-Lovell South Spring



# Pickett's Wall Seep



# Rick's Spring



# South Lockhart Spring

OR Orifice

Log



*Symphoricarpos occidentalis/ Maianthemum stellatum (Salix/Juncus)*

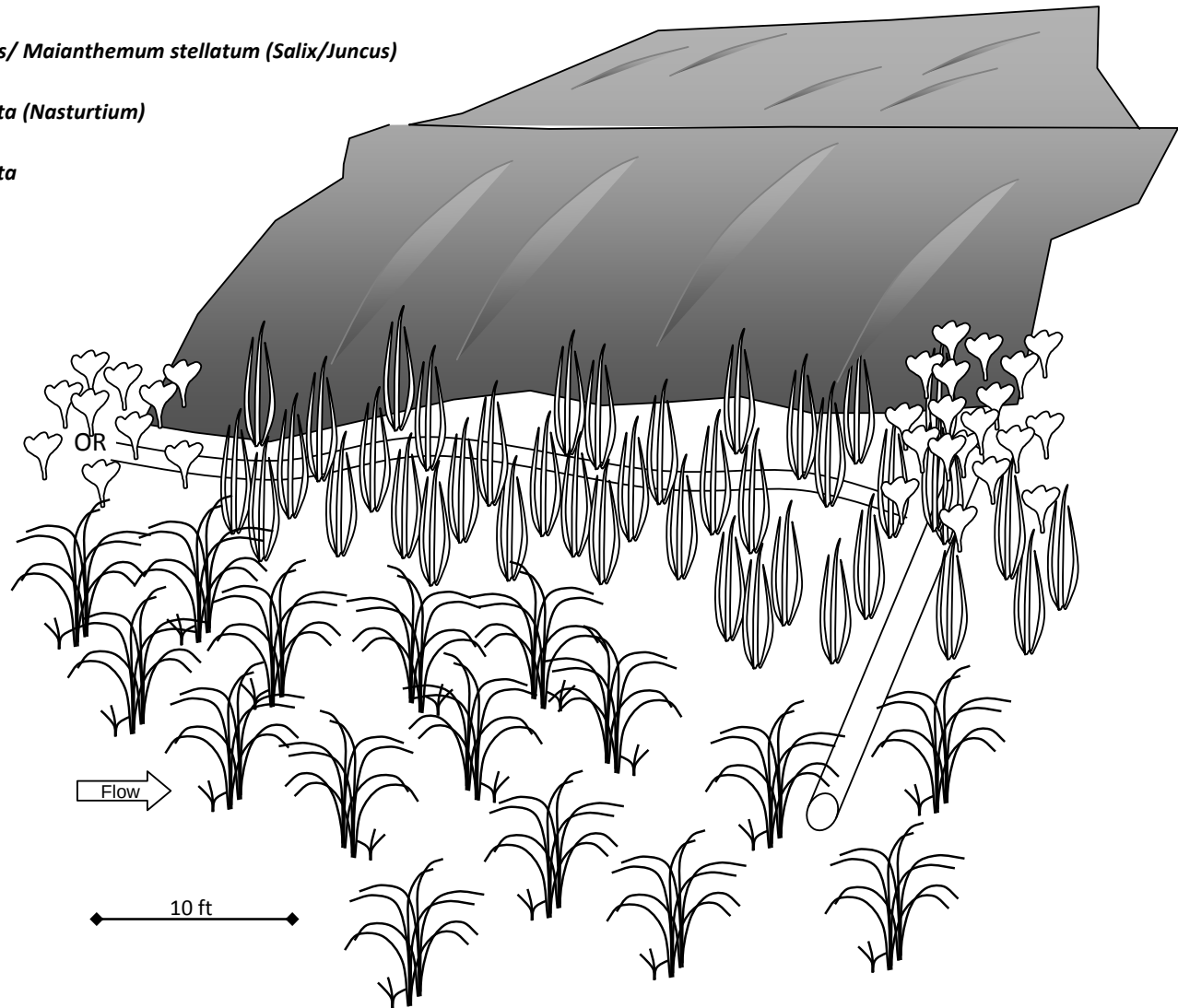


*Typha latifolia/ Berula erecta (Nasturtium)*



*Typha latifolia/ Berula erecta*

N ↑



## Appendix D. Species Traits

**Table 18. Data and plant traits for the *Symphoricarpos occidentalis*/ *Maianthemum stellatum* indicate a mix of native and introduced species and a history of disturbance. Constancy pertains to the percent of plots in the association in which each species was found. Species discrimination indicates specificity of the species to the association, given the dataset.**

|                                               | Constancy | Species Discrimination | Form      | Nativity | WIS   | Coarse Soil Texture | Fine Soil Texture | Medium Soil Texture | Anaerobic Tolerance | CaCO3 Tolerance | Drought Tolerance | Fertility Req. | Root Depth | Salinity Tolerance |
|-----------------------------------------------|-----------|------------------------|-----------|----------|-------|---------------------|-------------------|---------------------|---------------------|-----------------|-------------------|----------------|------------|--------------------|
| <i>Alyssum alyssoides</i>                     | 0.4       | 1.00                   | herb      | I        |       |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Artemisia cana</i>                         | 0.2       | 1.00                   | shrub     | N        | FACU  | Y                   | Y                 | Y                   | None                | M               | H                 | M              | 20         | L                  |
| <i>Bromus inermis</i>                         | 0.4       | 1.00                   | graminoid | NI       |       | N                   | Y                 | Y                   | L                   | L               | M                 | H              | 12         | L                  |
| <i>Camelina microcarpa</i>                    | 0.4       | 1.00                   | herb      | I        |       |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Cirsium arvense</i>                        | 0.6       |                        | herb      | I        | FACU+ |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Clematis ligusticifolia</i>                | 0.6       |                        | herb      | N        | FAC-  | Y                   | Y                 | Y                   | None                | L               | M                 | M              | 16         | L                  |
| <i>Cornus sericea</i>                         | 0.2       |                        | shrub     | N        | FACW  |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Equisetum laevigatum</i>                   | 0.2       |                        | graminoid | N        | FACW  | N                   | Y                 | Y                   | H                   | L               | None              | L              | 10         | L                  |
| <i>Festuca arundinacea</i>                    | 0.2       |                        | graminoid | I        | FAC-  | N                   | Y                 | Y                   | L                   | H               | M                 | M              | 12         | M                  |
| <i>Glycyrrhiza lepidota</i>                   | 0.4       |                        | herb      | N        | FAC+  | N                   | Y                 | Y                   | H                   | M               | None              | M              | 12         | None               |
| <i>Grindelia squarrosa</i>                    | 0.2       | 1.00                   | herb      | N        | UPL   |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Gutierrezia sarothrae</i>                  | 0.6       | 1.00                   | herb      | N        |       | Y                   | Y                 | Y                   | None                | M               | H                 | L              | 16         | L                  |
| <i>Heterotheca villosa</i>                    | 0.2       |                        | herb      | N        |       | Y                   | N                 | Y                   | N                   | M               | M                 | L              | 14         | L                  |
| <i>Juncus balticus</i>                        | 0.4       |                        | graminoid | N        | FACW+ | N                   | Y                 | Y                   | H                   | L               | L                 | L              | 20         | H                  |
| <i>Juniperus osteosperma</i>                  | 0.2       |                        | shrub     | N        |       | Y                   | N                 | Y                   | N                   | H               | H                 | L              | 20         | L                  |
| <i>Juniperus scopulorum</i>                   | 0.4       |                        | tree      | N        |       | Y                   | N                 | Y                   | N                   | H               | H                 | L              | 20         | L                  |
| <i>Maianthemum stellatum</i>                  | 1.0       |                        | herb      | N        | FAC-  |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Mentha arvensis</i> var. <i>canadensis</i> | 0.2       |                        | herb      | N        | FACW  | N                   | Y                 | Y                   | None                | M               | L                 | M              | 6          | None               |
| <i>Nasturtium officinale</i>                  | 0.2       |                        | herb      | I        | OBL   |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Poa pratensis</i>                          | 1.0       |                        | graminoid | I        | FAC   | N                   | Y                 | Y                   | L                   | H               | L                 | H              | 10         | M                  |
| <i>Populus acuminata</i>                      | 0.2       |                        | tree      | N        | FAC   |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Populus angustifolia</i>                   | 0.4       |                        | tree      | N        | FACW  | Y                   | N                 | Y                   | M                   | H               | L                 | L              | 12         | L                  |
| <i>Rhus trilobata</i>                         | 0.6       |                        | Shrub     | N        | FAC   | Y                   | N                 | Y                   | None                | L               | M                 | L              | 12         | L                  |
| <i>Rosa sayi</i>                              | 0.6       |                        | shrub     | N        | FACU  |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Salix exigua</i>                           | 0.2       |                        | shrub     | N        | OBL   | Y                   | N                 | Y                   | H                   | H               | M                 | L              | 20         | L                  |
| <i>Symphoricarpos occidentalis</i>            | 0.8       |                        | shrub     | N        | NI    | N                   | N                 | Y                   | None                | H               | H                 | M              | 18         | L                  |
| <i>Taraxacum officinale</i>                   | 0.2       | 1.00                   | herb      | NI       | FACI  | Y                   | Y                 | Y                   | N                   | L               | M                 | L              | 6          | None               |

**Table 19. Data and plant traits for the *Juncus parryi*/*Carex atrata* association indicate a native community found in seasonally wet areas. Constancy pertains to the percent of plots in the association in which each species was found. Species discrimination indicates specificity of the species to the association, given the dataset.**

|                                    | Constancy | Species Discrimination | Form        | Nativity | WIS   | Coarse Soil Texture | Fine Soil Texture | Medium Soil Texture | Anaerobic Tolerance | CaCO3 Tolerance | Drought Tolerance | Fertility Req. | Root Depth | Salinity Tolerance |
|------------------------------------|-----------|------------------------|-------------|----------|-------|---------------------|-------------------|---------------------|---------------------|-----------------|-------------------|----------------|------------|--------------------|
| <i>Carex aurea</i>                 | 1.0       |                        | graminoid   | N        | FACW+ | Y                   | N                 | Y                   | H                   | L               | None              | L              | 8          | None               |
| <i>Festuca arundinacea</i>         | 1.0       |                        | graminoid   | I        | FAC-  | N                   | Y                 | Y                   | L                   | H               | M                 | M              | 12         | M                  |
| <i>Juncus parryi</i>               | 1.0       | 0.75                   | graminoid   | N        | FAC+  | Y                   | N                 | N                   | L                   | L               | M                 | L              | 12         | None               |
| <i>Achillea millefolium</i>        | 0.5       | 1.00                   | herb        | NI       | FACU  | N                   | N                 | Y                   | None                | M               | M                 | M              | 8          | None               |
| <i>Carex atrata</i>                | 0.5       | 1.00                   | graminoid   | N        | FAC   |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Conardia compacta</i>           | 0.5       |                        | herb        | N        |       |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Cratoneuron filicinum</i>       | 0.5       |                        | nonvascular | N        |       |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Eleocharis palustris</i>        | 0.5       | 0.60                   | graminoid   | N        | OBL   | Y                   | Y                 | N                   | H                   | M               | L                 | M              | 14         | L                  |
| <i>Iris missouriensis</i>          | 0.5       |                        | herb        | N        | FACW+ | Y                   | Y                 | Y                   | H                   | H               | L                 | L              | 6          | None               |
| <i>Maianthemum stellatum</i>       | 0.5       |                        | herb        | N        | FAC-  |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Mentha arvensis</i>             | 0.5       |                        | herb        | N        | FACW  | N                   | Y                 | Y                   | None                | M               | L                 | M              | 6          | None               |
| <i>Najas guadalupensis</i>         | 0.5       | 1.00                   | herb        | N        | OBL   | Y                   | Y                 | Y                   | H                   | H               | None              | M              | 2          | M                  |
| <i>Nasturtium officinale</i>       | 0.5       |                        | herb        | I        | OBL   |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Symphoricarpos occidentalis</i> | 0.5       |                        | shrub       | N        | NI    | N                   | N                 | Y                   | None                | H               | H                 | M              | 18         | L                  |
| <i>Viola adunca</i>                | 0.5       |                        | herb        | N        | FAC   |                     |                   |                     |                     |                 |                   |                |            |                    |

**Table 20. Data and plant traits for the *Typha latifolia*/ *Berula erecta* association indicate a native community found in perennial springs. Constancy pertains to the percent of plots in the association in which each species was found. Species discrimination indicates specificity of the species to the association, given the dataset.**

|                                    | Constancy | Species Discrimination | Form        | Nativity | WIS  | Coarse Soil Texture | Fine Soil Texture | Medium Soil Texture | Anaerobic Tolerance | CaCO3 Tolerance | Drought Tolerance | Fertility Req. | Root Depth | Salinity Tolerance |
|------------------------------------|-----------|------------------------|-------------|----------|------|---------------------|-------------------|---------------------|---------------------|-----------------|-------------------|----------------|------------|--------------------|
| <i>Berula erecta</i>               | 0.50      | 1.00                   | herb        | N        | OBL  | N                   | Y                 | Y                   | H                   | L               | None              | M              | 10         | None               |
| <i>Funaria hygrometrica</i>        | 0.33      | 1.00                   | nonvascular | N        |      |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Galium boreale</i>              | 0.33      | 1.00                   | herb        | N        | FACU | Y                   | N                 | Y                   | None                | H               | M                 | M              | 6          | None               |
| <i>Marchantia polymorpha</i>       | 0.33      | 1.00                   | nonvascular | N        |      |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Populus deltoides</i>           | 0.33      | 1.00                   | tree        | N        | FAC  | Y                   | Y                 | Y                   | M                   | M               | H                 | M              | 24         | None               |
| <i>Typha latifolia</i>             | 0.33      | 1.00                   | herb        | N        | OBL  | Y                   | Y                 | Y                   | H                   | M               | None              | M              | 14         | L                  |
| <i>Juncus parryi</i>               | 0.16      | 0.75                   | graminoid   | N        | FAC+ | Y                   | N                 | N                   | L                   | L               | M                 | L              | 12         | None               |
| <i>Arctium minus</i>               | 0.16      | 1.00                   | herb        | I        |      |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Bryum gemmiparum</i>            | 0.16      | 1.00                   | nonvascular | N        |      |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Carex pellita</i>               | 0.16      | 0.75                   | graminoid   | N        | OBL  |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Cicuta bulbifera</i>            | 0.16      | 1.00                   | herb        | N        | OBL  |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Elymus spicatus</i>             | 0.16      | 1.00                   | graminoid   | N        | UPL  | Y                   | Y                 | Y                   | None                | H               | H                 | L              | 10         | L                  |
| <i>Fissidens grandifrons</i>       | 0.16      | 1.00                   | nonvascular | N        |      |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Gaura coccinea</i>              | 0.16      | 1.00                   | herb        | N        |      |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Glyceria striata</i>            | 0.16      | 1.00                   | graminoid   | N        | OBL  | N                   | Y                 | Y                   | H                   | M               | L                 | M              | 4          | None               |
| <i>Hypnum revolutum</i>            | 0.16      | 1.00                   | nonvascular | N        |      |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Juncus confusus</i>             | 0.16      | 1.00                   | graminoid   | N        | FAC  | Y                   | Y                 | Y                   | H                   | M               | L                 | M              | 10         | M                  |
| <i>Juncus ensifolius</i>           | 0.16      | 1.00                   | graminoid   | N        | FACW |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Luzula parviflora</i>           | 0.16      | 0.75                   | graminoid   | N        | FAC- | N                   | N                 | Y                   | M                   | L               | L                 | M              | 10         | None               |
| <i>Pseudoleskeella tectorum</i>    | 0.16      | 1.00                   | nonvascular | N        |      |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Ribes oxycanthoides</i>         | 0.16      | 1.00                   | shrub       | N        | FAC+ | N                   | N                 | N                   | L                   |                 | L                 |                | 12         | None               |
| <i>Shepherdia argentea</i>         | 0.16      | 1.00                   | shrub       | N        |      | Y                   | N                 | Y                   | N                   | H               | M                 | L              | 24         | M                  |
| <i>Sullivantia hapemannii</i>      | 0.16      | 0.78                   | herb        | N        | OBL  | Y                   |                   |                     | H                   | H               | L                 |                |            |                    |
| <i>Tamarix chinensis</i>           | 0.16      | 1.00                   | shrub       | I        | FACW |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Veronica anagallis-aquatica</i> | 0.16      | 1.00                   | herb        | N        | OBL  |                     |                   |                     |                     |                 |                   |                |            |                    |

**Table 21. Data and plant traits for the *Sullivantia hapemannii* association indicate a native community found in perennial calcareous springs. Constancy pertains to the percent of plots in the association in which each species was found. Species discrimination indicates specificity of the species to the association, given the dataset.**

|                                | Constancy | Species Discrimination | Form        | Nativity | WIS   | Coarse Soil Texture | Fine Soil Texture | Medium Soil Texture | Anaerobic Tolerance | CaCO <sub>3</sub> Tolerance | Drought Tolerance | Fertility Req. | Root Depth | Salinity Tolerance |
|--------------------------------|-----------|------------------------|-------------|----------|-------|---------------------|-------------------|---------------------|---------------------|-----------------------------|-------------------|----------------|------------|--------------------|
| <i>Sullivantia hapemannii</i>  | 1.0       | 0.78                   | herb        | N        | OBL   | Y                   |                   |                     | H                   | H                           | L                 |                |            |                    |
| <i>Carex scopulorum</i>        | 0.4       | 1.00                   | graminoid   | N        | FACW  | Y                   | Y                 | Y                   | H                   | M                           | L                 | M              | 8          | M                  |
| <i>Didymodon tophaceus</i>     | 0.2       | 1.00                   | nonvascular | N        |       |                     |                   |                     |                     |                             |                   |                |            |                    |
| <i>Distichium inclinatum</i>   | 0.2       | 1.00                   | graminoid   | N        |       |                     |                   |                     |                     |                             |                   |                |            |                    |
| <i>Gymnostomum aeruginosum</i> | 0.2       | 1.00                   | nonvascular | N        |       |                     |                   |                     |                     |                             |                   |                |            |                    |
| <i>Solidago missouriensis</i>  | 0.2       | 1.00                   | herb        | N        |       | Y                   | N                 | Y                   | L                   | M                           | H                 | L              | 8          | L                  |
| <i>Toxicodendron rydbergii</i> | 0.2       | 1.00                   | herb        | N        | FACW- |                     |                   |                     |                     |                             |                   |                |            |                    |
| <i>Urtica dioica</i>           | 0.2       | 1.00                   | herb        | N        | FAC+  |                     |                   |                     |                     |                             |                   |                |            |                    |

**Table 22. Data and plant traits for the *Carex pellita*/*Luzula parviflora* association indicate a native, wetland community able to tolerate anaerobic conditions. Constancy pertains to the percent of plots in the association in which each species was found. Species discrimination indicates specificity of the species to the association, given the dataset.**

|                               | Constancy | Species Discrimination | Form        | Nativity | WIS   | Coarse Soil Texture | Fine Soil Texture | Medium Soil Texture | Anaerobic Tolerance | CaCO <sub>3</sub> Tolerance | Drought Tolerance | Fertility Req. | Root Depth | Salinity Tolerance |
|-------------------------------|-----------|------------------------|-------------|----------|-------|---------------------|-------------------|---------------------|---------------------|-----------------------------|-------------------|----------------|------------|--------------------|
| <i>Carex pellita</i>          | 0.8       | 0.75                   | graminoid   | N        | OBL   |                     |                   |                     |                     |                             |                   |                |            |                    |
| <i>Luzula parviflora</i>      | 0.8       | 0.75                   | graminoid   | N        | FAC-  | N                   | N                 | Y                   | M                   | L                           | L                 | M              | 10         | None               |
| <i>Sisyrinchium idahoense</i> | 0.6       | 1.00                   | nonvascular | N        | FACW  | Y                   | Y                 | Y                   | M                   | M                           | L                 | M              | 8          | None               |
| <i>Juncus mertensianus</i>    | 0.4       | 1.00                   | graminoid   | N        | OBL   | Y                   | N                 | Y                   | H                   | M                           | L                 | M              | 8          | None               |
| <i>Carex nebrascensis</i>     | 0.4       | 1.00                   | graminoid   | N        | OBL   | Y                   | Y                 | Y                   | H                   | M                           | None              | L              | 10         | I                  |
| <i>Carex interior</i>         | 0.2       | 1.00                   | graminoid   | N        | FACW- | N                   | Y                 | Y                   | H                   | M                           | L                 | M              | 8          | None               |
| <i>Ericameria nauseosa</i>    | 0.2       | 0.75                   | herb        | N        |       |                     |                   |                     |                     |                             |                   |                |            |                    |
| <i>Juncus balticus</i>        | 0.2       | 1.00                   | graminoid   | N        | FACW+ | N                   | Y                 | Y                   | H                   | L                           | L                 | L              | 20         | H                  |
| <i>Juncus confusus</i>        | 0.2       | 1.00                   | graminoid   | N        | FAC   | Y                   | Y                 | Y                   | H                   | M                           | L                 | M              | 10         | M                  |

**Table 23. Data and plant traits for the *Salix amygdaloides*/*Phragmites australis* association indicate an introduced, facultative community that thrives in disturbed conditions. Constancy pertains to the percent of plots in the association in which each species was found. Species discrimination indicates specificity of the species to the association, given the dataset.**

|                                | Constancy | Species Discrimination | Form      | Nativity | WIS   | Coarse Soil Texture | Fine Soil Texture | Medium Soil Texture | Anaerobic Tolerance | CaCO3 Tolerance | Drought Tolerance | Fertility Req. | Root Depth | Salinity Tolerance |
|--------------------------------|-----------|------------------------|-----------|----------|-------|---------------------|-------------------|---------------------|---------------------|-----------------|-------------------|----------------|------------|--------------------|
| <i>Ericameria nauseosa</i>     | 1.00      | 0.75                   | herb      | N        |       |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Bassia sieversiana</i>      | 0.66      | 1.00                   | herb      | I        | FAC   |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Cardaria pubescens</i>      | 0.66      | 1.00                   | herb      | I        |       |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Asclepias speciosa</i>      | 0.33      | 1.00                   | herb      | N        | FAC+  | Y                   | Y                 | Y                   | L                   | M               | L                 | M              | 18         | None               |
| <i>Centaurea repens</i>        | 0.33      | 1.00                   | herb      | I        |       |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Elaeagnus angustifolia</i>  | 0.33      | 1.00                   | tree      | I        | FAC   | Y                   | N                 | Y                   | L                   | H               | H                 | M              | 20         |                    |
| <i>Iva axillaris</i>           | 0.33      | 1.00                   | herb      | N        | FAC   |                     |                   |                     |                     |                 |                   |                |            |                    |
| <i>Phragmites australis</i>    | 0.33      | 1.00                   | graminoid | N        | FACW+ | Y                   | Y                 | Y                   | H                   | M               | L                 | M              | 20         | L                  |
| <i>Salix amygdaloides</i>      | 0.33      | 1.00                   | shrub     | N        | FACW  | Y                   | N                 | Y                   | M                   | M               | L                 | M              | 30         | None               |
| <i>Sarcobatus vermiculatus</i> | 0.33      | 1.00                   | shrub     | N        | FACU+ | N                   | Y                 | Y                   | L                   | H               | H                 | L              | 12         | H                  |
| <i>Sporobolus airoides</i>     | 0.33      | 1.00                   | graminoid | N        | FAC   | Y                   | Y                 | Y                   | M                   | H               | H                 | M              | 16         | H                  |

## Appendix E. Spring geographic coordinates.

**Table 24. Geographic coordinates for surveyed springs in UTM 12N NAD83.**

| Feature             | UTMX_NAD83 | UTMY_NAD83 |
|---------------------|------------|------------|
| Cat Track           | 717244     | 4998801    |
| Finley              | 719282     | 4998555    |
| Headgate            | 713576     | 4996931    |
| Hillsboro Main      | 717144     | 4997926    |
| Hillsboro Side #2   | 717230     | 4997814    |
| Layout              | 712782     | 4997451    |
| Mason Lovell South  | 724569     | 4967582    |
| Pickett's Wall Seep | 717541     | 4998619    |
| Rick's              | 716910     | 5002153    |
| South Lockhart      | 716744     | 5001906    |