NATURAL RESOURCES
AND CONSERVATION

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FINAL
ENVIRONMENTAL ASSESSMENT

Project Name:	Dry Creek Irrigation Canal Improvement Project
Proposed Implementation Date:	April 2024-April 2025
Proponent:	Gallatin County Conservation District
Location:	45.853004°, -111.155732°
County:	Gallatin

I. TYPE AND PURPOSE OF ACTION

The Dry Creek Irrigation Canal Improvement project is being proposed by Gallatin County on behalf of the Dry Creek Irrigation Company. Dry Creek Irrigation Canal is in the northeastern corner of the Gallatin Valley, and conveys water diverted from the East Gallatin River and Ross Creek for 8.8 miles before returning to the East Gallatin River. The primary purpose of the proposed project is to improve irrigation efficiency by reducing seepage losses from the Dry Creek Canal. Seepage loss from the canal has been documented for decades and is sufficient to saturate and inundate portions of an adjacent hay field located between Theisen Road and Reese Creek Road (Figure 1). Because of excessive seepage, hay yield from this field is not as high as possible and by reducing seepage, more land could be put into agricultural production. To address this situation, the project proponents have proposed installing a liner in this 4000-foot section of canal. Improved irrigation efficiency will likely result in increased flows in the East Gallatin River and Ross Creek, as the Dry Creek Irrigation Company with not have to divert as much water to meet the needs of water users.

A secondary purpose of the proposed project is to reduce sediment loading in the canal and thus to the East Gallatin River and Dry Creek. This goal will be achieved by changing the channel geometry and elevation in the segment of the canal that will be lined and by constructing a 0.25-acre sediment trap approximately half-way down the length of the canal so that sediment may be captured and removed. Sediment accumulation has been noted in several places along the canal, especially in the vicinity of the Dry Creek fish passage structure. When closed, the fish passage allows water from Dry Creek to flow across the canal and potentially increase the sediment load to the reach downstream of the canal. The co-mingling of water from Dry Creek and the sediment-loaded canal water is particularly problematic because Dry Creek is on the 303(d) list for sediment. Installation of a sediment trap along the Dry Creek Canal will reduce the sediment load in the canal water and thus will decrease the potential of those sediments to enter either Dry Creek or the East Gallatin River.

Project implementation will begin in the spring of 2024 with preliminary design development. Final designs and design review will occur during the summer of 2024 with bids solicited and awarded in the fall of 2024 and construction planned for Winter 2024-2025. Construction shall be completed before the 2025 irrigation season and the proponents hope to close out the project by August of 2025.

Before implementing this project, the project proponents will need to secure matching funds, prepare a design set to be used during construction, obtain permission to construct the sediment trap in the desired location or find an alternative location, and obtain the necessary permits.

The Department of Natural Resources and Conservation's (DNRC) Conservation and Resource Development Division (CARDD) will fund this project with money from the American Rescue Plan Act (ARPA) grant program.

II. PROJECT DEVELOPMENT

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1. PUBLIC INVOLVEMENT, AGENCIES, GROUPS OR INDIVIDUALS CONTACTED:

Provide a brief chronology of the scoping and ongoing involvement for this project. List number of individuals contacted, number of responses received, and newspapers in which notices were placed and for how long. Briefly summarize issues received from the public.

The project proponents have not sought public input this project, however they have worked with the Gallatin Conservation District and Dry Creek Canal water users who all see the need for the project.

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2. OTHER GOVERNMENTAL AGENCIES WITH JURISDICTION, LIST OF PERMITS NEEDED:

Examples: cost-share agreement with U.S. Forest Service, 124 Permit, 3A Authorization, Air Quality Major Open Burning Permit.

- 310 Permit – Gallatin Conservation District
- 404 Permit – US Army Corps of Engineers
- 401 Certification – Montana Department of Environmental Quality
- 318 Authorization - Montana Department of Environmental Quality. This permit may or may not be required. Construction is scheduled to occur while the diches and canals are dry, however a sediment pulse is likely to occur when the diversions are activated for the irrigation season. MTDEQ will need to decide if they want to issue a 318 permit of if they want to provide a waiver.
- SWPP Authorization - Montana Department of Environmental Quality
- Cultural resources records check – Montana State Historic preservation Office

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3. ALTERNATIVE DEVELOPMENT:

Describe alternatives considered and, if applicable, provide brief description of how the alternatives were developed. List alternatives that were considered but eliminated from further analysis and why. Include the No Action alternative.

<u>Alternative 1 – Line a portion of the Dry Creek Irrigation Ditch and construct a sediment pond.</u>
This is the preferred alternative as it will address seepage in a critical portion of the Dry Creek Irrigation Canal. This alternative will benefit water users along the canal by allowing increased agricultural production in the field adjacent to the newly lined canal segment and increasing reliability of irrigation water supply for other water users along the canal. Alternative 1 will benefit the natural environment by keeping more water in the streams that feed the canal, and potentially reducing sediment loads to Dry Creek and the East Gallatin River.

Alternative 2 – Redesign and Line the Entire Canal (8.8 miles)
This alternative could address sediment conveyance and seepage issues through the Dry Creek Irrigation Canal. This alternative was not considered due to the high cost and amount of work associated.

Alternative 3 – No Action
The no action alternative would lead to continued loss of crop yield in the field adjacent to the canal section with high amounts of seepage and would perpetuate irrigation water loss. Additionally, if this canal section continues to experience high amounts of seepage, the canal is likely to fail at some point in time. No additional benefit to natural resources would be realized though the no action alternative.

III. IMPACTS ON THE PHYSICAL ENVIRONMENT

- *RESOURCES potentially impacted are listed on the form, followed by common issues that would be considered.*
- *Explain POTENTIAL IMPACTS AND MITIGATIONS following each resource heading.*
- *Enter "NONE" If no impacts are identified or the resource is not present.*

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4. GEOLOGY AND SOIL QUALITY, STABILITY AND MOISTURE:

Consider the presence of fragile, compactable or unstable soils. Identify unusual geologic features. Specify any special reclamation considerations. Identify direct, indirect, and cumulative effects to soils.

The project area is in an agricultural area with relatively flat to rolling topography. The soils within the project area are well-drained loams derived from alluvium that have been manipulated for agricultural use. The area where the proposed canal lining is slated to occur is:

- 50% Havre loam, calcareous surface, 0-2% slopes;
- 29% Amesha loam, 8-15% slopes;
- 7% Beanlake loam 35-60% slopes
- 5% Blossberg loam, 0-2% slopes;
- 5% Amesha loam, 35-60% slopes; and
- 4% Quagle-Brodyk silt loams, 8-15% slopes.

The soils in the proposed sediment trap area are comprised of approximately:

- 40% Havre loam, calcareous surface, 0-2% slopes; and
- 60% Brocko silt loam, 4-8% slopes.

The underlying geology in the area is primarily alluvium of braid plain from the Holocene and/or Pleistocene. These deposits have rounded to well-rounded, dominantly cobble gravel with clasts as large as boulders, and sand, silt and clay; mostly composed of Archean metamorphic rock fragments, and dark-colored volcanic rocks with subordinate Paleozoic limestone and Proterozoic Belt rocks. Clast lithologies in general order of decreasing abundance include Precambrian metamorphic rocks, mafic volcanic rocks, dacite porphyry, quartzite, sandstone, limestone, and chert. Two wells in this unit adjacent to the Gallatin River indicate thicknesses of Quaternary alluvium overlying Tertiary deposits of 9.5 meters and 65 meters (Hackett et al., 1960). Other geological features of the project and adjacent areas include alluvial fan deposits from the Holocene and Pleistocene. These deposits have preserved fan morphology at break in slope, composed of a heterogeneous mixture of subangular to moderately rounded coarse clasts as large as boulders, and fine-grained sediment (sand, silt, and clay) that is generally concentrated near fan margins. Clasts derived from adjacent uplands. Estimated thickness is about 30 meters at thickest part. There is also a small portion of the project area that may include Sixmile Creek Formation – Reese Creek Member of the Miocene: Clarendonian and Hemphillian. These are basal cobble or small boulder clast-supported conglomerate or gravel cemented by calcium carbonate, or unconsolidated with clasts coated by calcium carbonate overlain by orangish tan tuffaceous mudstone with lenes of fine-grained sandstone (Montana Bureau of Mines and Geology, 2014).

Proposed Alternative – The proposed alternative will have short-term, localized, nonrecurring adverse impacts on soil stability, as the soil surrounding the Dry Creek Canal will be disturbed during construction. Adverse impacts should be mitigated by following proper best management practices (BMPs) for erosion control. The proposed alternative is anticipated to have a long-term beneficial impact by reducing soil saturation and improving soil stability.

No Action Alternative – The current conditions are adversely impacting soil quality, stability and moisture. Soils are so frequently saturated that they are prone to erosion both inside and on the side slopes of the canal. The no action alternative perpetuates the risk of soil erosion surrounding the Dry Creek Irrigation Canal.

5. WATER QUALITY, QUANTITY AND DISTRIBUTION:

Identify important surface or groundwater resources. Consider the potential for violation of ambient water quality standards, drinking water maximum contaminant levels, or degradation of water quality. Identify direct, indirect, and cumulative effects to water resources.

The Dry Creek Irrigation Canal is located within the Smith Creek Watershed (HUC code 100200081102). The canal conveys water diverted from the East Gallatin River and Ross Creek for 8.8 miles, intermingling with water from Smith Creek and Dry Creek along the way, and returns water to the East Gallatin River. The East Gallatin River and Dry Creek are listed as impaired for nutrients, Smith and Ross Creek are listed for sediment, and all these waterbodies have Total Maximum Daily Load set (TMDL; MT DEQ 2013). The TMDL program identifies sources of pollution to streams, rivers, and lakes within Montana and determines how much pollution those waters can sustain and still fully support beneficial uses. The project area has three locations that are listed as water discharger sites: Trout Pond, Tom Milesnick – Ben Hart Creek 318 Permit, and Rieschel River Ranch (NEPAssist). As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating those three sources that discharge pollutants into water sources of the United States.

Water temperature and sediment load within the Canal most likely increases between the points of diversion and point of return to the East Gallatin River. Canal seepage creates a need to divert more water than necessary to ensure adequate supply for Canal users, which results in unnecessary dewatering of the source waters. Seepage from the Canal likely provides groundwater re-charge in the vicinity adjacent to the Canal.

Proposed Alternative – The proposed alternative will have a direct beneficial impact on water quantity in the East Gallatin River and Ross Creek by reducing water losses within the Canal due to seepage. Reduced seepage will result in less water being diverted to meet the needs of irrigators and will therefore keep more water in the East Gallatin and Ross Creek. The project may have an indirect beneficial impact on water quality in the Dry Creek and the East Gallatin River by reducing sediment loading. The project may have a short- and long-term, recurring, localized adverse impact on groundwater recharge due to reduced amounts of seepage. This minor adverse impact will be one-time, long-term, local, relatively unimportant, and should not establish any new precedent or open any new conflicts. Mitigation option exists for loss of groundwater recharge unless provided by the proposed sediment trap.

No Action Alternative – The no action alterative will perpetuate the adverse impacts on water quality and quantity in the East Gallatin River and Ross Creek. Given that the impact of the current conditions has not been precisely calculated, it is difficult to quantify the impact amounts associated with the no action alternative, however the potential impacts are not insignificant.

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6. AIR QUALITY:

What pollutants or particulate would be produced (i.e. particulate matter from road use or harvesting, slash pile burning, prescribed burning, etc)? Identify the Airshed and Impact Zone (if any) according to the Montana/Idaho Airshed Group. Identify direct, indirect, and cumulative effects to air quality.

The proposed project is not located in an air quality Attainment Area, as set by the U.S. Environmental Protection Agency's National Ambient Air Quality Standards. The project area is not listed as impaired in air quality particulates per the Montana DEQ Air Quality Nonattainment Status List (Montana DEQ Air Quality Website visit). No air pollution facilities are in, or near (within 1/2-mile) the project area. No nonattainment areas exist in the vicinity of the project. The nearest air pollution facility (MSU Central Heating Plant) is approximately 2.4 miles to the north of the project (NEPAssist).

Proposed Alternative – The proposed project may have short-term, minor to negligible, non-re-occurring, localized, direct adverse impacts to air quality from dust produced during construction. Impacts to air quality will be limited to the construction duration. Dust control and other Best Management Practices will be used to limit air quality impacts. Construction is anticipated to last approximately two months. The project will not have long term impacts to air quality.

No Action Alternative – No impact to air quality.

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7. VEGETATION COVER, QUANTITY AND QUALITY:

What changes would the action cause to vegetative communities? Consider rare plants or cover types that would be affected. Identify direct, indirect, and cumulative effects to vegetation.

The project area is located in a relatively undeveloped agricultural area, with rural residential development to the north and east of the project area and wetlands and stream channels to the south and east. The vegetation cover within the project area is 40% Montane Grassland (Rocky Mountain Lower Montane, Foothill, and Valley Grassland), 47% Human Land Use (27% Agriculture: Cultivated Crops, 14% Agriculture: Pasture/Hay, 3% Developed: Open Space, 3% Developed: Other Roads), 4% Wetland and Riparian Systems (Floodplain and Riparian), and 3% Sagebrush Steppe (Big Sagebrush Steppe; MTNHP). Terrestrial, avian, and aquatic life habitat is consistent with those typically found in natural and cultivated grasslands with adjacent stream and wetlands. There are

10 potential plant species of concern and one bryophyte which could occur within the project area (MTNHP Environmental Summary, Attachment C):

- Beaked Spikerush (*Eleocharis rostellata*)
- Pale-yellow Jewel-weed (*Impatiens aurella*)
- Panic Grass (*Dichanthelium acuminatum*)
- Mealy Primrose (*Primula incana*)
- Platte Cinquefoil (*Potentilla plattensis*)
- Railhead Milkvetch (*Astragalus terminalis*)
- Ute Ladies'-tresses (*Spiranthes diluvialis*)
- Fleshy Stitchwort (*Stellaria crassifolia*)
- Crawe's Sedge (*Carex crawei*)
- Slender Indian Paintbrush (*Castilleja gracillima*)
- Meesia Moss (*Meesia triquetra*)

According to the National Wetland Inventory (NWI), the project area contains several wetland and aquatic habitat types including emergent and scrub-shrub palustrine and riparian wetlands which exist primarily in the meadows and grasslands to the southeast of where the project work will occur. There are also two perennial waterways mapped to the southeast of where the project work will occur, Smith Creek and the East Gallatin River.

Proposed Alternative – A minor to major, indirect to direct, short- to long-term adverse impact may be experienced within the project area in that approximately 30 acres of irrigation-supported wetlands will be converted to productive hay fields. This will be a one-time, long-term impact occurring adjacent to the portion of Canal that will be lined. While all wetlands are important one of the goals of the project is to transform the wet areas into productive crop land.

The proposed alternative will have an indirect beneficial impact on water quantity and quality within the East Gallatin River as less water will be diverted into the Dry Creek Canal to meet water demand, and irrigation return water will contain less sediment.

No Action Alternative – No impact to vegetation cover, quantity, or quality.

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8. TERRESTRIAL, AVIAN AND AQUATIC LIFE AND HABITATS:

Consider substantial habitat values and use of the area by wildlife, birds or fish. Identify direct, indirect, and cumulative effects to fish and wildlife.

The project area provides habitat for birds and wildlife and limited habitat for aquatic life. MTNHP records indicate that there are 23 species of concern that have been observed within the project area and 38 species of concern that could potentially occur within the project area, based on their habitat preferences (Tables 1 to 3, MTNHP 2023; Attachment C). No portion of the project area falls within any terrestrial or aquatic focus areas identified by MT FWP in the State Wildlife Action Plan.

Table 1. Species Occurrences

Bald Eagle	*Haliaeetus leucocephalus*
Black-billed Cuckoo	*Coccyzus erythropthalmus*

Bobolink	*Dolichonyx oryzivorus*
Evening Grosbeak	*Coccothraustes vespertinus*
Golden Eagle	*Aquila chrysaetos*
Great Blue Heron	*Ardea herodias*
Green-tailed Towhee	*Pipilo chlorurus*
Grizzly Bear	*Ursus arctos*
Little Brown Myotis	*Myotis lucifugus*
Long-billed Curlew	*Numenius americanus*
Western Pearlshell	*Margaritifera falcata*
Bat Roost (non-cave)	

Table 2. Other Observed Occurrences

American White Pelican	*Pelecanus erythrorhynchos*
Barrow's Goldeneye	*Bucephala islandica*
Black-necked Stilt	*Himantopus mexicanus*
Broad-tailed Hummingbird	*Selasphorus platycercus*
Burrowing Owl	*Athene cunicularia*
Common Loon	*Gavia immer*
Ferruginous Hawk	*Buteo regalis*
Pinyon Jay	*Gymnorhinus cyanocephalus*
Sharp-tailed Grouse	*Tympanuchus phasianellus*
Short-eared Owl	*Asio flammeus*
Trumpeter Swan	*Cygnus buccinator*
White-faced Ibis	*Plegadis chihi*

Table 3. Potential Species

Canada Lynx	*Lynx canadensis*
Dwarf Shrew	*Sorex nanus*
Fringed Myotis	*Myotis thysanodes*
Hoary Bat	*Lasiurus cinereus*
Long-eared Myotis	*Myotis evotis*
Long-legged Myotis	*Myotis volans*
Merriam's Shrew	*Sorex merriami*
North American Porcupine	*Erethizon dorsatum*
Preble's Shrew	*Sorex preblei*
Silver-haired Bat	*Lasionycteris noctivagans*
Spotted Bat	*Euderma maculatum*
Townsend's Big-eared Bat	*Corynorhinus townsendii*
Western Spotted Skunk	*Spilogale gracilis*
Wolverine	*Gulo gulo*
Wyoming Ground Squirrel	*Urocitellus elegans*
American Bittern	*Botaurus lentiginosus*
Black Tern	*Chlidonias niger*

Black-crowned Night-Heron	*Nycticorax nycticorax*
Brewer's Sparrow	*Spizella breweri*
Common Poorwill	*Phalaenoptilus nuttallii*
Franklin's Gull	*Leucophaeus pipixcan*
Greater Sage-Grouse	*Centrocercus urophasianus*
Harlequin Duck	*Histrionicus histrionicus*
Hooded Merganser	*Lophodytes cucullatus*
Lewis's Woodpecker	*Melanerpes lewis*
Loggerhead Shrike	*Lanius ludovicianus*
Ovenbird	*Seiurus aurocapilla*
Rufous Hummingbird	*Selasphorus rufus*
Sage Thrasher	*Oreoscoptes montanus*
Sprague's Pipit	*Anthus spragueii*
Veery	*Catharus fuscescens*
Yellow-billed Cuckoo	*Coccyzus americanus*
Greater Short-horned Lizard	*Phrynosoma hernandesi*
Snapping Turtle	*Chelydra serpentina*
Western Milksnake	*Lampropeltis gentilis*
Northern Leopard Frog	*Lithobates pipiens*
Monarch	*Danaus plexippus*
Suckley Cuckoo Bumble Bee	*Bombus suckleyi*

Proposed Alternative – The habitat impacts for terrestrial, avian, and aquatic life that could result from this project are: 1) indirect beneficial impacts to aquatic habitat in Ross Creek, Dry Creek and the East Fork of the Gallatin River via increase flow volumes, and 2) indirect adverse impacts to waterfowl habitat through drying up the hay field that receives seepage water. The project is highly likely to have a negative impact on waterfowl and other bird habitat. These impacts will be moderate (impacting approximately 30 acres), local, long-term, and reoccurring.

No Action Alternative – No impact

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9. UNIQUE, ENDANGERED, FRAGILE OR LIMITED ENVIRONMENTAL RESOURCES:

Consider any federally listed threatened or endangered species or habitat identified in the project area. Determine effects to wetlands. Consider Sensitive Species or Species of special concern. Identify direct, indirect, and cumulative effects to these species and their habitat.

According to the NWI the project area contains several wetland and aquatic habitat types including emergent and scrub-shrub palustrine wetlands. There are also two perennial waterways mapped to the southeast of where the project work will occur, Smith Creek and the East Gallatin River. The wetland areas that could be impacted by the project are very small areas of riparian emergent (Rp1EM) and palustrine emergent (PEM) wetlands. There are no critical habitats for threatened or endangered species within the project area.

DNRC also used the U.S. Fish and Wildlife Service's Information Planning and Consultation (IPaC) tool to generate a resource list summarizing any endangered or threatened species that are known or expected to be near the project area. The IPaC list generated five (5) Federally listed species under the Endangered Species Act as potentially occurring in the greater project area, including: Canada Lynx (*Lynx canadensis*), Grizzly Bear (*Ursus arctos horibilis*), North American Wolverine (*Gulo gulo luscus*), Monarch Butterfly (*Danaus plexippus*), and Ute Ladies'-tresses (*Spirantes diluvialus*). It also listed seven (7) migratory bird species including two eagle species: Bald Eagle (Haliaeetus leucocephalus), Golden Eagle (Aquila chrysaetos), Bobolink (Dolichonyx oryzivorus), Lesser Yellowlegs (Tringa flavipes), Olive-sided Flycatched (Contopus cooperi), Western Grebe (Aechmophorus occidentalis), and Willet (Tringa semipalmata; USFWS IPaC). The seven bird species are protected under the Migratory Bird Treaty Act of 1918, the eagles are protected under the Bald and Golden Eagle Act of 1940, and the Bald Eagle is also protected under the Montana Bald Eagle Management Plan and the Lacey Act of 1900.

Proposed Alternative – The proposed project will have moderate to severe, long-term, local, re-occurring, direct and indirect adverse impacts on the wetlands that are down-gradient of the canal section to be lined. No wetland delineation has been conducted so the number of acres potentially impacted cannot be calculated. **Altering the hydrologic source that supports these wetlands is potentially in conflict with federal law, and the US Army Corps of Engineers should be consulted on the matter.**

No Action Alternative – No impact on unique, endangered, fragile, or limited environmental resources.

10. HISTORICAL AND ARCHAEOLOGICAL SITES:

Identify and determine direct, indirect, and cumulative effects to historical, archaeological or paleontological resources.

There are no known historical or archaeological sites within the project area. SHPO has not yet been consulted.

Proposed Alternative – No impact. However, the ditch will likely be considered historic and may require examination by a cultural resources expert. Regardless of the cultural resource search results, if any cultural or paleontological materials are identified during project related activities, all work will cease until a professional assessment of such resources can be made.

No Action Alternative – No impact to historical and archaeological sites.

11. AESTHETICS:

Determine if the project is located on a prominent topographic feature, or may be visible from populated or scenic areas. What level of noise, light or visual change would be produced? Identify direct, indirect, and cumulative effects to aesthetics.

The current conditions are typical of agricultural areas in Montana. Property tracts are typically 100 acres or more. Most of the roads in the area are two-lane dirt roads though the Dry Creek Road is paved in the vicinity of the project. The project will be visible to local property owners. Temporary impacts to noise from construction equipment will occur. In some cases, visual quality and aesthetics may be improved from planned activities for the project. Some noise will occur during the construction phase of the project.

Proposed Alternative – Potentially direct and indirect, negligible to minor, short-term, local, non-recurring adverse impacts to aesthetics during construction. The sediment trap installation will be an obvious change to the landscape near the intersection of Dry Creek and Duncan Roads. Indirect, adverse nuisance impacts from heavy construction equipment will be temporary during the project and may include noise and exhaust fumes. Noise mitigation techniques to minimize impacts to the surrounding areas will be used by the contractor whenever possible. Construction working hours should be limited to 7 AM to 7 PM.

No plans were provided that describe where the material excavated during the sediment trap construction will be placed. If the fill is hauled off site, fill placement will no cause any impact. Should the fill be placed somewhere within the project area, the probability for direct, adverse aesthetic impact is likely. Depending on where fill is placed and how it is graded and reclaimed, the impacts could range from negligible to major. The extent of these impacts would be local, and long term. However, if the site is reclaimed properly and graded to blend into the existing landscape, the impact area could eventually match the aesthetics of the current landscape and become non-noticeable. The impacts associated with fill placement could be precedent setting if poorly planned and executed. Permitting agencies should examine the project carefully and may require that fill be placed in particular areas and following certain specifications to not adversely impact the viewshed of the area.

A negligible, short-term, re-occurring, adverse aesthetic impact may be observed in association with the periodic cleaning out the sediment trap. Sediment trap clean-out impacts are likely to be short-term and negligible as the proposed plan for accumulated sediment disposal is to spread the sediment on adjacent agricultural fields as fertilizer. Fill placement is mostly likely to take place when the hay fields are already bare (i.e. in spring and fall) as placement at any other time would impede crop production.

No Action Alternative – No impact on aesthetics.

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12. DEMANDS ON ENVIRONMENTAL RESOURCES OF LAND, WATER, AIR OR ENERGY:

Determine the amount of limited resources the project would require. Identify other activities nearby that the project would affect. Identify direct, indirect, and cumulative effects to environmental resources.

The current condition of the Dry Creek Irrigation Canal creates an excessive demand on surface water, which is a finite resource. No other resources are impacted but the current condition.

Proposed Alternative – The proposed alternative would create a direct, long-term, beneficial impact on aquatic resources because it will increase the amount of surface water available in the East Gallatin River and Ross Creek. The project will not impact any land or energy resources.

No Action Alternative – The no action alternative would perpetuate adverse impacts through irrigation water inefficiencies.

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13. OTHER ENVIRONMENTAL DOCUMENTS PERTINENT TO THE AREA:

List other studies, plans or projects on this tract. Determine cumulative impacts likely to occur as a result of current private, state or federal actions in the analysis area, and from future proposed state actions in the analysis area that are under MEPA review (scoped) or permitting review by any state agency.

No other environmental review documents are known to exist for the project area.

Proposed Alternative & No Impact Alternative – No impact on environmental documents.

IV. IMPACTS ON THE HUMAN POPULATION

- *RESOURCES potentially impacted are listed on the form, followed by common issues that would be considered.*
- *Explain POTENTIAL IMPACTS AND MITIGATIONS following each resource heading.*
- *Enter "NONE" If no impacts are identified or the resource is not present.*

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14. HUMAN HEALTH AND SAFETY:

Identify any health and safety risks posed by the project.

The project area is primarily a sparsely developed residential and commercial area and may contain power lines and other potentially hazardous utilities. There are no known regulated underground storage tanks, sources of hazardous waste, potential source of toxic release, superfund, or brownfields sites in or near to the project area. The current condition of the canal is creating unsafe conditions for farmers and farming equipment downgradient from the canal seepage. The overly saturated soils in the area create hazards for when farmers are cutting hay or using heavy equipment.

Proposed Alternative – The project will have an overall beneficial impact on the health and safety of farmers working the land by reducing the amount of soil saturation in fields adjacent to the Canal. The sediment pond portion of the proposed alternative could cause a negligible, long-term, localized adverse impact by increasing the potential for drowning should passersby enter the sediment pond. The Dry Creek Canal is a significant irrigation conveyance structure within the Gallatin Valley. The Canal conveys enough water to pose a significant human health and safety hazard to people, especially children, who might fall or jump into the Canal. However, all proposed project areas occur on private land that can be adequately fenced and signed to protect the public.

No Action Alternative – No impact on human health and safety.

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15. INDUSTRIAL, COMMERCIAL AND AGRICULTURE ACTIVITIES AND PRODUCTION:

Identify how the project would add to or alter these activities.

The current condition has a direct adverse impact on agricultural production through the loss of farmland productivity due to irrigation water seepage. Accounting for the hay field adjacent to the Canal section proposed for lining, putting 30 acres back into hay production could generate approximately $22,000 in gross revenue (assuming 3.25 tons of hay produced/acre, and $233/ton sale price).

Proposed Alternative – The proposed project will have an indirect, direct, short- and long-term beneficial impacts by improving water retention within the Canal and reducing seepage. This will result in improved crop production for the users of the Dry Creek Canal.

No Action Alternative – The no action alternative would perpetuate adverse impacts to agricultural production. Land that could be agriculturally productive has been taken out of production due to soil saturation and inundation. Additionally, water supply is less reliable at the downstream end of the canal and may result in additional productivity losses.

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16. QUANTITY AND DISTRIBUTION OF EMPLOYMENT:

Estimate the number of jobs the project would create, move or eliminate. Identify direct, indirect, and cumulative effects to the employment market.

The project area is not within a residential or commercial area. It is located outside of the Cities of Belgrade and Manhattan, Montana. According to the U.S. Census Bureau, the median household income of the City of Belgrade in 2021 was $72,921 +/- $37,871 per capita income. The U.S. Census Bureau also determined that 88% of the population was living at or above the poverty level, with 12% living below the poverty level.

Proposed Alternative – This project will have a short-term beneficial impact to employment by the creation of short-term construction jobs. Additionally, the increase in contractors could benefit local shops, gas stations, trucking companies, suppliers, etc. The project will also maximize crop production for the users of the system, which could result in a small bump in agricultural employment.

No Action Alternative – No impact to the quantity and distribution of employment.

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17. LOCAL AND STATE TAX BASE AND TAX REVENUES:

Estimate tax revenue the project would create or eliminate. Identify direct, indirect, and cumulative effects to taxes and revenue.

Seepage from the canal is directly impacting crop production in the area. Annual crop production could be approximately $25,000-$40,000 higher than under the current conditions if the area was matching that of areas not impacted by seepage (Technical Memo, Attachment B). If seepage from the Canal gets worse over time, these losses could be higher in the future.

Proposed Alternative – The water resources conveyed by the Canal have a direct beneficial impact on agricultural production and therefore on the State income tax base. Farming income is likely to increase after the project is completed and therefore will benefit the tax base for the State by increasing farm production revenue.

No Action Alternative – The no action alternative has direct adverse impacts that lead to less agricultural production for the irrigation water users and farmers who hay the fields adjacent to the Canal.

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18. DEMAND FOR GOVERNMENT SERVICES:

Estimate increases in traffic and changes to traffic patterns. What changes would be needed to fire protection, police, schools, etc.? Identify direct, indirect, and cumulative effects of this and other projects on government services

The current condition does not pose much demand on government services besides road maintenance.

Proposed Alternative – Potential indirect beneficial impacts to the local schools, health and medical services and facilities, and parks, playgrounds and open space could be improved from the increase in tax revenue generated from agricultural production.

No Action Alternative – No impact on the demand for government services.

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19. LOCALLY ADOPTED ENVIRONMENTAL PLANS AND GOALS:

List State, County, City, USFS, BLM, Tribal, and other zoning or management plans, and identify how they would affect this project.

All property within the project area is private and not subject to zoning restrictions.

Proposed Alternative & No Action Alternative – No impact to locally adopted environmental plans and goals.

---

20. ACCESS TO AND QUALITY OF RECREATIONAL AND WILDERNESS ACTIVITIES:

Identify any wilderness or recreational areas nearby or access routes through this tract. Determine the effects of the project on recreational potential within the tract. Identify direct, indirect, and cumulative effects to recreational and wilderness activities.

All project activities will take place on private land and will not impact any recreational or wilderness activities for the public. However, current condition allows for the loss of irrigation water through seepage which results in an unwarranted diversion of water from the East Gallatin River, potentially having an indirect adverse impact on fish populations and on fishing within the river.

Proposed Alternative – The proposed project will have an indirect beneficial impact to recreation activities along the river by improving water quantity in the East Gallatin River. This impact is significant as the East Gallatin River is popular for recreational activities such as fishing, hiking, wildlife viewing, etc.

No Action Alternative – The no action alternative will lead to continued dewatering of the East Gallatin River thus having a minor, indirect adverse impact on the recreational opportunities in most years. In drought years, these adverse impacts may be more severe but is difficult to quantify. Such impacts are local, long-term, and re-occurring but do not create any new president or potential for conflict with current laws, requirements, or plans.

---

21. DENSITY AND DISTRIBUTION OF POPULATION AND HOUSING:

Estimate population changes and additional housing the project would require. Identify direct, indirect, and cumulative effects to population and housing.

Property adjacent or near to the project area is primarily used for residential, recreation, and agricultural uses which are serviced by the agricultural ditch. The land used within the project area is anticipated to have limited growth expected in the future.

Proposed Alternative & No Action Alternative – No impact on the density and distribution of population and housing.

---

22. SOCIAL STRUCTURES AND MORES:

Identify potential disruption of native or traditional lifestyles or communities.

The project area is largely made up of private agricultural farmland. No federally recognized Tribal land has been identified within the project area; however, the project does take place on land traditionally inhabited or used by the Cayuse, Umatilla, Walla Walla, and Salish (Native Land Digital web mapping application).

Proposed Alternative & No Action Alternative – No impact to social structures and mores.

---

23. CULTURAL UNIQUENESS AND DIVERSITY:

How would the action affect any unique quality of the area?

The current condition does not impact any cultural resources or diversity.

Proposed Alternative & No Action Alternative – No impact on cultural uniqueness and diversity.

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24. OTHER APPROPRIATE SOCIAL AND ECONOMIC CIRCUMSTANCES:

Include appropriate economic analysis. Identify potential future uses for the analysis area other than existing management. Identify direct, indirect, and cumulative economic and social effects likely to occur as a result of the proposed action.

The Gallatin Valley is growing rapidly and experiencing rapid population growth. The land area surrounding the project could easily be developed for housing or other commercial uses within the foreseeable future, especially in the dry areas not currently being impacted by seepage.

Proposed Alternative –The proposed alternative will have an indirect beneficial impact to lands that cannot currently support development due to the degree of soil saturation. Though unlikely due to high groundwater tables Groundwater tables in the Valley are naturally high as well and it is possible that the proposed alternative will not dry out the land enough to support building development.

No Action Alternative – The no action alternative my continue to prohibit building in the project area due to continually saturated soils.

25. DRINKING WATER AND/OR CLEAN WATER

Identify potential impacts to water and/or sewer infrastructure (e.g., community water supply, stormwater, sewage system, solid waste management) and identify direct, indirect, and cumulative effects likely to occur as a result of the proposed action.

Most residences in the vicinity of the project area obtain drinking water from private wells. The groundwater table in the area is quite high and most wells are less than 100 feet deep (often less than 50 feet) indicating that the aquifer is shallow. The seepage from the Dry Creek Irrigation Canal is likely to provide groundwater re-charge sufficient to impact some people's well depths and volumes.

Proposed Alternative – The proposed alternative will likely have an indirect, minor, long-term, local, re-occurring adverse impact groundwater re-charge in areas impacted by seepage. There are eight documented private wells that may be impacted by the lining of the Canal, all of which were dug much deeper than the reported static water level, which is less than 10 feet in several cases. While these well owners may notice slight changes in their well-water depths and recharge rates after the project is implemented, these changes are likely to be negligible due to the naturally high water table within the area. Loss of groundwater re-charge due to lining the Canal is not expected to set a precedent or create conflict.

No Action Alternative – No impact on drinking water or clean water.

26. ENVIRONMENTAL JUSTICE

Will the proposed project result in disproportionately high or adverse human health or environmental effects on minority or low-income populations per the Environmental Justice Executive Order 12898? Identify potential impacts to and identify direct, indirect, and cumulative effects likely to occur as a result of the proposed action.

The proposed project area is on private land and does not affect minority or low-income populations.

Proposed Alternative & No Action Alternative – No impact on environmental justice.

EA Prepared By:	**Name:**	Samantha Treu	**Date:**	10/05/2023
	Title:	MEPA/NEPA Coordinator	**Email:**	samantha.treu@mt.gov

V. FINDING

27. ALTERNATIVE SELECTED:

Alternative 1 – Line a portion of the Dry Creek Irrigation Ditch and construct a sediment pond.
This is the preferred alternative as it will address seepage in a critical portion of the Dry Creek Irrigation Canal. This alternative will benefit water users along the canal by allowing increased agricultural production in the field adjacent to the newly lined canal segment and increasing reliability of irrigation water supply for other water users along the canal. Alternative 1 will benefit

the natural environment by keeping more water in the streams that feed the canal, and potentially reducing sediment loads to Dry Creek and the East Gallatin River.

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28. SIGNIFICANCE OF POTENTIAL IMPACTS:

GEOLOGY AND SOIL QUALITY, STABILITY AND MOISTURE:
The proposed alternative will have short-term, localized, nonrecurring adverse impacts on soil stability, as the soil surrounding the Dry Creek Canal will be disturbed during construction. Adverse impacts should be mitigated by following proper best management practices (BMPs) for erosion control.

WATER QUALITY, QUANTITY, AND DISTRIBUTION
The project may have a short- and long-term, recurring, localized adverse impact on groundwater recharge due to reduced amounts of seepage. This minor adverse impact will be one-time, long-term, local, relatively unimportant, and should not establish any new precedent or open any new conflicts. Mitigation option exists for loss of groundwater recharge unless provided by the proposed sediment trap.

AIR QUALITY
The proposed project may have short-term, minor to negligible, non-re-occurring, localized, direct adverse impacts to air quality from dust produced during construction. Impacts to air quality will be limited to the construction duration. Dust control and other Best Management Practices will be used to limit air quality impacts. Construction is anticipated to last approximately two months. The project will not have long term impacts to air quality.

VEGETATION COVER, QUANTITY AND QUALITY:
A minor to major, indirect to direct, short- to long-term adverse impact may be experienced within the project area in that approximately 30 acres of irrigation-supported wetlands will be converted to productive hay fields. This will be a one-time, long-term impact occurring adjacent to the portion of Canal that will be lined. While all wetlands are important one of the goals of the project is to transform the wet areas into productive crop land.

TERRESTRIAL, AVIAN AND AQUATIC LIFE AND HABITATS:
The habitat impacts for terrestrial, avian, and aquatic life will have indirect adverse impacts to wetland habitat through drying up the hay field that receives seepage water. The project is highly likely to have a negative impact on waterfowl and other bird habitat. These impacts will be moderate to severe (impacting approximately 30 acres), local, long-term, and reoccurring.

UNIQUE, ENDANGERED, FRAGILE OR LIMITED ENVIRONMENTAL RESOURCES:
The proposed project will have moderate to severe, long-term, local, re-occurring, direct and indirect adverse impacts on the wetlands that are down-gradient of the canal section to be lined. No wetland delineation has been conducted so the number of acres potentially impacted cannot be calculated. **Altering the hydrologic source that supports these wetlands is potentially in conflict with federal law, and the US Army Corps of Engineers should be consulted on the matter.**

AESTHETICS
Potentially direct and indirect, negligible to minor, short-term, local, non-recurring adverse impacts to aesthetics during construction. The sediment trap installation will be an obvious change to the

landscape near the intersection of Dry Creek and Duncan Roads. Indirect, adverse nuisance impacts from heavy construction equipment will be temporary during the project and may include noise and exhaust fumes. Noise mitigation techniques to minimize impacts to the surrounding areas will be used by the contractor whenever possible. Construction working hours should be limited to 7 AM to 7 PM.

No plans were provided that describe where the material excavated during the sediment trap construction will be placed. If the fill is hauled off site, fill placement will no cause any impact. Should the fill be placed somewhere within the project area, the probability for direct, adverse aesthetic impact is likely. Depending on where fill is placed and how it is graded and reclaimed, the impacts could range from negligible to major. The extent of these impacts would be local, and long term. However, if the site is reclaimed properly and graded to blend into the existing landscape, the impact area could eventually match the aesthetics of the current landscape and become non-noticeable. The impacts associated with fill placement could be precedent setting if poorly planned and executed. Permitting agencies should examine the project carefully and may require that fill be placed in particular areas and following certain specifications to not adversely impact the viewshed of the area.

A negligible, short-term, re-occurring, adverse aesthetic impact may be observed in association with the periodic cleaning out the sediment trap. Sediment trap clean-out impacts are likely to be short-term and negligible as the proposed plan for accumulated sediment disposal is to spread the sediment on adjacent agricultural fields as fertilizer. Fill placement is mostly likely to take place when the hay fields are already bare (i.e. in spring and fall) as placement at any other time would impede crop production.

HUMAN HEALTH AND SAFETY

The sediment pond portion of the proposed alternative could cause a negligible, long-term, localized adverse impact by increasing the potential for drowning should passersby enter the sediment pond. The Dry Creek Canal is a significant irrigation conveyance structure within the Gallatin Valley. The Canal conveys enough water to pose a significant human health and safety hazard to people, especially children, who might fall or jump into the Canal. However, all proposed project areas occur on private land that can be adequately fenced and signed to protect the public.

DRINKING WATER AND/OR CLEAN WATER

The proposed alternative will likely have an indirect, minor, long-term, local, re-occurring adverse impact groundwater re-charge in areas impacted by seepage. There are eight documented private wells that may be impacted by the lining of the Canal, all of which were dug much deeper than the reported static water level, which is less than 10 feet in several cases. While these well owners may notice slight changes in their well-water depths and recharge rates after the project is implemented, these changes are likely to be negligible due to the naturally high water table within the area. Loss of groundwater re-charge due to lining the Canal is not expected to set a precedent or create conflict.

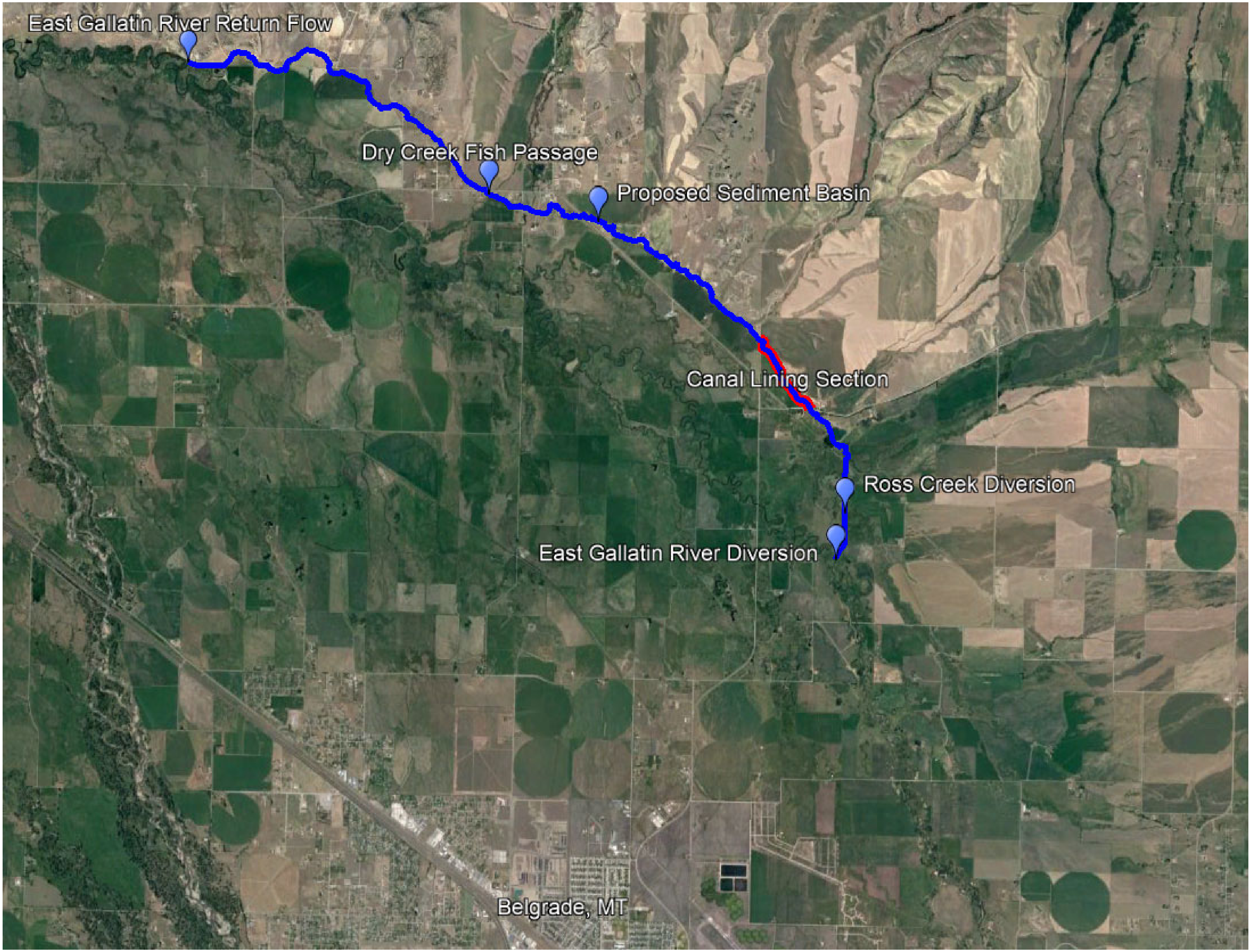
29. NEED FOR FURTHER ENVIRONMENTAL ANALYSIS:

No significant adverse impacts were identified during the preparation of this EA.

This is the final environmental review.

☐ EIS ☐ More Detailed EA ☒ No Further Analysis

EA Approved By:	**Name:** Mark W Bostrom **Title:** Division Administrator	
Signature:	DocuSigned by: Mark W Bostrom BF7A1C50B2AF4DE...	**Date:** 11/8/2023 | 2:02:31 PM MST


East Gallatin River Return Flow
Dry Creek Fish Passage
Proposed Sediment Basin
Canal Lining Section
Ross Creek Diversion
East Gallatin River Diversion
Belgrade, MT

ATTACHMENT B

MEPA CHECKLIST

Environmental Checklist

Applicant Name: Gallatin Conservation District

Project Title: Dry Creek Canal Improvements Project

Environmental Checklist Prepared by: On: 12/12/2021

Peter Haun, P.E.	WWC Engineering
Name of Person 1	Organization
406-624-3910	phaun@wwcengineering.com
Phone Number	Email
Click or tap here to enter text.	Click or tap here to enter text.
Name of Person 2	Organization
Click or tap here to enter text.	Click or tap here to enter text.
Phone Number	Email

Click or tap here to enter text.

List additional people above. Include organization, phone number and email for all.

<table>
<tr><th colspan="3">Physical Environment</th></tr>
<tr><th>Impact Code</th><th>Impact Type</th><th>Explanation of Impact to Resource</th></tr>
<tr><td colspan="3">1. Soil Suitability, Topographic and/or Geologic Constraints (example: soil lump, steep slopes, subsidence, seismic activity)</td></tr>
<tr><td>☐ No Impact
☐ Beneficial
☒ Adverse</td><td>☐ Direct
☐ Indirect
☐ Cumulative</td><td>Current Conditions:
There are no impacts to soil suitability, topographic, and/or geologic constraints.
Preferred Alternative Environmental Narrative:
There are no impacts to soil suitability, topographic, and/or geologic constraints.</td></tr>
<tr><td colspan="3">2. Hazardous Facilities (example: power lines, hazardous waste sites, acceptable distance from explosive and flammable hazards including chemical/petrochemical storage tanks, underground fuel storage tanks, and related facilities such as natural gas storage facilities and propane storage tanks)</td></tr>
<tr><td>☒ No Impact
☐ Beneficial
☐ Adverse</td><td>☐ Direct
☐ Indirect
☐ Cumulative</td><td>Current Conditions:
There are no hazardous facilities in the vicinity of the project area.
Preferred Alternative Environmental Narrative:
There are no hazardous facilities in the vicinity of the project area.</td></tr>
<tr><td colspan="3">3. Surrounding Air Quality (example: dust, odors, emissions)</td></tr>
<tr><td>☐ No Impact
☐ Beneficial
☒ Adverse</td><td>☒ Direct
☐ Indirect
☐ Cumulative</td><td>Current Conditions:
The current condition has no effect on surrounding air quality.
Preferred Alternative Environmental Narrative:
The proposed project may have short-term direct impacts to air quality from dust produced during construction. However, it will be specified in the contract documents that dust control measures will be taken in the event dust becomes excessive. The short duration of the project will limit air quality impacts to the</td></tr>
</table>

		timeframe of the project, approximately two months of construction. The project will not have long term impacts to air quality. Severity: The severity of air quality impacts from the proposed project will be minor or negligible. Duration: Impacts to air quality will be limited to the construction duration. It is anticipated that construction will last approximately two months. Extent: Impacts to air quality are expected to be localized and will only affect the immediate surrounding area of the construction site. Frequency: The impacts to air quality are anticipated to be non-recurring and will only be seen during construction of the proposed project. Dust control and other Best Management Practices will be used to construction to limit air quality issues.
4. Groundwater Resources and Aquifers (example: quantity, quality, distribution, depth to groundwater, sole source aquifers)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The proposed improvements will not affect local groundwater resources or aquifers. Preferred Alternative Environmental Narrative: The proposed improvements will not affect local groundwater resources or aquifers.
5. Surface Water/Water Quality, Quantity and Distribution (example: streams, lakes, storm runoff, irrigation systems, canals)		
☐ No Impact ☒ Beneficial ☐ Adverse	☒ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition results in moderate impacts to water quality through sediment transport through the canal to Dry Creek and the East Gallatin River. Preferred Alternative Environmental Narrative: Implementation of the proposed project will reduce sediment loading and improve water quality of the East Gallatin River and Dry Creek, which have known sedimentation issues. Reducing seepage by lining a portion of the canal will also conserve water diverted from the East Gallatin River, resulting in increased water quality and quantity within the waterway.
6. Floodplains and Floodplain Management (Identify any floodplains within one mile of the boundary of the project.)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The project area is located in an Area of Minimal Flood Hazard, or Flood Zone X. Preferred Alternative Environmental Narrative: The project area is located in an Area of Minimal Flood Hazard, or Flood Zone X.

7. Wetlands (Identify any wetlands within one mile of the boundary of the project and state potential impacts.)

☐ No Impact ☒ Beneficial ☐ Adverse	☐ Direct ☒ Indirect ☐ Cumulative	Current Conditions: A search of wetlands within one mile of the project area resulted in several wetland areas near the proposed project areas. The wetlands are located within the East Gallatin River Floodplain and Riparian Areas. Preferred Alternative Environmental Narrative: Care will be taken by the contractor to minimize the impacts of all wetland areas using BMPs and other measures. The proposed project will benefit wetlands by limiting sediment discharges to critical downstream areas.

8. Agricultural Lands, Production, and Farmland Protection (example: grazing, forestry, cropland, prime or unique agricultural lands) Identify any prime or important farm ground or forest lands within one mile of the boundary of the project.

☐ No Impact ☒ Beneficial ☐ Adverse	☒ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has the ability to negatively impact agricultural lands, production, and farmland protection through the loss of irrigation water due to seepage. Preferred Alternative Environmental Narrative: The proposed project will improve water retention within the canal by reducing seepage, resulting in improved crop production for the users of the Dry Creek Canal.

9. Vegetation and Wildlife Species and Habitats, Including Fish (example: terrestrial, avian and aquatic life and habitats)

☐ No Impact ☒ Beneficial ☐ Adverse	☒ Direct ☒ Indirect ☐ Cumulative	Current Conditions: The current condition provides negative impacts to vegetation and wildlife specifies and habitats through impairment of water quality due to sediment loading and loss of water to seepage. Preferred Alternative Environmental Narrative: The proposed project will improve the water quality and water quality of the East Gallatin River and Dry Creek by reducing sediment loading and conserving water.Improved water quality and water quantity will lead to improved vegetation and wildlife habitat, especially aquatic habitats within Dry Creek and the East Gallatin River.

10. Unique, Endangered, Fragile, or Limited Environmental Resources, Including Endangered Species (example: plants, fish or wildlife)

☐ No Impact ☒ Beneficial ☐ Adverse	☐ Direct ☒ Indirect ☐ Cumulative	Current Conditions: A search was performed for the project locations to obtain information on species of concern within the project area. The search indicated that the proposed project area is located near possible habitat for twenty one (21) species of concern. The implementation of the preferred alternative will effectively minimize sedimentation, improve water quality, and augment flows within the East Gallatin River. Preferred Alternative Environmental Narrative: The proposed project will improve water quality within both the East Gallatin River and Dry Creek and improve water quantity within the East Gallatin River, therefore improving aquatic habitats and potentially benefitting Unique, Endangered, Fragile, or Limited Environmental Resources.

11. Unique Natural Features (example: geologic features)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The project area contains no unique natural features that will be impacted by the proposed project. Preferred Alternative Environmental Narrative: There are no unique natural features within the project area that will be impacted by the proposed project.
12. Access to, and Quality of, Recreational and Wilderness Activities, Public Lands and Waterways, and Public Open Space		
☐ No Impact ☒ Beneficial ☐ Adverse	☐ Direct ☒ Indirect ☐ Cumulative	Current Conditions: The current condition allows for the loss of irrigation water through seepage which results in an unwarranted diversion of water from the East Gallatin River. Preferred Alternative Environmental Narrative: The proposed project will improve water quality and water quantity of the East Gallatin River, resulting in improved recreation activities along the river. The East Gallatin River is popular for recreationalists such as fisherman, hikers, wildlife viewer, etc. The proposed improvements may benefit the quality of recreational activities by increasing water quantity and quality.
Human Environment		
Impact Code	**Impact Type**	**Resource**
1. Visual Quality – Coherence, Diversity, Compatibility of Use and Scale, Aesthetics		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition for visual quality is irrigation canals. Preferred Alternative Environmental Narrative: The proposed improvements do not change the visual quality of the existing canals.
2. Nuisances (example: glare, fumes)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: There are no nuisances in the project area. Preferred Alternative Environmental Narrative: The proposed improvements will not create a nuisance.
3. Noise – Suitable Separation Between Housing and Other Noise Sensitive Activities and Major Noise Sources (example: aircraft, highways and railroads.)		
☐ No Impact ☐ Beneficial ☒ Adverse	☒ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition does not emit major noise sources, only the noise from flowing water and occasionally from equipment used for ditch maintenance. Preferred Alternative Environmental Narrative: Noise will only be created during the short-term construction period and will be limited to approximately 2 months. Noise will be localized to just the project area and the immediate surroundings. Noise will be reoccurring during construction. The contractor will minimize noise and steps will be taken to reduce noise impacts to the surrounding area.

4. Historic Properties, Cultural, and Archaeological Resources***(Please see end of Environmental Checklist for details if Cultural Survey has not been performed per SHPO Section 106)*		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: There have been no historic properties, cultural, or archaeological resources that have been identified within the proposed project areas. Preferred Alternative Environmental Narrative: There have been no historical properties, cultural, or archaeological resources that have been identified in the area. Should any resources
5. Changes in Demographic (Population) Characteristics (example: quantity, distribution, density)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no impact on demographic characteristics in the area. Preferred Alternative Environmental Narrative: The proposed improvements will not impact the demographic characteristics of the area.
6. General Housing Conditions – Quality, Quantity, Affordability		
☐ No Impact ☒ Beneficial ☐ Adverse	☐ Direct ☒ Indirect ☐ Cumulative	Current Conditions: The current condition has no impact on general housing conditions. Preferred Alternative Environmental Narrative: The proposed improvements will improve crop production and revenue, resulting in a direct benefit of the standard of living for local residents and potentially benefitting the housing conditions.
7. Businesses or Residents (example: loss of, displacement, or relocation)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no impact on local businesses or residents. Preferred Alternative Environmental Narrative: The proposed improvements will not displace or relocate businesses or residents.
8. Public Health and Safety		
☐ No Impact ☒ Beneficial ☐ Adverse	☒ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition of the canal is creating unsafe conditions for farmers and farming equipment downgradient from the canal seepage. The overly saturated soils in the area create hazards for when farmers are cutting hay or using heavy equipment. Preferred Alternative Environmental Narrative: The proposed improvements project will line the portion of the canal creating the seepage problem, thereby removing the hazard to public health and safety.
9. Local Employment – Quantity or Distribution of Employment, Economic Impact		
☐ No Impact ☒ Beneficial ☐ Adverse	☒ Direct ☒ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on local employment. Preferred Alternative Environmental Narrative: Short-term construction jobs will be created during construction of the proposed project. Additionally, the project could benefit local shops, gas stations, trucking companies, suppliers, etc. The project will also maximize crop production for the users of the system, resulting in maximized agricultural revenue for the canal's users.

10. Income Patterns – Economic Impact		
☐ No Impact ☒ Beneficial ☐ Adverse	☒ Direct ☒ Indirect ☐ Cumulative	Current Conditions: If the project does not take place, continues seepage of the canal could continue a reduction in crop revenue, resulting in negative economic impacts to the local economy. Preferred Alternative Environmental Narrative: The proposed project will indirectly benefit local shops, gas stations, trucking companies, suppliers, etc. during construction by bringing workers to the area. The project will also maximize crop production for the users of the system, resulting in improved agricultural revenue for the irrigation water users. Increased revendue in the area could potentially filter down into the local economy, providing a potential economic boost.
11. Local and State Tax Base and Revenues		
☐ No Impact ☒ Beneficial ☐ Adverse	☒ Direct ☒ Indirect ☐ Cumulative	Current Conditions: Click or tap here to enter text.If the project does not take place, continued seepage of the canal could continue to impact downstream users of the canal, resulting in crop revenue significantly reduced and negative economic impacts to the local economy. Preferred Alternative Environmental Narrative: Implementation of the proposed improvements will provide sustainable agricultural production in the area. The tax revenue from agricultural production will continue to be seen at both the local and state levels and an increase may occur due to construction activities.
12. Community and Government Services and Facilities (example: educational facilities; health and medical services and facilities; police; emergency medical services; and parks, playgrounds and open space)		
☐ No Impact ☒ Beneficial ☐ Adverse	☐ Direct ☒ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on community and government services and facilties. Preferred Alternative Environmental Narrative: Potential indirect benefits to the local schools, health and medical services and facilities, and parks, playgrounds and open space could be improved from the increase in tax revenue generated from agricultural production.
13. Commercial and Industrial Facilities – Production and Activity, Growth or Decline		
☐ No Impact ☒ Beneficial ☐ Adverse	☐ Direct ☒ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on commercial and industrial facilities. Preferred Alternative Environmental Narrative: During construction, the project could potentially benefit local shops, gas stations, trucking companies, suppliers, etc. indirectly. Increased sales at local businesses may be a result of the construction project.
14. Social Structures and Mores (example: standards of social conduct/social conventions)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on social structures and mores. Preferred Alternative Environmental Narrative: It is anticipated that the proposed project will not affect social structures in the area.

15. Land Use Compatibility (example: growth, land use change, development activity, adjacent land uses and potential conflicts)

☐ No Impact ☒ Beneficial ☐ Adverse	☒ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on land use compatibility. Preferred Alternative Environmental Narrative: The proposed project will allow the Dry Creek Irrigation Company to provide more water to it's downstream users following lining of the canal, thereby improving crop production and agricultural development in the area.

16. Energy Resources – Consumption and Conservation

☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on energy resources. Preferred Alternative Environmental Narrative: The proposed improvements will have no impact on energy resources.

17. Solid Waste Management

☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on solid waste management. Preferred Alternative Environmental Narrative: The proposed improvements will have no impact on solid waste management area.

18. Wastewater Treatment – Sewage System

☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on wastewater treatment. Preferred Alternative Environmental Narrative: The proposed project will have no impact on wastewater treatment in the area.

19. Storm Water – Surface Drainage

☐ No Impact ☐ Beneficial ☒ Adverse	☒ Direct ☒ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on storm water. Preferred Alternative Environmental Narrative: Potential impacts to storm water may occur during construction of the proposed project. Erosion control and potential impacts to surface drainage during construction will be managed using BMPs to protection nearby surface waters. Severity: Impacts to storm water are expected to be negligible. Duration: Any potential impacts to storm water will be limited to the duration of construction. Construction is anticipated to last two months.

20. Community Water Supply

☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition no effect on the community water supply. Preferred Alternative Environmental Narrative: The proposed improvements will have no effect on the community water supply.

21. Fire Protection – Hazards

☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition no effect on fire protection. Preferred Alternative Environmental Narrative: The proposed improvements will have no effect on fire protection.

22. Cultural Facilities, Cultural Uniqueness and Diversity		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition no effect on cultural facilities, cultural uniqueness, or diversity. Preferred Alternative Environmental Narrative: The proposed improvements will have no effect on cultural facilities, cultural uniqueness, or diversity.
23. Transportation Networks and Traffic Flow Conflicts (example: rail; auto including local traffic; airport runway clear zones – avoidance of incompatible land use in airport runway clear zones)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on transportation networks and traffic flow conflicts. Preferred Alternative Environmental Narrative: The proposed improvements project will not affect transportation networks or create traffic conflicts in the area.
24. Consistency with Local Ordinances, Resolutions, or Plans (example: conformance with local comprehensive plans, zoning, or capital improvement plans.)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on consistency with local ordinances, resolutions, or plans. Preferred Alternative Environmental Narrative: The proposed project will comply with all local ordinances resolutions, and plans in design and construction.
25. Private Property Rights (example: a regulatory action or project activity that reduces, minimizes, or eliminates the use of private property.)		
☒ No Impact ☐ Beneficial ☐ Adverse	☐ Direct ☐ Indirect ☐ Cumulative	Current Conditions: The current condition has no effect on private property rights. Preferred Alternative Environmental Narrative: The proposed improvements project will not result in regulatory action on private property rights.

Additional Information

****If no cultural survey has been performed, or is not expected to be needed, applicant must agree to the following statement:**

☒ I hereby agree that, to my knowledge, there are no cultural or paleontological materials in the proposed project site. If previously unknown cultural or paleontological materials are identified during project related activities, the DNRC grant manager will be notified, and all work will cease until a professional assessment of such resources can be made.

List all sources of information used to complete the Environmental Checklist. Sources may include studies, plans, documents, or the individuals, organizations, or agencies contacted for assistance. For individuals, groups, or agencies, please include a contact person and phone number. List any scoping documents or meetings and/or public meetings during project development.

WWC Engineering Site Visit 11-5-2021

Dry Creek Irrigation Company Staff

Montana Natural Heritage Program website accessed 12/13/2021

National Wetlands Inventory Website Accessed 12/13/2021

FEMA Map Service Center

Below is a list of electronic resources available for data gathering to aid in the development of the Environmental Checklist:

Abandoned Mines (DEQ): https://deq.mt.gov/Land/abandonedmines/bluebook

Agricultural Statistics (USDA): USDA - National Agricultural Statistics Service - Data and Statistics

Air Quality

- Nonattainment Areas: http://deq.mt.gov/Air/airquality/planning/airnonattainmentstatus
- Citizens' Guide: http://deq.mt.gov/Air/airmonitoring/citguide

Army Corps of Engineers: http://www.usace.army.mil/Home.aspx

Bureau of Business and Economic Research, UM: http://www.bber.umt.edu/

Cadastral (for property ownership info): http://svc.mt.gov/msl/mtcadastral

Census Information, MT Dept. of Commerce: http://ceic.mt.gov

Conservation Districts, MT: http://macdnet.org/

Cultural Records

- Montana Historical Society: http://mhs.mt.gov/shpo/culturalrecords.asp

DEQ data search tools: Montana DEQ's GIS Portal (mt.gov)

- Including Clean Water Act Info Center, Hazardous Waste Handlers, Petroleum Release Fund Claims, Unpermitted Releases, Underground Storage Tanks, Source Water Protection

EPA Enforcement and Compliance History Online http://echo.epa.gov/

Farmland Classification: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Fish (Also See Wildlife)

- Montana Fisheries Information System: Montana Fish, Wildlife & Parks GIS Data (arcgis.com)
- Aquatic Invasive Species: Montana FWP AIS Surveys Dashboard 2021 (arcgis.com)

Floodplain Maps, FEMA: https://msc.fema.gov/portal

Geographic Information, Natural Resources Information System: http://nris.mt.gov/gis

Geologic Information - MBMG - Publications - Download Geologic Maps (mtech.edu)

Maps of Montana for species observations, land cover, wetland and riparian areas, land management: Montana Natural Heritage Program (mtnhp.org); http://mtnhp.org/mapviewer/?t=6

Montana Department of Transportation Environmental Manual: http://www.mdt.mt.gov/publications/docs/manuals/env/preface.pdf

Montana Board of Oil and Gas Conservation Information System: http://bogc.dnrc.mt.gov/webApps/DataMiner/

Plants

- Plant database, USDA Natural Resources Conservation Service: http://plants.usda.gov/java
- Plant Species, MT Field Guide: http://fieldguide.mt.gov/default.aspx
- Plant Species of Concern: http://mtnhp.org/SpeciesOfConcern/Default.aspx?AorP=p
- Threatened and endangered plants, USDA: http://plants.usda.gov/threat.html

Soils

- USDA Natural Resource Conservation Service database: https://websoilsurvey.nrcs.usda.gov/app/
- Montana soil and water conservation districts: http://swcdmi.org/

State Historic Preservation Office: http://mhs.mt.gov/Shpo

Tourism, UM – Institute of Tourism & Recreation Research: http://www.itrr.umt.edu

Tribal Resources:

- Blackfeet Tribal Environmental Permits: http://www.blackfeetenvironmental.com
- CSKT Natural Resources Department: http://nrd.csktribes.org/
- Montana Office of Indian Affairs: http://tribalnations.mt.gov/
- Tribal Historic Preservation Officer List Search - NATHPO

Vehicle Traffic Count (MDT): http://www.mdt.mt.gov/publications/datastats/traffic.shtml

Water

- Stream Record Extension Facilitator, USGS: USGS | National Water Dashboard
- Streamstats basin characteristics, USGS: http://water.usgs.gov/osw/streamstats/
- Water Resources Division, DNRC: http://dnrc.mt.gov/divisions/water ; ArcGIS Web Application (mt.gov)
- Water Rights Bureau, DNRC: http://dnrc.mt.gov/divisions/water/water-rights
- Water Right Query System, DNRC: DNRC Water Right Query System (mt.gov)
- Wetlands database, USFWS: http://www.fws.gov/wetlands/Data/mapper.html

Wild and Scenic Rivers: http://www.rivers.gov/montana.php

Wildlife

- Animal Species, MT Field Guide: http://fieldguide.mt.gov/default.aspx
- Animal Species of Concern: http://mtnhp.org/SpeciesOfConcern/Default.aspx?AorP=a
- Aquatic Invasive Species: Montana FWP AIS Surveys Dashboard 2021 (arcgis.com)
- Critical Habitat Mapper, USFWS: http://ecos.fws.gov/crithab/
- Crucial Areas Planning System/Habitat Assessment Tool: Habitat MT (HB 526) Funded Lands (arcgis.com)
- FWP Contact Map: http://fwp.mt.gov/gis/maps/contactUs/ (includes biologist responsibility areas)
- Maps and GIS Data, FWP: Montana Fish, Wildlife & Parks GIS Data (arcgis.com)
- Sage grouse management, FWP: Montana Fish, Wildlife & Parks GIS Data : Sage-grouse Habitat/Current Distribution (Montana) : Sage-grouse Habitat/Current Distribution (Montana) (arcgis.com)
- Sage grouse habitat conservation program, DNRC: http://sagegrouse.mt.gov/
- Sage grouse habitat map: https://sagegrouse.mt.gov/ProgramMap

ATTACHMENT C

MTNHP ENVIRONMENTAL SUMMARY

Environmental Summary

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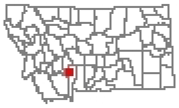
NATURAL HERITAGE PROGRAM mtnhp.org

1201 11th Ave ◦ P.O. Box 201800 ◦ Helena, MT 59620-1800 ◦ fax 406-444-0266 ◦ phone 406-444-3989



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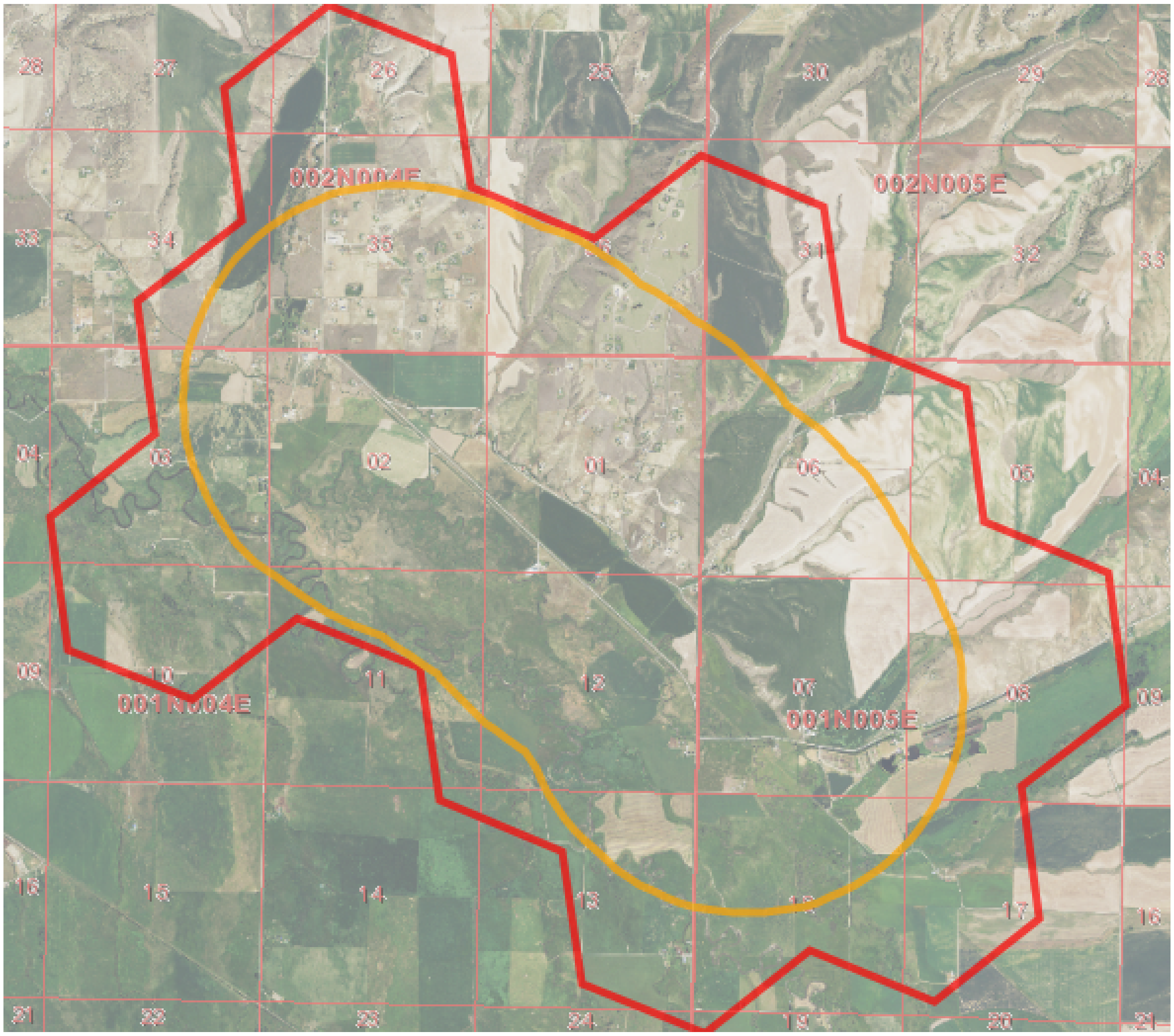
45.89960	-111.22135

Summarized by:
24prvt0053
(Custom Area of Interest)



Suggested Citation
Montana Natural Heritage Program. Environmental Summary Report.
for Latitude 45.82897 to 45.89960 and Longitude -111.11990 to -111.22135. Retrieved on 8/29/2023.

The Montana Natural Heritage Program is part of the Montana State Library's Natural Resource Information System. Since 1985, it has served as a neutral and non-regulatory provider of easily accessible information on Montana's species and biological communities to inform all stakeholders in environmental review, permitting, and planning processes. The program is part of the NatureServe network that is composed of over 60 member programs across North America that work to provide current and comprehensive distribution and status information on species and biological communities.

MONTANA STATE LIBRARY NATURAL HERITAGE PROGRAM   NATURESERVE

Table of Contents

- Species Report
- Structured Surveys
- Land Cover
- Wetland and Riparian
- Land Management
- Biological Reports
- Invasive and Pest Species
- Introduction to Montana Natural Heritage Program
- Data Use Terms and Conditions
- Suggested Contacts for Natural Resource Agencies
- Introduction to Native Species
- Introduction to Land Cover
- Introduction to Wetland and Riparian
- Introduction to Land Management
- Introduction to Invasive and Pest Species
- Additional Information Resources

Introduction to Environmental Summary Report

Environmental Summary Reports from the Montana Natural Heritage Program (MTNHP) provide information on species and biological communities to inform all stakeholders in environmental review, permitting, and planning processes. For information on environmental permits in Montana, please see permitting overviews by the Montana Department of Environmental Quality, the Montana Department of Natural Resources and Conservation, the Index of Environmental Permits for Montana and our Suggested Contacts for Natural Resource Management Agencies. The report for your area of interest consists of introductory and related materials in this PDF and an Excel workbook with worksheets summarizing information managed in the MTNHP databases for: (1) species occurrences; (2) other observed species without species occurrences; (3) other species potentially present based on their range, presence of associated habitats, or predictive distribution model output if available; (4) structured surveys that follow a protocol capable of detecting one or more species; (5) land cover mapped as ecological systems; (6) wetland and riparian mapping; (7) land management categories; and (8) biological reports associated with plant and animal observations. If your area of interest corresponds to a statewide polygon layer (e.g., watersheds, counties, or public land survey sections) information summaries in your report will exactly match those boundaries. However, if your report is for a custom area, users should be aware that summaries do not correspond to the exact boundaries of the polygon they have specified, but instead are a summary across a layer of hexagons intersected by the polygon they specified as shown on the report cover. Summarizing by these hexagons which are one square mile in area and approximately one kilometer in length on each side allows for consistent and rapid delivery of summaries based on a uniform grid that has been used for planning efforts across North America.

In presenting this information, MTNHP is working towards assisting the user with rapidly assessing the known or potential species and biological communities, land management categories, and biological reports associated with the report area. Users are reminded that this information is likely incomplete and may be inaccurate as surveys to document species are lacking in many areas of the state, species' range polygons often include regions of unsuitable habitat, methods of predicting the presence of species or communities are constantly improving, and information is constantly being added and updated in our databases. **Field verification by professional biologists of the absence or presence of species and biological communities in a report area will always be an important obligation of users of our data. Users are encouraged to only use this environmental summary report as a starting point for more in depth analyses and are encouraged to contact state, federal, and tribal resource management agencies for additional data or management guidelines relevant to your efforts. Please see the Appendix for introductory materials to each section of the report, additional information resources, and a list of relevant agency contacts.**

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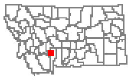
Model Icons
- N Suitable (native range)
- O Optimal Suitability
- M Moderate Suitability
- L Low Suitability
- I Suitable (introduced range)

Habitat Icons
- C Common
- O Occasional

Range Icons
- Y Native / Year-round
- S Summer
- W Winter
- M Migratory
- N Non-native
- H Historical

Num Obs
Count of obs with 'good precision' (<=1000m)
+ indicates additional 'poor precision' obs (1001m-10,000m)



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45.82897	-111.11990
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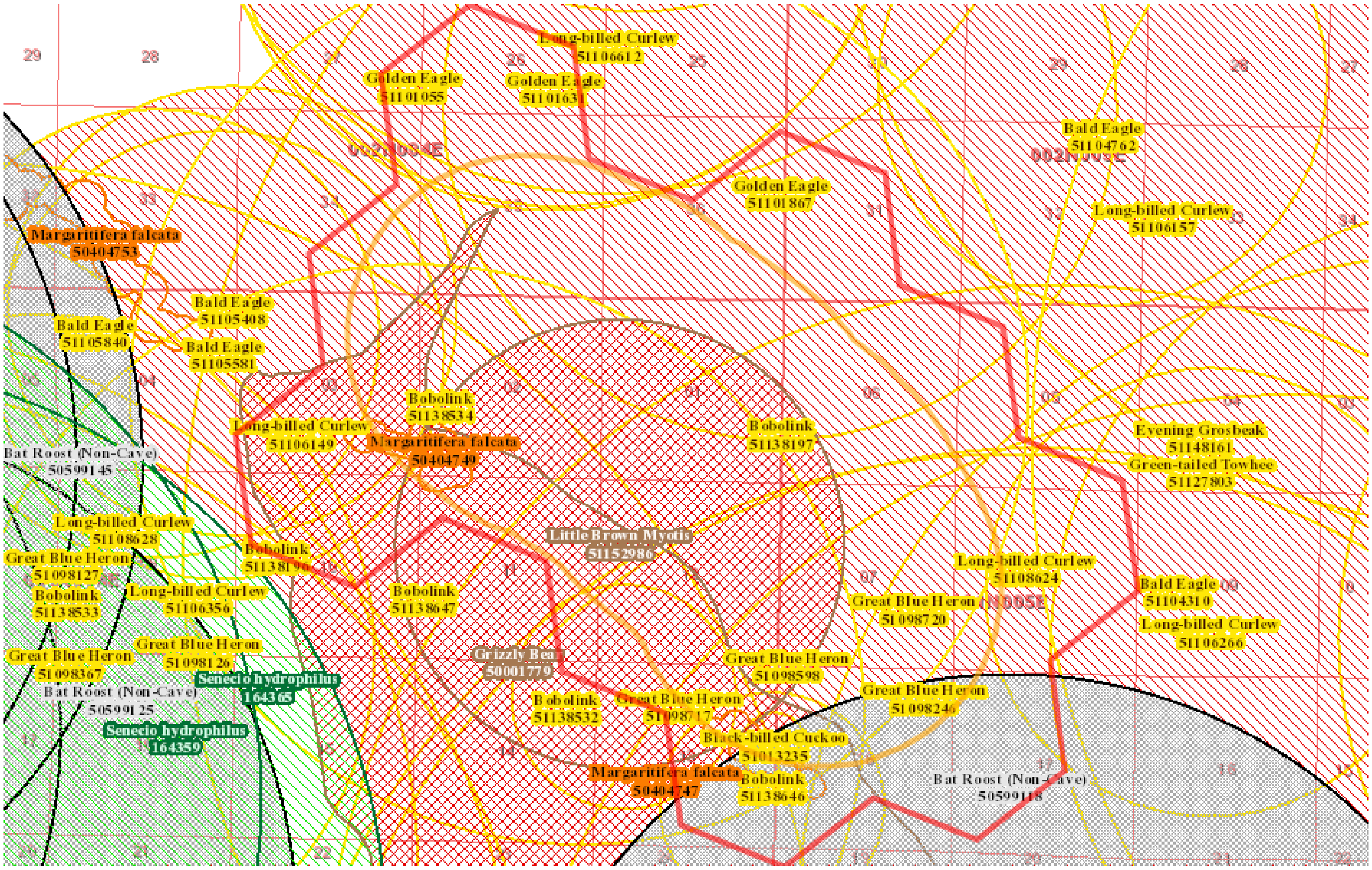
Native Species

Summarized by: **24prvt0053** *(Custom Area of Interest)*
Filtered by:
Native Species reports are filtered for Species with MT Status = Species of Concern, Special Status, Important Animal Habitat, Potential SOC



Species Occurrences

	USFWS Sec7	# SO	# Obs	Predicted Model	Range
⊟ **B - Bald Eagle** *(Haliaeetus leucocephalus)* SSS		4	34 +	🟥🟧🟨	Y

View in Field Guide **View Predicted Models** **View Range Maps**

Special Status Species - Native Species Global: **G5** State: **S4** USFWS: **BGEPA; MBTA** USFS: **Sensitive - Known in Forests (BD, BRT, KOOT, LOLO)** BLM: **SENSITIVE** PIF: **2**

Delineation Criteria Confirmed nesting area buffered by a minimum distance of 2,000 meters in order to be conservative about encompassing the breeding territory and area commonly used for renesting. Only nesting observations with a locational uncertainty of 1,000 meters or less will be used to delineate a nesting area. (Last Updated: Jun 28, 2023)

Predicted Models: O 15% Optimal (inductive), M 23% Moderate (inductive), L 46% Low (inductive)

	USFWS Sec7	# SO	# Obs	Predicted Model	Range
⊟ **B - Great Blue Heron** *(Ardea herodias)* SOC		7	15 +	🟧🟨	Y S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3** USFWS: **MBTA** FWP SWAP: **SGCN3**

Delineation Criteria Confirmed nesting area buffered by a minimum distance of 6,500 meters in order to be conservative about encompassing the areas commonly used for foraging near the breeding colony and otherwise buffered by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters. (Last Updated: Jun 27, 2023)

Predicted Models: M 31% Moderate (inductive), L 54% Low (inductive)

	USFWS Sec7	# SO	# Obs	Predicted Model	Range
⊟ **B - Bobolink** *(Dolichonyx oryzivorus)* SOC		7	4 +	🟧🟨	S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **MBTA; BCC10; BCC11; BCC17** FWP SWAP: **SGCN3** PIF: **3**

Delineation Criteria Confirmed breeding area based on the presence of a nest, chicks, or territorial adults during the breeding season. Point observation location is buffered by a minimum distance of 150 meters in order to conservatively encompass male territory size reported for the species and otherwise is buffered by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters. (Last Updated: Jun 30, 2023)

Predicted Models: M 23% Moderate (inductive), L 69% Low (inductive)

⊟ **M - Little Brown Myotis** *(Myotis lucifugus)* SOC 1 + Y

Species of Concern - Native Species Global: **G3G4** State: **S3** FWP SWAP: **SGCN3**

Delineation Criteria Confirmed area of occupancy based on the documented presence (mistnet captures, definitively identified acoustic recordings, or definitively identified roosting individuals) of adults or juveniles. Point observation location is buffered by a distance of 1,600 meters in order to encompass the greater than 1,500 meters foraging distance reported for the species in New Brunswick, Canada and otherwise buffered by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters. When cave locations are involved, point observations are mapped in the center of a one-square mile hexagon to protect the exact location of the cave entrance as per the Federal Cave Resource Protection Act and associated regulations (U.S. Code Title 16 Chapter 63, Code of Federal Regulations Title 43 Subtitle A Part 37). The outer edges of the hexagon are then buffered by a distance of 1,600 meters and otherwise by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters. All of the one-square mile hexagons intersecting this buffered area are presented as the Species Occurrence record. (Last Updated: Jul 06, 2023)

Predicted Models: L 100% Low (inductive)

⊟ **B - Long-billed Curlew** *(Numenius americanus)* SOC 6 2 S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **MBTA; BCC11** BLM: **SENSITIVE** FWP SWAP: **SGCN3** PIF: **2**

Delineation Criteria Confirmed breeding area based on the presence of a nest, chicks, or territorial adults during the breeding season. Point observation location is buffered by a minimum distance of 200 meters in order to approximate the breeding territory size reported for the species in Idaho and otherwise is buffered by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters. (Last Updated: Jun 28, 2023)

Predicted Models: L 100% Low (inductive)

⊟ **B - Golden Eagle** *(Aquila chrysaetos)* SOC 3 11 + Y

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3** USFWS: **BGEPA; MBTA** BLM: **SENSITIVE** FWP SWAP: **SGCN3**

Delineation Criteria Confirmed nesting area buffered by a minimum distance of 3,000 meters in order to be conservative about encompassing the entire breeding territory and area commonly used for renesting and otherwise buffered by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters.
(Last Updated: Jun 27, 2023)

Predicted Models: L 92% Low (inductive)

⊟ **B - Black-billed Cuckoo** *(Coccyzus erythropthalmus)* SOC 1 1 S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **MBTA; BCC11; BCC17** BLM: **SENSITIVE** FWP SWAP: **SGCN3, SGIN** PIF: **2**

Delineation Criteria Observations with evidence of breeding activity buffered by a minimum distance of 300 meters in order to be conservative about encompassing home ranges and otherwise buffered by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters. (Last Updated: Dec 30, 2022)

Predicted Models: L 92% Low (inductive)

⊟ **M - Grizzly Bear** *(Ursus arctos)* SOC 1 Y H

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G4** State: **S2S3** USFWS: **LT** BLM: **THREATENED** FWP SWAP: **SGCN2-3**

Delineation Criteria Species Occurrence polygons represent areas delineated by the U.S. Fish and Wildlife Service (USFWS) that encompass both home ranges and potential transitory movements based on verified sightings. Within these areas, the USFWS wants project proponents to consider whether the species â€œmay be presentâ€ when evaluating the potential impacts of a project and to work with the USFWS to develop and implement best management practices to minimize or eliminate project effects on the species. (Last Updated: Jul 06, 2023)

Predicted Models: L 54% Low (inductive)

⊟ **B - Green-tailed Towhee** *(Pipilo chlorurus)* SOC 1 S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **MBTA** FWP SWAP: **SGCN3** PIF: **3**

Delineation Criteria Confirmed breeding area based on the presence of a nest, chicks, or territorial adults during the breeding season. Point observation location is buffered by a minimum distance of 125 meters in order to encompass the breeding home range size reported for the species and otherwise is buffered by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters. (Last Updated: Jun 29, 2023)

Predicted Models: L 31% Low (inductive)

⊟ **B - Evening Grosbeak** *(Coccothraustes vespertinus)* SOC 1 Not Assessed Y W M

View in Field Guide **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3** USFWS: **MBTA; BCC10** FWP SWAP: **SGCN3**

Delineation Criteria Confirmed breeding area based on the presence of a nest, chicks, or territorial adults during the breeding season. Point observation location is buffered by a minimum distance of 1,000 meters in order to encompass the maximum foraging distance from nests reported for the species and otherwise is buffered by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters. (Last Updated: Jun 30, 2023)

⊟ **I - Margaritifera falcata** *(Western Pearlshell)* SOC 2 2 Not Assessed Y

View in Field Guide **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S2** USFS: **Sensitive - Known in Forests (BD, BRT, KOOT, LOLO)** **Species of Conservation Concern in Forests (CG, HLC)** BLM: **SENSITIVE** FWP SWAP: **SGCN2**

Delineation Criteria Stream reaches where the species recent presence has been confirmed through detection of live individuals or recent shells. Detection locations are buffered up and downstream by 500 meters to encompass potential adjacent populations and occupied stream reaches separated by less than 2000 meters are combined into a single species occurrence. In order to reflect the importance of adjacent terrestrial habitats to survival, stream reaches are buffered 100 meters into the terrestrial habitat based on PACFISH/INFISH Riparian Conservation Area standards. (Last Updated: Dec 21, 2022)

⊟ **O - Bat Roost (Non-Cave)** *(Bat Roost (Non-Cave))* IAH 1 Not Assessed

View in Field Guide

Important Animal Habitat - Native Species Global: **GNR** State: **SNR**

Delineation Criteria Confirmed area of occupancy based on the documented presence of adults or juveniles of any bat species at non-cave natural roost sites (e.g. rock outcrops, trees), below ground human created roost sites (e.g. mines), and above ground human created roost sites (e.g., bridges, buildings). Point observation locations are buffered by a distance of 4,500 meters in order to encompass the 95% confidence interval for nightly foraging distance reported for Townsendâ€™s Big-eared Bat (a resident Montana bat Species of Concern) and otherwise by the locational uncertainty associated with the observation up to a maximum distance of 10,000 meters. (Last Updated: Oct 22, 2019)

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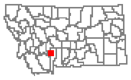
Model Icons
- N Suitable (native range)
- O Optimal Suitability
- M Moderate Suitability
- L Low Suitability
- I Suitable (introduced range)

Habitat Icons
- C Common
- O Occasional

Range Icons
- Y Native / Year-round
- S Summer
- W Winter
- M Migratory
- N Non-native
- H Historical

Num Obs
Count of obs with 'good precision' (<=1000m)

+ indicates additional 'poor precision' obs (1001m-10,000m)



Latitude	Longitude
45.82897	-111.11990
45.89960	-111.22135

Native Species

Summarized by: **24prvt0053** *(Custom Area of Interest)*
Filtered by:
Native Species reports are filtered for Species with MT Status = Species of Concern, Special Status, Important Animal Habitat, Potential SOC

Other Observed Species

	USFWS Sec7	# Obs	Predicted Model	Range
B - Black-necked Stilt *(Himantopus mexicanus)* SOC		2		S M
B - White-faced Ibis *(Plegadis chihi)* SOC		1		S M
B - American White Pelican *(Pelecanus erythrorhynchos)* SOC		7		S M
B - Short-eared Owl *(Asio flammeus)* PSOC		1		Y
B - Ferruginous Hawk *(Buteo regalis)* SOC		+		S M
B - Trumpeter Swan *(Cygnus buccinator)* SOC		2		Y M
B - Broad-tailed Hummingbird *(Selasphorus platycercus)* PSOC		1		S M
B - Sharp-tailed Grouse *(Tympanuchus phasianellus)* SOC		+		Y
B - Barrow's Goldeneye *(Bucephala islandica)* PSOC		+		Y W M
B - Pinyon Jay *(Gymnorhinus cyanocephalus)* SOC		+		Y
B - Burrowing Owl *(Athene cunicularia)* SOC		+	Not Assessed	S M
B - Common Loon *(Gavia immer)* SOC		1	Not Assessed	M

B - Black-necked Stilt *(Himantopus mexicanus)* SOC

View in Field Guide   View Predicted Models   View Range Maps
Species of Concern - Native Species   Global: **G5**   State: **S3B**   USFWS: **MBTA**   FWP SWAP: **SGCN3**   PIF: **3**
Predicted Models: O 23% Optimal (inductive), M 31% Moderate (inductive), L 38% Low (inductive)

B - White-faced Ibis *(Plegadis chihi)* SOC

View in Field Guide   View Predicted Models   View Range Maps
Species of Concern - Native Species   Global: **G5**   State: **S3B**   USFWS: **MBTA**   BLM: **SENSITIVE**   FWP SWAP: **SGCN3**   PIF: **2**
Predicted Models: M 62% Moderate (inductive), L 31% Low (inductive)

B - American White Pelican *(Pelecanus erythrorhynchos)* SOC

View in Field Guide   View Predicted Models   View Range Maps
Species of Concern - Native Species   Global: **G4**   State: **S3B**   USFWS: **MBTA**   FWP SWAP: **SGCN3**   PIF: **3**
Predicted Models: M 54% Moderate (inductive), L 38% Low (inductive)

B - Short-eared Owl *(Asio flammeus)* PSOC

View in Field Guide   View Predicted Models   View Range Maps
Potential Species of Concern - Native Species   Global: **G5**   State: **S4**   USFWS: **MBTA; BCC11; BCC17**   PIF: **3**
Predicted Models: M 38% Moderate (inductive), L 46% Low (inductive)

B - Ferruginous Hawk *(Buteo regalis)* SOC

View in Field Guide   View Predicted Models   View Range Maps
Species of Concern - Native Species   Global: **G4**   State: **S3B**   USFWS: **MBTA; BCC17**   BLM: **SENSITIVE**   FWP SWAP: **SGCN3**   PIF: **2**
Predicted Models: M 15% Moderate (inductive), L 62% Low (inductive)

B - Trumpeter Swan *(Cygnus buccinator)* SOC

View in Field Guide   View Predicted Models   View Range Maps
Species of Concern - Native Species   Global: **G4**   State: **S3**   USFWS: **MBTA**   USFS: **Sensitive - Known in Forests (BD)**   BLM: **SENSITIVE**   FWP SWAP: **SGCN3**   PIF: **1**
Predicted Models: M 8% Moderate (inductive), L 69% Low (inductive)

B - Broad-tailed Hummingbird *(Selasphorus platycercus)* PSOC

View in Field Guide   View Predicted Models   View Range Maps
Potential Species of Concern - Native Species   Global: **G5**   State: **S4B**   USFWS: **MBTA; BCC10**   FWP SWAP: **SGIN**
Predicted Models: M 8% Moderate (inductive), L 46% Low (inductive)

B - Sharp-tailed Grouse *(Tympanuchus phasianellus)* SOC

View in Field Guide   View Predicted Models   View Range Maps
Species of Concern - Native Species   Global: **G5**   State: **SX,S4**   FWP SWAP: **SGCN1**   PIF: **2**
Predicted Models: L 100% Low (inductive)

B - Barrow's Goldeneye *(Bucephala islandica)* PSOC

View in Field Guide   View Predicted Models   View Range Maps
Potential Species of Concern - Native Species   Global: **G5**   State: **S4**   USFWS: **MBTA**   FWP SWAP: **SGIN**   PIF: **2**
Predicted Models: L 69% Low (inductive)

B - Pinyon Jay *(Gymnorhinus cyanocephalus)* SOC

View in Field Guide   View Predicted Models   View Range Maps
Species of Concern - Native Species   Global: **G3**   State: **S3**   USFWS: **MBTA; BCC10; BCC17**   FWP SWAP: **SGCN3**
Predicted Models: L 38% Low (inductive)

B - Burrowing Owl *(Athene cunicularia)* SOC

View in Field Guide   View Range Maps
Species of Concern - Native Species   Global: **G4**   State: **S3B**   USFWS: **MBTA; BCC17**   BLM: **SENSITIVE**   FWP SWAP: **SGCN3**   PIF: **1**

B - Common Loon *(Gavia immer)* SOC

View in Field Guide   View Range Maps
Species of Concern - Native Species   Global: **G5**   State: **S3B**   USFWS: **MBTA**   USFS: **Sensitive - Known in Forests (KOOT, LOLO)**   FWP SWAP: **SGCN3**   PIF: **1**

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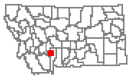
Model Icons
- N Suitable (native range)
- O Optimal Suitability
- M Moderate Suitability
- L Low Suitability
- I Suitable (introduced range)

Habitat Icons
- C Common
- O Occasional

Range Icons
- Y Native / Year-round
- S Summer
- W Winter
- M Migratory
- N Non-native
- H Historical

Num Obs
Count of obs with 'good precision' (<=1000m)
+ indicates additional 'poor precision' obs (1001m-10,000m)



Latitude	Longitude
45.82897	-111.11990
45.89960	-111.22135

Native Species

Summarized by: **24prvt0053** *(Custom Area of Interest)*
Filtered by:
Native Species reports are filtered for Species with MT Status = Species of Concern, Special Status, Important Animal Habitat, Potential SOC

Other Potential Species

USFWS Sec7 | Predicted Model | Range

⊟ **R - Snapping Turtle** *(Chelydra serpentina)* SOC — N

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native/Non-native Species - (depends on location or taxa) Global: **G5** State: **S3** BLM: **SENSITIVE** FWP SWAP: **SGCN3, SGIN**
Predicted Models: O 8% Optimal (inductive), M 54% Moderate (inductive), L 38% Low (inductive)

⊟ **M - North American Porcupine** *(Erethizon dorsatum)* PSOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Potential Species of Concern - Native Species Global: **G5** State: **S3S4** FWP SWAP: **SGIN**
Predicted Models: M 92% Moderate (inductive), L 8% Low (inductive)

⊟ **I - Bombus suckleyi** *(Suckley Cuckoo Bumble Bee)* SOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native Species Global: **G2G3** State: **S1**
Predicted Models: M 92% Moderate (inductive), L 8% Low (inductive)

⊟ **M - Wyoming Ground Squirrel** *(Urocitellus elegans)* PSOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Potential Species of Concern - Native Species Global: **G5** State: **S3S4**
Predicted Models: M 77% Moderate (inductive), L 23% Low (inductive)

⊟ **I - Danaus plexippus** *(Monarch)* SOC — S

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native Species Global: **G4** State: **S2S3** USFWS: **C**
Predicted Models: M 62% Moderate (inductive), L 31% Low (inductive)

⊟ **V - Eleocharis rostellata** *(Beaked Spikerush)* SOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native Species Global: **G5** State: **S3** USFS: **Species of Conservation Concern in Forests (CG, FLAT, HLC)** Plant Threat Score: **Unknown** CCVI: **Less Vulnerable**
Predicted Models: M 46% Moderate (inductive), L 38% Low (inductive)

⊟ **V - Impatiens aurella** *(Pale-yellow Jewel-weed)* SOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native Species Global: **G4** State: **S3** Plant Threat Score: **No Known Threats**
Predicted Models: M 46% Moderate (inductive), L 38% Low (inductive)

⊟ **V - Dichanthelium acuminatum** *(Panic Grass)* SOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native Species Global: **G5** State: **S2S3** Plant Threat Score: **Unknown**
Predicted Models: M 38% Moderate (inductive), L 31% Low (inductive)

⊟ **M - Merriam's Shrew** *(Sorex merriami)* SOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native Species Global: **G4** State: **S3** FWP SWAP: **SGCN3**
Predicted Models: M 31% Moderate (inductive), L 69% Low (inductive)

⊟ **B - Hooded Merganser** *(Lophodytes cucullatus)* PSOC — Y M

View in Field Guide **View Predicted Models** **View Range Maps**
Potential Species of Concern - Native Species Global: **G5** State: **S4** USFWS: **MBTA** FWP SWAP: **SGIN** PIF: **2**
Predicted Models: M 31% Moderate (inductive), L 62% Low (inductive)

⊟ **V - Primula incana** *(Mealy Primrose)* SOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native Species Global: **G5** State: **S3** USFS: **Sensitive - Known in Forests (BD)** Plant Threat Score: **High** CCVI: **Highly Vulnerable**
Predicted Models: M 31% Moderate (inductive), L 46% Low (inductive)

⊟ **V - Potentilla plattensis** *(Platte Cinquefoil)* SOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native Species Global: **G4** State: **S3** Plant Threat Score: **No Known Threats** CCVI: **Highly Vulnerable**
Predicted Models: M 23% Moderate (inductive), L 46% Low (inductive)

⊟ **M - Preble's Shrew** *(Sorex preblei)* SOC — Y

View in Field Guide **View Predicted Models** **View Range Maps**
Species of Concern - Native Species Global: **G4** State: **S3** FWP SWAP: **SGCN3**
Predicted Models: M 23% Moderate (inductive), L 31% Low (inductive)

⊟ **V - Astragalus terminalis** *(Railhead Milkvetch)* SOC Y

Species of Concern - Native Species Global: **G3** State: **S2S3** BLM: **SENSITIVE** Plant Threat Score: **Unknown** CCVI: **Moderately Vulnerable**

Predicted Models: M 23% Moderate (inductive), L 15% Low (inductive)

⊟ **M - Dwarf Shrew** *(Sorex nanus)* SOC Y

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G4** State: **S2S3** FWP SWAP: **SGCN2-3**

Predicted Models: M 15% Moderate (inductive), L 85% Low (inductive)

⊟ **M - Hoary Bat** *(Lasiurus cinereus)* SOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G3G4** State: **S3B** BLM: **SENSITIVE** FWP SWAP: **SGCN3**

Predicted Models: M 15% Moderate (inductive), L 85% Low (inductive)

⊟ **B - Rufous Hummingbird** *(Selasphorus rufus)* PSOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Potential Species of Concern - Native Species Global: **G4** State: **S4B** USFWS: **MBTA; BCC10** PIF: **3**

Predicted Models: M 15% Moderate (inductive), L 85% Low (inductive)

⊟ **R - Western Milksnake** *(Lampropeltis gentilis)* SOC Y

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S2** BLM: **SENSITIVE** FWP SWAP: **SGCN2**

Predicted Models: M 15% Moderate (inductive), L 62% Low (inductive)

⊟ **B - Yellow-billed Cuckoo** *(Coccyzus americanus)* SOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **PS: LT; MBTA** BLM: **THREATENED** FWP SWAP: **SGCN3, SGIN** PIF: **2**

Predicted Models: M 15% Moderate (inductive), L 54% Low (inductive)

⊟ **M - Western Spotted Skunk** *(Spilogale gracilis)* PSOC Y

View in Field Guide **View Predicted Models** **View Range Maps**

Potential Species of Concern - Native Species Global: **G5** State: **SU** FWP SWAP: **SGIN**

Predicted Models: M 15% Moderate (inductive), L 23% Low (inductive)

⊟ **B - Veery** *(Catharus fuscescens)* SOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **MBTA** BLM: **SENSITIVE** FWP SWAP: **SGCN3** PIF: **2**

Predicted Models: M 8% Moderate (inductive), L 92% Low (inductive)

⊟ **V - Spiranthes diluvialis** *(Ute Ladies'-tresses)* SOC 7 Y

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G2G3** State: **S1S2** USFWS: **LT** Plant Threat Score: **High** CCVI: **Extremely Vulnerable**

Predicted Models: M 8% Moderate (inductive), L 54% Low (inductive)

⊟ **B - Loggerhead Shrike** *(Lanius ludovicianus)* SOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G4** State: **S3B** USFWS: **MBTA** BLM: **SENSITIVE** FWP SWAP: **SGCN3** PIF: **2**

Predicted Models: M 8% Moderate (inductive), L 38% Low (inductive)

⊟ **M - Silver-haired Bat** *(Lasionycteris noctivagans)* PSOC Y

View in Field Guide **View Predicted Models** **View Range Maps**

Potential Species of Concern - Native Species Global: **G3G4** State: **S4**

Predicted Models: L 100% Low (inductive)

⊟ **B - Sage Thrasher** *(Oreoscoptes montanus)* SOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G4** State: **S3B** USFWS: **MBTA** BLM: **SENSITIVE** FWP SWAP: **SGCN3** PIF: **3**

Predicted Models: L 100% Low (inductive)

⊟ **M - Long-eared Myotis** *(Myotis evotis)* SOC Y

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3**

Predicted Models: L 92% Low (inductive)

⊟ **M - Spotted Bat** *(Euderma maculatum)* SOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G4** State: **S3** USFS: **Sensitive - Known in Forests (BD)** BLM: **SENSITIVE** FWP SWAP: **SGCN3, SGIN**

Predicted Models: L 92% Low (inductive)

⊟ **B - American Bittern** *(Botaurus lentiginosus)* SOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **MBTA** BLM: **SENSITIVE** FWP SWAP: **SGCN3** PIF: **3**

Predicted Models: L 92% Low (inductive)

⊟ **B - Brewer's Sparrow** *(Spizella breweri)* SOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **MBTA** BLM: **SENSITIVE** FWP SWAP: **SGCN3** PIF: **2**

Predicted Models: L 85% Low (inductive)

⊟ **B - Black Tern** *(Chlidonias niger)* SOC S M

View in Field Guide **View Predicted Models** **View Range Maps**

Species of Concern - Native Species Global: **G4G5** State: **S3B** USFWS: **MBTA; BCC10; BCC11; BCC17** BLM: **SENSITIVE** FWP SWAP: **SGCN3** PIF: **2**

Predicted Models: L 77% Low (inductive)

⊟ **M - Fringed Myotis** *(Myotis thysanodes)* SOC Y

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G4** State: **S3** BLM: **SENSITIVE** FWP SWAP: **SGCN3**
Predicted Models: L 69% Low (inductive)

⊟ **V - Stellaria crassifolia** *(Fleshy Stitchwort)* SOC Y

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G5** State: **S2** Plant Threat Score: **No Known Threats**
Predicted Models: L 69% Low (inductive)

⊟ **B - Lewis's Woodpecker** *(Melanerpes lewis)* SOC S M

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G4** State: **S2B** USFWS: **MBTA; BCC10; BCC17** USFS: **Species of Conservation Concern in Forests (HLC)**
BLM: **SENSITIVE** FWP SWAP: **SGCN2** PIF: **2**
Predicted Models: L 69% Low (inductive)

⊟ **V - Carex crawei** *(Crawe's Sedge)* SOC Y

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G5** State: **S2S3** Plant Threat Score: **Low**
Predicted Models: L 62% Low (inductive)

⊟ **B - Black-crowned Night-Heron** *(Nycticorax nycticorax)* SOC S M

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **MBTA** FWP SWAP: **SGCN3** PIF: **3**
Predicted Models: L 62% Low (inductive)

⊟ **M - Long-legged Myotis** *(Myotis volans)* SOC Y

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G4G5** State: **S3**
Predicted Models: L 54% Low (inductive)

⊟ **B - Greater Sage-Grouse** *(Centrocercus urophasianus)* SOC Y

View in Field Guide View Predicted Models View Range Maps
USFS: **Sensitive - Known in Forests (BD)**
Species of Concern - Native Species Global: **G3G4** State: **S2** **Species of Conservation Concern in Forests (CG)** BLM: **SENSITIVE** FWP SWAP: **SGCN2** PIF: **1**
Predicted Models: L 54% Low (inductive)

⊟ **V - Castilleja gracillima** *(Slender Indian Paintbrush)* SOC Y

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G3G4** State: **S2** Plant Threat Score: **Low** CCVI: **Highly Vulnerable**
Predicted Models: L 46% Low (inductive)

⊟ **B - Common Poorwill** *(Phalaenoptilus nuttallii)* PSOC S M

View in Field Guide View Predicted Models View Range Maps
Potential Species of Concern - Native Species Global: **G5** State: **S4B** USFWS: **MBTA** FWP SWAP: **SGIN** PIF: **3**
Predicted Models: L 46% Low (inductive)

⊟ **M - Townsend's Big-eared Bat** *(Corynorhinus townsendii)* SOC Y

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G4** State: **S3** USFS: **Sensitive - Known in Forests (BD, BRT, KOOT, LOLO)** BLM: **SENSITIVE** FWP SWAP: **SGCN3**
Predicted Models: L 38% Low (inductive)

⊟ **R - Greater Short-horned Lizard** *(Phrynosoma hernandesi)* SOC Y

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G5** State: **S3** BLM: **SENSITIVE** FWP SWAP: **SGCN3, SGIN**
Predicted Models: L 38% Low (inductive)

⊟ **A - Northern Leopard Frog** *(Lithobates pipiens)* SOC Y

View in Field Guide View Predicted Models View Range Maps
USFS: **Sensitive - Known in Forests (KOOT)**
Species of Concern - Native Species Global: **G5** State: **S1,S4** **Sensitive - Suspected in Forests (BRT, LOLO)** BLM: **SENSITIVE** FWP SWAP: **SGCN1**
Predicted Models: L 31% Low (inductive)

⊟ **B - Franklin's Gull** *(Leucophaeus pipixcan)* SOC S M

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G5** State: **S3B** USFWS: **MBTA; BCC10; BCC11; BCC17** BLM: **SENSITIVE** FWP SWAP: **SGCN3** PIF: **2**
Predicted Models: L 31% Low (inductive)

⊟ **B - Harlequin Duck** *(Histrionicus histrionicus)* SOC S M

View in Field Guide View Predicted Models View Range Maps
Species of Concern - Native Species Global: **G4** State: **S2B** USFWS: **MBTA** USFS: **Sensitive - Known in Forests (BD, KOOT, LOLO)** FWP SWAP: **SGCN2** PIF: **1**
Predicted Models: L 31% Low (inductive)

⊟ **B - Meesia triquetra** *(Meesia Moss)* SOC Y

View in Field Guide View Predicted Models View Range Maps
USFS: **Sensitive - Known in Forests (BRT, KOOT)**
Sensitive - Suspected in Forests (LOLO)
Species of Concern - Native Species Global: **G5** State: **S2** **Species of Conservation Concern in Forests (CG, FLAT)**
Predicted Models: L 23% Low (inductive)

⊟ **B - Ovenbird** *(Seiurus aurocapilla)* PSOC S M

View in Field Guide View Predicted Models View Range Maps
Potential Species of Concern - Native Species Global: **G5** State: **S4B** USFWS: **MBTA** PIF: **3**
Predicted Models: L 23% Low (inductive)

⊟ **M - Canada Lynx** *(Lynx canadensis)* SOC 7 Not Assessed Y

Species of Concern - Native Species Global: **G5** State: **S3** USFWS: **LT; CH** BLM: **THREATENED** FWP SWAP: **SGCN3**

⊟ **M - Wolverine** *(Gulo gulo)* SOC 7 Not Assessed Y

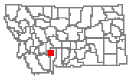
View in Field Guide View Range Maps

Species of Concern - Native Species Global: **G4** State: **S3** USFS: **Sensitive - Known in Forests (BD, BRT, KOOT, LOLO)** BLM: **SENSITIVE** FWP SWAP: **SGCN3**

⊟ **B - Sprague's Pipit** *(Anthus spragueii)* SOC 7 Not Assessed S M

View in Field Guide View Range Maps

Species of Concern - Native Species Global: **G3G4** State: **S3B** USFWS: **MBTA; BCC11; BCC17** BLM: **SENSITIVE** FWP SWAP: **SGCN3** PIF: **1**



Latitude	Longitude
45.82897	-111.11990
45.89960	-111.22135

Structured Surveys

Summarized by: **24prvt0053** *(Custom Area of Interest)*

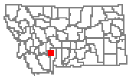
The Montana Natural Heritage Program (MTNHP) records information on the locations where more than 80 different types of well-defined repeatable survey protocols capable of detecting an animal species or suite of animal species have been conducted by state, federal, tribal, university, or private consulting biologists. Examples of structured survey protocols tracked by MTNHP include: visual encounter and dip net surveys for pond breeding amphibians, point counts for birds, call playback surveys for selected bird species, visual surveys of migrating raptors, kick net stream reach surveys for macroinvertebrates, visual encounter cover object surveys for terrestrial mollusks, bat acoustic or mist net surveys, pitfall and/or snap trap surveys for small terrestrial mammals, track or camera trap surveys for large mammals, and trap surveys for turtles. Whenever possible, photographs of survey locations are stored in MTNHP databases.

MTNHP does not typically manage information on structured surveys for plants; surveys for invasive species may be a future exception.

Within the report area you have requested, structured surveys are summarized by the number of each type of structured survey protocol that has been conducted, the number of species detections/observations resulting from these surveys, and the most recent year a survey has been conducted.

E-Eastern Heath Snail *(Eastern Heath Snail Survey)*	**Survey Count**: 2	**Obs Count**:	**Recent Survey**: 2012
E-Eurasian Water-milfoil Rake *(Rake tows/pulls for Eurasian Water-milfoil)*	**Survey Count**: 3	**Obs Count**: 6	**Recent Survey**: 2017
E-Invasive Mussel Plankton Tow *(Plankton tows for veligers of Invasive Mussels)*	**Survey Count**: 1	**Obs Count**:	**Recent Survey**: 2017
E-Kicknet *(Kicknet Collection Survey for Invasive Mussels and Snails)*	**Survey Count**: 1	**Obs Count**:	**Recent Survey**: 2017
E-Noxious Weed, Road-based *(Noxious Weed Road-based Visual Surveys)*	**Survey Count**: 6	**Obs Count**: 13	**Recent Survey**: 2004
E-Visual Aquatic Invasives *(Visual Encounter Surveys for Aquatic Invasives on Shorelines or Underwater)*	**Survey Count**: 1	**Obs Count**:	**Recent Survey**: 2017
F-Fish Other Survey *(Fish Other Survey (FWP Survey Type))*	**Survey Count**: 1	**Obs Count**: 1	**Recent Survey**: 1991
I-Mussel *(Stream Mussel Survey)*	**Survey Count**: 2	**Obs Count**: 2	**Recent Survey**: 2007
P-Algal scraping *(Algal Scraping)*	**Survey Count**: 3	**Obs Count**: 133	**Recent Survey**: 2007

MONTANA STATE LIBRARY
NATURAL HERITAGE PROGRAM
A program of the **Montana State Library's Natural Resource Information System**



Latitude	Longitude
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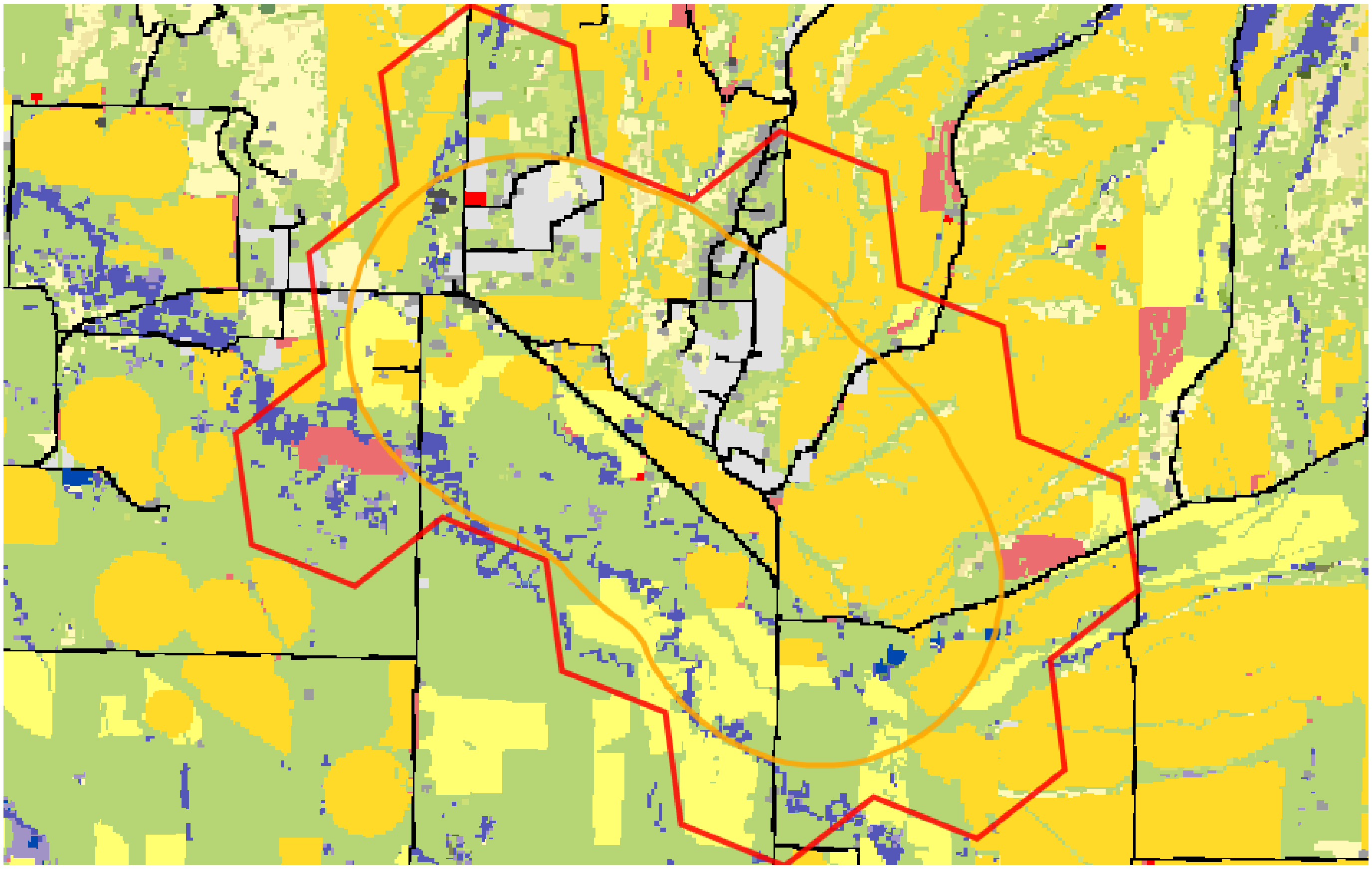
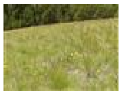
45.89960	-111.22135

Land Cover

Summarized by: **24prvt0053** *(Custom Area of Interest)*





35% (*2,901* *Acres*)

Grassland Systems
Montane Grassland

🟩 **Rocky Mountain Lower Montane, Foothill, and Valley Grassland**

This grassland system of the northern Rocky Mountains is found at lower montane to foothill elevations in mountains and valleys throughout Montana. These grasslands are floristically similar to Big Sagebrush Steppe but are defined by shorter summers, colder winters, and young soils derived from recent glacial and alluvial material. They are found at elevations from 548 - 1,650 meters (1,800-5,413 feet). In the lower montane zone, they range from small meadows to large open parks surrounded by conifers; below the lower treeline, they occur as extensive foothill and valley grasslands. Soils are relatively deep, fine-textured, often with coarse fragments, and non-saline. Microphytic crust may be present in high-quality occurrences. This system is typified by cool-season perennial bunch grasses and forbs (>25%) cover, with a sparse shrub cover (<10%). Rough fescue (*Festuca campestris*) is dominant in the northwestern portion of the state and Idaho fescue (*Festuca idahoensis*) is dominant or co-dominant throughout the range of the system. Bluebunch wheatgrass (*Pseudoroegneria spicata*) occurs as a co-dominant throughout the range as well, especially on xeric sites. Western wheatgrass (*Pascopyrum smithii*) is consistently present, often with appreciable coverage (>10%) in lower elevation occurrences in western Montana and virtually always present, with relatively high coverages (>25%), on the edge of the Northwestern Great Plains region. Species diversity ranges from a high of more than 50 per 400 square meter plot on mesic sites to 15 (or fewer) on xeric and disturbed sites. Most occurrences have at least 25 vascular species present. Farmland conversion, noxious species invasion, fire suppression, heavy grazing and oil and gas development are major threats to this system.

32% (*2,689* *Acres*)

Human Land Use
Agriculture

🟨 **Cultivated Crops**

These areas used for the production of crops, such as corn, soybeans, small grains, sunflowers, vegetables, and cotton, typically on an annual cycle. Agricultural plant cover is variable depending on season and type of farming. Other areas include more stable land cover of orchards and vineyards.

10% (*805* *Acres*)

Human Land Use
Agriculture

🟨 **Pasture/Hay**

These agriculture lands typically have perennial herbaceous cover (e.g. regularly-shaped plantings) used for livestock grazing or the production of hay. There are obvious signs of management such as irrigation and haying that distinguish it from natural grasslands. Identified CRP lands are included in this land cover type.

5% (*425* *Acres*)

Human Land Use
Developed

⬜ **Developed, Open Space**

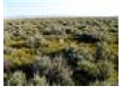
Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Impervious surfaces account for less than 20% of total cover. This category often includes highway and railway rights of way and graveled rural roads.

Wetland and Riparian Systems

🟦 Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland

4% (*294* Acres)

This ecological system is found throughout the Rocky Mountain and Colorado Plateau regions. In Montana, it ranges from approximately 945 to 2,042 meters (3,100 to 6,700 feet), characterristically occuring as a mosaic of multiple communities that are tree-dominated with a diverse shrub component. It is dependent on a natural hydrologic regime, especially annual to episodic flooding. Occurrences are found within the flood zone of rivers, on islands, sand or cobble bars, and on immediate streambanks. It can form large, wide occurrences on mid-channel islands in larger rivers or narrow bands on small, rocky canyon tributaries and well-drained benches. It is also typically found in backwater channels and other perennially wet but less scoured sites, such as floodplains swales and irrigation ditches. In some locations, occurrences extend into moderately high intermountain basins where the adjacent vegetation is sage steppe. Dominant trees may include boxelder maple (*Acer negundo*), narrowleaf cottonwood (*Populus angustifolia*), Plains cottonwood (*Populus deltoides*), Douglas-fir (*Pseudotsuga menziesii*), peachleaf willow (*Salix amygdaloides*), or Rocky Mountain juniper (*Juniperus scopulorum*). Dominant shrubs include Rocky Mountain maple (*Acer glabrum*), thinleaf alder (*Alnus incana*), river birch (*Betula occidentalis*), redoiser dogwood (*Cornus sericea*), hawthorne (*Crataegus spp*.), chokecherry (*Prunus virginiana*), skunkbush sumac (*Rhus trilobata*), Drummondâ€™s willow (*Salix drummondiana*), sandbar willow (*Salix exigua*), Pacific willow (*Salix lucida*), rose (*Rosa* species), silver buffaloberry (*Shepherdia argentea*), or snowberry (*Symphoricarpos* species). Exotic trees of Russian olive (*Elaeagnus angustifolia*) and saltcedar (*Tamarix* species) may invade some stands in southeastern and south-central Montana.



Shrubland, Steppe and Savanna Systems

Sagebrush Steppe

🟨 Big Sagebrush Steppe

3% (*253* Acres)

This widespread ecological system occurs throughout much of central Montana, and north and east onto the western fringe of the Great Plains. In central Montana, where this system occurs on both glaciated and non-glaciated landscapes, it differs slightly, with more summer rain than winter precipitation and more precipitation annually. Throughout its distribution, soils are typically deep and non-saline, often with a microphytic crust. This shrub-steppe is dominated by perennial grasses and forbs with greater than 25% cover. Overall shrub cover is less than 10 percent. In Montana and Wyoming, stands are more mesic, with more biomass of grass, and have less shrub diversity than stands farther to the west, and 50 to 90% of the occurrences are dominated by Wyoming big sagebrush with western wheatgrass (*Pascopyrum smithii*). Japanese brome (*Bromus japonicus*) and cheatgrass (*Bromus tectorum*) are indicators of disturbance, but cheatgrassis typically not as abundant as in the Intermountain West, possibly due to a colder climate. The natural fire regime of this ecological system maintains a patchy distribution of shrubs, preserving the steppe character. Shrubs may increase following heavy grazing and/or with fire suppression. In central and eastern Montana, complexes of prairie dog towns are common in this ecological system.

Grassland Systems

Montane Grassland

🟩 Rocky Mountain Subalpine-Montane Mesic Meadow

3% (*237* Acres)

This system is restricted to sites from lower montane to subalpine elevations where finely textured soils, snow deposition, or windswept conditions limit tree establishment. Many occurrences are small patches, and are often found in mosaics within woodlands, dense shrublands, or just below alpine communities. Elevations range from 600 to2,011 meters (2,000-6,600 feet) in the northern Rocky Mountains and up to 2,286- 2,682 meters (7,500-8,800 feet) in the mountains of southwestern Montana. This system occurs on gentle to moderate-gradient slopes and in relatively moist habitats. Soils are typically seasonally moist to saturated in the spring, but dry out later in the growing season. At montane elevations, soils are usually clays or silt loams, and some occurrences may have inclusions of hydric soils in low, depressional areas. At subalpine elevations, soils are derived a variety of parent materials, and are usually rocky or gravelly with good aeration and drainage, but with a well developed organic layer. Some occurrences are more heavily dominated by grasses, while others are more dominated by forbs. Common grasses include tufted hairgrass (*Deschampsia caespitosa*), showy oniongrass (*Melica spectabilis*), mountain brome (*Bromus carinatus*), blue wildrye (*Elymus glaucus*), awned sedge (*Carex atherodes*), and small wing sedge (*Carex microptera*). Forb dominated meadows usually comprise a wide species diversity which differs from montane to subalpine elevations. Shrubs such as shrubby cinquefoil (*Dasiphora fruticosa* ssp. *floribunda*) and snowberry (*Symphoricarpos* species) are occasional but not abundant. This system differs from the Rocky Mountain Alpine Montane Wet Meadow system in that it soils dry out by mid-summer.

No Image

Human Land Use

Developed

⬛ Other Roads

3% (*213* Acres)

County, city and or rural roads generally open to motor vehicles.

Human Land Use

Developed

◼ Low Intensity Residential

2% (*164* Acres)

Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-50% of total cover. These areas most commonly include single-family housing units in rural and suburban areas. Paved roadways may be classified into this category.

Recently Disturbed or Modified

Introduced Vegetation

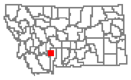
🟥 Introduced Upland Vegetation - Annual and Biennial Forbland

2% (*136* Acres)

Land cover is significantly altered/disturbed by introduced annual and biennial forbs. Natural vegetation types are no longer recognizable. Typical species that dominate these areas are knapweed, oxeye daisy, Canada thistle, leafy spurge, pepperweed, and yellow sweetclover.

Additional Limited Land Cover

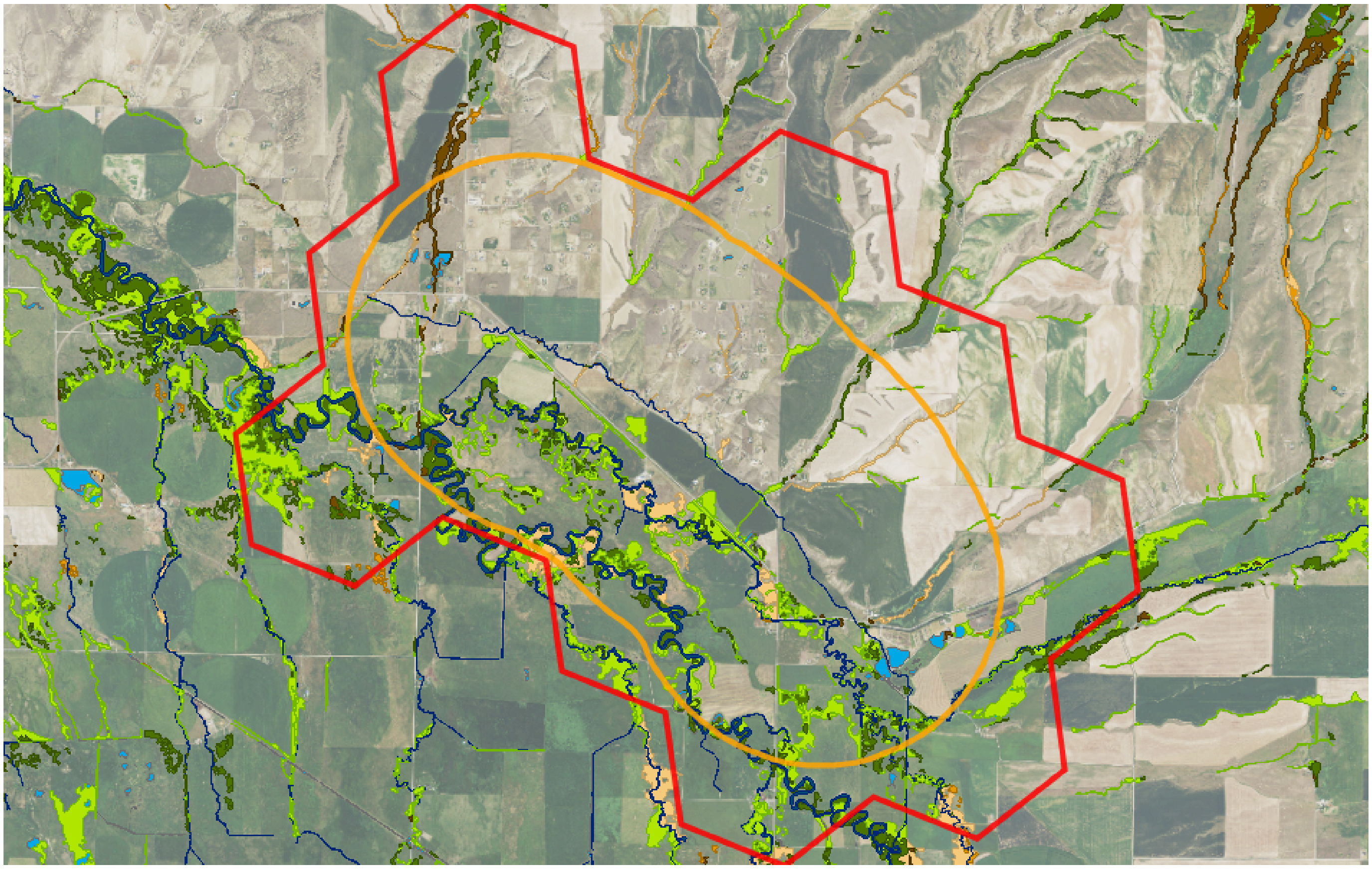
1% (*88 Acres*)	⬛ Major Roads
<1% (*40 Acres*)	🟨 Montane Sagebrush Steppe
<1% (*32 Acres*)	🟪 Alpine-Montane Wet Meadow
<1% (*13 Acres*)	⬛ High Intensity Residential
<1% (*13 Acres*)	🟦 Open Water
<1% (*6 Acres*)	🟥 Commercial / Industrial
<1% (*2 Acres*)	🟦 Emergent Marsh
<1% (*2 Acres*)	🟩 Rocky Mountain Foothill Limber Pine - Juniper Woodland
<1% (*1 Acres*)	🟩 Rocky Mountain Lodgepole Pine Forest
<1% (*1 Acres*)	🟩 Rocky Mountain Montane-Foothill Deciduous Shrubland



	Latitude	Longitude
	45.82897	-111.11990
	45.89960	-111.22135

Wetland and Riparian

Summarized by: **24prvt0053** *(Custom Area of Interest)*



Wetland and Riparian Mapping

Explain

P - Palustrine

🟦 AB - Aquatic Bed

F - Semipermanently Flooded	32 Acres	
(no modifier)	**6 Acres**	**PABF**
h - Diked/Impounded	**1 Acres**	**PABFh**
x - Excavated	**25 Acres**	**PABFx**
G - Intermittently Exposed	6 Acres	
x - Excavated	**6 Acres**	**PABGx**

P - Palustrine, AB - Aquatic Bed
Wetlands with vegetation growing on or below the water surface for most of the growing season.

🟦 US - Unconsolidated Shore

C - Seasonally Flooded	<1 Acres	
(no modifier)	**<1 Acres**	**PUSC**

P - Palustrine, US - Unconsolidated Shore
Wetlands with less than 75% areal cover of stones, boulders, or bedrock. AND with less than 30% vegetative cover AND the wetland is irregularly exposed due to seasonal or irregular flooding and subsequent drying.

🟩 EM - Emergent

A - Temporarily Flooded	439 Acres	
(no modifier)	**436 Acres**	**PEMA**
h - Diked/Impounded	**1 Acres**	**PEMAh**
x - Excavated	**2 Acres**	**PEMAx**
C - Seasonally Flooded	38 Acres	
(no modifier)	**38 Acres**	**PEMC**
x - Excavated	**<1 Acres**	**PEMCx**
F - Semipermanently Flooded	1 Acres	
(no modifier)	**1 Acres**	**PEMF**

P - Palustrine, EM - Emergent
Wetlands with erect, rooted herbaceous vegetation present during most of the growing season.

🟩 SS - Scrub-Shrub

A - Temporarily Flooded	281 Acres	
(no modifier)	**281 Acres**	**PSSA**
C - Seasonally Flooded	3 Acres	
(no modifier)	**3 Acres**	**PSSC**

P - Palustrine, SS - Scrub-Shrub
Wetlands dominated by woody vegetation less than 6 meters (20 feet) tall. Woody vegetation includes tree saplings and trees that are stunted due to environmental conditions.

R - Riverine (Rivers)

2 - Lower Perennial

🟦 UB - Unconsolidated Bottom

G - Intermittently Exposed 54 Acres

(no modifier) **54 Acres** **R2UBG**

H - Permanently Flooded 78 Acres

(no modifier) **78 Acres** **R2UBH**

R - Riverine (Rivers), 2 - Lower Perennial, UB - Unconsolidated Bottom
els where the substrate is at least 25% mud, silt or other fine particles.

🟦 US - Unconsolidated Shore

C - Seasonally Flooded <1 Acres

(no modifier) **<1 Acres** **R2USC**

R - Riverine (Rivers), 2 - Lower Perennial, US - Unconsolidated Shore
Shorelines with less than 75% areal cover of stones, boulders, or bedrock and less than 30% vegetation cover. The area is also irregularly exposed due to seasonal or irregular flooding and subsequent drying.

4 - Intermittent

🟦 SB - Stream Bed

C - Seasonally Flooded 9 Acres

x - Excavated **9 Acres** **R4SBCx**

R - Riverine (Rivers), 4 - Intermittent, SB - Stream Bed
Active channel that contains periodic water flow.

Rp - Riparian

1 - Lotic

🟧 SS - Scrub-Shrub
(no modifier) **9 Acres** **Rp1SS**

Rp - Riparian, 1 - Lotic, SS - Scrub-Shrub
This type of riparian area is dominated by woody vegetation that is less than 6 meters (20 feet) tall. Woody vegetation includes tree saplings and trees that are stunted due to environmental conditions.

🟫 FO - Forested
(no modifier) **35 Acres** **Rp1FO**

Rp - Riparian, 1 - Lotic, FO - Forested
This riparian class has woody vegetation that is greater than 6 meters (20 feet) tall.

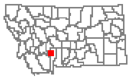
🟨 EM - Emergent
(no modifier) **115 Acres** **Rp1EM**

Rp - Riparian, 1 - Lotic, EM - Emergent
Riparian areas that have erect, rooted herbaceous vegetation during most of the growing season.

2 - Lentic

🟫 FO - Forested
(no modifier) **1 Acres** **Rp2FO**

Rp - Riparian, 2 - Lentic, FO - Forested
This riparian class has woody vegetation that is greater than 6 meters (20 feet) tall.



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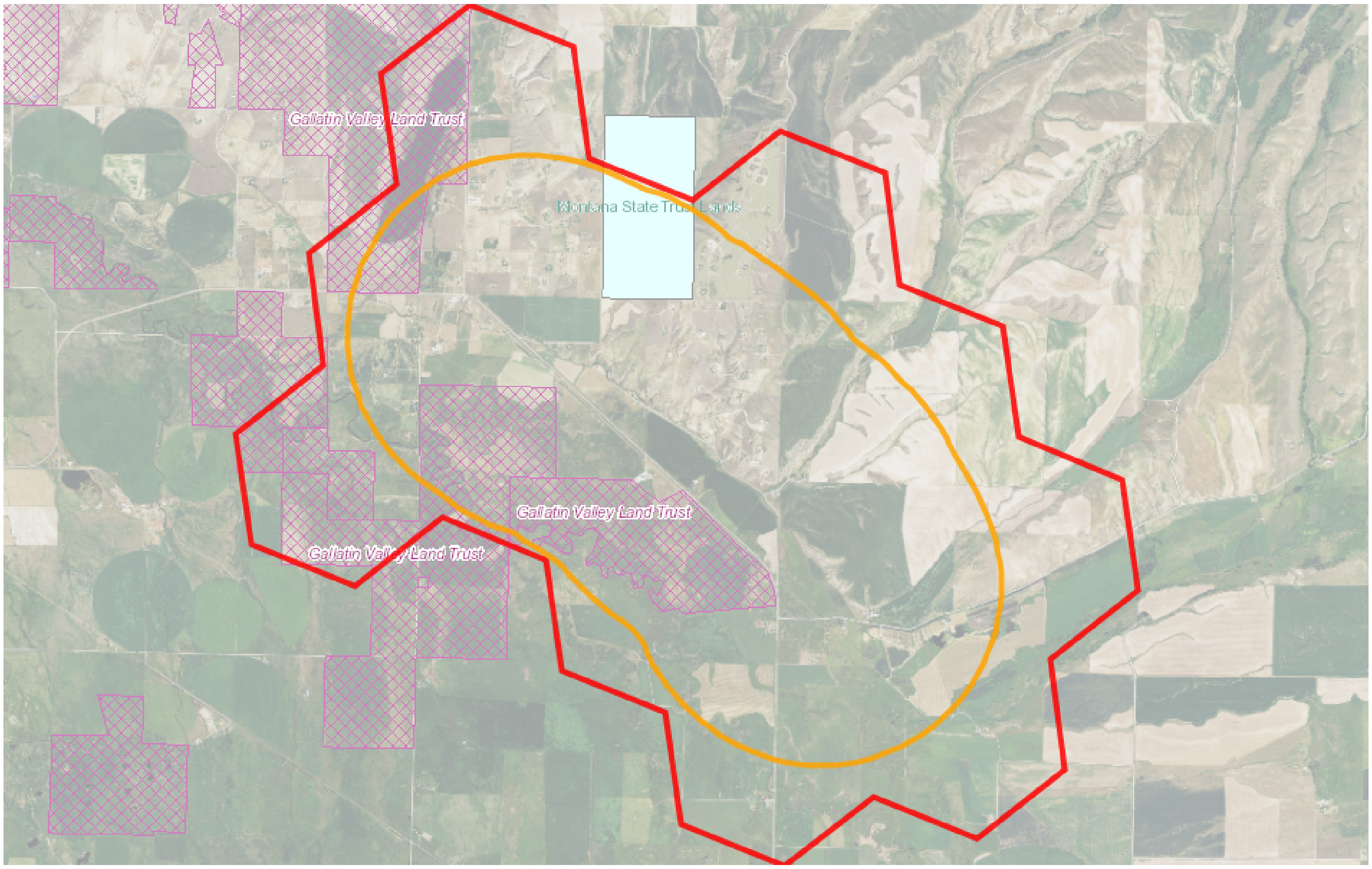
Land Management

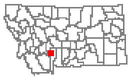
Summarized by: **24prvt0053** *(Custom Area of Interest)*



Land Management Summary

Explain

	Ownership	Tribal	Easements	Other Boundaries (possible overlap)
Public Lands	**208 Acres (3%)**			
State	208 Acres (3%)			
Montana State Trust Lands	208 Acres (3%)			
🟦 MT State Trust Owned	208 Acres (3%)			
Conservation Easements			**1,491 Acres (18%)**	
Private			1,491 Acres (18%)	
▨ Gallatin Valley Land Trust			1,491 Acres (18%)	
Private Lands or Unknown Ownership	**6,614 Acres (80%)**			



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Biological Reports

Summarized by: **24prvt0053** *(Custom Area of Interest)*

Within the report area you have requested, citations for all reports and publications associated with plant or animal observations in Montana Natural Heritage Program (MTNHP) databases are listed and, where possible, links to the documents are included.

The MTNHP plans to include reports associated with terrestrial and aquatic communities in the future as allowed for by staff resources. If you know of reports or publications associated with species or biological communities within the report area that are not shown in this report, please let us know: mtnhp@mt.gov

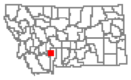
- Greater Yellowstone Coordinating Committee. ***GYA Weed Mapping Update and Database Augmentation***. 2000-04.

Model Icons
N Suitable (native range)
O Optimal Suitability
M Moderate Suitability
L Low Suitability
I Suitable (introduced range)

Habitat Icons
C Common
O Occasional

Range Icons
N Non-native

Num Obs
Count of obs with 'good precision' (<=1000m)
+ indicates additional 'poor precision' obs (1001m-10,000m)



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Invasive and Pest Species

Summarized by: **24prvt0053** *(Custom Area of Interest)*

\# Obs | Predicted Model | Range

Aquatic Invasive Species

⊟ **V - Iris pseudacorus** *(Yellowflag Iris)* N2A/AIS — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 2A - Aquatic Invasive Species - Non-native Species Global: **GNR** State: **SNA**
Predicted Models: O 23% Optimal (inductive), M 54% Moderate (inductive), L 23% Low (inductive)

⊟ **V - Potamogeton crispus** *(Curly-leaf Pondweed)* N2B/AIS — 3 — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 2B - Aquatic Invasive Species - Non-native Species Global: **G5** State: **SNA**
Predicted Models: M 38% Moderate (inductive), L 46% Low (inductive)

⊟ **V - Myriophyllum spicatum** *(Eurasian Water-milfoil)* N2A/AIS — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 2A - Aquatic Invasive Species - Non-native Species Global: **GNR** State: **SNA**
Predicted Models: L 69% Low (inductive)

⊟ **V - Nymphaea odorata** *(American Water-lily)* AIS — N

View in Field Guide **View Predicted Models** **View Range Maps**
Aquatic Invasive Species - Non-native Species Global: **G5** State: **SNA**
Predicted Models: I 54% Suitable (introduced range) (deductive)

⊟ **I - Potamopyrgus antipodarum** *(New Zealand Mudsnail)* AIS — 1 — Not Assessed

View in Field Guide
Aquatic Invasive Species - Non-native Species Global: **G5** State: **SNA**

Noxious Weeds: Priority 1A

⊟ **V - Centaurea solstitialis** *(Yellow Starthistle)* N1A — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 1A - Non-native Species Global: **GNR** State: **SNA**
Predicted Models: O 62% Optimal (inductive), M 31% Moderate (inductive), L 7% Low (inductive)

⊟ **V - Isatis tinctoria** *(Dyer's Woad)* N1A — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 1A - Non-native Species Global: **GNR** State: **SNA**
Predicted Models: O 38% Optimal (inductive), M 23% Moderate (inductive), L 38% Low (inductive)

⊟ **V - Taeniatherum caput-medusae** *(Medusahead)* N1A — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 1A - Non-native Species Global: **G4G5** State: **SNA**
Predicted Models: L 85% Low (inductive)

Noxious Weeds: Priority 1B

⊟ **V - Lythrum salicaria** *(Purple Loosestrife)* N1B — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 1B - Non-native Species Global: **G5** State: **SNA**
Predicted Models: O 23% Optimal (inductive), M 62% Moderate (inductive), L 15% Low (inductive)

⊟ **V - Echium vulgare** *(Blueweed)* N1B — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 1B - Non-native Species Global: **GNR** State: **SNA**
Predicted Models: L 62% Low (inductive)

⊟ **V - Polygonum cuspidatum** *(Japanese Knotweed)* N1B — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 1B - Non-native Species Global: **GNRTNR** State: **SNA**
Predicted Models: L 54% Low (inductive)

⊟ **V - Cytisus scoparius** *(Scotch Broom)* N1B — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 1B - Non-native Species Global: **GNR** State: **SNA**
Predicted Models: L 46% Low (inductive)

Noxious Weeds: Priority 2A

⊟ **V - Ventenata dubia** *(Ventenata)* N2A — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 2A - Non-native Species Global: **GNR** State: **SNA**
Predicted Models: O 38% Optimal (inductive), M 62% Moderate (inductive)

⊟ **V - Iris pseudacorus** *(Yellowflag Iris)* N2A/AIS — N

View in Field Guide **View Predicted Models** **View Range Maps**
Noxious Weed: Priority 2A - Aquatic Invasive Species - Non-native Species Global: **GNR** State: **SNA**
Predicted Models: O 23% Optimal (inductive), M 54% Moderate (inductive), L 23% Low (inductive)

⊟ **V - Rhamnus cathartica** *(Common Buckthorn)* N2A N

Noxious Weed: Priority 2A - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 54% Moderate (inductive), L 31% Low (inductive)

⊟ **V - Lepidium latifolium** *(Perennial Pepperweed)* N2A N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2A - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 31% Moderate (inductive), L 54% Low (inductive)

⊟ **V - Ranunculus acris** *(Tall Buttercup)* N2A N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2A - Non-native Species Global: **G5** State: **SNA**

Predicted Models: L 85% Low (inductive)

⊟ **V - Myriophyllum spicatum** *(Eurasian Water-milfoil)* N2A/AIS N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2A - Aquatic Invasive Species - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: L 69% Low (inductive)

Noxious Weeds: Priority 2B

⊟ **V - Berteroa incana** *(Hoary False-alyssum)* N2B N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: O 31% Optimal (inductive), M 54% Moderate (inductive), L 15% Low (inductive)

⊟ **V - Lepidium draba** *(Whitetop)* N2B 6 N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: O 15% Optimal (inductive), M 77% Moderate (inductive), L 8% Low (inductive)

⊟ **V - Centaurea diffusa** *(Diffuse Knapweed)* N2B N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: O 8% Optimal (inductive), M 62% Moderate (inductive), L 30% Low (inductive)

⊟ **V - Convolvulus arvensis** *(Field Bindweed)* N2B N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: O 8% Optimal (inductive), M 31% Moderate (inductive), L 61% Low (inductive)

⊟ **V - Linaria dalmatica** *(Dalmatian Toadflax)* N2B N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **G5** State: **SNA**

Predicted Models: O 8% Optimal (inductive), M 31% Moderate (inductive), L 61% Low (inductive)

⊟ **V - Cynoglossum officinale** *(Common Hound's-tongue)* N2B N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 92% Moderate (inductive), L 8% Low (inductive)

⊟ **V - Centaurea stoebe** *(Spotted Knapweed)* N2B 5 N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 69% Moderate (inductive), L 31% Low (inductive)

⊟ **V - Cirsium arvense** *(Canada Thistle)* N2B 9 N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **G5** State: **SNA**

Predicted Models: M 62% Moderate (inductive), L 38% Low (inductive)

⊟ **V - Tanacetum vulgare** *(Common Tansy)* N2B N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 38% Moderate (inductive), L 62% Low (inductive)

⊟ **V - Potamogeton crispus** *(Curly-leaf Pondweed)* N2B/AIS 3 N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Aquatic Invasive Species - Non-native Species Global: **G5** State: **SNA**

Predicted Models: M 38% Moderate (inductive), L 46% Low (inductive)

⊟ **V - Euphorbia virgata** *(Leafy Spurge)* N2B N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 31% Moderate (inductive), L 69% Low (inductive)

⊟ **V - Potentilla recta** *(Sulphur Cinquefoil)* N2B N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 8% Moderate (inductive), L 92% Low (inductive)

⊟ **V - Linaria vulgaris** *(Yellow Toadflax)* N2B N

View in Field Guide View Predicted Models View Range Maps

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 8% Moderate (inductive), L 69% Low (inductive)

⊟ **V - Leucanthemum vulgare** *(Oxeye Daisy)* N2B N

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: L 100% Low (inductive)

⊟ **V - Acroptilon repens** *(Russian Knapweed)* N2B N

View in Field Guide **View Predicted Models** **View Range Maps**

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: L 92% Low (inductive)

⊟ **V - Tamarix ramosissima** *(Salt Cedar)* N2B N

View in Field Guide **View Predicted Models** **View Range Maps**

Noxious Weed: Priority 2B - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: L 92% Low (inductive)

Regulated Weeds: Priority 3

⊟ **V - Bromus tectorum** *(Cheatgrass)* R3 N

View in Field Guide **View Predicted Models** **View Range Maps**

Regulated Weed: Priority 3 - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 62% Moderate (inductive), L 38% Low (inductive)

⊟ **V - Elaeagnus angustifolia** *(Russian Olive)* R3 N

View in Field Guide **View Predicted Models** **View Range Maps**

Regulated Weed: Priority 3 - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: L 69% Low (inductive)

Biocontrol Species

⊟ **I - Aphthona lacertosa** *(Brown-legged Leafy Spurge Flea Beetle)* BIOCNTRL N

View in Field Guide **View Predicted Models** **View Range Maps**

Biocontrol Species - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 85% Moderate (inductive), L 15% Low (inductive)

⊟ **I - Mecinus janthiniformis** *(Dalmatian Toadflax Stem-boring Weevil)* BIOCNTRL N

View in Field Guide **View Predicted Models** **View Range Maps**

Biocontrol Species - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 69% Moderate (inductive), L 31% Low (inductive)

⊟ **I - Mecinus janthinus** *(Yellow Toadflax Stem-boring Weevil)* BIOCNTRL N

View in Field Guide **View Predicted Models** **View Range Maps**

Biocontrol Species - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 54% Moderate (inductive), L 38% Low (inductive)

⊟ **I - Oberea erythrocephala** *(Red-headed Leafy Spurge Stem Borer)* BIOCNTRL N

View in Field Guide **View Predicted Models** **View Range Maps**

Biocontrol Species - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 54% Moderate (inductive), L 31% Low (inductive)

⊟ **I - Aphthona nigriscutis** *(Black Dot Leafy Spurge Flea Beetle)* BIOCNTRL N

View in Field Guide **View Predicted Models** **View Range Maps**

Biocontrol Species - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: M 15% Moderate (inductive), L 62% Low (inductive)

⊟ **I - Cyphocleonus achates** *(Knapweed Root Weevil)* BIOCNTRL N

View in Field Guide **View Predicted Models** **View Range Maps**

Biocontrol Species - Non-native Species Global: **GNR** State: **SNA**

Predicted Models: L 62% Low (inductive)

Introduction to Montana Natural Heritage Program

MONTANA STATE LIBRARY
NATURAL HERITAGE PROGRAM

P.O. Box 201800 • 1515 East Sixth Avenue • Helena, MT 59620-1800 • fax 406.444.0266 • phone 406.444.5363 • mtnhp.org

INTRODUCTION

The Montana Natural Heritage Program (MTNHP) is Montana's source for reliable and objective information on Montana's native species and habitats, emphasizing those of conservation concern. MTNHP was created by the Montana legislature in 1983 as part of the Natural Resource Information System (NRIS) at the Montana State Library (MSL). MTNHP is "a program of information acquisition, storage, and retrieval for data relating to the flora, fauna, and biological community types of Montana" (MCA 90-15-102). MTNHP's activities are guided by statute as well as through ongoing interaction with, and feedback from, principal data source agencies such as Montana Fish, Wildlife, and Parks, the Montana Department of Environmental Quality, the Montana Department of Natural Resources and Conservation, the Montana University System, the US Forest Service, and the US Bureau of Land Management. Since the first staff was hired in 1985, the Program has logged a long record of success, and developed into a highly respected, service-oriented program. MTNHP is widely recognized as one of the most advanced and effective of over 60 natural heritage programs that are distributed across North America.

VISION

Our vision is that public agencies, the private sector, the education sector, and the general public will trust and rely upon MTNHP as the source for information and expertise on Montana's species and habitats, especially those of conservation concern. We strive to provide easy access to our information to allow users to save time and money, speed environmental reviews, and make informed decisions.

CORE VALUES

- We endeavor to be a single statewide source of accurate and up-to-date information on Montana's plants, animals, and aquatic and terrestrial biological communities.
- We actively listen to our data users and work responsively to meet their information and training needs.
- We strive to provide neutral, trusted, timely, and equitable service to all of our information users.
- We make every effort to be transparent to our data users in setting work priorities and providing data products.

CONFIDENTIALITY

All information requests made to the Montana Natural Heritage Program are considered library records and are protected from disclosure by the Montana Library Records Confidentiality Act (MCA 22-1-11).

INFORMATION MANAGED

Information managed at the Montana Natural Heritage Program is botanical, zoological, and ecological information that describes the distribution (e.g., observations, structured surveys, range polygons, predicted habitat suitability models), conservation status (e.g., global and state conservation status ranks, including threats), and other supporting information (e.g., accounts and references) on the biology and ecology of species and biological communities.

Data Use Terms and Conditions

- Montana Natural Heritage Program (MTNHP) products and services are based on biological data and the objective interpretation of those data by professional scientists. MTNHP does not advocate any particular philosophy of natural resource protection, management, development, or public policy.
- MTNHP has no natural resource management or regulatory authority. Products, statements, and services from MTNHP are intended to inform parties as to the state of scientific knowledge about certain natural resources, and to further develop that knowledge. The information is not intended as natural resource management guidelines or prescriptions or a determination of environmental impacts. MTNHP recommends consultation with appropriate state, federal, and tribal resource management agencies and authorities in the area where your project is located.
- Information on the status and spatial distribution of biological resources produced by MTNHP are intended to inform parties of the state-wide status, known occurrence, or the likelihood of the presence of those resources. **These products are not intended to substitute for field-collected data, nor are they intended to be the sole basis for natural resource management decisions.**
- MTNHP does not portray its data as exhaustive or comprehensive inventories of rare species or biological communities. **Field verification of the absence or presence of sensitive species and biological communities will always be an important obligation of users of our data.**
- MTNHP responds equally to all requests for products and services, regardless of the purpose or identity of the requester.
- Because MTNHP constantly updates and revises its databases with new data and information, products will become outdated over time. Interested parties are encouraged to obtain the most current information possible from MTNHP, rather than using older products. We add, review, update, and delete records on a daily basis. Consequently, we strongly advise that you update your MTNHP data sets at a minimum of every four months for most applications of our information.
- MTNHP data require a certain degree of biological expertise for proper analysis, interpretation, and application. Our staff is available to advise you on questions regarding the interpretation or appropriate use of the data that we provide. See Contact Information for MTNHP Staff
- The information provided to you by MTNHP may include sensitive data that if publicly released might jeopardize the welfare of threatened, endangered, or sensitive species or biological communities. This information is intended for distribution or use only within your department, agency, or business. Subcontractors may have access to the data during the course of any given project, but should not be given a copy for their use on subsequent, unrelated work.
- MTNHP data are made freely available. Duplication of hard-copy or digital MTNHP products with the intent to sell is prohibited without written consent by MTNHP. Should you be asked by individuals outside your organization for the type of data that we provide, please refer them to MTNHP.
- MTNHP and appropriate staff members should be appropriately acknowledged as an information source in any third-party product involving MTNHP data, reports, papers, publications, or in maps that incorporate MTNHP graphic elements.
- Sources of our data include museum specimens, published and unpublished scientific literature, field surveys by state and federal agencies and private contractors, and reports from knowledgeable individuals. MTNHP actively solicits and encourages additions, corrections and updates, new observations or collections, and comments on any of the data we provide.
- MTNHP staff and contractors do not enter or cross privately-owned lands without express permission from the landowner. However, the program cannot guarantee that information provided to us by others was obtained under adherence to this policy.

Suggested Contacts for Natural Resource Management Agencies

As required by Montana statute (MCA 90-15), the Montana Natural Heritage Program works with state, federal, tribal, nongovernmental organizations, and private partners to ensure that the latest animal and plant distribution and status information is incorporated into our databases so that it can be used to inform a variety of permitting and planning processes and management decisions. We encourage you to contact state, federal, and tribal resource management agencies in the area where your project is located and review the permitting overviews by the Montana Department of Environmental Quality, the Montana Department of Natural Resources and Conservation and the Index of Environmental Permits for Montana for guidelines relevant to your efforts. In particular, we encourage you to contact the Montana Department of Fish, Wildlife, and Parks for the latest data and management information regarding hunted and high-profile management species and to use the U.S. Fish and Wildlife Service's Information Planning and Consultation (IPAC) website regarding U.S. Endangered Species Act listed Threatened, Endangered, or Candidate species.

For your convenience, we have compiled a list of relevant agency contacts and links below:

Montana Fish, Wildlife, and Parks

Fish Species	Zachary Shattuck zshattuck@mt.gov (406) 444-1231 or Eric Roberts eroberts@mt.gov (406) 444-5334
American Bison Black-footed Ferret Black-tailed Prairie Dog Bald Eagle Golden Eagle Common Loon Least Tern Piping Plover Whooping Crane	Kristian Smucker KSmucker@mt.gov (406) 444-5209
Grizzly Bear Greater Sage Grouse Trumpeter Swan Big Game Upland Game Birds Furbearers	Brian Wakeling brian.wakeling@mt.gov (406) 444-3940
Managed Terrestrial Game Data	Cara Whalen– MFWP Data Analyst cara.whalen@mt.gov (406) 444-3759
Fisheries Data and Nongame Animal Data	Ryan Alger – MFWP Data Analyst ryan.alger@mt.gov (406) 444-5365
Wildlife and Fisheries Scientific Collector's Permits	https://fwp.mt.gov/buyandapply/commercialwildlifeandscientificpermits/scientific Kristina Smucker for Wildlife ksmucker@mt.gov (406) 444-5209 Dave Schmetterling for Fisheries dschmetterling@mt.gov (406) 542-5514
Fish and Wildlife Recommendations for Subdivision Development	Charlie Sperry csperry@mt.gov (406) 444-3888 See https://fwp.mt.gov/conservation/living-with-wildlife/subdivision-recommendations
Regional Contacts 	Region 1 (Kalispell) (406) 752-5501 fwprg12@mt.gov Region 2 (Missoula) (406) 542-5500 fwprg22@mt.gov Region 3 (Bozeman) (406) 577-7900 fwprg3@mt.gov Region 4 (Great Falls) (406) 454-5840 fwprg42@mt.gov Region 5 (Billings) (406) 247-2940 fwprg52@mt.gov Region 6 (Glasgow) (406) 228-3700 fwprg62@mt.gov Region 7 (Miles City) (406) 234-0900 fwprg72@mt.gov

Montana Department of Agriculture
General Contact Information: https://agr.mt.gov/About/Office-Locations/Office-Locations-and-Field-Offices
Noxious Weeds: https://agr.mt.gov/Noxious-Weeds

Montana Department of Environmental Quality
Permitting and Operator Assistance for all Environmental Permits: https://deq.mt.gov/Permitting

Montana Department of Natural Resources and Conservation
Overview of, and contacts for, licenses and permits for state lands, water, and forested lands:
https://dnrc.mt.gov/Permits-Services

Stream Permitting (310 permits) and an overview of various water and stream related permits (e.g., Stream Protection Act 124, Federal Clean Water Act 404, Federal Rivers and Harbors Act Section 10, Short-term Water Quality Standard for Turbidity 318 Authorization, etc.).
https://dnrc.mt.gov/Licenses-and-Permits/Stream-Permitting

Wildfire Resources: https://dnrc.mt.gov/Forestry/Wildfire

Bureau of Land Management

Montana Field Office Contacts:

Billings	(406) 896-5013
Butte	(406) 533-7600
Dillon	(406) 683-8000
Glasgow	(406) 228-3750
Havre	(406) 262-2820
Lewistown	(406) 538-1900
Malta	(406) 654-5100
Miles City	(406) 233-2800
Missoula	(406) 329-3914

United States Army Corps of Engineers
Montana Regulatory Office for federal permits related to construction in water and wetlands
https://www.nwo.usace.army.mil/Missions/Regulatory-Program/Montana/ (406) 441-1375

United States Environmental Protection Agency
Environmental information, notices, permitting, and contacts https://www.epa.gov/mt
Gateway to state resource locators https://www.envcap.org/srl/index.php

United States Fish and Wildlife Service
Information Planning and Conservation (IPAC) website: https://ipac.ecosphere.fws.gov
Montana Ecological Services Field Office: https://www.fws.gov/office/montana-ecological-services (406) 449-5225

United States Forest Service

Regional Office – Missoula, Montana Contacts

Wildlife Program Leader	Tammy Fletcher	tammy.fletcher2@usda.gov	(406) 329-3086
Wildlife Ecologist	Cara Staab	cara.staab@usda.gov	(406) 329-3677
Aquatic Ecologist	Justin Jimenez	justin.jimenez@usda.gov	(435) 370-6830
TES Program	Lydia Allen	lydia.allen@usda.gov	(406) 329-3558
Interagency Grizzly Bear Coordinator	Scott Jackson	scott.jackson@usda.gov	(406) 329-3664
Regional Botanist	Amanda Hendrix	amanda.hendrix@usda.gov	(651) 447-3016
Regional Vegetation Ecologist	Mary Manning	marry.manning@usda.gov	(406) 329-3304
Invasive Species Program Manager	Michelle Cox	michelle.cox2@usda.gov	(406) 329-3669

Tribal Nations

Assiniboine & Gros Ventre Tribes – Fort Belknap Reservation
Assiniboine & Sioux Tribes – Fort Peck Reservation
Blackfeet Tribe - Blackfeet Reservation
Chippewa Creek Tribe - Rocky Boy's Reservation
Crow Tribe – Crow Reservation
Little Shell Chippewa Tribe
Northern Cheyenne Tribe – Northern Cheyenne Reservation
Salish & Kootenai Tribes - Flathead Reservation

Natural Heritage Programs and Conservation Data Centers in Surrounding States and Provinces

Alberta Conservation Information Management System
British Columbia Conservation Data Centre
Idaho Natural Heritage Program
North Dakota Natural Heritage Program
Saskatchewan Conservation Data Centre
South Dakota Natural Heritage Program
Wyoming Natural Diversity Database

Invasive Species Management Contacts and Information

Aquatic Invasive Species

Montana Fish, Wildlife, and Parks Aquatic Invasive Species staff
Montana Department of Natural Resources and Conservation's Aquatic Invasive Species Grant Program
Montana Invasive Species Council (MISC)
Upper Columbia Conservation Commission (UC3)

Noxious Weeds

Montana Weed Control Association Contacts Webpage
Montana Biological Weed Control Coordination Project
Montana Department of Agriculture - Noxious Weeds
Montana Weed Control Association
Montana Fish, Wildlife, and Parks - Noxious Weeds
Montana State University Integrated Pest Management Extension
Integrated Noxious Weed Management after Wildfires
Fire Management and Invasive Plants

Introduction to Native Species

Within the report area you have requested, separate summaries are provided for: (1) Species Occurrences (SO) for plant and animal Species of Concern, Special Status Species (SSS), Important Animal Habitat (IAH) and some Potential Plant Species of Concern; (2) other observed non Species of Concern or Species of Concern without suitable documentation to create Species Occurrence polygons; and (3) other non-documented species that are potentially present based on their range, predicted suitable habitat model output, or presence of associated habitats. Each of these summaries provides the following information when present for a species: (1) the number of Species Occurrences and associated delineation criteria for construction of these polygons that have long been used for considerations of documented Species of Concern in environmental reviews; (2) the number of observations of each species; (3) the geographic range polygons for each species that the report area overlaps; (4) predicted relative habitat suitability classes that are present if a predicted suitable habitat model has been created; (5) the percent of the report area that is mapped as commonly associated or occasionally associated habitat as listed for each species in the Montana Field Guide; and (6) a variety of conservation status ranks and links to species accounts in the Montana Field Guide. Details on each of these information categories are included under relevant section headers below or are defined on our Species Status Codes page. In presenting this information, the Montana Natural Heritage Program (MTNHP) is working towards assisting the user with rapidly determining what species have been documented and what species are potentially present in the report area. We remind users that this information is likely incomplete as surveys to document native and introduced species are lacking in many areas of the state, information on introduced species has only been tracked relatively recently, the MTNHP's staff and resources are restricted by budgets, and information is constantly being added and updated in our databases. **Thus, field verification by professional biologists of the absence or presence of species and biological communities will always be an important obligation of users of our data.**

If you are aware of observation datasets that the MTNHP is missing, please report them to the Program Botanist apipp@mt.gov or Senior Zoologist dbachen@mt.gov If you have animal or plant observations that you would like to contribute, you can also submit them via Excel spreadsheets, geodatabases, iNaturalist, or a Survey123 form. Various methods of data submission are reviewed in this playlist of videos: https://www.youtube.com/playlist?list=PLRaydtZpHu2qOHPoSPq9cnM9uXGmEXACx

Observations

The MTNHP manages information on several million animal and plant observations that have been reported by professional biologists and private citizens from across Montana. The majority of these observations are submitted in digital format from standardized databases associated with research or monitoring efforts and spreadsheets of incidental observations submitted by professional biologists and amateur naturalists. At a minimum, accepted observation records must contain a credible species identification (i.e. appropriate geographic range, date, and habitat and, if species are difficult to identify, a photograph and/or notes on key identifying features), a date or date range, observer name, locational information (ideally with latitude and longitude in decimal degrees), notes on numbers observed, and species behavior or habitat use (e.g., is the observation likely associated with reproduction). Bird records are also required to have information associated with date-appropriate breeding or overwintering status of the species observed. MTNHP reviews observation records to ensure that they are mapped correctly, occur within date ranges when the species is known to be present or detectable, occur within the known seasonal geographic range of the species, and occur in appropriate habitats. MTNHP also assigns each record a locational uncertainty value in meters to indicate the spatial precision associated with the record's mapped coordinates. Only records with locational uncertainty values of 10,000 meters or less are included in environmental summary reports and number summaries are only provided for records with locational uncertainty values of 1,000 meters or less.

Species Occurrences

The MTNHP evaluates plant and animal observation records for species of higher conservation concern to determine whether they are worthy of inclusion in the Species Occurrence (SO) layer for use in environmental reviews; observations not worthy of inclusion in this layer include long distance dispersal events, migrants observed away from key migratory stopover habitats, and winter observations. An SO is a polygon depicting what is known about a species occupancy from direct observation with a defined level of locational uncertainty and any inference that can be made about adjacent habitat use from the latest peer-reviewed science. If an observation can be associated with a map feature that can be tracked (e.g., a wetland boundary for a wetland associated plant) then this polygon feature is used to represent the SO. Areas that can be inferred as probable occupied habitat based on direct observation of a species location and what is known about the foraging area or home range size of the species may be incorporated into the SO. Species Occurrences generally belong to one of the following categories:

Plant Species Occurrences

A documented location of a specimen collection or observed plant population. In some instances, adjacent, spatially separated clusters are considered subpopulations and are grouped as one occurrence (e.g., the subpopulations occur in ecologically similar habitats, and their spatial proximity likely allows them to interbreed). Tabular information for multiple observations at the same SO location is generally linked to a single polygon. Plant SO's are only created for Species of Concern and Potential Species of Concern.

Animal Species Occurrences

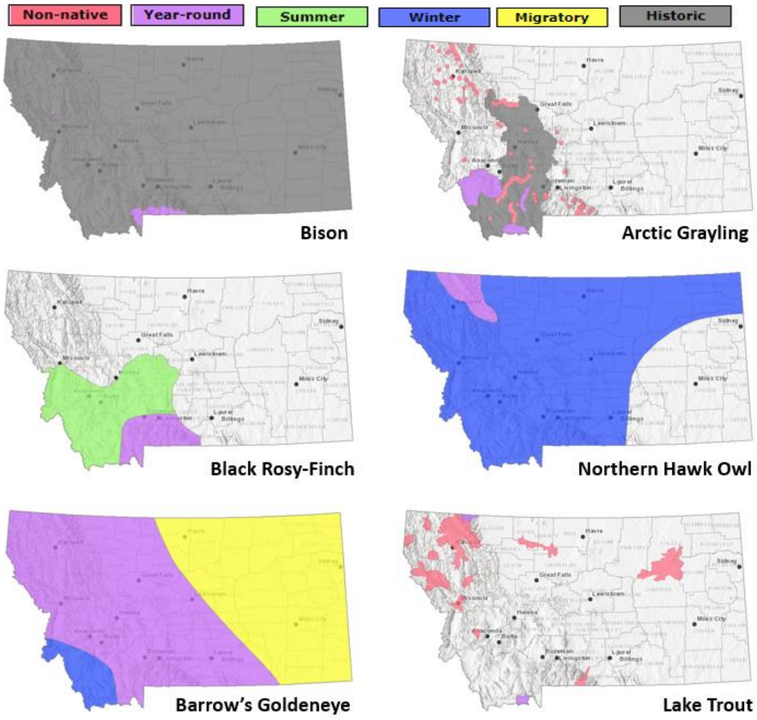
The location of a verified observation or specimen record typically known or assumed to represent a breeding population or a portion of a breeding population. Animal SO’s are generally: (1) buffers of terrestrial point observations based on documented species’ home range sizes; (2) buffers of stream segments to encompass occupied streams and immediate adjacent riparian habitats; (3) polygonal features encompassing known or likely breeding populations (e.g., a wetland for some amphibians or a forested portion of a mountain range for some wide-ranging carnivores); or (4) combinations of the above. Tabular information for multiple observations at the same SO location is generally linked to a single polygon. Species Occurrence polygons may encompass some unsuitable habitat in some instances in order to avoid heavy data processing associated with clipping out habitats that are readily assessed as unsuitable by the data user (e.g., a point buffer of a terrestrial species may overlap into a portion of a lake that is obviously inappropriate habitat for the species). Animal SO's are only created for Species of Concern and Special Status Species (e.g., Bald Eagle).

Other Occurrence Polygons

These include significant biological features not included in the above categories, such as Important Animal Habitats like bird rookeries and bat roosts, and peatlands or other wetland and riparian communities that support diverse plant and animal communities.

Geographic Range Polygons

Geographic range polygons are still under development for most plant and invertebrate species. Native year-round, summer, winter, migratory and historic geographic range polygons as well as polygons for introduced populations have been defined for most vertebrate animal species for which there are enough observations, surveys, and knowledge of appropriate seasonal habitat use to define them (see examples to left). These native or introduced range polygons bound the extent of known or likely occupied habitats for non-migratory and relative sedentary species and the regular extent of known or likely occupied habitats for migratory and long-distance dispersing species; polygons may include unsuitable intervening habitats. For most species, a single polygon can represent the year-round or seasonal range, but breeding ranges of some colonial nesting water birds and some introduced species are represented more patchily when supported by data. Some ranges are mapped more broadly than actual distributions in order to be visible on statewide maps (e.g., fish).



Predicted Suitable Habitat Models

Predicted habitat suitability models have been created for plant and animal Species of Concern and are undergoing development for non-Species of Concern. For species for which models have been completed, the environmental summary report includes simple rule-based associations with streams for aquatic species and seasonal habitats for game species as well as mathematically complex Maximum Entropy models (Phillips et al. 2006, Ecological Modeling 190:231-259) constructed from a variety of statewide biotic and abiotic layers and presence only data for individual species for most terrestrial species. For the Maximum Entropy models, we reclassified 90 x 90-meter continuous model output into suitability classes (unsuitable, low, moderate, and optimal) then aggregated that into the one square mile hexagons used in the environmental summary report; this is the finest spatial scale we suggest using this information in management decisions and survey planning. Full model write ups for individual species that discuss model goals, inputs, outputs, and evaluation in much greater detail are posted on the MTNHP's Predicted Suitable Habitat Models webpage. Evaluations of predictive accuracy and specific limitations are included with the metadata for models of individual species. **Model outputs should not be used in place of on-the-ground surveys for species. Instead model outputs should be used in conjunction with habitat evaluations to determine the need for on-the-ground surveys for species.** We suggest that the percentage of predicted optimal and moderate suitable habitat within the report area be used in conjunction with geographic range polygons and the percentage of commonly associated habitats to generate lists of potential species that may occupy broader landscapes for the purposes of landscape-level planning.

Associated Habitats

Within the boundary of the intersected hexagons, we provide the approximate percentage of commonly or occasionally associated habitat for vertebrate animal species that regularly breed, overwinter, or migrate through the state; a detailed list of commonly and occasionally associated habitats is provided in individual species accounts in the Montana Field Guide We assigned common or occasional use of each of the ecological systems mapped in Montana by: (1) using personal knowledge and reviewing literature that summarizes the breeding, overwintering, or migratory habitat requirements of each species; (2) evaluating structural characteristics and distribution of each ecological system relative to the species' range and habitat requirements; (3) examining the observation records for each species in the state-wide point observation database associated with each ecological system; and (4) calculating the percentage of observations associated with each ecological system relative to the percent of Montana covered by each ecological system to get a measure of numbers of observations versus availability of habitat. Species that breed in Montana were only evaluated for breeding habitat use, species that only overwinter in Montana were only evaluated for overwintering habitat use, and species that only migrate through Montana were only evaluated for migratory habitat use. In general, species were listed as associated with an ecological system if structural characteristics of used habitat documented in the literature were present in the ecological system or large numbers of point observations were associated with the ecological system. However, species were not listed as associated with an ecological system if there was no support in the literature for use of structural characteristics in an ecological system, even if point observations were associated with that system. Common versus occasional association with an ecological system was assigned based on the degree to which the structural characteristics of an ecological system matched the preferred structural habitat characteristics for each species as represented in the scientific literature. The percentage of observations associated with each ecological system relative to the percent of Montana covered by each ecological system was also used to guide assignment of common versus occasional association.

We suggest that the percentage of commonly associated habitat within the report area be used in conjunction with geographic range polygons and the percentage of predicted optimal and moderate suitable habitat from predictive models to generate lists of potential species that may occupy broader landscapes for the purposes of landscape-level planning. Users of this information should be aware that land cover mapping accuracy is particularly problematic when the systems occur as small patches or where the land cover types have been altered over the past decade. Thus, particular caution should be used when using the associations in assessments of smaller areas (e.g., evaluations of public land survey sections).

Introduction to Land Cover

Land Use/Land Cover is one of 15 Montana Spatial Data Infrastructure framework layers considered vital for making statewide maps of Montana and understanding its geography. The layer records all Montana natural vegetation, land cover and land use, classified from satellite and aerial imagery, mapped at a scale of 1:100,000, and interpreted with supporting ground-level data. The baseline map is adapted from the Northwest ReGAP (NWGAP) project land cover classification, which used 30m resolution multi-spectral Landsat imagery acquired between 1999 and 2001. Vegetation classes were drawn from the Ecological System Classification developed by NatureServe (Comer et al. 2003). The land cover classes were developed by Anderson et al. (1976). The NWGAP effort encompasses 12 map zones. Montana overlaps seven of these zones. The two NWGAP teams responsible for the initial land cover mapping effort in Montana were Sanborn and NWGAP at the University of Idaho. Both Sanborn and NWGAP employed a similar modeling approach in which Classification and Regression Tree (CART) models were applied to Landsat ETM+ scenes. The Spatial Analysis Lab within the Montana Natural Heritage Program was responsible for developing a seamless Montana land cover map with a consistent statewide legend from these two separate products. Additionally, the Montana land cover layer incorporates several other land cover and land use products (e.g., MSDI Structures and Transportation themes and the Montana Department of Revenue Final Land Unit classification) and reclassifications based on plot-level data and the latest NAIP imagery to improve accuracy and enhance the usability of the theme. Updates are done as partner support and funding allow, or when other MSDI datasets can be incorporated. Recent updates include fire perimeters and agricultural land use (annually), energy developments such as wind, oil and gas installations (2014), roads, structures and other impervious surfaces (various years): and local updates/improvements to specific ecological systems (e.g., central Montana grassland and sagebrush ecosystems). Current and previous versions of the Land Use/Land Cover layer with full metadata are available for download from the Montana State Library's GIS Data List More information on the land cover layer is available at: https://msl.mt.gov/geoinfo/msdi/land_use_land_cover/

Within the report area you have requested, land cover is summarized by acres of Level 1, Level 2, and Level 3 Ecological Systems.

Literature Cited

Anderson, J.R. E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. U.S. Geological Survey Professional Paper 964.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Introduction to Wetland and Riparian

Within the report area you have requested, wetland and riparian mapping is summarized by acres of each classification present. Summaries are only provided for modern MTNHP wetland and riparian mapping and not for outdated (NWI Legacy) or incomplete (NWI Scalable) mapping efforts; described here. MTNHP has made all three of these datasets and associated metadata available for separate download on the Montana Wetland and Riparian Framework web page.

Wetland and Riparian mapping is one of 15 Montana Spatial Data Infrastructure framework layers considered vital for making statewide maps of Montana and understanding its geography. The wetland and riparian framework layer consists of spatial data representing the extent, type, and approximate location of wetlands, riparian areas, and deep water habitats in Montana.

Wetland and riparian mapping is completed through photointerpretation of 1-m resolution color infrared aerial imagery acquired from 2005 or later. A coding convention using letters and numbers is assigned to each mapped wetland. These letters and numbers describe the broad landscape context of the wetland, its vegetation type, its water regime, and the kind of alterations that may have occurred. Ancillary data layers such as topographic maps, digital elevation models, soils data, and other aerial imagery sources are also used to improve mapping accuracy. Wetland mapping follows the federal Wetland Mapping Standard and classifies wetlands according to the Cowardin classification system of the National Wetlands Inventory (NWI) (Cowardin et al. 1979, FGDC Wetlands Subcommittee 2013). Federal, State, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands differently than the NWI. Similar coding, based on U.S. Fish and Wildlife Service conventions, is applied to riparian areas (U.S. Fish and Wildlife Service 2009). These are mapped areas where vegetation composition and growth is influenced by nearby water bodies, but where soils, plant communities, and hydrology do not display true wetland characteristics. **These data are intended for use at a scale of 1:12,000 or smaller. Mapped wetland and riparian areas do not represent precise boundaries and digital wetland data cannot substitute for an on-site determination of jurisdictional wetlands.**

See detailed overviews, with examples, of both wetland and riparian classification systems and associated codes as a storymap and companion guide

Literature Cited

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, FWS/OBS-79/31. Washington, D.C. 103pp.

Federal Geographic Data Committee. 2013. Classification of wetlands and deepwater habitats of the United States. FGDC-STD-004-2013. Second Edition. Wetlands Subcommittee, Federal Geographic Data Committee and U.S. Fish and Wildlife Service, Washington, D.C.

U.S. Fish and Wildlife Services. 2009. A system for mapping riparian areas in the western United States. Division of Habitat and Resource Conservation, Branch of Resource and Mapping Support, Arlington, Virginia.

Introduction to Land Management

Within the report area you have requested, land management information is summarized by acres of federal, state, and local government lands, tribal reservation boundaries, private conservation lands, and federal, state, local, and private conservation easements. Acreage for “Owned”, “Tribal”, or “Easement” categories represents non-overlapping areas that may be totaled. However, “Other Boundaries” represents managed areas such as National Forest boundaries containing private inholdings and other mixed ownership which may cause boundaries to overlap (e.g. a wilderness area within a forest). Therefore, acreages may not total in a straight-forward manner.

Because information on land stewardship is critical to effective land management, the Montana Natural Heritage Program (MTNHP) began compiling ownership and management data in 1997. The goal of the Montana Land Management Database is to manage a single, statewide digital data set that incorporates information from both public and private entities. The database assembles information on public lands, private conservation lands, and conservation easements held by state and federal agencies and land trusts and is updated on a regular basis. Since 2011, the Information Management group in the Montana State Library’s Digital Library Division has led the Montana Land Management Database in partnership with the MTNHP.

Public and private conservation land polygons are attributed with the name of the entity that owns it. The data are derived from the statewide Montana Cadastral Parcel layer Conservation easement data shows land parcels on which a public agency or qualified land trust has placed a conservation easement in cooperation with the landowner. The dataset contains no information about ownership or status of the mineral estate. For questions about the dataset or to report errors, please contact the Montana Natural Heritage Program at (406) 444-5363 or mtnhp@mt.gov. You can download various components of the Land Management Database and view associated metadata at the Montana State Library’s GIS Data List at the following links:

Public Lands
Conservation Easements
Private Conservation Lands
Managed Areas

Map features in the Montana Land Management Database or summaries provided in this report are not intended as a legal depiction of public or private surface land ownership boundaries and should not be used in place of a survey conducted by a licensed land surveyor. Similarly, map features do not imply public access to any lands. The Montana Natural Heritage Program makes no representations or warranties whatsoever with respect to the accuracy or completeness of this data and assumes no responsibility for the suitability of the data for a particular purpose. The Montana Natural Heritage Program will not be liable for any damages incurred as a result of errors displayed here. Consumers of this information should review or consult the primary data and information sources to ascertain the viability of the information for their purposes.

Introduction to Invasive and Pest Species

Within the report area you have requested, separate summaries are provided for: Aquatic Invasive Species, Noxious Weeds, Agricultural Pests, Forest Pests, and Biocontrol species that have been documented or potentially occur there based on the predicted suitability of habitat. Definitions for each of these invasive and pest species categories can be found on our Species Status Codes page.

Each of these summaries provides the following information when present for a species: (1) the number of observations of each species; (2) the geographic range polygons for each species, if developed, that the report area overlaps; (3) predicted relative habitat suitability classes that are present if a predicted suitable habitat model has been created; (4) the percent of the report area that is mapped as commonly associated or occasionally associated habitat as listed for each species in the Montana Field Guide; and (5) links to species accounts in the Montana Field Guide. Details on each of these information categories are included under relevant section headers under the Introduction to Native Species above or are defined on our Species Status Codes page. In presenting this information, the Montana Natural Heritage Program (MTNHP) is working towards assisting the user with rapidly determining what invasive and pest species have been documented and what species are potentially present in the report area. We remind users that this information is likely incomplete as surveys to document introduced species are lacking in many areas of the state, information on introduced species has only been tracked relatively recently, the MTNHP’s staff and resources are limited, and information is constantly being added and updated in our databases. **Thus, field verification by professional biologists of the absence or presence of species will always be an important obligation of users of our data.**

If you are aware of observation or survey datasets for invasive or pest species that the MTNHP is missing, please report them to the Program Coordinator bmaxell@mt.gov Program Botanist apipp@mt.gov or Senior Zoologist dbachen@mt.gov If you have animal or plant observations that you would like to contribute, you can also submit them via Excel spreadsheets, geodatabases, iNaturalist, or a Survey123 form. Various methods of data submission are reviewed in this playlist of videos:
https://www.youtube.com/playlist?list=PLRaydtZpHu2qOHPoSPq9cnM9uXGmEXACx

Additional Information Resources

MTNHP Staff Contact Information

Montana Field Guide

MTNHP Species of Concern Report - Animals and Plants

MTNHP Species Status Codes - Explanation

MTNHP Predicted Suitable Habitat Models (for select Animals and Plants)

MTNHP Request Information page

Montana Cadastral

Montana Code Annotated

Montana Fisheries Information System

Montana Fish, Wildlife, and Parks Subdivision Recommendations

Montana GIS Data Layers

Montana GIS Data Bundler

Montana Greater Sage-Grouse Project Submittal Site

Montana Ground Water Information Center

Montana Index of Environmental Permits, 21st Edition (2018)

Montana Environmental Policy Act (MEPA)

Montana Environmental Policy Act Analysis Resource List

Laws, Treaties, Regulations, and Agreements on Animals and Plants

Montana Spatial Data Infrastructure Layers

Montana State Historic Preservation Office Review and Compliance

Montana Stream Permitting: a guide for conservation district supervisors and others

Montana Water Information System

Montana Web Map Services

National Environmental Policy Act

Penalties for Misuse of Fish and Wildlife Location Data (MCA 87-6-222)

U.S. Fish and Wildlife Service Information for Planning and Consultation (Section 7 Consultation)

Web Soil Survey Tool

ATTACHMENT D

PROJECT TECHNICAL MEMO AND TIMELINE

DRY CREEK IRRIGATION CANAL IMPROVEMENTS PROJECT

PREPARED FOR:

DRY CREEK IRRIGATION COMPANY

5485 SPAULDING BRIDGE ROAD
BELGRADE, MT 59714

PREPARED BY:

WWC ENGINEERING

7600 SHEDHORN DRIVE, SUITE 7
BOZEMAN, MT 59718
(406) 624-3910
www.WWCengineering.com

DECEMBER 2021

DRY CREEK IRRIGATION CANAL IMPROVEMENTS PROJECT

Prepared for:
Dry Creek Irrigation Company
ATTN: Jeannie Anderson
5485 Spaulding Bridge Road
Belgrade, MT 59714

Prepared by:
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Bozeman, MT 59718
(406) 624-3910

Principal Authors: Peter Haun, P.E.

Reviewed by: Shawn Higley, P.E., Helena Branch Manager

Date: December 2021

WWC ENGINEERING
7600 SHEDHORN DRIVE SUITE 7, BOZEMAN, MT 59715 | 406.624.3910

Memo

TO: Dry Creek Irrigation Company
FROM: WWC Engineering
DATE: 12/13/2021
SUBJECT: Dry Creek Irrigation Canal Improvements Project

Project Identification

Project Description and Location

The Dry Creek Irrigation Company (Company) owns, operates, and maintains the Dry Creek Irrigation Canal (Canal), located approximately 4 miles north of Belgrade, MT. The Canal diverts water from both the East Gallatin River and Ross Creek to provide irrigation water for users along the 8.8 miles of canal before returning water to the East Gallatin River. The Canal was constructed in 1906, while the Company was incorporated in 1907. The Company currently has 31 users listed as shareholders with a combined water right of 63.75 cubic feet per second (cfs). The primary purpose of the Canal is to provide irrigation water to its users for irrigating crops and stock water. A map depicting the Canal is provided in Figure 1.

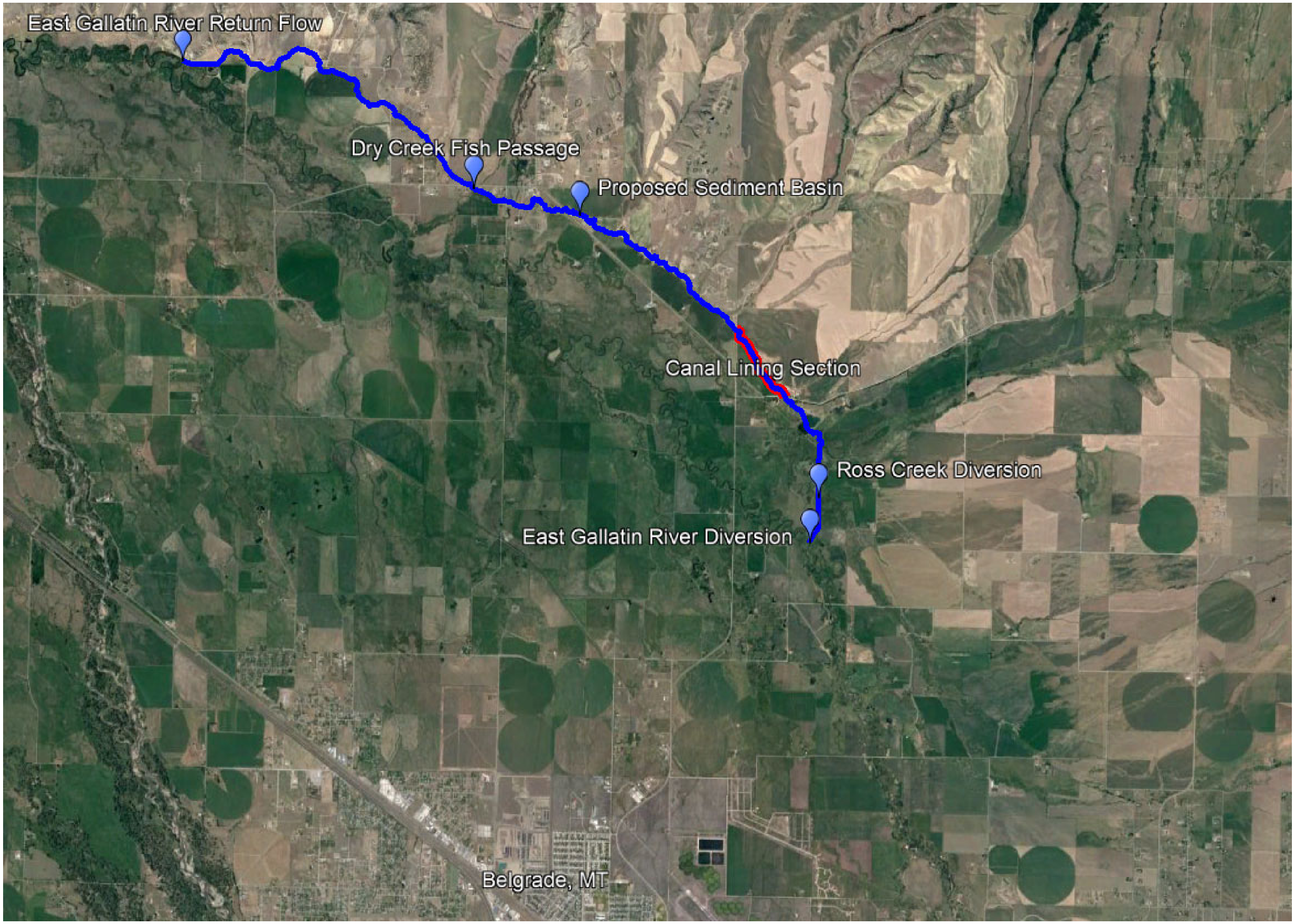
The proposed Dry Creek Irrigation Canal Improvements Project will include rehabilitation of approximately of 4,000 feet of the Canal and construction of a sediment pond. The project will provide significant water conservation benefits by reducing seepage losses along the canal and provide a reduction in irrigation induced sediment pollution. Dry Creek is listed for sedimentation/siltation on the 2012 303(d) list. The proposed sediment pond is intended to reduce sediment deposition along the length of the canal, reduce sediment loading into Dry Creek and the East Gallatin River, and improve water quality. Additionally, reducing sediment deposition along the Canal will reduce regular Operation and Maintenance (O&M) of the Canal.

Project History

Project Need

The Canal was constructed in 1906 and the Company was subsequently incorporated the following year in 1907. The Canal diverts water from both the East Gallatin River and Ross Creek during the normal irrigation season, from April 15th to November 1st. Approximately 32.5 cfs is diverted from the East Gallatin River and 31.25 cfs is diverted from Ross Creek approximately 0.4 miles north of the East Gallatin River Diversion. From these diversions, the irrigation water flows through the remainder of the 8.8-mile-long Canal where the users divert the water to irrigate 3,200 acres of fertile land using pivots, wheel lines, and flood irrigation methods. Irrigation water is used predominantly for grain, hay, potatoes, and stock water. According to the Company, the Canal has experienced problems associated water loss due to seepage within the canal and sediment deposition, which can disrupt the flow of the irrigation water needed by its users.

Figure 1. Dry Creek Irrigation Canal Vicinity Map



Seepage

The majority of the Canal's length was constructed on silts, sands, and gravels. While seepage issues may affect portions of the entire canal, the worst section involves an approximately 4,000-foot section between Reese Creek Road and Theisen Road. This section of the Canal was built up above the surrounding ground using an embankment composed of compacted native soil. According to the Company, seepage in this section of the Canal has been an ongoing issue for decades and annually impacts adjacent farmland. In the spring of 1997, the Gallatin River experienced the highest peak runoff in recorded history. Sections of the canal embankment throughout this section collapsed, which subsequently required repairs. During the repair, excavations exceeded the design bottom elevation of the Canal, which exacerbated the seepage problem following the repair. Burrowing rodents breaching the canal wall is another source of seepage that is common with irrigation canals. However, the primary cause of the Canal's seepage problem is most likely due to the soil conditions on which the Canal was constructed as well as the canal's location, perched above the adjacent field.

Approximately 67 acres of land on the southern side of the canal is leased for hay production. According to the Company, this area is often inundated with water originating from the canal seeps to the extent where large ponds form in the field, creating difficulties for hay production, particularly when using heavy farming equipment. This has been an ongoing issue for several decades which has directly impacted the productivity of this land and the safety of personnel and equipment.

The extent and quantity of seepage occurring through this section of the Canal has not been previously identified. To document seepage losses that would occur during design flows, the rate of seepage from the 4,000-foot section of the Canal was calculated. Seepage loss calculations were developed using Darcy's Law ($Q = kia$). WWC Engineering (WWC) performed a search of the NRCS Web Soil Survey to determine the drainage conditions for soils within the area. This search indicated that the soils in the area consisted of Havre Loam with a saturated hydraulic conductivity of 4 ft/day. The seepage loss (Q) through the 4,000-foot section was calculated to be 2.8 cfs, which equates to a total volume of 1,129 ac-ft/yr, assuming an irrigation season spanning from April 15th to November 1st. The seepage loss calculations are provided in Attachment 1. This estimate may be overly conservative since during a site visit conducted by WWC on November 5, 2021, the presence of porous granular soils was observed within the canal prism which would have a higher saturated hydraulic conductivity than the NRSC Web Soil Survey data. This type of soil was observed only within the 4,000-ft section between Reese Creek Road and Theisen Road and not found in other portions of the 8.8-mile-long Canal. These soils could possibly create seepage losses greater than the 2.8 cfs calculated above. These soil conditions are visible in Figures 1-3 provided in Attachment 2.

The East Gallatin River has documented impacts from Total Nitrogen, and Total Phosphorus and has Total Maximum Daily Loads (TMDLs) developed for each of these pollutants. However, there are pollution listings in the Lower Gallatin TMDL Planning Area that are probable causes of impairment. One of the probable causes of impairment for the East Gallatin River from Bridger Creek to Smith Creek, which includes the Canal's point of diversion, is low flow alterations. Low flow alterations occur by irrigation withdrawal leading to base flows that are too low to support beneficial uses and has the potential to impact fish and aquatic life. These low flow conditions can also lead to higher stream temperatures and lower dissolved oxygen concentrations to support some species of fish. It is important to note that TMDLs cannot impact Montana water rights and affect the allowable flows at various times of the year.

The loss of water from seepage results in the Company diverting additional water from the East Gallatin River and Ross Creek into their system than is necessary to ensure delivery to all users. This excess flow takes water away from Ross Creek and the East Gallatin River during certain times of the year and can contribute to low flow alterations, subsequently impacting fish and aquatic life. The rehabilitation of the 4,000-ft stretch of the Canal could conserve 2.8 cfs of water within the irrigation delivery system, allowing this water to remain in the East Gallatin River and Ross Creek to benefit fish and wildlife populations.

Sedimentation

Like other irrigation canals in the Gallatin Valley, the Canal is part of a network that intermixes with other water after its point of diversion. The Canal intermixes and diverts water from Ross Creek, which later combines with Reese Creek to form Smith Creek. The Canal crosses Dry Creek further downstream before discharging back into the East Gallatin River. Dry Creek is a tributary of the East Gallatin River and supports a variety of fish species. The Dry Creek drainage has experienced channelization, sedimentation, and fish passage problems. Dry Creek is listed for sedimentation/siltation on the 2012 303(d) List. It is also listed for alterations in vegetative covers and physical habitat alterations, which are non-pollutant listings commonly linked to sediment impairment.

Dry Creek was historically disconnected from the East Gallatin during the irrigation season. During the irrigation season, a headgate on Dry Creek was closed and intercepted flows from Dry Creek into the Canal. A fish bypass channel was constructed as part of the Future Fisheries Improvement Program in 2018 to reconnect the lower reaches of Dry Creek with the upper reaches to promote fish migration and reduce fish entrainment in the Canal. Dry Creek and the Canal are segregated during the irrigation season by stoplogs placed in the main channel of Dry Creek on the upstream and downstream side of the intersection with the Canal. This directs most of the flow through the fish passage under the Canal to permit fish migration. During the site visit conducted by WWC on November 5, 2021, the fish passage was closed, and Dry Creek was flowing freely across the intersection with the Canal and continuing into the lower reaches of Dry Creek. Sediment deposits were observed in and around the intersection of Dry Creek and the Canal. These conditions are visible in Figures 4-6 provided in Attachment 2. The source of the sedimentation is most likely contributed to a combination of diverted flow from the East Gallatin River and Ross Creek, Dry Creek, bank erosion within the Canal, and stormwater runoff collected by the Canal. It should be noted that no signs of significant bank erosion along the sections of the Canal visited were observed during the site visit conducted by WWC on November 5, 2021.

Sediment deposition along the Canal has not been quantified or documented but is a reoccurring problem which requires annual maintenance and sediment removal to ensure the Canal conveys the design flow rate. Even though the Canal and Dry Creek are segregated during the irrigation season, sediment deposition in and around the intersection may contribute to additional sediment loading in Dry Creek when the fish passage is closed in November. The Company does not regularly remove sediment within the Dry Creek streambed due to 310 permit requirements. Additionally, sediment deposition throughout the Canal can contribute to sediment loading to the East Gallatin River via return flows. A sediment pond is proposed as part of this project to help mitigate sediment deposition throughout the Canal and reduce sediment loading to Dry Creek and the East Gallatin River which would provide a tremendous improvement to the water quality of return flows to these water bodies to help meet the current TMDLs.

Proposed Project

This section will provide a detailed description of the project tasks designated to provide improvements based on the needs outlined in the previous section. These tasks include:

- Improve the irrigation system operations along the Canal by rehabilitating a 4,000-foot stretch of the Canal, thereby allowing the Canal to function as designed.
- Reduce sediment deposition along the Canal and reduce sediment loading to Dry Creek and the East Gallatin River by construction of a sediment basin, providing a centralized location for sediment removal.

Project Scope

Canal Lining

This project component involves installation of a canal liner within the 4,000-foot section of the Canal. Prior to the installation of the liner, the areas within the canal prism would be stripped of organic matter, and the canal would be reshaped to the desired dimensions including an 8-foot bottom width, 6-foot total depth, and 1.5H:1V side slopes. After completing these initial steps, the liner system and ballast material would be installed.

The canal liner system would be a geocomposite membrane sandwiched between nonwoven geotextile fabrics and bonded together to form an impervious membrane barrier with enhanced strength and friction capabilities. This system would negate the need for a separate geotextile fabric placed below the liner. Due to anticipated wildlife and livestock traffic as well as to prevent liner floatation, the installation would involve over-excavation of material at the bottom of the canal prism to a depth of 12 inches, placement of the liner, and then placement of a 12 inch thick imported gravel ballast material at the canal bottom. This work would be constructed during the irrigation off season.

The lining of the critical 4,000-foot section of the Canal would effectively eliminate seepage through this section. As a result, it would provide the Company the ability to use the Canal to its design flow rates and conserve water by reducing the excess flow taken away from Ross Creek and the East Gallatin River to provide adequate flow to users. The age-old practice of diverting excess water from the East Gallatin River and Ross Creek would be eliminated that was needed to compensate for the significant water losses through this section of the Canal. This would subsequently contribute to a reduction in low flow alterations as more water would remain in the East Gallatin River and Ross Creek and benefit fish and wildlife populations.

The capital costs associated with this task were established using bid tabulations from previous projects, manufacturer's quotes, and WWC's experience. Additional capital costs include contractor mobilization/bonding/insurance prices, construction contingencies, engineering, legal and administrative, and auditing. The anticipated capital costs associated with this task are provided in Table 1.

Table 1. Estimated Canal Liner Capital Costs

Description	Units	Quantity	Unit Price	Total Cost
Excavation	LF	4,000	$6.00	$24,000
Clearing & Grubbing	LF	4,000	$4.00	$16,000
Canal Liner Materials	SF	132,000	$1.00	$132,000
Canal Liner Installation	SF	132,000	$0.35	$46,200
Liner Appurtenances	EA	1	$4,520.00	$4,520
Ballast Placement	CY	830	$30	$24,900
			Subtotal	**$247,620**
Mobilization / Bonding / Insurance			8%	$19,900
Contingency			15%	$37,200
			Capital Costs Subtotal	**$304,720**
Engineering/Construction Administration			15%	$45,800
Legal & Administrative			2%	$6,100
Audit			LS	$3,000
			Total Project Costs	**$359,620**

Sediment Pond

This project component involves the installation of a sediment pond within the Canal delivery system at a preliminary location sited between Dry Creek Road and Duncan Road. The Company suggested this location due to the ease of access, relationship with the existing landowner, location upstream from Dry Creek and the East Gallatin River, and ongoing use by the Company to store riprap. Further analysis is needed prior to selecting a final location for the sediment pond to assess headwater and tailwater effects, future land use, and whether there is adequate space to meet treatment objectives.

The design of the pond may be adjusted based on site conditions, sizing requirements, or desired treatment outcomes following project approval. For a conceptual design, the pond will consist of a 0.25-acre sedimentation basin with an average depth of 5 feet to facilitate sedimentation settlement while providing sufficient space and depth to mitigate impacts from changes in velocity or temperature that would either effect treatment or return flow conditions. The depth of the pond will also need to be sized to provide sufficient storage capacity to minimize cleanout frequency while maintaining treatment efficacy. The pond may require a liner to prevent water loss due to seepage and ballast material to prevent liner floatation and damage to the liner during sediment removal. The pond may be lined with a material with a desired permeability to reduce seepage while providing drainage outside of the irrigation season. For the purpose of this preliminary design and cost estimate, it is assumed the pond is lined with an impermeable membrane to eliminate seepage and prevent potential interactions with groundwater. The outlet of the pond will consist of a rock-lined weir designed to promote sedimentation settlement while minimizing headwater or tailwater effects.

Prior to the installation of the sediment pond, the areas within the design area would be stripped of organic matter and excavated to the desired depth and shape to facilitate sedimentation. After these initial steps, the liner would be installed, followed by a ballast material consisting of either gravel or riprap. To ensure the desired residence time to facilitate sedimentation, maintain the design water level without producing undesirable headwater conditions, and prevent scouring a rock-lined weir would be installed at the outlet of the pond consisting of riprap.

The installation of the sediment pond would mitigate sediment deposition throughout the Canal and reduce sediment loading to Dry Creek and the East Gallatin River. The pond could potentially provide additional water quality benefits by treating other pollutants commonly present in irrigation canals such as nitrogen and phosphorus. Localizing sedimentation to a centralized location rather than throughout the entire stretch of the Canal would mitigate the impacts of regular sediment removal along the entire length of the Canal. Sediment removed from the pond could be used as fertilizer or topsoil amendment products in the surrounding area after risk and regulatory-based considerations.

The capital costs associated with this task were established using bid tabulations from previous projects, manufacture and contractor solicitation, and WWC's experience. Additional capital costs include contractor mobilization/bonding/insurance prices, construction contingencies, engineering, legal and administrative, and auditing. Engineering and construction administration costs were estimated on a lump sum basis to account for the work required to quantify sediment loading in the Canal and provide the pond siting, design, and modeling elements required to meet treatment objectives. The anticipated capital costs associated with this task are provided in Table 2.

Table 2. Estimated Sediment Pond Capital Costs

Description	Units	Quantity	Unit Price	Total Cost
Excavation	CY	2,017	$15.00	$30,250
Liner Materials	SF	10,890	$1.00	$10,890
Liner Installation	SF	10,890	$0.25	$2,723
Liner Appurtenances	EA	1	$500	$500
Ballast Placement	CY	403	$30	$12,100
Rip Rap	CY	26	$50	$1,300
			Subtotal	**$57,762**
Mobilization / Bonding / Insurance			8%	$4,700
Contingency			15%	$8,700
			Capital Costs Subtotal	**$71,162**

Engineering/Construction Administration	LS	$15,000
Legal & Administrative	2%	$1,500
Audit	LS	$3,000
	Total Project Costs	**$90,662**

Project Capital Costs

Cost estimates have been developed for the tasks outlined above and are provided in Table 3. The total project cost was assigned an approximate ten percent for contingency and costs for engineering services, oversight, and audit.

Table 3. Capital Cost Estimate for Proposed Project

Description	Units	Quantity	Unit Price	Total Cost
Canal Liner				
Excavation	LF	4,000	$6.00	$24,000
Clearing & Grubbing	LF	4,000	$4.00	$16,000
Canal Liner Materials	SF	132,000	$1.00	$132,000
Canal Liner Installation	SF	132,000	$0.35	$46,200
Liner Appurtenances	EA	1	$4,520	$4,520
Ballast Placement	CY	830	$30	$24,900
			Subtotal	**$247,620**
Sediment Pond				
Excavation	CY	2,017	$15.00	$30,250
Liner Materials	SF	10,890	$1.00	$10,890
Liner Installation	SF	10,890	$0.25	$2,723
Liner Appurtenances	EA	1	$500	$500
Ballast Placement	CY	403	$30	$12,100
Rip Rap	CY	26	$50	$1,300
			Subtotal	**$57,762**
Mobilization / Bonding / Insurance			8%	$24,600
Contingency			10%	$45,900
			Capital Costs Subtotal	**$375,882**
Engineering/Construction Administration				$60,800
Legal & Administrative			2%	$7,600
Audit			LS	$6,000
			Total Project Costs	**$450,282**

Implementation Schedule

To successfully implement the proposed project, the following tasks will be necessary:

- **Task 1 - Grant Award**: It is anticipated that the grant awards will be released in March – May 2022.
- **Task 2 - Improvements Design**: The Dry Creek Irrigation Company will contract with a licensed Professional Engineer to develop the final designs for the canal liner and sediment pond. The design will be completed from May 2022 – August 2022.
- **Task 3 - Regulatory Compliance**: The Dry Creek Irrigation Company, with assistance from the contracted Professional Engineer, will obtain the required permits to ensure that the project meets all regulatory requirements. This task will be completed from May – August 2022.
- **Task 4 - Contractor Selection**: The Dry Creek Irrigation Company, with assistance from the contracted Professional Engineer, will solicit for contractors to purchase materials and perform the improvements project per the design and specifications. This task will be completed following Tasks 2 and with a completion date of October 2022.
- **Task 5 - Construction**: The selected contractor will perform construction activities per the design and specification. Construction activities will include canal lining and installation of the sediment pond. Construction will be performed between November and December 2022.
- **Task 6 - Construction Closeout**: The Dry Creek Irrigation Company will work with the contracted Professional Engineer to ensure that all issues with the installation have been addressed. The Professional Engineer will also develop a set of as-built plans to document any changes made in the field. Construction will closeout from January – February 2023.
- **Task 7 - Grant Closeout**: The Dry Creek Irrigation Company will work with the contracted Professional Engineer to ensure that proper documentation including invoices, reports, etc. has been submitted, and the grant will be closed. Grant closure will occur from February – March 2023.
- **Task 8 - Project Completion**: The estimated project completion is March 2023.

Permit Requirements

The following permits may be obtained during the improvements design process:

- **318 Authorization** – The Short-Term Water Quality Standard for Turbidity requires a permit for any construction activities that will cause temporary violations of state surface water quality standards for turbidity. The rehabilitation project should have little or no effect on the turbidity of the nearby. Earth-disturbing work will be minimal due to the nature of the project, and all work will take place prior to the irrigation season with no water in the canals or laterals. The engineer or contractor shall work with the State to determine whether the construction of the project justifies a formal permit.

- **Storm Water Discharge General Permit** – State Storm Water Rules require a storm water discharge permit for any construction project over 1-acre in total disturbance that discharges into State waters. Although the potential for any runoff from the proposed construction site to reach State water is small, a permit will be obtained because of the hydraulic connection to Dry Creek and the East Gallatin River.

- **Montana Sage Grouse Habitat Conservation Program** – In response to Senate Bill 261 and Executive Orders 10-2014 and 12-2015, all construction project in counties hosting protected sage grouse habitat must include a letter of comment from the DNRC Sage Grouse Habitat Conservation Program. The program's role is to implement Montana's Sage Grouse Conservation Strategy including the conservation, restoration, and mitigation of changes to sage grouse habitat because of development. A review of the Montana Sage Grouse Habitat Conservation Map was performed in December 2021. This review showed that the project area is not within any sage grouse habitat areas.

Conclusion

The Company relies on dues paid by the users of the Canal who are listed as shareholders to provide the operation and maintenance services necessary to provide the apportioned irrigation water to each user. Insufficient surplus exists to undertake projects beyond anything that would be considered to maintenance of the Canal. It is also unlikely that an increase in dues from each user would be sufficient to cover any substantial project. Therefore, the Company is requesting American Rescue Plan Act (ARPA) funding through the Irrigation Competitive Grant to complete the above outlined project. Since the Company is not eligible to apply for funding per the definitions of a "local government" defined in House Bill 632, the Gallatin Conservation District and Gallatin County have agreed to sponsor this application and apply on behalf of the Company. Gallatin County and the Gallatin Conservation District are working together to assist local irrigators to sponsor applications or provide matching funds. The Company is requesting $225,141 from Gallatin County's Local Fiscal Recovery Funds as match and $225,141 from the Competitive Grant Program for a total project amount of $450,282.

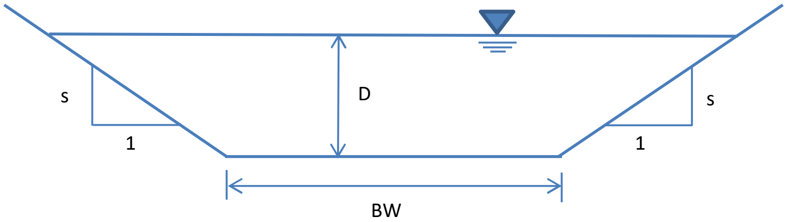
ATTACHMENT 1

SEEPAGE CALCULATIONS

Irrigating Water Loss Calculations - Canal Liner

Job Name: Dry Creek Irrigation Canal Improvements Project
Job No.:
Date: 12/8/2021
Name: PJH

Soil Description:
Soils observed during the site visit consisted of fine silty sand. Web Soil Survey showed hydraulic conductivity of 3.97 ft/day on average.



Inputs:

Input	Value	Units	Description
D	2.63	ft	Channel depth
BW	8	ft	Bottom width
s	1.00	ft/ft	Side Slope (sV:1H) - Approximate existing side slopes
L	4,000	ft	Channel length
k_{sat}	3.96851	ft/day	Saturated Hydraulic Conductivity - Websoil Survey
I	1	ft/ft	Gradient
ET	0.024	ft/day	Evapotranspiration rate, assumed rate for vegetation overgrowth
g	32.2	ft/s^2	Acceleration due to gravity

Seepage Losses:

$$Q_{SEEP} = k_{sat} * I * A_{wet} * L$$

Output	Value	Units	Description
P_{wet}	15.4	ft	Wetted Perimeter
A_{wet}	15.4	ft^2	Wetted Area per foot of channel length
Q_{SEEP}	245,076	ft^3/day	Seepage loss over length of channel
Q_{SEEP}	2.8	cfs	seepage loss over length of channel

Evapotranspiration Losses:

$$Q_{ET} = ET * A_{veg} * L$$

Output	Value	Units	Description
P_{veg}	7.4	ft	Vegetated Perimeter
A_{veg}	7.4	ft^2	Vegetated Perimeter per foot of channel length
Q_{ET}	714	ft^3/day	Evapotranspiration loss over length of channel
Q_{ET}	0.008	cfs	Evapotranspiration loss over length of channel

Total Losses:

Output	Value	Units	Description
Duration	200	days/yr	Assumed duration of irrigation season
$Q_{SEEP-TOTAL}$	1125.232	ac-ft/yr	Total seepage loss for entire year
$Q_{ET-TOTAL}$	3.279	ac-ft/yr	Total evapotranspiration loss for entire year
Q_{TOTAL}	**1,128.511**	**ac-ft/yr**	**Total yearly losses**
Q_{TOTAL}	**367.727**	**mil. gal/yr**	**Total yearly losses**

ATTACHMENT 2

SITE VISIT PHOTOGRAPHS

Figure 1. Center of Proposed Liner Section of Canal – Facing NW

Figure 2. Center of Proposed Liner Section of Canal – Facing SE

Figure 3. Theisen Road CMP – Facing West

Figure 4. Dry Creek Canal and Dry Creek Headgates at Fish Passage – Facing NW

Figure 5. Dry Creek Canal Headgate at Fish Passage – Facing NE

Figure 6. Dry Creek Fish Passage Headgate – Facing NE

ATTACHMENT E

PROJECT AREA SOIL DATA
AND GEOLOGIC MAPS

United States
Department of
Agriculture

NRCS

Natural
Resources
Conservation
Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Gallatin County Area, Montana

Dry Creek Irrigation Canal

August 29, 2023

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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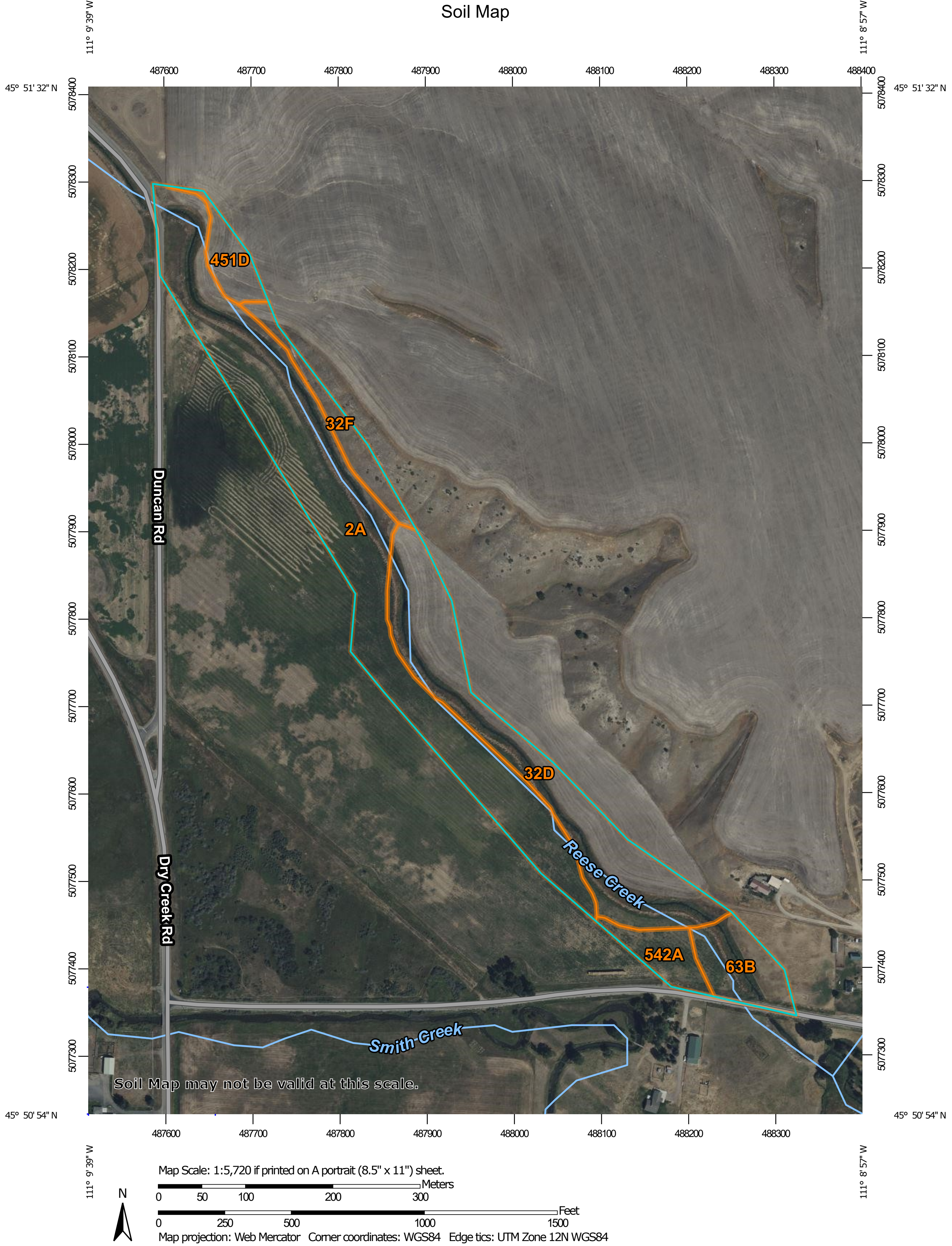
Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:5,720 if printed on A portrait (8.5" x 11") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)

□	Area of Interest (AOI)

Soils

□	Soil Map Unit Polygons
〰	Soil Map Unit Lines
■	Soil Map Unit Points

Special Point Features

◎	Blowout
⊠	Borrow Pit
✻	Clay Spot
◇	Closed Depression
✕	Gravel Pit
∴	Gravelly Spot
●	Landfill
ʎ	Lava Flow
ψ	Marsh or swamp
⚒	Mine or Quarry
◎	Miscellaneous Water
○	Perennial Water
∨	Rock Outcrop
+	Saline Spot
⁘	Sandy Spot
⊖	Severely Eroded Spot
◇	Sinkhole
≫	Slide or Slip
∅	Sodic Spot
≡	Spoil Area
◊	Stony Spot
⚇	Very Stony Spot
ψ	Wet Spot
△	Other
⋯	Special Line Features

Water Features

∼	Streams and Canals

Transportation

┼┼┼	Rails
〰	Interstate Highways
〰	US Routes
〰	Major Roads
〰	Local Roads

Background

▩	Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Gallatin County Area, Montana
Survey Area Data: Version 26, Aug 30, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 18, 2022—Aug 29, 2022

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
2A	Havre loam, calcareous surface, 0 to 2 percent slopes	13.7	49.9%
32D	Amesha loam, 8 to 15 percent slopes	7.9	28.8%
32F	Amesha loam, 35 to 60 percent slopes	1.5	5.4%
63B	Beanlake loam, 0 to 4 percent slopes	2.0	7.3%
451D	Quagle-Brodyk silt loams, 8 to 15 percent slopes	1.1	4.0%
542A	Blossberg loam, 0 to 2 percent slopes	1.2	4.5%
Totals for Area of Interest		**27.6**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Gallatin County Area, Montana

2A—Havre loam, calcareous surface, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 56pf
Elevation: 4,150 to 4,900 feet
Mean annual precipitation: 10 to 14 inches
Mean annual air temperature: 37 to 45 degrees F
Frost-free period: 95 to 115 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Havre and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Havre

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy alluvium

Typical profile

A - 0 to 8 inches: loam
C - 8 to 60 inches: stratified fine sandy loam to clay loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: RareNone
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 9.7 inches)

Interpretive groups

Land capability classification (irrigated): 4e
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: R044BA032MT - Loamy (Lo) LRU 01 Subset A
Hydric soil rating: No

Minor Components

Havre

Percent of map unit: 5 percent
Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear

Ecological site: R044BA001MT - Clayey (Cy) LRU 01 Subset A
Hydric soil rating: No

Fairway

Percent of map unit: 5 percent
Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R043BP814MT - Subirrigated Saline-Sodic Shrubland Group
Hydric soil rating: No

Ryell

Percent of map unit: 5 percent
Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA032MT - Loamy (Lo) LRU 01 Subset A
Hydric soil rating: No

32D—Amesha loam, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: 56pv
Elevation: 4,000 to 5,600 feet
Mean annual precipitation: 10 to 14 inches
Mean annual air temperature: 37 to 45 degrees F
Frost-free period: 95 to 115 days
Farmland classification: Farmland of local importance

Map Unit Composition

Amesha and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Amesha

Setting

Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy alluvium

Typical profile

A - 0 to 7 inches: loam
Bk1 - 7 to 25 inches: silt loam
Bk2 - 25 to 60 inches: loam

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 9.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: R044BA030MT - Limy (Ly) LRU 01 Subset A
Hydric soil rating: No

Minor Components

Trimad

Percent of map unit: 5 percent
Landform: Alluvial fans, stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA036MT - Droughty (Dr) LRU 01 Subset A
Hydric soil rating: No

Musselshell

Percent of map unit: 5 percent
Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA030MT - Limy (Ly) LRU 01 Subset A
Hydric soil rating: No

Amesha

Percent of map unit: 5 percent
Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA040MT - Loamy Steep (LoStp) LRU 01 Subset A
Hydric soil rating: No

32F—Amesha loam, 35 to 60 percent slopes

Map Unit Setting

National map unit symbol: 56px
Elevation: 4,300 to 5,250 feet
Mean annual precipitation: 10 to 14 inches
Mean annual air temperature: 37 to 45 degrees F
Frost-free period: 95 to 115 days
Farmland classification: Not prime farmland

Map Unit Composition

Amesha and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Amesha

Setting

Landform: Escarpments
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy alluvium loamy colluvium

Typical profile

A - 0 to 7 inches: loam
Bk1 - 7 to 25 inches: silt loam
Bk2 - 25 to 60 inches: loam

Properties and qualities

Slope: 35 to 60 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 9.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: B
Ecological site: R044BA040MT - Loamy Steep (LoStp) LRU 01 Subset A
Hydric soil rating: No

Minor Components

Trimad

Percent of map unit: 5 percent
Landform: Escarpments
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA038MT - Droughty Steep (DrStp) LRU 01 Subset A
Hydric soil rating: No

Cabbart

Percent of map unit: 5 percent
Landform: Escarpments
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA136MT - Shallow Loamy (SwLo) LRU 01 Subset A
Hydric soil rating: No

Varney

Percent of map unit: 5 percent
Landform: Escarpments
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA032MT - Loamy (Lo) LRU 01 Subset A
Hydric soil rating: No

63B—Beanlake loam, 0 to 4 percent slopes

Map Unit Setting

National map unit symbol: 56y8
Elevation: 4,300 to 5,850 feet
Mean annual precipitation: 15 to 19 inches
Mean annual air temperature: 39 to 45 degrees F
Frost-free period: 90 to 110 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Beanlake and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Beanlake

Setting

Landform: Stream terraces, alluvial fans
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

A - 0 to 6 inches: loam
Bk1 - 6 to 38 inches: loam
Bk2 - 38 to 60 inches: gravelly loam

Properties and qualities

Slope: 0 to 4 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 25 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: Moderate (about 8.6 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: B
Ecological site: R044BB030MT - Limy (Ly) LRU 01 Subset B
Hydric soil rating: No

Minor Components

Windham

Percent of map unit: 5 percent
Landform: Stream terraces, alluvial fans
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BB036MT - Droughty (Dr) LRU 01 Subset B
Hydric soil rating: No

Martinsdale

Percent of map unit: 5 percent
Landform: Stream terraces, alluvial fans
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BB032MT - Loamy (Lo) LRU 01 Subset B
Hydric soil rating: No

Beanlake

Percent of map unit: 5 percent
Landform: Stream terraces, alluvial fans
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BB030MT - Limy (Ly) LRU 01 Subset B
Hydric soil rating: No

451D—Quagle-Brodyk silt loams, 8 to 15 percent slopes

Map Unit Setting

National map unit symbol: 56sz
Elevation: 4,300 to 5,300 feet
Mean annual precipitation: 14 to 18 inches
Mean annual air temperature: 39 to 45 degrees F
Frost-free period: 90 to 110 days
Farmland classification: Farmland of local importance

Map Unit Composition

Quagle and similar soils: 60 percent
Brodyk and similar soils: 30 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Quagle

Setting

Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Silty calcareous loess

Typical profile

A - 0 to 6 inches: silt loam
Bw - 6 to 9 inches: silt loam
Bk - 9 to 60 inches: silt loam

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 10.8 inches)

Interpretive groups

Land capability classification (irrigated): 4e
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: R044BB030MT - Limy (Ly) LRU 01 Subset B
Hydric soil rating: No

Description of Brodyk

Setting

Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Silty calcareous loess

Typical profile

A - 0 to 6 inches: silt loam
Bk1 - 6 to 30 inches: silt loam
Bk2 - 30 to 60 inches: silt loam

Properties and qualities

Slope: 8 to 15 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)

Available water supply, 0 to 60 inches: High (about 10.5 inches)

Interpretive groups

Land capability classification (irrigated): 4e
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: R044BB030MT - Limy (Ly) LRU 01 Subset B
Hydric soil rating: No

Minor Components

Amsterdam

Percent of map unit: 8 percent
Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BB032MT - Loamy (Lo) LRU 01 Subset B
Hydric soil rating: No

Anceney

Percent of map unit: 2 percent
Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BB036MT - Droughty (Dr) LRU 01 Subset B
Hydric soil rating: No

542A—Blossberg loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 56wx
Elevation: 4,200 to 5,550 feet
Mean annual precipitation: 12 to 18 inches
Mean annual air temperature: 39 to 45 degrees F
Frost-free period: 90 to 110 days
Farmland classification: Farmland of local importance

Map Unit Composition

Blossberg and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Blossberg

Setting

Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

A - 0 to 15 inches: loam
Bg - 15 to 24 inches: sandy clay loam
2C - 24 to 60 inches: extremely gravelly loamy coarse sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 1.98 in/hr)
Depth to water table: About 12 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline to slightly saline (0.0 to 4.0 mmhos/cm)
Available water supply, 0 to 60 inches: Low (about 5.5 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 5w
Hydrologic Soil Group: B/D
Ecological site: R044BP815MT - Subirrigated Grassland
Hydric soil rating: Yes

Minor Components

Bonebasin

Percent of map unit: 10 percent
Landform: Terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BP815MT - Subirrigated Grassland
Hydric soil rating: Yes

Meadowcreek

Percent of map unit: 5 percent
Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BP815MT - Subirrigated Grassland
Hydric soil rating: No

References

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

National Research Council. 1995. Wetlands: Characteristics and boundaries.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_054262

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053577

Soil Survey Staff. 2010. Keys to soil taxonomy. 11th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053580

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053374

United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053624

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052290.pdf

United States
Department of
Agriculture

NRCS

Natural
Resources
Conservation
Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for
Gallatin County Area, Montana

Dry Creek Canal Sediment Trap

August 29, 2023

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map

Map Scale: 1:2,350 if printed on A landscape (11" x 8.5") sheet.

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Gallatin County Area, Montana
Survey Area Data: Version 26, Aug 30, 2022

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Aug 18, 2022—Aug 29, 2022

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
2A	Havre loam, calcareous surface, 0 to 2 percent slopes	6.1	58.7%
36C	Brocko silt loam, 4 to 8 percent slopes	4.3	41.2%
559A	Threeriv-Bonebasin loams, 0 to 2 percent slopes, irrigation induced wetness	0.0	0.1%
Totals for Area of Interest		**10.4**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Gallatin County Area, Montana

2A—Havre loam, calcareous surface, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 56pf
Elevation: 4,150 to 4,900 feet
Mean annual precipitation: 10 to 14 inches
Mean annual air temperature: 37 to 45 degrees F
Frost-free period: 95 to 115 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Havre and similar soils: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Havre

Setting

Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy alluvium

Typical profile

A - 0 to 8 inches: loam
C - 8 to 60 inches: stratified fine sandy loam to clay loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: RareNone
Frequency of ponding: None
Calcium carbonate, maximum content: 10 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 9.7 inches)

Interpretive groups

Land capability classification (irrigated): 4e
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: R044BA032MT - Loamy (Lo) LRU 01 Subset A
Hydric soil rating: No

Minor Components

Havre

Percent of map unit: 5 percent
Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear

Ecological site: R044BA001MT - Clayey (Cy) LRU 01 Subset A
Hydric soil rating: No

Fairway

Percent of map unit: 5 percent
Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R043BP814MT - Subirrigated Saline-Sodic Shrubland Group
Hydric soil rating: No

Ryell

Percent of map unit: 5 percent
Landform: Flood plains
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA032MT - Loamy (Lo) LRU 01 Subset A
Hydric soil rating: No

36C—Brocko silt loam, 4 to 8 percent slopes

Map Unit Setting

National map unit symbol: 56r1
Elevation: 4,000 to 5,100 feet
Mean annual precipitation: 10 to 14 inches
Mean annual air temperature: 37 to 45 degrees F
Frost-free period: 95 to 115 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Brocko and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Brocko

Setting

Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Silty calcareous loess

Typical profile

A - 0 to 7 inches: silt loam
Bk - 7 to 60 inches: silt loam

Properties and qualities

Slope: 4 to 8 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 10.2 inches)

Interpretive groups

Land capability classification (irrigated): 4e
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: R044BA030MT - Limy (Ly) LRU 01 Subset A
Hydric soil rating: No

Minor Components

Clarkstone

Percent of map unit: 5 percent
Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA032MT - Loamy (Lo) LRU 01 Subset A
Hydric soil rating: No

Kalsted

Percent of map unit: 3 percent
Landform: Stream terraces, alluvial fans
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA110MT - Sandy (Sy) LRU 01 Subset A
Hydric soil rating: No

Brocko

Percent of map unit: 2 percent
Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BA030MT - Limy (Ly) LRU 01 Subset A
Hydric soil rating: No

559A—Threeriv-Bonebasin loams, 0 to 2 percent slopes, irrigation induced wetness

Map Unit Setting

National map unit symbol: 56x7
Elevation: 4,100 to 4,650 feet
Mean annual precipitation: 12 to 18 inches
Mean annual air temperature: 39 to 45 degrees F
Frost-free period: 90 to 110 days

Farmland classification: Not prime farmland

Map Unit Composition

Threeriv and similar soils: 46 percent
Bonebasin and similar soils: 44 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Threeriv

Setting

Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

Oe - 0 to 4 inches: moderately decomposed plant material
Ag - 4 to 9 inches: loam
Cg - 9 to 29 inches: stratified sandy loam to silty clay loam
2Cg - 29 to 60 inches: extremely gravelly loamy sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: RareNone
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline to slightly saline (0.0 to 4.0 mmhos/cm)
Available water supply, 0 to 60 inches: Moderate (about 7.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 5w
Hydrologic Soil Group: C/D
Ecological site: R044BP815MT - Subirrigated Grassland
Hydric soil rating: Yes

Description of Bonebasin

Setting

Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Typical profile

Oa - 0 to 4 inches: muck
A - 4 to 15 inches: loam
Cg - 15 to 25 inches: stratified sandy loam to silty clay loam
2C - 25 to 60 inches: very gravelly coarse sand

Properties and qualities

Slope: 0 to 2 percent

Depth to restrictive feature: More than 80 inches
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: RareNone
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline to slightly saline (0.0 to 4.0 mmhos/cm)
Available water supply, 0 to 60 inches: Moderate (about 7.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 5w
Hydrologic Soil Group: B/D
Ecological site: R044BP815MT - Subirrigated Grassland
Hydric soil rating: Yes

Minor Components

Fairway

Percent of map unit: 5 percent
Landform: Stream terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R043BP814MT - Subirrigated Saline-Sodic Shrubland Group
Hydric soil rating: No

Blossberg

Percent of map unit: 5 percent
Landform: Terraces
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R044BP815MT - Subirrigated Grassland
Hydric soil rating: Yes

References

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

National Research Council. 1995. Wetlands: Characteristics and boundaries.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_054262

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053577

Soil Survey Staff. 2010. Keys to soil taxonomy. 11th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053580

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053374

United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelprdb1043084

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053624

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052290.pdf

GEOLOGIC MAP OF
WESTERN AND NORTHERN GALLATIN VALLEY
SOUTHWESTERN MONTANA

Montana Bureau of Mines and Geology Open-File Report 481

2003

Susan M. Vuke

Revised 11/04: *statement added regarding radiometric dates*

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11/03/04: ^{40}Ar/^{39}Ar dates recently obtained from ash beds in the Madison bluffs have not been incorporated into this report. The dates indicate that the contact between the Dunbar Creek Member and the Madison Valley formation, the mid-Tertiary (Hemingfordian) unconformity, was accurately mapped. However, dates on two ashes in the Madison bluffs indicate that the upper Dunbar Creek is Arikareen, not Whitneyan as interpreted in this report. Therefore, the hiatus represented by the mid-Tertiary unconformity spans more time in the Menard area than in the Madison bluffs.

TERTIARY GEOLOGY AND CENOZOIC STRUCTURE IN WESTERN AND NORTHERN GALLATIN VALLEY

Introduction

The *Geologic Map of Western and Northern Gallatin Valley* (Fig. 1, 2, and 3) is the second of two geologic maps of the Gallatin Valley prepared under STATEMAP contracts with the U.S. Geological Survey. The first, *Preliminary Geologic Map of the Eastern Part of the Gallatin Valley* (Lonn and English, 2002), is at the same scale and joins this map on the east. Another STATEMAP product, *Preliminary Geologic Map of the Bozeman 30'x 60' quadrangle* (Vuke and others, 2002), at 1:100,000 scale, includes the entire Gallatin Valley.

Tertiary geology is the focus of this report. Rocks older than Tertiary were not emphasized, and Quaternary deposits received only cursory attention, with information primarily taken from previous work. The Montana Bureau of Mines and Geology Ground-water Characterization Program will be conducting a detailed ground-water study of the Gallatin Valley in the future, so ground water was not a focus of this report. References cited in the bibliography provide more information on ground water (including Lonn and English, 2002), and more detailed mapping and discussion of older rocks.

A geologic map of most of the map area was compiled at 1:100,000 scale (Vuke and others, 2002, Plate II) from previous mapping (Hackett and others, 1960; Hughes, 1980; Mifflin, 1963; Schneider, 1970), and initial field work for the preliminary geologic map of the Bozeman 30'x 60' quadrangle (Vuke, and others, 2002). Additional field work was done during September, 2002. The Madison Bluffs, western Camp Creek Hills, and Madison Plateau (Fig. 2) were mapped on foot. The rest of the Camp Creek Hills area was mapped from roads and trails, and therefore is not as comprehensive. Mapping in the Dry Creek area (Fig. 2) is preliminary, based on mapping from roads and aerial photos only. The *Geologic Map of Western and Northern Gallatin Valley* represents a revision of the map by Vuke and others (2002) and supersedes Plate II of that report.

TERTIARY STRATIGRAPHY

Two stratigraphic approaches have been used to map Tertiary deposits of southwestern Montana: lithostratigraphic and sequence stratigraphic. Robinson (1963) designated several lithostratigraphic units in the Tertiary rocks of the Three Forks area. Kuenzi and Fields (1971) carried some of these units farther west into the Whitehall area, with modifications and additions. The lithostratigraphic units of Kuenzi and Fields (1971) have been used in most of the other valleys of southwestern Montana and rely in part on the recognition of a mid-Tertiary unconformity.

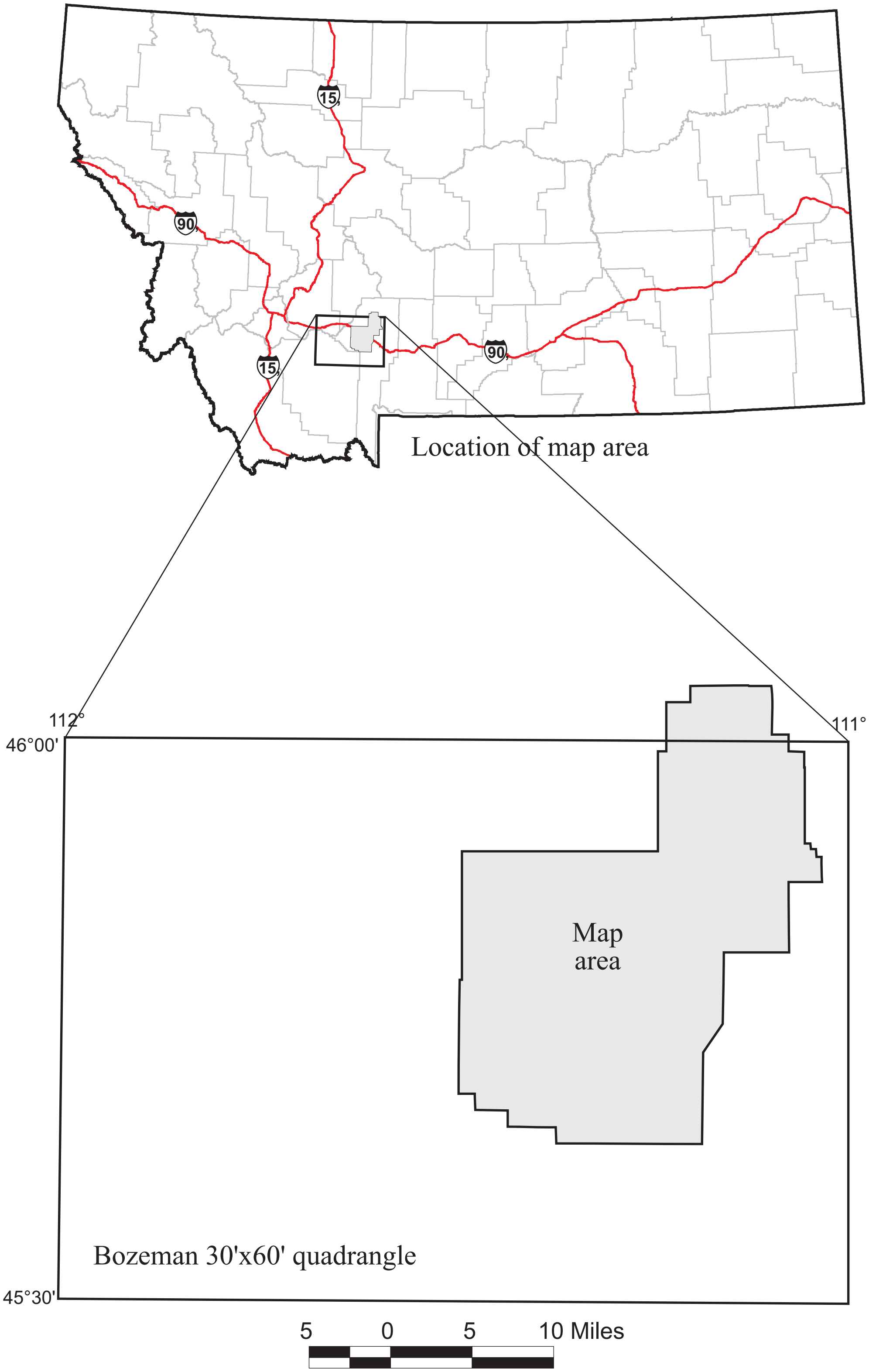


Figure 1. Location of map area relative to State of Montana and Bozeman 30'x60' quadrangle.

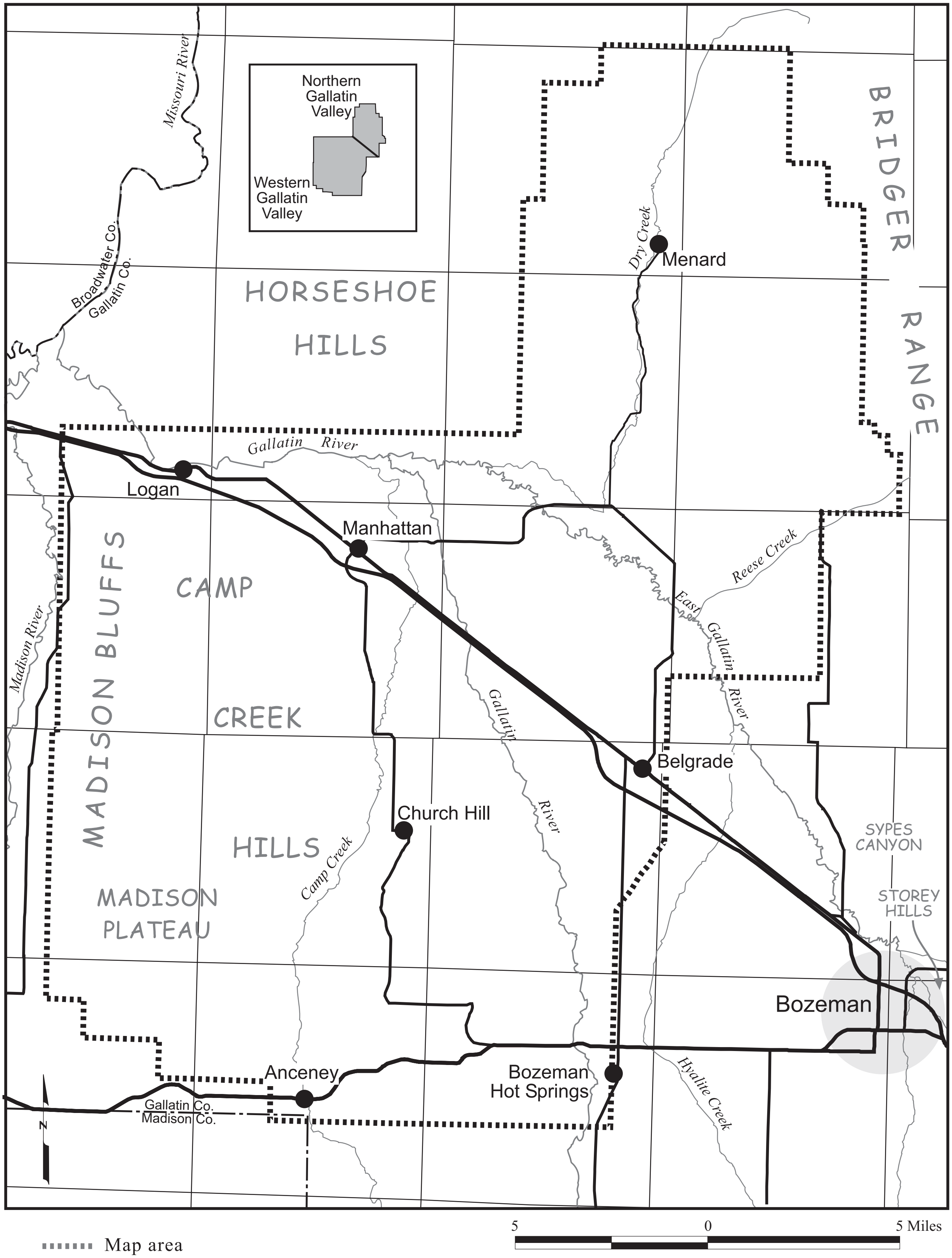


Figure 2. Geographic and cultural features referred to in text.

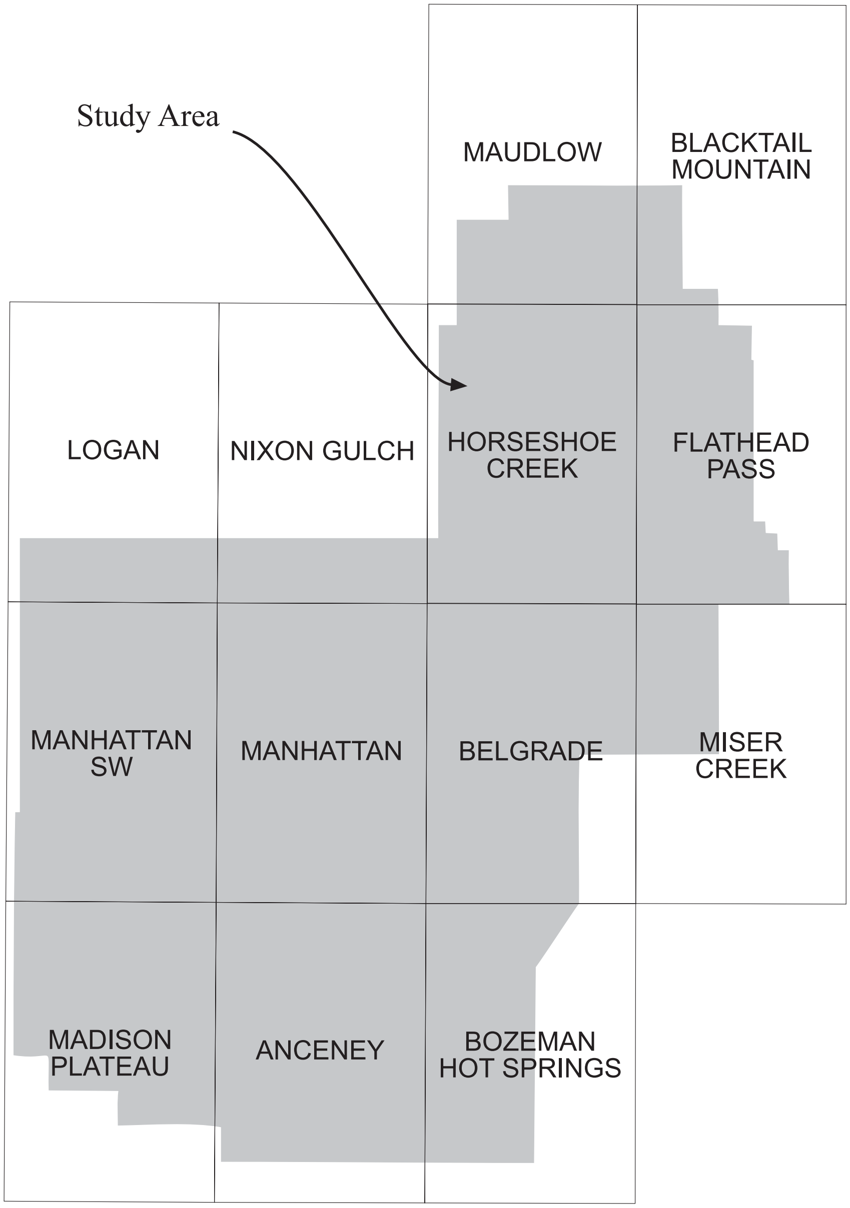


Figure 3. Index of 7.5' quadrangles.

Hanneman and Wideman (1991) discussed the problems of using lithostratigraphy for the Tertiary deposits of southwestern Montana, including abrupt facies changes and vertical repetition of lithologies. They proposed a sequence-stratigraphic approach, and recognized calcic paleosols at unconformities that can be followed on seismic lines as well as in outcrop.

The map of this report is adjacent to the Three Forks area where Robinson (1963) established some of the Tertiary lithostratigraphy, and the Madison Bluffs in the westernmost part of the map area provide miles of relatively good exposures. These advantages allowed tentative use of lithostratigraphic map units despite the abrupt facies changes and vertical repetition of lithologies encountered in this area.

Both the sequence-stratigraphic approach and the lithostratigraphic approach rely in part on accurate placement of a mid-Tertiary unconformity. Index fossils found in one of the units (Madison Valley formation, informal) indicate that the unit is younger than the unconformity. Two ash dates in the Dry Creek area span the unconformity (Hughes, 1980). Ash beds were sampled from three map units in the Madison Bluffs and submitted for dating. If the samples provide dates, they will serve as a check for the accuracy of the lithostratigraphic mapping relative to the mid-Tertiary unconformity. They may also allow extension of sequence-stratigraphic units into the Gallatin Valley from other parts of southwestern Montana.

Kuenzi and Fields (1971) divided the Tertiary of the Jefferson Valley into two redefined formations, the Sixmile Creek Formation (Robinson, 1967) and the Renova Formation (Robinson, 1963), separated by a mid-Tertiary unconformity that generally spans much of the Hemingfordian North American Mammal Age (NALMA), and may also span all or part of the Arikareean NALMA (Fig. 4). Kuenzi and Fields (1971) redefined the Sixmile Creek Formation as a coarse-grained unit *above* the unconformity, whereas Robinson's original type section (1967) included an Arikareean unit below the unconformity as well (Kuenzi and Fields, 1971; Fields, and others, 1985). Kuenzi and Fields (1971) redefined the members of the Renova Formation from what had been designated as formations by Robinson (1963) in the Three Forks area. Two of the members, Climbing Arrow and Dunbar Creek, are discussed in this report.

The map of this report is divided into two areas for the purpose of discussion, the northern Gallatin Valley, north of the Gallatin River, and the western Gallatin Valley, which is the remainder of the map (Fig. 2, inset). Although there are distinct similarities between the lithostratigraphic units in the northern Gallatin Valley and those in the western Gallatin Valley, there are also distinct differences. The four Tertiary units mapped in the northern Gallatin Valley resemble those in the western Gallatin Valley area in grain size, sedimentary structures, sand body shape, and morphology of coarse beds and lenses. The primary differences are clast composition in the coarser-grained units, and fossil abundance in one of the units. A thicker section of the uppermost unit is exposed in the Dry Creek area.

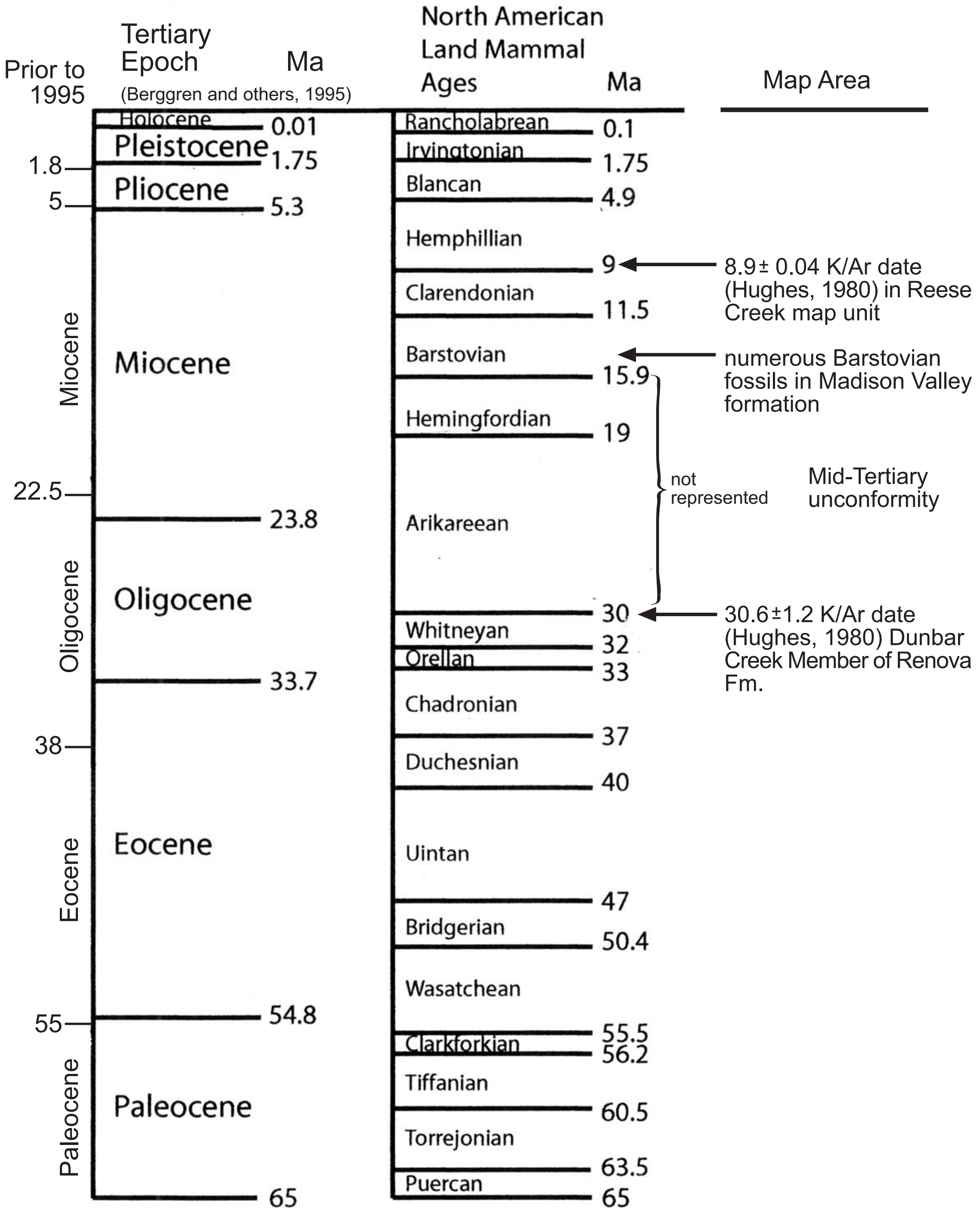


Figure 4. Tertiary dates in map area (two center columns from Hanneman and others, 2003).

Madison Plateau and Reese Creek map units

In both western and northern Gallatin Valley (Fig. 2, inset), a cobble or cobble and small boulder conglomerate, or gravel is present in the upper part of the section (Fig. 5). This unit is cemented by calcium carbonate where consolidated, or has clasts coated by calcium carbonate where it is unconsolidated. In both areas, the conglomerate is overlain by fine-grained, dominantly unconsolidated sediment.

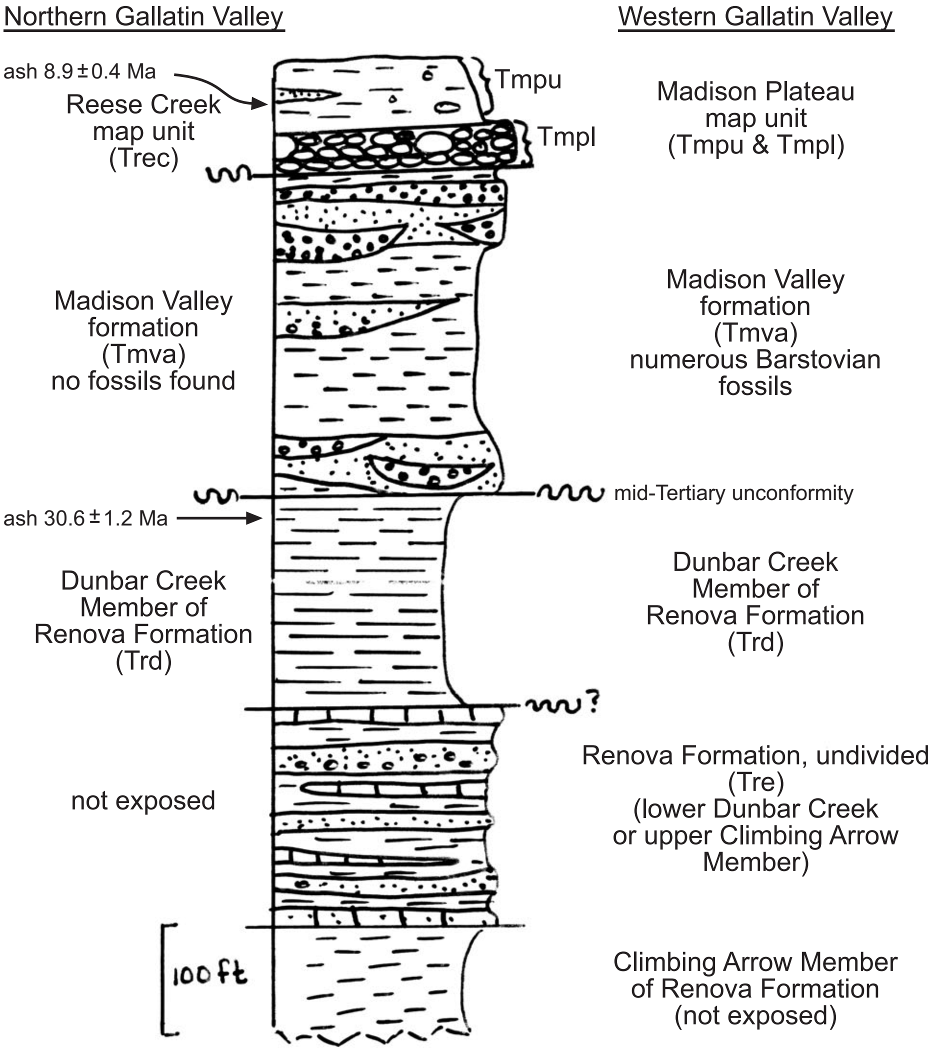
In other aspects the conglomerates differ between the two parts of the map area. In the western Gallatin Valley area, the contact between the Madison Plateau map unit and the underlying Madison Valley formation appears conformable. In the northern Gallatin Valley area, the conglomerate at this horizon (basal Reese Creek map unit, Fig. 5) rests with angular unconformity on the Madison Valley formation.

The clasts of the lower Madison Plateau map unit are dominantly Proterozoic Belt rocks from a western source and are well rounded. Clasts at the base may be reworked from the Madison Valley formation, but otherwise Archean metamorphic rocks and volcanic rocks are rare. Above the base of the unit, clasts are well rounded, moderately well sorted texturally and compositionally, and are dominantly cobble size. The conglomerate occurs as a sheet deposit on both sides of the Madison River. In contrast, the clasts in the basal Reese Creek map unit are composed of Proterozoic LaHood arkose, Paleozoic limestone, and volcanic and metamorphic rocks, and are subangular to subrounded, and locally poorly sorted texturally, but dominated by cobbles and small boulders. It was not determined if the conglomerate is distributed as a sheet deposit in this area.

In both areas, the conglomerates are overlain by poorly exposed fine-grained sediment. Some of this sediment is unmapped Quaternary loess, but a fine-grained Tertiary unit is recognized, too. In the Reese Creek area this unit was dated (K-Ar) as 8.9±0.4 (Hughes, 1980; Lange and others, 1980), late Clarendonian or early Hemphillian NALMA (Fig. 4).

The age of the fine-grained sediment of the Madison Plateau map unit in the western Gallatin Valley is not known, but the lower and upper parts of the map unit conform to the dip of the underlying Barstovian and Clarendonian? (Fig. 4) Madison Valley formation and overlie it with apparent conformity. For this reason, a late Clarendonian or early Hemphillian age also seems reasonable for the Madison Plateau map unit.

The conglomerate clasts in the lower Madison Plateau map unit came from a completely different source than those of the basal Reese Creek map unit. The Proterozoic Belt clasts in the Madison Plateau map unit (dominantly orthoquartzites) must have come from many miles to the west, whereas the clasts in the basal Reese Creek map unit were derived from the adjacent Bridger Range or Horseshoe Hills, and possibly also from the southeast (possible source of the volcanic and metamorphic rocks).



NOTES

- Ash dates from Hughes (1980).
- Climbing Arrow not exposed, but intercepted at Madison River level in a well just west of Madison Buffalo Jump State Park (Hackett and others, 1960).
- Placement of mid-Tertiary unconformity tentative pending $^{40}Ar/^{39}Ar$ dates on ash sampled in the Madison Bluffs.
- Correlation between Reese Creek map unit and Madison Plateau map unit is tentative.
- Schneider (1970) described three fining-upward sequences in the Madison Bluffs exposures, not recognized in this report.

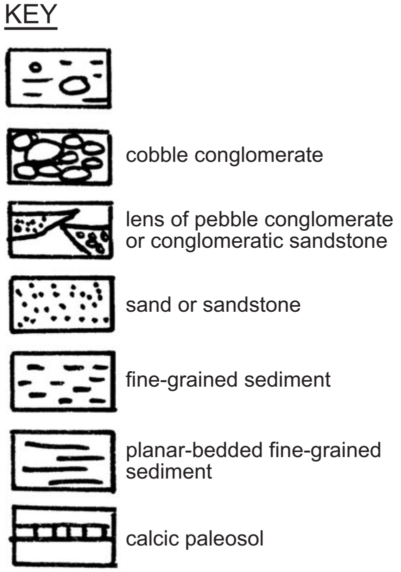


Figure 5. Generalized stratigraphic section of Tertiary deposits in the map area. See text for unit descriptions.

Madison Valley formation

The Madison Plateau and Reese Creek map units are underlain by tuffaceous siltstone and marl, interbedded with sheet deposits of cross-bedded sandstone that contain lenses of conglomeratic sandstone, pebble and granule conglomerate, and local cobble conglomerate (Fig. 5). This unit was mapped as the Sixmile Creek Formation by Hughes (1980) in the northern Gallatin Valley. He described the sandstones as blanket-like deposits with most clasts smaller than cobble size (Hughes, 1981). Hackett and others (1960) mapped this unit as the lower part of their unit 2 in both areas. Klemme (1949) correlated this unit (his unit B) near Menard with the “Madison Valley beds” south of Logan (Madison Bluffs area, Fig. 2). He recognized an unconformity at the contact between this unit and his underlying unit B (equivalent to the Renova Formation of Hughes (1980), and the Dunbar Creek Member of the Renova Formation of this report, discussed in the next section).

Color and clast composition of the Madison Valley formation vary between the western and northern parts of the Gallatin Valley. In western Gallatin Valley, the tuffaceous siltstones are pinkish tan, whereas in northern Gallatin Valley they are grayish orange. Silicified wood and fossil bone fragments are relatively abundant in the conglomerates of the western Gallatin Valley area , but were not found in the conglomerate of the northern area in this study or previous studies. Four *Merychippus* (horse) teeth (Bartstovian, Fig. 4) and a *Merychippus* jaw, were found at three different locations in the Madison Bluffs and Camp Creek Hills by the author (identified by Ralph Nichols, Museum of the Rockies, and by Alan Tabrum, Carnegie Museum of Natural History). Many other collections of Barstovian fossils in the Madison Valley formation of the Madison Bluffs and Camp Creek Hills have been made in the past (Tabrum and others, 2001; Douglass, 1899, 1901, 1903, 1907a, 1907b, 1908, 1909a, 1909b; Frick, 1937; Dorr, 1956; Sutton, 1977; Sutton and Korth, 1995, Evander, 1996).

Glassy ash beds are evident in the Madison Bluffs and south of the map area (Mifflin, 1963). They were not found in northern Gallatin Valley during field work for this report (perhaps because of the poor exposures, relative thinness of the unit in the area, and limited field work).

The pebbles and cobbles in the conglomerates of the Madison Valley formation in the western Gallatin Valley are dominantly Archean metamorphic rocks, and Mesozoic or Cenozoic volcanic rocks, including some scoria. Quartz and chert are much less abundant, and Paleozoic limestone and Proterozoic Belt orthoquartzites (from a western source) are generally rare, although south of Manhattan the amount of western-source Belt rocks is higher than elsewhere. The abundance of Archean metamorphic rock clasts suggests a southern, western, or eastern source. The composition of the Madison Valley formation clasts in northern Gallatin Valley varies with location. Near Menard, the clasts are dominantly Paleozoic limestone, Mesozoic sandstone, and volcanic rocks with sparse Archean metamorphic clasts. Hughes (1980) noted that the conglomerates in the Menard area lack Proterozoic LaHood clasts. He interpreted a northern source from the Maudlow basin and Horseshoe Hills with the volcanic rocks having come from the Livingston Formation exposed there. Closer to the Bridger Range, the Madison Valley formation conglomerate clasts are mostly Paleozoic limestone and Proterozoic LaHood arkose, the rocks exposed in the adjacent Bridger Range.

Outside the map area, Tertiary sediment in the lower Storey Hills north of Bozeman (Fig. 2) correlates lithostratigraphically (with the exception of conglomerate clast composition) and biostratigraphically (based on Barstovian fossils, Fig. 4) with the Madison Valley formation in the Madison Bluffs. The conglomerates contain clasts of mostly igneous rocks (basalt, andesite, porphyritic granodiorite, and porphyries of diorite, gabbro, granodiorite, and andesite) with minor Precambrian gneiss and rare Livingston Group sandstone, Paleozoic limestone, and other Paleozoic or Mesozoic rocks fragments (Glancy, 1964). Glancy (1964) interpreted an eastern and southeastern source. A granodiorite represented in the conglomerate clasts strongly resembles a granodiorite in the Crazy Mountains, that is apparently not found elsewhere (W. McMannis, personal communication in Glancy, 1964), suggesting an eastern source.

The conglomerate clasts are also composed of igneous rocks in the Sypes Canyon area north of the Storey Hills (J. Lonn, personal communication, 2003) even though the rocks exposed today in the east-adjacent Bridger Range are Archean metamorphic rocks. This clast composition suggests that the southern part of the Bridger Range was not exposed at the time of deposition (Barstovian and Clarendonian?).

In several local areas south of Manhattan, the Madison Valley formation conglomerates contain Proterozoic Belt orthoquartzite cobbles mixed with Archean metamorphic rocks and dark volcanic rocks. The Belt orthoquartzite clast composition suggests a contribution of sediment from the west.

The variety of clast compositions in the Madison Valley formation in different parts of the map area suggests either the presence of Miocene sub-basins, or drainage from multiple directions. A trunk drainage with a mixture of clasts from these different provenances was not found in the map area.

South of the map area, Mifflin (1963) described light-colored, fine-grained, tuffaceous sedimentary strata with beds of sandstone that contain granule to pebble conglomerate in cross-bedded channels. The conglomerate is composed of clasts of quartz, basic volcanic rock, metamorphic rock, chert, and silicified wood. This description closely resembles the lithology of the Madison Valley formation in the Madison Bluffs. Mifflin noted horse and camel fossils in this unit. Clast composition is similar in the Tertiary deposits east of Sourdough Creek near Bozeman that are lithologically similar to the Madison Valley formation of the western Gallatin Valley. Fix (1940) reported finding part of a fossil camel in this area.

The Madison Valley formation was mapped in both the western and northern Gallatin Valley for this report. It is in the stratigraphic position of the lower Sixmile Creek Formation of Kuenzi and Fields (1971) immediately overlying the mid-Tertiary unconformity. However, unlike the Sixmile Creek Formation, described by Kuenzi and Fields (1971) as predominantly coarse-grained, it is dominantly a fine-grained unit in much of the map area, although the presence of coarse-grained sand, and granule-, pebble-, or cobble-conglomerate lenses is characteristic. The informal name *Madison Valley formation*, applied to this unit by Douglass (1907) in the Madison Bluffs area, was used in this report to distinguish these deposits from dominantly coarse-grained Sixmile Creek Formation of other areas. Calcic paleosols are present at the base of the Madison Valley formation in the southern Madison Bluffs area. They were not seen anywhere else in the map area at this stratigraphic horizon.

At one location in the southeasternmost part of the map area, a breccia of dominantly Archean metamorphic clasts occurs within the Madison Valley formation. A similar breccia is present just south of Anceney. These breccias may reflect local sediment derivation from uplift of northwest-striking faults in the southern part of the map area and farther south that juxtapose Archean rocks against Tertiary strata.

Dunbar Creek Member of Renova Formation

In both western and northern Gallatin Valley, a planar-bedded, light-colored, tuffaceous, fine-grained unit that contains gastropods and ostracodes, underlies the Madison Valley formation (Fig. 5). This unit was mapped as Renova Formation by Hughes (1980) in the Dry Creek area, as unit 1 by Hackett and others (1960) in both areas, and as unit A by Klemme (1949) in the Dry Creek area. Hughes obtained a K-Ar date of 30.6±1.2 Ma (Whitneyan, Fig. 4) on an ash in his upper Renova Formation in the Dry Creek area which is consistent with the age of the Renova Formation in other areas (Hughes, 1981), and with its stratigraphic position below the mid-Tertiary unconformity. This unit was mapped as Dunbar Creek Member of the Renova Formation in both northern and western Gallatin Valley in this report. Its stratigraphic position in the Madison Bluffs is tentatively considered below the mid-Tertiary unconformity, pending the age analysis of an ash bed sampled from this unit that was submitted for ^{40}Ar/^{39}Ar dating.

Renova Formation, undivided

This map unit (Fig. 5) is exposed only in the Madison Bluffs area. It was mapped as *Renova Formation, undivided* because it was unclear whether the unit is upper Climbing Arrow Member or lower Dunbar Creek Member.

In the northern part of the Madison Bluffs, stacked calcic paleosols that underlie the unit mapped as Dunbar Creek Member (Fig. 5) are associated with what resembles upper Climbing Arrow conglomerate mapped by Robinson (1963) west of the Madison River. Farther south, in the Madison Buffalo Jump State Park area (Fig. 2), the calcic paleosols apparently occur in what Robinson (1963) mapped as Dunbar Creek Formation directly west of the Madison River. Robinson recognized that the upper Climbing Arrow and lower Dunbar Creek Formations (as he originally defined them) may interfinger, which may account for this discrepancy. Alternatively, a Tertiary fault where this interval is covered between the northern and central part of the bluffs may have juxtaposed Climbing Arrow and Dunbar Creek in this area.

The calcic paleosols near Madison Buffalo Jump State Park are similar to those recognized by Hanneman and others (1994) as located at unconformities in the Tertiary elsewhere (D. Hanneman, personal communication, 2002). Ash samples were collected from above and below the calcic paleosols near the park and submitted for ^{40}Ar/^{39}Ar dating. The calcareous beds have also been interpreted as travertine or hot springs deposits (Blake, 1953; Hackett and others, 1960; Schneider, 1970).

A Montana Power Company drill hole at river level just west of the middle part of the Madison Bluffs intercepted green and grayish-green bentonitic claystone, lignite, and other lithologies that Hackett and others (1960) correlated with Climbing Arrow west of the Madison River. The stratigraphic position of the drill hole is just below the Renova Formation, undivided, mapped in this report. Climbing Arrow lithologies at this stratigraphic position support the interpretation that the Renova Formation, undivided, is equivalent to the upper Climbing Arrow or lower Dunbar Creek as mapped by Robinson (1963) west of the Madison River.

CENOZOIC STRUCTURE

The Gallatin Valley lies at the eastern margin of basin-and-range extension in Montana, but does not fit the three general models of Tertiary extensional basins proposed for southwestern Montana: symmetrical horsts and grabens, differentially tilted hanging and footwall blocks, and rotated half-grabens, bounded on one side by a listric fault (Brodowy and others, 1991). Although gravity modeling suggests a rotated half-graben west of the Bridger Range along the Montana baseline (Lageson, 1989), other prominent structures have had a stronger influence on the Cenozoic deposits in other areas of the Gallatin Valley.

Tertiary strata were faulted, folded, and tilted in western and northern Gallatin Valley, dominantly along the trends of three major types of structures in the valley: northwest-striking basement faults (Schmidt and Garihan, 1983 and 1986), the Southwest Montana Transverse Zone (Schmidt and O’Neill, 1982), and the range-front faults of the Bridger Range (McMannis, 1955; Lageson, 1989). In addition, northeast-striking faults offset the Tertiary in two parts of the map area.

The Cenozoic structural influences in the western Gallatin Valley area were primarily reactivation of northwest-striking basement faults and movement on the Central Park Fault. The Cenozoic structural influences in the northern Gallatin Valley area were primarily movement on range-front faults of the Bridger Range and probable movement on the Willow Creek Fault.

Northwest-striking basement faults

In most of the western Gallatin Valley area, Tertiary strata dip to the northeast, perpendicular to northwest-striking faults and linear features. The northwest-striking faults are likely reactivated basement faults (Ruppel, 1982; Schmidt and Garihan, 1983 and 1986). Regionally, high-angle faults with this strike had a complex history of recurrent movement that changed direction in response to changed stress fields (O'Neill, and others, 1986; Ruppel, 1993). The faults were reactivated during the Laramide with left-reverse/oblique-slip movement (O'Neill, and others, 1986; Schmidt and Garihan, 1986) and during Tertiary extension with right-normal/oblique-slip movement (Schmidt and Garihan, 1986).

Northwest-striking faults offset the Tertiary and juxtapose Tertiary and Archean crystalline rocks in the southern part of the map area where Tertiary cover is thin over the Archean rocks. Faults that juxtapose Tertiary sediment and Archean crystalline rock are even more apparent south of the map area (Vuke and others, 2002). Farther north, where depth to basement rock increases, linear features with a northwest strike suggest that the basement faults continue into that area. Some of these linear features are indicated on the map. Others are more subtle, but can be traced on aerial photos in the Madison Plateau area and throughout the map area on shaded relief digital elevation models. These linear features also probably reflect the influence of basement faults. Cenozoic reversal of movement is apparent on other northwest-striking faults just west of the map area (Feichtinger, 1970).

Wells 9 and 10 (Table 1) were drilled through Tertiary sediment to Archean rocks at depths of 826 feet and 575 feet, respectively (Hackett and others, 1960). Hot water was intercepted in both wells, suggesting deep circulation of water along the basement faults (Hackett, and others, 1960).

Northeast-southwest-directed extension for this area was determined from fault plane solutions for hundreds of earthquakes recorded in southwestern Montana since 1982 (Stickney, 1999). This extension direction results in normal slip on NW-striking faults (Stickney, 1999). East-west-directed extension has been interpreted for the post-Laramide Tertiary resulting in right normal/oblique slip on the northwest-striking reactivated basement faults (Schmidt and Garihan, 1986).

Southwest Montana Transverse Zone

The Southwest Montana Transverse Zone is a significant Laramide structural boundary between tectonic features of the thrust belt on the north and structures related to basement-cored foreland uplifts on the south (Schmidt and O'Neill, 1982; Lageson, 1989). It is a reactivated basement structure that separates Proterozoic Belt Supergroup sedimentary rocks to the north from Archean crystalline rocks to the south (Harrison and others, 1974). Two major structures of this zone are interpreted in the Cenozoic deposits of the map area: the Central Park Fault and Willow Creek Fault.

Central Park Fault: The influence of the Central Park Fault is evident in the Tertiary deposits of the Madison Bluffs and Camp Creek Hills by the presence of a narrow zone of folds, including an anticline-syncline pair with a secondary monocline within the south-dipping limb of the anticline and syncline. The monocline suggests that more than one fault was involved. This narrow fold zone disrupts the regional northeast dip of the Tertiary beds.

Hackett and others (1960) located the position of the Central Park Fault beneath the Quaternary alluvial valley deposits based on a change in the thickness of Holocene and Pleistocene alluvium of the Gallatin River Valley. The following data are taken from their report. Thirty feet of alluvium overlie the Tertiary deposits at well 4 (Table 1) north of the fault, yet well 5 on the south side of the fault, was drilled through more than 300 feet of alluvium without intercepting the Tertiary deposits. North of the fault, well 3 penetrated 31 feet of alluvium, 104 feet of alluvium or Tertiary strata, and 72 feet of Tertiary strata. Well 6 was drilled through 215 feet of alluvium and 100 feet of Tertiary deposits. South of the interpreted location of the fault, Well 7 penetrated more than 400 feet of alluvium without reaching the Tertiary, and an oil test well, well 8 on the map, was drilled through more than 800 feet of alluvium without reaching the Tertiary.

Stermits and Boner, in Hackett and others (1960), noted that more ground water was discharged at the surface in the Central Park area during their study than in any other part of the Gallatin Valley. They concluded that because the alluvium north of the Central Park Fault cannot transmit all the water entering the area by underflow, some of the ground water is forced to the surface where it is discharged by spring flow and effluent seepage into streams and lost by evapotranspiration. The map of the present report shows a patterned area with seasonal high water tables less than 6 ft (U.S. Soil Conservation Service, 1992), and its possible relation to the Central Park Fault.

Fix (1940, Plate I) noted a broad swampy area just north of the fault in the Central Park area with numerous thermal springs. No other reference to thermal springs in this area was found during research for the present report. Information in the Montana Bureau of Mines and Geology Ground-water Information Center data base indicates that water in wells of the area is currently somewhat warmer than adjacent areas. The warmer temperatures could represent thermal water diluted by irrigation water (John Metesh, MBMG, personal communication, 2002). Alternatively, seismic activity in the area (e.g. Stickney and Lageson, 1999) may have changed the pattern of thermal ground-water movement. In either case, the presence of thermal water suggests a deep fault or fracture.

It is assumed that the Madison Plateau map unit (Fig. 5) was involved in the same folding as the underlying Madison Valley formation, even though it has presumably been eroded from the immediate area of folding. It appears to maintain a dip consistent with that of the underlying Madison Valley formation and maintains a consistent stratigraphic position in this area. If the Madison Plateau map unit and overlying sediment correlate with the Reese Creek map unit (dated as latest Clarendonian or earliest Hemphillian [Fig. 5] in the Reese Creek area), the fault movement responsible for folding the Tertiary beds must be younger than that. The influence of the fault on the thickness of the Pleistocene braid plain alluvium (Hackett and others, 1960) suggests that fault movement occurred before or during the Pleistocene, bracketing the age of movement between latest Miocene and latest Pleistocene.

Hackett and others (1960) projected the Central Park Fault eastward, toward an anomalous alluvial fan, the Springhill Fan, just outside the map area (Lonn and English, 2002), that they believed was controlled by the Central Park Fault. Davis and others (1965) interpreted a fault beneath the straight Reese Creek valley based on bouguer

Table 1. Data from selected wells and a test hole, summarized from Hackett and others (1960). Numbers correspond to numbers next to well symbols on map.

1. 22 ft of alluvium
   Greater than 4 ft of Paleozoic limestone

2. 69 ft of alluvium
   245 ft of Tertiary sedimentary strata
   Greater than 150 ft of Proterozoic Belt rocks

3. 31 ft of alluvium
   104 ft of Tertiary? sedimentary strata
   Greater than 72 ft of Tertiary sedimentarv strata

4. 30 ft of alluvium
   Greater than 45 ft of Tertiary sedimentary strata

5. Greater than 301 ft of alluvium

6. 215 ft of alluvium
   Greater than 100 ft of Tertiary sedimentary strata

7. Greater than 400 ft of alluvium

8. Greater than 800 ft of alluvium

9. 826 ft of Tertiary sedimentary strata
   Greater than 23 ft of Archean metamorphic rock
   This well intercepted hot water.

10. 18 ft of loess?*
    42 ft of terrace deposit?*
    515 ft of Tertiary sedimentary strata
    Greater than 25 ft of Archean metamorphic rock
    This well intercepted hot water.

*The interpretation of the present study is that these units are Tertiary.

gravity and aeromagnetic data. Strike-slip or oblique slip movement may have occurred on the Central Park Fault (Brodowy and others, 1991). Left-lateral strike-slip along a vertical fault was interpreted from composite focal-plane solutions for the Central Park Fault zone (Zim and Lageson, 1985). If that is the case, the fault underlying Reese Creek (Davis and others, 1965) lies at an appropriate angle to the Central Park Fault to have been involved in second-order shear.

Willow Creek Fault: The Willow Creek Fault is well documented west of the map area where it offsets pre-Tertiary bedrock (e.g., Schmidt and O’Neill, 1982). Its position was inferred in western Gallatin Valley from the southern limit of Paleozoic and Proterozoic rock exposures. Well 2 on the map, which is north of the inferred position of the fault, intercepted Proterozoic Belt rocks beneath 245 ft of Tertiary strata (Hackett and others, 1960). Presumably, Archean rocks or Archean rocks overlain by Paleozoic rocks are south of the fault, as they are in outcrop to the west. The fault is interpreted to extend east of the Horseshoe Hills based on a syncline in the Tertiary deposits near the mouth of Reese Creek in northern Gallatin Valley.

The interpretation of a syncline in the southern Dry Creek area is based on two tentative assumptions: that the conglomerate at Reese Creek, south of the axial trace of the syncline shown on the map, is the same conglomerate north of the trace, and that the fine-grained sediment overlying the conglomerate is the same unit on both sides of the trace. Hackett and others (1960) interpreted all these deposits as their Tertiary unit 2. Hughes (1980), on the other hand, interpreted the upper part of these deposits as Quaternary and Pliocene alluvial fan deposits that overlie the fine-grained unit from which the ash date was obtained. The tentative interpretation of the present report is that the Reese Creek map unit from which the 8.9±0.4 ash date (Hughes, 1980; Lange and others, 1980) was obtained is the same as the Quaternary and Pliocene alluvial fan deposits of Hughes (1980) with the exception of a veneer of Quaternary gravel that mantles some of the deposits, and that the Reese Creek map unit (late Clarendonian or early Hemphillian, Fig. 4), was involved in the folding. In a published synopsis of his thesis, Hughes’ interpretation changed from Quaternary or Tertiary alluvial fan deposits to Quaternary or Tertiary gravel (Hughes, 1981). In the present report, conglomerate was recognized at the base of the unit, but the sediment overlying it is fine grained.

The Holocene drainage pattern in this area follows the wider valleys of the Pleistocene braided-stream deposits. An abrupt change in the drainage pattern occurs in the area of the syncline, from westward toward Dry Creek, to southward, following the same pattern as the Tertiary strata, suggesting that the folding may have taken place during the Pleistocene.

The thickness of Pleistocene alluvium of the Gallatin Valley, across the inferred location of the Willow Creek Fault, does not suggest Pleistocene high-angle fault movement that influenced the Pleistocene valley fill as it does for the Central Park Fault, although the presence of a syncline along its strike may indicate a high-angle component of movement. The most recent movement on this fault may be strike-slip. A westward curve in the south-flowing tributaries on the north side of Reese Creek may indicate Pleistocene deflection by left-lateral strike-slip movement on the Willow Creek Fault. Laramide movement on the Willow Creek Fault was right-lateral (Schmidt and O'Neill, 1982), but reversal of previous fault movement during the Cenozoic is well documented on many faults in this area (e.g., Lageson, 1989; Feichtinger, 1970).

The eastern part of the map area is located within or near a transition zone between the mid-continent stress regime and basin-and-range extension (Stickney and Bartholomew, 1987). Fault-plane solutions for hundreds of earthquakes in southwest Montana suggest NE-SW-directed extension for most of southwestern Montana within the basin-and-range province (Stickney, 1999; Stickney and Bartholomew, 1987). This would result in right-lateral strike-slip movement on east-west-striking faults. However, the 1925 Clarkston Valley earthquake just west of the northern Gallatin Valley part of the map area reflects the NW-SE-directed extension of the mid-continent stress regime (Stickney and Bartholomew, 1987). This would result in left-lateral strike-slip movement on east-west-striking faults such as the Willow Creek fault.

An August 25, 1989, seismic event in the southernmost Horseshoe Hills showed nearly pure left-lateral strike-slip movement on a northeast-striking fault or right-lateral slip on a northwest-striking fault within a cluster of other nearby events compatible with (but not limited to) strike-slip movement (Stickney, 1997). This may suggest that slip is still occurring on second-order shear faults related to left-lateral movement on the Willow Creek fault.

The distance between pre-Tertiary rocks of the Horseshoe Hills and the Bridger Range widens southward in the Dry CreekValley, and the west margin of the valley fits the pattern of the range-front faults of the Bridger Range. The Dry Creek Valley may have opened by recurrent Cenozoic left-lateral strike-slip movement on the Willow Creek Fault. West-directed thrust faults in the Negro Hollow area (Schmidt and O'Neill, 1982) and in the southern Bull Mountains (Alexander, 1951; Coppinger, 1983) about 30 miles west of the Dry Creek Valley, may have accommodated the opening of the Dry Creek Valley. Glaman (1991, Plate 1) apparently shows Paleozoic rocks thrust over Tertiary debris-flow deposits in the southern Negro Hollow area, and Richard (1966, Plate 1) also apparently shows Paleozoic strata overlying Tertiary sediment in the same area. West-directed thrust faults were also mapped south of the Negro Hollow area on strike with those to the north (Vuke and others, 2002). A similar relation was seen in the Milligan Canyon area. In both cases, Mississippian Mission Canyon Limestone appears thrust to the west over the "Sphinx Conglomerate" of Robinson, the basal Tertiary unit in the area. More detailed mapping of Tertiary deposits in these areas should clarify whether Tertiary deposits were involved in the west-directed thrusting. Cenozoic left-lateral movement in the zone of the Willow Creek Fault (Southwest Montana Transverse Zone) may also have resulted in a much lower net translation distance for the Southwest Montana Transverse Zone compared to major Laramide thrust faults to the north, such as the Eldorado Thrust System north of Helena. This discrepancy is discussed in Burton and others (1987).

In the northernmost Madison Bluffs, near the stone ruins of an old cement plant (visible just south of Interstate 90 from the east-bound side), the Madison Valley formation dips more steeply than underlying beds and more steeply than the formation dips to the south. The base of the formation rests on successively lower parts of the underlying section toward the north. The hinge for this increased dip coincides with the inferred position of the Willow Creek Fault in this area.

Northeast-striking faults

Northeast-striking faults are inferred from geologic map patterns in the northernmost part of the Madison Bluffs and in the southeasternmost part of the map area. In addition, a fault or faults with this strike may be present in the subsurface in an area east of Anceney where the regional northeast dip of Tertiary strata is interrupted by a zone of dips to the northwest that continues south of the map area.

In the northernmost part of the Madison Bluffs, a facies change in the unit mapped as the Dunbar Creek Member of the Renova Formation may generally coincide with the zone of inferred northeast-southwest-striking faults. Just north of this zone, an August 3, 1996 seismic event occurred beneath the Gallatin River with a strike-slip mechanism consistent with left-lateral slip on a northeast-trending vertical fault (Stickney, 1997), suggesting possible reactivation of this fault zone.

Range-front faults of Bridger Range

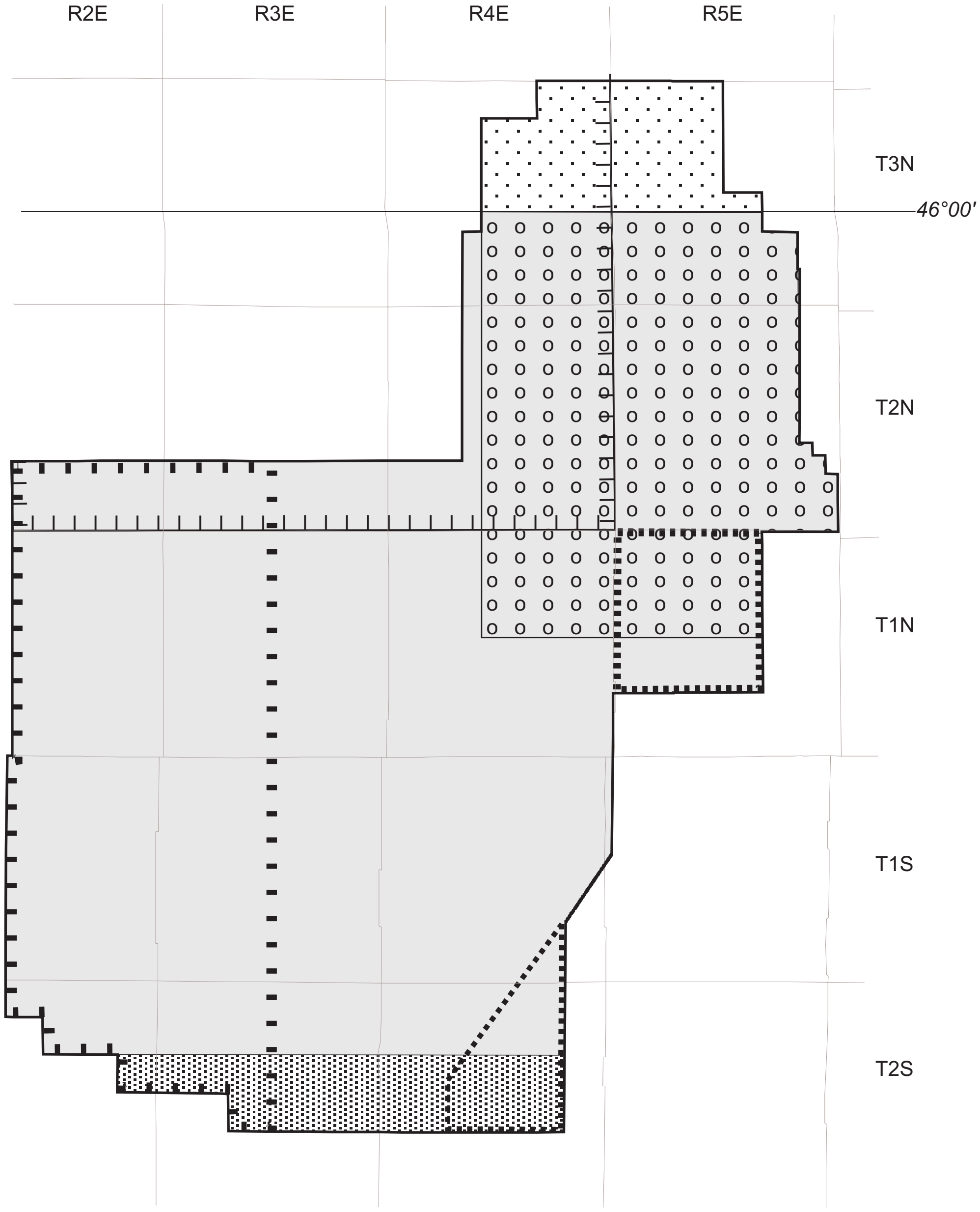
An angular unconformity is tentatively interpreted in the northern Gallatin Valley between what was mapped as Madison Valley formation and the Reese Creek map unit (Fig. 5). This angular unconformity is apparently not present in western Gallatin Valley.

Exposures are poor, but east of Dry Creek, the Madison Valley formation appears to dip consistently to the east in the area north of the syncline. East-dipping attitude measurements were taken in several places near Dry Creek and closer to the Bridger Range by Hughes (1980), and at one location in the present study. In contrast, the overlying Reese Creek map unit dips to the southwest on the east side of Dry Creek and north of the syncline, based on map pattern. If correlations with datable units and attitude measurements are accurate, an unconformity must have developed during the late Barstovian or Clarendonian (Fig. 4), following downward movement of the valley and eastward rotation of the Madison Valley formation beds, resulting from down-to-the-west movement on a range-front fault of the Bridger Range as discussed by Lageson (1989). The contrasting dip of the overlying Reese Creek map unit, away from the Bridger Range, may reflect primary dip of sediment shed from the mountains during an episode of tectonic quiescence. Hughes' (1980) ash date in the Reese Creek area indicates a late Clarendonian or early Hemphillian age for this sediment. The possible movement on the Willow Creek Fault that caused subsequent synclinal folding of these beds was later than late Clarendonian, and likely occurred during the Pleistocene as discussed above.

Gravity modeling north of Bozeman and south of the Central Park Fault, along the Montana Baseline, indicates a westward-thinning wedge of Tertiary sediment, with Miocene deposits dipping from 2º to 35º toward the range-front fault, suggesting a listric normal fault geometry at depth (Lageson, 1989). The best-fit model is a half-graben with a maximum sediment thickness of 6560 ft, and with 7,200 ft of throw on the adjacent normal fault (Lageson, 1989). The gravity data further suggest that there is probably not a significant Paleozoic section beneath the Tertiary in this area (Lageson, 1989). A seismic event with an epicenter about 7 km northeast of Belgrade (Fig. 2) occurred on November 6, 1997 (Stickney and Lageson, 1999). The focal mechanism indicated dominantly normal slip with a dextral component on a N15ºW, 60°E fault, interpreted as an intra-valley normal fault that was antithetic to the range-front fault of the Bridger Range. The epicenter lies between the Willow Creek and Central Park Faults as interpreted in this report.

Barstovian fossils have been found extensively in the Madison Bluffs (Douglass, 1899, 1901, 1903, 1907a, 1907b, 1908, 1909a, 1909b), in the Anceney area (Dorr, 1956; Sutton, 1977; Sutton and Korth, 1995; Evander, 1996), south of Manhattan (this report), in the lower Storey Hills east of Bozeman (Glancy, 1964), and in the Tertiary hills southeast of Bozeman (Fix, 1940). Lithostratigraphy of the Madison Valley formation is consistent in these areas except for the change in clast composition in the Storey Hills (see Madison Valley formation discussion). The Madison Valley formation is bracketed by K/Ar ash dates in the Dry Creek area (Hughes, 1980). The Madison Valley formation is only about 200 ft thick in the Madison Bluffs, and 100 ft thick in the Menard area. Although the Barstovian Madison Valley formation is tilted eastward near the Bridger Range, probably as a result of movement on the Bridger range-front fault, the bulk of the 7,200 ft of throw on the fault (Lageson, 1989), must have occurred prior to the Barstovian for these deposits to extend across such a broad area. The base of the Madison Valley formation is exposed near Anceney. It is unlikely that the formation thickens dramatically between Anceney and Bozeman. Movement on northwest-striking basement faults seems to have had the most regional structural influence on the exposed Tertiary of the western Gallatin Valley, followed by subsequent movement on the Central Park Fault.

The Tertiary deposits in northern Gallatin Valley appear to thicken much more toward the Bridger Range than they do farther south. This difference may be related to the interplay between the Southwest Montana Transverse Zone and the possible pull-apart origin of the Dry Creek Valley, and to movement on the range-front faults of the Bridger Range. Cross-section A-A’ was not continued through this area because of the lack of subsurface data.



░	Hackett, O.M., Visher, F.N., McMurtrey, R.G., and Steinhilber, W.L., 1960, pl. 2, scale 1:63,360.
o o o o	Hughes, G.C., 1980, pl. 1, scale 1: 63,000.
⋯	Lonn, J.D., and English, A.R., 2002, scale 1:48,000.
▒	Mifflin, M.D., 1963, scale 1:31,680.
▪ ▪ ▪	Schneider, G.B., 1970, pl. 1, scale 1:24,000.
∴	Skipp, Betty, and Peterson, A.D., 1965, sheet 1, scale 1:24,000.
⊥⊥⊥	Verrall, Peter, 1955, pl. 1, scale 1:24,000.

Figure 6. Previous geologic mapping.

CORRELATION DIAGRAM
Geologic Map of Western and Northern Gallatin Valley

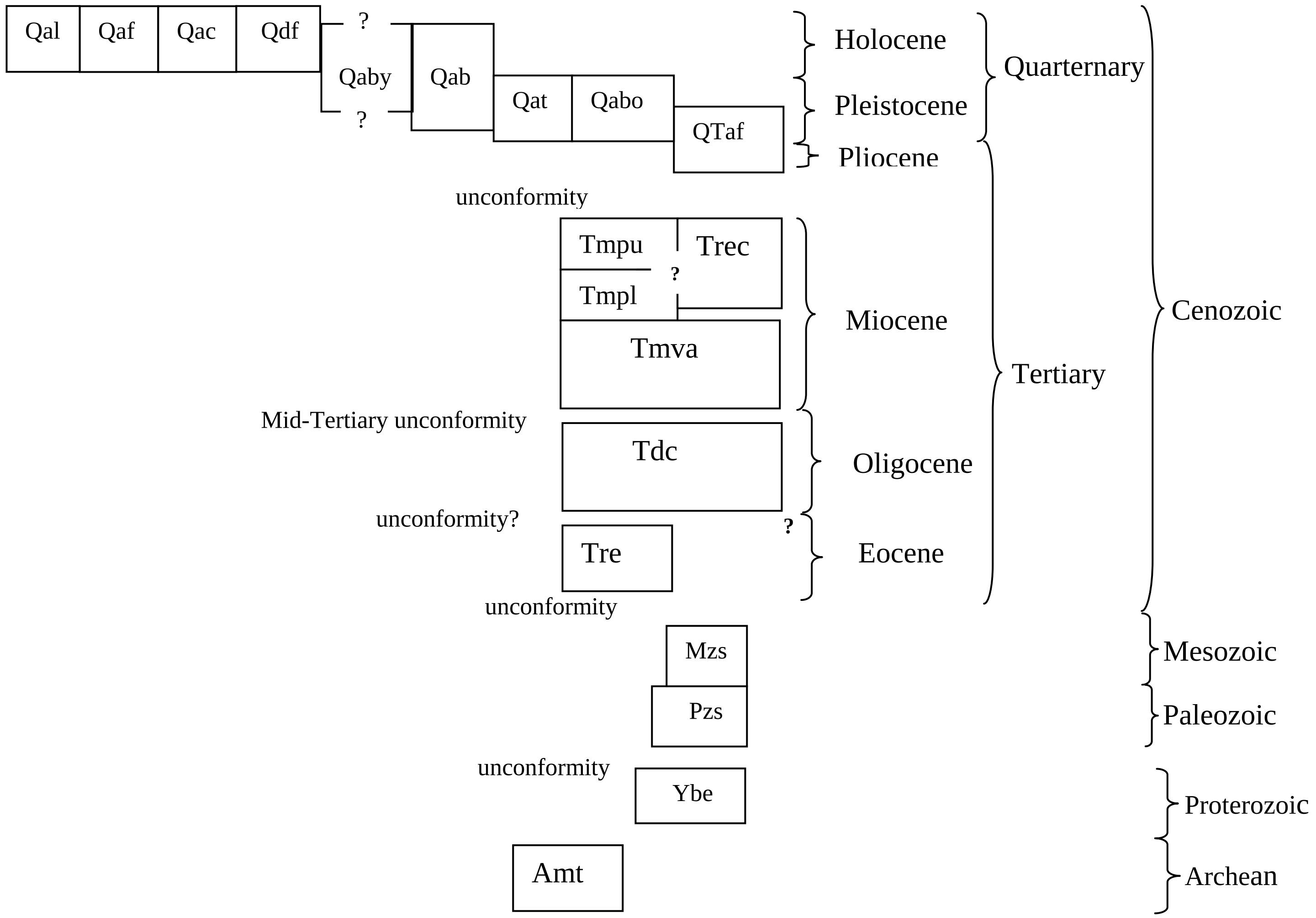


Figure 7. Correlation diagram.

DESCRIPTION OF MAP UNITS
Western and Northern Gallatin Valley

Note: Thicknesses are given in feet because original field maps were on 7.5' quadrangles with topographic contour intervals in feet. To convert feet to meters (the contour interval unit on this map), multiply feet x 0.3048.

See Figure 2 for location of geographic and cultural features referred to in this section.

Qal **Alluvium (Holocene)—**Gallatin and East Gallatin Rivers: Rounded to well-rounded small boulders, cobbles, gravel, sand, silt, and clay, dominantly composed of Archean metamorphic rocks, and dark-colored volcanic rocks, with subordinate Paleozoic limestone, and Precambrian Belt rocks.

Madison River: Subrounded to rounded, gravel and sand with clasts rarely larger than cobble size (Robinson, 1963) dominantly composed of Archean metamorphic rocks, dark-colored igneous rocks, Paleozoic limestone, quartz, and chert.

Tributaries of Gallatin and East Gallatin River: Clast composition varies. Clasts of tributaries from the Tertiary of the Camp Creek Hills are derived primarily from the pebbles and cobbles of Tertiary fluvial deposits. Dry Creek and its tributaries contain clasts derived from the Maudlow Basin, Horseshoe Hills, Bridger Range, and local Tertiary and older Quaternary deposits. Estimated thickness of Holocene alluvium of Gallatin River is 50 to 80 ft based on thicknesses in well logs where Qal rests directly on bedrock.

Qaf **Alluvial fan deposit (Holocene)—**Heterogeneous mixture of subangular to moderately rounded coarse clasts as large as boulder size, and fine sediment (sand, silt, and clay) that is generally more concentrated near fan margins. Clasts composition dominantly Proterozoic LaHood Formation (Belt Supergroup). Estimated thickness is about 100 ft at thickest part.

Qac **Alluvium and colluvium, undivided (Holocene and Pleistocene)—** Locally derived sediment on slopes. Color reflects that of parent material. Ranges from clay and silt to gravel, depending on source. North of Menard composed of angular fragments of underlying bedrock and includes gravel of subangular to subrounded cobbles and boulders from an upstream source (Skipp and Peterson, 1965). Thickness generally less than 20 ft.

Qdf **Debris flow deposit (Holocene)—**Angular, subangular and subrounded clasts of compositionally well-sorted, texturally poorly sorted boulders and cobbles with subordinate finer sediment. Some fine sediment probably has been removed by erosion from around coarser clasts leaving them as lag. Clasts composed of Paleozoic limestone with some chert in northern deposit and Precambrian LaHood Formation arkose in other deposits. Thickness probably about 50 ft in thickest part.

Qaby **Younger braided-stream deposit of Gallatin River (Holocene? and Pleistocene?)—**Rounded to well-rounded, dominantly cobble gravel with clasts as large as boulder size, and sand, silt, and clay; mostly composed of Archean metamorphic rock fragments, and dark-colored volcanic rocks, with subordinate Paleozoic limestone and Proterozoic Belt rocks. Thickness not known because indistinguishable from Qal and Qago in well logs.

Qab **Braid-plain deposit of the Madison River Valley (Holocene and Pleistocene)—**Deposit that underlies the Madison River Valley and underlies and is adjacent to Qal of the valley. Deposit composed of subrounded to rounded, fairly well sorted gravel with few clasts larger than cobble size, and sand (Robinson, 1963). Deposit covered by organic material, silt, and mud in many swampy areas east of the Madison River. Thickness probably not more than 50 ft (Robinson, 1963).

Qat **Alluvial terrace deposit (Pleistocene)—**Remnant of older braided-stream deposit adjacent to and about 5 to 15 ft above modern stream or river. Estimated thickness about 20 ft.

Qabo **Older braided-stream or braid plain deposit (Pleistocene)—**Extensive deposit underlying and adjacent to Gallatin and East Gallatin Rivers and their tributaries and on slopes flanking the Bridger Range. Clast composition on the valley floor same as younger alluvium of Gallatin River, but also includes locally derived clasts. Clasts in deposits of tributary valleys and slopes flanking Bridger Range are locally derived. Thickness highly variable. More than 800 ft thick in Belgrade area (Hackett and others, 1960), but thins to 30 ft or less in at least one area north of the Central Park fault (Hackett and others, 1960).

QTaf **Alluvial fan deposit (Pleistocene? or Pliocene?)**—Remnants of old alluvial fans dissected by Pleistocene braided streams. Heterogeneous mixture of subangular to moderately rounded coarse clasts that range to boulder size, and fine sediment (sand, silt, and clay). Clasts composed of Paleozoic limestone and Proterozoic LaHood Formation arkose. Thickness about 50 ft.

Trec **Reese Creek map unit, informal (Miocene: Clarendonian or Hemphillian NALMA)—**Basal cobble or small boulder clast-supported conglomerate or gravel cemented by calcium carbonate, or unconsolidated with clasts coated by calcium carbonate, overlain by orangish-tan tuffaceous mudstone with lenses of fine-grained sandstone. Fine-grained upper part of unit best exposed near the mouth of Reese Creek. In most other areas, the poorly resistant, fine-grained part is poorly exposed. A vitric ash was sampled from near the mouth of Reese Creek and provided a K/Ar date of 8.9±0.4 Ma (youngest Clarendonian or oldest Hemphillian; Figure 4). The ash has an abrupt basal contact and climbing ripples at the top, and is 0.9 to 1.5 m thick (Hughes, 1980). The contact between this map unit and the underlying Madison Valley formation is an angular unconformity in the northern Gallatin Valley.

Tmpu **Upper Madison Plateau map unit (Miocene: Clarendonian? and/or Hemphillian? NALMA)—**Dark brown, clayey silt and fine-grained sand with sparsely distributed, matrix-supported pebbles and some cobbles, dominantly of Proterozoic Belt othoquartzite. Interpretation that this unit is Tertiary is based on the conformity of its distribution to the underlying Tertiary units and the presence of matrix-supported pebbles and cobbles. May correlate with the fine-grained part of the Reese Creek map unit in the northern Gallatin Valley from which an ash sample provided a K/Ar date of 8.9±0.4 (Hughes, 1980; Lange and others, 1980).

Tmpl **Lower Madison Plateau map unit, informal (Miocene?: Clarendonian? and/or Hemphillian? NALMA)**—Sheet deposit of moderately well-sorted and well-rounded clast-supported cobble conglomerate or gravel; color reflects maroon, gray, and brown calcium-carbonate-coated cobbles of dominantly Belt orthoquartzites. Archean metamorphic clasts are found only at the base as pebble size or smaller. They were likely reworked from underlying Madison Valley formation pebble conglomerates with Archean clasts. May correlate with clast-supported cobble conglomerate in Reese Creek area at base of Reese Creek map unit, from which an ash bed yielded a K/Ar date of 8.9 ±0.4 Ma (Hughes, 1980; Lange and others, 1980). If so, the Madison Plateau map unit is likely youngest Clarendonian or oldest Hemphillian (Fig. 4). West of the Madison River, unit appears to rest conformably on the Madison Valley Formation, but unconformably on the Dunbar Creek Formation of Robinson (1963) (Vuke, and others, 2002). East of the Madison River, unit appears to rest conformably on the Madison Valley formation and was involved in northeastward tilting and folding of underlying units with apparent conformity. Alternatively, unit may be younger and rest disconformably on the underlying Madison Valley formation, but regardless, was deposited prior to northeastward tilting and folding of Tertiary strata. Thickness 20-30 ft.

Tmva **Madison Valley formation (informal [Douglass, 1907]) (Miocene: Barstovian and Clarendonian? NALMA)—**

Madison Bluffs, Madison Plateau, and Camp Creek Hills area: Pinkish-tan or tan, tuffaceous silt or siltstone and marl interbedded with cross-bedded, texturally immature, coarse sandstone that contains lenses of pebble conglomerate or local cobble conglomerate that ranges from matrix- to clast-supported, and from cemented to unconsolidated. Conglomerate clasts are dominantly Archean gneiss and extrusive volcanic rocks, with subordinate Belt rocks, and occasional Paleozoic limestone clasts. Sandstone has large root casts locally, and marl beds are typically full of small root casts. Several vitric ash beds are present throughout the unit. Opalized wood fragments are abundant in many of the conglomerate lenses. Conglomerate also contains relatively abundant disarticulated bones and bone fragments and occasional teeth. Numerous articulated Barstovian fossils have been collected and studied from the fine-grained parts of this unit (Tabrum and others, 2001; Douglass, 1899, 1901, 1903, 1907a, 1907b, 1908, 1909a, 1909b; Frick, 1937; Dorr, 1956; Sutton, 1977; (Sutton and Korth, 1995; Evander, 1996), including the Anceney beds of Dorr (1956).

The contact between this unit and the underlying Dunbar Creek Member of the Renova Formation is sharp and locally appears unconformable as noted by Hackett and others (1960). In the northernmost part of the Madison Bluffs (Fig. 2) the contact appears to be an angular unconformity. A relatively resistant bed at the base of the Madison Valley formation cuts down to nearly the level of the conglomerate of the Renova Formation, undivided, as mapped in this report. In the southernmost part of the Madison Bluffs, calcic paleosols that closely resemble those described below in the Renova Formation, undivided map unit, occur at the contact between the Madison Valley formation and the underlying Dunbar Creek Member of the Renova Formation.

Thickness 200 ft throughout most of the Madison Bluffs area, but thickens to 300 ft in the southern bluffs.

Dry Creek area: Grayish-orange, cross-bedded sandstone and pebble conglomerate interbedded with brownish-orange tuffaceous siltstone and marl. Sandstone beds are crossbedded and contain large lenses of dominantly pebble conglomerate with occasional cobble-size clasts or local cobble conglomerate. Conglomerates vary from matrix supported to clast supported. Unlike the clast composition in the Madison Bluffs and Camp Creek Hills areas, the clasts in the Menard area are dominantly Paleozoic limestone and Mesozoic sandstone, with subordinate andesitic volcanic rock and minor metamorphic rocks. Hughes (1980) interpreted the volcanic rock source as the Maudlow Basin where Livingston Group rocks are exposed. Closer to the Bridger Range, the clasts are dominantly Proterozoic LaHood Formation arkose, Paleozoic limestone, and quartz. Thickness near Menard about 100 ft. It is not known if the Madison Valley formation thickens dramatically to the east, or if it has been downfaulted from the Bridger Range to Dry Creek. It is at a much higher elevation close to the Bridger Range in the northern Gallatin Valley area than at Dry Creek.

Some of the coarser-grained beds of the Madison Valley formation are shown on the map with a dotted pattern. In general, these are medium to coarse grained, fairly laterally persistent sandstone beds with numerous lenses of conglomerate and conglomeratic sandstone. Hughes (1981) describes these conglomeratic sandstones as “blanket-like” deposits in the Dry Creek area.

In local areas south of Manhattan and in the southeastern part of the map area, some of the conglomerate lenses contain dominantly cobble- rather than the more typical pebble-size clasts of other areas. These cobble conglomerates serve as caprocks with overlying fine-grained sediment stripped away. They have been interpreted as alluvial terrace deposits (Hackett and others, 1960) and pediment gravels (Mifflin, 1963), but were traced into the Madison Valley formation in several places. In this report, they are mapped as coarser-grained beds of the Madison Valley formation.

Gravel pits are numerous in the coarser-grained beds of the Madison Valley formation. Many of the gravel pits are shown on the map.

Trd **Dunbar Creek Member of Renova Formation (Oligocene: Whitneyan and Orellan? NALMA)—**

Madison Bluffs and Camp Creek Hills: White to very light gray and light-tan, tuffaceous planar-bedded siltstone and fine-grained sandstone with numerous tiny root casts, glassy ash beds, light-gray tuffaceous limestone beds, and an interval of white diatomite beds near the top that extends the length of the Madison Bluffs. Distinguished from Madison Valley formation by color, diatomite marker beds, and lack of significant conglomerate lenses. Tentatively correlated (pending ^{40}Ar/^{39}Ar date from ash sampled east of the Madison River) with Renova Formation near Menard in Dry Creek area from which an ash yielded a K/Ar date of 30.6±1.2 Ma (Whitneyan; Fig. 4) (Hughes, 1980; Lange and others, 1980).

Hackett and others (1960) also correlated this unit (their unit 1) in the Madison Bluffs and Camp Creek Hills with the Whitneyan unit near Menard. Ostracodes, gastropods, and fish have been reported from this unit in the Madison Bluffs (Blake, 1953; Dorr, 1956; Schneider, 1970).

An abrupt facies change occurs in this unit in the northeastern part of the Madison Bluffs from dominantly planar-bedded siltstone to the south, to gray, unconsolidated to poorly cemented, medium-grained immature sandstone overlain by the white diatomite marker beds described for the Dunbar Creek Member above. This facies change in the northern part of Madison Bluffs was walked out, but can also be viewed from a distance from the Madison Valley Road.

Dry Creek area: White to very light gray and light-tan, tuffaceous siltstone, fine-grained sandstone and mudstone, tuffaceous marl and limestone, and ash. Ostracodes and gastropods have been reported from this unit in the Dry Creek area (Hughes, 1980; Hackett and others, 1960; Verrall, 1955), and Klemme (1949) reported mammal fragments in this unit in the Dry Creek area.

Isolated patches of Tertiary sediment in the southern Horseshoe Hills are tentatively interpreted as this unit because of similar lithologies and the presence of gastropods similar to those found west of Menard (Verrall, 1955). Although gastropods are not good index fossils (R.W. Fields, personal communication in Hughes, 1980), poorly preserved gastropods are widespread in the Dunbar Creek Formation [Member] (Robinson, 1963). Gastropods have not been reported from the overlying Madison Valley formation in the map area.

Thickness of unit about 150 ft in central Madison Bluffs, but may be thicker in the southern part of the Madison Bluffs where it is obscured by slope alluvium and colluvium. In the northernmost bluffs it thins abruptly to about 50 ft.

Tre **Renova Formation, undivided, map unit (Oligocene or Eocene: Chadronian? NALMA)**—It is unclear whether this unit is lower Dunbar Creek or upper Climbing Arrow as mapped by Robinson (1963) west of the Madison River. In the northernmost part of the Madison Bluffs, conglomerates in this unit seem to correlate with similar conglomerates in the uppermost Climbing Arrow south of Three Forks (west of the Madison River). Farther south, near the buffalo jump, the unit seems to correlate with the lower part of the Dunbar Creek, directly across the river. Robinson (1963) states that the Climbing Arrow and Dunbar Creek may interfinger. The

Chadronian? age interpretation is based on a late Chadronian fauna (Tabrum and others, 2001) in the lower Dunbar Creek approximately 6 miles to the northwest.

In the exposures near Madison Buffalo Jump State Park, unit is dominantly light to medium gray, orange or tan, fine- to coarse-grained sandstone or conglomeratic sandstone with clasts as large as granule or small pebble size, interbedded with thinner gray siltstone and mudstone. Grain size is significantly coarser in the northern bluffs where unit is dominantly texturally and compositionally immature conglomerate with subangular to subrounded clasts ranging to small boulder size. In the northern part of the map area, the conglomerate has extensive orange zones from iron oxide staining and a sharp base where it rests on finer-grained beds.

Calcic paleosols as described by Hanneman and others (1994) occur near road level in the area of Madison Buffalo Jump State Park (D. Hanneman, personal communication, 2002). They also occur where this unit is exposed in the northernmost and southernmost parts of the bluffs. The maximum exposed thickness of this map unit is about 100 ft.

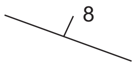
Units not emphasized in this report

Pzs	**Paleozoic sedimentary rocks, undivided**
Mzs	**Mesozoic sedimentary rocks, undivided**
Ybe	**Belt Supergroup rocks, undivided**
Amt	**Archean metamorphic rocks, undivided**

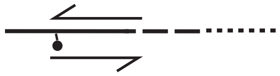
For more detailed mapping of these units, refer to Vuke and others (2002).

MAP SYMBOLS
GEOLOGIC MAP OF THE WESTERN AND NORTHERN GALLATIN VALLEY

Contact—Dashed where inferred, dotted where concealed.

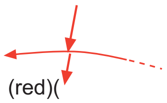


Strike and dip of bedding—Number indicates angle of dip in degrees.

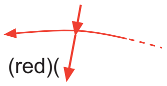


Fault, high-angle—Dashed where inferred, dotted where inferred and concealed. Ball and bar on downthrown side. Arrows indicate strike-slip movement. Some faults have undergone reversal of movement. Only last movement or net movement is shown.

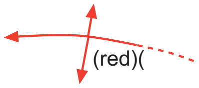
Syncline—Showing trace of axial plane and direction of plunge; dotted where concealed.



Anticlinal bend of monocline—Showing trace of axial plane and direction of plunge. Dashed where inferred; dotted where concealed; short arrow on more steeply dipping limb.

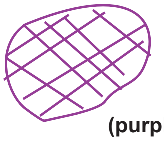


Synclinal bend of monocline—Showing trace of axial plane and direction of plunge. Dashed where inferred; dotted where concealed; short arrow on more steeply dipping limb.

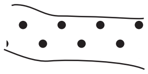


Anticline—Showing trace of axial plane and direction of plunge; dotted where concealed.

Linear feature—Straight, northwest-striking geologic map pattern. Strike is consistent with basement structural grain, so may be controlled by faults or fractures. Shaded relief images from digital elevation models reveal many more linear features in the region.



Gravel pit in Madison Valley formation or basal Reese Creek map unit—Not all gravel pits shown. Several permits have been issued for more gravel pits in the Madison Valley formation in the area south of Logan (Montana Department of Environmental Quality, Industrial and Energy Mineral Bureau). Two Barstovian *Merychippus* (horse) teeth were found in a gravel pit south of Logan. Some of the Madison Valley formation gravel on valley floors south of the Gallatin River between Logan and Manhattan may have been very locally reworked during the Pleistocene.



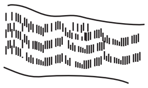
Coarser beds—

<u>Madison Plateau map unit:</u> Rounded caliche-coated cobble conglomerate or gravel with some pebbles and rare small boulders.

<u>Reese Creek map unit:</u> Basal bed of rounded cobble or small boulder conglomerate or gravel shown with dotted pattern on map. May be more extensive than shown. In part, traced on aerial photographs but not yet field-checked.

<u>Madison Valley formation:</u> Sand or sandstone with lenses of dominantly pebble conglomerate or gravel, but also with local lenses of cobble conglomerate or gravel. Not all such beds were mapped.

<u>Renova Formation, undivided</u>: Sandstone and poorly size-sorted conglomerate in northernmost part of Madison Bluffs with sharp basal contact; sandstone and locally conglomeratic sandstone or sandstone with thin stringers of conglomerate elsewhere. Many sandstone beds in Renova Formation, undivided, were not individually mapped.



Anceney map unit (informal) in Madison Valley formation—Light-colored planar-bedded, tuffaceous siltstone and light-gray ash. Includes Anceney beds of Dorr (1956).

Area with seasonal high water table less than 6 ft—Modified from *Seasonal high water tables, Bozeman area, Gallatin County, Montana*: U.S. Department of Agriculture, Soil Conservation Service, Bozeman, MT, 1992, approximate scale: 1:50,0000.

〰	**Limit of seasonal high-water table data.**
⌖ 1,	**Drill hole location**—Numbers refer to data from Hackett and others (1960) in Table 1 of present report.

REFERENCES CITED AND BIBLIOGRAPHY
Geologic Map of Western and Northern Gallatin Valley

Alexander, R.G., Jr., 1951, The geology of the Whitehall area, Montana: Princeton, Princeton University, Ph.D. dissertation, 150 p.

Berggren, W.A., Kent, D.V., Aubry, M.-P., Swisher, C.C., III, and Miller, K.G., 1995, A revised Paleogene geochronology and chronostratigraphy: Society of Economic Paleontologists and Mineralogists Special Publication 54, p. 129–212.

Blake, O.D., Hanson, A.M., and Hackett, O.M., 1953, Field Trip no. 1, Stratigraphy and structure in the Three Forks area, *in* Blake, O.M., ed., Guidebook of field excursions: Geological Society of America, Rocky Mountain Section, 6th Annual Conference Guidebook, p. 19–30.

Brodowy, J.M., Lageson, D.R., Ryan, Christine, Snyder, Bob, 1991, Structure and neotectonics of the eastern Three Forks basin, northern intermountain seismic belt, southwest Montana: Geological Society of America, Abstracts with Programs, Annual Meeting, v. 23, no. 5, p. A233-A234.

Burton, B.R., Lageson, D.R., Schmidt, C.J., Ballard, D.W., and Warne, J.R., 1997, Large-magnitude shortening of the Lombard Thrust System, Helena Salient, Montana Fold and Thrust Belt: Implications for reconstruction of the Belt Basin, *in* Berg, R.B., ed., Belt Symposium III, Montana Bureau of Mines and Geology Special Publication 112, p. 229–243.

Chadwick, R.A., 1981, Geologic Road Log—Livingston to Three Forks, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society Field Conference and Symposium Guidebook, p. 380–387.

Clabaugh, S.E., 1952, Corundum deposits of Montana: U.S. Geological Survey Bulletin 983, 100 p.

Clabaugh, S.E., and Armstrong, F.C., 1950, Corundum deposits of Gallatin and Madison Counties, Montana: U.S. Geological Survey Bulletin 969-B, p. 29–53.

Coppinger, W., 1983, Unpublished map, Golden Sunlight Mines, Inc.

Davis, W.E., Kinoshita, W.T., and Robinson, G.D., 1965, Bouguer gravity, aeromagnetic, and generalized geologic map of the eastern part of the Three Forks Basin, Broadwater, Madison, and Gallatin Counties, Montana: U.S. Geological Survey Geophysical Investigations Map GP-497, scale 1:62,500.

Donohue, D.A., 1989, Paleochannel aquifer potential at Montana State University—a test of hypotheses: Bozeman, Montana State University, M.S. thesis, 94 p.

Donovan, J.J., Stickney, M.C., and Sonderegger, J.L., 1982, Subsurface investigations at Bozeman Hot Springs: Geological Society of America Abstracts with Programs, v. 14, no. 6, p. 310.

Dorr, J.A., 1954, *Hypsoparia bozemanensis*, a new genus and species of leptarctine mustelid from the late Miocene Madison Valley Formation of Montana: Carnegie Museum Annals, v. 33, p. 179–184.

Dorr, J.A., 1956, Anceney local mammal fauna, latest Miocene, Madison Valley Formation, Montana: Journal of Paleontology, v. 30, p. 62–74.

Douglass, E., 1899, Neocene lake beds of western Montana and descriptions of some new vertebrates from the Loup Fork: Missoula, University of Montana, M.S. thesis, 27 p.

Douglass, E., 1901, New species of *Merycochoerus* in Montana, Part II: American Journal of Science, v. 11, p. 73–83.

Douglass, E., 1903, New vertebrates from the Montana Tertiary: Annals of the Carnegie Museum, v. 2, p. 145–199.

Douglass, E., 1907a, *Merycochoerus* and a new genus of merycoidodonts with some notes on other Agriochoeridae: Annals of the Carnegie Museum, v. 4, no. 2, p. 84–98.

Douglass, E., 1907b, New Merycoidodonts from the Miocene of Montana: Bulletin of the American Museum of Natural History, v. 23, p. 202–222.

Douglass, E., 1908, Rhinoceroses from the Oligocene and Miocene deposits of North Dakota and Montana: Carnegie Museum Annals, v. 4, no. 3-4, p. 256–266.

Douglass, E., 1909a, Description of a new species of *Procamelus* from the Upper Miocene of Montana with notes upon *Procamelus madisonius* Douglass: Annals of the Carnegie Museum, v. 5, p. 159–165.

Douglass, E., 1909b, *Dromomeryx,* a new genus of American ruminants: Annals of the Carnegie Museum, v. 5, no. 4, p. 457–479.

Feichtinger, S.H., 1970, Geology of a portion of the Norris quadrangle, Madison and Gallatin Counties, Montana: Bozeman, Montana State University, M.S. thesis, 89 p.

Fields, R.W., Rasmussen, D.L., Tabrum, A.R., and Nichols, R., 1985, Cenozoic rocks of the intermontane basins of western Montana and eastern Idaho: A summary, *in* Flores, R.M., and Kaplan, S.S., eds., Cenozoic paleogeography of west-central United States: Rocky Mountain Paleogeography Symposium 3, Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists, p. 9–36.

Fix, P.F., 1940, Structure of Gallatin Valley, Montana: Boulder, University of Colorado, Ph.D. dissertation, 68 p.

Frick, C., 1937, Horned ruminants of North America: Bulletin of the American Museum of Natural History, v. 69, no. 1, p. 669.

Glancy, P.S., 1964, Cenozoic geology of the southeastern part of the Gallatin Valley, Montana: Bozeman, Montana State University, M.S. thesis, 66 p.

Glaman, L.R.B., 1991, The geology of Negro Hollow, Jefferson County, Montana: Butte, Montana College of Mineral Science and Technology, M.S. thesis, 69 p.

Hackett, O.M., Visher, F.N., McMurtrey, R.G., and Steinhilber, W.L., 1960, Geology and ground-water resources of the Gallatin Valley, Gallatin County, Montana, with a section on surface-water resources by Stermitz, Frank, and Boner, F.C., and a section on chemical quality of the water by Krieger, R.A.: U.S. Geological Survey Water-Supply Paper 1482, 28 p.

Hanneman, D.L., Cheney, E.S., and Wideman, C.J., 2003 (in press), Cenozoic sequence stratigraphy of northwestern USA, *in* Raynolds, R.G., and Flores, R.M., eds., Cenozoic Systems of the Rocky Mountain Region: Society for Sedimentary Geology, Rocky Mountain Section.

Hanneman, D.L., and Wideman, C.J., 1991, Sequence stratigraphy of Cenozoic continental rocks, southwestern Montana: Geological Society of America Bulletin, v. 103, p. 1335-1345.

Hanneman, D.L., Wideman, C.J., and Halvorson, J.W., 1994, Calcic paleosols: Their use in subsurface stratigraphy: American Association of Petroleum Geologists Bulletin, v. 78, no. 9, p. 1360–1371.

Harrison, J.E., Griggs, A.B., and Wells, J.D., 1974, Tectonic features of the Precambrian Belt Basin and their influence on post-Belt structures: U.S. Geological Survey Professional Paper 866, 15 p.

Hill, C.L., 2001a, Late Pliocene and Pleistocene geology and paleontology in the Three Rivers Basin, Montana, *in* Nichols, R., ed., Cenozoic vertebrate paleontology and geology of southwestern Montana and adjacent areas, *in* Hill, C.L., ed., Mesozoic and Cenozoic paleontology in the western plains and Rocky Mountains: Society of Vertebrate Paleontology 61st annual field trip guidebook, Museum of the Rockies Occasional Paper no. 3, p. 113–125.

Hill, C.L., 2001b, Pleistocene mammals of Montana and their geologic context, *in* Nichols, R., ed., Cenozoic vertebrate paleontology and geology of southwestern Montana and adjacent areas, *in* Hill, C.L., ed., Mesozoic and Cenozoic paleontology in the western plains and Rocky Mountains: Society of Vertebrate

Paleontology 61st annual field trip guidebook, Museum of the Rockies Occasional Paper no. 3, p. 127–144.

Hughes, G.C., 1980, Tertiary stratigraphy and depositional history of the Dry Creek Valley, Gallatin County, Montana: Bozeman, Montana State University, M.S. thesis, 147 p.

Hughes, G.C., 1981, Tertiary stratigraphy and depositional history of the Cry [sic] Creek Valley, Montana, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 111–119.

Klemme, H.D., 1949, The geology of the Sixteen Mile Creek area, Montana: Princeton, N.J., Princeton University, Ph.D. dissertation, 197 p.

Kuenzi, W.D., and Fields, R.W., 1971, Tertiary stratigraphy, structure, and geologic history, Jefferson Basin, Montana: Geological Society of America Bulletin, v. 82, p. 3373–3394.

Kuenzi, W.D., and Richard, B.H., 1969, Middle Tertiary unconformity, North Boulder and Jefferson Basins, southwest Montana: Geological Society of America Bulletin, v. 80, p. 115–120.

Lageson, D.R., 1989, Reactivation of a Proterozoic continental margin, Bridger Range, southwestern Montana, *in* French, D.E., and Grabb, R.F., eds., Geological Resources of Montana, Volume I: Montana Geological Society Field Conference Guidebook, Centennial Edition, p. 279–298.

Lageson, D.R., 1985, Tectonic evolution of the Bridger Range and adjacent regions, southwest Montana: *in* Beaver, P.C., ed., Geology and Mineral Resources of the Tobacco Root Mountains and adjacent region: Tobacco Root Geological Society, 10th Annual Field Conference, p. 14.

Lange, I.M., Fields, R.W., Fountain, D.M., Moore, J.N., Qamar, A.I., Silverman, A.J., Thompson, G.R., Chadwick, R.A., Custer, S.G., and Smith, D.L., 1980, Uranium resource evaluation, Bozeman quadrangle, Montana: U.S. Department of Energy, Grand Junction, Colorado.

Lillegraven, J.A., and Tabrum, A.R., 1983, A new species of *Centetodon* (Mammalia, Insectivora, Geolabididae) from southwestern Montana and its biogeographical implications: Contributions to Geology, University of Wyoming, v. 22, no. 1, p. 57–73.

Lonn, J.D., and English, A.R., 2002, Preliminary geologic map of the eastern part of the Gallatin Valley, Montana: Montana Bureau of Mines and Geology Open-File Report MBMG 457, scale 1:48,000.

McMannis, W.J., 1952, Geology of the Bridger Range: Princeton, N.J., Princeton University, Ph.D. dissertation, 172 p.

McMannis, W.J., 1955, Geology of the Bridger Range, Montana: Geological Society of America Bulletin, v. 66, p. 1385–1430.

M'Gonigle, J.W., and Dalrymple, G.B., 1993, $^{40}Ar/^{39}Ar$ ages of Challis volcanic rocks and the initiation of Tertiary sedimentary basins in southwestern Montana: Rocky Mountain Association of Geologists, v. 30, no. 4, p. 112—118.

Mifflin, M.D., 1963, Geology of a part of the southern margin of the Gallatin Valley, southwestern Montana: Bozeman, Montana State University, M.S. thesis, 111 p.

Miller, E.W., and Lageson, D.R., 1993, Influence of basement foliation attitude on geometry of Laramide basement deformation, southern Bridger Range and northern Gallatin Range, Montana: Geological Society of America Special Paper 280, p. 73–88.

Nichols, R., Tabrum, A.R., and Hill, C.L., 2001, Introduction: Cenozoic mammals, southwest Montana, *in* Nichols, R., ed., Cenozoic vertebrate paleontology and geology of southwestern Montana and adjacent areas, *in* Hill, C.L., ed., Mesozoic and Cenozoic paleontology in the western plains and Rocky Mountains: Society of Vertebrate Paleontology 61st annual field trip guidebook, Museum of the Rockies Occasional Paper no. 3, p. 79–81.

Rasmussen, D.L., 2003 (in press), Tertiary geology of western Montana and east-central Idaho: a synopsis, *in* Raynolds, R.G., and Flores, R.M., eds., Cenozoic Systems of the Rocky Mountain Region: Society for Sedimentary Geology, Rocky Mountain Section.

Rasmussen, D.L., and Fields, R.W., 1985, Cenozoic structural and depositional history, Jefferson and Madison intermountain basins, southwestern Montana, *in* Beaver, P.C., ed., Geology and Mineral Resources of the Tobacco Root Mountains and adjacent region: Tobacco Root Geological Society, 10th Annual Field Conference, p. 14.

Richard, B.H., 1966, Geologic history of the intermontane basins of the Jefferson Island Quadrangle, Montana: Bloomington, Indiana University, Ph.D. dissertation, 73 p.

Robinson, G.D., 1960, Middle Tertiary unconformity in southwestern Montana: U.S. Geological Survey Professional Paper 400-B, Article 101, p. B227–B228.

Robinson, G.D, 1961, Origin and development of the Three Forks basin, Montana: Geological Society of America Bulletin, v. 72, p. 1003–1014.

Robinson, G.D., 1963, Geology of the Three Forks quadrangle, Montana: U.S. Geological Survey Professional Paper 370, 143 p.

Robinson, G.D., 1967, Geologic map of the Toston quadrangle, southwestern Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-486, scale 1:24,000.

Ruppel, E.T., 1982, Cenozoic block uplifts in southwest Montana and east-central Idaho: U.S. Geological Survey Professional Paper 1224, 24 p.

Ruppel, E.T., 1993, Cenozoic tectonic evolution of southwest Montana and east-central Idaho: Montana Bureau of Mines and Geology Memoir 65, 62 p.

Schneider, G.B., 1970, Cenozoic geology of the Madison Bluffs area, Gallatin County, Montana: Bozeman, Montana State University, M.S. thesis, 56 p.

Schmidt, C.J., 1975, An analysis of folding and faulting in the northern Tobacco Root Mountains, southwest Montana: Bloomington, Indiana University, Ph.D. dissertation, 480 p.

Schmidt, C.J., and Garihan, J.M., 1986, Role of recurrent movement of northwest-trending basement faults in the tectonic evolution of southwestern Montana: Proceedings of the 6th International Conference of Basement Tectonics, p. 1–15.

Schmidt, C.J., and Garihan, J.M., 1983, Laramide tectonic development of the Rocky Mountain foreland of southwestern Montana, *in* Lowell, J.D., Rocky Mountain foreland basins and uplifts: Rocky Mountain Association of Geologists, Denver, p. 271–294.

Schmidt, C.J., and O’Neill, J.M., 1982, Structural evolution of the Southwest Montana Transverse Zone, *in* Blake, R., ed., Geologic Studies of the Cordilleran Thrust Belt, v. 1: Rocky Mountain Association of Geologists, Field Guidebook v. 1, p. 193–218.

Sears, J.W., and Ryan, P., 2003 (in press), Cenozoic evolution of the Montana cordillera: evidence from paleovalleys, *in* Raynolds, R.G., and Flores, R.M., eds., Cenozoic Systems of the Rocky Mountain Region: Society for Sedimentary Geology, Rocky Mountain Section.

Skipp, Betty, and Peterson, A.D., 1965, Geologic map of the Maudlow quadrangle, southwestern Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-452, scale 1:24,000.

Stickney, M.C., 1999, Characteristics of Recent seismicity in southwest Montana and its relation to Late Quaternary faults: Seismological Research Letters Abstracts, v. 70, no. 2, p. 237.

Stickney, M.C., 1997, Seismic source zones in southwest Montana: Montana Bureau of Mines and Geology Open File Report MBMG 366, 51 p.

Stickney, M.C., and Bartholomew, M.J., 1987, Seismicity and Late Quaternary faulting of the northern Basin and Range Province, Montana and Idaho: Bulletin of the Seismological Society of America, v. 77, no. 5, p. 1602–1625.

Stickney, M.C., and Lageson, D.R., 1999, The Nov. 6, 1997 M 3.7 Blegrade [sic], MT earthquake: Unusual aspects and their implications to regional seismicity: Geological Society of America, Rocky Mountain Section Abstracts with Programs, p. A-57.

Sutton, J.F., 1977, Mammals of the Anceney local fauna (Late Miocene) of Montana: Lubbock, Texas Tech University, Ph.D. dissertation, 241 p.

Tabrum, A.R., Prothero, D.R., and Garcia, Daniel, 1996, Magnetostratigraphy and biostratigraphy of the Eocene-Oligocene transition, southwestern Montana, *in* Prothero, D.R., and Emry, R.J., eds., The terrestrial Eocene-Oligocene transition in North America, Cambridge University Press, New York, p. 278–311.

Tabrum, A.R., and Nichols, R., and Barnosky, A.D., 2001, Tertiary paleontology of southwest Montana and adjacent Idaho, *in* Nichols, R., ed., Cenozoic vertebrate paleontology and geology of southwestern Montana and adjacent areas, *in* Hill, C.L., ed., Mesozoic and Cenozoic paleontology in the western plains and Rocky Mountains: Society of Vertebrate Paleontology 61st annual field trip guidebook, Museum of the Rockies Occasional Paper no. 3, p. 88–112.

Thompson, G.R., Fields, R.W., and Alt, D., 1981, Tertiary paleoclimates, sedimentation patterns, and uranium distribution in southwestern Montana, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 105–109.

Tuck, L.K., Dutton, D.M., and Nimick, D.A., 1997, Hydrologic and water-quality data related to the occurrence of arsenic for areas along the Madison and Upper Missouri Rivers, southwestern and west-central Montana: U.S. Geological Survey Open-File Report 97-203, 124 p.

U.S. Soil Conservation Service, 1992, Seasonal high water tables, Bozeman area, Gallatin Valley: U.S. Department of Agriculture, Soil Conservation Service Office, Bozeman, MT, approximate scale: 1:50,000.

Verrall, P., 1955, Geology of the Horseshoe Hills area, Montana: Princeton, NJ, Princeton University, Ph.D. dissertation, 371 p.

Vuke, S.M., Lonn, J.D., Berg, R.B., and Kellogg, K.S., 2002, Preliminary geologic map of the Bozeman 30’x 60’ quadrangle, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 468, scale 100,000.

Warne, J.R., Sterne, E.J., and Thompson, G.G., 1997, Road Log—From Livingston to Helena via Bridger Range, Lombard Thrust, Jefferson Canyon, Devils Fence Anticline, and Gates of the Mountains marina, *in* Sterne, E.J., and Warne, J.R., eds., Thrust Systems of the Helena Salient-Montana Thrust Belt: Montana Geological Society and Tobacco Root Geological Society Joint Field Conference Guidebook, p. 13–35.

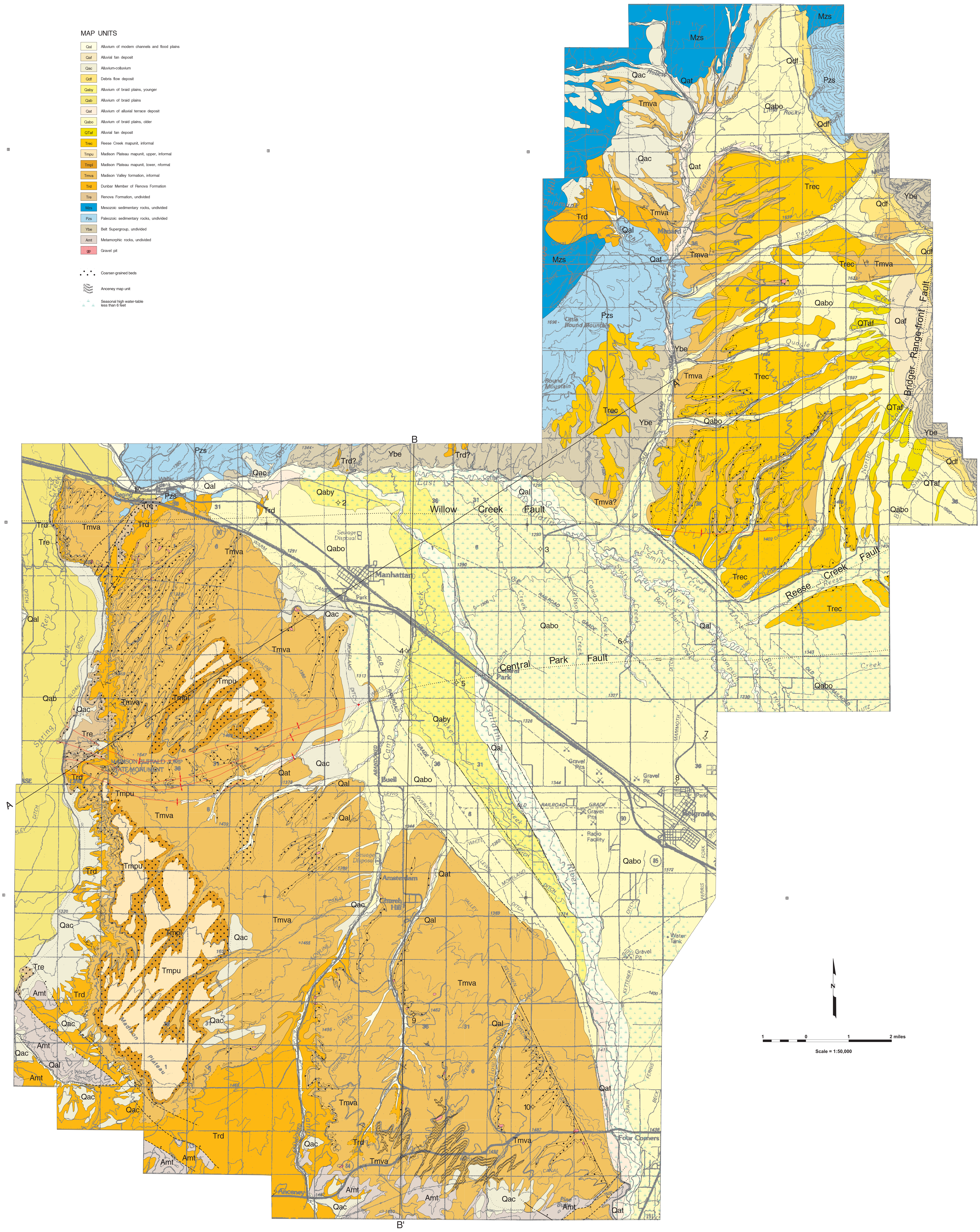
Wood, H.E., Jr., 1933, A fossil rhinoceros (*Diceratherium armatum*) from Gallatin County, Montana: U.S. National Museum Proceedings, v. 82, p. 1–4.

Woodburne, M.O., 1987, A prospectus of the North American mammal ages, *in* Woodburne, M.O., ed., Cenozoic Mammals of North America, Geochronology and Biostratigraphy: University of California Press, Berkeley, p. 285–290.

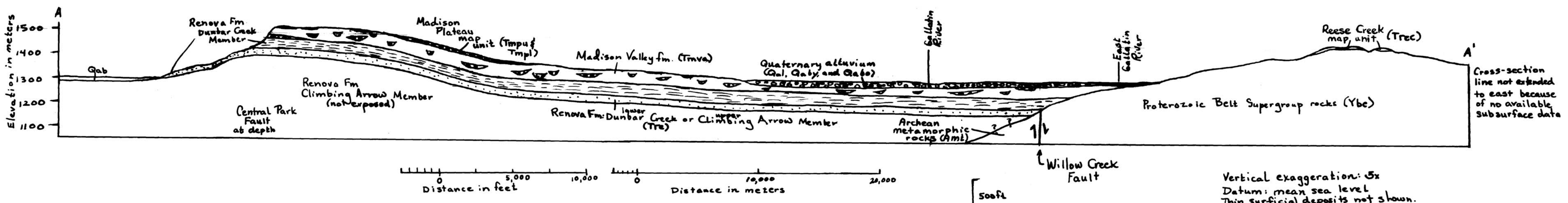
Zim, J.C., and Lageson, R., 1985, Neotectonics and seismicity of the eastern Three Forks Basin, Montana: Geological Society of America, Rocky Mountain Section Abstracts with Programs, v. 17, no. 4, p. 273.

MAP UNITS

Qal	Alluvium of modern channels and flood plains
Qaf	Alluvial fan deposit
Qac	Alluvium-colluvium
Qdf	Debris flow deposit
Qaby	Alluvium of braid plains, younger
Qab	Alluvium of braid plains
Qat	Alluvium of alluvial terrace deposit
Qabo	Alluvium of braid plains, older
QTaf	Alluvial fan deposit
Trec	Reese Creek mapunit, informal
Tmpu	Madison Plateau mapunit, upper, informal
Tmpl	Madison Plateau mapunit, lower, nformal
Tmva	Madison Valley formation, informal
Trd	Dunbar Member of Renova Formation
Tre	Renova Formation, undivided
Mzs	Mesozoic sedimentary rocks, undivided
Pzs	Paleozoic sedimentary rocks, undivided
Ybe	Belt Supergroup, undivided
Amt	Metamorphic rocks, undivided
gp	Gravel pit
⁘	Coarser-grained beds
≋	Anceney map unit
⁂	Seasonal high water-table less than 6 feet

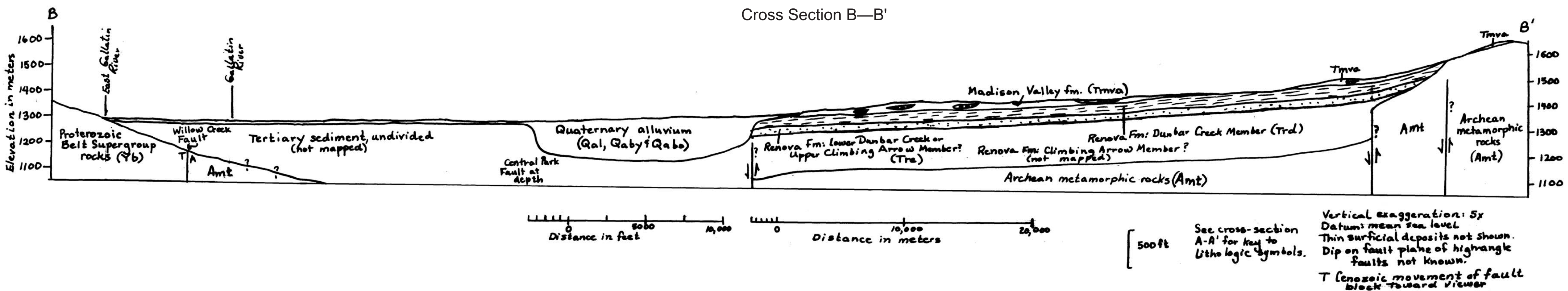


Cross Section A—A'



Vertical exaggeration: 5x
Datum: mean sea level
Thin surficial deposits not shown.
cobbles
lenses of pebble conglomerate
fine-grained, planar bedded
sand stone beds
? not based on subsurface data

Cross Section B—B'



500 ft

See cross-section A-A' for key to litho logic symbols.

Vertical exaggeration: 5x
Datum: mean sea level
Thin surficial deposits not shown.
Dip on fault plane of highangle faults not known.
T Cenozoic movement of fault block toward viewer
A Cenozoic movement of fault block away from viewer
? not based on subsurface data

Maps may be obtained from
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street, Butte, Montana 59701-8997
Phone: (406) 496-4167   Fax: (406) 496-4451
http://www.mbmg.mtech.edu

Montana Bureau of Mines and Geology
Open File No. 481

Geologic Map of Western and Northern Gallatin Valley Southwestern Montana

Susan M. Vuke

2003

Partial support has been provided by the STATEMAP component of the National Cooperative Geologic Mapping Program of the U.S.Geological Survey under Contract Number 02HQAG0038.

GIS production: Ken Sandau and Paul Thale, MBMG. Map layout: Susan Smith, MBMG.

IPaC resource list

This report is an automatically generated list of species and other resources such as critical habitat (collectively referred to as *trust resources*) under the U.S. Fish and Wildlife Service's (USFWS) jurisdiction that are known or expected to be on or near the project area referenced below. The list may also include trust resources that occur outside of the project area, but that could potentially be directly or indirectly affected by activities in the project area. However, determining the likelihood and extent of effects a project may have on trust resources typically requires gathering additional site-specific (e.g., vegetation/species surveys) and project-specific (e.g., magnitude and timing of proposed activities) information.

Below is a summary of the project information you provided and contact information for the USFWS office(s) with jurisdiction in the defined project area. Please read the introduction to each section that follows (Endangered Species, Migratory Birds, USFWS Facilities, and NWI Wetlands) for additional information applicable to the trust resources addressed in that section.

Location

Gallatin County, Montana

Local office

Montana Ecological Services Field Office

☎ (406) 449-5225
📠 (406) 449-5339

585 Shephard Way, Suite 1

585 Shephard Way, Suite 1
Helena, MT 59601-6287

Endangered species

This resource list is for informational purposes only and does not constitute an analysis of project level impacts.

The primary information used to generate this list is the known or expected range of each species. Additional areas of influence (AOI) for species are also considered. An AOI includes areas outside of the species range if the species could be indirectly affected by activities in that area (e.g., placing a dam upstream of a fish population even if that fish does not occur at the dam site, may indirectly impact the species by reducing or eliminating water flow downstream). Because species can move, and site conditions can change, the species on this list are not guaranteed to be found on or near the project area. To fully determine any potential effects to species, additional site-specific and project-specific information is often required.

Section 7 of the Endangered Species Act **requires** Federal agencies to "request of the Secretary information whether any species which is listed or proposed to be listed may be present in the area of such proposed action" for any project that is conducted, permitted, funded, or licensed by any Federal agency. A letter from the local office and a species list which fulfills this requirement can **only** be obtained by requesting an official species list from either the Regulatory Review section in IPaC (see directions below) or from the local field office directly.

For project evaluations that require USFWS concurrence/review, please return to the IPaC website and request an official species list by doing the following:

1. Draw the project location and click CONTINUE.
2. Click DEFINE PROJECT.
3. Log in (if directed to do so).
4. Provide a name and description for your project.
5. Click REQUEST SPECIES LIST.

Listed species[1] and their critical habitats are managed by the Ecological Services Program of the U.S. Fish and Wildlife Service (USFWS) and the fisheries division of the National Oceanic and Atmospheric Administration (NOAA Fisheries[2]).

Species and critical habitats under the sole responsibility of NOAA Fisheries are **not** shown on this list. Please contact NOAA Fisheries for species under their jurisdiction.

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1. Species listed under the Endangered Species Act are threatened or endangered; IPaC also shows species that are candidates, or proposed, for listing. See the listing status page for more information. IPaC only shows species that are regulated by USFWS (see FAQ).

2. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

The following species are potentially affected by activities in this location:

Mammals

NAME	STATUS
Canada Lynx Lynx canadensis There is **final** critical habitat for this species. Your location does not overlap the critical habitat. https://ecos.fws.gov/ecp/species/3652	Threatened
Grizzly Bear Ursus arctos horribilis There is **proposed** critical habitat for this species. https://ecos.fws.gov/ecp/species/7642	Threatened
North American Wolverine Gulo gulo luscus Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/5123	Proposed Threatened

Insects

NAME	STATUS
Monarch Butterfly Danaus plexippus Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/9743	Candidate

Flowering Plants

NAME	STATUS
Ute Ladies'-tresses Spiranthes diluvialis Wherever found No critical habitat has been designated for this species. https://ecos.fws.gov/ecp/species/2159	Threatened

Critical habitats

Potential effects to critical habitat(s) in this location must be analyzed along with the endangered species themselves.

There are no critical habitats at this location.

You are still required to determine if your project(s) may have effects on all above listed species.

Bald & Golden Eagles

Bald and golden eagles are protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act.

Any person or organization who plans or conducts activities that may result in impacts to bald or golden eagles, or their habitats, should follow appropriate regulations and consider implementing appropriate conservation measures, as described below.

Additional information can be found using the following links:

- Eagle Managment https://www.fws.gov/program/eagle-management
- Measures for avoiding and minimizing impacts to birds https://www.fws.gov/library/collections/avoiding-and-minimizing-incidental-take-migratory-birds
- Nationwide conservation measures for birds https://www.fws.gov/sites/default/files/documents/nationwide-standard-conservation-measures.pdf

There are bald and/or golden eagles in your project area.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to migratory birds on your list,click on the PROBABILITY OF PRESENCE SUMMARY at the top of your list to see when these birds are most likely to be present and breeding in your project area.

NAME	BREEDING SEASON

Bald Eagle *Haliaeetus leucocephalus* This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities.	Breeds Jan 1 to Aug 31
Golden Eagle *Aquila chrysaetos* This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities. https://ecos.fws.gov/ecp/species/1680	Breeds Jan 1 to Aug 31

Probability of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds. Please make sure you read and understand the FAQ "Proper Interpretation and Use of Your Migratory Bird Report" before using or attempting to interpret this report.

Probability of Presence (🟩)

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.
3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the

probability of presence score.

To see a bar's probability of presence score, simply hover your mouse cursor over the bar.

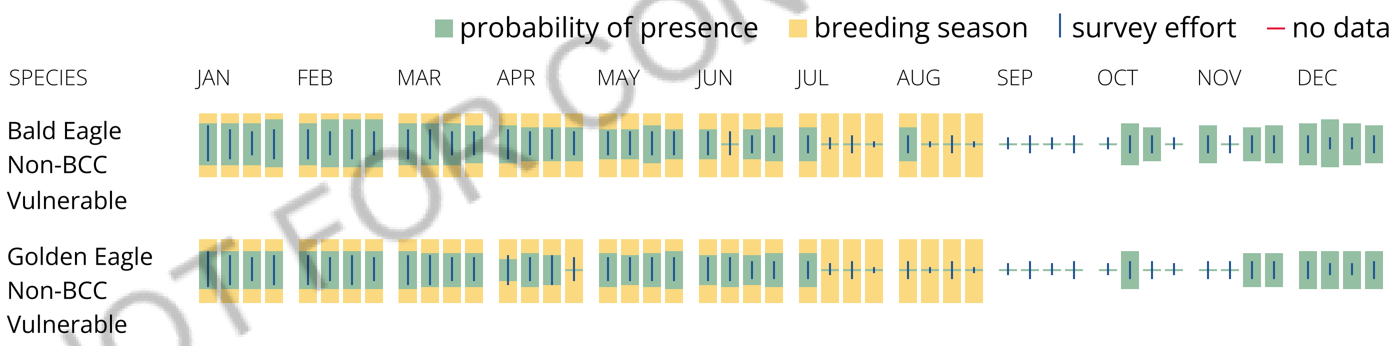
Breeding Season (🟨)
Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort (|)
Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

To see a bar's survey effort range, simply hover your mouse cursor over the bar.

No Data (–)
A week is marked as having no data if there were no survey events for that week.

Survey Timeframe
Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.



What does IPaC use to generate the potential presence of bald and golden eagles in my specified location?

The potential for eagle presence is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply). To see a list of all birds potentially present in your project area, please visit the Rapid Avian Information Locator (RAIL) Tool.

What does IPaC use to generate the probability of presence graphs of bald and golden eagles in my specified location?

The Migratory Bird Resource List is comprised of USFWS Birds of Conservation Concern (BCC) and other species that may warrant special attention in your project location.

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, please visit the Rapid Avian Information Locator (RAIL) Tool.

What if I have eagles on my list?

If your project has the potential to disturb or kill eagles, you may need to obtain a permit to avoid violating the Eagle Act should such impacts occur. Please contact your local Fish and Wildlife Service Field Office if you have questions.

Migratory birds

Certain birds are protected under the Migratory Bird Treaty Act[1] and the Bald and Golden Eagle Protection Act[2].

Any person or organization who plans or conducts activities that may result in impacts to migratory birds, eagles, and their habitats should follow appropriate regulations and consider implementing appropriate conservation measures, as described below.

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1. The Migratory Birds Treaty Act of 1918.
2. The Bald and Golden Eagle Protection Act of 1940.

Additional information can be found using the following links:

- Birds of Conservation Concern https://www.fws.gov/program/migratory-birds/species
- Measures for avoiding and minimizing impacts to birds https://www.fws.gov/library/collections/avoiding-and-minimizing-incidental-take-migratory-birds
- Nationwide conservation measures for birds https://www.fws.gov/sites/default/files/documents/nationwide-standard-conservation-measures.pdf

The birds listed below are birds of particular concern either because they occur on the USFWS Birds of Conservation Concern (BCC) list or warrant special attention in your project location. To learn more about the levels of concern for birds on your list and how this list is generated, see the FAQ below. This is not a list of every bird you may find in this location, nor a guarantee that every bird on this list will be found in your project area. To see exact locations of where birders and the general public have sighted birds in and around your project area, visit the E-bird data mapping tool (Tip: enter your location, desired date range and a species on your list). For projects that occur off the Atlantic Coast, additional maps and models detailing the relative occurrence and abundance of bird species on your list are available. Links to additional information about Atlantic Coast birds, and other important information about your migratory bird list, including how to properly interpret and use your migratory bird report, can be found below.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to migratory birds on your list, click on the PROBABILITY OF PRESENCE SUMMARY at the top of your list to see when these birds are most likely to be present and breeding in your project area.

NAME	BREEDING SEASON
Bald Eagle Haliaeetus leucocephalus This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities.	Breeds Jan 1 to Aug 31
Bobolink Dolichonyx oryzivorus This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds May 20 to Jul 31
Golden Eagle Aquila chrysaetos This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities. https://ecos.fws.gov/ecp/species/1680	Breeds Jan 1 to Aug 31
Lesser Yellowlegs Tringa flavipes This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/9679	Breeds elsewhere
Olive-sided Flycatcher Contopus cooperi This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/3914	Breeds May 20 to Aug 31
Western Grebe aechmophorus occidentalis This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/6743	Breeds Jun 1 to Aug 31

Willet *Tringa semipalmata* Breeds Apr 20 to Aug 5

This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.

Probability of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds. Please make sure you read and understand the FAQ "Proper Interpretation and Use of Your Migratory Bird Report" before using or attempting to interpret this report.

Probability of Presence (🟩)

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.
3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

To see a bar's probability of presence score, simply hover your mouse cursor over the bar.

Breeding Season (🟨)

Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort (|)

Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

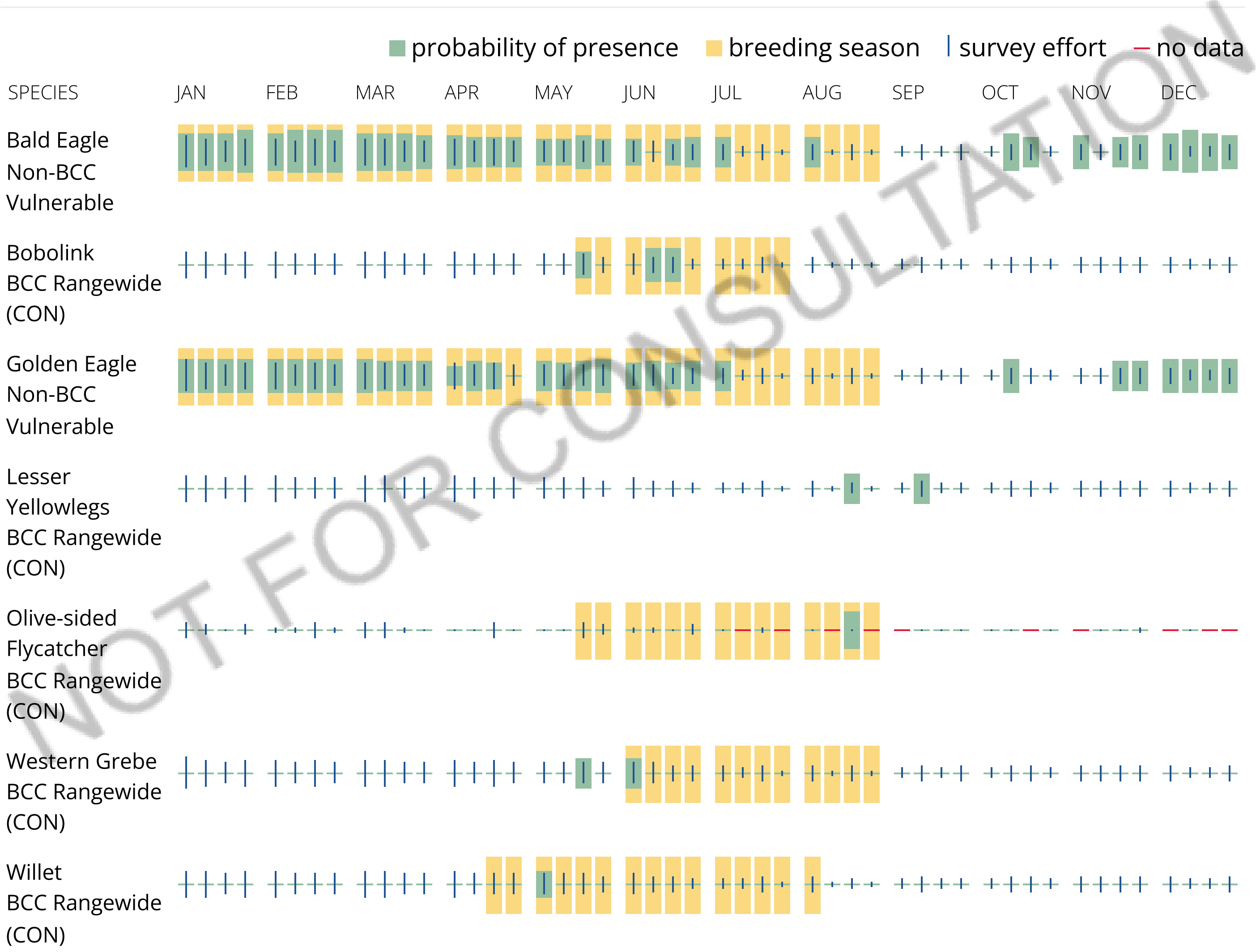
To see a bar's survey effort range, simply hover your mouse cursor over the bar.

No Data (–)

A week is marked as having no data if there were no survey events for that week.

Survey Timeframe

Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.



Tell me more about conservation measures I can implement to avoid or minimize impacts to migratory birds.

Nationwide Conservation Measures describes measures that can help avoid and minimize impacts to all birds at any location year round. Implementation of these measures is particularly important when birds are most likely to occur in the project area. When birds may be breeding in the area, identifying the locations of any active nests and avoiding their destruction is a very helpful impact minimization measure.

To see when birds are most likely to occur and be breeding in your project area, view the Probability of Presence Summary. Additional measures or permits may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

What does IPaC use to generate the list of migratory birds that potentially occur in my specified location?

The Migratory Bird Resource List is comprised of USFWS Birds of Conservation Concern (BCC) and other species that may warrant special attention in your project location.

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, please visit the Rapid Avian Information Locator (RAIL) Tool.

What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?

The probability of presence graphs associated with your migratory bird list are based on data provided by the Avian Knowledge Network (AKN). This data is derived from a growing collection of survey, banding, and citizen science datasets.

Probability of presence data is continuously being updated as new and better information becomes available. To learn more about how the probability of presence graphs are produced and how to interpret them, go the Probability of Presence Summary and then click on the "Tell me about these graphs" link.

How do I know if a bird is breeding, wintering or migrating in my area?

To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating or year-round), you may query your location using the RAIL Tool and look at the range maps provided for birds in your area at the bottom of the profiles provided for each bird in your results. If a bird on your migratory bird species list has a breeding season associated with it, if that bird does occur in your project area, there may be nests present at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

What are the levels of concern for migratory birds?

Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the Eagle Act requirements (for eagles) or (for non-eagles) potential susceptibilities in

offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).

Although it is important to try to avoid and minimize impacts to all birds, efforts should be made, in particular, to avoid and minimize impacts to the birds on this list, especially eagles and BCC species of rangewide concern. For more information on conservation measures you can implement to help avoid and minimize migratory bird impacts and requirements for eagles, please see the FAQs for these topics.

Details about birds that are potentially affected by offshore projects

For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the Northeast Ocean Data Portal. The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the NOAA NCCOS Integrative Statistical Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf project webpage.

Bird tracking data can also provide additional details about occurrence and habitat use throughout the year, including migration. Models relying on survey data may not include this information. For additional information on marine bird tracking data, see the Diving Bird Study and the nanotag studies or contact Caleb Spiegel or Pam Loring.

What if I have eagles on my list?

If your project has the potential to disturb or kill eagles, you may need to obtain a permit to avoid violating the Eagle Act should such impacts occur.

Proper Interpretation and Use of Your Migratory Bird Report

The migratory bird list generated is not a list of all birds in your project area, only a subset of birds of priority concern. To learn more about how your list is generated, and see options for identifying what other birds may be in your project area, please see the FAQ "What does IPaC use to generate the migratory birds potentially occurring in my specified location". Please be aware this report provides the "probability of presence" of birds within the 10 km grid cell(s) that overlap your project; not your exact project footprint. On the graphs provided, please also look carefully at the survey effort (indicated by the black vertical bar) and for the existence of the "no data" indicator (a red horizontal bar). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low survey effort bar or no data bar means a lack of data and, therefore, a lack of certainty about presence of the species. This list is not perfect; it is simply a starting point for identifying what birds of concern have the potential to be in your project area, when they might be there, and if they might be breeding (which means nests might be present). The list helps you know what to look for to confirm presence, and helps guide you in knowing when to implement conservation measures to avoid or minimize potential impacts from your project activities, should presence be confirmed. To learn more about conservation measures, visit the FAQ "Tell me about conservation measures I can implement to avoid or minimize impacts to migratory birds" at the bottom of your migratory bird trust resources page.

Facilities

National Wildlife Refuge lands

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

There are no refuge lands at this location.

Fish hatcheries

There are no fish hatcheries at this location.

Wetlands in the National Wetlands Inventory (NWI)

Impacts to NWI wetlands and other aquatic habitats may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal statutes.

For more information please contact the Regulatory Program of the local U.S. Army Corps of Engineers District.

Please note that the NWI data being shown may be out of date. We are currently working to update our NWI data set. We recommend you verify these results with a site visit to determine the actual extent of wetlands on site.

This location overlaps the following wetlands:

FRESHWATER EMERGENT WETLAND

- PEM1A
- PEM1C
- PEM1Ax
- PEM1Cx

FRESHWATER FORESTED/SHRUB WETLAND

- PSSA

- PSSC

FRESHWATER POND

- PABGx
- PABFx
- PABF
- PABFh
- PUSC

RIVERINE

- R2UBH
- R2UBF
- R2UBG
- R4SBCx
- R4SBC
- R2UBGx

A full description for each wetland code can be found at the National Wetlands Inventory website

NOTE: This initial screening does **not** replace an on-site delineation to determine whether wetlands occur. Additional information on the NWI data is provided below.

Data limitations

The Service's objective of mapping wetlands and deepwater habitats is to produce reconnaissance level information on the location, type and size of these resources. The maps are prepared from the analysis of high altitude imagery. Wetlands are identified based on vegetation, visible hydrology and geography. A margin of error is inherent in the use of imagery; thus, detailed on-the-ground inspection of any particular site may result in revision of the wetland boundaries or classification established through image analysis.

The accuracy of image interpretation depends on the quality of the imagery, the experience of the image analysts, the amount and quality of the collateral data and the amount of ground truth verification work conducted. Metadata should be consulted to determine the date of the source imagery used and any mapping problems.

Wetlands or other mapped features may have changed since the date of the imagery or field work. There may be occasional differences in polygon boundaries or classifications between the information depicted on the map and the actual conditions on site.

Data exclusions

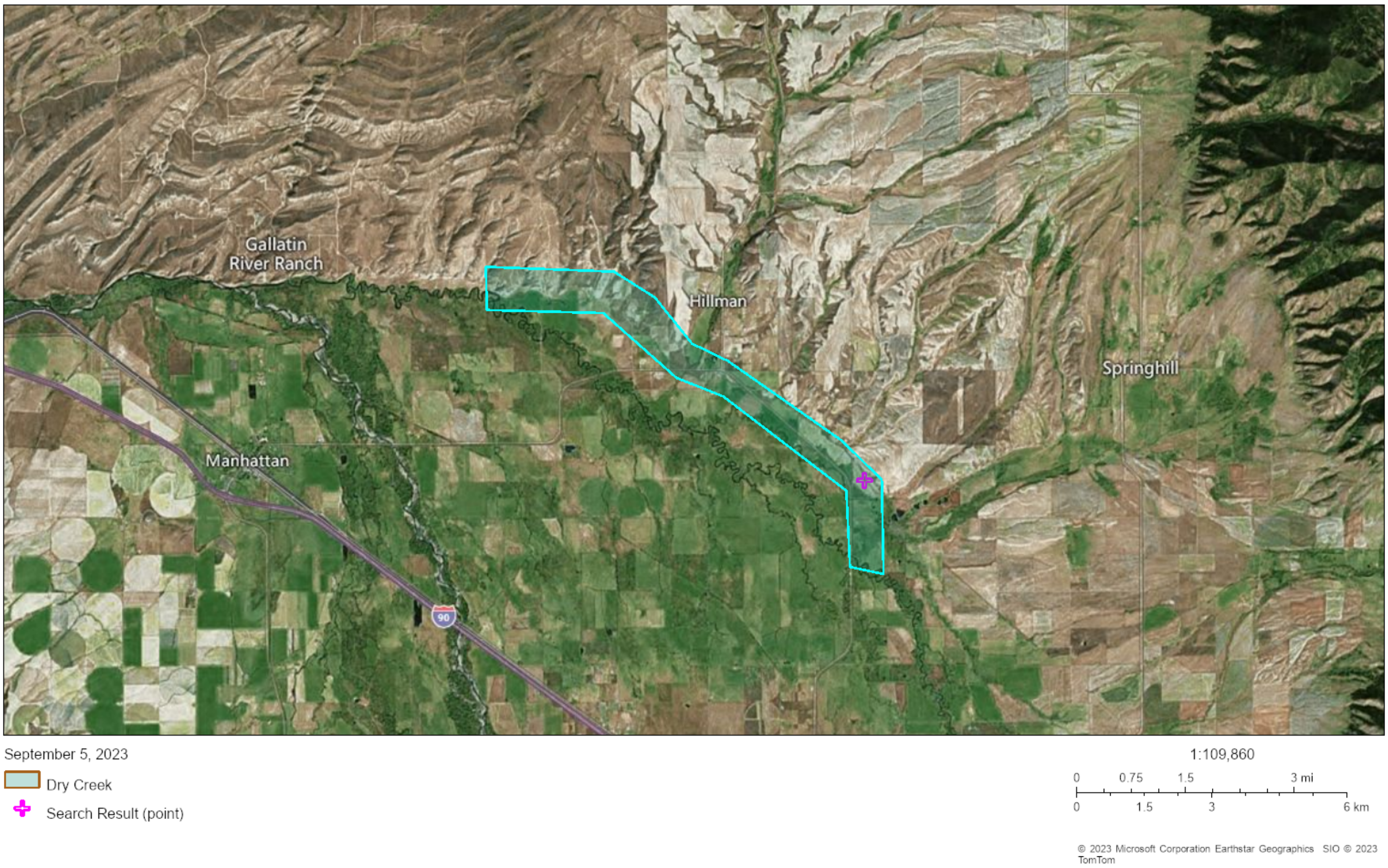
Certain wetland habitats are excluded from the National mapping program because of the limitations of aerial imagery as the primary data source used to detect wetlands. These habitats include seagrasses or submerged aquatic vegetation that are found in the intertidal and subtidal zones of estuaries and nearshore coastal waters. Some deepwater reef communities (coral or tuberficid worm reefs) have also been excluded from the inventory. These habitats, because of their depth, go undetected by aerial imagery.

Data precautions

Federal, state, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any Federal, state, or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate Federal, state, or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.

NEPAssist Report

Dry Creek



September 5, 2023

▨ Dry Creek

✚ Search Result (point)

Input Coordinates: 45.893278,-111.263938,45.895548,-111.264109,45.894592,-111.227374,45.889455,-111.215701,45.880254,-111.205058,45.876788,-111.194758,45.860891,-111.162142,45.853120,-111.150813,45.834345,-111.150298,45.835781,-111.159911,45.850968,-111.160941,45.869736,-111.196131,45.873442,-111.209521,45.886348,-111.230464,45.886946,-111.263766,45.893278,-111.263938	
Project Area	3.79 sq mi
Within an Ozone 8-hr (1997 standard) Non-Attainment/Maintenance Area?	no
Within an Ozone 8-hr (2008 standard) Non-Attainment/Maintenance Area?	no
Within a Lead (2008 standard) Non-Attainment/Maintenance Area?	no
Within a SO2 1-hr (2010 standard) Non-Attainment/Maintenance Area?	no
Within a PM2.5 24hr (2006 standard) Non-Attainment/Maintenance Area?	no
Within a PM2.5 Annual (1997 standard) Non-Attainment/Maintenance Area?	no
Within a PM2.5 Annual (2012 standard) Non-Attainment/Maintenance Area?	no
Within a PM10 (1987 standard) Non-Attainment/Maintenance Area?	no
Within a Federal Land?	no
Within an impaired stream?	yes
Within an impaired waterbody?	no
Within a waterbody?	yes
Within a stream?	yes
Within an NWI wetland?	Available Online
Within a Brownfields site?	no
Within a Superfund site?	no
Within a Toxic Release Inventory (TRI) site?	no

Within a water discharger (NPDES)?	yes
Within a hazardous waste (RCRA) facility?	no
Within an air emission facility?	no
Within a school?	no
Within an airport?	no
Within a hospital?	no
Within a designated sole source aquifer?	no
Within a historic property on the National Register of Historic Places?	no
Within a Toxic Substances Control Act (TSCA) site?	no
Within a Land Cession Boundary?	yes
Within a tribal area (lower 48 states)?	no
Within the service area of a mitigation or conservation bank?	yes
Within the service area of an In-Lieu-Fee Program?	yes
Within a Public Property Boundary of the Formerly Used Defense Sites?	no
Within a Munitions Response Site?	no
Within an Essential Fish Habitat (EFH)?	no
Within a Habitat Area of Particular Concern (HAPC)?	no
Within an EFH Area Protected from Fishing (EFHA)?	no
Within a Bureau of Land Management Area of Critical Environmental Concern?	no
Within an ESA-designated Critical Habitat Area per U.S. Fish & Wildlife Service?	no
Within an ESA-designated Critical Habitat river, stream or water feature per U.S. Fish & Wildlife Service?	no

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GEOLOGIC MAP OF THE BOZEMAN 30' x 60' QUADRANGLE
SOUTHWESTERN MONTANA

Montana Bureau of Mines and Geology Open-File Report 648

2014

Compiled and mapped by

Susan M. Vuke[1], Jeffrey D. Lonn[1], Richard B. Berg[1] and Christopher J. Schmidt[2]

[1]Montana Bureau of Mines and Geology, [2]Western Michigan University

Partial support has been provided by the STATEMAP component of the National Cooperative Geologic Mapping Program of the U.S. Geological Survey under Contract Number G09AC00186

GEOLOGIC SOURCE MAPS AND INDEX OF 7.5′ QUADRANGLES
BOZEMAN 30′ x 60′ QUADRANGLE

112° 111º

46°

Doherty Mtn 1, 5, 14, 15, 22, 23, 25, 30, 32, 40, 46, 48, 50, 51, 53, 55	Negro Hollow 10, 23, 25, 32, 36, 46, 50	Milligan Canyon 33, 46, 54	Three Forks 29, 37, 46	Logan 34, 37, 39, 43, 45, 55	Nixon Gulch 9, 12, 34, 39, 43, 45	Horseshoe Creek 9, 18, 43, 45	Flathead Pass 9, 18, 26, 45
Jefferson Island 35, 46, 53, 54	Sappington 35, 46, 44	Willow Creek 35, 46, 44, 48	Three Forks SE 4, 33, 46	Manhattan SW 12, 37, 45	Manhattan 9, 12, 18, 37, 45	Belgrade 9, 12, 18, 24, 45	Miser Creek 3, 9, 12, 18, 24, 26, 45
Pony 13, 31, 35, 38, 44, 46	Harrison 6, 17, 35, 44, 46	Willow Creek Reservoir 8, 21, 46, 48	Norris NE 8, 21, 45	Madison Plateau 12, 24, 37, 41, 45, 48, 52	Anceney 2, 9, 12, 24, 28, 45	Bozeman Hot Springs 9, 12, 24 28, 45	Bozeman 9, 11, 12, 24
Potosi Peak 13, 16, 38, 44, 54	Maltbys Mound 7, 16, 27, 38, 44, 55	Norris 8, 20, 48	Bear Trap Creek 2, 8, 20	Cherry Creek Canyon 2, 9, 28, 41	Ruby Mountain 2, 9, 24, 28, 41	Gallatin Gateway 2, 9, 24, 42, 48, 52	Wheeler Mountain 3, 9, 11, 24, 42, 47, 48, 52

45°30′

Numbers above correspond with reference list on next page.

GEOLOGIC MAP SOURCES
BOZEMAN 30′ x 60′ QUADRANGLE

Numbers below correspond with index of map sources on previous page.

Published, thesis, and dissertation maps

1. Alexander, R.G., Jr., 1951, pl. 1, scale 1:25,344.
2. Clabaugh, S.E., and Armstrong, F.C., 1950, pl. 11, scale 1:125,000.
3. Custer, S.G., 1995a, figs. 7-9.
4. Davis, W.E., Kinoshita, W.T., and Robinson, G.D., 1965.
5. Dixon, R.M., and Wolfgram, Diane, 1998, scale 1:24,000.
6. Elliott, W.S., 1998a, scale 1:24,000.
7. Elliott, W.S., 1998b, scale 1:24,000.
8. Feichtinger, S.H., 1970, pl. 1, scale 1:24,000.
9. Fix, P.F., 1940, pl. 21, scale 1:126,720.
10. Glaman, L.R.B., 1991, pl. 1, scale 1:12,000.
11. Glancy, P.A., 1964, pl. 1, scale 1:24,000.
12. Hackett, O.M., Visher, F.N., McMurtrey, R.G., and Steinhilber, W.L., 1960, pl. 2, scale 1:63,360.
13. Hall, R.D., and Heiney, J.S., 1983, fig. 2.
14. Harlan, S.S., and others, 2008b, fig. 2.
15. Hendrix, T.E., and Stellavato, N., 1976, fig. 10–1, scale 1:62,500.
16. Hess, D.F., 1967, pl. 3, scale 1:24,000.
17. Hoh, A.M., 1997.
18. Hughes, G.C., 1981, pl. 1, scale 1:63,000.
19. Kellogg, K.S., 1994, scale 1:24,000.
20. Kellogg, K.S., 1995, scale 1:24,000.
21. Kellogg, K.S., and Vuke, S.M., 1996, scale 1:24,000.
22. Kuenzi, W.D., 1966, scale 1:24,000.
23. Lofgren, D.L., 1985, pl. 1, scale 1:24,000.
24. Lonn, J.D., and English, A.R., 2002, scale 1:48,000.
25. Ludman, Alan, 1965, pl. 1, scale 1:6,000.
26. McMannis, W.J., 1955, pls. 1 and 2, scale 1:48,000.
27. Meyers, S.A., 1991, pl. 2, scale 1:6,000.
28. Mifflin, M.D., 1963, scale 1:31,680.
29. Mitchell, M.M., 1987, pl. 1, scale 1:24,000.
30. Moore, G.T., 1954, pl. 1, scale 1:6,000.
31. O’Neill, J.M., 1983, pl. 1, scale 1:50,000.
32. Richard, B.H., 1966, pls. 1-4, scale 1:24,000; pl. 5, scale 1:60,000; fig. 10, scale 1:31,680.
33. Robinson, G.D., 1963, pl. 1, scale 1:48,000.
34. Sayers, F.E., 1962, pl. 8, scale 1:33,000.
35. Schmidt, C.J., 1975, pl. 1, scale 1:24,000.
36. Schmidt, C.J., and O’Neill, J.M., 1982, fig. 17, scale 1:168,960.
37. Schneider, G.B., 1970, pl. 1, scale 1:24,000.
38. Smith, J.L., 1970, pl. 1, scale 1:48,000.
39. Spahn, R.A., Jr., 1967, pl. 1, scale 1:24,000.
40. Streeter, M.E., 1983, scale 1:24,000.
41. Tilley, C.W., 1976, pl. 1, scale 1:24,000.
42. Tysdal, R.G., 1966, pl. 1, scale 1:31,680.
43. Verrall, Peter, 1955, pl. 1, scale 1:24,000.
44. Vitaliano, C.J., and Cordua, W.S., 1979, scale 1:62,500.
45. Vuke, S.M., 2003, pl. 1, scale 1:50,000.
46. Vuke, S.M., 2006, pl. 1, scale 1:50,000.
47. Weber, W.M., 1965, pl. 1, scale 1:28,800.

Unpublished maps, excluding thesis and dissertation maps

48. Berg, R.B., Montana Bureau of Mines and Geology.
49. Cox, Bruce, Earthworks, Inc., for Golden Sunlight Mines, Inc.
50. Dresser, Hugh, Butte, MT, *A stereo picture guide to some of Montana’s thrust faults* (1996).
51. Hanneman, D., Whitehall GeoGroup, Inc., for Golden Sunlight Mines, Inc.
52. Lonn, J.D., Montana Bureau of Mines and Geology.
53. Nilsen, Tor, for Golden Sunlight Mines, Inc.
54. Schmidt, C.J., Western Michigan University
55. Vuke, S.M., Montana Bureau of Mines and Geology

Entire quadrangle

Vuke, S.M., Berg, R.B., Lonn, J.D., and Kellogg, K.S., 2002, scale 1:100,000.

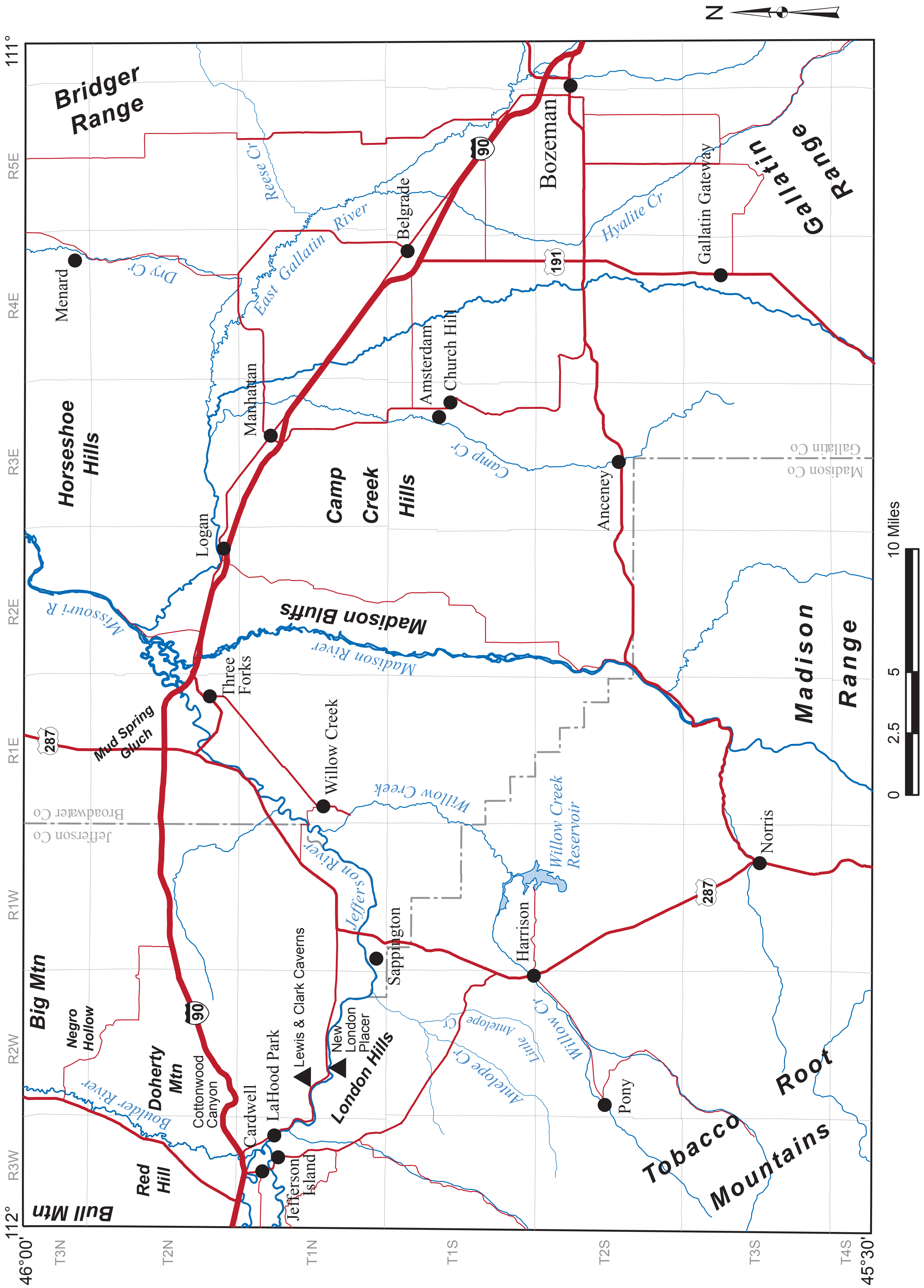

Figure 1. Location map for Bozeman 30' x 60' quadrangle.

DESCRIPTION OF MAP UNITS
BOZEMAN 30′ x 60′ QUADRANGLE

Qal **Alluvium (Holocene)**—Light gray to light brown gravel, sand, silt, and clay deposited in stream and river channels, on their floodplains, and on low terraces as much as about 6 m (20 ft) above modern streams and rivers. Moderately sorted to well sorted. Larger clasts subangular to well rounded. Composition varies, but includes clasts of Archean metamorphic rocks, Precambrian orthoquartzite, Paleozoic limestone and quartzite, vein quartz, and volcanic rocks. Clasts of some small streams originating in Tertiary uplands are dominantly granule size and smaller, and may include rip-up clasts.

River alluvium:

Gallatin and East Gallatin Rivers: Rounded to well-rounded small boulders, cobbles, gravel, sand, silt, and clay, dominantly composed of Archean metamorphic rocks, and dark-colored volcanic rocks, with subordinate Paleozoic limestone, and Precambrian Belt rocks.

Madison River: Subrounded to rounded, gravel and sand with clasts rarely larger than cobble size (Robinson, 1963) dominantly composed of Archean metamorphic rocks, dark-colored igneous rocks, Paleozoic limestone, quartz, and chert.

Tributaries of Gallatin and East Gallatin River: Clast composition varies. Clasts of tributaries from the Tertiary of the Camp Creek Hills are derived primarily from the pebbles and cobbles of Tertiary fluvial deposits. Dry Creek and its tributaries contain clasts derived from the Maudlow Basin, Horseshoe Hills, Bridger Range, and local Tertiary and older Quaternary deposits. Estimated thickness of Holocene alluvium of Gallatin River is 15-25 m (50-80 ft) based on thicknesses in well logs where Qal rests directly on bedrock.

Jefferson River: Dominantly subrounded to rounded and fairly well sorted with clasts rarely larger than cobble size. Thickness probably less than 15 m (50 ft) in most areas.

Qc **Colluvium (Holocene)**—Unstratified, unconsolidated, poorly sorted, angular to subangular clasts derived from local sources. Thickness unknown, but maximum thickness is probably less than 10 m (33 ft).

Qls **Landslide deposit (Holocene)**—Unstratified, unsorted mixtures of sediment that moved downslope through mass wasting processes. Includes rotated or slumped blocks of bedrock and surficial sediment, earthflow deposits, and mudflow deposits. Color and lithology and grain size reflect that of parent rock and transported surficial material. Thickness probably less than 30 m (100 ft).

Qpa **Paludal deposit (Holocene)**—Sand, silt, and organic matter deposited in swamp, pond, or small lake environment. Thickness probably less than 10 m (33 ft).

Qdf **Debris-flow deposit (Holocene)**—Angular, subangular and subrounded clasts of poorly sorted, locally derived boulders and cobbles in a matrix of fine-grained sediment. Thickness probably about 15 m (50 ft) in thickest part.

Qe **Eolian deposit (Holocene and Pleistocene)**—Yellowish gray to very pale orange, silt and clay-size sediment with scattered grains and thin lenses of rounded fine-grained sand. Dominantly volcanic glass, quartz, and clay minerals with minor amounts of mica, feldspar, and calcite, also silt, and clay. Thinly mantles many more areas than shown on map. Thickness highly variable. Locally as much as 30 m (100 ft), but generally 1 m (3 ft) or less.

Qac **Alluvium and colluvium, undivided (Holocene and Pleistocene)**—Locally derived sediment on slopes. Color reflects that of parent material. Ranges from clay and silt to gravel, depending on source. Thickness generally less than 6 m (20 ft).

Qgr **Gravel deposit (Holocene and Pleistocene)**—Variable deposits of gravel, sand, silt, and clay that include alluvium, pediment veneer, colluvium, outwash, and fan deposits. Clast composition, rounding, and sorting vary depending on deposit location and type. The most extensive deposits are in the Gallatin Valley and include dissected blankets of sub-rounded to rounded pebbles, cobbles, small boulders, and rare large boulders. Composition is dominantly orthoquartzite, vein quartz, quartz-rich gneiss, and dark volcanic rocks. North of the Jefferson River, most gravel deposits are fan and alluvial deposits that overlie pediment surfaces. Clast composition reflects local sources and clasts range from angular to rounded depending on the type of deposit. Near the headwaters of the Missouri River, some of the deposits on pediment surfaces consist dominantly of angular limestone clasts. Thickness ranges from pediment veneer about 2.5 cm (1 inch) thick to valley fill as much as 120 m (400 ft) thick.

Qaf **Alluvial fan deposit (Holocene and Pleistocene)**—Deposit with preserved fan morphology at break in slope, composed of a heterogeneous mixture of subangular to moderately rounded coarse clasts as large as boulders, and fine-grained sediment (sand, silt, and clay) that is generally concentrated near fan margins. Clasts derived from adjacent uplands. Estimated thickness is about 30 m (100 ft) at thickest part.

Qab **Alluvium of braid plain (Holocene and/or Pleistocene)**—Rounded to well-rounded, dominantly cobble gravel with clasts as large as boulders, and sand, silt, and clay; mostly composed of Archean metamorphic rock fragments, and dark-colored volcanic rocks, with subordinate Paleozoic limestone and Proterozoic Belt rocks. Clast lithologies in general order of decreasing abundance include Precambrian metamorphic rocks, mafic volcanic rocks, dacite(?) porphyry, quartzite, sandstone, limestone, and chert. Two wells in this unit adjacent to the Gallatin River indicate thicknesses of Quaternary alluvium overlying Tertiary deposits of 9.5 m (31 ft) and 65 m (215 ft) (Hackett and others, 1960).

Qat **Alluvial terrace deposit (Holocene and/or Pleistocene)—**Subrounded and rounded pebbles, cobbles, and sand with some thin beds of clayey silt. Underlies distinct terraces adjacent to and at elevations higher than modern streams. Clast lithologies variable, but may include Precambrian metamorphic rock, igneous rock, quartzite, and sandstone. Thickness about 6 m (20 ft).

Qafh **Hyalite Alluvial Fan (Pleistocene)**—Deposit with distinct fan morphology composed of light gray to light brown gravel, sand, silt, and clay deposited where Hyalite Creek crosses an abrupt change in slope gradient (where the fault-bounded northern Gallatin Range meets the Bozeman Valley) extending for about 11 km (7 mi) into the valley. Distribution of clast sizes varies. In general, coarse-grained sediment is dominant near the head of the fan and fine-grained sediment near the margins. Clasts are dominantly matrix supported and poorly sorted, although sediment deposited in distributary channels is moderately to well sorted and clast supported. Large clasts subrounded to rounded. May be as much as 60 m (200 ft) thick.

Qafo **Alluvial-fan deposit, older than Qaf (Pleistocene)**—Light brown, gray, and locally reddish gray, angular and subangular, locally derived gravel in a coarse sand and granule matrix. Clast size ranges from pebble to small boulder. Fan morphology dissected. Maximum thickness probably about 45 m (150 ft).

Qabo **Braid plain alluvium, older than Qab (Pleistocene)**—Rounded to well-rounded, dominantly cobble gravel with clasts as large as boulders, and sand, silt, and clay; mostly composed of clasts of Archean metamorphic rock, and dark-colored volcanic rock, with subordinate Paleozoic limestone and Proterozoic Belt rocks. Clast lithologies in general order of decreasing abundance include Precambrian metamorphic rocks, mafic volcanic rocks, dacite(?) porphyry, quartzite, sandstone, limestone, and chert. A well in this unit indicates a thickness of 9 m (30 ft) of alluvium overlying Tertiary deposits.

Qalo **Alluvium, older than Qal (Pleistocene)**—Subrounded to rounded, fairly well sorted gravel with relatively few clasts larger than cobble size, and sand. Deposit covered by organic material, silt, and mud in some areas. Late Pleistocene bison and Holocene animal bones have been found in these deposits near Three Forks (Robinson, 1963). Thickness probably no more than 15 m (50 ft) in the Three Forks area (Robinson, 1963).

Qlso **Landslide deposit, older than Qls (Pleistocene)**—Unstratified, unsorted mixtures of yellowish brown Tertiary sediment that moved downslope through mass wasting processes north and east of Bozeman. Offsets from landslide displacement apparent in roadcut exposures. Thickness probably less than 30 m (100 ft).

Qep **Eolian and pediment deposits, undivided (Pleistocene)**—Yellowish gray, fine-grained tuffaceous sand and silt overlying pediment veneer of coarser sediment. Thickness generally less than 1 m (3 ft).

Qm **Mantle (Pleistocene)**—Regolith and lag deposits with clasts as large as boulders derived from underlying Tertiary deposits and from Quaternary debris-flow deposits, subordinate water-transported deposits, and colluvium.

Qp **Pediment deposit (Pleistocene)**—Sediment veneer that ranges from angular to rounded, dominantly pebble size or smaller clasts, to gravel on pediment surface.

Qg **Glacial deposits, undivided (Pleistocene)**—Poorly sorted, angular to rounded, unconsolidated clasts of dominantly cobbles and boulders, but also pebbles, sand, silt, and clay. Large clasts are of dominantly Archean metamorphic rocks, and igneous rocks of the Tobacco Root Batholith. Includes unstratified till and stratified outwash, and thin cirque lake deposits that probably include some Holocene sediment. Thickness of deposits less than 45 m (150 ft).

Qgk **Glacial kame deposit (Pleistocene)**—Moderately well sorted and stratified deposit in Tobacco Root Mountains associated with other glacial features.

Qgt **Glacial till (Pleistocene)**—Unconsolidated, poorly sorted, angular to rounded clasts of dominantly cobbles and boulders, but also pebbles, sand, silt, and clay. Large clasts dominantly composed of Archean metamorphic rocks, and igneous rocks of the Tobacco Root Batholith. Includes some stratified outwash. Thickness less than 45 m (150 ft).

Qgo **Glacial outwash deposit (Pleistocene)**—Moderately to well sorted, subrounded to well rounded gravel immediately downslope from glacial till (Qgt deposits).

Qrg **Rock glacier deposit (Pleistocene)**—Angular rock debris cemented by interstitial ice.

QTaf **Alluvial fan deposit (Pleistocene and/or Pliocene)**—Deposit similar to Qaf, but underlies Qaf, and is separated from it by a pediment surface. Thickness as much as 35 m (115 ft).

QTafy **Alluvial fan deposit, younger than QTafo (Pleistocene and/or Pliocene)**—Overlies QTafo in Negro Hollow area. Light gray unconsolidated, angular to subangular, and subordinate subrounded gravel. Clasts are almost exclusively locally derived from Paleozoic limestone but also include locally derived chert and Quadrant Formation. Thickness probably less than 30 m (100 ft).

QTafo **Alluvial fan deposit, older than QTafy (Pleistocene and/or Pliocene)**—Underlies QTafy in Negro Hollow area. Light gray unconsolidated, angular to subangular, and subordinate subrounded gravel, and well cemented breccia, especially at the base. Basal breccia matrix is reddish brown in most places and patches of reddish brown matrix also occur locally, higher in the unit. Clasts are almost exclusively locally derived Paleozoic limestone but also include locally derived chert and Quadrant Formation. Includes slightly bentonitic, pinkish gray and very light gray, tuffaceous sandstone west of the southern part of Big Mountain. Thickness probably less than 30 m (100 ft).

QTat **Alluvial terrace deposit (Pleistocene and/or Pliocene)**—Angular clasts of Elkhorn Mountains Volcanics associated with a pebble gravel in a very limited linear distribution on the tops of low hills along a tributary of Spring Gulch in the northwestern part of the map. A Miocene Barstovian fossil was found in this unit (Robinson, 1963). Thickness about 1 m (4 ft).

QTep **Eolian, paleosol, and pediment deposits (Pleistocene and/or Pliocene)**—Dark brown, clayey silt and fine-grained eolian sand with sparsely distributed, matrix-supported pebbles and some cobbles that alternates with weakly developed paleosols. Pediment surface on deposit veneered with pebble-size and smaller clasts transported by sheetwash. Thickness probably less than 15 m (50 ft).

QTge **Gravel and eolian deposits, undivided (Pleistocene and/or Pliocene)**—Deposits in Jefferson Canyon with two distinct components – a gravel with mostly boulders, overlain by fine-grained sediment of probable eolian origin. At the New London placer, near Lewis and Clark Caverns, clast composition includes Archean metamorphic, Belt Supergroup quartzite, subangular and subrounded clasts of LaHood Formation conglomerate, individual quartzite clasts recycled from the LaHood Formation conglomerate, and Paleozoic limestone.

QTdf **Debris-flow deposit (Pleistocene and/or Pliocene)**—Angular, subangular, and subrounded clasts of poorly sorted, locally derived boulders and cobbles in a matrix of fine-grained sediment.

QTgr **Gravel deposits (Pleistocene and/or Pliocene, and patchy remnants of Miocene)**—Near Willow Creek, gravel consists of angular to rounded matrix-supported cobbles, most of which are white quartz, schist, and amphibolite. Some of the clasts have caliche rinds. Matrix is sand and silt. An immature, matrix-supported breccia with angular to subangular granules, pebbles, and cobbles of Archean metamorphic rocks is below the gravel and included in the map unit. Combined thickness of both deposits is 6-12 m (20-40 ft). The deposit in the Tobacco Root Mountains contains matrix-supported, well-rounded pebbles, cobbles, and boulders up to 9 m (30 ft) thick in a sandy matrix. Clast composition includes Archean metamorphic rocks, granodiorite of the Tobacco Root Batholith, and well-cemented sandstone. Deposits west of Gallatin Gateway have the same clast composition as pebbles and cobbles in the underlying Tertiary rocks, and may be local deposits related to faulting. In addition, several fossils indicate that there are patchy remnants of Miocene deposits (Robinson, 1963) that are included in this map unit west of the Madison River. Thickness about 9 m (30 ft).

Tertiary deposits of unknown age

Ts Sediment or sedimentary rocks, undivided (Tertiary)

Trs Rhyolite sediment (Tertiary)—Very light gray to white, well-bedded, well-indurated siltite, sandstone, and clast-supported sedimentary breccia composed almost entirely of rhyolite vitrophyre; clasts are angular and as much as 0.9 m (3 ft) long. Interlayered and locally intermixed with abundant white air-fall ash. Exposed thickness about 30 m (100 ft).

Trb Red Bluff Formation (Tertiary) (Kellogg, 1994):

Upper: White and light yellowish brown siltstone, sandstone, conglomerate, and subordinate, but conspicuous, brick red and maroon mudstone and siltstone; locally tuffaceous. Most clasts are Archean gneiss, and vein or pegmatite quartz, with some quartz monzonite and granodiorite from Tobacco Root Batholith. Locally, highly silicified.

Lower: Subrounded to well-rounded, matrix supported, bouldery diamictite. Clast composition dominantly quartz monzonite or granodiorite of the Tobacco Root Batholith, with matrix of immature decomposed quartz monzonite or granodiorite. Boulders are very large, some as much as 15 m (50 ft) wide. Type locality is within quadrangle in W½ sec. 13, T. 3 N ., R. 1 W.

Sixmile Creek Formation (younger than Hemingfordian unconformity)

Tscr Reese Creek member (Miocene: Clarendonian and Hemphillian)—Basal cobble or small boulder clast-supported conglomerate or gravel cemented by calcium carbonate, or unconsolidated with clasts coated by calcium carbonate overlain by orangish tan tuffaceous mudstone with lenses of fine-grained sandstone. Fine-grained upper part of unit best exposed near the mouth of Reese Creek. In most other areas, the poorly resistant, fine-grained part is poorly exposed. A vitric ash was sampled from near the mouth of Reese Creek that provided a K/Ar date of 8.9±0.4 Ma (youngest Clarendonian or oldest Hemphillian). The ash has an abrupt basal contact and climbing ripples at the top, and is 0.9-1.5 m (3-5 ft) thick (Hughes, 1980). The contact between this map unit and the underlying Madison Valley member is an angular unconformity in the northern Gallatin Valley.

Tsccb Clarkston Basin member (Miocene)—Brownish gray and brownish yellow breccia or unconsolidated deposit with clast-supported or matrix-supported, fine to coarse, angular clasts of dominantly Greyson, Newland, and Spokane Formation, and Paleozoic quartzite and limestone. Paleozoic clasts are as large as boulder size. Coarse- and fine-grained beds may alternate. Cementation may be variable producing irregular surfaces.

Tscmp **Madison Plateau member (Miocene: Clarendonian or Hemphillian)**—Sheet deposit of moderately well-sorted and well-rounded clast-supported cobble conglomerate or gravel; color reflects maroon, gray, and brown calcium-carbonate-coated cobbles of dominantly Belt quartzite duraclasts. Archean metamorphic clasts are found only at the base as pebble size or smaller. The clasts were likely reworked from underlying Madison Valley member pebble conglomerates that contain Archean clasts. May correlate with clast-supported cobble conglomerate in Reese Creek area at base of Reese Creek member, from which an ash bed yielded a K/Ar date of 8.9 ±0.4 Ma (Hughes, 1980; Lange and others, 1980). If so, the Madison Plateau member is likely youngest Clarendonian or oldest Hemphillian. West of the Madison River, unit appears to rest conformably on the Madison Valley member, but unconformably on the Dunbar Creek Member (Dunbar Creek Formation of Robinson, 1963) (Vuke and others, 2002). East of the Madison River, unit appears to rest conformably on the Madison Valley member and was involved in northeastward tilting and folding of underlying units with apparent conformity. Alternatively, unit may be younger than, and rest disconformably on the underlying Madison Valley member. Regardless, unit was deposited prior to northeastward tilting and folding of Tertiary strata. Thickness 6-10 m (20-30 ft).

Tsccc **Cottonwood Canyon member (Miocene)**—Brown conglomerate or gravel dominantly of rounded cobbles of Elkhorn Mountains Volcanics and Belt Supergroup quartzite, although almost exclusively derived from Elkhorn Mountains Volcanics west of the Boulder River. Conglomerate/gravel clasts include pebbles and small boulders in matrix of granules and coarse sand. Clasts are commonly stained with iron oxide. Conglomerate and gravel are in sheets and lenses interbedded with subordinate light gray, coarse-grained sandstone with conglomeratic stringers and floating granules, greenish brown or reddish brown, slightly bentonitic mudstone, tan siltstone, and micaceous, silty mudstone. Other than immediately west of the Negro Hollow uplift and east of Bull Mountain, unit contains abundant to occasional subrounded boulders of granitic rock with weathering rinds as much as ¼-inch thick. At one location south of the Negro Hollow uplift, extremely large boulders of granitic rock and Elkhorn Mountains Volcanics are present. Near Cottonwood Canyon this unit was called Ballard gravel by Aram (1979).

Near Cottonwood Canyon there appear to be two levels of deposits, both mapped as Cottonwood Canyon member. The upper deposit overlies a syncline in Cambrian units. It contains more clasts of intrusive rocks than the lower deposit, but similar to the lower deposit, does not contain Archean clasts. In the Cottonwood Canyon area, unit rests on LaHood Formation and Paleozoic rocks but does not contain clasts of either.

Barstovian fossils were found in the finer grained component of the unit between the Boulder River and the Negro Hollow uplift (Lofgren, 1985). Maximum exposed thickness as much as 100 m (330 ft).

Tsch **Harrison member (Miocene and/or Pliocene?)**—Grayish brown matrix-supported conglomerate or gravel with subrounded, texturally poorly sorted and disorganized clasts, ranging from pebbles to large boulders in iron oxide-stained matrix of granule and smaller size clasts. Clast composition dominantly Archean metamorphic rocks (mostly gneiss and schist) with subordinate quartzite, granitic rock including pegmatite, and Paleozoic limestone. Locally well-cemented, but generally unconsolidated. Linear distribution of unit extends along Antelope and Little Antelope Creeks to Sappington. Appears cut into older Tertiary units and in places rests on Archean and Paleozoic rocks. Linear geometry and presence of granitic boulders are similar to the Red Bluff Formation near Norris, Montana, about ten miles to the southeast (Kellogg, 1994 and 1995). Maximum thickness as much as 60 m (200 ft).

Tscmv Madison Valley member (Miocene: Clarendonian and Barstovian)

Madison Bluffs, Madison Plateau, and Camp Creek Hills area. Pinkish tan or tan, tuffaceous silt or siltstone and marl interbedded with crossbedded, texturally immature, coarse-grained sandstone that contains lenses of pebble conglomerate or local cobble conglomerate ranging from matrix- to clast-supported, and from cemented to unconsolidated. Conglomerate clasts are dominantly Archean gneiss and extrusive volcanic rocks, with subordinate Belt rocks, and occasional Paleozoic limestone clasts. Sandstone has large root casts locally, and marl beds are typically full of small root casts. Several vitric ash beds are present throughout the unit. Opalized wood fragments are abundant in many conglomerate lenses. Conglomerate also contains relatively abundant disarticulated bones, bone fragments, and occasional teeth. Numerous articulated Barstovian fossils have been collected and studied from the fine-grained parts of this unit (Tabrum and Nichols, 2001; Douglass, 1899, 1901, 1903, 1907a, 1907b, 1908, 1909a, 1909b; Frick, 1937; Dorr, 1956; Sutton, 1977; Sutton and Korth, 1995; Evander, 1996), including the Anceney beds of Dorr (1956).

The contact between this unit and the underlying Dunbar Creek Member of the Renova Formation is sharp and locally appears unconformable as noted by Hackett and others (1960). In the northernmost part of the Madison Bluffs, the contact appears to be an angular unconformity. A relatively resistant bed at the base of the Madison Valley formation cuts down to nearly the level of the Climbing Arrow Member. In the southernmost part of the Madison Bluffs, calcic paleosols occur at the contact between the Madison Valley member and the underlying Dunbar Creek Member of the Renova Formation. Thickness 60 m (200 ft) throughout most of the Madison Bluffs area, but thickens to 90 m (300 ft) in the southern bluffs.

Dry Creek area. Grayish orange, crossbedded sandstone and pebble conglomerate interbedded with brownish orange tuffaceous siltstone and marl. Sandstone beds contain large lenses of dominantly pebble conglomerate with occasional cobble-size clasts or local cobble conglomerate. Conglomerates vary from matrix supported to clast supported. Unlike the clast composition in the Madison Bluffs and Camp Creek Hills areas, the clasts in the Menard area are dominantly Paleozoic limestone and Mesozoic sandstone, with subordinate andesitic volcanic rock and minor metamorphic rocks. Hughes (1980) interpreted the volcanic rock source as the Maudlow Basin where Livingston Group rocks are exposed. Near the Bridger Range, the clasts are dominantly Proterozoic LaHood Formation arkose, Paleozoic limestone, and quartz. Thickness near Menard about 30 m (100 ft). It is not known if the Madison Valley member thickens dramatically to the east, or if it has been down-faulted from the Bridger Range to Dry Creek. It is at a much higher elevation close to the Bridger Range than at Dry Creek.

Some of the coarse-grained beds of the Madison Valley member are shown on the map with a dotted pattern. In general, these are medium to coarse grained, fairly laterally persistent sandstone beds with numerous lenses of conglomerate and conglomeratic sandstone. Hughes (1981) describes these conglomeratic sandstones as “blanket-like” deposits in the Dry Creek area.

In local areas south of Manhattan and in the southeastern part of the map area, some of the conglomerate lenses contain dominantly cobble- rather than the more typical pebble-size clasts of other areas. These cobble conglomerates serve as caprocks with overlying fine-grained sediment stripped away. The cobble conglomerates have been interpreted as alluvial terrace deposits (Hackett and others, 1960) and pediment gravels (Mifflin, 1963), but were traced into the Madison Valley member in several places. They are shown as coarse-grained beds of the Madison Valley member. Gravel pits are numerous in the coarse-grained beds of the Madison Valley member.

Tscpb **Parrot Bench member (Middle Miocene: Barstovian)**—Brown conglomerate and gravel dominantly of subrounded to rounded cobbles of Elkhorn Mountains Volcanics and Belt Supergroup quartzite. Conglomerate/gravel clasts range from pebbles to small boulders in matrix of granules and coarse sand. Clasts are commonly stained with iron oxide. Resembles Cottonwood Canyon member which is also Barstovian, but has been included as part of the Parrot Bench map unit to the west (Vuke and others, 2004). Middle to Late Miocene Barstovian and Hemphillian fossils have been found in the Parrot Bench member immediately to the west of the map area on Parrot Bench (Kuenzi, 1966), but only the lower, probably Barstovian, part of the member is exposed in the map area.

Renova Formation (older than Hemingfordian unconformity)

Trnh **Negro Hollow member (Early Miocene**: **Arikareean)**—(Description modified from Lofgren, 1985). Dominantly poorly sorted, unconsolidated to moderately well cemented matrix-supported pebble conglomerate with granitic clasts dominant, and subordinate clasts of Elkhorn Mountains Volcanics, in a tuffaceous silt matrix. Conglomerate locally crossbedded. Lenses of clast-supported conglomerate generally at top of beds. Matrix-supported conglomerate grades laterally into, or is interbedded with, tabular beds of thinly laminated vitric silt and ash. Late Arikareean age determined from fossils (Lofgren, 1985). East of North Boulder River tuffaceous silt is dominant, and conglomerate is subordinate. Thickness about 275 m (900 ft).

Trdc **Dunbar Creek Member (Eocene and Oligocene: Arikareean, Whitneyan, Orellan, and Chadronian)**—The type section for the Dunbar Creek is within quadrangle in E½ sec. 7, T. 1 S., R. 2 E. (Robinson, 1963). Name derived from Dunbar Creek, a now obsolete name for a tributary of Mud Creek in the Three Forks area north of I-90.

Madison Bluffs and Camp Creek Hills. White to very light gray and light tan, tuffaceous planar-bedded siltstone and fine-grained sandstone with numerous tiny root casts, glassy ash beds, light gray tuffaceous limestone beds, and an interval of white diatomite beds near the top that extends the length of the Madison Bluffs. Distinguished from Madison Valley member by color, diatomite marker beds, and lack of significant conglomerate lenses. An $^{40}Ar/^{39}Ar$ date from the Dunbar Creek Formation in the Madison Bluffs on a single crystal feldspar yielded a range of 15-23 Ma with a weighted mean ~21.5 Ma, making it likely Arikareean North American Land Mammal age (upper Oligocene or lower Miocene). Hackett and others (1960) correlated the Dunbar Creek Member (their unit 1) in the Madison Bluffs and Camp Creek Hills with deposits near Menard in the Dry Creek area. Ostracode, gastropod, and fish fossils have been reported from the Dunbar Creek Formation in the Madison Bluffs (Blake, 1959; Dorr, 1956; Schneider, 1970). Thickness of unit about 45m (150 ft) in central Madison Bluffs, but may be thicker in the southern part of the Madison Bluffs where it is obscured by slope alluvium and colluvium. In the northernmost bluffs, it thins abruptly to about (15 m) 50 ft.

Calcic paleosols as described by Hanneman and others (1994) occur near road level in the area of Madison Buffalo Jump State Park (D. Hanneman, oral communication, 2002). They also occur where this unit is exposed in the northernmost and southernmost parts of the bluffs. Maximum exposed thickness about 45 m (150 ft).

Dry Creek area. White to very light gray and light tan, tuffaceous siltstone, fine-grained sandstone and mudstone, tuffaceous marl and limestone, and ash. Ostracode and gastropod fossils have been reported from this unit in the Dry Creek area (Hughes, 1980; Hackett and others, 1960; Verrall, 1955), and Klemme (1949) reported mammal fragments in this unit in the Dry Creek area. An ash in the Dry Creek area yielded a K/Ar date of 30.6±1.2 Ma (Whitneyan, Oligocene) (Hughes, 1980; Lange and others, 1980).

Willow Creek Reservoir area. Interbedded white, light gray, and light tan, very fine grained locally vuggy limestone and sandy limestone, white to light brown, tuffaceous, micaceous, calcareous siltstone and sandstone, and massive white ash. Contains silicified stems 1 cm in diameter with visible internal structure, and tubular root casts. Exposed thickness about 60 m (200 ft). Called Norwegian Creek beds by Feichtinger (1970).

Three Forks area. Very light gray to grayish yellow, thick-bedded, tuffaceous silt and siltstone with subordinate sand, sandstone, conglomerate, and rare bentonitic clay and very light gray limestone. North of the Jefferson River, unit includes many tongues of poorly sorted, poorly rounded carbonate-rich gravel not present south of the Jefferson River. The tuffaceous rocks and sediment are dominantly composed of fine volcanic ash. An Arikareean fossil, *Diceratherium armatum* Marsh, was found in a sandstone bed four miles south of Three Forks (Wood, 1933) in the lower Dunbar Creek Member. Also, an Arikareean beaver was described from the bluffs on the west side of the Madison River "about nine or ten miles south of Three Forks" (Douglass, 1901) in the Dunbar Creek Member. North of the Jefferson River the Dunbar Creek Member contains Chadronian (Eocene) fossils (Tabrum and others, 2001). North of the Jefferson River the contact between the Climbing Arrow and Dunbar Creek Members is conformable, and south of the Jefferson River, the contact is disconformable. Thickness as much as 90 m (300 ft) in the southeastern part of the map area.

Trca **Climbing Arrow Member (Eocene: Uintan, Duchesnean, Chadronian)**—Pale olive, light olive brown, and reddish brown, bentonitic, sandy clay and claystone that displays "popcorn" weathering; yellowish gray, coarse-grained, argillaceous sand and sandstone; and white, tuffaceous siltstone and fine-grained sandstone composed almost entirely of volcanic glass. Throughout, coarse sand grains are typically subangular to subrounded, and composed of quartz, feldspar, and biotite. A K/Ar date of 50.4±1 (Eocene) was obtained from an ash in the NE¼ NE¼ NE¼ sec. 11, T. 2 N., R.1 W. (Lange and others, 1980). Type section is within quadrangle in W½ sec. 12, T. 1 N., R. 1 E. (Robinson, 1963). Thickness not less than 230 m (750 ft), but may be considerably more than 300 m (1,000 ft) (Robinson, 1963).

Trmc **Milligan Creek Member (Eocene)**—(Robinson, 1963): Light gray, fine-grained, tuffaceous, argillaceous limestone, marlstone, and calcareous mudstone units that interfinger with sandstone and conglomerate with rounded to subrounded clasts that are dominantly quartz and volcanic rock. Type section is within quadrangle in E½ sec. 11, NW¼ sec. 12, and SW¼ sec. 1, T. 1 N., R. 1 W.

Trrh **Red Hill member (Eocene: early Chadronian)**—Dominantly moderate red, reddish orange, and reddish brown kaolinitic mudstone with thin beds and lenses of pale olive gray or moderate red, very coarse grained, immature sandstone with clasts that include limestone, shiny black chert, clear and rose quartz, and red mudstone rip-up clasts; granule, pebble, and conglomerate lenses of similar composition in red mudstone matrix; and limestone breccia with red mudstone matrix, and red immature granitic sandstone. Unit typically weathers to red soil. Several vertebrate fossils found in member on Bull Mountain are early Chadronian (A. Tabrum, personal communication *in* Rothfuss, 2007). Member present on southern Bull Mountain and southern Doherty Mountain, and in Milligan Canyon and possibly Timber Canyon. Includes Sphinx conglomerate of Robinson (1963). Deposited in alluvial fan environments proximal to basin-margin uplifts (Rothfuss, 2007). Thickness variable; locally more than 90 m (300 ft) thick (Robinson, 1963).

Igneous rock

Tan **Andesite (Eocene)**—Medium gray, dominantly andesite porphyry, but also includes porphyritic latite, and latite porphyry. Many small phenocrysts of feldspar and mafic minerals are only slightly larger than the groundmass (Robinson, 1963). Exposed thickness as much as 110 m (360 ft).

Trvi **Rhyolite, vitrophyre (Eocene)**—White, pink, and gray, flow-banded, sparsely porphyritic rhyolite of dominantly brown cloudy glass and subordinate sanidine with sparse phenocrysts of altered biotite. Extensively brecciated near margin. Exposed thickness 260 m (850 ft).

Tav **Absaroka Volcanics (Eocene)**—Light brown-weathering, dark gray to black, basic, slightly porphyritic andesite with plagioclase, augite, and hypersthene phenocrysts in individual flows interlayered with stratified flow breccias. Exposed thickness 260 m (850 ft).

Tba **Basalt (Eocene?)**—(Robinson, 1963): Black, very dark gray, and grayish brown, fine-grained, intergranular basalt and basalt breccia flows along Cherry Creek fault. Commonly vesicular or flow banded. Vesicles in many places encrusted by yellow, fine-grained zeolite. Exposed thickness as much as 200 m (650 ft). Olivine basalt near Three Forks mostly compact but vesicular in some places. Homogeneous flow bands and minor flow breccia.

TKa **Andesite (Eocene or Late Cretaceous)**—(Dixon and Wolfgram, 1998): Porphyritic basaltic andesite on Bull Mountain, blocky to massive, 40-50 percent plagioclase phenocrysts that average 5 mm to 1 cm (0.2-2 in.) within a deep red to gray matrix. Silicified and argillic along contact with Mission Canyon Formation.

TKl **Latite (Eocene or Late Cretaceous)—***Three Forks area* (Robinson, 1963): Medium gray to medium dark gray latite that weathers to steely purplish tones similar to the Elkhorn Mountains Volcanics. Latite has sparse and small phenocrysts of feldspar and pyroxene in a dense, nonvesicular holocrystalline matrix.

TKda **Dacite (Eocene or Upper Cretaceous)**—(Robinson, 1963): Medium light gray, with local yellowish brown or yellowish green splotches from oxidation of iron-bearing minerals; uniformly fine-grained. Dominantly dacite, but includes some quartz latite. Exposed thickness as much as 75 m (250 ft).

TKfi	**Felsic intrusive rocks, undivided (Eocene or Late Cretaceous)**—*Red Mountain area* (Kellogg, 1995): Gray, pinkish gray, and purple porphyritic rhyolite or dacite with an aphanitic, cherty matrix. Plagioclase phenocrysts as long as 8 mm, but typically 3 mm. In most places flow banded. A columnar-jointed sill as thick as 25 m (82 ft) intruded the contact or lower part of the Flathead Formation southeast of Red Mountain.
TKjb	**Jasperoid breccia (Eocene or Upper Cretaceous)**—Yellow, tan, and reddish brown, banded jasperoid that is almost entirely brecciated, and consists of angular clasts as much as 0.5 m (1.5 ft) thick. Exposed thickness as much as 75 m (250 ft).
Ki	**Intrusive rocks, undivided**
Kem	**Elkhorn Mountains Volcanics (Late Cretaceous)**—Dominantly dark gray, grayish black, greenish black, light gray, and very dusky reddish purple andesite porphyry, tuff, conglomerate, breccia, and minor flows; and subordinate basalt. Andesite porphyry displays variable texture and resistance. Conglomerates contain clasts that are rounded and as much as 50 cm (20 inches) wide in a coarse-grained sand matrix. Rests unconformably on units as old as the Lodgepole Limestone. As much as 2,750 m (9,000 ft) thick (Alexander, 1955).
Kan	**Andesite (Late Cretaceous)**—Rocks with variable generally andesitic composition.
Kdia	**Diabase (Late Cretaceous)**—*Horseshoe Hills* (Sayers, 1962): Highly altered, porphyritic augite diabase.
Kg	**Granite (Late Cretaceous)**—*Tobacco Root Batholith* (Smith, 1970): Equigranular and fine- to medium-grained. Generally finer grained than other batholith rock types. Potassium feldspar megacrysts generally rare and relatively small, but occasionally as large as 3.0 cm. Plagioclase generally in euhedral crystals; quartz and potassium feldspars almost invariably anhedral. Potassium feldspars are poikilitic and include all other mineral types. Biotite, magnetite, apatite, sphene, and zircon accessory minerals.
Kgd	**Granodiorite (Late Cretaceous)**—*Tobacco Root Batholith* (Smith, 1970): Dominantly fine-grained and equigranular to subordinate coarse-grained porphyries. Hornblende and biotite are visible megascopically. Potassium feldspar phenocrysts are typically smaller and less numerous than hornblende and biotite phenocrysts.
Khd	**Hornblende diorite (Late Cretaceous)**—*Tobacco Root Batholith* (Smith, 1970): Hypidiomorphic granular to panidiomorphic fine- to medium-grained; 12-28% hornblende, 3-8%, quartz with accessory minerals biotite, pyroxene, sphene, magnetite, zircon, apatite, allanite, and rutile. (Kellogg, 1994): Dark gray, fine- to coarse-grained, equigranular to inequigranular, well indurated hornblende diorite and hornblende monzodiorite.
Khto	**Hornblende tonolite (Late Cretaceous)**—*Tobacco Root Batholith* (Smith, 1970): Medium-grained and equigranular to porphyritic tonolite with 5-13% hornblende. Elongated ferromagnesian minerals emphasize flow structures. Potassium feldspars are poikilitic and quartz occurs as intergrowths with these and plagioclase. Granitoid texture is common and subhedral-euhedral crystals are completely interlocking. Quartz is interstitial and feldspars are zoned.

Kto **Tonalite (Late Cretaceous)**—*Tobacco Root Batholith* (Smith, 1970): Medium-grained and equigranular to porphyritic with pink potassium feldspar megacrysts in about 1/3 of the exposures. Platy elongated ferromagnesian minerals emphasize flow structures. Potassium feldspars are poikilitic and quartz occurs as intergrowths with ferromagnesian minerals and plagioclase. Granitoid texture is common and subhedral-euhedral crystals are completely interlocking. Quartz is interstitial and feldspars are zoned.

Kqm **Quartz monzonite or monzogranite (Late Cretaceous)**—*10N Pluton* (Robinson, 1963): Pink, pale grayish brown or moderate brown weathering, dominantly quartz monzonite and monzogranite, but also includes monzonite porphyry, diorite porphyry, and quartz latite porphyry. Strongly lineated. Exposed thickness 75 m (250 ft). *Tobacco Root Batholith* (Smith, 1970): Medium-grained (1.2-2.0 mm) ranging from equigranular to coarse porphyritic with 5 cm (2 in.) long potassium feldspar megacrysts. Most quartz monzonite at least slightly porphyritic.

Ksk **Skarn (Late Cretaceous**)—Contact metamorphosed Paleozoic carbonate rocks adjacent to the 10N Pluton north of Three Forks. Includes isolated, small igneous intrusive bodies (Michael Garverich, oral communication, 2012).

Kmod **Monzonite and diorite (Late Cretaceous)**—(Robinson, 1963): Porphyritic monzonitic and dioritic rocks of the 10N Pluton north of Three Forks

Kse **Sedan Formation (Upper Cretaceous)**—(Skipp and others, 1999):

Mudstone member: Greenish gray and brownish gray volcaniclastic mudstone, siltstone, sandstone, and minor interbedded conglomerate and altered vitric tuff.

Middle sandstone member: Olive green and dark greenish gray, volcaniclastic sandstone, conglomerate, mudflow conglomerate, and minor siltstone and mudstone.

Ash-flow tuff member: Pale yellowish green, light greenish gray, grayish red, and pale yellowish brown, welded to non-welded tuff and ash-flow tuff conglomerate, interbedded with volcaniclastic conglomerate, sandstone, mudstone, and porcellanite.

Lower sandstone member: Dark olive gray, greenish gray, and yellowish gray, volcaniclastic sandstone, siltstone, mudstone, altered crystal vitric tuff, minor hornblende dacite, and minor lignitic coal.

Equivalent to Miner Creek and Cokedale Formations of the Livingston Group (Berg and others, 2000).

Thickness of formation in map area about 915 m (3,000 ft).

Ket **Eagle and Telegraph Creek Formations, undivided**

Eagle Sandstone—Grayish orange to light olive gray, arkosic, cross-bedded fine- to medium-grained thin-bedded sandstone interbedded with siltstone. Contains carbonaceous siltstone, carbonaceous shale, and thin coal beds at base and top. Thickness about 75 m (250 ft).

Telegraph Creek Formation—Light olive gray to pale yellowish brown, thin-bedded to massive, very fine grained calcareous, arkosic sandstone and siltstone, interbedded with silty mudstone. Thickness about 75 m (250 ft).

Kcot **Cody through Thermopolis formations, undivided**

Kcof **Cody Shale and Frontier Formation, undivided (Upper Cretaceous)**

Cody Shale—Dark gray to brown mudstone interbedded with siltstone and very fine grained sandstone. Greenish gray, thin-bedded, glauconitic, fine-grained sandstone in middle of formation. Thickness about 150 m (500 ft).

Frontier Formation—Light brownish gray, fine- to coarse-grained thick-bedded to massive sandstone with subordinate siltstone. Dark gray to black, thin, chert-pebble conglomerate in some localities generally at bases of thick sandstone beds (Dyman and others, 1996; McMannis, 1952). Thickness about 170 m (550 ft).

Kbl **Blackleaf Formation (Upper and Lower Cretaceous)**—*Jefferson Canyon area* (McLane, 1971).

Upper: Gray, soft, ripple-marked, lithic sandstone and dark gray shale with marine fossils.

Basal: Brownish gray, very fine grained, crossbedded, resistant, quartz sandstone with quartz overgrowths. Exposed thickness of formation in Jefferson Canyon less than 30 m (100 ft).

Kmdt **Muddy Sandstone and Thermopolis Shale, undivided**

Muddy Sandstone: Interbedded micaceous, planar bedded or crossbedded sandstone and subordinate dark gray to black, fissile shale or mudstone.

Thermopolis Shale

Upper: Medium gray, fissile, micaceous, clayey shale with a few thin interbeds of siltstone (Dyman and others, 1996).

Basal: Yellowish gray- to pale olive-weathering, light gray, fine- to medium-grained sandstone with quartz overgrowths, crossbedded or ripple marked, clean, well-sorted quartz sandstone that may have interspersed limonite specks. Unconformably overlain by Elkhorn Mountains Volcanics in western part of map area. Thickness about 90-105 m (300-350 ft).

Kt **Thermopolis Formation (Lower Cretaceous)**

Upper: Dark gray to black, fissile shale to mudstone, that contains thin interbeds of micaceous, planar- or cross-bedded, lithic sandstone.

Middle: Medium gray, fissile, micaceous, clayey shale with a few thin interbeds of siltstone (Dyman and others, 1996).

Basal: Yellowish gray- to pale olive-weathering, light gray, fine- to medium-grained sandstone with quartz overgrowths, crossbedded or ripple marked, clean, well-sorted quartz sandstone that may have interspersed limonite specks. Unconformably overlain by Elkhorn Mountains Volcanics in western part of map. Thickness about 90-105 m (300-350 ft).

Kk **Kootenai Formation**

Upper: Light gray gastropod coquina or gastropod-rich limestone that may also contain charophyte and ostracode fossils. The gastropod limestone is not present in the Bridger Range (McMannis, 1952).

Middle: Variegated shale and mudstone, dominated by red, orange, and purple with subordinate light and medium gray colors, interbedded with light gray “salt-and-pepper” limonitic or non-limonitic, fine- to coarse-grained, poorly to well-sorted, massive or crossbedded, chert-rich, locally conglomeratic sandstone.

Basal: Light brown to yellowish gray “salt-and-pepper” conglomeratic, cross-bedded, chert-rich sandstone or conglomerate. Thickness about 120 m (400 ft).

Jme **Morrison Formation and Ellis Group, undivided**

Jm **Morrison Formation (Jurassic)**—Green, red, and gray variegated mudstone, shale, and siltstone with thin, interbedded yellowish brown to grayish orange, very fine grained sandstone and siltstone beds, and thin, gray limestone beds. Carbonaceous shale or coal at the top in some areas of the northern part of the quadrangle. Thickness about 105 m (350 ft).

Je **Ellis Group (Jurassic)**

Jsw **Swift Formation**—Grayish orange, calcareous, limonitic or glauconitic, crossbedded, coarse-grained, fossiliferous, quartz sandstone. Thickness about 20 m (65 ft).

Rierdon Limestone—Light gray, oölitic, fossiliferous limestone, and calcareous shale. Quartz and chert sand grains are interspersed throughout some of the limestone beds. Locally, quartz and chert clasts are granule or small pebble size. Thickness about 15 m (50 ft).

Sawtooth Formation

Upper: Yellowish brown, fossiliferous mudstone; thin-bedded fossiliferous carbonaceous siltstone and dolomite; and light gray, thin-bedded, fossiliferous limestone.

Lower: Gray to dark brown conglomeratic quartz and chert sandstone of variable thickness, with subangular to subrounded chert and light gray limestone pebbles. Formation not present in western part of map. Thickness 0-25 m (0-80 ft).

T̄Rd **Dinwoody Formation (Triassic)**—Reddish brown to dark brown, fossiliferous, silty limestone with abundant *Lingula* brachiopods. Thickness 30-40 m (100-130 ft) (Elliott, 1998a).

PIPMps **Phosphoria, Quadrant, and Snowcrest Range Group, undivided (Permian, Pennsylvanian, and Mississippian)**

PIPpq **Phosphoria and Quadrant Formations, undivided (Permian and Pennsylvanian)**

Pp **Phosphoria Formation (Permian)**—Brown, to greenish brown, laminated or thin- to thick-bedded chert, yellow to yellowish orange sandstone and siltstone, greenish gray, medium- to coarse-grained, oölitic, phosphatic sandstone, and yellowish gray, dolomitic limestone. May also include conglomerate with well-rounded chert pebbles or cobbles. Thickness ranges from 30-60 m (100-200 ft).

IPq **Quadrant Formation (Pennsylvanian**)—Light gray, pinkish gray, and yellowish gray, medium- to thick-bedded, medium- to fine-grained, well-sorted, quartz sandstone with rounded clasts; cemented by quartz overgrowths. Very light gray, medium to thick dolomite beds may be present in the lowermost and uppermost parts, interbedded with quartz sandstone. Thickness variable, ranging from 15 m (50 ft) (McMannis, 1952) to 150 m (500 ft) (Robinson, 1963).

IPMsr **Snowcrest Range Group, undivided (Pennsylvanian and Mississippian)**

Conover Ranch Formation (Pennsylvanian and Mississippian)—Red, blackish red, and pale red, irregularly bedded calcareous mudstone, siltstone, and sandstone, and gray dolomitic limestone. Not present locally in Three Forks area. Thickness 0-25 m (0-80 ft).

Lombard Limestone (Mississippian)—Dark gray, reddish gray, or black, fossiliferous shale, shaly limestone, and cherty limestone. Yellowish brown, silty, laminated to flaggy, finely crystalline limestone with interbeds of yellowish brown, highly calcareous siltstone, and thin interlaminae of dark gray chert. Thickness 0-130 m (0-425 ft).

Kibbey Formation (Mississippian)—Thin-bedded to massive, calcareous red, pink, and pale yellowish orange orthoquartzite, yellowish brown, silty, laminated to flaggy, finely crystalline limestone with interbeds of yellowish brown, highly calcareous siltstone, and thin interlaminae of dark gray chert. Medium gray to yellowish orange fissile to hackly shale. Lower part has numerous thin interbeds of medium to dark gray, impure, calcareous, hard, quartzitic sandstone with grayish orange shale beneath each bed. Thickness 0-38 m (125 ft).

Mm **Madison Group, undivided (Mississippian)**

Mmc **Mission Canyon Limestone (Mississippian)**—Gray, microcrystalline, thick-bedded, locally fossiliferous limestone with abundant gray, black, olive black, and pale yellowish brown lentil-shaped or elongate chert nodules. Solution breccia and paleo-karst features are apparent in some areas. Variable thickness ranging from 115 m (375 ft) in the Gallatin Range (Tysdal, 1966) to 130 m (430 ft) in the Bridger Range (McMannis, 1952) to 460 m (1,510 ft) in the Three Forks area (Robinson, 1963).

Ml **Lodgepole Limestone (Mississippian)**—Dark gray, thin-bedded, microcrystalline limestone, with yellowish brown and grayish orange thin partings and interbeds of calcareous mudstone. Basal Cottonwood Canyon Member black shale present in northwestern part of map area. Thickness ranges from 60-260 m (200-855 ft).

MDt **Three Forks Formation (Mississippian and Devonian)**—Sappington Member: Yellowish orange and yellowish gray thin- to thick-bedded, flaggy siltstone and fine-grained sandstone. May contain U-shaped trace fossils. Type section is in map area near Logan (Holland, 1952), and type locality is in the map area in Milligan Canyon near Sappington (Berry, 1943). Thickness 15-30 m (50-100 ft) (Sandberg, 1965).

Trident Member: Greenish gray, light olive gray, and yellowish gray calcareous to slightly calcareous fossiliferous clay shale with yellowish gray, dark yellowish orange, and medium gray dolomitic limestone, silty dolomite, and calcitic dolomite at the base. Massive bed of fossiliferous argillaceous limestone at the top. Type section is in map area about five miles northwest of Logan (Sandberg, 1965).

Logan Gulch Member: Yellowish gray and grayish red, argillaceous limestone or shale breccia that may be partly interbedded with dolomitic shale, dolomitic siltstone, and silty dolomite; yellowish gray, thin-bedded, contorted limestone; and red mudstone. Type section (Sandberg, 1962) is in the map area within the Three Forks type section (Sloss and Laird, 1947) north of the Gallatin River at Logan. Thickness ranges from 25-45 m (80-150 ft).

DꞒjms **Jefferson, Maywood, and Snowy Range Formations, undivided**

Dj **Jefferson Formation (Devonian)**—Birdbear Member: Light brownish gray to medium gray, very finely crystalline to microcrystalline, sucrosic, partly pseudo-brecciated dolomite. Type section of member (Sandberg, 1965) is in map area within the type section of the Jefferson Formation (Sloss and Laird, 1947) on the north side of the Gallatin River near Logan. Thickness about 25 m (80 ft).

Lower member: Dark yellowish brown, brownish gray, medium dark gray, and light olive gray, finely crystalline, fetid dolomite, and calcitic dolomite. Thickness ranges from 145 to 200 m (475-655 ft).

DꞒmr **Maywood and Red Lion Formations, undivided**

Maywood Formation (Devonian)—Grayish red, thin- to medium-bedded, aphanitic to very finely crystalline, dense to friable and shaly dolomite. Locally contains a bright pale yellow sucrosic limestone bed in the upper part. Grayish red to yellowish orange calcareous siltstone at base in some places. Not present in the northern Gallatin Range (Tysdal, 1966). Thickness as much as 27 m (90 ft).

Red Lion Formation (Cambrian) (Western part of map area only, lateral equivalent of Snowy Range Formation)—Light pinkish gray, greenish gray, and light gray, sucrosic dolomite; grayish orange dolomite with silicified wavy shale partings; local flat pebble dolomite conglomerate. Thickness as much as 18 m (60 ft) in western part of map area.

D€msr **Maywood and Snowy Range Formations, undivided**

€sr **Snowy Range Formation (Cambrian)** (Eastern part of map area only, lateral equivalent of Red Lion Formation)—Sage Pebble Conglomerate Member: Medium light gray to light olive gray, thin- to medium-bedded, flat-pebble limestone conglomerate with subangular to subrounded clasts; and very finely crystalline to aphanitic, dense limestone with minor interbeds and interlaminae of greenish to red fissile shale and subordinate light grayish red, irregular-bedded or laminated siltstone, banded or mottled with yellowish orange. In the Bridger Range there is a persistent 1.22-7.62 m (4-25 ft) biostromal columnar limestone composed of calcareous fossil algae at the base of the member (McMannis, 1952). In the Horseshoe Hills, the biostromal columnar limestone is at the base up to the middle of the member, but is missing east of Nixon Gulch and northeast of Trident (Verrall, 1955). Thickness as much as 62 m (204 ft) in the Bridger Range (McMannis, 1952). Flat-pebble conglomerate is not present in the Gallatin Range, but a limestone member is present in the stratigraphic position of the Sage Pebble Conglomerate Member that also has a biostromal columnar limestone at its base (Tysdal, 1966).
Dry Creek Member: Light olive gray, grayish green, or bluish gray, fissile shale with interbedded pale orange to yellowish brown, calcareous, fine-grained sandstone and siltstone beds that commonly have scour bases. Thickness is irregular, ranging from 2-23 m (6-76 ft) (Tysdal, 1966; McMannis, 1952) in eastern part of map area.

€pi **Pilgrim Limestone (Cambrian)**—Light gray or bluish gray limestone or dolomite, typically with yellowish orange mottles. May be sandy or sucrosic; may contain intraformational flat-pebble conglomerate, or lenses of dark gray limestone or dolomite that are glauconitic, oölitic, and/or fossiliferous; weathers hackly. Thickness ranges from 60 m (200 ft) (eastern part of map area) to as much as 137 m (450 ft) (western part of map area).

€pm **Park and Meagher Formations, undivided**

€p **Park Shale (Cambrian)**—Grayish green and pale purple, fissile shale and silty shale. May contain a thin limestone bed or limestone flat-pebble conglomerate at the top, and thin interbeds of grayish red purple, coarsely crystalline, ferruginous limestone. Thickness ranges from 12-106 m (40-350 ft).

€m **Meagher Limestone (Cambrian)**—Light gray or bluish gray limestone, dolomite, or dolomitic limestone, with yellowish orange or moderate orange pink mottles; weathers hackly. Dominantly thick-bedded, but thin-bedded in part with siltstone partings. In the eastern part of the map area, may contain interbeds of greenish gray, micaceous, fissile shale. May contain oölitic beds with some oncolites and intraformational conglomerate. Thickness ranges from 90-167 m (300-550 ft).

Ꞓw **Wolsey Shale (Cambrian)**—Dominantly grayish green, but also grayish purple and grayish red purple, micaceous, fissile, wavy-bedded shale with trace fossils on many bedding surfaces. In western part of map area includes a greenish brown, carbonaceous, silty limestone in middle of unit. May be interbedded with thin quartzite beds at base. May contain trilobite casts and molds. In some areas plutonic rocks take the place of the Wolsey Shale (Robinson, 1963). Thickness ranges from 12 m (40 ft) in the Gallatin Range (Tysdal, 1966) to as much as 120 m (400 ft) (western part of map).

Ꞓf **Flathead Formation (Cambrian)**—Very light gray, pinkish gray, or light brownish gray quartzose sandstone or orthoquartzite and well-cemented granule to pebble conglomerate. May be massive or crossbedded and contain subordinate grayish green, grayish purple or grayish red purple, micaceous, fissile shale beds. In some areas in the central part of the map area, the Flathead Formation is missing. Basal unconformity places the Flathead on Archean rocks south of the Willow Creek fault, and on Proterozoic rocks north of the fault. Where present, thickness ranges from 12-45 m (40-150 ft).

Yg **Greyson Formation (Mesoproterozoic)**—Greenish gray and yellowish brown siltite and fine-grained quartzite with subordinate limestone (Robinson, 1967). Exposed thickness 200 m (650 ft).

Yn **Newland Formation (Mesoproterozoic)**—Gray and yellowish brown, calcareous siltite, limestone, and fine-grained quartzite (Robinson, 1967). Exposed thickness 150 m (490 ft).

Yla **LaHood Formation, undivided (Mesoproterozoic)**—Dark gray, dark brownish green, and locally reddish brown, arkosic boulder to granule conglomerate, arkose, arkosic siltite, arkosic argillite, and some impure carbonate beds. Clasts composed primarily of various Archean metamorphic, and igneous rocks; matrix light olive gray mudstone. Type section in map area near LaHood Park (Alexander, 1955; McMannis, 1963). Clast size as much as 3.6 m (12 ft) wide in local areas, but size decreases dramatically in lobate patterns that fan northward. Clasts are angular to subround.

Shale facies (Greyson Shale of Alexander, 1955): Black, brown, or purple, fissile, to non-fissile, carbonaceous or silty shale, interbedded with gray siltite and argillite, coarse- to fine-grained arkose, and thin carbonate beds.

Carbonate facies (Newland Limestone of Alexander, 1955): Dark gray to light gray, thin-bedded to laminated limestone, and olive-gray dolomite; locally contains algal structures (Verrall, 1955).

LaHood Formation facies descriptions that follow were taken from an unpublished report by Tor Nilsen for the Golden Sunlight Mines, Inc.

Ylaf **LaHood Formation, alluvial-fan and fan-delta facies**

The best observed exposures are in the Huller Spring area and vicinity of Lewis and Clark Caverns.

Debris-flow component: Reddish to purplish weathering, massively bedded sandstone that lacks internal current-formed sedimentary structures. Displays reverse grading, matrix-supported angular clasts, poor sorting of both matrix and clasts, and isotropic fabrics.

Stratified component: Grayish-weathering, planar-bedded and low-angle crossbedded sandstone with local shale drapes and interbeds, moderately to well sorted, subangular to rounded clasts and rip-up clasts of shale; local channel-form geometries, and fining-upward cycles at several localities. Shale interbeds characteristically weather to brown and olive brown and locally exhibit mudcracks, wave ripples, and parallel lamination. At Huller Spring, large angular blocks of migmatite, and angular to rounded clasts of quartzofeldspathic gneiss characterize the basal part of the facies. Overlying deposits consist chiefly of massive, pebbly, arkosic sandstone, interbedded with crossbedded and planar bedded pebbly arkosic sandstone, and minor amounts of argillite.

Facies fines to north, and has larger component of stratified beds with better rounded and sorted clasts than to the south. Unit locally represents fan-delta deposits into small lakes.

Ylsh **LaHood Formation, shelf facies**

Crops out south of Jefferson River along western border of map.
Massive to parallel bedded, pebbly sandstone; stratigraphically between submarine-canyon and alluvial fan facies.

Ylsl **LaHood Formation, slope facies**

Crops out in the Cave Fault area.
Characterized by abundant synsedimentary slumps. Consists dominantly of mudstone with thin siltstone turbidites and graded non-turbidite intra-flow deposits. Highly tectonized because of the lack of competent beds and appears to consist mostly of sheared and deformed argillite.

Ylsc **LaHood Formation, submarine-canyon facies**

Crops out in Lewis and Clark Caverns State Park area, where it appears to have cut directly into the alluvial fan/fan-delta facies.
Boulder to pebble conglomerate and conglomeratic sandstone that is poorly stratified and highly channelized. Canyons relatively small–less than 2 km (6,560 ft) wide–and are cut into shallow marine units, so exposures are principally of the upper parts of the canyons.

Ylis **LaHood Formation, inner submarine-fan facies**

Crops out in LaHood Canyon and in the Cave Fault area.
Channel axis component: Boulder to pebble conglomerate and pebbly sandstone with thin shale interbeds.
Channel-margin component: Argillite with thin interbeds of turbidite siltstone and very fine grained sandstone.

Ylms **LaHood Formation, middle submarine-fan facies**

Crops out east of the Golden Sunlight Mine, in LaHood Canyon, and in the Cave Fault area.
Characteristic repetitive fining- and thinning-upward sequences with channelized bases and interbedded, thin-bedded overbank turbidites. Overbank turbidites consist of thin, but coarse-grained, laterally discontinuous deposits with abundant small-scale slump folds that generally indicate directions of slumping away from channel axes. Locally contains large boulders of marble and limestone in LaHood Canyon and Cave fault areas. Apron-like fan geometries along the steep Proterozoic Willow Creek fault promoted transport of boulders into the middle-fan channels.

Ylos **LaHood Formation, outer submarine-fan facies**

Crops out east of the Golden Sunlight Mine, north and east of Cardwell, and in LaHood Canyon.

Typically well exposed because of the abundant resistant sandstone beds that make up stacked, thickening and coarsening-upward sequences. Characteristic Bouma sequences and abundant sole markings. Fan-fringe deposits commonly contain thinner and finer-grained beds organized into thinner coarsening-upward sequences with lower sandstone-to-shale ratios than central parts of fans. Individual beds are typically planar, well-graded, and separated by shale intervals. Slurried beds, in which the Bouma B division contains shale rip-up clasts that are locally very large, are common in many sections and can be mistaken for slump folds.

Ylbp **LaHood Formation, basin-plain facies**

Crops out south and east of the Golden Sunlight Mine.

Generally poorly exposed because consists mostly of argillite with thinly interbedded, laterally continuous and planar-bedded, distal turbidites. Abundant sole markings on relatively thick beds of sandstone. Generally has a lower sandstone-to-shale ratio, thinner beds of turbidite sandstone, and lacks thickening- and coarsening-upward sequences compared to the outer fan facies. Facies generally has lower sandstone-to-shale ratio and thinner and finer-grained beds of sandstone to the north.

The following two units are found in Precambrian basement rock in the map area. Although important, they could not be shown well at the map scale.

Diabase (Neoproterozoic)—Numerous dikes that cut across Archean rocks, but do not extend into younger rocks. (Schmidt and Garihan, 1986b).

Pegmatite and quartz veins (Late Cretaceous, and Paleoproterozoic)—White to pink, coarse-grained to very coarse grained, massive and foliated dikes and sills composed mostly of potassium feldspar, quartz, plagioclase, muscovite, and rarely, biotite. In some places grades into quartz veins that are white, massive quartz in lenticular, generally discordant veins and irregular pods. Very widespread in areas of Archean rocks.

Xsp **Spuhler Metamorphic Series (Paleoproterozoic)**—Light gray to reddish brown, purplish brown, or deep golden brown anthophyllite-gedrite gneiss and subordinate schist. Weathers to dark brown or blackish brown.

Xg **Granite (Paleoproterozoic?)**—Possibly Cretaceous.

XAah **Amphibolite and hornblende gneiss (Paleoproterozoic and Archean?)**—Gray to black, medium-grained, hypidiomorphic, equigranular, moderately foliated to well-foliated hornblende-plagioclase gneiss and amphibolite.

XAif **Banded iron formation (Paleoproterozoic and Archean?)**—Dark reddish brown to orange brown, massive to layered quartz-hematite rock locally containing abundant quartz veins; limonitic, especially along fractures.

XAq **Quartzite (Paleoproterozoic and Archean?)**—White, gray, and brown, medium- to coarse-grained, inequigranular, moderately foliated to massive quartzite.

XAqa **Quartzite and amphibolite (Paleoproterozoic and Archean?)**—Interlayered white quartzite and amphibolite.

XAqfg **Quartzofeldspathic gneiss (Paleoproterozoic and Archean?)**—(Vitaliano and Cordua, 1979): Includes plagioclase-microcline-quartz biotite ("granitic") gneiss, plagioclase-quartz-biotite ("tonalitic") gneiss, banded biotite gneiss, aluminous gneiss and schist, gedrite gneiss, and garnet gneiss.

Plagioclase-microcline-quartz-biotite gneiss. Light gray to light pinkish gray, medium-grained, weakly to moderately foliated gneiss ranging from granodiorite to syenogranite.

Plagioclase-quartz-biotite gneiss. Gray, medium grained, inequigranular, weakly to moderately foliated, tonalitic gneiss. Includes some trondhjemitic and granodioritic gneiss.

Banded biotite gneiss. White, light gray, dark gray, and black, medium-grained, well-foliated, inequigranular, tonalitic to quartz monzonitic gneiss, commonly migmatitic.

Aluminous schist and gneiss. Gray to dark brownish gray, medium-grained, inequigranular, generally well foliated, commonly micaceous gneiss and schist containing aluminosilicate minerals.

Gedrite gneiss. Brown to grayish brown, moderately well foliated, medium-grained, gedrite gneiss. Generally occurs in small lenses and concordant layers in other Archean rocks.

Garnet gneiss. Highly garnetiferous assemblage of various colors that includes biotite-garnet schist, sillimanite-garnet schist, garnetiferous quartzite, quartzite, garnetiferous quartzofeldspathic gneiss, corundum gneiss, gedrite schist, cummingtonite schist, and garnetiferous amphibolite.

XAum **Ultramafic rock (Paleoproterozoic and Archean?)**—Includes mafic to intermediate gneiss, hornblende-plagioclase gneiss, amphibolite, granulite, and intrusive metabasite.

CITED REFERENCES AND BIBLIOGRAPHY

Achauer, C.W., 1959, Stratigraphy and microfossils of the Sappington Formation in southwestern Montana, *in* Hammond, C.R. and Trapp, H., Jr., eds., Sawtooth-Disturbed Belt area: Billings Geological Society 10th Annual Field Conference Guidebook, p. 41–49.

Alexander, R.G., Jr., 1951, The geology of the Whitehall area, Montana: Princeton, N.J., Princeton University, Ph.D. dissertation, 150 p.

Alexander, R.G., Jr., 1955, The geology of the Whitehall area, Montana: Yellowstone-Bighorn Research Association Contribution 195, 111 p.

Andretta, D.B., and Alsup, S.A., 1960, Geology and Cenozoic history of the Norris-Elk Creek area, southwest Montana, *in* Campau, D.E., and Anisgard, H.W., eds., West Yellowstone—earthquake area: Billings Geological Society 11th Annual Field Conference Guidebook, p. 185–190.

Angeloni, L.M., 1988, The role of water in the formation of granulite and amphibolite facies rocks, Tobacco Root Mountains, Montana: Missoula, University of Montana, M.S. thesis, 51 p.

Aram, R.B., 1979, Cenozoic geomorphic history relating to Lewis and Clark Caverns, Montana: Bozeman, Montana State University, M.S. thesis, 150 p.

Aram, R.B., 1981, Geologic history of Lewis and Clark Caverns, Montana, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society Field Conference and Symposium Guidebook, p. 285–300.

Archibald, F.W., 1940, The geology of the Limespur-Sappington area: Butte, Montana School of Mines*, B.S. thesis, 14 p.

Axelrod, R.B., 1984, Tertiary sedimentary facies, depositional environments, and structure, Jefferson Basin, southwest Montana: Missoula, University of Montana, M.S. thesis, 64 p.

Ballard, J.K., 1939, Geology report on field trip near Whitehall, Montana: Butte, Montana School of Mines*, B.S. thesis, 25 p.

Barnes, J., 1954, Structural analysis of the northern end of the Tobacco Root Mountains, Madison County, Montana: Bloomington, Indiana University, Ph.D. dissertation, 194 p.

Basu, Abhijit, Molinaroli, Emanuela, and Andersson, Steen, 1998, Diversity of physical and chemical properties of detrital zircons and garnets in Cenozoic sediments of southwestern Montana: The Mountain Geologist, v. 35, no. 1, p. 23–29.

Bean, C.L., 1981, A geochemical study of the North Doherty intrusive complex, Jefferson County, Montana: Bloomington, Indiana University, M.S. thesis, 134 p.

Berg, A.B., 1959, Geology of the northwestern corner of the Tobacco Root Mountains, Madison County, Montana: St. Paul, University of Minnesota, M.S. thesis, 75 p.

Berg, R.B., Lopez, D.A., and Lonn, J.D., 2000, Geologic map of the Livingston 30′x 60′ quadrangle, south-central Montana: Montana Bureau of Mines and Geology Open-File Report MBMG 406, 1:100,000 scale [adjacent to this map].

Berry, G.W., 1943, Stratigraphy and structure at Three Forks, Montana: Geological Society of America, v. 54, p. 1–30.

Blake, O.D., 1959, Big Snowy stratigraphy in the area adjacent to the Rocky Mountain front [Montana], *in* Hammond, C.R., and Trapp, H., Jr., eds., Sawtooth-Disturbed Belt area: Billings Geological Society 10th Annual Field Conference Guidebook, p. 64–68.

Blake, O.D., Hanson, A.M., and Hackett, O.M., 1953, Field Trip no. 1, Stratigraphy and structure in the Three Forks area, *in* Blake, O.M., ed., Guidebook of field excursions: Geological Society of America, Rocky Mountain section, 6th Annual Conference Guidebook, p. 19–30.

Bole, G.R., 1962, The geology of part of the Manhattan quadrangle, Gallatin County, Montana: Berkeley, University of California, M.A. thesis, 82 p.

Bonnet, A.T., 1979, Lithostratigraphy and depositional setting of the limestone-rich interval of the LaHood Formation (Belt Supergroup), southwestern Montana: Bozeman, Montana State University, M.S. thesis, 87 p.

Boyce, R., 1975, Depositional systems in the LaHood Formation, Belt Supergroup, Precambrian, southwest Montana: Austin, University of Texas, Ph.D. dissertation, 247 p.

Boyd, W.D., 1968, Simulation via time-partitioned linear programming: a ground and surface water allocation model for the Gallatin Valley of Montana: Bozeman, Montana State University, M.S. thesis, 217 p.

Brady, J.B., 2004, General geology and tectonic setting of the Tobacco Root Mountains, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p. 1-14.

Brady, J.B., Mohlman, H. K., Harris, Caroline, Carmichael, S.K., Jacob, L.J., and Chaparro, W.R., 2004, General geology and geochemistry of metamorphosed Proterozoic mafic dikes and sills, Tobacco Root Mountains, Montana, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p. 89-129.

Brady, J.B., Kovaric, D.N., Cheney, J.T., Jacob, L.J., and King, J.T., 2004, ^{40}Ar/^{39}Ar ages of metamorphic rocks from the Tobacco Root Mountains region, Montana, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p. 131-149.

Brodowy, J.M., Lageson, D.R., Ryan, C., and Snyder, B., 1991, Structure and neotectonics of the eastern Three Forks Basin, northern Intermountain seismic belt, southwest Montana: Geological Society of America Abstracts with Programs, v. 23, no. 5, p. A233–A234.

Brunsvold, L.D., 1989, A seismic reflection study of the Jefferson Basin, southwest Montana: Butte, Montana College of Mineral Science and Technology*, M.S. thesis, 45 p.

Brustkern, R.L., 1977, The impact of land use change on the groundwater resources of the Bozeman, Montana area: Montana State University Joint Water Resources Center Report 88, 35 p.

Burger, H.R., and eleven others, 2004, Geology and geochemistry of the Spuhler Peak Metamorphic Suite, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p. 47-70.

Burger, H. R., III, and Thompson, M.D., 1970, Fracture analysis of the Carmichael Peak Anticline, Madison County, Montana: Geological Society of America Bulletin, v. 81, p. 1821–1836.

Burfeind, W.J., 1967, A gravity investigation of the Tobacco Root Mountains, Jefferson basin, Boulder Batholith, and adjacent areas of southwestern Montana: Bloomington, Indiana University, Ph.D. dissertation, 146 p.

Burton, B.R., Lageson, D.R., Schmidt, C.J., Ballard, D.W., and Warne, J.R., 1993, Large-magnitude shortening of the Lombard thrust system, Helena salient, Montana fold and thrust belt: implications for emplacement of the Boulder Batholith and reconstruction of the Belt Basin, *in* Berg, R.B., ed., Belt Symposium III: Montana Bureau of Mines and Geology Special Publication 112, p. 229–243.

Capozza, F.C., 1967, The geology of the Bone Basin and Perry Canyon intrusions, Madison County, Montana: Bloomington, Indiana University, M.A. thesis, 48 p.

Carl, J.D., 1970, Block faulting and development of drainage, northern Madison Mountains, Montana: Geological Society of America Bulletin, v. 81, p. 2287–2298.

Chadwick, R.A., 1981, Geologic Road Log—Livingston to Three Forks, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society Field Conference and Symposium Guidebook, p. 380–387.

Chadwick, R.A., 1969, The northern Gallatin Range, Montana: northwestern part of the Absaroka-Gallatin volcanic field: University of Wyoming Contributions to Geology, v. 8, p. 150–166.

Chadwick, Tom, compiler, 1996, Geology of the Whitehall district, Jefferson County, Montana, plate 2, 1:12,000 scale, *in* Taylor, E.K., 1997, Formation of ferricretes from acid rock drainage at Golden Sunlight Mine, Jefferson County, Montana: Butte, Montana Tech of The University of Montana, M.S. thesis, 179 p., 2 plates.

Chase, R.B., Schmidt, C.J., and Genovese, P.W., 1993, Influence of Precambrian rock compositions and fabrics on the development of Rocky Mountain foreland folds, *in* Schmidt, C.J., Chase, R.B., and Erslev, E.A., eds., Laramide basement deformation in the Rocky Mountain foreland of the western United States: Geological Society of America Special Paper 280, p. 45-72.

Cheney, J.T., Webb, A.A.G., Coath, C.D., and McKeegan, K.D., 2004, *In situ* ion microprobe ^{207}Pb/^{206}Pb dating of monazite from Precambrian metamorphic suites, Tobacco Root Mountains, Montana, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p. 151-179.

Christiansen, J.H., 1970, Gravity, magnetic, and electrical resistivity investigation of selected fault and stratigraphic contacts in southern Jefferson County and northern Madison County, Montana: Bloomington, Indiana University, M.A. thesis, 63 p.

Clabaugh, S.E., 1952, Corundum deposits of Montana: U.S. Geological Survey Bulletin 983, 100 p.

Clabaugh, S.E., and Armstrong, F.C., 1950, Corundum deposits of Gallatin and Madison Counties, Montana: U.S. Geological Survey Bulletin 969-B, p. 29–53.

Cooley, J.T., 1993, Fluvial systems of the upper Jurassic Morrison Formation, northern Beartooth and Gallatin Ranges, southwest Montana: Bozeman, Montana State University, M.S. thesis, 55 p.

Condit, D.D., 1919, Oil shale in western Montana, southeastern Idaho, and adjacent parts of Wyoming and Utah, *in* White, David, and Ashley, G.H., eds., Contributions to economic geology: U.S. Geological Survey Bulletin 711, p. 15–40 [includes information for Bozeman 30′x 60′ quadrangle.]

Cordua, W.J., 1973, Precambrian geology of the southern Tobacco Root Mountains, Madison County, Montana: Bloomington, Indiana University, Ph.D. dissertation, 147 p.

Craiglow, C.J., 1986, Tectonic significance of the Pass fault, central Bridger Range, southwest Montana: Bozeman, Montana State University, M.S. thesis, 37 p.

Cressman, E.R., 1955, Physical stratigraphy of the Phosphoria Formation in part of southwestern Montana: U.S. Geological Survey Bulletin 1027-A, p. 1–31.

Cressman, E.R., and Swanson, R.W., 1960, Permian rocks in the Madison, Gravelly, and Centennial Ranges, Montana: *in* Campau, D.E., and Anisgard, H.W., eds, West Yellowstone—Earthquake area: Billings Geological Society 11th Annual Field Conference Guidebook, p. 226–232.

Cressman, E.R., 1964, Stratigraphy and petrology of the Permian rocks of southwestern Montana: U.S. Geological Survey Professional Paper 313-C, p. 275–569.

Congdon, C., 1935, The general geology of the Cardwell Mining District: Butte, Montana School of Mines*, B.S. thesis, 11 p.

Cowen, M.T., 1958, The petrography of volcanic rocks of the Jefferson Island quadrangle, Montana: Bloomington, Indiana University, M.A. thesis, 57 p.

Cummings, M.L., and McCulloch, W.R., 1992, Geochemistry and origin of amphibolite and ultrmafic rocks, Branham Lakes area, Tobacco Root Mountains, southwestern Montana, *in* Bartholomew, M.J., Hyndman, D.W., Mogk, D.W., and Mason, Robert, eds., Basement Tectonics 8–Characterization and comparison of ancient and Mesozoic continental margins: Proceedings of the Eighth International conference on basement tectonics held in Butte, Montana, USA, August 1988, Dordrecht/Boston/London, Kluwer Academic Publishers, p. 323-340.

Custer, S.G., 1995a, A walking tour of the geology of the southeastern Gallatin Valley, *in* Self-Guided Field Trips Near Bozeman: 47th Annual Meeting Rocky Mountain Section of the Geological Society of America, Guidebook, p. 1–10.

Custer, S.G., 1995b, Paleozoic and Mesozoic stratigraphy of the Bridger Range, *in* Self-Guided Field Trips Near Bozeman: 47th Annual Meeting Rocky Mountain Section of the Geological Society of America, Guidebook, p. 35–48.

Davis, W.E., Kinoshita, W.T., and Smedes, H.W., 1963, Bouguer gravity, aeromagnetic and generalized geologic map of the western part of the Three Forks Basin, Jefferson, Broadwater, Madison, and Gallatin Counties, Montana: U.S. Geological Survey Geophysical Investigation Map GP-498, scale 1:62,500.

Davis, W.E., Kinoshita, W.T., and Robinson, G.D., 1965, Bouguer gravity, aeromagnetic, and generalized geologic map of the eastern part of the Three Forks Basin, Broadwater, Madison, and Gallatin Counties, Montana: U.S. Geological Survey Geophysical Investigations Map GP-497, scale 1:62,500.

DeWitt, Ed, Foord, E.E., Zartman, R.E., Pearson, R.C., and Foster, Fess, 1996, Chronology of Late Cretaceous igneous and hydrothermal events at the Golden Sunlight gold-silver breccia pipe, southwestern Montana: U.S. Geological Survey Bulletin 2155, 48 p.

Dixon, R.M. and Wolfgram, Diane, 1998, Bedrock geology of the Elkhorn Mountains Volcanics in the southern Bull Mountain area, Jefferson County, Montana: Montana Bureau of Mines and Geology Open-File Report MBMG 374, scale 1:24,000.

Donohue, D.A., 1989, Paleochannel aquifer potential at Montana State University—a test of hypotheses: Bozeman, Montana State University, M.S. thesis, 94 p.

Dorobek, S.L., and Smith, T.M., 1989, Cyclic sedimentation and dolomitization history of the Devonian Jefferson Formation, southwestern Montana: *in* French, D.E. and Grabb, R.F., eds., Geologic Resources of Montana: Montana Geological Society Field Conference Guidebook: Montana Centennial Edition, p. 31–46.

Dorf, Erling, and Lochman, Christina, 1940, Upper Cambrian formations in southern Montana: Geological Society of America Bulletin, v. 51, p. 541–556.

Dorr, J.A., 1954, *Hypsoparia bozemanensis*, a new genus and species of leptarctine mustelid from the late Miocene Madison Valley Formation of Montana: Annals of Carnegie Museum, v. 33, p. 179–184.

Dorr, J.A., 1956, Anceney local mammal fauna, latest Miocene, Madison Valley Formation, Montana: Journal of Paleontology, v. 30, p. 62–74.

Douglass, Earl, 1899, The Neocene lake beds of western Montana and descriptions of some new vertebrates from the Loup Fork: Missoula, University of Montana, M.S. thesis, 27 p.

Douglass, Earl, 1901, Fossil Mammalia of the White River beds of Montana: American Philosophical Society Transactions, v. 21, p. 227–279.

Douglass, Earl, 1903, New vertebrates from the Montana Tertiary: Annals of Carnegie Museum, v. 2, p. 145–199.

Douglass, Earl, 1907a, *Merycochoerus* and a new genus of Merycoidodonts with some notes on other Agriochoeridae: Annals of Carnegie Museum, v. 4, p. 84–98.

Douglass, Earl, 1907b, New Merycoidodonts from the Miocene of Montana: Bulletin of the American Museum of Natural History, v. 23, p. 202–222.

Douglass, Earl, 1908, Rhinoceroses from the Oligocene and Miocene deposits of North Dakota and Montana: Annals of Carnegie Museum, v. 4, p. 256–266.

Douglass, Earl, 1909a, A description of a new species of *Procamelus* from the upper Miocene of Montana with notes upon *Procamelus madisonius* Douglass: Annals of Carnegie Museum, v. 5, p. 159–165.

Douglass, Earl, 1909b, *Dromomeryx,* a new genus of American ruminants: Annals of Carnegie Museum, v. 5, p. 457–479.

Dresser, H.W., 1996, A stereo picture guide to some of Montana's thrust faults: Montana Bureau of Mines and Geology Open-File Report, 76 p.

Dresser, H.W., 1996, Faults, fans, and pediments of southwestern Montana: A stereo picture guide, 57 p., *in press* as Montana Bureau of Mines and Geology Open-File Report

Dull, Kathleen, 1994, A gravity study of the North Boulder Basin in southwestern Montana: Bloomington, Indiana University, M.S. thesis, 145 p.

Dyman, T.S., Tysdal, R.G., Porter, K.W., and Thompson, G.A., 1996, Measured sections and correlations of mid-Cretaceous rocks near the Lombard Thrust of the Helena Salient in southwestern Montana: U.S. Geological Survey Open-File Report 95-841, 6 p.

Eckerty, D.G., 1968, The geology of the Elkhorn Mountains Volcanics in southern Jefferson and northern Madison Counties, Montana: Bloomington, Indiana University, M.S. thesis, 180 p.

Elliott, W.S., 1998a, Geologic map of the Harrison 7.5-minute quadrangle, Madison County, Montana: Montana Bureau of Mines and Geology Open File Report MBMG 375, Part 1, scale 1:24,000.

Elliott, W.S., 1998b, Geologic map of the Maltbys Mound 7.5-minute quadrangle, Madison, County, Montana: Montana Bureau of Mines and Geology Open-File Report MBMG 375, Part 2, scale 1:24,000.

Elliott, W.S., 1998c, Tectono-stratigraphic control of Quaternary and Tertiary sediments and structure along the northeast flank of the Tobacco Root Mountains, Madison County, Montana: Bloomington, Indiana University, M.S. thesis, 113 p.

Evander, R.L., 1996, Horses (*Mammalia, Equidae*) from the Barstovian (Miocene) Anceney Local Fauna, Montana: Paludicola, v. 2, p. 248–257.

Feichtinger, S.H., 1970, Geology of a portion of the Norris quadrangle, Madison and Gallatin Counties, Montana: Bozeman, Montana State University, M.S. thesis, 89 p.

Fields, R.W., and Petkewick, R.M., 1967, Tertiary stratigraphy and geologic history of the upper Jefferson, Ruby, lower Beaverhead, and lower Big Hole Valleys, *in* Centennial Basin of southwestern Montana: Billings Geological Society 18th Annual Field Conference Guidebook, p. 71–78.

Fields, R.W., Tabrum, A.R., Rasmussen, D.L., and Nichols, R., 1985, Cenozoic rocks of the intermontane basins of western Montana and eastern Idaho: A summary, *in* Flores, R.M., and Kaplan, S.S., eds., Cenozoic Paleogeography of West-Central United States: Rocky Mountain Paleogeography Symposium 3, Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists, p. 9–36.

Fix, P.F., 1940, Structure of Gallatin Valley, Montana: Boulder, University of Colorado, Ph.D. dissertation, 68 p.

Frick, C., 1937, Horned ruminants of North America: Bulletin of the American Museum of Natural History, v. 69, no. 1, p. 669.

Foster, Fess, 1991, Geology and general overview of the Golden Sunlight Mine, Jefferson County, Montana, *in* Mineral Deposits of Montana: The Association of Exploration Geochemists, 15th International Geochemical Exploration, Symposium, Field Trip Guidebook, p. 26–36.

Foster, Fess and Chadwick, Tom, 1999, Some observations regarding formation, correlations, and regional paleogeography of the southern Helena Embayment, *in* Berg, R.B., ed., Belt Symposium III Abstracts, 1993: Montana Bureau of Mines and Geology Open-File Report MBMG 381, p. 20–22.

Foster, Fess, and Chadwick, Tom, 1990, Relationship of the Golden Sunlight Mine to the Great Falls Tectonic Zone, *in* Moye, F.J., ed., Geology and ore deposits of the Trans-Challis Fault System/Great Falls Tectonic Zone: Tobacco Root Geological Society, 15th Annual Field Conference Guidebook, p. 77–81.

Foster, Fess, Chadwick, Tom, and Nilsen, T.H., 1999, Paleodepositional setting and synsedimentary mineralization in Belt Supergroup rocks of the Whitehall, Montana area, *in* Berg, R. B., ed., Belt Symposium III Abstracts, 1993: Montana Bureau of Mines and Geology Open-File Report MBMG 381, p. 23–25.

Foster, Fess, Cox, Bruce, and Chadwick, Tom, 1993, Field Trip—Economic, environmental and "socioeconomic" geology of the Whitehall Valley, southwestern Montana, *in* Childs, J.F., and Lageson, D.R., eds., Economic and Regional Geology of the Tobacco Root-Boulder Batholith region, Montana: Tobacco Root Geological Society, 18th Annual Field Conference, Northwest Geology, v. 22, p. 79–102.

Foster, Fess, and Smith, T., 1995, A summary of the geology and environmental programs at the Golden Sunlight Mine, Whitehall, Montana, *in* Mogk, D.W., ed., Field Guide to Geologic Excursions in southwest Montana: Geological Society of America, Rocky Mountain Section, Northwest Geology, v. 24, p. 77–83.

Fountain, D.M., and Desmarais, N.R., 1980, The Wabowden Terrane of Manitoba and the Pre-Belt basement of southwestern Montana: a comparison: Montana Bureau of Mines and Geology Special Publication 82, p. 35–46.

Fryxell, J.C., and Smith, D.L., 1986, Paleotectonic implications of arkose beds in Park Shale (Middle Cambrian), Bridger Range, south-central Montana, *in* Peterson, J.A., ed., Paleotectonics and sedimentation in the Rocky Mountain region, United States: American Association of Petroleum Geologists Memoir, v. 41, p. 159–171.

Gardner, L.S., 1959, Revision of Big Snowy Group in central Montana: American Association of Petroleum Geologists Bulletin, v. 43, p. 329–349.

Garihan, J.M., Schmidt, C.J., Young, S.Y., and William, M.A., 1983, Geology and recurrent movement history of the Bismark-Spanish Peaks-Gardiner fault system, southwest Montana, *in* J.D. Lowell, ed., Rocky Mountain Foreland Basins and Uplifts: Rocky Mountain Association of Geologists, p. 295–314.

Gary, S.D., 1980, Quaternary geology and geophysics of the upper Madison Valley, Madison County, Montana: Missoula, University of Montana, M.S. thesis, 61 p.

Gehman, C., 1997, Interpretation of a Tertiary-fill basin in southwestern Montana through the use of geophysical techniques, *in* Proceedings: Tenth Keck Research Symposium in Geology, The College of Wooster, Wooster, Ohio, p. 298–301.

Gillmeister, N.M., 1971, Petrology of Precambrian rocks in the central Tobacco Root Mountains, Madison County, Montana: Cambridge, Massachusetts, Harvard University, Ph.D. dissertation, 201 p.

Gillmeister, N.M., 1972, Cherry Creek-Pony Group relationship in the central Tobacco Root Mountains, Madison County, Montana: Northwest Geology, v. 1, p. 21–24.

Glaman, L.R.B., 1991, The geology of Negro Hollow, Jefferson County, Montana: Butte, Montana College of Mineral Science and Technology*, M.S. thesis, 69 p.

Glancy, P.A., 1964, Cenozoic geology of the southeastern part of the Gallatin Valley, Montana: Bozeman, Montana State University, M.S. thesis, 66 p.

Graham, S.A., and Suttner, L.J., 1974, Occurrence of Cambrian islands in southwest Montana: The Mountain Geologist, v. 11, no. 2, p. 71–84.

Grant, R.E., 1965, Faunas and stratigraphy of the Snowy Range Formation in southwestern Montana and northwestern Wyoming: Geological Society of America Memoir 96, 171 p.

Griffith, E.F., 1982, Environmental geology of the southwest margin of the Gallatin Valley, Gallatin County, Montana: Bozeman, Montana State University, M.S. thesis, 106 p.

Guthrie, G.A., 1984, Stratigraphy and depositional environment of the Upper Mississippian Big Snowy Group in the Bridger Range, southwest Montana: Bozeman, Montana State University, M.S. thesis, 105 p.

Gutschick, R.C., Suttner, L.J., and Switek, M.J., 1962, Biostratigraphy of transitional Devonian-Mississippian Sappington Formation of southwest Montana, *in* Devonian System of Montana: Billings Geological Society 13th Annual Field Conference, p. 79–89.

Hackett, O.M., Visher, F.N., McMurtrey, R.G., and Steinhilber, W.L., 1960, Geology and ground-water resources of the Gallatin Valley, Gallatin County, Montana: U.S. Geological Survey Water-Supply Paper 1482, 28 p.

Hall, R.D., and Heiney, J.S., 1983, Glacial and postglacial physical stratigraphy and chronology, North Willow Creek and Cataract Creek drainage basins, eastern Tobacco Root Range, southwestern Montana, U.S.A.: Arctic and Alpine Research, v. 15, p. 19–52.

Hall, R.D., and Michaud, D., 1988, The use of hornblende etching, clast weathering, and soils to date alpine glacial and periglacial deposits: A study from southwestern Montana: Geological Society of America Bulletin, v. 100, p. 458–467.

Hallock, A.R., 1955, The geology of a portion of the Horseshoe Hills: Butte, Montana School of Mines*, M.S. thesis, 69 p.

Hamilton, T.S., 1974, The petrology of the North Doherty mafic sill, Jefferson County, Montana: Bloomington, Indiana University, M.A. thesis, 117 p.

Hanley, T.B., 1976, Stratigraphy and structure of the central fault block, northwestern Tobacco Root Mountains, Madison County, Montana, *in* Lankston, M.M., ed., Tobacco Root Geological Society, Field Conference Guidebook: Montana Bureau of Mines and Geology Special Publication 73, p. 7–14.

Hanley, T.B., 1975, Structure and petrology of northwestern Tobacco Root Mountains, Madison County, Montana: Bloomington, Indiana University, Ph.D. dissertation, 206 p.

Hanneman, D.L., and Wideman, C.J., 1991, Sequence stratigraphy of Cenozoic continental rocks, southwestern Montana: Geological Society of America Bulletin, v. 103, p. 1335–1345.

Hanneman, D.L., Wideman, C.J., and Halvorson, James, 1994, Calcic paleosols: their use in subsurface stratigraphy: American Association of Petroleum Geologists Bulletin, v. 78, p. 1360-1371.

Hanson, A.M., 1952, Cambrian stratigraphy in southwestern Montana: Montana Bureau of Mines and Geology Memoir 33, 46 p.

Harlan, S.S., Geissman, J.W., and Snee, L.W., 2008a, Paleomagnetism of Proterozoic mafic dikes from the Tobacco Root Mountains, southwest Montana: Precambrian Research, v. 163, Issue 3-4, p. 239-264.

Harlan, S.S., Geissman, J.W., Whisner, S.C., and Schmidt, C.J., 2008b, Paleomagnetism and geochronology of sills of the Doherty Mountain area, southwestern Montana: Implications for the timing of fold and thrust belt deformation and vertical-axis rotations along the southern margin of the Helena Salient: Geological Society of America Bulletin, v. 120, p. 1091-1104.

Harlan, S.S., Snee, L.W., and Geissman, J.W., 1990, Paleomagnetic and $^{40}Ar/^{39}Ar$ results from mafic dikes and basement rocks, southwest Montana: EOS, Transactions of the American Geophysical Union, v. 71, p. 1297.

Harms, T.A., Burger, H.R., Blednick, D.G., Cooper, J.M., King, J.T., Owen, D.R., Lowell, Josh, Sincock, M.J., Kranenburg, S.R., Pufall, Ann, and Picornell, C.M., 2004, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p. 203-226.

Harms, T.A., Brady, J.B., Burger, H.R., and Cheney, J.T., 2004, Advances in the geology of the Tobacco Root Mountains, Montana, and their implications for the history of the northern Wyoming province, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian Geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p. 227–243.

Harrison, J.E., Griggs, A.B., and Wells, J.D., 1974, Tectonic features of the Precambrian Belt Basin and their influence on post-Belt structures: U.S. Geological Survey Professional Paper 866, 15 p.

Hawley, David, Bonnet-Nicolaysen, Adrienne, and Coppinger, Walter, 1982, Stratigraphy, depositional environments, and paleotectonics of the LaHood Formation, *in* Smith, D.L., ed., Field Trip Guidebook, Rocky Mountain Section, Geological Society of America, 35th Annual meeting, 20 p.

Hawley, David, and Schmidt, C.J., 1976, Some aspects of the LaHood Formation and structure in the Jefferson Canyon area, *in* Lankston, M.M., ed., Tobacco Root Geological Society, Field Conference Guidebook: Montana Bureau of Mines and Geology Special Publication 73, p. 151–165.

Hay, J.E., 1997, An investigation of groundwater recharge along the western flank of the southern Bridger Range: Bozeman, Montana State University, M.S. thesis, 129 p.

Haynes, W.P., 1916, The Lombard overthrust and related geological features: Journal of Geology, v. 24, p. 269–290.

Hendrix, T.E., and Stellavato, Nick, 1976, Pervasive deformation of the Meagher oölitic limestone, North Boulder Valley, Montana, *in* Lankston, M.M., ed., Tobacco Root Geological Society, Field Conference Guidebook: Montana Bureau of Mines and Geology Special Publication 73, p. 131–139.

Hess, D.F., 1967, Geology of pre-Beltian rocks in the central and southern Tobacco Root Mountains, with reference to superposed effects of the Laramide-age Tobacco Root Batholith: Bloomington, Indiana University Ph.D. dissertation, 333 p.

Hess, D.F., 1976, Road log and field guide—geology of Norris-McAllister area, *in* Lankston, M.M., ed., Tobacco Root Geological Society, Field Conference Guidebook: Montana Bureau of Mines and Geology Special Publication 73, p. 131–90.

Hewitt, C., and Olson, H.D., 1951, Geology of a postulated volcanic vent northeast of Whitehall, Montana: Butte, Montana School of Mines*, B.S. thesis, 22 p.

Hill, C.L., 2001a, Late Pliocene and Pleistocene geology and paleontology in the Three Rivers Basin, Montana, *in* Nichols, R., ed., Cenozoic vertebrate paleontology and geology of southwestern Montana and adjacent areas, *in* Hill, C.L., ed., Mesozoic and Cenozoic paleontology in the western plains and Rocky Mountains: Society of Vertebrate Paleontology 61st annual field trip guidebook, Museum of the Rockies Occasional Paper no. 3, p. 113–125.

Hill, C.L., 2001b, Pleistocene mammals of Montana and their geologic context, *in* Nichols, R., ed., Cenozoic vertebrate paleontology and geology of southwestern Montana and adjacent areas, *in* Hill, C.L., ed., Mesozoic and Cenozoic paleontology in the western plains and Rocky Mountains: Society of Vertebrate Paleontology 61st annual field trip guidebook, Museum of the Rockies Occasional Paper no. 3, p. 127–144.

Hill, T.P., Werner, M.A., and Horton, M.J., 1967, Chemical composition of sedimentary rocks in Colorado, Kansas, Montana, Nebraska, North Dakota, South Dakota, and Wyoming: U.S. Geological Survey Professional Paper 561, 241 p. [includes data from Bozeman 30′ x 60′ quadrangle].

Hoh, A.M., 1997, Gravity survey of a Cenozoic basin in Madison County, Montana, *in* Proceedings: Tenth Keck Research Symposium in Geology: The College of Wooster, Wooster, Ohio, p. 306–309.

Holland, F.D., Jr., 1952, Stratigraphic details of Lower Mississippian rocks of northeastern Utah and southwestern Montana: American Association of Petroleum Geologists Bulletin, v. 36, no. 9, p. 1697–1734.

Hughes, G.C., 1980, Tertiary stratigraphy and depositional history of the Dry Creek Valley, Gallatin County, Montana: Bozeman, Montana State University, M.S. thesis, 147 p.

Hughes, G.C., 1981, Tertiary stratigraphy and depositional history of the Cry [sic] Creek Valley, Montana, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 111–119.

Immega, I.P., and Klein, C., Jr., 1975, Mineralogy and petrology of some metamorphic Precambrian iron-formations in southwestern Montana: American Mineralogist, v. 61, p. 1117–1144.

Jacobs, A.M., 1969, Pleistocene proto-cirque hollows in the Cataract Creek Valley, Tobacco Root Mountains, Montana: Indiana University, Ph.D. dissertation, 95 p.

James, H.L., and Hedge, C.E., 1980, Age of the basement rocks of southwest Montana: Geological Society of America Bulletin, v. 91, p. 11–15.

James, W.C., 1977, Origin of nonmarine-marine transitional strata at the top of the Kootenai Formation, southwestern Montana: Bloomington, Indiana University, Ph.D. dissertation, 433 p.

Johns, W.M., Straw, T., Bergantino, R.N., Dresser, H.W., Hendrix, T.E., McClernan, H.G., Palmquist, J.C., and Schmidt, C.J., 1982, Neotectonic features of southern Montana east of 112°30’ west longitude: Montana Bureau of Mines and Geology Open-File Report MBMG 91, 79 p., 2 pls.

Johns, W.M., 1961, Geology and ore deposits of the southern Tidal Wave mining district, Madison County, Montana: Montana Bureau of Mines and Geology Bulletin 24, 53 p.

Johns, W.M., 1951, Description and geology of the Milligan Canyon area and the South Boulder section: Butte, Montana School of Mines*, B.S. thesis, 22 p.

Johns, W.M., Berg R.B., and Dresser, H.W., 1981, Road Log—Three Forks to Twin Bridges via U.S. Highways 10 and 287 and State Highway 287, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 388–391.

Johnson, K.E., Brady, J.B., MacFarlane, W.A., Thomas, R.B., Poulsen, C.J., Sincock, M.J., 2004, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p.71-87.

Jones, N.A., 1949, The Livingston Formation of the South Boulder area: Butte, Montana School of Mines*, B.S. thesis, 16 p.

Kavanagh, J., 1965, A study of selected igneous bodies of the Norris-Red Bluff area, Madison County, Montana: Bozeman, Montana State University, M.S. thesis, 60 p.

Kellogg, K.S., 1994, Geologic map of the Norris quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-1738, scale 1:24,000.

Kellogg, K.S., 1995, Geologic map of the Beartrap Creek quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map-1757, scale 1:24,000.

Kellogg, K.S., Schmidt, C.J., and Young, S.W., 1995, Basement and cover-rock deformation during Laramide contraction in the northern Madison Range (Montana) and its influence on Cenozoic basin formation: American Association of Petroleum Geologists Bulletin, v. 79, no. 8, p. 1117–1137.

Kellogg, K.S., and Vuke, S.M., 1996, Geologic map of the Willow Creek Reservoir and Norris NE quadrangles, Gallatin and Madison Counties, Montana: U.S. Geological Survey Open-File Report 96-012, scale 1:24,000.

Kellogg, K.S., and Williams, V.S., 2000, Geologic map of the Ennis 30′ x 60′ quadrangle, Madison and Gallatin Counties, Montana, and Park County, Wyoming: U.S. Geological Survey Geologic Investigations Map I-2690, scale 1:100,000.

Kendall, T.K., Miller, D.R., and Woodward, L.A., 1993, Field Trip—Mineral Hill Mining District Road Log, *in* Childs, J.F., and Lageson, D.R., eds., Economic and Regional Geology of the Tobacco Root-Boulder Batholith region, Montana: Tobacco Root Geological Society, 18th Annual Field Conference, Northwest Geology, v. 22, p. 119–129.

Kinley, T.M., 1987, The occurrence and timing of gold mineralization at the Red Pine mine, western Tobacco Root Mountains, southwestern Montana: Bozeman, Montana State University, M.S. thesis, 129 p.

Kittel, D.F., 1950, Basic sills in Cottonwood Creek Canyon, Jefferson County, Montana: Butte, Montana School of Mines*, B.S. thesis, 21 p.

Klemme, H.D., 1949, The geology of Sixteen Mile Creek area, Montana: Princeton, N.J., Princeton University, Ph.D. dissertation, 197 p.

Klepper, M.R., Weeks, R.Z., and Ruppel, E.T., 1957, Geology of the southern Elkhorn Mountains, Jefferson and Broadwater Counties, Montana: U.S. Geological Survey Professional Paper 292, 82 p.

Koehler, S.W., 1976, Petrology of the diabase dikes of the Tobacco Root Mountains, Montana, *in* Lankston, M.M., ed., Tobacco Root Geological Society, Field Conference Guidebook: Montana Bureau of Mines and Geology Special Publication 73, p. 27–35.

Kolodziejski, K.D., 1997, Gravity and seismic refraction survey of the contact between Cenozoic deposits and Archean bedrock in the Willow Creek watershed, Madison County, Montana, *in* Proceedings: Tenth Keck Research Symposium in Geology Proceedings, p. 310–313.

Kozak, S.J., 1961, Structural geology of the Cherry Creek basin area, Madison County, Montana: Iowa City, Iowa University, Ph.D. dissertation, 136 p.

Krogh, T.E., Kamo, S.L., Hanley, T.B., Hess, D.F., Dahl, P.S., and Johnson, R.E., 2011, Geochronology and geochemistry of Precambrian gneisses, metabasites, and pegmatite from the Tobacco Root Mountains, northwestern Wyoming craton, Montana: Canadian Journal of Earth Sciences, v. 48, p. 161–185.

Krothe, N.C., and Bergeron, M.P., 1981, The relationship between fracture traces and joints in a Tertiary basin, southwest Montana: Ground Water, v. 19, no. 2, p. 138–143.

Kulik, D.M., and Schmidt, C.J., 1988, Region of overlap and styles of interaction of Cordilleran Thrust Belt and Rocky Mountain Foreland, *in* Schmidt, C.J., and Perry, W.J., Interaction of the Rocky Mountain Foreland and the Cordilleran Thrust Belt: Geological Society of America Memoir 171, p. 75–98.

Kuenzi, W.D., 1966, Tertiary stratigraphy in the Jefferson River Basin, Montana: Missoula, University of Montana, Ph.D. dissertation, 293 p.

Kuenzi, W.D., and Fields, R.W., 1971, Tertiary stratigraphy, structure, and geologic history, Jefferson Basin, Montana: Geological Society of America Bulletin, v. 82, p. 3373–3394.

Kuenzi, W.D., and Richard, B.H., 1969, Middle Tertiary unconformity, North Boulder and Jefferson Basins, southwest Montana: Geological Society of America Bulletin, v. 80, p. 315.

Lageson, D.R., 1992, Structural analysis of the Horseshoe Hills transverse fold-thrust zone, Gallatin County, Montana: a preliminary report, *in* Elliott, J.E., ed., Guidebook for the Red Lodge-Beartooth Mountains-Stillwater Area: Tobacco Root Geological Society 17th Annual Field Conference Guidebook, Northwest Geology, v. 20/21, p. 117–124.

Lageson, D.R., 1989, Reactivation of a Proterozoic continental margin, Bridger Range, southwestern Montana, *in* French, D.E., and Grabb, R.F., eds., Geological Resources of Montana, volume I: Montana Geological Society Field Conference Guidebook, Centennial Edition, p. 279–298.

Lageson, D.R., and Montagne, J., 1981, Geologic road log—Dillon to Three Forks, Montana, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society Field Conference and Symposium Guidebook, p. 399–406.

Lageson, D.R., Schmidt, C.J., Dresser, H.W., Welker, M., Berg, R.B., and James, H.L., 1983, Road Log—Helena to Bozeman via MacDonald Pass, Garrison, Deer Lodge, Butte, Homestake Pass, Jefferson Canyon, and Three Forks, *in* Smith, D.L., ed., Guidebook of the Fold and Thrust Belt, west-central Montana: Montana Bureau of Mines and Geology Special Publication 86, p. 33–82.

Lamberton, H.M., III, 1948, Structure and stratigraphy near Whitehall, Montana: Princeton, N.J., Princeton University, B.S. thesis, 83 p.

Lange, I.M., Fields, R.W., Fountain, D.M., Moore, J.N., Qamar, A.I., Silverman, A.J., Thompson, G.R., Chadwick, R.A., Custer, S.G., and Smith, D.L., 1980, National uranium resource evaluation, Bozeman quadrangle, Montana: prepared for U.S. Department of Energy, Grand Junction, CO, 87 p.

Lewis, S.E., 1988, Field guide to mesoscopic features in the LaHood Formation, Jefferson River Canyon area, southwestern Montana, *in* Lewis, S.E., and Berg, R.B., eds., Precambrian and Mesozoic Plate Margins: Montana, Idaho, and Wyoming: Montana Bureau of Mines and Geology Special Publication 96, p. 155-158.

Lillegraven, J.A., and Tabrum, A.R., 1983, A new species of *Centetodon* (Mammalia, Insectivora, Geolabididae) from southwestern Montana and its biogeographical implications: Contributions to Geology, University of Wyoming, v. 22, no. 1, p. 57–73.

Lillis, H.E., 1942, Geologic field mapping eight miles north of Three Forks, Montana: Butte, Montana School of Mines*, B.S. thesis, 14 p.

Lindquist, A., 1966, Structure and mineralization of the Whitehall mining district, Jefferson County, Montana: Butte, Montana College of Mineral Science and Technology*, M.S. thesis, 104 p.

Lofgren, D.L., 1985, Tertiary vertebrate paleontology, stratigraphy, and structure, North Boulder River Basin, Jefferson County, Montana: Missoula, University of Montana, M.S. thesis, 113 p.

Lonn, J.D., 1993, Phanerozoic mineralization in the Tobacco Root Mountains, Madison County, Montana: a review, *in* Childs, J.F., and Lageson, D.R., eds., Economic and Regional Geology of the Tobacco Root-Boulder Batholith region, Montana: 18th Annual Field Conference, Tobacco Root Geological Society, Northwest Geology, v. 22, p. 5–7.

Lonn, J.D., and English, A.R., 2002, Preliminary geologic map of the eastern part of the Gallatin Valley, Montana: Montana Bureau of Mines and Geology Open-File Report 457, scale 1:48,000.

Lowell, Josh, 1994, Pieces of the puzzle: a metamorphic and deformational history of the Spuhler Peak Formation, Tobacco Root Mountains, Montana: Colorado Springs, Colorado College, 100 p.

Ludman, Alan, 1965, Geology of the Doherty igneous complex, Jefferson County, Montana: Bloomington, Indiana University, M.A. thesis, 48 p.

Marvin, R.F., 1952, Description and geologic history of selected areas in the vicinity of Gallatin Canyon, Gallatin County, Montana: Butte, Montana School of Mines*, M.S. thesis, 68 p.

Maughan, E.K., and Roberts, A.E., 1967, Big Snowy and Amsden Groups and the Mississippian-Pennsylvanian boundary in Montana: U.S. Geological Survey Professional Paper 554-B, 27 p.

May, K.A., 1985, Archean geology of a part of the northern Gallatin Range, southwest Montana: Bozeman, Montana State University, M.S. thesis, 91 p.

McBride, B.D., Schmidt, C.J., Guthrie, G.E., and Sheedlo, M.K., 1992, Multiple reactivation of a collisional boundary: An example from southwestern Montana, *in* Bartholomew, M.J., Hyndman, D.W., Mogk, D.W., and Mason, Robert, eds., Basement Tectonics 8–Characterization and comparison of ancient and Mesozoic continental margins: Proceedings of the Eighth International conference on basement tectonics held in Butte, Montana, USA, August 1988, Dordrecht/ Boston/ London, Kluwer Academic Publishers, p. 341-357.

McLane, M.J., 1971, Phanerozoic detrital rocks at the north end of the Tobacco Root Mountains, southwestern Montana: a vertical profile: Bloomington, Indiana University, Ph.D. dissertation, 253 p.

McMannis, W.J., 1952, Geology of the Bridger Range: Princeton, N.J., Princeton University, Ph.D. dissertation, 172 p.

McMannis, W.J., 1955, Geology of the Bridger Range, Montana: Geological Society of America Bulletin, v. 66, p. 1385–1430.

McMannis, W.J., 1960, Exit geologic road log: Ennis to Bozeman, *in* Campau, D.E. and Anisgard, H.W., eds, West Yellowstone—Earthquake area: Billings Geological Society 11th Annual Field Conference Guidebook, p. 312–313.

McMannis, W.J., 1962, Devonian stratigraphy between Three Forks, Montana and Yellowstone Park, *in* Billings Geological Society Guidebook, 13th Annual field Conference, p. 4–12.

McMannis, W.J., 1963, LaHood Formation—a coarse facies of the Belt Series in southwestern Montana: Geological Society of America Bulletin, v. 74, p. 407–436.

McMannis, W.J., 1965, Résumé of depositional and structural history of western Montana: American Association of Petroleum Geologists Bulletin, v. 49, no. 11, p. 1802–1823.

McNamee, R.C., 1938, Study and correlation of Belt and Cambrian arkoses near Limespur, Montana: Butte, Montana School of Mines*, B.S. thesis, 14 p.

McThenia, A.W., Jr., 1960, Geology of the Madison River Canyon area north of Ennis, Montana, *in* Campau, D.E., and Anisgard, H.W., eds., West Yellowstone—earthquake area: Billings Geological Society, 11th Annual Field Conference Guidebook, p. 155–164.

Meyers, J.H., 1980, Tidal-flat carbonates of the Maywood Formation (Frasnian) and the Cambrian-Devonian unconformity, southwestern Montana, *in* Fouch, T.D., and Magathan, E.R., eds., Paleozoic Paleogeography of the west-central United States, Rocky Mountain Paleogeography Symposium 1: Rocky Mountain Section, Society of Economic Paleontologists and Mineralogists, p. 39–54.

Meyers, J.H., 1981, Carbonate sedimentation in the Ellis Group (Jurassic) on the southern flank of Belt Island, southwestern Montana: *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 83–91.

Meyers, S.A., 1991, Structural analysis of the Upper Hot Springs Mining District, Madison County, Montana: Moscow, University of Idaho, 153 p.

Mifflin, M.D., 1963, Geology of a part of the southern margin of the Gallatin Valley, southwestern Montana: Bozeman, Montana State University, M.S. thesis, 111 p.

Miller, E.W.B., 1987, Laramide basement deformation in the northern Gallatin Range and southern Bridger Range, southwest Montana: Bozeman, Montana State University, M.S. thesis, 78 p.

Miller, E.W., and Lageson, D.R., 1993, Influence of basement foliation attitude on geometry of Laramide basement deformation, southern Bridger Range and northern Gallatin Range, Montana, *in* Schmidt, C.J., Chase, R.B., and Erslev, E.A., eds., Laramide basement deformation in the Rocky Mountain foreland of the western United States: Geological Society of America Special Paper 280, p. 73–88.

Mitchell, M.M., 1987, Geometric and mesofabric analysis of the Hossfeldt Anticline-Eustis Syncline and the Lombard thrust zone near Three Forks, southwestern Montana: Knoxville, University of Tennessee, M.S. thesis, 160 p.

Mitchell, M.M., and Woodward, N.B., 1988, Kink detachment fold in the southwest Montana Fold and Thrust Belt: Geology, v. 16, p. 162–165.

Mogk, D.W., Burger, H.R., Mueller, P.A., D’Arcy, Kimberly, Heatherington, A.L., Wooden, J.L., Abeyta, R.L., Martin, Jennifer, and Jacob, L.J., 2004, Geochemistry of quartzofeldspathic gneisses and metamorphic mafic rocks of the Indian Creek and Pony-Middle Mountain Metamorphic Suites, Tobacco Root Mountains, Montana, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p. 15-46.

Mogk, D.W., and Henry, D.J., 1988, Metamorphic petrology of the northern Archean Wyoming province, southwestern Montana: evidence for Archean collisional tectonics, *in* Ernst, W.G., ed., Metamorphism and crustal evolution of the western United States (Rubey Volume VII): Englewood Cliffs, New Jersey, Prentice Hall, p. 362–382.

Montagne, J.M., and Chadwick, R.A., 1976, Road log from Bozeman to Specimen Creek via Gallatin Canyon and U.S. 191, *in* Lankston, M.M., ed., Tobacco Root Geological Society, Field Conference Guidebook: Montana Bureau of Mines and Geology Special Publication 73, p. 38–52.

de la Montagne, J.M., 1960, Geomorphic problems in the Madison Valley, Madison County, Montana: An introduction and synthesis, *in* Campau, D.E., and Anisgard, H.W., West Yellowstone—Earthquake area: Billings Geological Society 11th Annual Field Conference Guidebook, p. 165–169.

de la Montagne, J.M, and six others, 1960, Preliminary geomorphic map of the Madison Valley, Montana (showing Recent tectonic features), *in* Campau, D.E., and Anisgard, H.W., West Yellowstone—Earthquake area: Billings Geological Society, 11th Annual Field Conference Guidebook, Plate 1.

Moore, B.K., 1984, Controls on ground-water availability and quality in the Bridger Canyon area: Bozeman, Montana State University, M.S. thesis, 187 p.

Moore, G.T., 1954, Intrusions in the Middle Cambrian formations, Cottonwood Canyon, Jefferson County, Montana: Bloomington, Indiana University, M.A. thesis, 45 p.

Morgan, W.T., and Hall, R.D., 1982, Pediments in the North Boulder River Basin, southwestern Montana: American Quaternary Association program and Abstracts, University of Washington, Seattle, p. 143.

Moritz, C.A., 1951, Triassic and Jurassic stratigraphy of southwestern Montana: American Association of Petroleum Geologists Bulletin, v. 35, p. 1781–1814.

Mueller, P.A., Burger, H.R., Wooden, J.L., Heatherington, A.L., Mogk, D.W., and D’Arcy, Kimberly, 2004, Age and evolution of the Precambrian crust of the Tobacco Root Mountains, Montana, *in* Brady, J.B., Burger, H.R., Cheney, J.T., and Harms, T.A., eds., Precambrian geology of the Tobacco Root Mountains, Montana: Geological Society of America Special Paper 377, p. 181-202.

Mueller, P.A., Heatherington, A.L., D'Arcy, K.A., Wooden, J.L., and Nutman, A.P., 1996, Contrasts between Sm-Nd whole-rock and U-Pb zircon systematics in the Tobacco Root Batholith, Montana: implications for the determination of crustal age provinces: Tectonophysics, v. 265, p. 169–179.

Neibaur, H., 1940, A geological report on an area five miles southeast of Renova, Montana, and on an area seven miles south of Jefferson Island, Montana: Butte, Montana School of Mines*, M.S. thesis, 25 p.

Nelson, W.L., 1962, A seismic study of North Boulder Valley and other selected areas, Jefferson and Madison Counties, Montana: Bloomington, Indiana University, M.S. thesis, 32 p.

Nichols, Ralph, Tabrum, A.R., and Hill, C.L., 2001, Introduction: Cenozoic mammals, southwest Montana, *in* Nichols, R., ed., Cenozoic vertebrate paleontology and geology of southwestern Montana and adjacent areas, *in* Hill, C.L., ed., Mesozoic and Cenozoic paleontology in the western plains and Rocky Mountains: Society of Vertebrate Paleontology 61st annual field trip guidebook, Museum of the Rockies Occasional Paper no. 3, p. 79–81.

Nichols, T.L., 1989, Resistivity and seismic refraction exploration for ground water near Bozeman, Gallatin County, Montana: Butte, Montana College of Mineral Science and Technology*, M.S. thesis, 104 p.

O'Neill, J.M., 1993, The Great Falls tectonic zone, Montana-Idaho: an Early Proterozoic collisional orogen beneath and south of the Belt Basin, *in* Berg, R.B., ed., Belt Symposium III: Montana Bureau of Mines and Geology Special Publication 112, p. 222–228.

O'Neill, J.M., 1983, Geologic map of the Middle Mountain-Tobacco Root Roadless Area, Madison County, Montana: U.S. Geological Survey Map MF-1590-A, scale 1:50,000.

O'Neill, J.M., and Cather, E.E., 1984, Middle Mountain-Tobacco Root Roadless Area, Montana, *in* Marsh, S.P., Kropschot, S.J., and Dickinson, R.J., Wilderness mineral potential, assessment of mineral-resource potential in U.S. Forest Service lands studied 1964-1984, v. 2, p. 721–723.

O'Neill, J.M., Schmidt, C.J., and Genovese, P.W., 1990, Dillon cutoff—basement-involved tectonic link between the Disturbed Belt of west-central Montana and the Overthrust Belt of extreme southwestern Montana: Geology, v. 18, p. 1107–1110.

Orr, J.B., 1958, The Tertiary of western Montana, *in* 8th Annual Field Conference Guidebook: Society of Vertebrate Paleontology, p. 25–33.

Qamar, Anthony, and Hawley, Bronson, 1979, Seismic activity near the Three Forks Basin, Montana: Bulletin of the Seismological Society of America, v. 69, no. 6, p. 1917–1929.

Paine, M.H., 1970, A reconnaissance study of the gastropod limestone (Lower Cretaceous) in southwest Montana: Bloomington, Indiana University, M.A. thesis, 124 p.

Pardee, J.T., 1950, Late Cenozoic block faulting in western Montana: Geological Society of America Bulletin, v. 61, p. 356–406.

Parker, J.S., 1961, A preliminary seismic investigation of Tertiary basin fill in the Jefferson Island quadrangle, Montana: Bloomington, Indiana University, M.S. thesis, 35 p.

Paull, R.A., Paull, R.K., and Kraemer, B.R., 1989, Depositional environments of Lower Triassic rocks in southwestern Montana and adjacent parts of Wyoming and Idaho: *in* French, D.E., and Grabb, R.F., eds., Geologic Resources of Montana: Montana Geological Society, Field Conference Guidebook: Montana Centennial Edition, p. 69–90.

Peale, A.C., 1896, Three Forks Folio, no. 24: U.S. Geological Survey Atlas.

Peale, A.C., and Merrill, G.P, 1893, The Paleozoic section in the vicinity of Three Forks, Montana: U.S. Geological Survey Bulletin 110, 56 p.

Perry, E.S., 1950, Highlights of geology between Three Forks and Whitehall: Billings Geological Society, 1st Annual Field Conference Guidebook, p. 56–59.

Peterson, J.A., 1972, Permian sedimentary facies, southwestern Montana, *in* Lynn, J., Balster, C., and Warne, J., eds., Crazy Mountains Basin: Montana Geological Society, 21st Annual Field Conference Guidebook, p. 69–74.

Petricca, A.M., 1985, Sedimentology and diagenesis of the interbedded carbonate and siliciclastic rocks of the Big Snowy, Amsden, and Quadrant Formations, Tobacco Root Mountains region, southwestern Montana: Bloomington, Indiana University, M.S. thesis, 160 p.

Peugh, S.K., 1997, Gravity and seismic refraction survey of Cenozoic deposits in the Willow Creek watershed and the region surrounding Harrison, southwest Montana, *in* Proceedings: Tenth Keck Research Symposium in Geology, Colorado Springs, The Colorado College, p. 318–321.

Porter, E.W., and Ripley, E.M., 1985, Petrologic and stable isotope study of the gold-bearing breccia pipe at the Golden Sunlight deposit, Montana: Economic Geology, v. 80, p. 1689–1706.

Precht, W.F., and Shepard, W.W., 1989, Waulsortian carbonate buildups of Mississippian age from Montana and relations to rifting, *in* French, D.E., and Grabb, R.F., eds., Geologic Resources of Montana: Montana Geological Society Field Conference Guidebook: Centennial Edition, p. 65–68.

Rambosek, A.F., 1946, Geology and ore deposits of the Golden Sunlight mine and vicinity: Butte, Montana School of Mines*, M.S. thesis, 28 p.

Reid, R.R., 1957, Bedrock geology of the north end of the Tobacco Root Mountains, Madison County, Montana: Montana Bureau of Mines and Geology Memoir 36, 68 p.

Reid, R.R. 1963, Metamorphic rocks of the northern Tobacco Root Mountains, Madison County, Montana: Geological Society of America Bulletin, v. 74, p. 293–306.

Reid, S.K., and Dorobek, S.L., 1989, Application of sequence stratigraphy in the Mississippian Mission Canyon Formation and stratigraphic equivalents, southwestern Montana and east-central Idaho, *in* French, D.E., and Grabb, R.F., eds., Geologic Resources of Montana: Montana Geological Society Field Conference Guidebook: Centennial Edition, p. 47–53.

Reiter, F.H., 1962, The geology of a portion of the Manhattan quadrangle, the Horseshoe Hills area, Gallatin County, Montana: Ann Arbor, University of Michigan, M.S. thesis, 46 p.

Reshkin, M., 1963, Geomorphic history of the Jefferson Basin, Jefferson, Madison, Silver Bow Counties, Montana: Bloomington, Indiana University, Ph.D. dissertation, 146 p.

Reyner, M.L., 1947, Geology of the Tidal Wave district, Madison County, Montana: Butte, Montana School of Mines*, M.S. thesis, 27 p.

Richard, B.H., 1966, Geologic history of the intermontane basins of the Jefferson Island quadrangle, Montana: Bloomington, Indiana University, Ph.D. dissertation, 121 p.

Robinson, G.D., 1960, Middle Tertiary unconformity in southwestern Montana: U.S. Geological Survey Professional Paper 400-B, Article 101, p. B227–B228.

Robinson, G.D, 1961, Origin and development of the Three Forks basin, Montana: Geological Society of America Bulletin, v. 72, p. 1003–1014.

Robinson, G.D., 1963, Geology of the Three Forks quadrangle, Montana: U.S. Geological Survey Professional Paper 370, 143 p.

Robinson, G.D., 1967, Geologic map of the Toston quadrangle, southwestern Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-486, scale 1:24,000.

Robinson, G.D., Klepper, G.C., and Obradovich, J.D., 1968, Overlapping plutonism, volcanism, and tectonism in the Boulder Batholith region, western Montana, *in* Coats, R.R., Hay, R.L., and Anderson, C.A., eds., Studies in volcanology: Geological Society of America Memoir 116 p. 557–576.

Robinson, G.D., and Marvin, R.F., 1967, Upper Cretaceous volcanic glass from western Montana: Geological Society of America Bulletin, v. 78, p. 601–608.

Root, F., 1965, Structure, petrology and mineralogy of pre-Beltian metamorphic rocks of the Pony-Sappington area, Madison County, Montana: Bloomington, Indiana University, Ph.D. dissertation, 230 p.

Rothfuss, J.L., 2007, Alluvial facies of the Eocene Red Hill map unit of the Renova Formation in context of Cenozoic paleotopography and extensional tectonism in southwestern Montana: Allegeny, Pennsylvania, Allegheny College, Senior Comprehensive Project, 74 p.

Rothfuss, J.L., 2012, Application of detrital zircon provenance in paleogeographic reconstruction of an intermontane basin system, Paleogene Renova Formation, southwest Montana: Geological Society of America Special Paper 487, p. 63-95.

Roy, W.R., 1980, Glacial geology of the South Boulder Valley, Tobacco Root Range, Montana: Bloomington, Indiana University, M.S. thesis, 163 p.

Roy, W.R., and Hall, R.D., 1981, Glacial geology of the South Boulder Valley, Tobacco Root Range, Montana: *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society Field Conference and Symposium Guidebook, p. 125–132.

Ruppel, E.T., 1982, Cenozoic block uplifts in southwest Montana and east-central Idaho: U.S. Geological Survey Professional Paper 1224, 24 p.

Ruppel, E.T., 1993, Cenozoic tectonic evolution of southwest Montana and east-central Idaho: Montana Bureau of Mines and Geology Memoir 65, 62 p.

Ruleman, C.A., III, 2002, Quaternary tectonic activity within the northern arm of the Yellowstone tectonic parabola and associated seismic hazards, southwest Montana: Bozeman, Montana State University, M.S. thesis, 158 p.

Rutland, Carolyn, 1985, Geochemistry of the Elkhorn Mountains Volcanics, southwestern Montana: East Lansing, Michigan State University, Ph.D. dissertation, 96 p.

Sagar, Joe, and Childs, John, 1993, Field Trip—Maltbys Mound, *in* Childs, J.F., and Lageson, D.R., eds., Economic and Regional Geology of the Tobacco Root-Boulder Batholith region, Montana: Tobacco Root Geological Society, 18th Annual Field Conference: Northwest Geology, v. 22, p. 103–116.

Sahinen, U.M., 1939, Geology and ore deposits of the Rochester and adjacent mining districts, Madison County, Montana: Montana Bureau of Mines and Geology Memoir 19, 53 p.

Salt, K.J., 1987, Archean geology of the Spanish Peaks area, southwestern Montana: Bozeman, Montana State University, M.S. thesis, 81 p.

Samuelson, K.J., and Schmidt, C.J., 1981, Structural geology of the western Tobacco Root Mountains, southwestern Montana, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 191–199.

Sandberg, C.A., 1962, Stratigraphic section of type Three Forks and Jefferson Formations at Logan, Montana, *in* Billings Geological Society Guidebook, 13th Annual Field Conference, p. 47–50.

Sandberg, C.A., 1965, Nomenclature and correlation of lithologic subdivisions of the Jefferson and Three Forks Formations of southern Montana and northern Wyoming: U.S. Geological Survey Bulletin 199, p. N1–N18.

Sandberg, C.A., and McMannis, W.J., 1964, Occurrence and paleogeographic significance of the Maywood Formation of Late Devonian age in the Gallatin Range, southwestern Montana: U.S. Geological Survey Professional Paper 501-C, p. C50–C54.

Sando, W.J., 1990, HUM Lithosome: An example of regional stratigraphic synthesis in the Mississippian of the Western Interior of the United States: U.S. Geological Survey Bulletin 1881, p. E1–E17.

Sando, W.J, and Dutro, J.T., Jr., 1960, Stratigraphy and coral zonation of the Madison Group and Brazer Dolomite in northeastern Utah, western Wyoming, and southwestern Montana, *in* Wyoming Geological Association 15th Annual Field Conference Guidebook, p. 117–126.

Sando, W.J., Sandberg, C.A., and Perry, W.J., Jr., 1985, Revision of Mississippian stratigraphy, northern Tendoy Mountains, southwest Montana, *in* Sando, W.J., ed., Mississippian and Pennsylvanian Stratigraphy in southwest Montana and adjacent Idaho: U.S. Geological Survey Bulletin 1656, p. A1–A5.

Saterdal, A., 1945, Vermiculite, occurrence, character, and concentration of minerals from the Pony District, Madison County, Montana: Butte, Montana School of Mines*, B.S. thesis, 5 p.

Sayers, F.E., 1962, The geology of a portion of the Manhattan quadrangle, the Horseshoe Hills area, Gallatin County, Montana: Santa Barbara, University of California, M.S. thesis, 61 p.

Schmidt, C.J., 1975, An analysis of folding and faulting in the northern Tobacco Root Mountains, southwest Montana: Bloomington, Indiana University, Ph.D. dissertation, 480 p.

Schmidt, C.J., 1976, Structural development of the Lewis and Clark Caverns State Park area, southwest Montana, *in* Lankston, M.M., ed., Tobacco Root Geological Society, Field Conference Guidebook: Montana Bureau of Mines and Geology Special Publication 73, p. 141–150.

Schmidt, C.J., 1979, Discussion of origin of west-directed thrusts on the east flank of the Negro Hollow syncline, Jefferson County, Montana, *in* Suttner, L.J., ed., Near surface batholiths, related volcanism, tectonism, sedimentation, and mineral deposition: Geological Society of America, Granite II Penrose Conference Guidebook, p. 84–91.

Schmidt, C.J., 1988, Comment and reply on "Kink detachment fold in the southwest Montana fold and thrust belt": Geology, v. 16, p. 1052–1055.

Schmidt, C.J., Aram, Richard, and Hawley, David, 1987, The Jefferson River Canyon area, southwestern Montana, *in* Beus, S., ed.: Geological Society of America, Centennial Field Guide-Rocky Mountain Section, p. 63–68.

Schmidt, C.J., Evans, J.P., and Douglas, B., 1991, Pull apart origin for the Tobacco Root Batholith, southwestern Montana: Geological Society of America, Abstracts with Programs, Rocky Mountain Section, v. 23, no. 4, p. 90.

Schmidt, C.J., and Garihan, J.M., 1983, Role of recurrent movement of northwest-trending basement faults in the tectonic evolution of southwestern Montana, *in* Lowell, J., ed., Rocky Mountain foreland basins and uplifts: Rocky Mountain Association of Geologists, p. 271–294.

Schmidt, C.J., and Garihan, J.M., 1986a, Middle Proterozoic and Laramide tectonic activity along the southern margin of the Belt Basin, *in* Roberts, S.M., ed., Belt Supergroup—A guide to Proterozoic rocks of western Montana and adjacent areas: Montana Bureau of Mines and Geology Special Publication 94, p. 217–235.

Schmidt, C.J., and Garihan, J.M., 1986b, Role of recurrent movement of northwest-trending basement faults in the tectonic evolution of southwestern Montana, *in* Alderich, M.J., and Laughlin, R., eds.: Proceedings of the 6th International Conference on Basement Tectonics, p. 1–15.

Schmidt, C.J., and Geiger, Beth, 1985, Nature of deformation in foreland anticlines and impinging thrust belt: Tobacco Root and southern Highland Mountains, Montana: Tobacco Root Geological Society, 10th Annual Field Conference Guidebook, p. 41–65.

Schmidt, C.J., Genovese, P.W., and Chase, R.B., 1993, Role of basement fabric and cover-rock lithology on the geometry and kinematics of twelve folds in the Rocky Mountain foreland, *in* Schmidt, C.J., Chase, R.B., and Erslev, E.A., eds., Laramide basement deformation in the Rocky Mountain foreland of the western United States: Geological Society of America Special Paper 280, p. 1-44.

Schmidt, C.J., Genovese, P.W., and Foster, Fess, 1989, Road Log—Structure and economic geology along the transverse thrust zone of southwestern Montana, *in* French, D.E., and Grabb, R.F., eds., Geologic Resources of Montana: Montana Geological Society Field Conference Guidebook: Centennial Edition, p. 482–501.

Schmidt, C.J., and Hendrix, T.E., 1981, Tectonic controls for thrust Belt and Rocky Mountain foreland structures in the northern Tobacco Root Mountains–Jefferson Canyon area, southwestern Montana, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 167–180.

Schmidt, C.J., James, C., and Shearer, J., 1981, Estimate of displacement in major zone of tear-thrusting in the Fold and Thrust Belt, southwest Montana: American Association of Petroleum Geologists Bulletin, v. 65, p. 986–987.

Schmidt, C.J., and O'Neill, J.M., 1982, Structural evolution of the Southwest Montana Transverse Zone, *in* Powers, R.B., ed., Geologic studies of the Cordilleran Thrust Belt: Rocky Mountain Association of Geologists field guidebook, v. 1, p. 193–218.

Schmidt, C.J., O'Neill, J.M., and Brandon, W.C., 1988, Influence of Rocky Mountain foreland uplifts on the development of the frontal fold and thrust belt, southwestern Montana, *in* Schmidt, C.J., and Perry, W.J., Jr., eds., Interaction of the Rocky Mountain foreland and the Cordilleran thrust belt: Geological Society of America Memoir 171, p. 171–201.

Schmidt, C.J., Smedes, H.W., and O'Neill, J.M., 1990, Syncompressional emplacement of the Boulder and Tobacco Root Batholiths (Montana–USA) by pull-apart along old fault zones: Geological Journal, v. 25, p. 305–318.

Schmitt, J.G., 1988, Sedimentation and tectonic setting of the middle Proterozoic LaHood Formation, Belt Supergroup, southwestern Montana, *in* Lewis, S.E., and Berg, R.B., eds., Precambrian and Mesozoic Plate Margins: Montana, Idaho, and Wyoming: Montana Bureau of Mines and Geology Special Publication 96, p. 89–96.

Schmitt, J.G., Haley, J.C., Lageson, D.R., Horton, B.K., Azevedo, P.A., 1995, Sedimentology and tectonics of the Bannack-McKnight Canyon-Red Butte area, southwest Montana: new perspectives on the Beaverhead Group and Sevier Orogenic Belt, [includes road logs—Bozeman to Three Forks, and Three Forks to Whitehall], *in* Mogk, D.W., ed., Field Guide to Geologic Excursions in southwest Montana: Northwest Geology, v. 24, p. 245–313.

Schneider, G.B., 1970, Cenozoic geology of the Madison Bluffs area, Gallatin County, Montana: Bozeman, Montana State University, M.S. thesis, 56 p.

Scholten, R., and Hait, M.H., Jr., 1962, Devonian System from shelf edge to geosyncline, southwestern Montana-central Idaho, *in* Montana Geological Society 13th Annual Field Conference Guidebook, p. 13–22.

Schwartz, R.K., 1972, Stratigraphic and petrographic analysis of the Lower Cretaceous Blackleaf Formation, southwestern Montana: Bloomington, Indiana University, Ph.D. dissertation, 268 p.

Schwartz, R.K., 1982, Broken Early Cretaceous foreland basin in southwestern Montana: sedimentation related to tectonism, *in* Blake, R., ed., Geologic Studies of the Cordilleran Thrust Belt: Rocky Mountain Association of Geologists, Field Guidebook v. 1, p. 159–183.

Schwartz, R.K., and DeCelles, P.G., 1988, Cordilleran foreland basin evolution in response to interactive Cretaceous thrusting and foreland portioning, southwestern Montana, *in* Schmidt, C.J., and Perry, W.J., Jr., eds., Interaction of the Rocky Mountain Foreland the Cordilleran Thrust Belt: Geological Society of America Memoir 171, p. 489-513.

Schwartz, T.M., and Schwartz, R.K., 2013, Paleogene postcompressional intermontane basin evolution along the frontal Cordilleran fold-and-thrust belt of southwestern Montana: Geological Society of America Bulletin, v. 125, no. 5-6, p. 961-984.

Skeels, D.C., 1939, Structural geology of the Trail Creek-Canyon Mountain area, Montana: Journal of Geology, v. 47, p. 816–840.

Skipp, Betty, Lageson, D.R., and McMannis, W.J., 1999, Geologic map of the Sedan quadrangle, Gallatin and Park Counties, Montana: U.S. Geological Survey Geologic Investigation Map I-2634, version 2.0, scale 1:48,000 [adjacent to Bozeman 30′ x 60′ quadrangle].

Skipp, Betty, and Peterson, A.D., 1965, Geologic map of the Maudlow quadrangle, southwestern Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-452, scale 1:24,000 [adjacent to Bozeman 30′ x 60′ quadrangle].

Sloss, L.L., and Hamblin, R.H., 1942, Stratigraphy and insoluble residues of the Madison Group (Mississippian) of Montana: American Association of Petroleum Geologists, v. 26, p. 305–335.

Sloss, L.L., and Laird, W.M., 1947, Devonian System in central and northwestern Montana: American Association of Petroleum Geologists Bulletin, v. 31, no. 8, p. 1404–1430.

Sloss, L.L., and Moritz, C.A., 1951, Paleozoic stratigraphy of southwestern Montana: American Association of Petroleum Geologists Bulletin, v. 35, p. 2135–2169.

Smedes, H.W., 1966, Geology and igneous petrology of the northern Elkhorn Mountains, Jefferson and Broadwater Counties, Montana: U.S. Geological Survey Professional Paper 510, 116 p.

Smith, D.L., Welker, Molly, and students, 1995, Driving tour of the geology of the southeastern Gallatin Valley, Bridger Range, and western margin of the Crazy Mountains Basin, *in* Self-guided field trips near Bozeman, Montana: Geological Society of America-Rocky Mountain Section, 47th Annual Meeting Guidebook, p. 12–34.

Smith, J.L., 1970, Petrology, mineralogy, and chemistry of the Tobacco Root Batholith, Madison County, Montana: Bloomington, Indiana University, Ph.D. dissertation, 198 p.

Spahn, R.A., Jr. 1967, Geology of the southwestern Horseshoe Hills area, Gallatin County, Montana: Bozeman, Montana State University, 95 p.

Spry, P.G., Paredes, M.M., Foster, Fess, Truckle, Jack, and Chadwick, Tom, 1996, A genetic link between gold-silver telluride and porphyry molybdenum mineralization at the Golden Sunlight deposit, Whitehall, Montana: Fluid inclusion and stable isotope studies: Economic Geology, v. 91, p. 507–526.

Spry, P.G., Foster, Fess, and Chadwick, T.H., 1997, The mineralogy of the Golden Sunlight gold-silver telluride deposit, Montana, USA: Mineralogy and Petrology, v. 59, p 143–164.

Sonderegger, J.L., and Ohguchi, T., 1988, Irrigation related arsenic contamination of a thin, alluvial aquifer, Madison River Valley, Montana, U.S.A.: Springer Verlag, Environmental Geology and Water Science, v. 11, no. 2, p. 153–161.

Sterne, E.J., 1990, Using surface geology of folded thrusts to explore hidden, subsurface thrust packages; three examples from the Montana thrust belt: American Association of Petroleum Geologists Bulletin, v. 74, p. 1346.

Stickney, M.C., 1997, Seismic source zones in southwest Montana: Montana Bureau of Mines and Geology Open-File Report MBMG 366, 51 p.

Stickney, M.C., 1993, Seismicity of the Tobacco Root Mountains and surrounding region, Montana, *in* Childs, J.F. and Lageson, D.R., eds., Economic and Regional Geology of the Tobacco Root-Boulder Batholith region, Montana: Tobacco Root Geological Society, 18th Annual Field Conference, Northwest Geology, v. 22, p. 49–54.

Stickney, M.C., and Bartholomew, M.J., 1987, Seismicity and Quaternary faulting of the northern Basin and Range province, Montana and Idaho: Bulletin of the Seismological Society of America, v. 77, p. 1602–1625.

Stickney, M.C., and Lageson, D.R., 1999, The Nov. 6, 1997 M 3.7 Belgrade, MT earthquake: Unusual aspects and their implications to regional seismicity: Geological Society of America Abstracts with Programs, v. 31, no. 4, p. A-57.

Streeter, M.E., 1983, The geology of the southern Bull Mountain area, Jefferson County, Montana: Kalamazoo, Western Michigan University, M.S. thesis, 88 p.

Suttner, L.J., 1968a, Clay minerals in the Upper Jurassic-Lower Cretaceous Morrison and Kootenai Formations, southwestern Montana: Earth Science Bulletin, v. 1, p. 1–14.

Suttner, L.J., 1968b, Stratigraphic and petrographic analysis of Upper Jurassic-Lower Cretaceous Morrison and Kootenai Formations, southwest Montana: American Association of Petroleum Geologists Bulletin, v. 53, p. 1391–1410.

Suttner, L.J., Schwartz, R.K., and James, W.C., 1981, Late Mesozoic to Early Cenozoic foreland sedimentation in southwest Montana, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 93–103.

Sutton, J.F., 1977, Mammals of the Anceney local fauna (Late Miocene) of Montana: Lubbock, Texas Tech University, Ph.D. dissertation, 241 p.

Sutton, J.F., and Korth, W.W., 1995, Rodents (Mammalia) from the Barstovian (Miocene) Anceney local fauna, Montana: Annals Carnegie Museum 64, p. 267–314.

Tabrum, A.R., and Nichols, Ralph, 2001, Tertiary paleontology of southwest Montana and adjacent Idaho, *in* Nichols, R., ed., Cenozoic vertebrate paleontology and geology of southwestern Montana and adjacent areas, *in* Hill, C.L., ed., Mesozoic and Cenozoic paleontology in the western plains and Rocky Mountains: Society of Vertebrate Paleontology 61st annual field trip guidebook, Museum of the Rockies Occasional Paper no. 3, p. 88–112.

Talpt, Arthur, 1938, The Jefferson Canyon gypsum deposit: Butte, Montana School of Mines*, B.S. thesis, 22 p.

Tansley, W., Schafer, P.A., and Hart, L.H., 1933, A geological reconnaissance of the Tobacco Root Mountains, Madison County, Montana: Montana Bureau of Mines and Geology Memoir 9, 57 p.

Tendall, B.A., 1978, Mineralogy and petrology of Precambrian ultramafic bodies from the Tobacco Root Mountains, Madison County, Montana: Bloomington, Indiana University, M.S. thesis, 126 p.

Thomas, R.C., 1995, Cambrian mass extinction ("biomere") boundaries: a summary of thirty years of research, *in* Mogk, D.W., ed., Field guide to geologic excursions in southwest Montana: Rocky Mountain section, Geological Society of America Meeting, Northwest Geology, v. 24, p. 67–75.

Thomas, W.A., 2011, Cambrian-Devonian stratigraphy along the southwest Montana transverse zone and tectonic history of the Willow Creek fault system: Montana Bureau of Mines and Geology Geologic Map 55, 40 p., 1 sheet.

Thomas, W.A., Allen, J.L., Mars, J.C., McDowell, R.J., Azevedo, P.A., Buck, B.J., Corner, H.J., and Dodd, J.R., 1996, Willow Creek basement fault zone beneath the southwest Montana transverse zone: dormant during Cambrian-Devonian time: Mountain Geologist, v. 33, no. 4, p. 115–124.

Thomas, W.A., 1990, Controls on locations of transverse zones in thrust belts: Eclogae Geologicae Helvetiae, v. 83, p. 727–744.

Thompson, G.R., Fields, R.W., and Alt, David, 1982, Land-based evidence for Tertiary climatic variations: northern Rockies: Geology, v. 10, p. 413–447.

Thompson, G.R., Fields, R.W., and Alt, David, 1981, Tertiary paleoclimates, sedimentation patterns, and uranium distribution in southwestern Montana: *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 105–109.

Tilley, C.W., 1976, Geology of the Spanish Creek area, Madison and Gallatin Counties, Montana: Bozeman, Montana State University M.S. thesis, 111 p.

Tuck, L.K., Dutton, D.M., and Nimick, D.A., 1997, Hydrologic and water-quality data related to the occurrence of arsenic for areas along the Madison and Upper Missouri Rivers, southwestern and west-central Montana: U.S. Geological Survey Open-File Report 97-203, 124 p.

Tysdal, R.G., 1966, Geology of a part of the north end of the Gallatin Range, Gallatin County, Montana: Bozeman, Montana State University, M.S. thesis, 92 p.

Tysdal, R.G., 1986, Thrust faults and back thrusts in the Madison Range of southwestern Montana foreland: American Association of Petroleum Geologists Bulletin, v. 70, p. 360–376.

Tysdal, R.G., and Simons, F.S., 1985, Geologic map of the Madison roadless area, Gallatin and Madison Counties, Montana: U.S. Geological Survey Miscellaneous Map MF-1605-B, scale 1:96,000.

Verrall, Peter, 1955, Geology of the Horseshoe Hills area, Montana: Princeton, N.J., Princeton University, Ph.D. dissertation, 371 p.

Vice, D.H., 1982, A review of the thermal infrared imagery for the Jefferson River Survey, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 98, 69 p.

Vitaliano, C.J., and Cordua, W.S., 1979, Geologic map of the southern Tobacco Root Mountains, Madison County, Montana: Geological Society of America Map and Chart Series MC-31, scale 1:62,500.

Vitaliano, C.J., Kish, S.A., and Towell, D.G., 1976, K-Ar dates and Sr isotopic values for rocks of the Tobacco Root Batholith, southwestern Montana: Isochron/West, no. 28, p.13–15.

Vuke, S.M., 2003, Geologic map of western and northern Gallatin Valley, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 481, scale 1:100,000.

Vuke, S.M., 2006, Geologic map of the Cenozoic deposits of the lower Jefferson Valley, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 537, 41 p., 1 sheet, scale 1:50,000, 1:50,000.

Vuke, S.M., Lonn, J.D., Berg, R.B., Kellogg, K.S., 2002, Preliminary geologic map of the Bozeman 30′ x 60′ quadrangle, southwestern Montana: Montana Bureau of Mines and Geology: Open-File Report 469, 39 p., 1 sheet, scale 1:100,000.

Vuke, S.M., Coppinger, W.W., and Cox, B.E., 2004, Geologic map of Cenozoic deposits in the Upper Jefferson Valley, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 505, 35 p., scale 1:50,000.

Wagner, S.L., 1963, Effect of Laramide folding on previously folded Precambrian metamorphic rocks, Madison County, Montana: Bloomington, Indiana University, M.S. thesis, 27 p.

Wantland, D., 1951, Seismic investigations in connection with U.S. Geological Survey groundwater studies in the Gallatin River Valley, Montana: U.S. Bureau of Reclamation Geology Report no. G-115, 8 p.

Wardlaw, B.R., and Pecora, W.C., 1985, New Mississippian-Pennsylvanian stratigraphic units in southwest Montana and adjacent Idaho: U.S. Geological Society Bulletin 1656, p. B1–9.

Warne, J.R., Sterne, E.J., and Thompson, G.G., 1997, Road Log—From Livingston to Helena via Bridger Range, Lombard Thrust, Jefferson Canyon, Devils Fence Anticline, and Gates of the Mountains marina, *in* Sterne, E.J. and Warne, J.R., eds., Thrust Systems of the Helena Salient-Montana Thrust Belt: Montana Geological Society and Tobacco Root Geological Society Joint Field Conference Guidebook p. 13–35.

Weber, W.M., 1965, General geology and geomorphology of the Middle Creek area, Gallatin County, Montana: Bozeman, Montana State University, M.S. thesis, 86 p.

Werkema, M., Hendrix, T.E., and Schmidt, C.J., 1981, Analysis of the Sappington fault in the "J" structure, Jefferson County, Montana, *in* Tucker, T.E., ed., Southwest Montana: Montana Geological Society, Field Conference and Symposium Guidebook, p. 93–103.

Werner, A.V., 1994, Sedimentology of alpine debris-flow and talus deposits in Sacajawea Cirque, Bridger Range, Montana: Bozeman, Montana State University, M.S. thesis, 92 p.

Wilson, A.B., and Elliott, J.E., 1977, Geologic map of the western and northern parts of the Gallatin National Forest, south-central Montana: U.S. Geological Survey Geologic Investigation Map I-2584, scale 1:126,270.

Wilson, D.A., 1962, A seismic and gravity investigation of the North Boulder River and Jefferson River Valleys, Madison and Jefferson Counties, Montana: Bloomington, Indiana University, M.S. thesis, 43 p.

Wilson, M.C., and Davis, L.B., 1994, Late Quaternary stratigraphy, paleontology, and archaeology of the Sheep Rock Spring Site (24JF292), Jefferson County, Montana: Current Research in the Pleistocene, v. 11, p. 100–102.

Wilson, T.L., 1948, Karst Kamp asbestos deposits, Gallatin County, Montana: Butte, Montana School of Mines*, B.S. thesis, 17 p.

Winston, Don, 1986, Middle Proterozoic tectonics of the Belt Basin, western Montana and northern Idaho, *in* Roberts, S.M., ed, Belt Supergroup: a guide to Proterozoic rocks of western Montana and adjacent areas: Montana Bureau of Mines and Geology Special Publication 94, p. 245–257.

Wood, H.E., Jr., 1933, A fossil rhinoceros (*Diceratherium armatum*) from Gallatin County, Montana: U.S. National Museum Proceedings, v. 82, p. 1–4.

Wooden, J.L., Vitaliano, C.J., Koehler, S.W., and Ragland, P.C., 1978, The Late Precambrian mafic dikes of the southern Tobacco Root Mountains, Montana: Geochemistry, Rb-Sr geochronology, and relationship to Belt tectonics: Canadian Journal of Earth Sciences, v. 15, p. 467–473.

Woodward, L.A., 1983, Structural geology of the Helena salient: a synopsis, *in* Smith, D.L., Guidebook of the Fold and Thrust Belt, west-central Montana: Montana Bureau of Mines and Geology Special Publication 86, p. 83-87.

Woodward, L.A., Miller, D.R., and Kendall, T.K., 1993, Geology and ore deposits of the Mineral Hill Mining District, Madison County, Montana, *in* Childs, J.F., and Lageson, D.R., eds., Economic and Regional Geology of the Tobacco Root-Boulder Batholith region, Montana: Tobacco Root Geological Society, 18th Annual Field Conference, Northwest Geology, v. 22, p. 9–17.

Young, S.W., 1985, Structural history of the Jordan Creek area, northern Madison Range, Madison County, Montana: Austin, University of Texas, M.S. thesis, 112 p.

Zen, E-an, 1977, Fault connections in southwestern Montana: U.S. Geological Survey Professional Paper 1050, p. 66–67.

Zietz, Isidore, 1960, Configuration of the 10N pluton, Three Forks, Montana: U.S. Geological Survey Professional Paper 400-B, p. B229–230.

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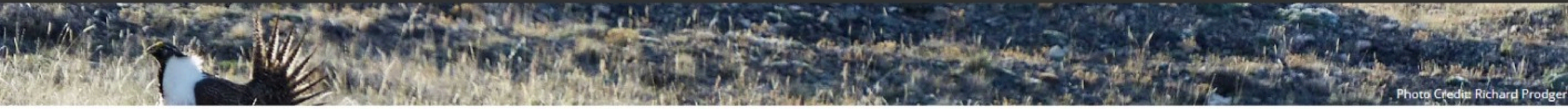
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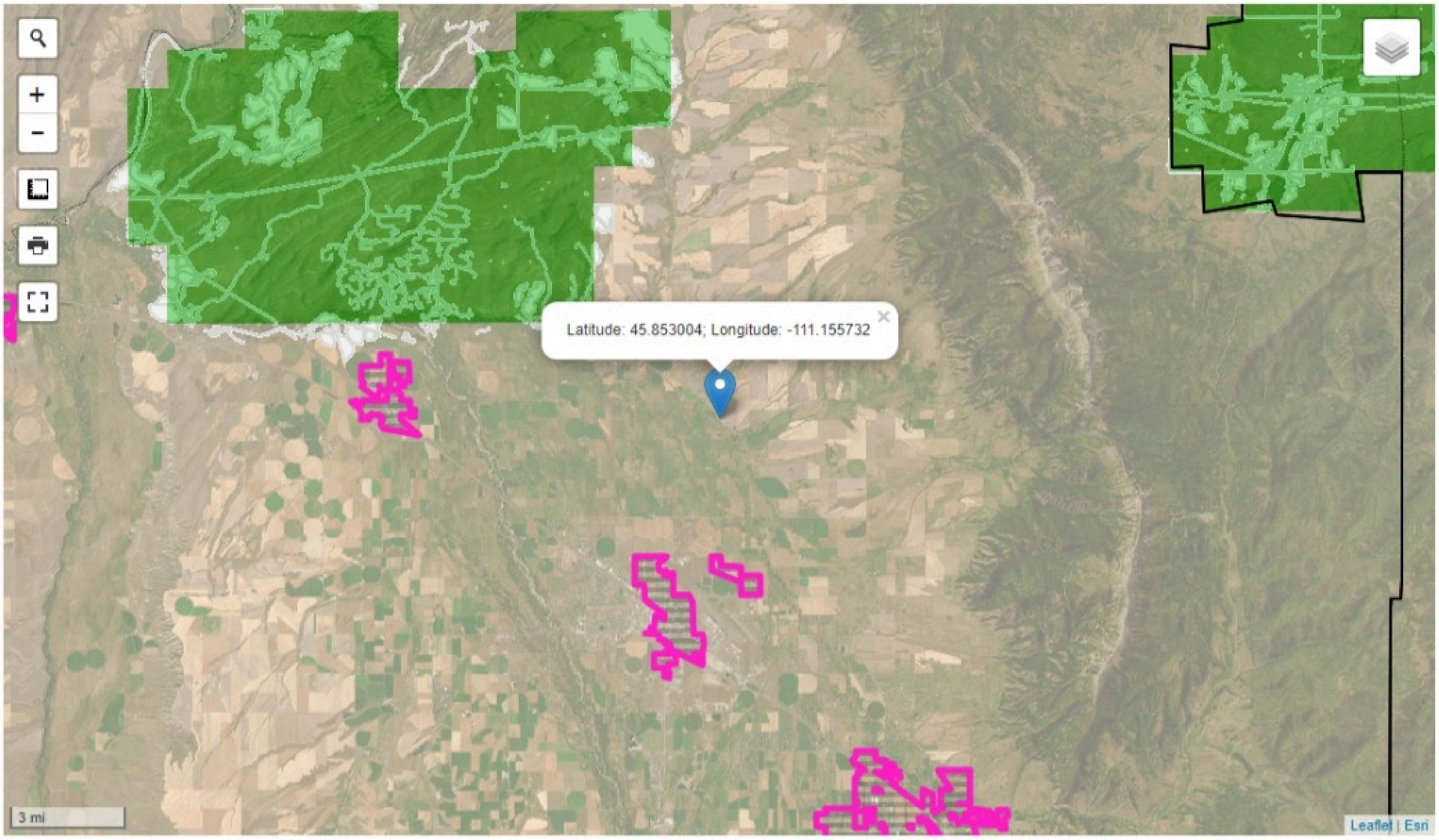
Home › Montana Sage Grouse Habitat Conservation Map

Montana Sage Grouse Habitat Conservation Map

Use this map to view and explore types of sage grouse habitat designated as core (blue), general (green), connectivity (light-blue) habitats or BLM priority areas. To zoom into an area, hold the Shift key and draw a rectangle. Anyone proposing new development activities in sage grouse habitat must submit a development project application for consultation.

If your project is close to designated sage grouse habitat or BLM Priority area, or if you are unsure your project is within designated sage grouse habitat or BLM Priority area, please submit your project for review as permitting agencies will be checking to see if your project is located within these designated sage grouse habitats. If your permitting agency requires evidence that your project is outside of designated sage grouse habitat, we recommend that you log in and start a project application and take a screenshot of your project's location.



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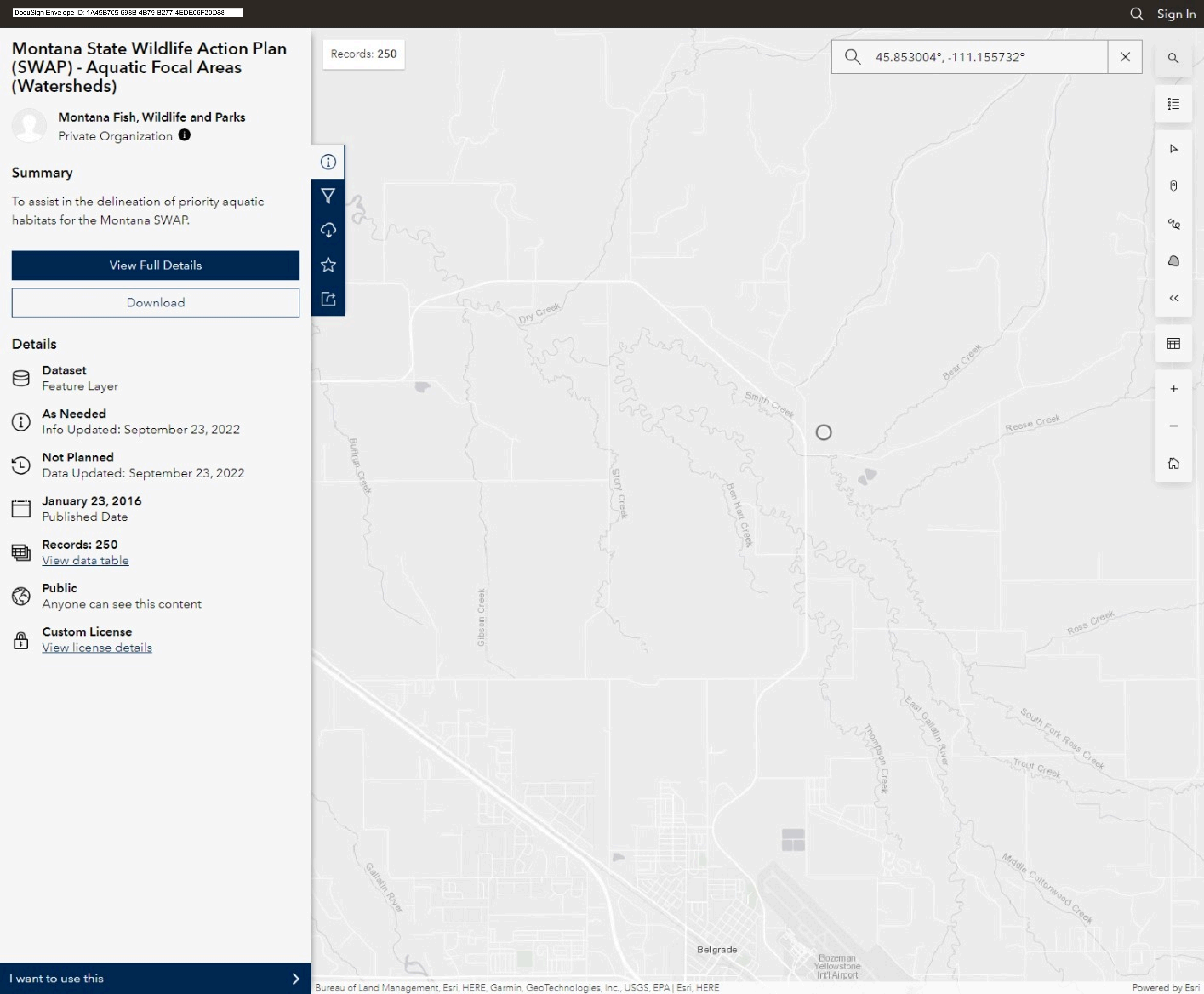

Montana State Wildlife Action Plan (SWAP) - Aquatic Focal Areas (Watersheds)

Montana Fish, Wildlife and Parks
Private Organization

Summary

To assist in the delineation of priority aquatic habitats for the Montana SWAP.

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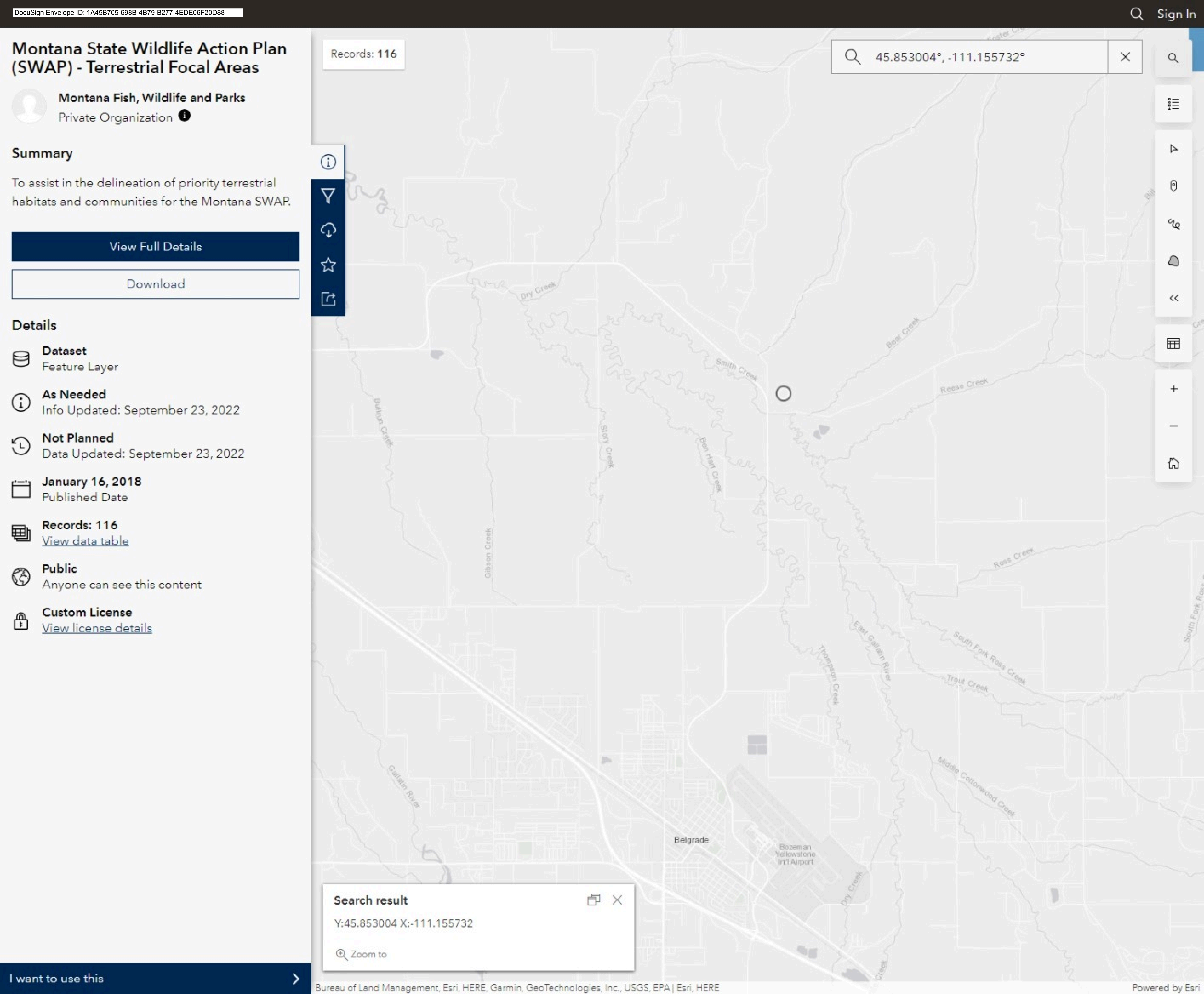

Montana State Wildlife Action Plan (SWAP) - Terrestrial Focal Areas

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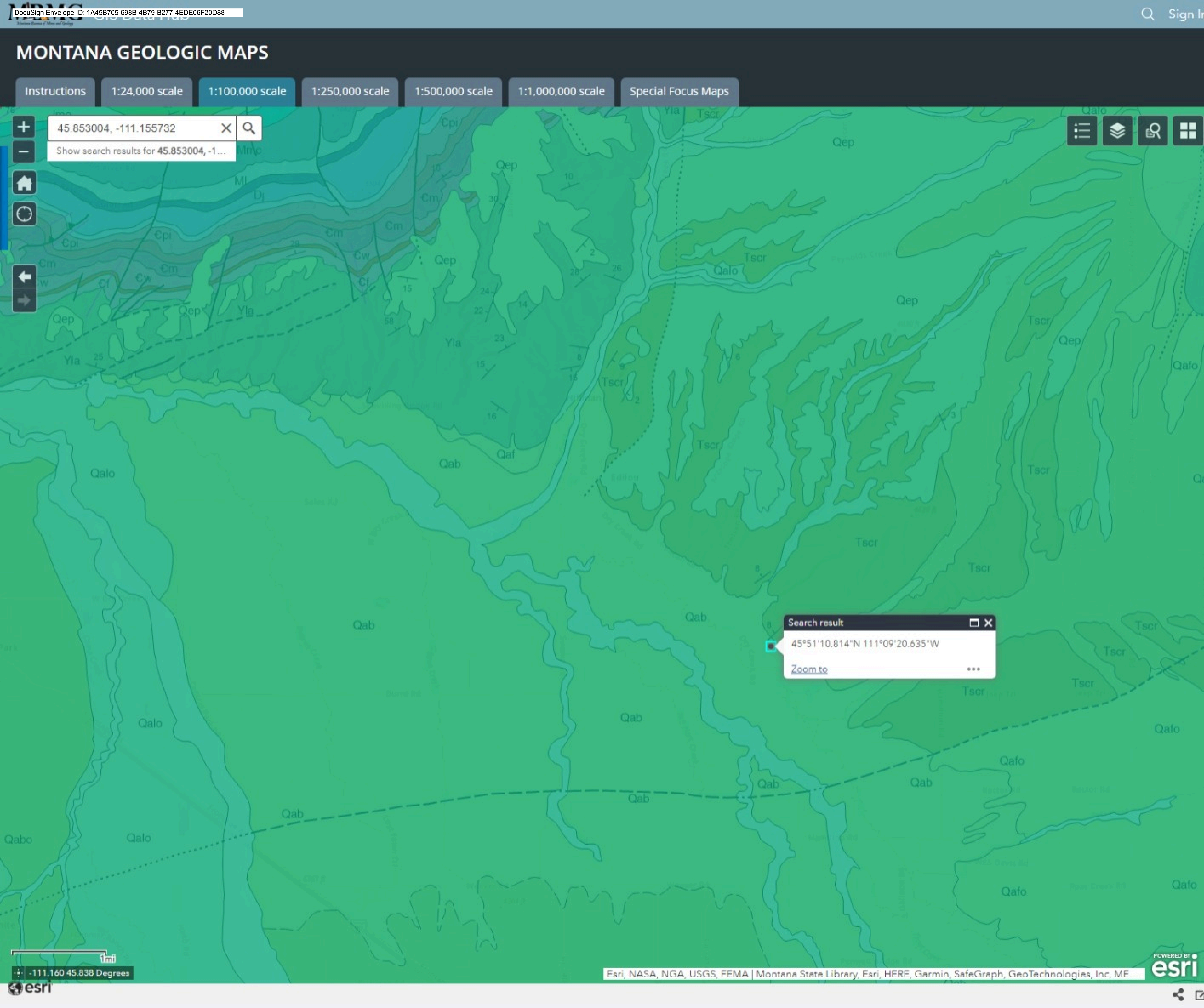

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