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# Engineering Services

# FINAL REPORT

## Greybull River Watershed
## Level I Study No. 17-3

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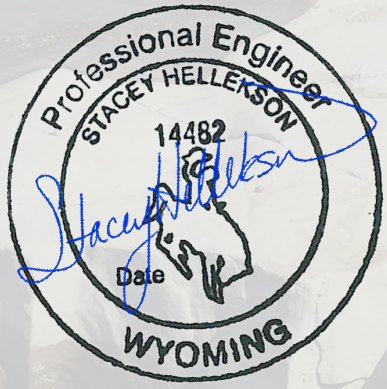
Wyoming Water Development Commission
Cheyenne, Wyoming
November 16, 2018

# Engineering Services

# FINAL REPORT

Greybull River Watershed
Level I Study No. 17-3

*I hereby certify that I have prepared or directly supervised the preparation of these reports and that I am a duly registered professional in the State of Wyoming.*

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**Cheyenne, Wyoming**
**November 16, 2018**

# TABLE OF CONTENTS


**1. INTRODUCTION ..... 1-1**

1.1 PROJECT BACKGROUND ..... 1-2
1.2 PUBLIC OUTREACH ..... 1-4
1.2.1 Public Meetings ..... 1-4
1.2.2 Surveys and Outreach ..... 1-7

**2. INVENTORY AND EVALUATION ..... 2-11**

2.1 PHYSICAL SYSTEMS ..... 2-13
2.1.1 Climate ..... 2-13
2.1.2 Topography ..... 2-14
2.1.3 Geology ..... 2-16
2.1.4 Soils ..... 2-19
2.1.5 Groundwater ..... 2-23
2.1.6 Surface Water ..... 2-25
2.2 BIOLOGICAL SYSTEMS IN THE GREYBULL RIVER WATERSHED ..... 2-51
2.2.1 Fish, Wildlife and Landcover ..... 2-51
2.2.2 Landcover ..... 2-65
2.2.3 Wildlife Habitat, Game and Sensitive Species ..... 2-84
2.3 ANTHROPROGENIC SYSTEMS ..... 2-97
2.3.1 Land Use and Ownership ..... 2-97
2.3.2 Land Management ..... 2-101
2.3.3 Agricultural Water Use ..... 2-116
2.3.4 Domestic, Municipal and Industrial Water ..... 2-127

**3. REHABILITATION AND MANAGEMENT PLAN ..... 3-146**

3.1 REHABILITATION TOPICS ..... 3-146
3.1.1 Watershed-wide Rehabilitation Topics ..... 3-146
3.1.2 Specific Rehabilitation Topics ..... 3-161
3.2 MANAGEMENT TOPICS ..... 3-180
3.2.1 Watershed Improvement Districts ..... 3-181
3.2.2 Greybull River WID ..... 3-182

**4. PERMITTING ..... 4-187**

4.1 Federal Permitting/Regulations ..... 4-187
4.1.1 NEPA Process ..... 4-187
4.1.2 USACE Section 404 Permit ..... 4-187
4.1.3 BLM Permitting ..... 4-190
4.1.4 USFS Permitting ..... 4-191

4.1.5 USFWS Consultation ..... 4-191
4.1.6 Other Permitting Requirements ..... 4-191
4.2 State Permitting/Regulations ..... 4-192
4.2.1 Wyoming State Engineer's Office Surface Water Storage/Groundwater Permits 4-192
4.2.2 WDEQ Permitting ..... 4-193
4.2.3 Wyoming Game and Fish Department ..... 4-194
4.2.4 Wyoming State Historical Preservation Office ..... 4-194
4.2.5 Wyoming Board of Land Commissioners ..... 4-194
4.3 County Permits ..... 4-194
**5. FUNDING OPPORTUNITIES ..... 5-195**
5.1 Local Agencies / Funding Opportunities ..... 5-196
5.1.1 Local Weed and Pest Control Districts ..... 5-196
5.2 State Funding Sources ..... 5-196
5.2.1 Wyoming Water Development Commission (WWDC) ..... 5-197
5.2.2 Wyoming Department of Environmental Quality (WDEQ) ..... 5-200
5.2.3 Wyoming Department of Agriculture (WDA) ..... 5-201
5.2.4 Wyoming Game and Fish Department (WGFD) ..... 5-203
5.2.5 Wyoming Wildlife and Natural Resource Trust (WWNRT) ..... 5-203
5.3 Federal Funding Sources ..... 5-204
5.3.1 Bureau of Reclamation (Reclamation) ..... 5-204
5.3.2 US Army Corps of Engineers (USACE) ..... 5-205
5.3.3 Bureau of Land Management (BLM) ..... 5-206
5.3.4 USDA Natural Resources Conservation Service (NRCS) ..... 5-206
5.3.5 Environmental Protection Agency (EPA) ..... 5-208
5.3.6 USDA Farm Service Agency (FSA) ..... 5-209
5.3.7 US Fish and Wildlife Service (USFWS) ..... 5-210
5.3.8 Other Funding Sources ..... 5-212
5.3.9 Summary of Funding Sources and Opportunities ..... 5-212
**6. SUMMARY ..... 6-213**
**7. REFERENCES ..... 7-215**

## Tables

Table 1 Soil Groups of the Greybull River Watershed (in text)
Table 2 Hydrologic Feature Types (in text)
Table 3 Rosgen Stream Type Summary (in text)
Table 4 WDEQ Stream Classifications
Table 5 Surface Water Classes and Use Designations (in text)
Table 6 45-Year Stream Gauge Dry, Average, Wet Years

Table 7 Annual Available Flow and Shortage for Greybull Watershed (in text)
Table 8 Aquatic Species Observed Within the Greybull River Basin
Table 9 Aquatic Species Observed Within the Dry Creek Basin (in text)
Table 10 Fish Passage Barriers
Table 11 Instream Flow Segments in Greybull Watershed (in text)
Table 12 Species of Concern in the Greybull Watershed (in text)
Table 13 Land Ownership Distribution (in text)
Table 14 Agricultural Land Use (in text)
Table 15 Active Mine and Gravel Permits (in text)
Table 16 Grazing Permit Comparison between USFS and BLM
Table 17 BLM Grazing Allotments in Greybull River Watershed
Table 18 USFS Grazing Allotments in Greybull River Watershed
Table 19 Conservation Easement Summary (in text)
Table 20 Historic Sites within Greybull River Watershed (in text)
Table 21 Greybull River Watershed Irrigation Surface Water Rights (in text)
Table 22 Major Diversion Canal Totals (in text)
Table 23 Public Water Systems in Greybull River Watershed (in text)
Table 24 SEO Permitted Well Types (in text)
Table 25 Groundwater Well Depths (in text)
Table 26 Groundwater Well Static Water Level Depths (in text)
Table 27 Groundwater Well Yield (in text)
Table 28 WYPDES Surface Water Outfalls
Table 29 Capacity Percentages for the Three Major Storage Reservoirs (in text)
Table 30 National Inventory of Dams in Greybull River Watershed
Table 31 Upland Water Storage Features (in text)
Table 32 Riprap Revetment Opinion of Probable Cost (in text)
Table 33 Revegetation Bank Stabilization Opinion of Probable Cost (in text)
Table 34 Denil Fishway Opinion of Probable Cost (in text)
Table 35 Fish Ladder Sediment Removal at Sunshine Diversion Opinion of Probable Cost (in text)
Table 36 7K Ranch Concrete Ditch Lining Opinion of Probable Cost (in text)
Table 37 German Ditch PVC Pipe Conversion Opinion of Probable Cost (in text)
Table 38 Horse Creek Stock Pond Dam Opinion of Probable Cost (in text)
Table 39 Watershed Improvement District SWOT
Table 40 Summary of Permitting Agencies
Table 41 Summary of Rehabilitation Project Permit Needs
Table 42 Local Agency / Local Office Contact Information (in text)
Table 43 Local Entity Funding Sources
Table 44 State Entity Funding Sources
Table 45 Federal Entity Funding Sources
Table 46 Project Funding Opportunities

# Figures


Figure 1 Watershed Area Map
Figure 2 Watershed Study Area Topography
Figure 3 Regional Geology
Figure 3a Regional Geology Legend
Figure 4 Bedrock Geology
Figure 4a Bedrock Geology Legend
Figure 5 Surficial Geology
Figure 5a Surficial Geology Legend and Table
Figure 6 STATSGO Soils Map
Figure 6A STATSGO Soils Map Legend
Figure 7 Springs and Seeps
Figure 8 Stream Classification and Stream Gages
Figure 9 Rosgen's Hierarchy of River Inventory and Assessment (in text)
Figure 10 Key to the Rosgen Classification of Natural Rivers (in text)
Figure 11 Watershed Rosgen Stream Classification
Figure 12 Wyoming Department of Environmental Quality Stream Classifications
Figure 13 Impaired Stream Designations
Figure 14 HUC-10 and Revised Hydrologic Units
Figure 15 Stream Gauge Locations
Figure 16 Hydrograph at Gauge Locations for Averaged Dry Flow Conditions (1973-2017) {in text}
Figure 17 Hydrograph at Gauge Locations for Averaged Flow Conditions (1973-2017) {in text}
Figure 18 Hydrograph at Gauge Locations for Averaged Wet Conditions (1974-2017) {in text}
Figure 19 Hydrograph of Greybull River at Gauge 06276500 (in text)
Figure 20 Available Flow (ac-ft) for All Reaches in HUC
Figure 21 Shortages (ac-ft) for All Reaches in HUC
Figure 22 Hydrographs at HUC Main Reaches
Figure 23 Shortages by Diversion (AECOM, 2017) {in text}
Figure 24 State-wide Aquatic Basins
Figure 25 LANDFIRE Canopy Types
Figure 26 SWAP Terrestrial Habitat Types
Figure 27 Introduced Vegetation
Figure 28 Wetlands Map
Figure 29 Aquatic Crucial and Enhancement Priority Areas
Figure 30 Terrestrial Crucial and Enhancement Habitat Priorities
Figure 31 Combined Crucial and Enhancement Habitat Priorities
Figure 32 Antelope Habitat
Figure 33 Bighorn Sheep Habitat
Figure 34 Elk Habitat
Figure 35 Moose Habitat

Figure 36 Mule Deer Habitat
Figure 37 Whitetail Deer Habitat
Figure 38 Sage Grouse Core Areas and Lek Locations
Figure 39 Land Ownership
Figure 40 Land Use
Figure 41 Grazing Allotments
Figure 42 NRCS Conservation Practice Effects – Network Diagram
Figure 43 Ecological Site Map – Park County
Figure 44 Ecological Site Map – Big Horn County
Figure 45 Conservation Easements
Figure 46 Cultural Resources
Figure 47 Wyoming SEO Water Divisions
Figure 48 Wyoming SEO Water Division Districts
Figure 49 Irrigation Infrastructure
Figure 50 Burlington Municipal System
Figure 51 Meeteetse Municipal System
Figure 52 Greybull Municipal System
Figure 53 SEO Permitted Wells
Figure 54 SEO Potable Water Wells
Figure 55 SEO Non-Potable Water Wells
Figure 56 WYPDES Effluent Outfalls
Figure 57 NID Dams and Reservoirs
Figure 58 Upland Water Features
Figure 59 Location of Specific Rehabilitation Topics
Figure 60 Concrete Irrigation Canal Details
Figure 61 German Ditch Pipe Conversion
Figure 62 Horse Creek Stock Water Reservoir Vicinity Map
Figure 63 Horse Creek Stock Pond Dam Details

## Images

Image 1 Stream Channel Survey
Image 2 Example A Type Channel
Image 3 Example D Type Channel – Greybull River
Image 4 Example E type Channel – Dry Creek
Image 5 Example C Type Channel – Dry Creek
Image 6 Example B Type channel
Image 7 Guardrail Damage by Eroded Streambank – Greybull River
Image 8 Approximate Land Area Lost to Streambank Erosion – Greybull River

Image 9 Diversion Channel Damage by Streambank Erosion – Greybull River
Image 10 Sheets Flat Diversion
Image 11 Yellowstone Cutthroat Trout
Image 12 Upper Sunshine Diversion Fish Ladder
Image 13 Big Sagebrush
Image 14 Cheatgrass
Image 15 Desert Shrublands
Image 16 Russian Olive and Tamarisk Trees
Image 17 Utah Juniper
Image 18 Mountain Pine Beetle
Image 19 Greater Sage Grouse
Image 20 Bridger Immigrant Road at the Dry Creek Crossing
Image 21 Main U.S. Post Office in Greybull
Image 22 The Anderson Lodge
Image 23 First National Bank of Meeteetse
Image 24 The Carey Block in Greybull
Image 25 The Bridger Trail
Image 26 Upper Sunshine Diversion
Image 27 Wood River Diversion
Image 28 Sheets Flat Diversion *(two pictures: one is an inlay)*
Image 29 Perennial Stock Pond
Image 30 Intermittent Stock pond
Image 31 Mountain Lake
Image 32 Marsh/Swamp area
Image 33 Road 4Eu Damage due to streambank migration and erosion
Image 34 Road and Irrigation Damage
Image 35 Greybull Historic Migration Pathway
Image 36 Bank Loss Due to Adjacent Landowner River Modifications
Image 37 Riprap Revetment Design Cross-section
Image 38 Stream Barb Near Bank Velocity Reduction
Image 39 Willow Stake Planting for Streambank Stabilization
Image 40 Avg Annual Shortage by Diversion Structure Ac-ft
Image 41 Avg Annual Percent Shortage by Diversion Structure
Image 42 Nonfunctioning Diversion Due to Channel Migration
Image 43 Conceptual Design Denil Fishway
Image 44 Example Vertical Slot fishway
Image 45 Sediment Accumulation at Top of Fish Ladder
Image 46 Sediment at Upper Gate of Fish Ladder
Image 47 7K Ranch Proposed Concrete Channel Alignment

## Graphs

Graph 1 Survey Respondent Summary
Graph 2 Acres per Canopy Type (LANDFIRE)
Graph 3 Acres per SWAT Habitat Type

## Appendices

Appendix A GIS Data References and Sources
Appendix B Geologic and Soil Descriptions

# 1. INTRODUCTION

This Level I Greybull River watershed study was prepared under contract to the Wyoming Water Development Commission (WWDC) with Woodard & Curran. There are two sponsors, the South Big Horn Conservation District (SBHCD) and the Meeteetse Conservation District (MCD) who applied for this study with the WWDC. The primary purpose of this study is to gather relevant existing information to inventory and evaluate the watershed and develop a Management and Rehabilitation Plan for the watershed. The study will present a comprehensive report of the Greybull River watershed that landowners and entities can use as a tool to focus on improvements and find appropriate funding for those improvements. The study's specific objectives include:

- Conduct public project meetings and encourage public participation in those meetings. Public meetings included an initial scoping meeting followed by a series of public meetings to provide updates of the study's progress and findings to date. A summary of these meetings is provided in Section 1.2;
- Gather and review existing historical and scientific background information of the watershed. This information was gathered through a number of resources including but not limited to the WWDC, the MCD and SBHCD, landowners and stakeholders, local county agencies, the University of Wyoming's Water Resources Data System (WRDS), Wyoming State Engineer's Office (SEO), Wyoming Oil & Gas Conservation Commission (WOGCC), Wyoming State Geological Survey (WSGS), Wyoming State Game & Fish Department (WGFD), and Wyoming Department of Environmental Quality (WDEQ), and many others. The national agencies included the U.S. Geological Survey (USGS), Natural Resources Conservation Service (NRCS), U.S. Fish & Wildlife Service (USFWS), U.S. Army Corp of Engineers (USACE), U.S. Forest Service (USFS) and the Bureau of Land Management (BLM) among others. A complete set of data references and sources is provided in Appendix A.
- Develop an inventory, description and evaluation of the watershed's physical, biological and anthropogenic systems. Essentially, this task was to provide a 'snapshot' of the watershed as it exists today.
    - The physical systems include surface water conditions, groundwater conditions, the geomorphology of the watershed and the geology of the area;
    - The biological systems include the fish and wildlife of the watershed, and the land cover of the area;
    - The anthropogenic systems include agricultural water use (irrigated land and irrigation systems), domestic, municipal and industrial water uses in the watershed, water storage, and a description of the land itself (ownership, uses, cultural resources, etc.).
- Characterize the streamflow of the watershed utilizing previously prepared hydrologic models, existing flow estimates, newly collected gage data and/or applicable techniques for such characterization;
- Develop a Management and Rehabilitation Plan which includes specific suggestions to improve the condition and function of the watershed.

- Identify cost estimates for the Plan which allow the sponsors to evaluate any proposed project recommendations. The estimates also identify Plan components which are eligible/non-eligible for funding from WWDC and the Small Water Project Program;
- Provide information for potential local, state, and federal funding sources to include the application and eligibility requirements including additional information regarding any Wyoming entities which may be eligible to apply for any funds; and
- Identify all the easements, clearances and/or permits which may be necessary for implementation of the Plan to include the associated proposed project/construction activities.

## 1.1 PROJECT BACKGROUND

This study includes the entire Greybull River watershed but also encompasses the adjoining Dry Creek watershed. Together they drain more than a million acres of land in both Big Horn and Park counties located in the Bighorn Basin of northwestern Wyoming. Figure 1 provides an overview of the area including rivers, major towns and roadways. Sources for all data and GIS mapping is provided in Appendix A. Following provides a brief overview of the components of the watershed all of which are described in detail in Section 2 – Inventory and Evaluation.

The topography and climate of the watershed vary greatly from one end of the study area to the other. The Greybull River headwaters begin in the westernmost portions of the watershed on 13,000-foot mountain tops in the Absaroka Range in the Shoshone National Forest where the annual snowfall routinely exceeds 150 inches a year. In contrast, the city of Greybull is located in the easternmost boundary of the watershed at an elevation just under 3,800 feet and typically receives less than seven inches of precipitation annually.

The Greybull River is the third largest tributary to the Bighorn River and, like Dry Creek, confluences with the Bighorn River at the easternmost boundary of the study area. The three largest communities in the watershed, Greybull, Burlington and Meeteetse, total only 2,563 people. Despite the relatively low populace, there are extensive agricultural and stock-grazing water demands from both the Greybull River and Dry Creek. As a result, the watershed's surface water storage and surface water usage are critical factors, especially during the annual May to October irrigation period.

The Greybull River and its tributaries drain approximately 75 percent of the watershed study area, although Greybull's main tributary, the Wood River, drains a large portion of the southwestern area of the watershed. Elsewhere, Dry Creek and its tributaries drain about 25 percent of the watershed study area in parallel fashion to the Greybull River in the northern portion of the watershed.

Compounding the ever-increasing water demands within the study area is the fact that the watershed contains an abundant array of fish, wildlife and native habitats which require a functioning watershed and often need comprehensive wildlife conservation strategies. This work falls mostly under the auspices of the WGFD and includes special protection areas or instream flow segments set aside to protect the native Yellowstone Cutthroat trout.

Land ownership within the watershed mirrors many other watersheds in Wyoming. Over 63 percent of the land within the Greybull River watershed study area is federally owned while private landowners control less than 28 percent. The state of Wyoming owns less than ten percent of the watershed.

Historical land use of the watershed closely resembles current land use. This includes water storage, agricultural uses/livestock grazing, industrial development, recreation, limited transportation uses and a wide variety of wildlife habitat.

A majority of the watershed's populace utilize groundwater wells for its potable water including the communities of Greybull and Burlington. Meeteetse obtains its potable water through an infiltration gallery at the toe of the Lower Sunshine Reservoir located in the western portion of the watershed. Elsewhere, the area's residents utilize groundwater for their potable, stock water and irrigation needs.

Outside of oil and gas operations, there is little industrial use of land within the watershed though some timber harvesting exists in the southwestern portion of the watershed. The predominant area for oil and gas is the Oregon Basin field located north of Meeteetse though some operations exist in the Greybull area. Currently, there are over 1,000 producing oil and gas wells in the watershed. More than 600 of those are in the Oregon Basin field.

Irrigation is the predominant water use within the watershed. The majority of irrigated land is located in areas of the watershed defined as semiarid and even arid. As noted earlier, this includes some areas where annual precipitation rarely exceeds seven inches a year. Previous irrigation and storage enlargement studies have concluded the watershed operates as a water-short system.

Within the watershed there are areas where surface water quality is compromised. These are mainly in the lower stretches of both the Greybull River and Dry Creek. According to previous studies, a majority of *Escherichia coli (E-coli)* loading in these impaired stream segments is the result of overland runoff from livestock and/or wildlife defecation (RESPEC, 2013). A later report concluded the trend of increasing bacterial concentrations from upstream to downstream in the Greybull River was attributed to increases in the occurrence of irrigated agriculture land and livestock activity (WDEQ, 2016).

Most of the watershed's surface water storage area is operated by the Greybull Valley Irrigation District (GVID). This public entity controls the daily operations of managing the watershed's three main off-channel storage facilities, the Upper Sunshine, the Lower Sunshine and the Roach Gulch reservoirs. Together these three reservoirs provide approximately 145,000 ac-ft of storage capacity.

Though the GVID manages the majority of the water storage facilities in the watershed, the bulk of the irrigation water is supplied by several privately-owned irrigation companies including the Farmers Canal Company, the Bench Canal Company, plus the Keystone, Jimmerfield, Smith and Avent ditch companies. The irrigators in these companies are all located in the eastern half of the watershed.

Concerns established in previous studies prior, and subsequent findings during this study indicate several challenges facing the landowners, stakeholders and the public within the watershed including:

- Aging water resource infrastructure;
- Aging irrigation infrastructure;
- Continued water quality issues in the impaired sections of streams;
- Erosion and channel stability; and
- Distribution of water resources.

## 1.2 PUBLIC OUTREACH

One of the objectives of this study was to create public awareness and stimulate public participation through a series of public meetings and presentations. Notifications for these meeting were completed through mailings, newspaper advertisements, website notices through the MCD and SBHCD, and email and phone calls to landowners and entities showing interest in the study. These efforts plus field trips to visit various landowners, tours of various aspects of the watershed with sponsors and other stakeholders were all performed to accumulate as much public input as possible regarding the management and rehabilitation of the watershed's water and environmental resources. The field trips and hands-on site visits were conducted to assist in determining the first-hand suggestions, concerns and thoughts of the sponsors, landowners and other stakeholders. Conversation logs and meeting summaries are included in the project notebook.

The meetings were conducted to familiarize the two sponsors, and any landowners and stakeholders in attendance, of the progress and findings of the study to date, as well as to continue to gain feedback and public input.

In addition to the site visits and meetings, questionnaires were mailed out to a percentage of landowners in the watershed. Those which were returned added insight to the concerns and allowed the study to focus on the larger-scale issued prevalent throughout the watershed.

### 1.2.1 Public Meetings

As mentioned previously, a series of public meetings were held throughout the watershed study area to update and inform the study's two sponsors and others in attendance of the study's progress and findings to date. The first meeting was a scoping meeting to present the tasks and approach to developing this study. Scoping meetings were held in two locations on back-to-back nights to promote the most attendance throughout the watershed. Similarly, two draft public meetings were held in two locations. A summary of the meetings held during this study is summarized below. Detailed notes are provided in the project notebook.

- **Scoping Meetings** (Meeteetse: August 29, 2017 and Burlington: August 30, 2017): Two publicly advertised scoping meetings were held in Meeteetse at the office of the Meeteetse Conservation District and the Burlington Town Hall which is located within the SBHCD. Those in attendance included representatives of the WWDC, both sponsors, several members of the public and representatives from Woodard & Curran. Following a discussion of the roles and a presentation of approach to the scope of work, the attendees were encouraged to voice their thoughts and concerns. Some of those items included:

- Dave Myer of the WWDO encouraged the participation of landowners which will help to develop and identify the issues of the watershed;
- Members of the public asked what non-profits the study will involve;
- The consensus was the sponsor's two Facebook pages and the MCD bi-weekly newsletter was sufficient regarding public communication;
- One attendee inquired about the quantification of how many wetlands are supported by irrigation and possibly created by irrigation and/or produced water in the Dry Creek area;
- One attendee reminded everyone how Russian Olive and Saltcedar trees are becoming invasive;
- One attendee noted the USFS already has Rosgen analysis of the streams in the USFS area;
- Another attendee noted the ever-changing geomorphology of the Wood River with significant channel alterations occurring;
- Several attendees noted the Greybull River is causing significant damage, mostly channel migration and bank erosion which damages head gates and diversion structures;
- One commenter reminded everyone there are several unlined irrigation ditches up to eight miles long which lose nearly half their flow by the time the water reaches the fields;
- One attendee commented the Farmers Canal is failing;
- Another stated 70 to 80 percent of the Bench Canal's infrastructure is failing; and
- More than one attendee stated the State of Wyoming should manage the river and not the federal government.

- **Watershed Study Status Meeting** (Meeteetse, February 1, 2018)**:** A publicly advertised meeting in Meeteetse was held at the office of the Meeteetse Conservation District. Those in attendance included representatives of the WWDO, both sponsors, several members of the public and representatives from Woodard & Curran. The meeting presented the progress of the study and presented primary findings including the potential to develop a watershed-wide entity for management, funds assessment and organization. Following the presentation, attendees were encouraged to voice their thoughts and concerns. Some of those items included:
  - Stakeholders had the opinion that Roach Gulch Reservoir and not Lower Sunshine should be expanded for the downstream irrigators;
  - Stakeholders expressed that the Greybull River watershed should serve everyone in the watershed and not just those in the downstream portions of the watershed;
  - Stakeholders expressed that the Greybull River was just a ditch serving the needs of the downstream irrigators, i.e., landowners upstream from the Sheet's Flat diversion operated completely different than those downstream;

- Lack of water can't just be fixed by expanding storage; improved efficiency for irrigation and its infrastructure, and improved efficiency in irrigation practices can help with the storage problems;
- It was suggested the Bench and Farmers Canals be combined;
- Community members were open to the idea of forming more districts and instituting taxes or some form of funding to maintain irrigation infrastructure;
- It seemed evident there is a struggle between the upstream and downstream users regarding availability of funding, perceptions and, in general, a lot of political logistics to develop a combined district.

- **Watershed Study Status Meeting** (Emblem, June 14, 2018)**:** A publicly advertised meeting hosted by the GVID was held at the Emblem (WY) Gym which is located within the boundary of the SBHCD. Those in attendance included representatives of the WWDO, both sponsors, several members of the public, representatives from Woodard & Curran and a representative from the U.S. Army Corps of Engineers (USACE). Following a presentation of the findings to date, the attendees were encouraged to voice their thoughts and concerns. Some of those items included:
  - Develop the differences between a Conservation District and a Watershed Improvement District;
  - Kevin Little of the USACE discussed the issues his agency encounters regarding the two Conservation Districts relating to two current BLM projects;
  - Members asked what the maximum amount of funding was available for a small water project.
- **Draft Report Status Meeting** (Meeteetse, Sept. 26, 2018): A publicly advertised meeting in Meeteetse was held at the office of the Meeteetse Conservation District. Those in attendance included representatives of the WWDO, both sponsors, several members of the public and representatives from Woodard & Curran. The meeting presented an overview of the Draft Report submitted earlier to the WWDO and both sponsors. Following the presentation, attendees were encouraged to voice their thoughts and concerns. Some of those items included:
  - Have you identified specific areas for stream stabilization opportunities?
  - The biggest problem with consolidating several landowners to form a single ditch is cooperation among those landowners.
  - The maximum grant for a WWDC Small Water Project is $35,000 but a public benefit must be shown; sometimes nearly impossible for a single landowner.
  - Why can't we find a way to consolidate all the various irrigation districts into a single Watershed Irrigation District? Wouldn't that be a positive? It seems like this is the way to go. Once a landowner sees a benefit then this could work.
  - The water sources for this watershed are the upper Wood River and Greybull River. There aren't any ways to add more water into this watershed so is there anything in your assessments on things to do to plan for the future? Ways to maintain lifestyles?

- From a state level, are there other levels of studies to address potential climate changes?
- I see these Level I studies are an opportunity to address possible future scenarios regarding water shortage, climate changes, etc. We need to start thinking of implications and plant the seeds for the need to address future problems and their solutions.
- Formation of a WID might allow the opportunity to address these situations.
- Yes, you could also expand on the current irrigation districts.

- **Draft Report Status Meeting** (Burlington, Sept. 27, 2018): A publicly advertised meeting in Meeteetse was held at the town hall in Burlington, WY. Those in attendance included representatives of the WWDO, both sponsors, several members of the public and representatives from Woodard & Curran. The meeting presented an overview of the Draft Report submitted earlier to the WWDO and both sponsors. Following the presentation, attendees were encouraged to voice their thoughts and concerns. Some of those items included:
  - What are the artificial paths? *(relating to the hydrography presentation)*. The answer provided was they were mapped that way as part of the National Hydrography Data.
  - For Classification D *(relating to the hydrography presentation)* what are the variables for this classification such as width-to-depth, entrenchment ration, stream gradient, the braided nature of the Greybull, the high sediment supply and the sinuosity.
  - Our major flow is right around July 4.
  - One thing is this river floods every year. The landowners are unable to remove sediment preventing loss of land. This didn't used to be the case so flooding is more prevalent now than in the past.
  - We've put the barbs in and they work like a charm.
  - I don't think funding is available for mechanical removal of Russian olives and Salt cedar; only the chemical treatment afterward. *Note:* Later in the evening this comment was clarified by the South Big Horn Conservation District that funding is, in fact, available for the mechanical removal.
  - Does becoming a public entity give them *(the WID)* the right to raise our property taxes?
  - Do you really believe all the landowners will form a WID? I would rethink such a recommendation.
  - What about taking into account water rights and water exchange rights? *(relating to the formation of a WID)*
  - Everything you've done here is already in previous reports.

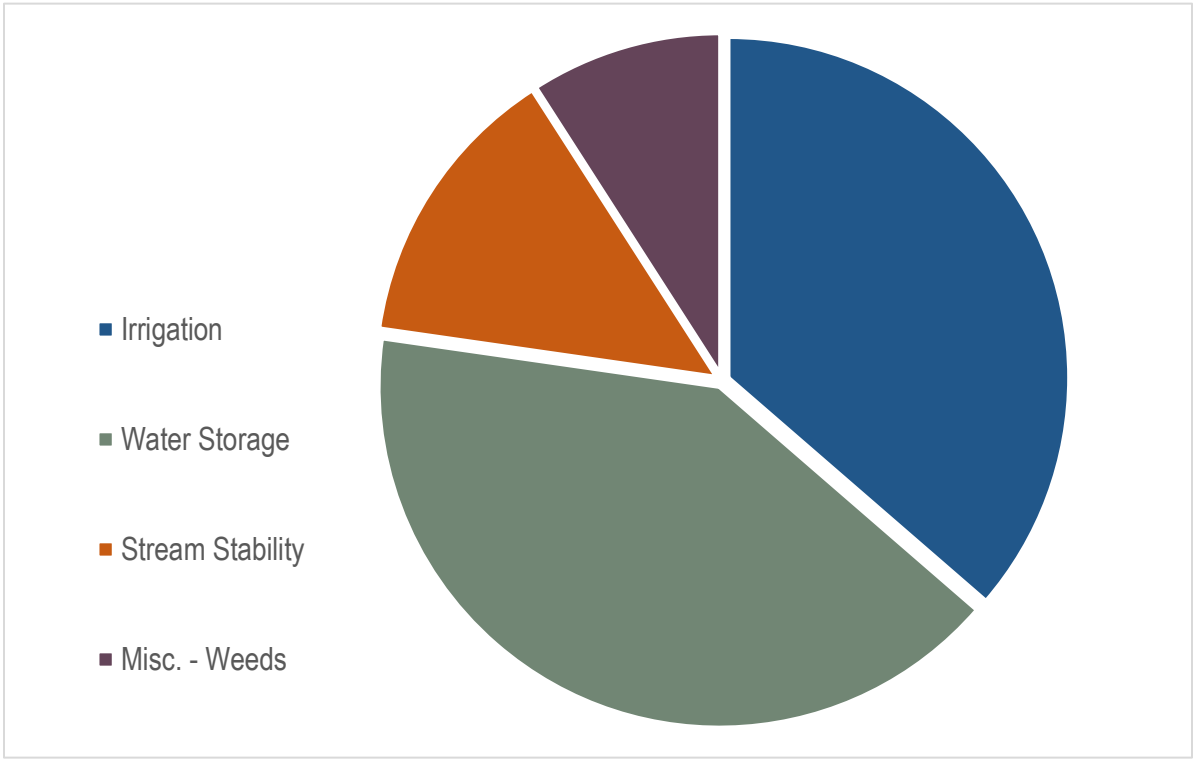
### 1.2.2 Surveys and Outreach

A brief survey was developed to promote additional feedback from landowners within the watershed. Parcel data was purchased from Park and Big Horn County to identify stakeholders which resulted in 1,125 individual parcels. Mailing surveys to every parcel was cost prohibitive and it was decided to mail surveys to approximately 60 percent of the parcel data. Landowners in a more urban setting (near Greybull) were filtered

out, although a small percentage was included to represent that aspect of the watershed. Additionally, landowners with contact addresses out of state were also excluded since it was theorized the owners may not live full-time in the watershed or may be leasing land, both indicating the landowner may be less likely to have a comprehensive understanding of potential issues on their land. In an effort to provide an avenue for the other 40 percent of landowners to complete the survey, the survey was also promoted on the MCD and SBHCD website with a Survey Monkey link to the same survey. A copy of the survey packet that was mailed out is provided in the project notebook.

The survey was mailed in Fall 2018 with self-addressed stamped envelopes to further promote participation. Of the 672 surveys that were mailed, 59 responses were received resulting in a participation rate of nearly 9 percent. The majority of the responses did not provide details or any concerns of issues in the watershed and a minimal number of respondents wanted to participate through additional contact. Twenty-five respondents provided feedback of concerns which were categorized into four grouping including irrigation, water storage, flooding and erosion, and miscellaneous (weeds, water rights, etc.) Graph 1 provides a pie chart representation of the categories based on the number of times the issue was mentioned by respondents.

**Graph 1: Survey Respondent Summary**




Additional discussion of the issues identified by the survey and from public surveys are discussed in Section 3 – Rehabilitation and Management Plan.

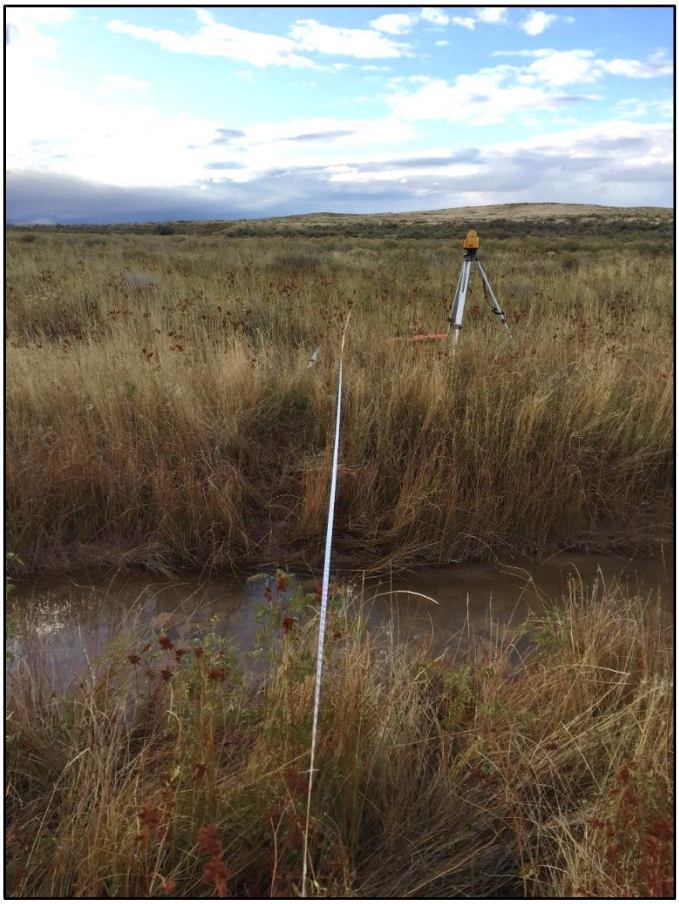
If the survey respondent indicated they would like to be contacted for further discussion, Woodard & Curran's team reached out to gain additional understanding and insight to the issues. In some instances, the landowners preferred to keep their communication confidential and did not want specifics of their issues on their property specifically discussed within this report. In respect of these wishes, specifics in some cases are excluded.

### *Field Surveys*

Two field visits were completed to meet with landowners to observe active erosion issues related to encroachment of the river towards homes and to observe the extend of erosion that some landowners have experienced over the years. Both of these field visits were located in the lower portion of the watershed and property abutted the Greybull River.

In addition to field visits completed in response to landowner comments, staff conducted stream surveys for streams that were ambiguous from GIS analysis (see Image 1). The stream surveys consisted of collecting stream parameters including channel width and a cross-sectional survey for depth. The Greybull River, Wood River and Dry Creek were visited in the field where entrenchment ratio and width to depth ratio could be measured or estimated.

**Image 1: Stream Channel Survey**



Combined with the Inventory and Evaluation discussed in the next section, the surveys, public meetings, landowner feedback, and input from other stakeholders within the watershed are an integral component to developing a meaningful study that identifies appropriate rehabilitation and management topics for the watershed.

Woodard & Curran thanks everyone for their support, input and interest in the Greybull River Watershed Study.

# 2. INVENTORY AND EVALUATION

This section discusses the inventory and evaluation of the resources and physical setting of the Greybull River watershed and adjoining Dry Creek watershed located in northwestern Wyoming. Collectively, both watersheds will be discussed as the Greybull watershed within this report. The inventory and evaluation discussions feature an overview of existing conditions of those resources and physical settings. The sources for the data and information collected are nearly as varied as the data itself. Those sources include but are not limited to:

- Greybull Valley Irrigation District (GVID)
- Meeteetse Conservation District (MCD)
- South Big Horn Conservation District (SBHCD)
- Trout Unlimited
- Wyoming Water Development Commission (WWDC)
- Wyoming Department of Environmental Quality (WDEQ)
- Wyoming Game and Fish Department (WGFD)
- Wyoming State Historic Preservation Office (SHPO)
- Wyoming State Engineer's Office (WSEO)
- Wyoming Oil and Gas Conservation Commission (WOGCC)
- Wyoming State Geological Survey (WSGS)
- Wyoming Geographic Information Science Center (WyGISC)
- Wyoming Natural Diversity Database (WYNDD)
- U.S. Bureau of Land Management (BLM)
- U.S. Geological Survey (USGS)
- U.S. Department of Agriculture/Natural Resources Conservation Service (NRCS)
- U.S. Environmental Protection Agency (EPA)
- U.S. Fish and Wildlife Service (FWS)
- U.S. Forest Service (USFS)
- U.S. Department of Interior (DOI)

The data and information collected span a wide array of disciplines and includes:

- **Climate:** Of all the forces which have shaped the watershed study area, climate may be the most central of all. The prevalence of sun and heat, high winds, infrequent rain events, and bitter cold and snow is all experienced on a yearly basis within the watershed.
- **Topography:** Due to ongoing geologic, wind, erosional, glacial and fluvial actions, the watershed's topography varies considerably. The watershed's elevations range from 13,000-foot mountain peaks in the west to less than 4,000 feet above sea level in the east.
- **Geology:** Like many of the disciplines within the watershed, the area's geology differs from one end of the watershed to the other, and ranges from old volcanic regions in the west to the sedimentary basin of Laramide-age and -style in the eastern portion of the watershed.
- **Soils:** The soils in the study area vary from the eastern valley floors which consist of recent alluvial deposits created from eroded sands, silts, shales and volcanic rock to the western portion's Absaroka volcanics consisting of deeply eroded Eocene andesitic volcanic rocks.
- **Groundwater:** Differing geologic units underlay the watershed and function as storage reservoirs and groundwater filters. Both unconsolidated and bedrock aquifers are important water resources in the watershed. The two principle unconsolidated aquifers in the study area are among the most productive and predictable sources of groundwater in the area and is the principle municipal water source for Burlington and Emblem. The Lance and Mesaverde Formations are the two bedrock aquifers and have the most potential for development as a water supply
- **Surface Water:** Because most of the watershed is defined as semi-arid, surface water is a valuable commodity. For example, only 11 percent of the Greybull River watershed's stream miles are considered perennial or flow year-round. The Dry Creek watershed's numbers are even lower at four percent. Subsequently, the allocation and management of water resources within the watershed becomes a critical function for all stakeholders and landowners.
- **Fish and Wildlife:** The watershed's wide array of topography yields a variety of fisheries and wildlife habitat. There are at least 32 species of fish known to exist within the Greybull River basin including the native Yellowstone Cutthroat Trout which has special protection barriers within the watershed. Terrestrial wildlife is plentiful, and the watershed contains crucial and enhancement habitat priority areas managed by the WGFD.
- **Land Cover:** Over 90 percent of the landcover within the watershed is comprised of vegetated areas. Non-vegetated land areas are often a concern to land managers due to the reduced soil protection and higher potential for erosion. Landcover plays a large role in the hydrologic system of a watershed since nearly all precipitation must interact with this feature in some way.
- **Land Uses/Ownership:** Historical land use of the watershed closely resembles current land use. This includes water storage, agricultural, livestock grazing, industrial development, recreation, limited transportation uses and a wide variety of wildlife habitat. Land ownership within the watershed is

reflective of much of Wyoming. Those figures include federally-owned land totaling over 62 percent, private ownership is nearly 28 percent while the state owns approximately 9 percent.

- **Cultural Resources:** According to the Wyoming SHPO, there have been over 78,000 acres inventoried for cultural resources within the watershed area. To date, nearly 2,400 cultural resource sites have been recorded. More than 600 of those sites are known to be eligible for the National Register of Historic Sites though only five within the watershed area are currently listed as historic sites.
- **Domestic, Municipal and Industrial Water:** As noted earlier, water is a valuable commodity within the watershed study area. There are only three Public Water Systems within the watershed which use either surface water or groundwater as sources. Most outlying areas use individual groundwater wells as a water source, with some individuals in remote areas of the watershed needing truck their water in from nearby communities. Agricultural interests rely mainly on irrigation for their water source while industrial users rely on both surface and groundwater reserves.

## 2.1 PHYSICAL SYSTEMS

### 2.1.1 Climate

Among the many forces which have shaped the landscape of the watershed, climate may be the most central of all. Whether sun action, wind, frost, snow or rain, each is prevalent in the watershed. The Greybull River and Dry Creek watersheds sit within the Bighorn Basin. Geographically, this basin is surrounded by several mountain ranges which influence the climate of the entire watershed. One of those ranges is the Absaroka Mountain Range in the western part of the watershed. This range, like many of Wyoming's ranges, plays a key role in the watershed's climate due its mainly north-south orientation. Such an orientation is perpendicular to the prevailing westerlies which presents an effective barrier forcing the air currents to rise and drop their moisture (WRDS, 2017).

Dominated by high plains, a majority of the watershed is classified as semiarid because most of the watershed receives less than 20 inches of precipitation per year. The mountainous regions in the western portion of the area can receive over 40 inches of precipitation in one year usually in the form of snow.

When comparing communities at either end of the watershed, the town of Greybull on the eastern-most edge of the watershed receives an average of just 6.84 inches of precipitation per year, though in the ten-year period ending in 2008 that figure was only 5.04 inches. Statistics include an average of 20 inches of snowfall per year. In contrast, the community of Meeteetse in the foothills of the Absaroka Mountains in the south-western area of the watershed, receives nearly 14 inches of precipitation per year which includes 71 inches of yearly snowfall (WRCC, 2017).

Most of the watershed's yearly rainfall comes in the form of spring and summer showers and thunderstorms which is typical for most the watershed. On an average, Greybull receives over 76 percent of its annual precipitation from April to August. Storms can be of high intensity and low duration which influences sediment transport, streambank migration and stream flows. Such dramatic flow events are common and occur throughout the watershed. Thunderstorms tend to yield higher turbidity in the runoff and increase suspended

solids downstream. Subsequently, these geomorphic processes alter both stream channel dynamics and channel locations.

Elevation also plays a critical role in the watershed's climate yielding a wide variety of temperature extremes. At 3,789 feet above sea level, the Town of Greybull's average maximum and minimum temperatures are 60.8 and 30.9 degrees Fahrenheit, respectively. Meeteetse, on the other hand, records averages of 54.2 and 23.8 degrees, respectively, at an elevation of nearly 5,800 feet above sea level.

Wyoming's high percentage of sunshine, low humidity and high, sometimes persistent winds, all contribute to a relatively high evaporation rate. According to National Weather Service data, the free water surface evaporation from May to October within the watershed is as high as 30 inches per year (WRDS, 2017).

### 2.1.2 Topography

The topography of the Greybull River watershed varies considerably because of historic and ongoing geologic, glacial, erosional, wind and fluvial processes. The Greybull River drains the major portion (736,000 acres) of the project's one-million-acre area. Dry Creek, which flows in a west-to-east direction north of the Greybull River, drains approximately 280,000 acres of the northern portion of the watershed. Both orient northeast from their respective headwaters then eastward through topography which includes mesas, buttes, lowlands, badlands, plus irrigated farm and ranch land before both confluence with the Bighorn River on the eastern edge of the watershed. Figure 2 depicts the watershed's topography. The landscape of the watershed consists of:

- The forested Absaroka Mountain Range in the western portion of the area;
- The stream valleys and low terraces;
- The bedrock slopes and badlands; and
- The flat-topped interstream divides.

The Greybull River's headwaters are in the Absaroka Mountain Range, within the Shoshone National Forest, which rise to elevations over 13,000 feet above sea level.

From the Continental Divide in the Absaroka Range, the eastward transition from mountain to stream valley terrain is approximately 20 miles with an elevation drop of over 6,000 feet. The stream valley area is uplifted and faulted sedimentary rock, consisting of interbedded sandstone, siltstone and shale yield areas typical of this lower region below the Shoshone National Forest. Beginning at an elevation of roughly 8,000 feet above sea level (asl), the watershed slopes gradually to 4,000 feet over 100 miles to the confluence of the Greybull River with the Bighorn River.

At the base of the mountain terrain, the Wood River confluences with the Greybull River approximately one mile downstream of the Lower Sunshine Reservoir in the southwest portion of the watershed. The Upper Sunshine Reservoir is located approximately 2.5 miles upstream of the Lower Sunshine Reservoir.

Farther downstream are river and stream terraces composed of soil and gravel benches. These are the result of depositional and erosional actions of glaciers and high precipitation events. Floodplains are prevalent in

the river and stream bottoms throughout the watershed. These floodplains are subject to cyclical flooding, stream channel migration and depositional/erosional events.

The width of the Greybull valley floor ranges from less than a half mile to more than three miles. In places the alluvial valley is flanked by low terraces. These low terraces and bedrock slopes rise above the valley floor. They are gently sloping and smooth in some places near Otto WY, but have eroded into rugged badlands below the YU Bench (USGS, 1963). The YU Bench is a geologic feature located north of the Greybull River between the communities of Meeteetse and Burlington. Beginning approximately eight miles northeast of Meeteetse, the Bench stretches eastward to Burlington totaling approximately 26 miles in length. The floodplains and some benches are where most agricultural operations take place within the watershed.

Approximately 30 miles downstream from its headwaters the Greybull River flows through the town of Meeteetse at an elevation near 5,800 feet. Here the drainage area totals approximately 441,600 acres. From this location, the river flows northeast along the southern flank of the YU Bench which itself rises to an altitude of nearly 5,400 feet.

South of both the YU Bench and the Greybull River between Meeteetse and Burlington is the Roach Gulch area which includes the Roach Gulch Reservoir. This water supply is located approximately ten miles southwest of Burlington. Farther downstream and northeast of Burlington the river is forced eastward due the rising influence of the 5,000-foot Table Mountain.

From Burlington, the river meanders through mostly agricultural land for 22 miles where its 90-mile journey concludes with the confluence of the Bighorn River. Located on the eastern edge of the watershed, this confluence is less than a mile south of the town of Greybull. Here the elevation is just under 3,800 feet above sea level. At this point the river's drainage area totals approximately 736,000 acres (USGS, 2017a).

As noted earlier, Dry Creek drains the northern portion of the watershed totaling approximately 280,000 acres. When compared to the Greybull River, its headwaters begin at lower elevations within the Absaroka Range and are located farther north. The creek meanders along the northern flank of the YU Bench before reaching Burlington. Much like the Greybull River, it too is influenced by Table Mountain's higher elevation and forced eastward through similar agricultural land. From Burlington the creek continues its eastward movement until it confluences with the Bighorn River on the northern outskirts of Greybull.

The gradient at the upper portion of the watershed is nearly 5.6 percent grade. Near Meeteetse, the grade of the landscape is still quite steep at approximately 4.5 percent from the top of the watershed to the Town of Meeteetse. The gradients, combined with the sandstone and shale composition of the bedrock and soil, contribute to many of the concerns observed during field visits. High energy flow of snow melt during spring run-off erodes the soil and causes rapid stream channel migrations as observed during the spring and summer of 2017.

Sediment collected from bank erosion is deposited farther downstream where the river gradient tends to drop to less than one percent with wide floodplains that are now developed into agricultural use. Natural stream morphology is constrained by anthropogenic modifications which become at-risk during flooding events. This has also been observed over the years with eroded cropland, damaged diversion structures, eroded canal / ditch embankments, and sediment / silt removal needs for downstream landowners.

### 2.1.3 Geology

#### 2.1.3.1 Regional Geology

The Greybull River Watershed lies within the Bighorn Basin which is situated in the northwest section of Wyoming. The Bighorn Basin is a large depression and comprises approximately 10,000 square miles. The existing structural configuration of the basin was the result of the Laramide orogeny (tectonic plate interaction) from the Late Cretaceous through the Early Eocene periods. During this time the peripheral mountain uplifts experienced major growth. This folding and faulting eventually formed the mountain ranges surrounding the basin and the oil-producing anticlines so prevalent in the basin (Blackstone, 1963). Figure 3 provides a regional geologic map depicting the Bighorn Basin depression (blue line) and the Greybull River Watershed boundary (red line) with data obtained from the Wyoming State Geological Survey. The legend for the figure follows on the ensuing page.

Listed in clockwise fashion, the Bighorn Basin is bounded to the north by the Pryor Mountains which form a plug forcing the basin's two major rivers, the Bighorn River and the Clark's Fork of the Yellowstone River, on either side of the plug. Both rivers orient northward and drain the oval-shaped basin. The east side of the basin is bounded by the Bighorn Mountains, the Bridger Mountains lie southeast, the Beaver Rim Range is on the south side of the basin while the Owl Creek and Wind River Mountains are situated on the southwest. The Absaroka Mountain Range is on the west while the Bear Tooth Mountains lie northwest.

Similar to many river basins, the Bighorn Basin water quality is strongly influenced by geology and terrain. The natural water quality characteristics of streams head-watered in the Wind River Range and Bighorns are relatively similar due to similar climate, terrain and geology.

As the streams and rivers flow across the basin into the Bighorn River the water quality gradually changes due to natural erosion and stream processes which increase sediment and total dissolved solids (TDS). Discharge from oil and gas development, irrigated agriculture runoff, accelerated erosion and human activity all contribute to the potential for degradation of water quality (Robinove, 1956; Zelt, 1999).

In the Absaroka Mountain Range, streams head-watered from these mountains generally carry very high sediment loads due to the volcanic geology which erodes easily from the young mountain range (WDEQ, 2006). Within the Greybull River watershed there are three major rivers/streams. Of those three, the Greybull and Wood Rivers headwater in the Abaroka Range, while Dry Creek headwaters in lower elevations in the west-central portion of the watershed. All three drain the watershed and eventually discharge into the Bighorn River.

Much of the lower portions of the Bighorn Basin express thin soils extracted from phosphate-rich, alkaline and saline geologic materials which are highly erodible. Within these lower portions much of the precipitation is the result of summer thunderstorms where sudden bursts of rain tend to cause flash flooding and severe erosion of normally dry soils. This area typically receives less than nine inches of precipitation a year.

Subsequently, the Bighorn River naturally carries high sediment loads which have increased due to human influences. It is understood man's influences in the lower elevations of the basin date back to the 1880s, when old grazing practices comprised of primarily long-term periods when high densities of stock removed existing grasses. This, in turn, began a cycle of gullying and intense runoff which intensified the naturally

occurring existing condition (Marston and Anderson, 1991). To further complicate the cycle is the construction of dams and other activities which in turn adds to the natural flow regime of the basin (Robinove, 1956; Bray, 1996).

#### 2.1.3.2 Greybull River Watershed Geology

The Greybull River is the third largest tributary of the Bighorn River. It flows approximately 90 miles from its headwaters in the Absaroka Range to its confluence with the Bighorn River near Greybull WY. The Greybull and Wood Rivers and their tributaries, and Dry Creek and its tributaries drain the watershed which totals over 1,584 square miles (1,013,991 acres).

A portion of the Absaroka Range is situated in the far western part of the Greybull watershed. This rugged, northwest-trending range stretches from northwest Wyoming into southwestern Montana and includes elevations over 13,000 feet above sea level. Its 155-mile-long spine is the result of the Absaroka volcanic providence composed mainly of deeply eroded Eocene andesitic volcanic rocks. These include breccia, conglomerate, claystone, siltstone and sandstone. The facies relations and thicknesses of the volcanic-rich strata along the east edge of the range indicate the volcanic debris may have originally covered most of the Bighorn Basin (Smedes, 1972).

Many assume the Absaroka volcanic deposits are the result of Yelllowstone's volcanic activity. However, the volcanics in the Absaroka range are not related to the younger Yellowstone activity. Much of the volcanic materials in the range are sourced as a result of four primary vent areas from stratovolcanoes and shield volcanoes. Some portions of the range's volcanic field are up to 5,000 feet thick (WSGS, 2017).

Beginning with its headwaters in the Absaroka Range, the axis of the Greybull River valley generally lies from southwest to northeast. In general, the area is characterized by the Quaternary and Tertiary alluvial and terrace deposits which are underlain by older bedrock formations. Beginning with the oldest and deepest formations, these include the Frontier Formation, Cody Shale, Mesaverde Formation, Meeteetse Formation and the Lance Formation of Cretaceous age. Closer to the surface, these are followed by the Fort Union and Willwood Formations of the Tertiary age (AECOM, 2017).

Along the Greybull River valley are alluvial deposits which are generally fine to coarse gravels, sands and cobbles. Floodplain deposits of silts and clays are typically interlayered within these alluvial deposits and include the occasional bed of gravel and sand. Flat-topped interstream divides above the valleys are covered by terrace deposits. These terrace deposits consist of silts, sands, fine to coarse gravels and cobbles. The central portion of the watershed near the Roach Gulch Reservoir includes the more erosion-resistant sandstone which forms the nearby flat-lying benches. The less erosion-resistant claystone and siltstone form convex slopes below these sandstone beds (AECOM, 2017).

**Greybull River Watershed Stratigraphy**

The rocks exposed in the Greybull River watershed, include:

- Triassic system (Chugwater Group);
- Jurassic system (Morrison Formation) (Hewett, 1926);
- Lower Cretaceous system (Cloverly Formation, Thermopolis Shale and Muddy Sandstone);

- Upper Cretaceous system (Mowry Shale, Frontier Formation, Cody Shale, Mesaverde Formation, Meeteetse Formation, Bearpaw Shale and Lance Formation);
- Tertiary system (Fort Union Formation and the Willwood Formation) (Finn, 2010); and
- Quaternary (surficial) system (Terrace deposits and Alluvium) (Hewett, 1926).

A brief discussion of the bedrock geologic systems is provided in Appendix B. The Quaternary system is described in further detail below. Figures 4 and 4a, and Figure 5 and 5a provide generalized bedrock and surficial geology maps for the Greybull River watershed. In addition, Figure 5 provides an inventory of various surficial geology in acreage and percent of total study area.

The Bighorn Basin and much of the Greybull River watershed is a sedimentary basin of Laramide-age and -style. The basin's interior is a thick sequence of relatively flat-lying Eocene and Paleocene rocks surrounded by folded Mesozoic and Paleozoic rocks. The asymmetric syncline basin is deepest near its western margin. Its Precambrian-Cambrian contact (from its greatest depth in the basin to its highest elevation in the surrounding mountains) is approximately 30,000 feet (WSGS, 2017).

The flanks of the watershed express many geologic structures that are well exposed as a result of fluvial systems cutting down through the Tertiary sedimentary cover. The axis of the Greybull River valley generally lies from southwest to northeast. In general, the watershed's surficial geology is characterized by the Quaternary and Tertiary alluvial and terrace deposits.

These surficial deposits are underlain by older bedrock formations Beginning with the oldest and deepest formations, these include the Frontier Formation, Cody Shale, Mesaverde Formation, Meeteetse Formation and the Lance Formation of Cretaceous age. Closer to the surface, these are followed by the Fort Union and Willwood Formations of the Tertiary age (AECOM, 2017).

Two of the three larger storage reservoirs in the watershed, the Upper Sunshine and Lower Sunshine Reservoirs, are in the western portion of the watershed west of the town of Meeteetse. Both reservoirs express bedrock consisting of Upper Cretaceous Cody Shale. The foundation of the upper reservoir's dam consists of interbedded shale and fine-grained sandstone. The bedrock at the Lower Sunshine Reservoir's dam is a sedimentary formation. Here the upper portion is composed of sandy shale while the lower portion is composed of dark gray, thinly bedded marine shale (Pierce, 1997).

Previous reports have expressed concerns about the Lower Sunshine dam's safety due to the potential for internal erosion or even a piping mode failure along the embankment/foundation contact on the right abutment (AECOM, 2017). Though designed to accommodate a future raise, this dam at Lower Sunshine reservoir does experience very high seepage in the sandstone and shale foundation and abutments. The seepage has been a historic concern of the Wyoming State Engineer's Office (AECOM, 2017). Here the sandstone crops out at or near the seepage exit areas downstream of the abutment.

Downstream from Meeteetse and near Burlington in the Roach Gulch area, the bedrock consists of the Willwood Formation. This sedimentary formation is mainly composed of claystone and siltstone with interbedded layers of sandstone. It slopes generally from three to six degrees to the northeast. These beds range from poorly indurated, or hardened, in the claystone to moderately indurated for some of the siltstone

and even portions of the sandstone. These claystones in the region tend to be moderately to highly dispersive (GEI, 1994). The landscape in this area of the watershed is the result of the three major geomorphic features which include:

- The stream valleys and low terraces;
- The bedrock slopes of the Willwood Formation which form the badlands of the area; and
- The relatively flat-topped interstream divides.

The badlands in this area of the watershed are essentially the slopes of the Willwood Formation which rise above the river valley floor to the interstream divides. Typically, these slopes contain erosional sinks and cavities which are associated with the dispersive claystone bedrock (GEI, 1994). The Bedrock Geology Figure 4 depicts the badlands as the area labeled 'Twl' which covers much of the eastern portion of the watershed.

The Roach Gulch Reservoir, the third of the three larger storage reservoirs in the watershed, is located in this area and was constructed in 1999. Similar to the Sunshine Reservoirs, this is an 'off channel' reservoir and filled utilizing a diversion dam with a feeder canal.

Much like the Lower Sunshine Reservoir, there are seepage concerns at the Roach Gulch Reservoir. The seeps appeared in July 2000 shortly after construction was completed. These seeps were noticed downstream in the left abutment area and reportedly have continued to the present. A year later after the reservoir reached its maximum level, new seeps were reported 600 feet downstream of the right abutment. They subsided in the summer of 2001 after the reservoir was drawn down but then reappeared in 2004 when the level was raised once again after a drought period (AECOM, 2017).

It is believed sandstone beds are conveying water to both the left and right seeps. In this area, the bedrock bedding is generally horizontal and includes a slight dip in the downstream direction. Though the left seep may be related to incomplete closure of the grout curtain during construction, the right seep seems to be especially influenced by the slight downstream dipping bedrock (AECOM, 2017).

### 2.1.4 Soils

Soils in Wyoming show a close relationship to the geologic parent materials and vegetation communities under which they form. Equally important are the landscape stability and age relationships in understanding soil occurrence throughout the state. The soils within the Greybull Watershed vary from the types found in the Absaroka volcanics to those found in the Bighorn Basin. Figure 6 depicts the soil types, within the watershed, sourced from the USDA Natural Resources Conservation Service's State Soil Geographic (STATSGO) for Wyoming. The legend (Figure 6a) follows on the figure's ensuing page.

The watershed soil parent materials, topography and climate vary significantly throughout the watershed. In the western mountainous areas, the presence of a well-defined soil structure is minimal at best. As noted in the geology discussion, the valley floors have recent alluvial deposits characteristically created from eroded sands, silts, shales and volcanic rock.

#### 2.1.4.1 Soil Moisture and Temperature Regimes

According to a soils map developed by the University of Wyoming, the soil moisture and temperature regimes in the watershed are important characteristics of soils regarding classification. In addition to direct effects of climate, the soils are also influenced by slope, aspect, plant cover, permeability and water table (Munn,1998).

The seasonal incidence and amounts of water that enter the soil and infiltrate, or are held and used by plants, are important properties regarding the uses of soil. Moisture regimes are generally related to climate and estimated from climatic data (Munn,1998). Moisture regimes recognized in Wyoming include:

- ***Aridic:*** These soils are dry more than half the time and warm enough for plant growth. They are never moist in any part for 90 consecutive days when they are warmer than 46 degrees F. Typically they have an annual precipitation of less than 14 inches and are too dry for annual cropping. Many require irrigation for crop production.
- ***Ustic***: Soils in this regime are dry in some or all parts for 90 or more cumulative days. Still, they are not dry in all parts more than half the time when they are warm. They do not have a prolonged summer dry period. There is limited moisture and typically occurs during the growing season. These soils can be annually cropped in years of average or above average rainfall.
- ***Udic:*** Moist conditions typify these soils. They are not dry in any part for as long as 90 cumulative days. They do not have a prolonged summer dry period though they are never wet for short periods. Often, they are described as humid. There is sufficient moisture for annual cropping or for good forest and range production. Wyoming's mountain regions often include udic soils and most are cold.
- ***Aquic:*** These soils are saturated by a seasonal or permanent high-water table. Often, they are subject to reducing conditions reflected by grayish and mottled colors.
- ***Xeric:*** These soils are moist in some part for more than half the cumulative days per year when the soil temperature at a depth of nearly 20 inches is higher than 41 degrees F.

The soil temperature regimes are defined in relation to the mean summer soil temps and the mean annual soil temps at a depth of 20 inches (Munn,1998). The first three temperature regimes below occur extensively in Wyoming while the last three are recognized but rarely occur in the state:

- ***Frigid:*** This regime has a mean annual temp below 47 degrees F but above 32 degrees. These soils are described as cool but not cold.
- ***Cryic:*** This temperature regime also has a mean temp between 32 to 47 degrees. In addition, it also has cool summer soil temperatures below 59 degrees in July through August. Plus, they are below 47 degrees if the surface expresses an organic layer such as a forest floor. If the soil is saturated, and has no surface organic layer, then the temp is below 55 degrees.
- ***Mesic:*** This regime has a mean annual soil temp between 47 to 59 degrees and is typically found in the middle latitudes. In Wyoming, these soils can be found in the Bighorn Basin, which the Greybull Watershed is included, and out on the eastern plains.
- ***Perfellic***: The mean annual soil temp here is below 32 degrees F where permafrost occurs in moist soils. In Wyoming, small areas at very high elevations in the alpine can have this regime.

- ***Thermic:*** In this regime, the mean annual soil temp is between 59 to 72 degrees where the difference between summer and winter at 20 inches is 41 degrees. This is common in the of the cotton belt in the southern U.S.
- ***Hyperthermic:*** Much like the thermic above, the mean annual soil temp is between 59 to 72 degrees. But the difference between summer and winter at 20 inches is greater than 41 degrees. This is common in the tropics of the world.

#### 2.1.4.2 Moisture and Temperature Regimes Within the Watershed

In the watershed, the western portions within the Absaroka volcanics include the cryic temperature regime, and the udic and aquic moisture regimes. Three types of soils in this area include (Munn,1998):

- Loamy-skeletal, and fine-loamy over sandy or sandy skeletal soils which reflect the volcanic parent material;
- Loamy-skeletal, rock outcrop and fine-loamy over sandy or sandy-skeletal soils where bedrock outcrops dominate the landscape. In the riparian areas between steep slopes, fine-loamy over sandy or loamy-skeletal soil has developed in accumulations of fine materials weathered from the surrounding uplands; and
- Fine-loamy over sandy or sandy-skeletal, and loamy-skeletal soils. In the alpine settings, the soils over most of the landscape are an association of fine-loamy over sandy in the riparian areas with loamy-skeletal on uplands.

The remainder of the watershed basin includes soils with a mesic temperature regime and an aridic moisture regime. Here, seven types of soil can be described (Munn,1998):

- Fine-loamy over sandy, sandy-skeletal, fine-loamy and coarse-loamy with saline or alkaline soils (Aridisols) on the colluvial and alluvial landscapes. Typically, these contain very little organic matter. Elsewhere on the residual landscapes are soils comprised of mineral soils (Entisols) which have not differentiated into distinct horizons or layers.
- Stabilized sand dunes exhibit soils (Typic Torripsamments) with little horizon development where thin ‘A’ horizons are the most apparent change from the parent material.
- Another type of soil (Calcic Haplosalids) is associated with marine shales and occurs in depressions where run-off from the surrounding area accumulates and evaporates concentrating the salt.
- Loamy and rock outcrop soils form in a variety of sedimentary parent materials and are exposed along the perimeter of the basin. These soils are shallow or moderately deep to soft bedrock.
- Other soils form over fine-textured Cretaceous bedrock. These outcrops of shale occur as small badlands; outcrops of coarser textured rock support long, narrow ridges with finer textured soils along the flanks.
- Fine-loamy or coarse-loamy soils occur on low-gradient (less than 15%) colluvial slopes. They reflect the texture of the underlying bedrock as well as the effects of the slope processes.
- Sandy-skeletal, fine-loamy over sandy or sandy-skeletal soils occur on Holocene-age terraces and slopes along small streams. Typically, they occupy the first two terraces above the modern channel.

### 2.1.4.3 Descriptions of Soil Groups Located Within the Watershed

Within the watershed, the soil parent materials, topography and climate vary significantly throughout the watershed. In the western mountainous areas, the presence of a well-defined soil structure is minimal at best. As noted in the geology discussion earlier, the valley floors have recent alluvial deposits characteristically created from eroded sands, silts, shales and volcanic rock.

Figure 6 depicts the overview of the soils groups within the watershed according to their United States Department of Agriculture (USDA) code. Table 1 shows those corresponding codes, names, approximate acreage and the percentage of each group within the watershed.

**Table 1: Soil Groups of the Greybull River Watershed**

| Soil Code | Name | Approximate Number of Acres | Percentage of Watershed |
|---|---|---|---|
| s8978 | Rock outcrop-Nielsen-Hobacker-Clayburn-Blaine-Bachus (s8978) | 230,453 | 23.7 |
| s8946 | Travson-Shingle-Rock outcrop-Midway-Keyner-Hiland-Bowbac (s8946) | 170,489 | 16.8 |
| s8974 | Yamac-Evanston-Attewan (s8974) | 83,626 | 8.3 |
| s8949 | Youngston-Worland-Persayo-Oceanet-Greybull (s8949) | 79,899 | 7.9 |
| s9123 | Rubble land-Rock outcrop-Cowood (s9123) | 73,260 | 7.3 |
| s8951 | Youngston-Willwood-Sharland-Preatorson-Lostwells-Garland-Apron (s8951) | 62,670 | 6.3 |
| s8967 | Youngston-Rock outcrop-Persayo-Neiber (s8967) | 57,679 | 5.7 |
| s8976 | Zillman-Evanston-Delphill-Crago-Brownsto-Blazon-Blackhall (s8976) | 55,261 | 5.5 |
| s8973 | Yamac-Moyerson-Forelle-Diamondville-Delphill-Blazon-Blackhall-Alcova (s8973) | 49,740 | 4.9 |
| s8971 | Youngston-Sharland-Garland (s8971) | 47,991 | 4.7 |
| s8975 | Yamac-Vanda-Evanston-Alcova (s8975) | 47,963 | 4.7 |
| s8950 | Youngston-Uffens-Stutzman-Lostwells-Apron (s8950) | 42,927 | 4.2 |
| s9076 | Woosley-Starman-Rock outcrop-Mosroc-Fornor-Decross (s9076) | 11,105 | 1.10 |
| s8369 | Water (s8369) | 927 | 0.10 |

Source: USDA, 2017

Utilizing the data and soil descriptions available from the USDA Natural Resources Conservation Service (NRCS) website, Appendix A provides descriptions the 13 groups of soils most common in the watershed beginning with the highest percentage found within the watershed (USDA, 2017).

### 2.1.5 Groundwater

The Greybull River watershed study area lies within the Bighorn Basin which is situated in the northwest section of Wyoming. This basin is a large, oval-shaped depression and comprises approximately 10,000 square miles. The watershed study area is situated in the western portion of the basin and occupies approximately 1,600 square miles.

Like many basins in the western U.S., the Bighorn Basin is bounded by several mountain ranges. Most notably is the Bighorn range to the east, the Absarokas to the west, the Bear Tooth range to the northwest and the Pryor Mountains to the north.

Various geologic units underlay the watershed and function as storage reservoirs and groundwater filters. The steep terrain of the Absaroka Mountain Range in the westernmost portion of the study contains the headwaters for both the Greybull River and Wood River. This terrain is situated atop Eocene formations consisting of interlayered sedimentary and volcanic rocks. The headwaters for Dry Creek are in the west-central portion of the study area and are underlain by sedimentary layers of Eocene, Upper Cretaceous and Paleocene formations. The areas downstream within the watershed are underlain almost exclusively by sedimentary Eocene formations.

#### 2.1.5.1 Aquifers

Both unconsolidated and bedrock aquifers are important water resources in the watershed. The groundwater in unconsolidated aquifers is unconfined while the water in bedrock aquifers is under either confined or unconfined conditions. The aquifers are typically named after the formations that hold the water and can be seen geographically on the Bedrock Geology Figure 4.

##### *2.1.5.1.1 Unconfined Aquifers*

The two principle unconsolidated aquifers in the study area are the alluvium and colluvium deposits and the gravel, pediment and fan deposits. These aquifers are among the most productive and predictable sources of groundwater in the area and is the principle municipal water source for Burlington and Emblem. The groundwater level in these aquifers is influenced by irrigation and crop uptake. Groundwater levels rise in the spring as irrigation begins and declines in the fall after irrigation ceases. Minor fluctuations occur during the irrigation season which are caused mostly by water use by crops. Irrigation accounts for the majority of groundwater recharge in agricultural areas. (Robinove and Langford, 1963)

The alluvium and colluvium deposits are located along the major streams including the Greybull River, Wood River, Dry Creek, and Meeteetse Creek. The thickness of these deposits is typically less than 30 feet.

The gravel, pediment and fan deposits are mainly located along the Emblem Bench, the YU Bench, Table Mountain, Rose Creek, and the Meeteetse Rim. These deposits typically overlie bedrock such as the Willwood Formation which causes the groundwater to be perched above the stream. These deposits are typically thicker than the alluvium and colluvium deposits and can be as thick as 100 feet. Flow direction along the Emblem Bench has been documented to flow down valley, toward the Bighorn River (Plafcan et. al., 1993).

#### *2.1.5.1.2 Bedrock Aquifers*

Several bedrock geologic formations that are known to hold water to some degree are present in the study area, however the four most notable are the Willwood, Lance, and Mesaverde Formations, and the Madison Limestone.

The Willwood Formation underlies a large portion of the eastern half of the watershed and ranges from 1,500 to 2,300 feet thick. It was formed in the Eocene epoch from fluvial deposits and consists of mudstone, claystone, siltstone, carbonaceous shale and thin sandstone layers. The sandstone layers yield the most water but are laterally disconnected and are only two feet thick on average so the feasibility of drilling into this layer is low. Yields range from less than one to 120 gallons per minute (gpm) though most common yields are less than ten gpm.

The Lance and Mesaverde Formations are two of the Upper Cretaceous rocks and range from 1,300 (Mesaverde Formation) to 1,800 (Lance Formation) feet thick and made up of primarily of claystone, siltstone and shale. These formations have the most potential for development as a water supply. The nearby town of Manderson and the Orchard Bench area have already successfully developed the Lance Formation as its primary water supply (Plafcan et. al., 1993). Depth to water ranges from five to 200 feet in nine existing wells completed in the Lance Formation. The Mesaverde Formation contains sandstone lenses that are five to 40 feet thick and has reported water yields of ten to 35 gpm. Depth to water ranges from 2.4 to 176 feet.

The Madison Limestone is a formation of carbonate rocks layered during the Mississippian Period and is considered one of the major cliff-forming units. The formation's thickness exceeds 1,600 feet in some areas of Wyoming. The Madison Limestone, in combination with the Darby Formation and the Bighorn Dolomite, form the Madison-Bighorn aquifer which has reported water yields from 40 to 14,000 gpm. "The difference in altitude between recharge areas in the mountains and the well locations in the basin in combination with aquifer confinement by impermeable beds, creates highly pressurized artesian conditions in many areas" (Plafcan et. al., 1993).

Much of the populace in the Bighorn Basin obtains its domestic water from the Madison-Bighorn aquifer. This includes the community of Greybull located on the eastern fringe of the Greybull watershed. It is thought that the Madison Limestone may be contaminated with radioactive particles since a well at Frannie consistently exceeded the EPA maximum level for radioactive contaminants. (Plafcan et. al., 1993) The town of Frannie has since installed a pipeline from Buffalo Bill Reservoir for their municipal water source.

### 2.1.5.2 Groundwater Wells

The state of Wyoming defines groundwater or underground water as follows: any water, including hot water and geothermal steam, under the surface of the land or the bed of any stream, lake, reservoir, or other body of surface water, including water that has been exposed to the surface by an excavation, such as a gravel pit or some type of mining operation (WSEO, 1974).

The Wyoming State Engineer's Office (WSEO) maintains the database of permitted groundwater wells within the Greybull River watershed. Section 2.3.4 (Domestic, Municipal and Industrial Water) of this report details the specifics of groundwater wells located within the watershed. The section includes tables which depict:

- Groundwater well types;
- Groundwater well depths;
- Static water level depths in feet; and
- Groundwater well yields in gallons per minute.

#### 2.1.5.3 Springs

Springs typically form when the ground intersects a flowing body of groundwater. This can occur at changes in lithology, faults, or fractures. The USGS National Hydrography Dataset includes 32 springs within the study area, with most springs located in the western half (Figure 7). Most of the springs form the headwaters of streams although there are four springs located near the Greybull River upstream of Sheets Flat.

### 2.1.6 Surface Water

#### 2.1.6.1 Hydrography

The National Hydrography Dataset (NHD) was used to inventory the hydrologic features in the study area. Table 2 below summarizes the feature types found in the Greybull River and Dry Creek Watersheds. These features are also displayed on Figure 8.

**Table 2: Hydrologic Feature Types**

| System | Feature Type | Length (Miles) | | |
|---|---|---|---|---|
| | | Greybull River Watershed | Dry Creek Watershed | Combined |
| **Irrigation:** | | **388.45** | **138.41** | **526.85** |
| | Connector: | 0.09 | 0 | 0.09 |
| | Canal/Ditch: | 387.71 | 135.62 | 523.33 |
| | Aqueduct: | 0 | 0.03 | 0.03 |
| | Pipeline: | 0.25 | 0 | 0.25 |
| | Underground Pipeline: | 0.12 | 2.73 | 2.85 |
| | Siphon Pipeline: | 0.28 | 0.03 | 0.32 |
| | | | | |
| **Streams:** | | **4709.48** | **1385.59** | **6095.07** |
| | Stream/River: | 1.47 | 0 | 1.47 |
| | Intermittent: | 2711.05 | 1304.54 | 4015.59 |
| | Perennial: | 540.9 | 62.2 | 603.1 |
| | Ephemeral: | 1271.21 | 0 | 1271.21 |
| | Artificial Path: | 184.86 | 18.85 | 203.71 |
| | **Total:** | **5097.93** | **1524.00** | **6621.93** |

Nearly all (99 percent) of the irrigation features in both the Greybull River and Dry Creek Watersheds are canals or ditches. The highest concentration of canals/ditches is located around Burlington, Otto, and Emblem. More details regarding agricultural water use can be found in Section 2.3.3.

For clarification purposes, the WDEQ definitions for intermittent, ephemeral and perennial streams are as follows (WDEQ, 2018):

- An intermittent stream means a stream or part of a stream where the channel bottom is above the local water table for some part of the year, but is not a perennial stream;
- An ephemeral stream means a stream which flows only in direct response to a single precipitation event in the immediate watershed or in response to a single snow melt event, and which has a channel bottom that is always above the prevailing water table; and
- A perennial stream means a stream or part of a stream that flows continually during all of the calendar year as the result of a groundwater discharge or surface runoff.

Intermittent streams make up the highest proportion of stream miles in both Dry Creek and Greybull watersheds, comprising 94 percent of stream miles in the Dry Creek Watershed. The NHD does not classify any streams in the Dry Creek watershed as ephemeral while 27 percent of the streams in the Greybull River watershed are classified as ephemeral. Eleven percent of streams in the Greybull Watershed are classified as perennial while four percent of streams in the Dry Creek Watershed are classified as perennial. The artificial path classification was included under the streams system because a significant portion of the Greybull and Wood Rivers were classified as an artificial path. These streams are actually perennial streams that were misidentified. Artificial paths also appear where streams have been dammed to create stock ponds or reservoirs.

#### 2.1.6.2 Fluvial Geomorphology

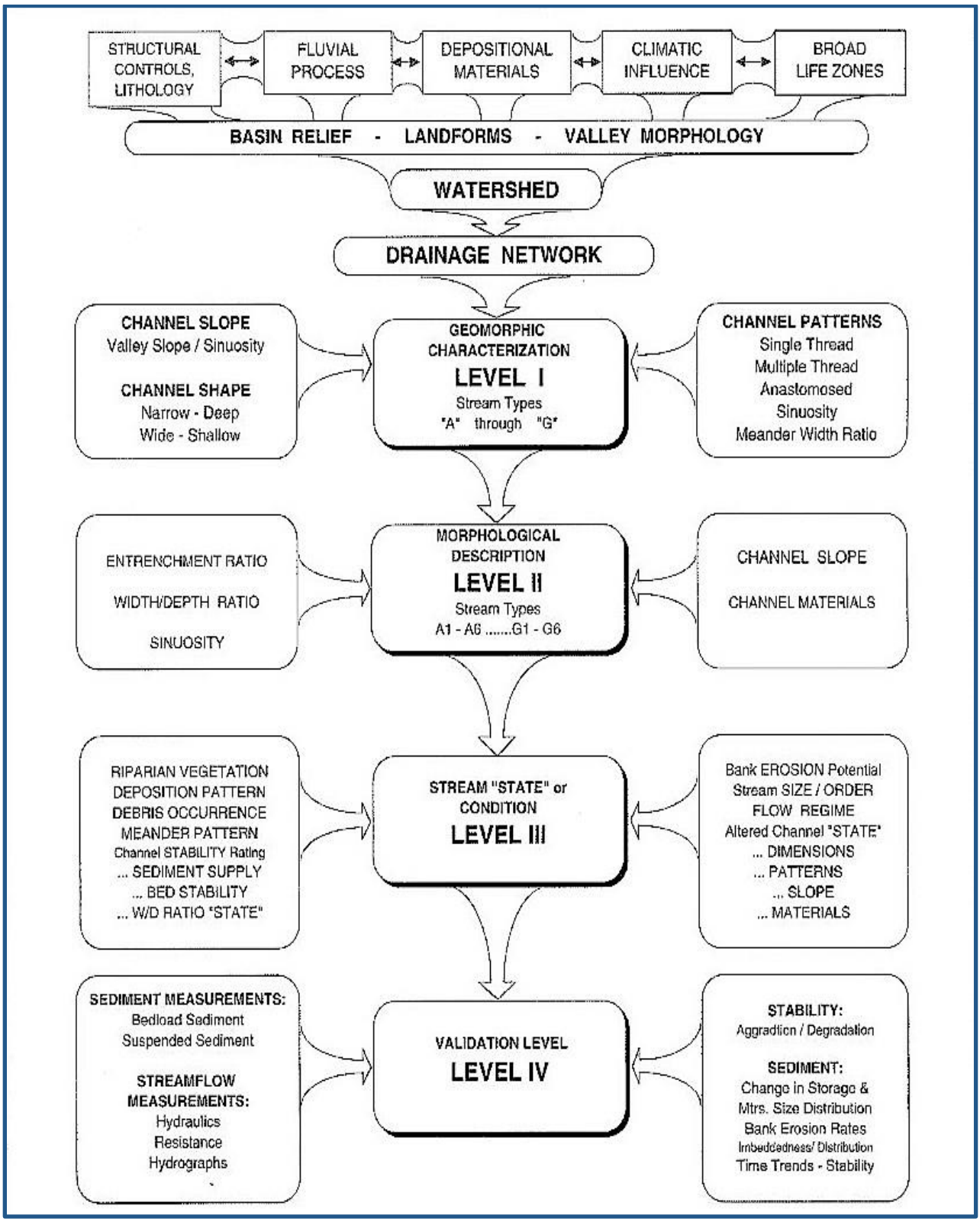
Fluvial geomorphology is the study of how flowing water forms landscapes. Water continually erodes and deposits sediment within a watershed. Water collects in common flow paths to create streams which act as veins of a watershed, transporting sediment and nutrients from one area to another. Each stream has slightly different characteristics, whether it be its sinuosity and planform, its bedform, gradient, valley type, entrenchment, channel materials or width to depth ratio. These characteristics are important to watershed and land managers because they can indicate channel stability, sediment transport or deposition rates. Fluvial geomorphologists have developed several classification systems grouping streams with similar characteristics to allow scientists and land managers to communicate about streams using a consistent framework.

##### *2.1.6.2.1 Rosgen Stream Classification*

The Rosgen Stream Classification system is one of the most widely accepted stream classification systems. There are four levels of the Rosgen Stream Classification system; each one more detailed and site-specific than the previous (Rosgen, 1996). Given the cumulative stream lengths in the study area and determined level of effort during the initial scoping meeting, streams were classified using Level I methodology which divides the streams into eight major stream types. A Level I Rosgen Classification can provide a general

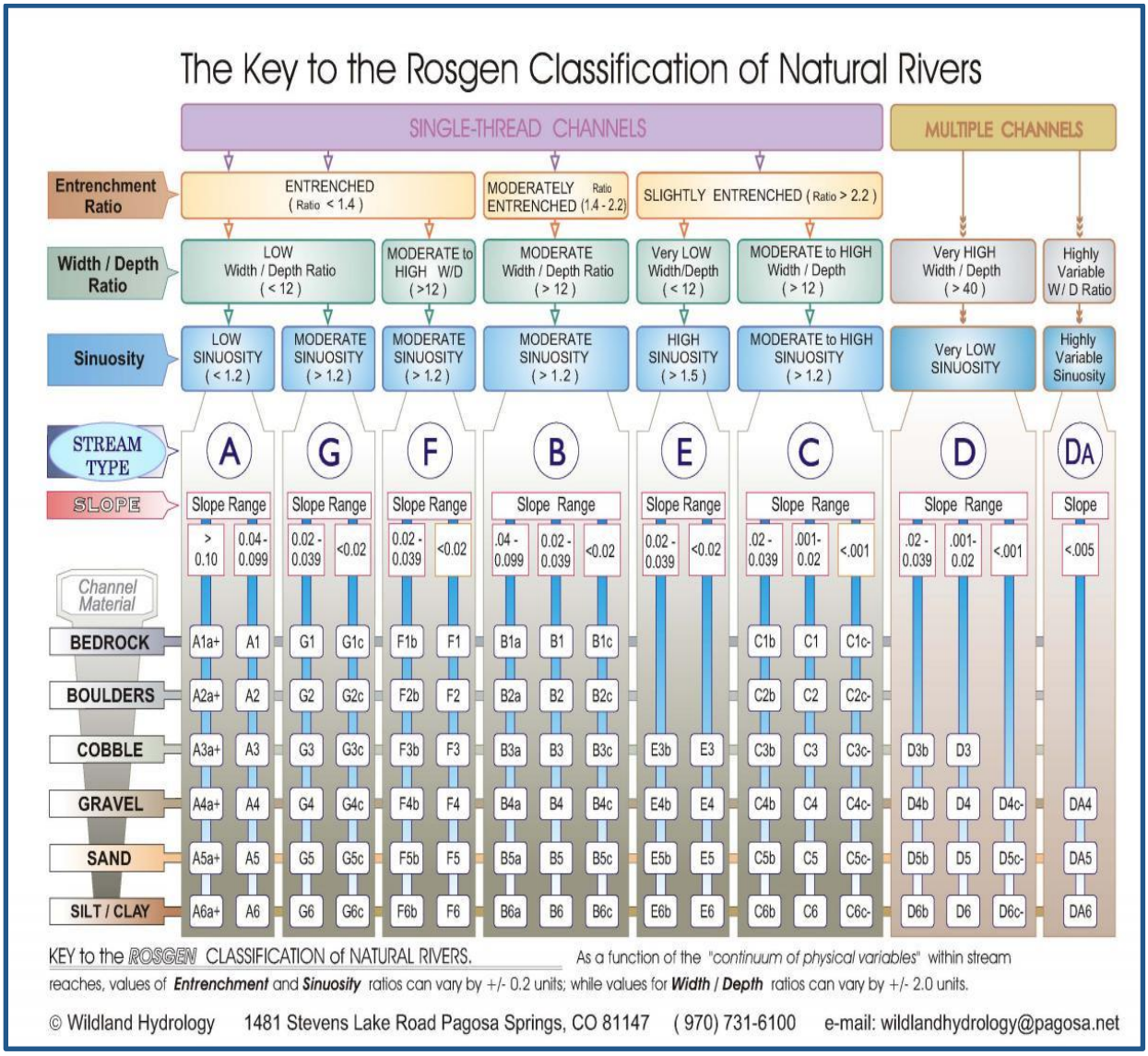
sense of how streams will function in the future and can assist with prioritizing more detailed assessments. Many of the Level I criteria can be determined from topographic and landform maps, and from aerial photography. (Rosgen, 1996)

**Figure 9: Rosgen's Hierarchy of River Inventory and Assessment (Rosgen, 1996)**



All continuously perennial streams were evaluated within the study area according to the Level I methodology, resulting in 659 miles of classified streams. Spatial data of perennial streams was obtained from the National Hydrography Dataset (NHD) provided by the US Geological Survey. Streams were delineated into reaches based on changes in valley type, stream planform, tributaries, and valley slope. A GIS analysis was performed on these reaches to determine stream gradient and sinuosity. Entrenchment and width to depth ratio, typical of a Level II Rosgen analysis, usually cannot be measured with much accuracy using GIS due to inadequate resolution of digital elevation models and the lack of accurate elevation data of land covered by water. Stream classifications were estimated based on the stream gradient, sinuosity, position in the watershed, and valley type according to The Key to the Rosgen Classification of Natural Rivers (Rosgen, 1996). Streams that were ambiguous from GIS analysis were visited in the field where entrenchment ratio and width to depth ratio could be measured or estimated.

**Figure 10: Key to the Rosgen Classification of Natural Rivers (Rosgen, 1996)**



Rosgen stream classification was obtained from the Shoshone National Forest (SNF) and compared against the GIS analysis results. Twenty reaches classified by the SNF overlapped with the perennial streams classified by the GIS analysis. The GIS classification of six reaches matched the SNF classification. Analysis of the remaining 14 reaches were usually classified as a steeper and less sinuous stream type than the SNF classified stream type. This is likely the result of using the NHD stream layer that does not accurately map all meander bends of the streams. These inaccuracies are especially apparent in areas of dense forest. Most of the reaches whose GIS-based classification did not match the SNF classification were changed to match the SNF classification. The GIS analysis was also adjusted to account for this trend of inaccuracy by assuming a higher sinuosity and lower gradient for smaller or tree-covered streams.

In general, the streams classified out to types as expected for their position in the watershed with A type streams in the headwaters, switching to B type streams at lower elevations in mountain valleys, then becoming C, D, or E type streams in the foothills and valley (See Figure 11). Table 3 displays the percentage of stream length and miles of each stream type in the Study Area.

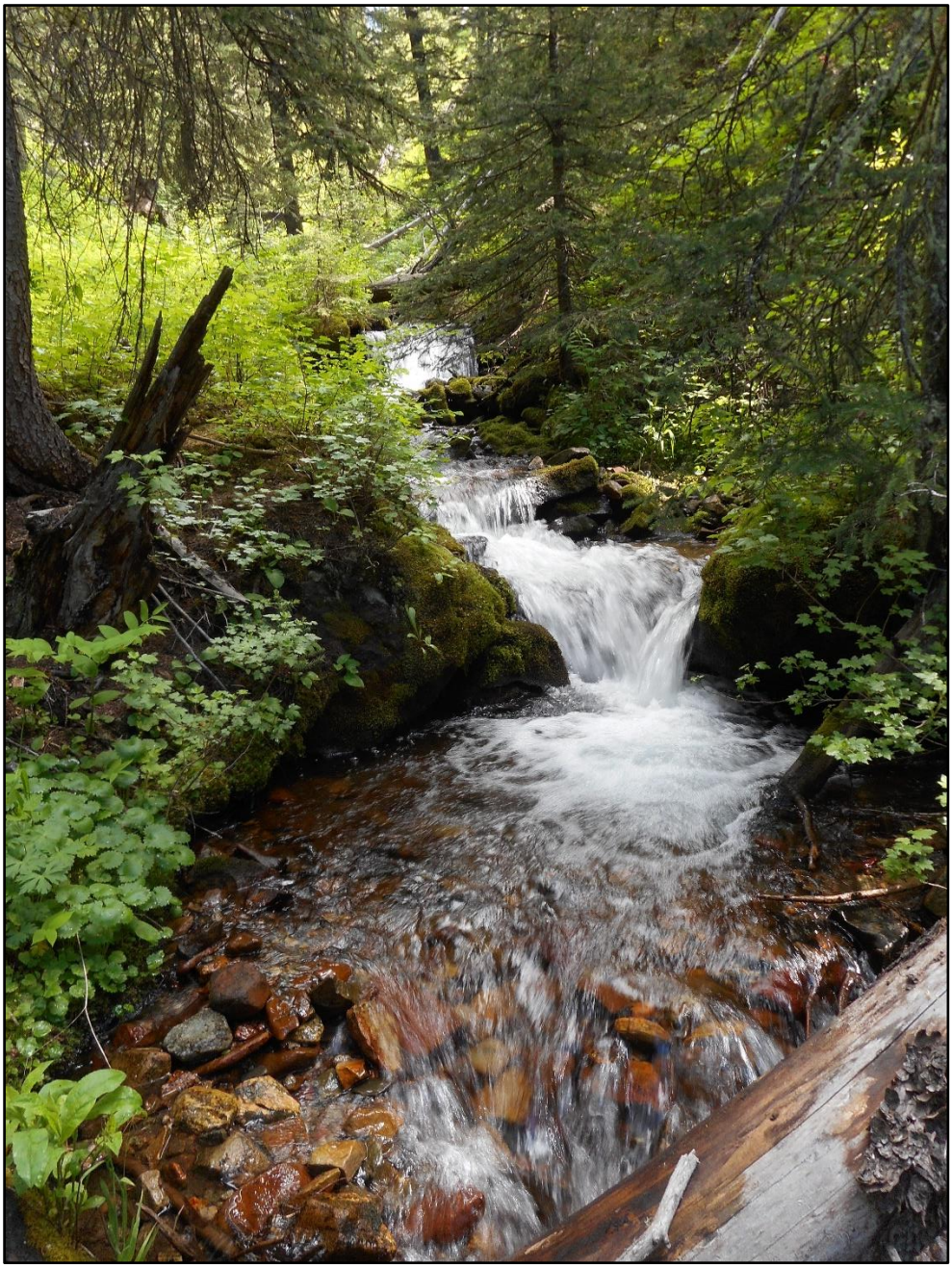
**Table 3: Rosgen Stream Type Summary**

| Stream Type | Miles | Percent of Miles | Percent of Reaches |
|---|---|---|---|
| **A** | 245 | 37 | 55 |
| **B** | 65 | 10 | 10 |
| **C** | 92 | 14 | 12 |
| **D** | 154 | 23 | 15 |
| **E** | 96 | 15 | 8 |
| **F** | 1 | 0 | 0 |
| **G** | 7 | 1 | 1 |
| **Total** | **660** | **100** | **100** |

Type A

The most common Rosgen stream type in the study area is the A type. This is expected due to the dendritic stream network in the upper Greybull watershed. Many small streams form the headwaters of the Greybull and Wood Rivers. These headwaters streams are generally steep and entrenched. A-type streams generally exhibit a high sediment transport potential and a relatively low in-channel sediment storage capacity due to their steep gradients (Rosgen, 1996). Most of the A type streams are located in the Shoshone National Forest.

**Image 2 – Example A Type Channel**



Type D

The second most common Rosgen stream type in the study area is the D type. Most of the Greybull and Wood Rivers were classified as D type streams due to their multiple channels. D type streams have characteristically high bank erosion rates and sediment supply is generally unlimited. Bed features are the result of a convergence/divergence process of local bed scour and sediment deposition. Typically, the runoff regime is "flashy", especially in arid landscapes with highly variable extremes of stage occurring on an annual basis which generates a very high sediment supply. (Rosgen, 1996) Flashy runoff regimes typically have rapid rates of change in flow rather than gradual increases and decreases in flow typical of stable flow regimes.

**Image 3: Example D Type Channel – Greybull River**

Type E

E type streams are common in the study area with the majority of Dry Creek being classified as an E type stream. The lower portions of Rawhide Creek, Spring Creek, and Meeteetse Creek are also mostly classified as E type channels. Valley slopes are gentle in these areas and channel substrate is generally cobble sized or smaller. E type channels are slightly entrenched, exhibit very low channel width to depth ratios, and have very high channel sinuosity. They have the highest number of pools per unit distance when compared with other riffle/pool stream types. E stream types are highly stable but are very sensitive to disturbance, either natural (e.g. wildfire, flood) or human-caused (e.g. urban development, grazing, agriculture). (Rosgen, 1996)

**Image 4: Example E Type Channel – Dry Creek**

Type C

Type C streams are located at the transition zones from D or E type streams to B or A type streams. The upper portion of Dry Creek is classified as channel type C which have well-developed floodplains, are relatively sinuous and low gradient and have a riffle/pool bedform configuration. “Channels of the “C” stream type can be significantly altered and rapidly destabilized when the effects of imposed changes in bank stability, watershed condition or flow regime are combined to cause an exceedance of a channel stability threshold” (Rosgen, 1996).

**Image 5: Example C Type Channel – Dry Creek**

Type B

B type streams are found in the foothills and lower mountains of the Greybull Watershed and are typically found in narrow valleys that restrict development of a wide floodplain. B type streams are moderately entrenched, have low sinuosity, and exhibit a “rapids” dominated bed morphology. Streambank erosion and channel aggradation/degradation rates are normally low. (Rosgen, 1996)

**Image 6: B Type Channel**

G type streams or "gullies" are the least common in the study area and only comprise one percent of the perennial streams by length. G type streams are normally higher gradient, entrenched, and have moderate sinuosity. They have very high bank erosion rates and high sediment supply. (Rosgen, 1996)

Only one reach on Dick Creek was identified as an F type through the Level I stream classification. F type streams are deeply incised in valleys of relatively low elevational relief, containing highly weathered rock and/or erodible materials. They have very high width/depth ratios and have a riffle/pool bedform. The F type streams can have high bank erosion rates and accelerated aggradation and/ or degradation while providing for very high sediment supply and storage capacities. (Rosgen, 1996)

While analyzing several years of aerial photographs of the Greybull River, it was noted that the stream appears to be trending toward a C type channel near the confluence with the Bighorn River. Vegetation appears in recent aerial photographs where previous aerial photographs display sparsely-vegetated point bars and islands. This may be partially due to invasion by noxious riparian plants such as Russian Olive and Tamarisk.

#### 2.1.6.3 Flooding and Runoff

Flooding and streambank erosion is expected to occur with any river and is a natural process and allows the stream to dissipate its energy. Flooding also causes sediment transport and allows nutrient-rich stream sediments to disperse throughout the floodplain, improving the soil for riparian plant species. Lateral stream movement allows the stream to maintain its slope such that the stream system neither degrades nor aggrades. Most of the Greybull River and more than half of the Wood River were classified as Rosgen "D" stream types. The following quote from *Applied River Morphology* describes the movement and erosion expected of "D" stream types:

> *"Bank erosion rates are characteristically high and meander width ratios are very low. Sediment supply is generally unlimited and bed features are the result of a convergence/divergence process of local bed scour and sediment deposition. The multiple channel features are displayed as a series of various bar types and unvegetated islands that shift position frequently during runoff events. Adjustments in channel patterns can be initiated with either natural or imposed changes in the conditions of the encompassing landform, contributing watershed area, or the existing channel system. Aggradation and lateral extension are dominant channel adjustment processes occurring within a range of landscapes from desert to glacial outwash plains*." (Rosgen, 1996)

While streambank erosion is expected for the Greybull and Wood Rivers, certain bank protection measures and best management practices can help to protect infrastructure and other high value resources places within the natural floodplain. Certain streambank factors create a higher potential for erosion such as a bank height greater than the bankfull height, a low rooting depth compared to the bank height, low rooting density, steep bank angle, low surface protection, and fine bank materials. Knowing the erosion risk potential of streambanks can aid in prioritizing stabilization projects.

#### *2.1.6.3.1 Flooding Occurrences and Issues*

Peak flows generally occur from May through July and can cause significant flooding and streambank erosion, especially along the Greybull and Wood Rivers. Peak runoff generally corresponds with spring snowmelt and peak streamflow in recent years (2017 and 2015) have been higher than average. (Refer to Table 6 in Section 2.1.6.6.2 Hydrologic Modeling for a summary of wet years occurring in the watershed which were determined as the top 20 percent of gauged flow.) Multiple land owners reported through surveys, site visits and phone conversations, that erosion and flooding was a primary issue in the watershed. Locations of the landowners providing feedback range primarily along the Greybull and Wood Rivers. Flooding historically has been a concern over the years, but an increased awareness and increase in damage has made this a more prominent issue because of the recent high flows over the past several years. Landowners mention that it is typical to need to repair head gates about every ten years due to flooding; recent flow increase correlates to more frequent damage and more expensive repairs. Following are some examples of reported damage that has occurred over the last several years.

- Large areas of farmland and rangeland were eroded away by the stream and multiple water diversion structures were damaged.
- One rancher reported losing nearly half an acre of land to the river.
- A guardrail along the streambank between the Greybull River and Road 4EU was undermined (Image 7).
- During the recent high flows, new flow paths were created across the floodplain of the Wood River and flooded Wood River Road near the junction with Road 4CP.
- Water backed up from the bridge on CR 3NG caused flooding on the road south of the crossing.
- At a location downstream of Sheets Flat Bridge, the Greybull River eroded back into an irrigation channel, causing pre-mature release of irrigation water as well as head cutting and incision of the irrigation channel (Image 8).
- A similar situation occurred near Meeteetse where the Greybull River eroded into a diversion channel such that the diversion was unusable (see Image 9).

Flooding issues have not been reported along Dry Creek except for near the confluence with the Bighorn River. During winter months, ice dams on the Bighorn River tend to back water up Dry Creek causing flooding.

**Image 7: Guardrail Damaged by Eroded Streambank - Greybull River**

**Image 8: Approximate Land Area Lost to Streambank Erosion – Greybull River *(shown with red line)***

**Image 9: Diversion Channel Damage by Streambank Erosion – Greybull River**

*2.1.6.3.2 Runoff*

Increased runoff in the watershed can contribute to high streamflow and flooding. Land management activities can contribute to increased runoff such as flood irrigation return flow, impervious surfaces from roads and buildings, compacted soils from grazing or industrial use, and the removal or change in vegetation cover and composition. In the Greybull watershed, flood irrigation return flow contribute a significant volume of water back to irrigation canals and the Greybull River which has been attributed as a cause of river impairment for *E.Coli* (RESPEC, 2013). Natural events and processes can also cause increased runoff such as wildfire, hydrophobic soils, weather conditions, and antecedent moisture condition. Natural overland runoff does not appear to be an issue of increased streamflow and erosion within the study area but may also be contributing to elevated *E. Coli* concentrations. The best management practices found in WYDEQ's Livestock/Wildlife Best Management Practice Manual and Urban Best Management Practice Manual provide several methods to reduce runoff and protect soils and streambanks from erosion (WYDEQ, 2013a, b). Some examples include riparian buffers, grassed swales, diversion structures, infiltration basins, and vegetated filter strips.

### 2.1.6.4 Sediment Transport

Water, wind, and gravity transport soil and rock material to streams. Sediment transport is a natural stream process and, "for a stream to be stable, it must be able to consistently transport its sediment load, both in size and type, associated with local deposition and scour" (Rosgen, 1996).

> *"Extensive research has shown that natural rivers attempt to maintain a dynamic and continuing balance between sediment loads and the energy available from streamflow to perform work" (Rosgen, 1996).*

Since a large portion of streamflow is diverted from the Greybull River, there is less stream energy to convey sediment below irrigation diversion structures. This can lead to channel aggradation, which is an increase of streambed elevation due to deposition of sediment and may result in channel instability. As the channel aggrades through point bar and mid-channel bar development, the river's flow path can be redirected unpredictably towards streambanks where extensive erosion and flooding is likely to occur. This is highlighted through one landowner's issue of stream stability due to a large mid-channel bar that has developed in the lower reaches of the Greybull River; over the past several years, the landowner has experienced bank erosion of several feet per year, creating concern over protection of their home.

In addition, climate change models predict that peak stream flows may increase 40 to 154 percent while summer flows may decrease 30 to 62 percent, with total annual flow decreasing by five to 24 percent. Peak flows are expected to occur four to five weeks earlier than normal. (Rice, et al., 2012) This estimated change in flow regime could exacerbate channel aggradation and bank erosion since flows will be lower most of the year resulting in aggradation, but peak flows will be higher, resulting in more bank erosion and flooding.

Increased fine sediment or suspended sediment loading from irrigation return flows also have adverse impacts on aquatic life. Fine sediment can fill the void spaces between gravel where many fish species spawn and can suffocate eggs and aquatic insect larvae. Sediment interferes with recreational activities and aesthetic enjoyment of rivers. Nutrients, bacteria, and chemicals can adhere to sediment particles and be transported to streams. Studies have shown that E. Coli can survive in fine sediments along streambeds for several months (USDA, 2011). Lining irrigation canals and ditches can reduce the amount of fine sediment available to be transported to the stream.

### 2.1.6.5 Water Quality

#### *2.1.6.5.1 WDEQ Stream Classifications*

The State of Wyoming has a hierarchical categorization of surface water classes which are defined by their existing and designated uses. The state lists four major classes of surface water with various subcategories for each class (WDEQ, 2013). Except for Class 1, each classification is protected for its specified uses and the uses contained in each lower classification. Class 1 designations are based on value determinations rather than use support and are protected for all uses.

According to WDEQ, most of the surface waters and their associated fisheries within the Greybull River watershed are classified within the Class 2 sub-classifications though some are listed in the other classes (WDEQ, 2013a). Figure 12 shows the WDEQ stream designations as wells as additional information

regarding fish passage barriers and instream flow water rights which are discussed in Section 2.2.1.5. Table 4 depicts the classifications of Dry Creek, the Greybull River and the Wood River plus their designated tributaries. Each surface water class has designated uses that the water quality is expected to support, whenever attainable. The designated uses are displayed below in Table 5 for each surface water classification. Following the table is a brief description of each classification.

**Table 5: Surface Water Classes and Use Designations**

| Class | Drinking Water | Game Fish | Non-Game Fish | Fish Consumption | Other Aquatic Life | Recreation | Wildlife | Agriculture | Industry | Scenic Value |
|---|---|---|---|---|---|---|---|---|---|---|
| 1* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2AB | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2A | Yes | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 2B | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2C | No | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2D | No | When Present | When Present | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 3A | No | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 3B | No | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 3C | No | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 3D | No | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 4A | No | No | No | No | No | Yes | Yes | Yes | Yes | Yes |
| 4B | No | No | No | No | No | Yes | Yes | Yes | Yes | Yes |
| 4C | No | No | No | No | No | Yes | Yes | Yes | Yes | Yes |

* Class 1 waters are not protected for all uses in all circumstances. For example, all waters in the National Parks and Wilderness are Class 1, however all do not support fisheries or other aquatic life uses (e.g. hot springs).
Source: Wyoming Surface Water Classification List, Water Quality Division, Surface Water Standards, 2013.

The four surface water classifications and their sub-classifications include:

- **Class 1 (Outstanding waters):** These are surface waters in which no further water quality degradation by point source discharges other than from dams will be allowed. The nonpoint sources of pollution for these waters are controlled through implementation of appropriate best management practices.
- **Class 2 (Fisheries and drinking water):** These are waters other than Class 1 which are known to support fish, drinking water supplies, or where those uses are attainable. These waters may be perennial, intermittent or ephemeral;

- Class 2AB: These waters are known to support game fish populations, or spawning and nursery areas at least seasonally, and all perennial tributaries and adjacent wetlands where game fishery and drinking water use is otherwise attainable. All Class 2AB waters are designated as cold-water game fisheries where cold water game fish are predominant. Those identified as warm-water fisheries will include a 'ww' designation signifying the predominance of warm water species;
- Class 2A: Waters not known nor have the potential to support fish but are used for public or domestic drinking water supplies including aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value;
- Class 2B: Waters known to support or have the potential to support game fish populations, or spawning and nursery areas at least seasonally, and all their perennial tributaries and adjacent wetlands where it has been shown that drinking water uses are not attainable. Uses designated as Class 2B waters include game and nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value;
- Class 2C: Waters known to support or have the potential to support only nongame fish populations, or spawning and nursery areas at least seasonally, including their perennial tributaries and adjacent wetlands. These include all permanent and seasonal nongame fisheries and are considered warm water. Uses designated as Class 2C waters include nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value;
- Class 2D: These are effluent-dependent waters known to support fish populations and where the resident fish populations would be significantly degraded in terms of numbers or species diversity if the effluent flows were removed or reduced. These waters are protected to the extent that the existing fish communities and other designated uses are maintained, and that the water quality does not pose a health risk or hazard to humans, livestock or wildlife. Uses designated as Class 2D waters include game or nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value;

- **Class 3 (Aquatic life other than fish):** Other than those designated as Class 1, these waters are intermittent, ephemeral or isolated waters and, because of natural habitat condition, do not support nor have the potential to support fish populations or spawning, or certain perennial waters which lack the natural water quality to support fish (e.g. geothermal areas). These waters provide support for invertebrates, amphibians, or other flora/fauna which inhabit waters of the state at some stage of their life cycles. Uses designated as Class 3 waters include aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value. Generally, waters suitable for this classification have wetland characteristics, and such characteristics are a primary indicator used by WDEQ for identification;
    - Class 3A: These waters are isolated waters including wetlands that are not known to support fish populations or drinking water supplies and where those uses are not attainable;

- Class 3B: These waters are tributary waters including adjacent wetlands that are not known to support fish populations or drinking water supplies, and where those uses are not attainable. Class 3B waters are intermittent and ephemeral streams with sufficient hydrology to normally support and sustain communities of aquatic life including invertebrates, amphibians, or other flora and fauna which inhabit waters of the state at some stage of their life cycles. In general, 3B waters are characterized by frequent linear wetland occurrences or impoundments within or adjacent to the stream channel over its entire length;
- Class 3C: These waters are perennial streams without the natural water quality potential to support fish or drinking water supplies but do support wetland characteristics. These may include geothermal waters and waters with naturally high concentrations of dissolved salts or metals or pH extremes;
- Class 3D: These are effluent-dependent waters which are known to support communities of aquatic life other than fish, and where the existing aquatic habitat would be significantly reduced in terms of aerial extent, habitat diversity or ecological value if the effluent flows are removed or reduced. These waters are protected to the extent that the existing aquatic community, habitat and other designated uses are maintained, and the water quality does not pose a health risk or hazard to humans, livestock or wildlife;

- **Class 4 (Agriculture, Industry, Recreation and Wildlife):** These are waters other than Class 1 where it has been determined that aquatic life uses are not attainable pursuant to the provisions of specific WDEQ regulations. Uses include recreation, wildlife, industry, agriculture and scenic value.
  - Class 4A: These waters are artificial canals and ditches that are not known to support fish populations;
  - Class 4B: These waters are intermittent and ephemeral stream channels that have been determined to lack the hydrologic potential to normally support and sustain aquatic life pursuant to the provisions listed in the regulations. Generally, these streams are characterized by only infrequent wetland occurrences or impoundments within or adjacent to the stream channel over its entire length;
  - Class 4C: These waters are isolated waters that have been determined to lack the potential to normally support and sustain aquatic life according to provisions listed in the regulations. They include, but aren't limited to, off-channel effluent dependent ponds where it has been determined that removing a source of pollution to achieve full attainment of aquatic life uses would cause more environmental damage than leaving the source in place.

#### *2.1.6.5.2 Waters Requiring Total Maximum Daily Loads (TMDL)*

Section 303(d) of the Clean Water Act (CWA) requires Wyoming to identify waters where the effluent limits are not effective at attaining designated uses. The list of streams that do not support their designated uses is called the 303(d) List of Impaired and Threatened Waters. Wyoming must submit a 303(d) List to the EPA by April 1 of each even-numbered year. The EPA reviews the list and approves or disapproves the list within

30 days. Wyoming must then develop a Total Maximum Daily Load (TMDL) for each pollutant/segment combination on the 303(d) list. A TMDL specifies the amount of a pollutant that a waterbody can receive and still meet water quality standards.

Sections of both the Greybull River and Dry Creek have TMDLs for *Escherichia coli*. The impaired section of the Greybull River originates at the Sheets Flat Bridge and continues downstream to the confluence with the Bighorn River. The impaired section of Dry Creek begins 4.7 miles upstream from its confluence with the Bighorn River and continues downstream to that confluence (see Figure 13). In 2002, both stream segments were put on the 303(d) List of impaired and threatened waters because recreational use was not supported.

The South Bighorn Conservation District evaluated the water quality in the lower Bighorn Basin for two EPA Section 319 Nonpoint Source Program projects. The first data set submitted in 2005 was inconclusive. The intent of the second Section 319 project was to improve failing septic systems and replace or relocate animal feeding operations (AFOs). Three septic systems and three AFO improvements were completed in the lower Greybull watershed and one septic system was improved in the Dry Creek watershed, but the study reported continued elevated *E. coli* levels along the impaired section of the Greybull River. The project also reported a trend of increasing bacterial concentrations from upstream to downstream which was attributed to increases in the occurrence of irrigated agriculture and livestock. The SBCD also noted that water quality in Dry Creek tends to change from the bridge on Highway 32, which is downstream from the Agrarian Ditch; after this location *E. coli* can be detected. The SBCD thinks list is likely because there are historic tile drains/septic systems that drain and may also be attributed to livestock and agricultural practices. The Conservation District is currently working to resolve these potential sources.

The TMDLs for the impaired sections of the Greybull River and Dry Creek were approved by the EPA in April 2014 at which point both streams were removed from the 303(d) List and placed in EPA's category 4A, meaning that they are impaired waters with TMDLs approved by the EPA. (WDEQ, 2016). A summer recreation (May 1 through September 30) TMDL value of 126 organisms per 100 milliliters (org/100 mL) is in effect. During the winter recreation period (October 1 through March 30) the TMDL value is 630 org/100 mL. The conservation districts typically only sample during the summer recreation time frame (RESPEC, 2013).

According to the model used to determine the TMDLs for the Bighorn River Watershed, point sources were an insignificant portion (less than one percent) of *E. coli* loading for all impaired segments within the watershed. The model indicated that 97 percent of the loading resulted from overland runoff while three percent originates from direct stream loading. The report indicates that defecation from livestock or wildlife accounts for nearly all direct source loading. Source allocations for the Greybull River determined from the model include rangeland at 54.5 percent and cropland at 33.7 percent. The remaining 12 percent is allocated to direct stream loading, urban/residential, human/pet, forest, and other sources. Source allocations for Dry Creek determined from the model include rangeland at 60.4 percent and cropland at 37.1 percent. The remaining 2.5 percent is allocated to urban/residential, direct stream loading, and forest sources. (RESPEC, 2013)

Recent scientific research (Beaugh, 2012) has shown that *E. coli* can persist in stream sediments for months and may not be accounted for when water samples are collected from the water column except during high

water flows when the sediment is mixed in to the water column. This may lead to overestimating the amount of *E. coli* contamination that may be coming from pasture/crop runoff. (USDA, 2011)

### 2.1.6.6 Hydrologic Modeling

The Greybull River watershed lies within the Bighorn Basin in the northwest corner of Wyoming and includes a drainage area of roughly 717,000 acres (1,120 square miles). In this report, the Greybull watershed includes Dry Creek, which joins with the Greybull river just downstream or east of the Greybull watershed's outlet. The watershed is bounded by the Absaroka Range in its upstream end (to the west), the Wind River Mountains on the southwest, the Beaver Rim Mountains to the south, the Bridger Mountains to the southeast, and the Bighorn Mountains in its downstream end (to the east). The highest point of the watershed is 13,140 feet in its upstream end, and the watershed's outlet is at roughly 4,700 feet, with varying topography throughout the watershed. The Greybull River, which is the third largest tributary of the Bighorn Basin, has a stream length of roughly 94 miles.

To provide hydrologic results based on a sub-basin scale for the Greybull watershed, analysis in this study was completed based on a modification to the original six 10-digit Hydrologic Unit Code's (HUC-10s). Based on available gauging station data, lower flow in the Upper and Lower Dry Creek HUC-10 units, and professional judgement for boundaries, the HUCs for hydrologic modeling were slightly revised to five HUC units. The Upper and Lower Dry Creek units were combined into one unit. In addition, the Middle and Lower Greybull River HUC units were revised to the location of the end reach (Reach 1300) that is already existing in the hydrologic excel model spreadsheet (Wind / Bighorn Basin Plan). The original HUC-10 boundaries and the revised HUC boundaries for the hydrologic analysis is shown on Figure 14. The main rivers that make up the watershed include the Greybull River which flows through the revised HUC-1, HUC-3 and HUC-4, the Wood River which flows through HUC-2 and serves as the primary upstream tributary of the Greybull River, and Dry Creek, which flows through HUC-5.

#### *2.1.6.6.1 Overview of Wind/Bighorn Hydrologic Model*

In 2003, MWH Americas, Inc. created an excel spreadsheet model to investigate general surface water availability for the Wind / Bighorn River Basin Plan. The model consisted of 12 sub-basins (HUC 8) with the Greybull River Watershed and Dry Creek Watershed combined to represent one of the 12 sub-basins (MWH, 2003). The spreadsheet model was then updated by MWH in 2010. The Wind / Bighorn River Basin model is based on excel spreadsheets and linked to a Microsoft Access database which stores streamflow, diversions, irrigation return, reservoir operations, and other pertinent hydrologic data and calculations to streamline the modeling process. A comprehensive overview of the database and the spreadsheet model can be found in MWH's 2010 technical memorandum 4B. The model framework allows for the estimation of available flow and shortages over a one-year period, on a monthly time step, for a dry, average and wet hydrologic year. The Greybull River sub-basin model was updated as part of this study.

#### *2.1.6.6.2 Greybull Study Area Updates*

For this Greybull River Watershed Study, the 2010 model stream gauge and diversion data were extended to 2017 by adding available data. Data was added from 2010 to 2017 by using existing gauge information or regression equations, thus creating a 45-year period of record (1973 to 2017). Crop Irrigation requirements

were left unchanged from the 2010 model, with the assumption that crop type and irrigated land has generally not changed, from a macroscopic scale, since the 2010 update. Also, natural flow data in the model was left unchanged based on the static inputs to the empirical formula, previously developed in the original spreadsheet model, used to populate the flows.

The modeling process started with analyzing available gauge data to determine the necessary processing to obtain a complete data set, based on a water year. Due to the minimal current gauge data in the study area, significant data filling was required for the hydrologic analysis, see Figure 15 for available gauges and their periods of record. The only active gauge in the watershed is station 06276500 – Greybull River near Meeteetse, WY. Gauge station 06276000 was excluded from analysis because any measured data during the period of record (1910-1916) was outside the 45-year period of record applied to the hydrologic model update.

Data gaps were filled using existing linear and polynomial regression equations developed in the 2010 model update. All gauge station regression equations utilized flow values from station 06276500 – Greybull River at Meeteetse, WY as the input variable. Gauge station 06276500 is the only active gauge in the watershed. All gauging stations required some data gap filling to complete the data set. The completed data sets were then analyzed to determine dry, average, and wet flow conditions. This was performed by summing the flows for each year between 1973 and 2017 and then separating wet years as the top 20 percent, dry years as the bottom 20 percent, and average conditions as the middle 60 percent. For dry, average, and wet years, the mean flow for a given month was then determined. This procedure was completed on a monthly time step to produce an average dry, average of average, and average wet condition hydrograph. The dry, average, and wet condition hydrographs are displayed, respectively in Figures 16 to Figure 18, for all gauge stations. An additional plot of Station 06276500's dry, average, wet, and median flows are displayed in Figure 19 since this was the primary gauge, and only current gauges, used for the gauge station regression equations.

**Figure 16: Hydrograph at Gauge Locations for Averaged Dry Flow Conditions (1973-2017)**

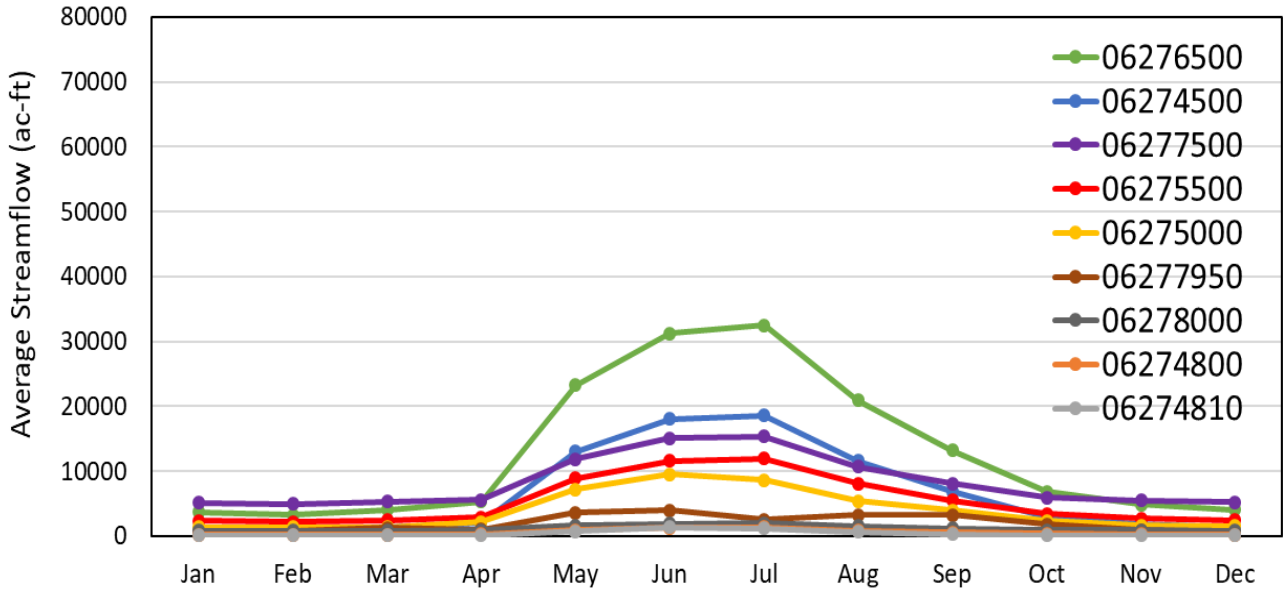


**Figure 17: Hydrograph at Gauge Location for Average Flow Conditions (1973-2017)**

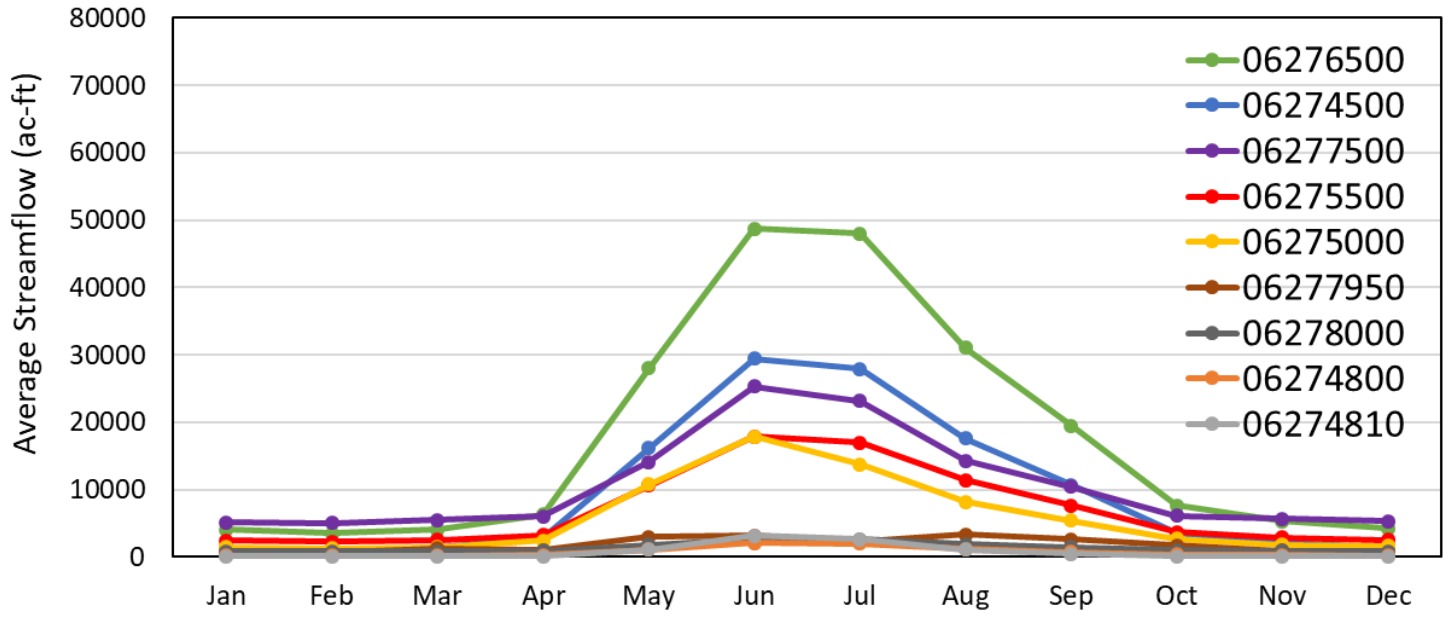



**Figure 18: Hydrograph at Gauge Locations for Averaged Wet Conditions (1973-2017)**

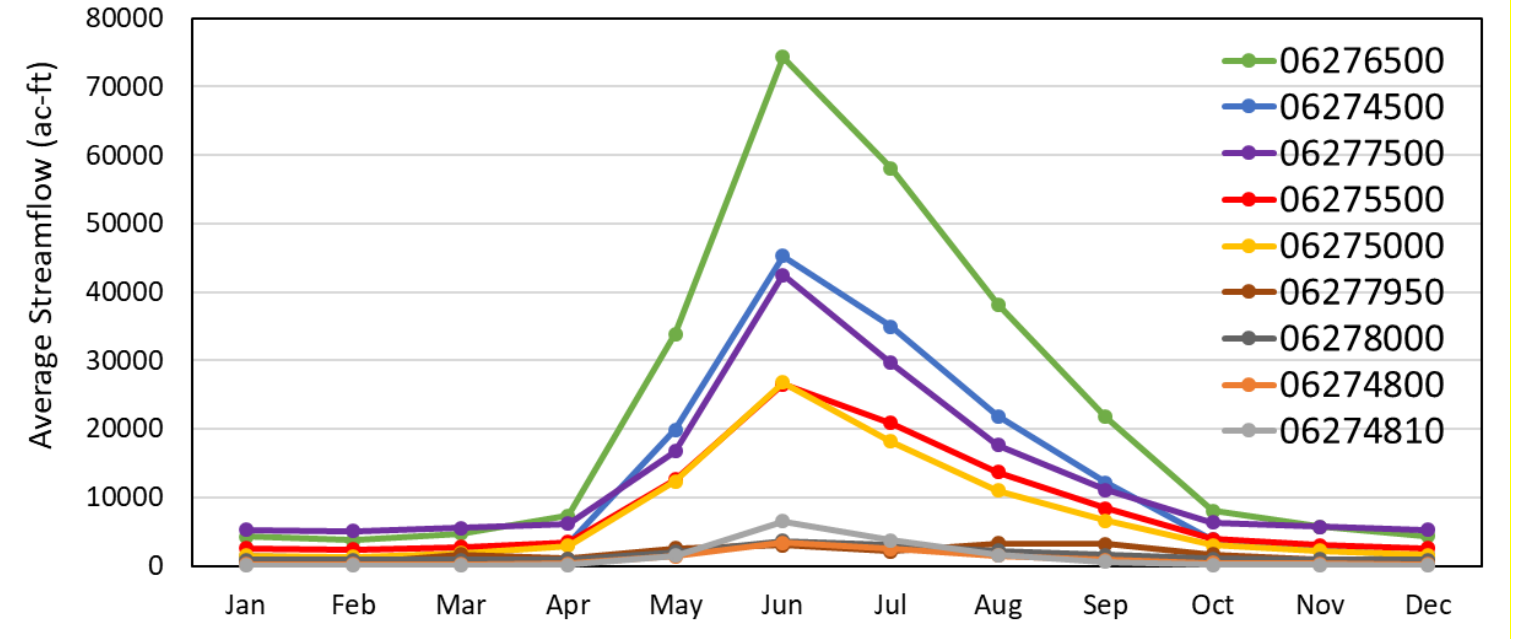
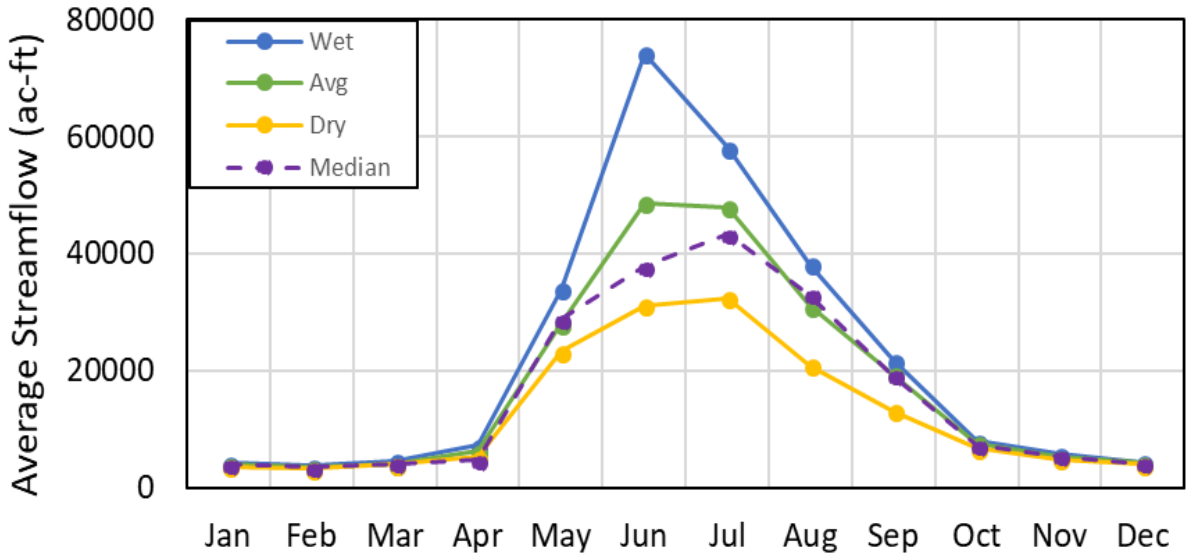


**Figure 19: Hydrograph of Greybull River at Gauge 06276500 (1973-2017)**




The dry, average and wet flow classification of years 1973 to 2017 for each gauge station are given in Table 6. However, the spreadsheet model uses USGS gauge station 06275000 – Wood River at Sunshine, WY as the sole indicator gauge in the Greybull River Watershed and a gauge (06278500) in Shell Creek near Shell, WY to determine dry, average and wet conditions in the Dry Creek Watershed. Note, although the gauge data for 06278500 was updated, its flow data is not included in this write-up since it is located outside of the Greybull / Dry Creek watershed area of interest. As you can see in Table 6, the high dependence on synthetic flow (originating from station 06276500) creates similar if not identical dry, average and wet trends for gauge stations in the study area.

Diversion data for the period 2010 to 2017 was also obtained and included in the Microsoft Access database. The diversion data originated from State Engineer's Office Division III – District 8 and 16 annual hydrographer reports. The diversion data was differentiated between spot data and continuous data in the database and then transferred to the spreadsheet model.

Instream flow requirements were also updated within the spreadsheet model based on the most up to date instream flow data obtained from the Wyoming Water Development Office website.

After extending the stream gauge and diversion data period of record to 2017 within the Microsoft Access hydrologic database, the spreadsheet model for the Greybull River sub-basin was updated using the pivot tables in the "Data" worksheet of the spreadsheet model. The updated model was then used to simulate flows during dry, average and wet hydrologic conditions.

#### *2.1.6.6.3 Hydrologic Model Results*

The hydrologic model produces various data including simulated streamflow, diversions, shortages, and available flow. Shortages are calculated by subtracting the actual simulated diversions from the full supply diversion requirements for each reach. Available flow represents the amount of flow that could be diverted

from the river without affecting other diversions and while meeting compact requirements and permitted instream flows. However, as stated in the MWH's 2010 technical memorandum of the model, "the method of determining availability does not take into account any legal entitlements to downstream users; rather it is assumed that the legal water used is reflected in the hydrologic and diversion records." Model results are provided at varying spatial resolutions, including the nodes along a reach, each reach, and for the entire Greybull watershed. In this study, results were additionally determined for revised HUC's by summing shortages or available flow for all of the reaches within a given revised HUC unit.

The model results for the entire Greybull watershed under dry, average and wet hydrologic conditions are reported in Table 7. Annual available flow and shortages are additionally presented for the revised HUCs in Figure 20 and Figure 21, respectively. Available flow is fairly high for all of the revised HUC's; however, shortages primarily occur in the Lower Greybull River (HUC 4). The shortage for dry conditions and available flow for dry, average, and wet conditions are additionally presented for the main reach of each HUC-10 in Figure 22. Note that Figure 22 includes shortages and available flow only from the main reaches, while Figures 20 and 21 takes into account all reaches of a given HUC-10. Hence, while a given HUC-10 may have shortages from minor reaches as demonstrated by Figures 20 and 21, the main reach of a HUC-10 may not have any shortage. As demonstrated in Figure 22, none of the main reaches experience shortages except for the Lower Greybull River. As demonstrated by the hydrographs in Figure 22, shortages experienced within the Lower Greybull River primarily occur from late Spring (April) to early Fall (September). Available flow is greatest at a slightly later date than the occurrence of shortages, and peaks for all of the HUC's main reaches during the summer (from June to September). The available flow is significant throughout all the main reaches, but noticeably lower along Dry Creek.

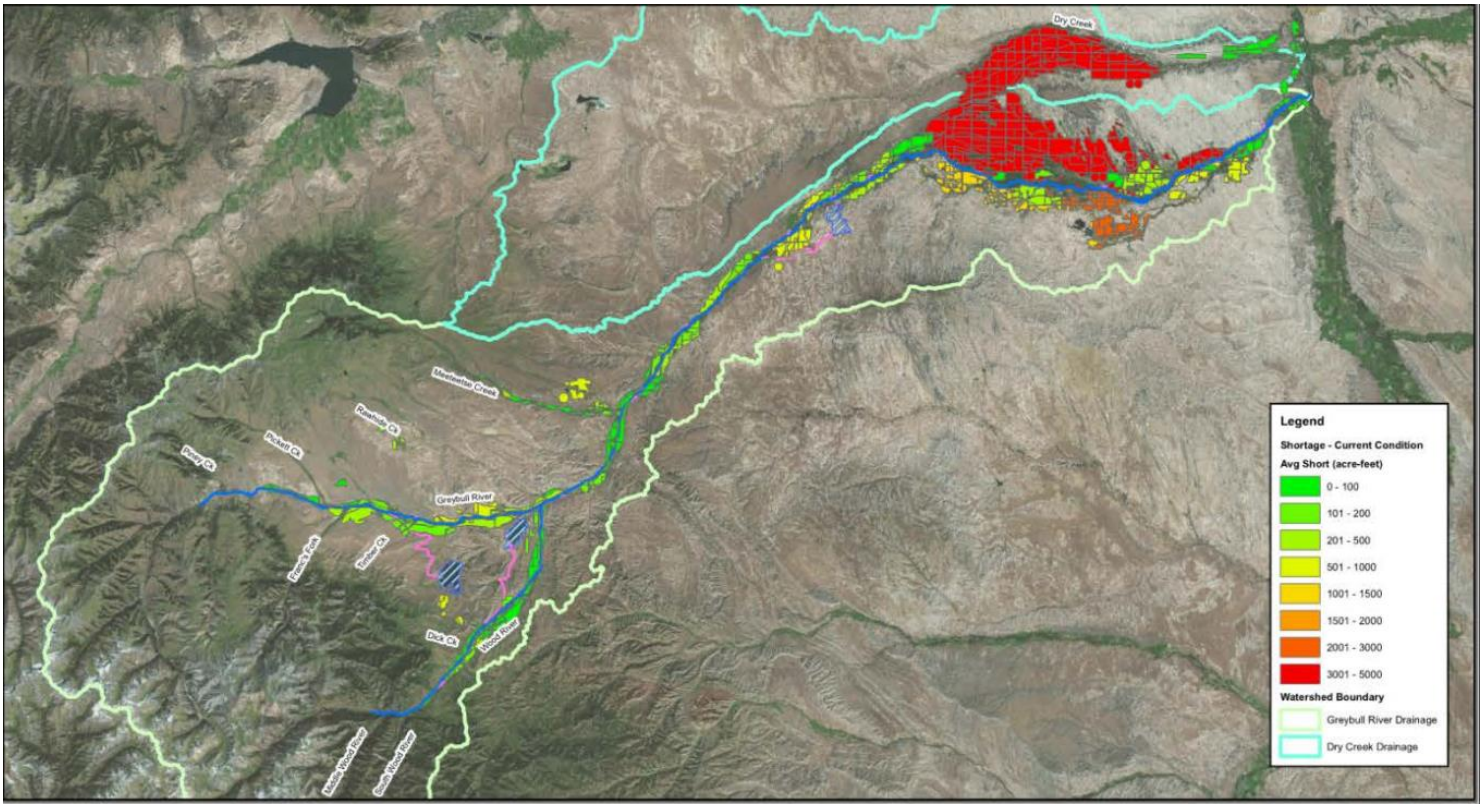
**Table 7. Annual Available Flow and Shortages for Greybull Watershed**

| Dry (ac-ft) | | Average (ac-ft) | | Wet (ac-ft) | |
|---|---|---|---|---|---|
| Available Flow | Shortage | Available Flow | Shortage | Available Flow | Shortage |
| 151,561 | 75,800 | 306,430 | 18,615 | 587,641 | 6,818 |

Another recent hydrologic model was developed for the *Greybull Valley Irrigation District (GVID) Storage Enlargement Level II, Phase I Study* (AECOM, 2017) used StateCU and StateMOD to analyze Greybull River watershed surface water availability, shortages and potential storage projects. The GVID study simulated surface water interactions over the period 1970 to 2014. The study determined the average annual shortage is 22,900 ac-ft for the baseline scenario, which evaluates the currently irrigated acreage estimate of 72,681 acres. This average is similar to the shortage determined in the updated hydrologic model as shown in Table 7 (18,615 ac-ft). The baseline scenario for this report did not include an additional 24,512 acres of land that is currently not irrigated, which if brought into production would only compound the water shortage scenario in the Greybull River watershed. The study also concluded that 44,700 ac-ft of shortage occurs during dry years as defined in this study (i.e. two out of every ten years) whereas our results show significantly more shortages during dry years. This may be due to the more detailed analytical results stemming from the StateMOD modeling which incorporates water right priority into the model. Results from the *Greybull Valley Irrigation District Storage Enlargement Level II, Phase I Study* are shown by diversion structure in Figure 23

(AECOM, 2017). Similar to the updated spreadsheet model, the majority of shortages occur in the Lower Greybull River (HUC 4); however, the AECOM study found significant shortages along Dry Creek that did not appear in the updated spreadsheet model's results. Proposed enlargements described in the GVID Study help to diminish shortages, but the enlargements do not provide a full water supply eight out of ten years, which is the WWDC threshold for satisfactory irrigation supply.

**Figure 23. Shortages by Diversion (ac-ft) from AECOM 2017 Report**




### *2.1.6.6.4 Summary*

Both the updated spreadsheet model for the Greybull River reach of the Wind/Bighorn Basin and the GVID study suggests that the Greybull River Watershed is a water short system on a yearly basis, with significant shortages occurring during dry years. A majority of the water shortage is observed in the Lower Greybull watershed. However, increased storage throughout the watershed, rather than limiting use in the lower watershed, would be beneficial and increase available flow (AECOM, 2017). There are continuing efforts by the GVID and other stakeholders to increase the storage within the watershed, as described in the 2017 enlargement study completed by AECOM.

## 2.2 BIOLOGICAL SYSTEMS IN THE GREYBULL RIVER WATERSHED

Wyoming has an abundant array of fish, wildlife and native habitats which are defining features of the state. To ensure the health and diversity of wildlife within Wyoming, the development and application of comprehensive wildlife conservation strategies are necessary and are a critical priority for the Wyoming Game and Fish Department (WGFD). As noted in the habitat vision detailed in Wyoming's Strategic Habitat Plan, the WGFD is the steward of all Wyoming's wildlife (WGFD, 2015) and as human population grows, and natural resource demands increase, sustaining suitable wildlife habitat may become a limiting factor regarding the maintenance of viable wildlife populations (WGFD, 2017).

Such an abundance of wildlife and native habitats are often linked to the outdoor recreational opportunities available for both residents and non-residents of the state. According to the WGFD, Wyoming enjoys some of the highest recreational participation rates in the country (WGFD, 2017). Many of these participation rates are high because Wyoming is host to some of the largest migratory populations of big game animals in North America. Nearly 39 percent of the state's population enjoys fishing while 18 percent are hunters. Wyoming is home to:

- 120 species of mammals;
- 426 species of birds;
- 78 species of fish;
- 27 species of reptiles;
- 12 species of amphibians;
- Several thousand species of invertebrates; and
- Over 13,000 species of plants (WGFD, 2017).

### 2.2.1 Fish, Wildlife and Landcover

The Greybull River watershed area is in the western portion of the Bighorn Basin and encompasses more than one million acres in size. The elevational changes within the watershed are dramatic and range from the 13,000-foot Absaroka Mountain Range in the westernmost portion of the area to 3,800 feet above sea level at the Town of Greybull on the easternmost portion of the area.

As expected with such elevational changes, the watershed's wide array of topography yields a variety of land cover, vegetation, fisheries and wildlife habitat. The differing landscapes reflect the diversity for highly variable vegetation communities, climate and terrain. In this context, the following discussion will encompass:

- Fisheries – fish distribution, fish passage barriers, stream classifications related to fisheries and existing state-held instream flow water rights within the watershed;
- Land Cover and Vegetation – terrestrial habitat types, riparian zones and vegetation cover including canopy cover and height;

- Wildlife and Sensitive Species – wildlife and habitat distribution to include species of concern, non-game species of concern which may include some fish, birds, amphibians, mollusks, reptiles and mammals, plus sensitive and/or endangered plants and animals; and
- Greater sage-grouse – the discussion regarding this potential species-of-concern will focus on the grouse's core habitat area and applicable stipulation buffers which may be related to the watershed area as defined by State of Wyoming Executive Orders 2015-4 and 2017-2.

This discussion is based on a comprehensive review and research of materials and agency documents. This research included such sources as the WWDC, the University of Wyoming Natural Diversity Database (WYNDD), the WGFD, previous Greybull River watershed studies and reports, U.S. Bureau of Land Management (BLM), the Meeteetse Conservation District, the South Big Horn Conservation District, the U.S. Forest Service (USFS), the U.S. Fish & Wildlife Service (USFWS), and the Wyoming Ecological Services Field Office.

#### 2.2.1.1 Fisheries

The term 'fishery' is defined as the interaction of aquatic organisms, aquatic environments and their human users to produce sustained benefits (WGFD, 2003). A fishery is a product of chemical, biological and physical processes including societal expectations and uses. Here, each element is critical, because each element affects the other and offers opportunities for affecting the character of a fishery resource. Fish populations are simply one attribute of a fishery. The following discussion includes several key elements of the fisheries within the Greybull River watershed including:

- Fish distribution;
- Fish passage barriers;
- Stream classifications; and
- Existing state-held instream flow rights.

Maintaining sustainable wildlife populations and their habitats is a fundamental challenge in Wyoming which includes the fisheries of the state. These challenges include the unknown availability of suitable habitat in the future which becomes the most limiting factor for maintaining viable wildlife populations. There are growing forces such as expanding human populations, demands for natural resources and rapid changes in climate which all put pressure on available fisheries habitat and resident wildlife populations (WGFD, 2017). A healthy fishery is comprised of more than just the water in the river, but also includes lands adjacent to the river such as floodplains, riparian areas and upland areas.

In general, and within the context of this report, the word habitat is defined as the environment for both plants and animals. This includes the physical and biological resources necessary to provide food, water, space and shelter for terrestrial and aquatic organisms. Management of these habitats varies in Wyoming depending upon the jurisdictional boundaries of several governmental agencies including the BLM, USFS, USFWS, WGFD, and private landowners.

According to the Wyoming State Wildlife Action Plan (SWAP) developed by the WGFD, Wyoming features six aquatic basins used for conservation planning purposes (WGFD, 2017). These basins are based upon hydrographic boundaries and fish assemblages among other factors and are shown in Figure 24. As depicted in Figure 24, the Greybull River watershed is located within the Yellowstone River Basin. The Yellowstone River Basin covers over 34,000 square miles in nine Wyoming counties including Big Horn and Park Counties which contain the Greybull River watershed. More than 35 percent of the basin is private land while 26 percent of the area is managed by the BLM. In addition, the USFS manages 17 percent, the National Park Service seven percent, and the Wind River Indian Reservation occupies approximately seven percent of the Yellowstone River Basin.

Basin management plans developed by the WGFD Fish Division provide necessary background and history of aquatic wildlife to assist in aquatic wildlife management as well as management direction. The following discussion focuses on the Greybull River Watershed.

#### 2.2.1.2 Fish Distribution

The report area encompasses two watershed basins including the Greybull River basin and the Dry Creek basin. Each are discussed below.

##### *2.2.1.2.1 Greybull River Basin*

The Greybull River basin covers approximately 736,000 acres of drainage or about 72 percent of the watershed study area. The Dry Creek drainage area contains the remaining acreage of the study area. A majority of the land in the western portion of the basin is administered by the USFS while the eastern portion of the basin is a mixture of BLM, State of Wyoming and privately held land. In the western portion of the watershed the Greybull River tributaries are characterized as torrential, high elevation, mountain streams which include high channel slopes, unstable substrates and large discharge fluctuations from spring to late summer (WGFD, 2017f).

The basin consists of 75 lakes, ponds and reservoirs totaling 3,148 acres of standing water. Upper and Lower Sunshine Reservoirs constitute over 90 percent of that standing water acreage totaling 3,048 acres.

Portions of the basin are identified as a Crucial Aquatic Habitat because of its importance to the Yellowstone cutthroat trout habitat among other aquatic concerns. Portions of the basin are also within WGFD-designated riparian Crucial Combined Habitat area which is discussed later in Section 2.2.3.

There are at least 32 species of fish known to exist within the Greybull River basin which includes its main tributary, the Wood River (see Table 8). Only five species of fish are native in the basin above the confluence of Wood River and Greybull River. This conforms to a simple high-mountain pattern and includes the Yellowstone cutthroat trout (YCT) *(Oncorhynchus clarki bouvieri)*, the mountain whitefish *(Prosopium williamsoni),* the mountain sucker *(Catastomus platyrhynchus),* the longnose sucker (*Catostomus catostomus)* and the longnose dace *(Rhinichthys cataractae)* (WGFD, 2004.) A survey conducted in 2000 revealed genetically pure YCT in all sampled streams within the Greybull River watershed (WGFD, 2005).

The Greybull River basin is essentially 'divided' regarding fish distribution. This 'dividing' line on the Greybull River is the Sheets Flat Diversion which feeds the Roach Gulch Reservoir and is located near the Park-

Bighorn County line (see Fig. 11). It is a complete barrier to fish passage which was designed to prevent downstream, non-native species from migrating upstream into the habitat of the YCT. Because of WGFD management, YCT and a sterile hybrid trout are the only game fish allowed upstream from this diversion (see Image 10). All the other species in the basin may be found downstream of this diversion (WGFD, 2017f) in the Greybull River or in the Dry Creek watershed.

**Image 10: Sheets Flat Diversion**

*Photo courtesy of Wayne Cummings*

There is evidence of fish stocking in the Yellowstone basin dating back to 1893 (Everman and Cox, 1896) when nonnative Brook trout were present, and as early as 1915 in the Greybull River (Kruse, 1995). Streams with suitable habitat to support trout often received annual plants of fingerling brook trout (*Salvelinus fontinalis*), brown trout *(Salmo trutta),* rainbow trout (*Oncorhynchus mykiss*) or Snake River cutthroat trout *(Oncorhynchus clarkii)* (Kent, 1975). The WGFD conducted and still conducts the majority of those introductions, but others have been illegal or even inadvertent.

Through 1971, several species or strains of trout were stocked in the Wood River drainage above its confluence with the Greybull River. These included brook, rainbow and unknown cutthroat trout strains. In 1972 and 1975, Snake River cutthroat trout, a fine-spotted variant of the Yellowstone cutthroat trout, were stocked. Surveys conducted in1995 failed to find YCT in the Wood River upstream of a waterfall near the upper end of the Wood River above the Middle Fork segment. Subsequently, YCT were reintroduced to this segment in 2004 (WGFD, 2005). More stocking discussions within the basin follows.

Table 8 depicts the aquatic species (fish, amphibian and reptiles) either observed or which may be present in the Greybull River basin. The table also identifies the aquatic Species of Greatest Conservation Need (SGCN) located within the watershed. According to the WGFD, the SGCN designation process is based upon its Native Species Status (NSS) classification system which compares population and limiting-factor variables to arrive at a rank (NSS1 through NSS7) for a species. Those limiting factors include habitat, human activity levels, genetics, invasive species, disease, environmental contaminants and climate change. The lower the NSS rank the more extreme or severe those factors affect the population of a species. For example, a rank of NSS1 means a species population can be imperiled. Conversely, the higher the rank the more moderate or minimal those factors are for a species population. For example, a rank of NSS7 means the threat to a species population is minimal.

Rankings of NSS1 through NSS4 are considered significant and the species is given an SGCN designation. Plants and invertebrates (excluding crustaceans and mollusks) are outside the authority of the WGFD and are not considered for SGCN status (WGFD, 2017).

As shown in Table 8, the only aquatic species within the Greybull River basin with a ranking of NSS1 is the Western (Boreal) Toad while one other species (Eastern Spiny Softshell) has a ranking of NSS2.

#### *2.2.1.2.2 Yellowstone Cutthroat Trout*

Historically, the YCT occupied the Wyoming waters of the Snake River and Yellowstone River drainages including the Bighorn River, Greybull River and Wood River. Today, both the Greybull River and Wood River contain genetically pure populations of the fish. In 1998 the YCT was petitioned for listing under the Endangered Species Act but following a 90-day petition review in 2001, the USFWS determined the listing was not warranted. As a result of the status assessment of YCT, it was found that all 15 upper Greybull River tributaries contained genetically pure YCT. These populations were a driving force to securing instream flow water rights which began as early as 2003 for protection of the habitat for the YCT (WGFD, 2003).

A Memorandum of Agreement (MOA) was signed in 2000 for the conservation and management of the YCT, one of only two native gamefish found in the upper sections of the watershed. The MOA was signed by the states of Montana, Idaho, Wyoming, Nevada and Utah, the USFS, plus Yellowstone and Grand Teton National Parks (WGFD, 2017d). The MOA led to subsequent conservation agreements and conservation strategies which were all developed to assist in eliminating potential threats that could lead to the YCT being listed under the Endangered Species Act (ESA).

The WGFD manages seven conservation populations of the YCT within the Greybull River basin which are separated by anthropogenic barriers (see Figure 12) to limit the genetic exchange between the populations (WGFD, 2017d). The department maintains YCT populations through annual stocking in several fisheries within the basin. Those include the Upper and Lower Sunshine Reservoirs, and Spud Lake. In addition, the Lower Sunshine reservoir is also stocked with Splake *(Salvelinus fontinalis × Salvelinus namaycush)* and Tiger Trout *(Salmo trutta × Salvelinus fontinalis).* These two species are used to avoid the introduction of non-native trout which could be detrimental to the YCT populations. The Splake is a Brook Trout/Lake Trout hybrid while the Tiger Trout is a Brook Trout/Brown Trout hybrid (WGFD, 2017f). It should be noted the YCT and sterile hybrid trout are the only trout approved for private fish plants within the Park County portions of

the watershed. Elsewhere within the basin, the Harrington and Wardwell reservoirs are managed as yield fisheries. Both reservoirs are stocked with annual plants of walleye (*Sander vitreus*) while Wardwell also receives black crappie (*Pomoxis nigromaculatus).*

Also, the state of Wyoming via the WGFD maintains the instream-flow water rights for 13 segments of the Greybull River and Wood River. Each of these has been set aside for protection of the habitat of the native YCT. A more detailed discussion regarding these water rights can be found later in this section.

**Image 11: Yellowstone Cutthroat Trout**

*Photo courtesy of WGFD*

### *2.2.1.2.3 Dry Creek Basin*

The Dry Creek basin drains the northern portion of the watershed study area and covers approximately 280,000 acres. The basin is xeric in nature and originates in the west-central portion of the watershed in Park County. The basin does not contain any WGFD priority habitat areas as discussed later in Section 2.2.3.

Most of the Dry Creek basin land area is under public ownership administered by the BLM. However, the lower portion of Dry Creek contains the largest block of private ownership. The private land is cultivated and

is irrigated by the Bench Canal via a water transfer from the Greybull River. Return flow irrigation water has likely increased the spatial and temporal use of the drainage by fish. In turn, return flow also affects the quality and quantity of water in Dry Creek which limits the fishery to those species tolerant of relatively warm, turbid and shallow waters (WGFD, 2017g).

There are only two fisheries within the Dry Creek basin, Mayland Reservoir and Dry Creek which are both supported by the trans-basin diversion from the Greybull River. Both fisheries are perennial. Only the Mayland Reservoir is stocked annually with fingerling largemouth bass *(Micropterus salmoides)* and bluegill/green sunfish hybrids.

At least 14 species of fish have been reported in the Dry Creek basin. There are no sport fish in Dry Creek which is managed by WGFD for native non-game fish. Table 9 below depicts the list of known aquatic species reported within the Dry Creek basin.

**Table 9: Aquatic Species Within the Dry Creek Basin**

| Common Name | Scientific Name | Status |
|---|---|---|
| **Fish** | | |
| Carp | *Cyprinus carpio* | Nonnative |
| Flathead Chub | *Platygobio gracilis* | **NSS3** |
| Flathead Minnow | *Pimephales promelas* | NSS6 |
| Lake Chub | *Couesius plumbeus* | NSS3 |
| Largemouth Bass | *Micropterus salmoides* | Nonnative |
| Longnose Dace | *Rhinichthys cataractae* | NSS7 |
| Longnose Sucker | *Catostomus catostomus* | **NSS4** |
| Mountain Sucker | *Catostomus platyrhynchus* | **NSS3** |
| Shorthead Redhorse | *Moxostoma macrolepidotum* | **NSS4** |
| River Carpsucker | *Carpiodes carpio* | **NSS4** |
| Stonecat | *Noturus flavus* | **NSS4** |
| Walleye | *Sander vitreus* | Nonnative |
| White Sucker | *Catostomus commersoni* | NSS7 |
| Yellow Perch | *Perca flavescens* | Nonnative |
| **Amphibians** | | |
| Boreal Chorus Frog | *Pseudacris maculata* | **NSS4** |
| Northern Leopard Frog | *Lithobates pipiens* | **NSS4** |
| Plains Spadefoot | *Spea bombifrons* | **NSS4** |
| **Reptiles** | | |
| Bullsnake | *Pituophis catenifer sayi* | **NSS4** |
| Greater Short-horned Lizard | *Phrynosoma hernandesi* | **NSS4** |
| Wandering Gartersnake | *Thamnophis elegans vagrans* | **NSS4** |
| Northern Sagebrush Lizard | *Sceloporus graciosus graciosus* | **NSS4** |
| Prairie Rattlesnake | *Crotalus viridis* | **NSS3** |

Source: WGFD, 2017g
**BOLD** indicates SGCN

### 2.2.1.3 Fish Passage Barriers

Simply defined, a fish passage barrier is anything which limits the upstream or downstream passage for fish. Barriers can be categorized as either partial or complete barriers and can be seasonal in nature based upon factors such as water diversion practices. Natural barriers include waterfalls or beaver dams, while irrigation

diversion structures are an example of an anthropogenic barrier. In some instances, barriers can be beneficial. For example, when a nonnative and/or invasive species is present below a barrier then that barrier could act to protect native, upstream fisheries. Some barriers can also limit the downstream movement of fish. Typically, downstream limiting barriers are diversion structures where the fish are diverted with the water and are subsequently entrained or lost from the river system (WGFD, 2017f).

Numerous problems can arise as the result of barriers. For example, barriers can limit the access for fish to critical habitats including the rearing habitat for all life stages of the fish. They can also limit the gene flow within the populations and limit the expression of migratory life histories. Barriers can also be the root cause of decreased populations, including the loss of shelter and food (WGFD, 2017f).

Within the watershed, the diversions for the Upper and Lower Sunshine reservoirs are located in the upper reaches of the watershed can have direct impacts on stream flows. This is especially true during the critical low-flow periods of winter and early spring prior to the spring runoff (WGFD, 2017d). Elsewhere, the lower portions of the watershed are characterized by numerous irrigation withdrawals, eroding stream banks and extreme day-to-day fluctuations in discharge (Zafft and Annear, 1992). Irrigation diversion structures pose the potential to entrain large proportions of the fish populations and serve as fish migration barriers (WGFD, 2017d).

Within the Greybull River watershed the most common anthropogenic barriers are irrigation structures, culverts and dewatered reaches. Figure 12 shows the locations of the 98 documented fish passage barriers. (Note: due to the scale of the map, several of these locations are overlapping.) There are several barriers in place in the watershed specifically to protect the YCT from the hybridization, competition and predation from nonnative or invasive species. Specifically, the Sheets Flat Diversion to the Roach Gulch Reservoir is a complete barrier to fish passage designed to protect YCT. This is previously described in the Fish Distribution section above. Of the 98 documented locations, 15 of the barriers are designated as not passable, or partially passable for fish species. Table 10 provides a summary and description of the barriers. Seven of the impassable barriers are natural and are not recommended for modification. The remaining barriers are primarily diversion structures that prevent fish migration, but also are not screened and have the potential to entrain fish in the ditches.

There are various remedies for improving, removing or replacing barriers. Each barrier site is specific regarding its required needs. One of the more common remedies used at irrigation diversion structures is a series of rock cross veins which raise the stream bed's elevation. This still allows the upstream/downstream movement for aquatic life yet provides the irrigator the allotted water right necessary (WGFD, 2017f).

Within the watershed, to increase connectivity where appropriate, WGFD biologists have instituted passage projects which benefit the Yellowstone Cutthroat Trout. Some of those projects include a fish ladder on the Greybull River, and fish screen and diversion passage improvements along some the Greybull River's tributaries (WGFD, 2017). The existing fish ladder on the Greybull River is located at the diversion dam which diverts water to the Upper and Lower Sunshine Reservoirs. This ladder was installed in 2012 and although there is not a lot of data on the functionality of the ladder, there is documentation of cutthroat trout using the ladder. During site visits in August 2017, it was observed that some maintenance was required on the ladder structure to remove sediment which was deposited from operations of the inflatable-weir on the

diversion dam. During a subsequent site visit in June 2018 it was observed that the ladder had been recently cleaned of sediment. According to GVID, this was the first ladder cleaning in five years (see Image 12).

**Image 12: Upper Sunshine Diversion Fish Ladder**

*Photo courtesy of Wayne Cummings*

Currently, the GVID is working with the WGFD and Trout Unlimited to address the fish barrier concerns located at the Wood River diversion which diverts water to the Lower Sunshine Reservoir. This new project includes the addition of a new fish ladder similar to the one located at the Upper Sunshine as seen in Image 12. Survey work on the new ladder at the Wood River diversion was expected to begin in July 2018 with actual construction scheduled for the spring of 2019. Once completed it will allow fish migration upstream

and downstream via the ladder. Once completed, the new ladder opens up several new miles of native upstream habitat for the YCT in the Wood River drainage.

#### 2.2.1.4 Fisheries Stream Classifications

Fisheries are included in the State of Wyoming's hierarchical categorization of surface water classes which are defined by their existing and designated uses. The state lists four major classes of surface water with various subcategories for each class (WDEQ, 2013). With the exception of Class 1, each classification is protected for its specified uses and the uses contained in each lower classification. Class 1 designations are based on value determinations rather than use support and are protected for all uses. Section 2.1.6.5 previously detailed the watershed's stream classifications. Stream Classifications are provided on Figure 12.

#### 2.2.1.5 Instream Flow Water Rights

In Wyoming, water flowing in streams is referred to as instream flow which protects water in streams for the benefit of fish and fish management. The WGFD files for instream flow water rights to acquire the legal means for protection of the water flow. Securing this protection is critical for fish management because water is the most important aspect of a fish habitat. Once an instream flow water right is obtained, it lasts forever without the need for future maintenance costs or repair (WGFD, 2017a). To date, the WGFD has filed applications for 142 stream segments throughout the state including 13 stream segments within the Greybull River watershed. Each of those 13 segments within the watershed has been set aside for protection of the habitat of the native YCT. A brief overview of the WGFD Administrative Reports for those 13 segments is included later in this section. In addition, a brief overview of the two Feasibility Studies conducted for WWDC for these 13 segments is also included later in this section.

Within the watershed the 13 instream flow segments total over 45 miles of river and stream protection. All are located on state or federally administered public lands in the western portion of the watershed near the community of Meeteetse. The longest is a 5.2-mile segment on Francs Fork while the shortest is a one-mile segment on the Wood River below Middle Fork. Those watershed segments are depicted on Figure 12 with more information provided in Table 11 below.

Five segments are located in the Shoshone National Forest in the upper Wood River basin. Those segments include the Wood River above Middle Fork, the Middle Fork Wood River, the South Fork Wood River, the Wood River below Middle Fork and Dick Creek. These particular segments were specifically targeted by the WGFD because they contained viable, genetically pure populations of the YCT. Just as important, they provide an interconnected stream system of over 15 miles that covers a broad geographic region.

**Table 11. Instream Flow Segment in Greybull Watershed**

| Stream Name | Segment Number | Segment Length (mi.) | Permit # | Source | Status and Date of Status | Adjudicated Flow Rates (CFS) |
|---|---|---|---|---|---|---|
| Pickett Creek | 1 | 4.74 | 79 IF | Direct flow | Adjudicated 8/22/2016 | Minimum 1.40 (Feb.) Maximum 19.00 (May-June) |
| Pickett Creek | 2 | 3.44 | 80 IF | Direct flow | Adjudicated 9/25/2017 | Minimum 0.90 (Jan-Feb) Maximum 25.00 (June) |
| Francs Fork | 1 | 5.20 | 81 IF | Direct flow | Adjudicated 3/01/2018 | Minimum 4.80 (Jan-Feb) Maximum 160.00 (June) |
| Jack Creek | 1 | 2.48 | 82 IF | Direct flow | Adjudicated 3/01/2018 | Minimum 1.80 (Jan-Feb) Maximum 19.00 (May-June) |
| West Timber Cr. | 1 | 4.35 | 83 IF | Direct flow | Adjudicated 8/22/2016 | Minimum 0.30 (Sept.) Maximum 5.60 (May-June) |
| Piney Creek | 1 | 2.32 | 76 IF | Direct flow | Adjudicated 3/01/2018 | Minimum 1.90 (Jan-Feb) Maximum 55.00 (June-July) |
| Greybull River | 1 | 4.31 | 77 IF | Direct flow | Adjudicated 3/01/2018 | Minimum 19.00 (Jan-Feb) Maximum 65.00 (May-June) |
| N. Fork Picket Cr. | 1 | 2.48 | 78 IF | Direct flow | Adjudicated 8/22/2016 | Minimum 0.40 (Jan-April) Maximum 8.00 (June-July) |
| Middle Fork Wood River | n/a | 4.90 | 68 IF | Direct flow | Adjudicated 12/15/2015 | Minimum 9.50 (Feb) Maximum 20.00 (Oct.) |
| Wood River above Middle Fork | n/a | 3.60 | 69 IF | Direct flow | Adjudicated 12/15/2015 | Minimum 14.00 (Feb) Maximum 31.00 (Oct.) |
| Wood River below Middle Fork | n/a | 1.00 | 70 IF | Direct flow | Adjudicated 12/15/2015 | Minimum 24.00 (Feb) Maximum 51.00 (Oct.) |
| South Fork Wood River | n/a | 3.90 | 71 IF | Direct flow | Adjudicated 12/15/2015 | Minimum 6.00 (Feb) Maximum 25.00 (May-June) |
| Dick Creek | n/a | 2.20 | 72 IF | Direct flow | Adjudicated 12/15/2015 | Minimum 0.85 (Feb) Maximum 11.50 (June) |

Source: Wyoming Water Development Office, 2018a

To prioritize potential waters for instream flow water rights, the WGFD regularly reviews new information on species status and habitat condition. In addition, prioritization can change as the result of public input or changes to instream flow legislation or policy. Such prioritization is conducted under a "protect the best first" approach (WGFD, 2017c) and include factors such as:

- Genetic purity of target species;
- Streams identified as high priority by fish management personnel;

- Segments where recent habitat or population restoration efforts have been conducted or are planned; and
- Ribbon category (blue, red or yellow only) as defined in the following paragraph.

The ribbon category for Wyoming streams is ranked according to the number of pounds of trout per mile measured in any given stream segment and include:

- Blue: national importance priority with > 600 pounds of trout per mile;
- Red: statewide importance priority with 300-600 pounds per mile;
- Yellow: regional importance priority with 50-300 pounds per miles; and
- Green: local importance priority with < 50 pounds per mile (WGFD, 2017a).

Any water development projects would require consultation with the WGFD to ensure the protection of the fish habitat in question in any given stream segment.

*2.2.1.5.1 WGFD Administrative Reports for Instream Flow Segments*

Each of the 13 instream flow segment studies listed below were conducted by the WGFD prior to their approval as segments to be used as habitat for the YCT. These studies on both the Greybull River and Wood River verified the need for these segments to be set aside for various aspects of the life cycle of the YCT including spawning habitat during spring runoff and the necessary flow levels for all the YCT life stages throughout the year. The studies also included specific recommendations of instream flow amounts to ensure the necessary hydraulic habitat was maintained during those particular times of the year. Those studies included:

- Dey, Paul D. and Annear, Thomas C., Wood River Drainage Instream Flow Studies: Development of Instream Flow Water Right Recommendations for 4 Wood River Segments and Dick Creek; (Middle Fork); Project: AW-CY-IF1-511, AW-CY-IF2-511, AW-CY-IF3-511, AW-CY-2GR-511; May 2005;
- Dey, Paul D. and Annear, Thomas C., Wood River Drainage Instream Flow Studies: Development of Instream Flow Water Right Recommendations for 4 Wood River Segments and Dick Creek; (Above the Middle Fork); Project: AW-CY-IF1-511, AW-CY-IF2-511, AW-CY-IF3-511, AW-CY-2GR-511; May 2005;
- Dey, Paul D. and Annear, Thomas C., Wood River Drainage Instream Flow Studies: Development of Instream Flow Water Right Recommendations for 4 Wood River Segments and Dick Creek; (Below the Middle Fork); Project: AW-CY-IF1-511, AW-CY-IF2-511, AW-CY-IF3-511, AW-CY-2GR-511; May 2005;
- Dey, Paul D. and Annear, Thomas C., Wood River Drainage Instream Flow Studies: Development of Instream Flow Water Right Recommendations for 4 Wood River Segments and Dick Creek; (South Fork); Project: AW-CY-IF1-511, AW-CY-IF2-511, AW-CY-IF3-511, AW-CY-2GR-511; May 2005;

- Dey, Paul D. and Annear, Thomas C., Wood River Drainage Instream Flow Studies: Development of Instream Flow Water Right Recommendations for 4 Wood River Segments and Dick Creek; (Dick Creek); Project: AW-CY-IF1-511, AW-CY-IF2-511, AW-CY-IF3-511, AW-CY-2GR-511; May 2005;
- Dey, Paul D. and Annear, Thomas C., Greybull River Instream Flow Studies; Project: IF-CY-2GR-510, February 2004;
- Dey, Paul D. and Annear, Thomas C., Instream Flow Studies on North Fork Pickett Creek, a Greybull River Tributary; Project: IF-CY-2GR-510, February 2004;
- Dey, Paul D. and Annear, Thomas C., Instream Flow Studies on Piney Creek, a Greybull River Tributary; Project: IF-CY-2GR-510, February 2004;
- Dey, Paul D. and Annear, Thomas C., Instream Flow Studies on Pickett Creek, a Greybull River Tributary; Segment 1, Project: IF-CY-2GR-510, June 2003;
- Dey, Paul D. and Annear, Thomas C., Instream Flow Studies on Pickett Creek, a Greybull River Tributary; Segment 2, Project: IF-CY-2GR-510, June 2003;
- Dey, Paul D. and Annear, Thomas C., Instream Flow Studies on Francs Fork, a Greybull River Tributary; Project: IF-CY-2GR-510, February 2002;
- Dey, Paul D. and Annear, Thomas C., Instream Flow Studies on Jack Creek, a Greybull River Tributary; Project: IF-CY-2GR-510, February 2002;
- Dey, Paul D. and Annear, Thomas C., Instream Flow Studies on Timber Creek, a Greybull River Tributary; Project: IF-CY-2GR-510, February 2002;

#### *2.2.1.5.2 Instream Flow Segment Feasibility Studies*

In 2006 the WWDC received the two requested feasibility studies listed below which were conducted to include all 13 instream flow segments. These studies were completed in order to determine the feasibility of providing various amounts of unappropriated direct flow in the five instream segments on tributaries of the Wood River and the eight segments on tributaries of the Greybull River.

**Five Segments on the Wood River**

This study concluded the mean monthly instream flow requests are not met for all months in any segments except for the Wood River Above Middle Fork Instream Flow segment. Typically, there are surplus flows in the summer months, but the winter months show significant shortages. In addition, the study indicated there are no secondary storage water rights upstream of any of the segments which could be used to supply the instream flow requests shortages.

Reports on the Feasibility of Providing Instream Flows on Wood River Tributaries; prepared for WWDC, prepared by Rio Verde Engineering, PO Box 642, Pinedale, Wyoming 82941; November 2006.

**Eight Segments on the Greybull River**

This study concluded the mean monthly instream flow requests are not met for all months in any of the eight segments. Typically, there are surplus flows in June and July, but the remaining months show significant

shortages. In addition, the study indicated there are no secondary storage water rights upstream of any of the segments which could be used to supply the instream flow requests shortages.

Reports on the Feasibility of Providing Instream Flows on Greybull River Tributaries; prepared for WWDC, prepared by Rio Verde Engineering, PO Box 642, Pinedale, Wyoming 82941; April 2006.

### 2.2.2 Landcover

Landcover plays a large role in the hydrologic system of a watershed since nearly all precipitation must interact with this feature in some way. Landcover influences how quickly precipitation reaches the ground surface, the amount of precipitation that is intercepted and evaporates or sublimates before reaching the ground, soil evaporation rates, the soil infiltration and runoff rates, groundwater recharge, soil erosion, sediment transport, and water quality. Landcover also influences the biological integrity of an area as many wildlife species depend on the presence of certain landcover types and even microbiological ecosystems are influenced by landcover.

Landcover can be described in many ways including permeability, vegetative community class, lifeform, age class, and density. Several landcover datasets are available for the Study area including the National Land Cover Database, LANDFIRE, National GAP Analysis Program, University of Wyoming Land Cover Dataset, and State Wildlife Action Plan (SWAP) Habitat Type Database. These datasets have varying numbers of land cover categories, attributes, and resolutions. The vegetation types discussed in this report are based on the SWAP Dataset since it is more specific to the region than the nation-wide datasets and has a manageable number of vegetation types, although the other datasets were taken into consideration as well. The LANDFIRE dataset was used to describe the relative abundance of each vegetation lifeform and canopy types.

Non-vegetated land areas are often a concern to land managers due to the reduced soil protection and higher potential for erosion. They are also often considered lower value wildlife habitat due to the absence of cover and forage provided by vegetation. Non-vegetated area makes up less than ten percent of the study area and is comprised of alpine rock and soil, basin rock and soil, cliffs, roads, open water, perennial snow and ice, and developed areas.

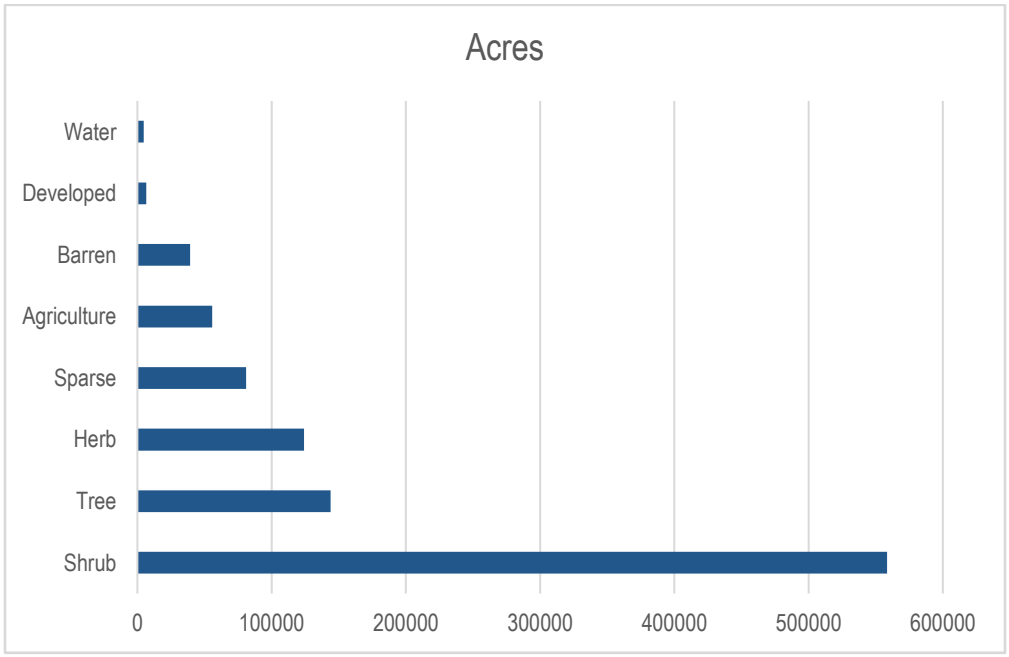
#### 2.2.2.1 Vegetation and Plant Communities

Over 90 percent of the landcover in the Greybull River/Dry Creek watershed study area is comprised of vegetated areas. The plant communities, or canopy types, present in a landscape is determined by several environmental factors including soil depth, texture, salt content, precipitation, wind, elevation, aspect, and slope. Plant communities are also influenced by human and wildlife activities such as grazing, farming, development, wildlife foraging and burrowing, and ant hills.

According to the LANDFIRE dataset, 55 percent of the Watershed is dominated by vegetation of the shrub lifeform (Graph 2). The dominant shrub in the area is big sagebrush (*Artemesia tridentata*) which normally grows to be between two and four feet tall. Vegetation of the tree lifeform dominates in 14 percent of the study area. Common tree species in the watershed are Douglas fir (*Pseudotsuga menziesii*), lodgepole pine

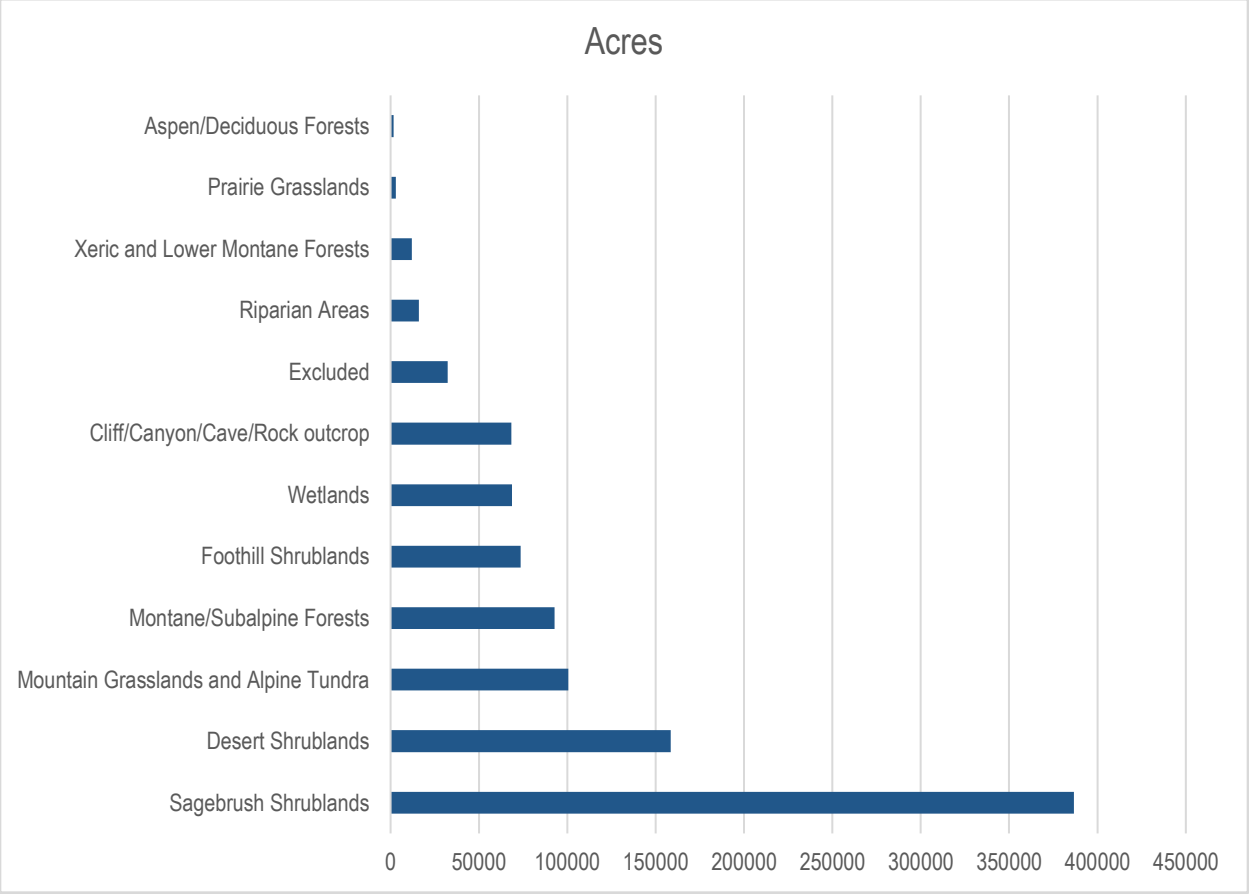
(*Pinus contorta*), subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), whitebark pine (*Pinus albicaulis*), cottonwood (*Aigeiros*), and Utah juniper (*Juniperus osteosperma*) which grow to be between 30 and 150 feet tall. Of the area dominated by the tree lifeform, about half has a closed canopy and half has an open canopy (seven percent of the study area each). Twelve percent of the Watershed is dominated by vegetation of the herb lifeform which includes graminoids and forbs and are typically less than three feet tall. Figure 25 provides a spatial representation of the various LANDFIRE canopy types within the watershed.

**Graph 2: Acres per Canopy Type (LANDFIRE)**




In Wyoming, the SWAP lists 11 terrestrial habitat types which are depicted in Figure 26. Highlighting the diversity of the Greybull River watershed, all 11 habitat types can be found within the watershed's boundary. Graph 3 lists the 11 types (plus "excluded") and shows the relative abundance by acreage in the Study area.

**Graph 3: Acres per SWAP Habitat Type**




Of the 11 habitat types, the Sagebrush Shrublands is the most prevalent while the Aspen/Deciduous Forests is the least prevalent as shown on the table inset on Figure 26. A brief description of each type, ordered by abundance, is provided below. Much of the information which follows is credited to the WGFD's SWAP.

***Sagebrush Shrublands***

Considered an icon of Wyoming's landscape and open spaces, the sagebrush shrublands is a habitat found in cold, semi-desert climates. Sagebrush shrublands is the most common vegetation type in the study area and accounts for about 38 percent of the land cover. The high proportion of precipitation occurring in winter or early spring is a defining attribute of sagebrush ecosystems. These sagebrush communities can be found in elevations from less than 4,000 feet to over 9,500 feet, and occur from basins to valley bottoms, steep slopes and mountainous areas or undulating terraces and foothills.

Major sagebrush species that dominate or co-dominate sagebrush systems include big sagebrush (*Artemisia tridentate*), mountain, Wyoming, and basin subspecies/varieties; two varieties of silver sagebrush *(Artemisia cana);* low sagebrush *(Artemisia arbuscular)*; black sagebrush (*Artemisia nova*); two varieties of three-tip sagebrush *(Artemisia tripartite);* low or early sagebrush (*Artemisia arbuscular*); birdsfoot sagebrush (*Artemisia pedatifida*); spiked sagebrush (*Artemisia spiciformis*); bud sagebrush (*Artemisia spinescens*); sand sagebrush (*Artemisia filifolia*); and fringed sagewort (*Artemisia frigida*). These stands vary from large patches

of single species or a mosaic of multiple species including rabbitbrush (*Chrysothamnus*), antelope bitterbrush (*Purshia tridentata*), greasewood (*Sarcobatus*), shadscale (*Atriplex confertifolia*), winter-fat (*Krascheninnikovia lanata*), and spiny hop-sage (*Grayia spinose*). Sometimes occurring in association with sagebrush are aspen (*Populus tremuloides*), mountain shrubs, salt desert shrubs, and open conifer.

Within the Study area, the most common sagebrush is the Wyoming big sagebrush which is the smaller of the three big sagebrush varieties and is found on harsh, dry sites. Wyoming big sagebrush have deep, well-developed root systems with the majority of their roots in the upper one foot of soil. The sagebrush shrubland transitions to a dominance of mountain big sagebrush in the montane ecozone of the Study area. Mountain big sagebrush is a larger shrub and typically grows on deep, well-drained, non-saline soils.

**Image 13: Big Sagebrush**

*Photo courtesy of Sue Weis, United States Forest Service*

Within this ecosystem is habitat for approximately 87 species of mammals; 297 species of birds; and 63 species of fish, reptiles, and amphibians. Sagebrush not only offers the best chance to sustain healthy populations of sage-grouse and other sagebrush dependent species, this ecosystem provides crucial habitats for some of the largest migratory populations of ungulates in North America. Elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), and pronghorn (*Antilocapra americana*) are the primary wild ungulates that utilize sagebrush habitat. Sagebrush obligates in Wyoming include the sage sparrow *(Artemisiospiza*

*nevadensis)*, Brewer's sparrow (*Spizella breweri*), sage thrasher (*Oreoscoptes montanus*), sage-grouse (*Centrocercus urophasianus*), pygmy rabbit (*Brachylagus idahoensis*), sagebrush vole (*Lemmiscus curtatus*), and sagebrush lizard (*Sceloporus graciosus*).

Conservation

There has been increased attention and awareness toward sagebrush habitat conservation as a result of increasing levels of energy development corresponding to decreased numbers of sage-grouse and mule deer. These concerns are a priority at WGFD which began with the development of the *Wyoming Greater Sage-grouse Conservation Plan* completed in 2003. Since then, sagebrush conservation challenges, recommendations and planning projects have been established. Sagebrush was also identified as one of eight priority habitats to maintain or enhance with the WGFD Strategic Habitat Plan. These strategies direct state agencies to focus sagebrush, and sage-grouse conservation and protection efforts within the core population areas of sage-grouse. A more detailed discussion regarding the protection of the habitat and sage-grouse can be found later in Section 2.2.3.8.

Threats

Some of the threats to the sagebrush shrublands include:

- Incompatible energy development and mining practices;
- Rural subdivision development;
- Off-road vehicle uses;
- Varying management goals and conflicting views about sagebrush ecosystem ecology and wildlife habitat management;
- Incompatible grazing management practices;
- Conifer encroachment;
- Drought and climate change; and
- Invasive plants such as cheatgrass (*Bromus tectorum*) are overtaking many wildland areas at an estimated historical annual spread rate of about 14 percent (UW/CSU, 2013). The higher and cooler sagebrush habitats of western Wyoming are experiencing invasive species establishing on disturbed sites such as roadways and well pads. The lower and warmer areas of the Study area are experiencing the invasive species establishing the understory of the sagebrush communities. The LANDFIRE dataset classifies 18,667 acres of introduced upland vegetation-annual grassland, which commonly includes cheatgrass (see Figure 27) showing the distribution of introduced annual grasses and other introduced vegetation). Stand-replacing fire frequency was normally 40 to 60 years with smaller fires every 20 to 25 years (CNHP, 2005), but sites invaded by cheatgrass can have return interval of zero to three years (MCD). Frequent fire inhibits re-establishment of big sagebrush due to slow regeneration and can cause the area to convert to annual grasslands, displacing many wildlife species dependent on big sagebrush. Other invasive species include Leafy spurge (*Euphorbia*

*esula*), spotted knapweed (Centaurea maculosa), Russian knapweed (*Rhaponticum repens*), hound's-tongue (*Cynoglossum officinale*), halogeton (*Halogeton glomeratus*), Dalmatian toadflax (*Linaria dalmatica*), Canada thistle (*Cirsium arvense)*, musk thistle (*Carduus nutans*), black henbane (*Hyoscyamus niger*), and white-top (*Lepidium draba*);.

**Image 14: Cheatgrass**

*Photo courtesy of Bruce Bosley, Colorado State University*

### *Desert Shrublands*

Occupying approximately 16 percent of the land cover in the Study area, desert shrublands occur in basins in elevations between 4,980 to 7,220 feet which typically experience less than ten inches of precipitation annually. Here, poorly developed soils are commonplace with fine texture, lower infiltration rates and a tendency of alkalinity or salinity. These areas are especially vulnerable to water and wind erosion due to the naturally sparse vegetative cover and fine textured soils. Disturbance to the soils and vegetation can accelerate erosion (CNHP, 2005). Desert shrublands share many features with sagebrush habitats including a predominance of shrubs, sensitivity to various forms of herbivory and nutrient limitation to plant growth. The distribution and composition of plant species is heavily influenced by complex relations among topographic gradients, chemical, moisture and physical aspects.

**Image 15: Desert Shrublands**

Photo courtesy of BLM

The dominant species is Gardner's saltbush (*Atriplex gardneri*) although other common shrubs include greasewood, shadscale, fourwing saltbush, winter-fat, spiny hop-sage and kochia (*Bassia scoparia).* A variety of both cool-season and warm-season grasses are common in these areas. The herbaceous layer is

generally sparse. Land uses often feature livestock production, energy/mining production, wildlife habitat and outdoor recreational activities.

The diverse wildlife in this habitat unit range from small insects and mammals to large herbivores. Wyoming's only endemic mammal, the pocket gopher (*Geomyidae*), is found in this habitat. Game species include mourning dove (*Zenaida macroura*), sage-grouse, mountain and desert cottontails (*Sylvilagus nuttallii* and *Sylvilagus audubonii*), pronghorn antelope and mule deer. Predators found in these areas include coyote (*Canis latrans*), bobcat (*Lynx rufus*), badger (*Taxidea taxus*), great horned owl (*Bubo virginianus*), golden eagle (*Aquila chrysaetos*), Swainson's hawk (*Buteo swainsoni*), red-tailed hawk (*Buteo jamaicensis*) and prairie falcon (*Falco mexicanus*).

*Mountain Plover (Photo courtesy rockiesaudubon.org)*

Among the many species of birds found in this habitat is the Mountain plover (*Charadrius montanus*) which is a species of special concern due to its nesting needs within desert shrubland. In 2009, the USFWS proposed to list the plover as a threatened species under the Endangered Species Act due to its shrinking habitat availability. In 2011, the USFWS announced it would withdraw that proposal stating the species was making a comeback. The Mountain plover prefers flat terrain with low-growing vegetation and a minimum of 30 percent bare ground. One of the main concerns regarding the plover stems from the use of pesticides used to control grasshoppers and crickets which can reduce prey availability for grassland birds. According to the Audubon Society, the short-grass prairie where it once thrived has been converted largely to farmland. However, this adaptable bird has found new habitat in grasslands overgrazed by cattle (Audubon, 2017). Though rarely encountered, the elusive Mountain Plover is a Level I Priority Bird on the WGFD SGCN list. Its predicted breeding range does include the central and eastern portions of the Greybull River watershed.

Conservation

Because of low productivity and poor vegetative states, controlling invasive species has received less attention in desert shrublands though they remain a significant concern. Due to extended soil residence time because of low organic soil content, herbicide use includes restrictions as directed by the BLM. There are programs such as the Wyoming Landscape Conservation Initiative which focus on data collection, monitoring, research and facilitating land management action. This includes a focus on enhancing wildlife compatibility regarding energy development. In addition, improved grazing management practices have reduced impacts within this habitat.

Threats

Some of the threats to desert shrublands include:

- Invasive annual plant species such as halogeton, Russian thistle *(Kali tragus)* and cheatgrass are significant concerns; other species in bare ground areas include Alyssum (*Lobularia maritima*), pepperweed (*Lepidium*), hound's-tongue, Russian knapweed, and whitetop *(Lepidium draba)*;
- Incompatible energy development and mining practices;
- Off-road vehicle uses; and
- Inappropriate grazing practices.

***Mountain Grasslands and Alpine Tundra***

Alpine areas above timberline and grasslands in montane landscapes above 6,500 to 7,000 feet are essentially the definition of this unit. Within the Study area, this type occupies ten percent of the land cover as shown in Figure 26. Typically, alpine areas are referred to as turf fellfield or dwarf-shrubland, while mountain grasslands are often called parks or mountain meadows. Wild geranium *(Geranium maculatum)*, nettleleaf *(Urtica dioica)*, arrowleaf balsamroot *(Balsamorhiza sagittata)*, western coneflower *(Rudbeckia occidentalis)*, asters, fleabanes, yarrow, some sedges, alpine timothy (*Phleum alpinum*), mountain brome *(Bromus marginatus)*, and a few plants of mountain big sagebrush, or dwarf willows *(Salix herbacea)* and snowberry *(Symphoricarpos)* are the tall forb communities which dominate the mountain grasslands. At lower elevations bluebunch wheatgrass *(Pseudoroegneria spicata)*, needle-and-thread *(Hesperostipa comate)*, Junegrass *(Koeleria macrantha),* Sandberg's bluegrass *(Poa secunda)* and fringed sagebrush *(Artemisia frigida)* are common. Sheep fescue *(Festuca ovina),* spike trisetum *(Trisetum spicatum)*, kobresia, tufted hair grass *(Deschampsia cespitosa*), alpine bluegrass *(Poa alpine),* alpine avens *(Dryas octopetala),* dwarf willows, and numerous cushion plants and sedges are found in alpine tundra which features more diversity.

Alpine habitats feature abiotic conditions both harsh and highly variable. Thus, animals must food cache, diet-switch, utilize subterranean habitat, torpor and/or hibernate to survive. Because of these conditions, many species, including big game and passerine birds migrate to lower elevations and latitudes before the onset of winter. One of the few holdouts is the non-native mountain goat *(Oreamnos americanus)* which resides year-round. Of note, due to its very short, cold growing season and extremely slow soil formation, recovery after disturbance in alpine tundra is very long.

Elk, mule deer, moose, and bighorn sheep (*Ovis canadensis*) utilize the summer forage found in mountain grasslands. Some of the small mammals found in mountain grasslands and alpine tundra include water vole *(Arvicola amphibious),* montane vole *(Microtus montanus),* long-tailed vole *(Microtus longicaudus),* short-tailed weasel *(Mustela erminea),* and yellow-bellied marmot *(Marmota flaviventris)*. Pocket gophers *(Geomyidae)* play a keystone role in this environment. Their constant soil disturbance and root herbivory facilitates nutrient cycling which includes air and water penetration into the soil. This creates a fine-grained patchwork of understory plant communities.

Conservation

In order to consolidate land and facilitate more efficient land management for both private landowners and public agencies, land exchanges and purchases have occurred on some mountain grassland habitats. In addition, to protect in-holdings or adjacent lands with high ecological and/or recreational value, land exchanges and purchases have occurred on some mountain grassland habitats. Also, certified weed-free hay is utilized by livestock producers and recreational horseback riders using many federal lands as part of an effort to reduce invasive species.

Threats

Some of the threats regarding this habitat unit include:

- Invasive plant spread which has increased dramatically since the 1960s;
- Mountain systems are highly sensitive to climate change;
- Overgrazing by ungulates; and
- Recreational activities (camping, hiking, biking, horse-packing, and off-road travel) can degrade mountain grasslands and alpine tundra.

***Montane/Subalpine Forests***

Within the Study area, this terrestrial habitat type occupies ten percent of the land cover as shown in Figure 26. Here, the nutrient conditions, temperature and moisture are sufficient to allow tree seedling establishment. Vegetation communities within the montane and subalpine forest habitat type often follow a predictable elevational distribution. For example, Douglas fir generally can be found at lower elevations; lodgepole pine at mid-elevations; and Engelmann spruce, subalpine fir, and whitebark pine at higher elevations. Intermingled with these coniferous forests are mountain grasslands and meadows, aspen groves, wetlands, riparian areas, and mountain shrublands with mountain lakes and streams. The dominant lifeforms of this habitat type are graminoids and forbs due to these open areas. Common species include American bistort (*Polygonum bistortoides*), Thurber bentgrass (*Agrostis thurberiana*), least lewisia (*Lewisia pygmaea*), Drummonds rush (*Juncus drummondii*), alpine timothy, nodding bluegrass (*Poa reflexa*), alpine veronica (*Veronica wormskjoldii*), and subalpine arnica (*Arnica mollis*) (WyGISC, 2014).

Most wildlife species occupy this habitat in spring, summer, and fall. This includes big game and passerine birds which migrate to lower elevations and latitudes in the winter. Due to the mountainous restrictions, many forests are regionally fragmented yielding several species genetically isolated. This includes the Bighorn Mountain snowshoe hare (*Lepus americanus*) among others. Forest carnivores such as pacific marten (*Martes americana*), wolverine (*Gulo gulo*), Canada lynx (*Lynx canadensis*), and fisher (*Martes pennanti*) find the woody debris in this unit to be particularly important because it creates thermoregulatory shelter and foraging sites in the winter. Grizzly bears (*Ursus arctos*), red squirrels (Sciurus vulgaris), black bears (*Ursus americanus*), ground squirrels (*Marmotini*), chipmunks (*Tamias*), woodpeckers (*Picidae*), nuthatches (*Sitta*), Steller's jay (*Cyanocitta stelleri*), raven (*Corvus corax*), and pine grosbeak (*Pinicola enucleator*) often reside in high mountain ecosystems where the whitebark pine seeds are a critical food source.

Conservation

Long-term comprehensive, coordinated strategies for investing state, federal, and local resources in addressing priority landscapes are outlines identified in the Wyoming State Forestry Division's Statewide Forest Resource Assessment and designated national priorities. These include protecting forest from catastrophic events including fire, insect and disease outbreaks, and invasive species; enhancing public benefits from forests including air and water quality, biological diversity, forest products, renewable energy, and wildlife; and conserving working forest lands for multiple uses.

Threats

Some of the threats to this unit include:

- Fire suppression;
- Insects where the montane and subalpine forest habitats are home to a variety of beetles in particular the bark and spruce beetles whose infestation has caused large-scale tree mortality among Douglas fir, true firs and Engelmann spruce. Lodgepole and ponderosa pine (*Pinus ponderosa*) are attached and killed by the mountain pine beetle (*Dendroctonus ponderosae*) and pine engraver beetle (*Hylastes ater);*
- Diseases including the white pine rust;
- Drought and elevated temperatures reduce winter mortality rates for beetles; and
- Conflicting forest-management objectives and timber-harvesting practices.

### *Foothills Shrublands*

Approximately seven percent of the Study area is occupied by foothills shrublands. This habitat unit is commonly known as mixed mountain shrubs as exhibited by its diverse plant communities which are dominated by an equally diverse number of shrub species. Some of the dominant shrub species include true mountain-mahogany *(Cercocarpus montanus),* curl-leaf mountain mahogany *(Cercocarpus ledifolius),* serviceberry *(Amelanchier),* antelope bitterbrush, skunkbush sumac *(Rhus trilobata),* currant *(Ribes),* gooseberry *(Ribes uva-crispa)* and snowberry. Also common are mountain big sagebrush and silver sagebrush with the occasional choke cherry (*Prunus virginiana)* sometimes in abundance in moist sites. Associated forbs and grasses include arrow-leaf balsam-root *(Balsamorhiza sagittate),* bluebunch wheatgrass, hairy golden-aster *(Heterotheca villosa),* Junegrass and lupine *(Lupinus)*.

The antelope bitterbrush is a key preferred forage for both big game and grazing livestock. It also provides cover for small animals and birds including both the Greater sage-grouse and Columbian sharp-tailed grouse *(Tympanuchus phasianellus columbianus).* There has been noticeable encroachment by the curl-leaf mountain-mahogany into adjacent plant communities due to fire suppression over time, though some stands become decadent over time and are unable to compete with nearby conifers.

Because the foothill shrublands support many berry-producing shrubs, the unit features many mammals and birds that forage these shrubs. This includes both black and grizzly bears, and dusty (blue) grouse

*(Dendragapus obscurus)* and waxwings *(Bombycilla).* Rock outcrops are frequent and can serve as important substrates for bats, bighorn sheep, and bushy-tailed woodrats among other species. Some of the unit's more rugged topography, micro-climates and crucial winter ranges provide cover for mule deer, elk, moose and bighorn sheep.

Land uses include hiking, camping, hunting, and motorized vehicle use. These units receive considerable recreational activity, especially in the warmer seasons. Some areas are popular for housing while livestock grazing is common in other areas. There is limited oil and gas development in foothill shrublands but wind energy development is on the rise.

Conservation

This habitat has been identified as a target habitat by the WGFD regarding the monitoring of shrub production and utilization on big game winter ranges. Here, invasive species management efforts involving multiple land management agencies and landowners have increased. Most of these collaborative efforts focus on managing or eradicating one or more invasive plant species and promoting native vegetation generally along watershed boundaries. This habitat unit provides the opportunity for mule deer to accumulate fat prior to winter. Collaborative efforts between the WGFD and statewide partners focus on improving habitat conditions for mule deer.

Threats

Some of the threats to foothills shrublands include:

- Prolonged drought and extreme drought cause detrimental effects on this unit's shrub species;
- Juniper and limber pine encroachment into true mountain-mahogany and bitterbrush shrub communities;
- Wildlife browsing pressures;
- Fire suppression;
- Rural subdivision and development;
- Incompatible grazing practices;
- Off-road motor vehicle uses;
- Invasive plant species especially cheatgrass; and
- Incompatible energy development practices.

### *Riparian Areas*

Immediately adjacent to rivers, streams and creeks are areas known as riparian areas. These habitats are crucial interface between the terrestrial and aquatic ecosystems. Regarding function, they are bounded on their outer edge by the limits of flooding and at their upper edge by the extent of the canopy vegetation. Simply put, the riparian area is the distinct ribbon of green demarcating streams from uplands across much

of the West. Many species depend upon this habitat even though wetlands and riparian areas only constitute about two percent of the land cover in the Study area.

When healthy, these areas buffer water loss from upland drainages and recharge aquifers. In addition, riparian areas filter chemical and organic wastes, trap sediment, build and maintain stream banks, reduce soil erosion, and moderate stream temperatures. Fish and invertebrates are provided habitats from the woody debris contributions of the riparian areas. This debris also influences stream channel stability and dynamics. Human activity and development in riparian areas are among the most used and altered activity of any other habitat unit.

Historically, cottonwoods have been the dominant lowland riparian tree species. Other common tree species include boxelder *(Acer negundo)*, lanceleaf cottonwood *(Populus angustifolia),* peachwood willow *(Ehretia saligna),* and occasionally American elm *(Ulmus Americana).* Chokecherry, hawthorn *(Crataegus),* rubber rabbitbrush *(Ericameria nauseosa),* silver buffaloberry *(Shepherdia argentea),* silver sagebrush, skunkbush sumac, wild rose (*Rosa)* and various species of willow constitute the understory shrubs in this habitat.

Small mammals, as well as their predators, all have strong seasonal or year-long associations with riparian habitats as do elk, moose, mule deer, white-tailed deer and pronghorn. Riparian habitats are used by bats for commuting, migrating, roosts, and foraging. Beavers create meadows and broaden the floodplain as they build dams. Such activity increases sedimentation and encourages growth of riparian vegetation. Their ponds also provide habitat for native fish species including Colorado River cutthroat trout *(Oncorhynchus clarkia),* Yellowstone cutthroat trout, Bonneville cutthroat trout (*Oncorhynchus clarkii utah*), and Snake River cutthroat trout. Those same ponds help support numerous aquatic mammals such as river otter (*Lontra canadensis*), mink (*Neovison vison*), and muskrat (*Ondatra zibethicus*), while providing overwintering habitat for fish.

Many Wyoming amphibian and reptile assemblages require riparian areas including frogs, toads, and salamanders. Aquatic turtles utilize loose soils within riparian areas for nesting.

Conservation

Ongoing efforts in the state utilize collective strategies to maintain and/or improve riparian areas. These include individual habitat protection and restoration projects which provide significant benefits. Also benefiting riparian areas are instream flow water rights which provide an ancillary protective benefit. Riparian vegetation communities can be strongly influenced by the type, timing and extent of irrigation. Improved irrigation practices such as technological changes like side role systems and gated pipe deliver water more efficiently to agricultural crops. This has the potential to conserve water for other uses such as maintaining stream flow.

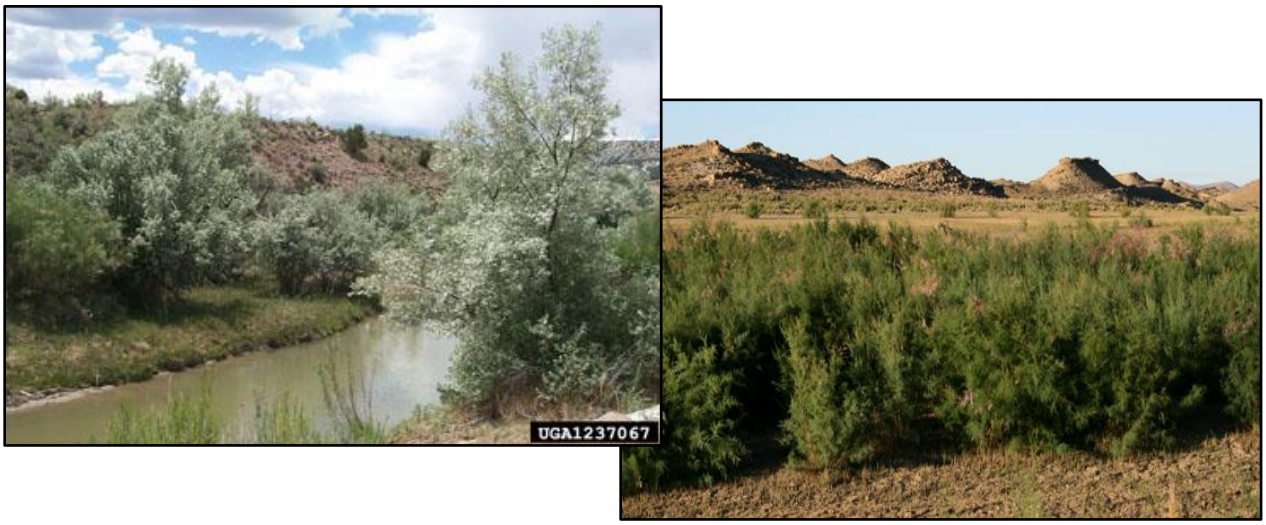
Threats

Some of the more critical threats to riparian areas include:

- Water development and/or altered flow regimes including irrigation diversions and water developments for enhanced water supply, hydropower and/or flood control;
- Drought and climate changes in temperatures influence precipitation patterns which can produce peak flows earlier in the yearly cycle and lower base flows. Also, drought lowers water tables reducing plant growth and plant reproduction;

- Invasive species such as tamarisk (saltcedar) and Russian olive produce the most negative impacts in Wyoming. Tamarisk is an aggressive colonizer which outcompetes and can even replace native willows, cottonwoods and other species. Russian olives are similar and also add increased water consumption. After fire, each species sprouts vigorously and usually gains the upper hand over native species. The LANDFIRE dataset classifies 8,636 acres in the Study Area of introduced riparian forest and woodland, which is most-likely dominated by tamarisk and Russian olive (Figure 27;
- Overgrazing and browsing by ungulates; and
- Rural subdivision and development.

**Image 16: Russian Olive (left) and Tamarisk (saltcedar) (right) Trees**




### *Wetlands*

Wetlands are a specific type of riparian area that meets certain requirements pertaining to soils, vegetation, and hydrology. In general, wherever the soil is annually saturated with water or covered by water at some point during the growing season of each year is referred to as wetlands. These habitats include wet meadows, potholes, playas, oxbows, beaver ponds, marshes, bogs, seeps, vegetated shorelines of ponds and lakes, and other types of open water. According to the SWAP dataset, approximately seven percent of the Study area is occupied by wetlands. Figure 28 shows the spatial distribution of wetlands according to the USFWS National Inventory.

Morphologically, the plains and intermountain basins are typified by low densities of shallow, playa-type wetlands that formed either in blowouts or because of tectonic activity. In higher elevation the type of wetlands include kettle, cirque, and moraine. Manmade wetlands have been created, both deliberately and coincidentally, as a result of human activities ever since the late 1800s and vary in quality.

Approximately 90 percent of Wyoming's wildlife species use wetlands and riparian habitats daily or seasonally during their life cycle, while nearly 70 percent of bird species are wetland or riparian obligates. Notable

waterfowl include mallard (*Anas platyrhynchos*), pintail (*Anas acuta*), American widgeon (*Anas Americana*), gadwall *(Anas Strepera*), green-winged teal (*Anas carolinensis*), blue-winged teal (*Anas discors*), cinnamon teal (*Anas cyanoptera*), redhead (*Aythya Americana*), ring-necked duck (*Aythya collaris*), goldeneye (*Bucephala clangula*), snow goose (*Chen caerulescens*), and Canada goose (*Branta canadensis*). Shorebirds commonly seen include American avocet (*Recurvirostra Americana*), black-necked stilt (*Himantopus mexicanus),* Wilson's phalarope (*Phalaropus tricolor*), greater (*Tringa melanoleuca* )and lesser yellowlegs (*Tringa flavipes*), long-billed dowitcher (*Limnodromus scolopaceus),* killdeer (*Charadrius vociferous),* common snipe (*Gallinago gallinago*), spotted sandpiper (*Actitis macularius*), solitary sandpiper (*Tringa solitaria*), western sandpiper (*Calidris mauri*), semipalmated sandpiper (*Calidris pusilla*), willet (*Tringa semipalmata*), longbilled curlew (*Numenius americanus*), and white-faced ibis (*Plegadis chihi*). All of Wyoming's amphibians rely upon wetlands to complete their life cycle. Many of the state's reptiles prefer the habitat of wetlands.

Conservation

In Wyoming, this particular type of habitat receives a great deal of attention from the WGFD and many prominent conservation organizations. Wyoming ranks as the fifth driest state in the United States with an average rainfall of only 16.8 inches per year. Thus, the state lacks the precipitation necessary to support expansive wetland complexes. Because a majority of wildlife species in Wyoming utilize wetland habitat on a daily or seasonal basis, the conservation of these areas becomes critical. Some of those conservation groups include Ducks Unlimited, USFWS Partners for Fish and Wildlife Program, the Natural Resource Conservation Service, and the Nature Conservancy in addition to the two local conservation (Meeteetse and South Big Horn) districts who both operate within the watershed area. Some conservation efforts include:

- Working with private landowners to build, restore and conserve wetlands through conservation easements, fee title acquisitions, management agreements and technical assistance;
- Facilitate the long-term conservation of key avian habitat including planning, funding and developing habitat projects;
- Promote wetland restoration projects on private lands; and
- Offering programs which can be used to address wetland conservation needs on the land such as:
    - The Environmental Quality Incentives Program (EQIP) which provides technical and financial assistance to agricultural producers to address natural resource concerns;
    - The Agricultural Conservation Easement Program which provides financial and technical assistance to help conserve agricultural lands and wetlands;
    - The Agricultural Land Easements which protects working agricultural lands; and
    - The Wetlands Reserve Easements which helps restore, protect and enhance wetlands.

Threats

Some of the threats to wetlands includes:

- Climate change and drought are concerns; variable weather patterns and periodic drought are common throughout the West. Since the 1980s the frequency and duration of droughts have increased dramatically producing undesirable changes in wetland hydrology and the long-term loss of some wetlands;
- Rural subdivision and development;
- Invasive plant species, particularly Russian olive and tamarisk;
- Water development projects;
- Energy development and mining practices;
- Transportation infrastructure;
- Management and maintenance of existing wetland projects; and
- Alteration of existing irrigation delivery systems.

### *Cliff/Canyon/Cave/Rock Outcrops*

Found throughout the intermountain West, this habitat type features a wide variety of elevational range, from 4,000 to 11,000 feet. This can include high, wet, cold alpine landscapes all the way down to dry desert and warm plains environments. About seven percent of the Study area is composed of this habitat type. Cliffs are steep rocky outcrops with a slope of more than 65 degrees and four feet in height. Little snow accumulates here with sparse vegetation. Caves or rock shelters are defined as being large enough for humans to traverse. Typically, they feature stable temperatures, low evaporation rates and an absence of light. Because they take centuries to form, caves are considered irreplaceable natural resources which contain unique biological communities.

Though this habitat occupies a relatively small percentage of land base, it includes a disproportionately abundance of wildlife by providing shelter and breeding sites for many birds and mammals. The persistence and stability of cliffs, rocks and canyons encourage the repeated use as habitat. Lower elevations include a diverse vegetation structure such as skunkbush suma, chokecherry, currant and juniper. This habitat type can be found throughout the Greybull River watershed area.

Big game including bighorn sheep and mountain goats feed on vegetation found in this habitat. In addition to providing breeding habitat and roosts for several species of bats, many birds depend upon the permanent snow and ice found in proximity to exposed rock features. A wide variety of reptiles utilize this type of habitat due to its favorable refuges, cover and hibernacula; particularly a variety of snakes.

Conservation

Caves on federal lands are protected by the Federal Cave Resources Protection Act. The WGFD has developed the *Conservation Plan for Bats in Wyoming* to protect bats and their habitats through management

recommendations for cliff, rock outcrop and caves. This is a cooperative venture among government agencies and private landowners.

Threats

Some of the threats to this unit include:

- Recreational activities by humans such as rock climbing, bouldering, bicycling and spelunking can cause disturbances to wildlife and excessive erosion; and
- Mining, construction, oil shale development or inappropriate wind-energy development siting/design can disturb or destroy buttes, cliffs, cracks and crevices within wildlife habitats, or create collision sources for birds.

### *Xeric and Lower Montane Forests*

These forested habitat units exist in a variety of areas and elevations. Mature forest landscapes are more fragmented and denser with younger trees today than they were a century ago due to more frequent fires in those earlier times. Typically, the annual precipitation in these areas range from eight to 20 inches in the form of snow, spring rain and infrequent summer thunderstorms.

Regarding tree species found in this habitat, the most common juniper is the Utah juniper which is typically found along escarpments and in arid basins in elevations ranging from 4,000 to 10,000 feet. Considered a cold- and drought-tolerant species, the limber pine is a generalist and pioneer species which allows it to grow under a wide variety of environmental and physiological circumstances. Its elevational range is the greatest of all conifers ranging from 5,250 feet to almost 11,000 feet. It shares habitat with ponderosa pine, juniper and Douglas fir yet is often associated with whitebark pine. The enormous ponderosa pine can grow to over 130 feet tall in a wide variety of soils. It is often found in foothills and escarpments and is considered to be a fire-adaptive tree.

Juniper stands are important wintering habitat for mule deer and elk where the deer browse on the juniper. White-tailed deer, black bear, wild turkey, blue and ruffed grouse (*Bonasa umbellus*), migratory songbirds, blackbacked (*Picoides arcticus*) and American three-toed woodpeckers (*Picoides dorsalis*), olive-sided flycatcher (*Contopus cooperi*), mountain bluebird (*Sialia currucoides*), flying squirrels (*Pteromyini*), and red squirrels, as well as various other rodent and squirrel species all take advantage of the abundant habitat provided in ponderosa pine forests.

**Image 17: Utah Juniper Tree**

*Photo courtesy of National Park Services*

Conservation

The WGFD, BLM and various conservation districts continue to be involved with multiple projects regarding conifer removal and thinning. These treatments vary depending upon the stand density, location, existing understory vegetation and threats of invasive species, primarily cheatgrass. Other efforts include reduction of ponderosa pine density.

Threats

Xeric and montane forest threats include:

- Fire suppression which has resulted in greater tree densities, buildup of dead, downed material and reduced understory plant species diversity;
- Diseases and insects include the bark beetles *(Scolytinae)* which are serious pests for ponderosa pine, pinon pine and limber pine. These infestations are often aided by increased temperatures and persistent drought. Currently all age classes of limber pine are being infected with white pine blister; another disease affecting both limber pine and ponderosa pine is dwarf mistletoe with infection rates up to 33 percent in some areas;
- Invasive species such as cheatgrass and other grasses have the potential to increase fire frequency and reduce native grasses and forbs which supply forage for wildlife and support insect diversity;

- Varied perceptions on the location and extent of removal and thinning treatments;
- Drought and climate change;
- Habitat fragmentation due to rural development and subdivision; and
- Off-road vehicle uses.

### *Prairie Grasslands*

Typically found in elevations below 7,000 feet, prairie grasslands usually include shortgrass prairie or mixed-grass prairie. Shortgrasses include buffalo grass (*Bouteloua dactyloides*) and blue grama (*Bouteloua gracilis*). Needle-and-thread, western wheatgrass (*Pascopyrum smithii*), blue grama, Sandberg's bluegrass, prairie Junegrass (*Koeleria macrantha*), upland sedges, and Indian ricegrass (*Oryzopsis hymenoides*) comprise the mixed grasses.

This habitat, which is less than 0.5 percent of the Study Area, is characterized by occasionally intense natural and frequent disturbances such as grazing, drought and fire. These encourage the predominance of perennial grasses including a number of sedges and herbaceous forbs. The ability of organizations to engage private landowners in conservation efforts and the persistence of ranching as an economically viable land use within the state will be closely tied to the future preservation of this habitat type.

Large numbers of wildlife are supported in these grasslands including expansive colonies of prairie dogs (*Cynomys*) which thrive in the watershed. Their burrows create habitat for other wildlife species including the black-footed ferret (*Mustela nigripes*), burrowing owls (*Athene cunicularia*), long-tailed weasel (*Mustela frenata*), mountain plover, and swift fox (*Vulpes velox*). In addition, these same prairie dogs provide a prey base for black-footed ferrets, ferruginous hawks (*Buteo regalis*) and golden eagles.

These grasslands are home to Wyoming's best-known wildlife species, namely the pronghorn antelope and Wyoming's state bird, the western meadowlark (*Sturnella neglecta*). One popular game species, the prairie sharp-tailed grouse, can also be found in this habitat unit. Other bird inhabitants include the rough-legged hawk (*Buteo lagopus*), hoary redpoll (*Carduelis hornemanni*), Lapland longspur *(Calcarius lapponicus*), snow bunting (*Plectrophenax nivalis*), and the occasional snowy owl (*Bubo scandiacus*) and gyrfalcon (*Falco rusticolus*).

*Western Meadowlark (Photo courtesy of Birdnote)*

### *Aspen/Deciduous Forests*

Typically, this habitat is dominated by aspen, bur oak, Gambel oak (*Quercus macrocarpa*) or bigtooth maple (*Acer grandidentatum*) and spans a range of sites from pure upland to riparian in nature. Within the system, other dominant species include narrowleaf (*Populus angustifolia*) and plains cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), box elder (Acer negundo), elm, choke cherry, Rocky Mountain maple

(*Acer glabrum*), alder (*Alnus*) and peachleaf willow (*Salix amygdaloides*). This unit features range of sites from pure upland to almost completely riparian in nature.

Aspen stands support high grass and forb production in their understories. These are key foraging sites for large and small herbivores (deer, elk, moose, bear, chipmunks, etc.). Though dominant in much of Wyoming (about 467,000 acres), there is less than 0.5 percent of this habitat type in the Study Area.

### 2.2.3Wildlife Habitat, Game and Sensitive Species

Not unlike the fisheries in Wyoming, maintaining sustainable wildlife populations and their habitats is a fundamental challenge in Wyoming. As noted earlier, management of these habitats varies in Wyoming depending upon the jurisdictional boundaries of several governmental agencies including the BLM, USFS, USFWS, WGFD and private landowners.

Typically, it is a cooperative effort among these governmental agencies, biologists, conservationists, land managers and the private landowners to collaborate and maintain sustainable wildlife populations. As noted earlier, the diversity of plant and animal species, and their associated habitat can be extensive within the watershed area depending upon climate and location. Several sources of information were utilized for this discussion including habitat priority areas and big game crucial areas as identified by WGFD.

#### 2.2.3.1 Wildlife Habitat

According to the SWAP, habitats are classified by plant and/or animal assemblages, geographic features, ecological attributes, or a combination of any of these features. Though the goal is to make each unit distinct, the reality is there can be considerable overlap among the units (WGFD, 2017).

Conservation actions and even threats can vary considerably between habitat types. To best meet the purposes of the SWAP, a habitat classification system with the following attributes was developed:

- Identifies habitats with similar flora, fauna, and conservation concerns;
- Uses a scale frequently used in wildlife management;
- Describes habitats that are easily recognized by the public and policy makers; and
- Arrives at a result where the number of habitats is manageable for planning purposes.

One of the many challenges facing WGFD wildlife managers is identifying habitat priority areas throughout the state including areas within the Greybull River watershed. To determine habitat priorities, the WGFD has established a fundamental distinction between wildlife habitats that are “crucial” for wildlife and those habitats which have been degraded yet have potential for “enhancement” (WGFD, 2015). Figures 29 and 30 depict the crucial and enhancement aquatic and terrestrial habitat areas for the watershed.

<u>Crucial Habitat Priority Areas</u>

Crucial habitat priority areas are based on significant biological and/or ecological values which need protection and management to maintain viable healthy populations of terrestrial and aquatic wildlife for both present and future value. These areas are considered the first goal for the WGFD regarding wildlife habitat. Examples include sage grouse core area seasonal habitats, Species of Greatest Conservation Need

(SGCN), diversity and uniqueness, quality and condition of vegetative communities, movement corridors, and quality of watershed hydrologic function among others (WGFD, 2017e). Crucial habitat priority areas within the Greybull River watershed are depicted in Figures 29 and 30 and include:

- Aquatic areas for the Yellowstone cutthroat trout habitat;
- Aquatic areas for the lower Bighorn River complex; this complex consists of Bighorn Lake, the Bighorn River and its tributary corridors which includes a portion of the Greybull River. The one particular portion within the watershed begins at the Highway 30 Bridge on the Greybull River (see Figure 29) and continues downstream to its confluence with the Bighorn River;
- Terrestrial areas for aspen community habitats;
- Terrestrial areas for spruce-fir stands;
- Terrestrial areas for the sage grouse core areas; and
- Terrestrial areas for big game habitats.

For those habitat priority areas identified as aquatic or riparian corridors, the WGFD utilizes a standard width of two kilometers for mapping display or acreage calculations. The true widths of riparian zones differ among different streams and at different locations along the same stream. Therefore, the riparian priority area and efforts to conserve or enhance that area include the functional riparian zone defined by vegetation and hydrology rather than some standard and arbitrary distance (WGFD, 2017e).

Enhancement Habitat Priority Areas

Enhancement habitat priority areas represent those which express a realistic potential to address issues associated with wildlife habitat including the improvement, enhancement or restoration of those habitats. These areas are considered the second goal by the WGFD regarding wildlife habitat. This designation is based on issues associated with the specific habitat features including the loss of aspen communities, the fragmentation of habitats, loss of connectivity, water quality effects and water quantity limitations, conifers killed by beetles, lack of fish passage or loss of fish diversions (WGFD, 2017e). Enhancement habitat priority areas within the Greybull River watershed are depicted in Figures 29 and 30 and include:

- Aquatic areas for the Yellowstone cutthroat trout habitat;
- Aquatic areas for the lower Bighorn River complex;
- Combined enhancement area for Wildlife Habitat Management Areas (WHMAs);
- Terrestrial areas for sagebrush habitat threatened by conifer encroachment;
- Terrestrial areas where forage competition exists between livestock and big game; and
- Terrestrial areas where aspen communities are at risk.

Combined Habitat Areas

The WGFD created combined habitat areas whenever significant overlaps existed between specific aquatic and terrestrial areas. Within the watershed, the Combined Crucial Habitat area is a combination of the aquatic lower Bighorn River complex and the terrestrial aspen community area as depicted on Figure 31. The watershed's Combined Enhancement area is a combination of those same lower Bighorn River complex and aspen community areas which are also depicted on Figure 31.

#### 2.2.3.2 Game Review

As steward of Wyoming's game herds, the WGFD has developed several strategies and management plans to maintain the habitat and populations of the state's wildlife. The department's first Strategic Habitat Plan was completed in 2001 and includes a revision completed in 2015. This plan and its accompanying SWAP present the framework and management goals to conserve and improve habitat to maintain Wyoming's abundant wildlife now and in the future. Included in these plans are strategies to help maintain migration corridors, seasonal ranges, birthing areas and critical habitat for game species. Within the watershed boundaries Figures 32 through 37 depict the various seasonal ranges, migration corridors, crucial ranges and/or parturition areas for antelope, bighorn sheep, elk, moose, mule deer and whitetail deer (*Odocoileus virginianus).*

***Migration Corridors***

The WGFD defines migration corridors as the linear habitat across which the individual migration routes of many animals occur (WGFD, 2015a). Subsequently, migration corridors and their inherent stopover areas for Wyoming's ungulates are vital to maintaining big game populations. Wyoming, in particular, contains some of North America's longest corridors for mule deer, elk and pronghorn. Studies have found that nearly 95 percent of the migratory period is spent foraging at stopover areas along migration corridors (Sawyer and Coffman, 2011). Listed below are the corridors within the Greybull River watershed including:

- Antelope: there are several routes in the area that antelope utilize for migration mostly in the central and north-central portion of the watershed;
- Bighorn sheep: there are a handful of short yet documented migration for bighorn sheep in the far western portions of the watershed;
- Elk: much of the western and northwestern portions of the watershed contain elk corridors; and
- Mule deer: much like the elk, the western portion of the watershed includes many routes utilized by mule deer.

***Seasonal Ranges (all photos courtesy of WGFD)***

The seasonal ranges for big game species in the watershed are mapped by the WGFD and are depicted in Figures 32 through 37. According to the WGFD, seasonal wildlife ranges are based on repeated observations of substantial numbers of individual animals or groups of animals consistently using or moving through the same area year after year during the appropriate time period (WGFD, 2015a). Within a seasonal range there can be a crucial range which is the component which has been documented as the determining factor in a

population's ability to maintain itself at a certain level over the long term. Within the Greybull River watershed there are seasonal ranges for:

- Pronghorn: more than 75 percent of the watershed is utilized by the pronghorn in one season or another with much of the area used as year-long habitat though the southern border areas are often used as winter occupancy;

*Photo courtesy of WGFD*

*Photo courtesy of WGFD*

Bighorn sheep: the far western reaches of the watershed in the Absaroka Mountain Range are all home to the bighorn sheep with the lower elevation of the mountain range occupied during the winter season;

- Elk: a sizable portion of western part of the watershed is used by elk for its winter and yearlong habitat;

*Photo courtesy of WGFD*

*Photo courtesy of WGFD*

- Moose: much like the Bighorn sheep, moose reside in the western portion of the watershed for both winter and year-long occupation;

- Mule deer: this deer utilizes nearly the entire watershed area during one portion of the year or another. The eastern half is mostly a year-long habitat, the western third of the area is mostly a spring/summer affair while the central portion of the watershed is utilized for much of its winter or winter/year-long appearances; and

*Photo courtesy of wyomingpublicmedia.org*

*Photo courtesy of outdoornews.com*

- Whitetail deer: this species of deer occupies much of the land throughout the watershed on a year-round basis.

### *Crucial / Parturition Areas*

Documented birthing areas commonly used between mid-May and the end of June by the female segment members of a given population, are often referred to as parturition areas. These are the crucial areas for calving, fawning and lambing, and are often used as "nursery areas" by some species (WGFD, 2015a). Within the Greybull River watershed there are such areas for:

- Antelope: there is a relatively confined area in the south-central portion of the watershed which antelope utilize and is considered its crucial range;
- Bighorn sheep: the western portion of the watershed, particularly in the highest of elevations, contains both crucial habitat and parturition habitat for the sheep;
- Elk: there are areas of the western portion of the watershed the elk utilized for both parturition and its crucial range;
- Moose: the western portion of the watershed, particularly in wetland areas, contains both crucial habitat and parturition habitat for moose; and
- Mule deer: there are crucial ranges for the mule deer in the central and western portions of the watershed.

#### 2.2.3.3 Critical Habitat

In 1973 the U.S. Congress passed the Endangered Species Act (ESA). As a result, the U.S. Fish & Wildlife Service (USFWS) determines eligibility regarding a species being listed as either threatened or endangered. Because habitat loss is the primary threat to most imperiled species, the ESA empowers the USFWS to designate specific areas as protected "critical habitat" zones. These habitats are required to contain all the areas essential to the conservation of any imperiled species and may be on private or public lands. Any actions which may destroy or adversely modify critical habitats will be prohibited by any authorizing federal agency including the USFWS.

As defined by the USFWS, there are no critical habitat areas located within the Greybull River watershed though the border for the critical habitat area of the Canada Lynx does abut the western border of the Greybull River watershed.

#### 2.2.3.4 Species of Concern

The Wyoming Natural Diversity Database (WYNDD) maintains lists of species found within the state which are rare, endemic, disjunct, threatened or otherwise biologically sensitive. These lists of both plants and animals are considered Species of Concern (SOC) and are sometimes referred to as *tracked species* (WYNDD, 2017). Species of plants or animals are considered for inclusion as a SOC if they are vulnerable to extirpation at the global or state level due to:

- Rarity (e.g., restricted distribution, small population size or low population density);
- Inherent vulnerability (e.g., specialized habitat requirements or restrictive life history); or
- Threats (e.g., significant loss of habitat or sensitivity to disturbances).

In addition, this University of Wyoming database also updates a Species of Potential Concern (SOPC) list or *watched species*. This list includes species which appear to be secure at the present but because of limited distribution as regional or state endemics, they could become vulnerable under large-scale habitat changes, and warrant periodic checks (WNDD, 2017).

The WYNDD uses standard rankings to demonstrate the probability of extirpation. The ranking of all species within Wyoming is designated with an "S" for subnational ranking assigned by WYNDD biologists and are based on criteria at a state level. Numerical ranking following the S is identified as follows:

- 1 – Critically imperiled
- 2 – Imperiled
- 3 – Vulnerable
- 4 – Apparently secure
- 5 - Secure

Table 12 below lists those SOC and SOPC species ranked as critically imperiled or imperiled that are found within the Greybull River watershed. The table also provides the USFS ranking of the species related to sensitive, threatened or endangered species described in more detail below.

**Table 12. Species of Concern in the Greybull Watershed**

| Scientific Name | Common Name | Major Group | USFS Federal Status | State Status |
|---|---|---|---|---|
| *Centrocercus urophasianus* | Greater Sage-Grouse | Birds | | S4 |
| *Cymopterus evertii* | Evert's Waferparsnip | Flowering Plants | | S2S3 |
| *Descurainia torulosa* | Wyoming Tansy-mustard | Flowering Plants | | S2 |
| *Mustela nigripes* | Black-footed Ferret | Mammals | XN: Experimental Population, Non-essential | S1 |
| *Penstemon absarokensis* | Absaroka Beardtongue | Flowering Plants | | S2 |

2.2.3.5 Sensitive Species

The United States Forest Service (USFS) determines the eligibility and maintains a list of Sensitive Species found throughout the country. The agency defines Sensitive Species as those plant and animal species identified by a Regional Forester for which population viability is a concern, as evidenced by:

- Significant current or predicted downward trends in population numbers or density;

- Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution (USFS, 2017).

The Greybull River watershed is located within Region 2 of the nine USFS jurisdictional areas. Region 2 is referred to as the Rocky Mountain Region of the USFS whose jurisdiction consists of five states including Colorado, Nebraska, Kansas, most of Wyoming and South Dakota. The sections of the Shoshone National Forest east of the continental divide are located in the western portion of the watershed and fall under the jurisdiction of Region 2. There are no listed Sensitive Species located with the Study Area.

#### 2.2.3.6 Threatened and Endangered Species

As a result of the Endangered Species Act (ESA) passed by Congress in 1973, the USFWS determines eligibility regarding a species being listed as either threatened or endangered. As defined by the ESA, endangered means any species which is in danger of extinction throughout all or a significant portion of its range. Threatened is defined as any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Because habitat loss is the primary threat to most imperiled species, the ESA empowers the USFWS to designate specific areas as protected "critical habitat" zones. These habitats are required to contain all the areas essential to the conservation of any imperiled species and may be on private or public lands. Any actions which may destroy or adversely modify critical habitats will be prohibited by any authorizing federal agency including the USFWS.

Utilizing the USFWS website, it was determined the Greybull River Watershed area includes one experimental species, the black-footed ferret (USFWS, 2017).

According to the USFWS, an experimental species is defined as a special designation under the ESA that the USFWS can apply to a population of a threatened or endangered species prior to reestablishing it in an un-occupied portion of its former range.

The black-footed ferret falls into this category as a result of the efforts of the WGFD to reintroduce the ferret back into its native territory beginning in 1991 with a release of 228 ferrets in the Shirley Basin area located south of Casper. Such ferret releases have continued in Wyoming over the years including recent releases within the Greybull River watershed area west of Meeteetse in the fall of 2018 (PT, 2018).

There were no bird, fish, reptile or amphibian species listed as Threatened or Endangered within the Greybull River Watershed area though several of those species are found elsewhere within the state of Wyoming.

#### 2.2.3.7 Bark Beetle Outbreak

For over two decades, the forests throughout western North America have experienced widespread and unprecedented outbreaks of bark beetles. This includes the forested areas within the Greybull River watershed study area most notably in the Shoshone National Forest in the western portion of the watershed. Acreage of beetle impacted forest in the watershed totaled 153.5 acres in 2015 with an additional 225 acres noted in 2017. It should be noted that the area documented each year is not cumulative, but notes new affected areas not documented from previous years.

Native bark beetle infestations are a natural regulating process in most forests, but recent outbreaks are the result of several different species causing severe tree mortality at a scale and rate which is historically unparalleled. Under normal conditions these infestations do not destroy forests though they do alter forests for some time. Typically, bark beetles focus their attacks on mature trees. Thus, during such infestations, established young trees and seeds released from dropped cones are the sources of subsequent new forest growth (USFS, 2011).

As noted by the Wyoming State Forestry Division, entomologists agree this current epidemic is an anomaly because all the major bark beetles are expressing epidemic levels simultaneously (WSFD, 2010). The mortality in some areas approaches 100 percent. However, there is one species responsible for most of the current forest mortalities; namely the Mountain Pine Beetle (MPB), (*Dendroctonus ponderosae)*.

**Image 18: Mountain Pine Beetle**

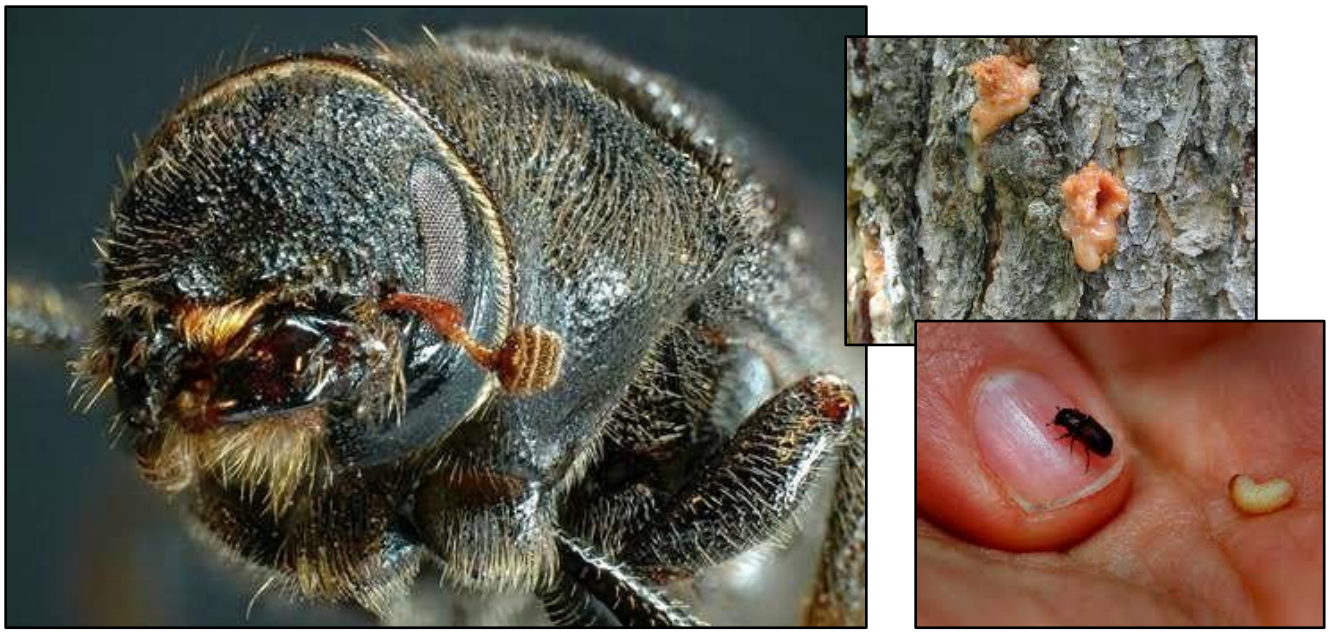


*Photo courtesy of PhysOrg*

Typically, such landscape-level epidemics require a complex set of factors (Pappas, 2013). The recent outbreaks seem to be driven by two main factors which both favor MPB survival and reproduction including:

- Dense concentrations of host trees consisting of large, mature trees; and
- Changing climate conditions consisting of prolonged drought and warmer temperatures.

The following discussion outlines additional risks posed by bark beetle infestation which includes the MPB.

***Fire Risks – Bark Beetle***

One of the primary disturbance agents in forest ecosystems is fire. According to the USFS (Gibson and Negron, 2007), there are two primary types of interactions between beetles and wildfire:

- Fires can influence bark beetle populations including the MPB by providing significant amounts of susceptible trees; and
- Outbreaks of beetle infestation can influence the likelihood and behavior of future fires.

Bark beetles can influence a fire's behavior by altering the fuel aspects of the fire (NPS, 2017). Before a fire begins, beetle infestation can transform fuel from live fuel in the canopy to dead fuels on the ground in the form of dead needles. Beetle infestation also reduces the foliar moisture of a tree which could facilitate movement of a fire up into the crown of the tree (Gibson and Negron, 2007). Once in the crown, a fire's behavior can become more erratic and the potential to spread increases dramatically.

The number of dead or dying trees from beetle infestation has not only raised concerns regarding wildfire risk, but also brings up issues related to critical ecosystem services and functions such as:

- Water regulation;
- Nutrient cycling;
- Carbon sequestration;
- Timber production; and
- Recreational/aesthetic opportunities and values.

***Surface Water Impacts As a Result of Bark Beetle Infestation and Fires***

Surface water quality can suffer as the result of forest fires. As noted earlier, the outbreaks of beetle infestation including the MPB can influence the likelihood and behavior of future fires. There are numerous potential impacts from wildfires regarding water quality not only for public consumption but for fisheries and aquatic habitats alike (USGS, 2013). Some of those surface water impacts include:

- Irrigation systems, water treatment operations, drinking water supplies and fisheries can all be adversely affected by large increases in runoff following a forest fire;
- The runoff from burned soils and surrounding area can exhibit shorter-duration and higher peak water flows which is controlled by the interaction of the ash layer and precipitation. This increase in flow can induce erosion and mobilize debris for movement downstream;
- The chemistry of surface water is altered significantly as a result of the ash chemistry and the altered soil hydraulics;
- Decreased canopy cover yields more solar radiation which warms the soils and increases spring runoff. Often times this results in summer/autumn flows exhibiting warmer temperatures;
- Watershed basins that experience high-severity burn areas often produce water with elevated nitrate and turbidity levels for up to five years (USGS, 2013);
- Microbiological pathogens have been observed in source waters due to the increased movement of debris and sediment; and

- The intakes for reservoirs may become unusable because of the increase sediment load settling at the bottom of the reservoir thus reducing capacity and can force costly dredging or clean-outs.

***Control of Mountain Pine Beetle***

During MPB outbreaks, natural controls often fail to prevent further attack by the MPB. Those natural controls may include woodpeckers and even other insects such as clerid beetles (*Cleridae)* which both prey on adult MPBs and the larvae burrowed under the tree bark. However, during large outbreaks natural predators have little overall effect on the MPB population (USFS, 2011).

One natural phenomenon for control is extreme cold temperatures during winter. These cold temps can be a significant factor for controlling larvae. These larvae are most susceptible to cold temperatures in the fall or springtime (Leatherman, et.al., 2011). However, for the cold temperatures to be effective, it must be at least 30 degrees below zero Fahrenheit and sustained for at least five days.

Downed logs infested with the MPB can be treated in several ways before the beetle emerges as an adult in summertime. One method to kill larvae is by mechanically peeling the bark away thus exposing them to the elements where they will dehydrate and die.

Another option is preventive spraying. These chemical options include carbaryl, permethrin and bifenthrin among others (WSFD, 2017). According to the USFS, controls being applied in the Shoshone National Forest in the western portion of the Greybull watershed include chemical applications on high-value trees, timber harvesting, firewood sales and even controlled burns (USFS, 2017a).

Humans can assist in the spread of the MPB outbreak by transporting affected firewood. To avoid this problem, the USFS (2011) recommends:

- Select dead and dry firewood from the forest where collection is allowed;
- Standing trees with no needles are the best choice;
- Any tree with all red needles is also acceptable for firewood; and
- Burn firewood before the end of June to prevent remaining beetles from emerging to infect other trees.

#### 2.2.3.8 Sage Grouse

Survival for many birds, mammals and plants in the western United States depends upon sagebrush ecosystems. Those plants and animals whose habitats are dominated by sagebrush are referred to as obligate species of these ecosystems. For the past century, sagebrush ecosystems have experienced changes as a result of livestock grazing, introduction of exotic species, fire, industrial uses such as oil and gas exploration, and the conversion of lands for agriculture uses. Such changes have resulted in the alteration of the vegetative communities which includes extensive fragmentation and losses of portions of the sagebrush-steppe habitat. Throughout the intermountain West these losses are negatively affecting many of the more than 350 species of plants and animals whose very existence is often dependent upon the sagebrush ecosystems. One such obligate is the Greater Sage-grouse. In Wyoming, this bird is associated with and dependent upon sagebrush ecosystems (Knick, 2002).

**Image 19: Greater Sage Grouse**

*Photo courtesy of WGFD*

In 2010, the United States Fish and Wildlife Service (USFWS) issued a decision that the Greater Sage-grouse was warranted for listing under the ESA. However, at that time the listing was precluded by a higher priority species. Subsequently, in 2015 the USFWS concluded the sage grouse did not meet the standards for protection under the ESA. In the same year, Wyoming Governor Matt Mead signed Executive Order (EO) 2015-4 which details Wyoming's management of the areas inhabited by the Greater Sage-grouse. Its goal is

to “minimize future disturbance by co-locating proposed disturbances within areas already disturbed or naturally unsuitable” (EO, 2015).

### *Wyoming’s Sage Grouse Core Population Areas*

Central to Wyoming’s sage grouse management strategy is the establishment of its core population areas which, as stated in the EO 2015-4, “protects significant quantity and quality of Greater sage-grouse habitat and protects a substantial portion of Wyoming’s Greater sage-grouse.” The EO was developed in an effort to head off listing the sage grouse as an endangered and threatened species because once the grouse is given an ESA designation, the subsequent conservation measures could sharply curtail energy development throughout the state. Wyoming’s biggest industry is energy-related minerals extraction and mining.

Wyoming manages approximately 15 million acres of core habitat. The sage grouse core area located within the watershed is depicted in Figure 38 and totals 316,523 acres, nearly one-third of the watershed area. These areas were officially established in 2008 when then-governor Dave Freudenthal signed EO 2008-2.

On July 10, 2017 Gov. Mead signed EO 2017-2 which supplements the 2015 EO. This latest EO expands on the definition of “suitable” habitat for riparian, wet meadow (native or introduced) or areas of alfalfa or other suitable forbs (brood rearing habitat). Previously, the distance from these riparian areas to be protected was 275 meters from sagebrush where it was proven through pellet counts, documented sightings or other defensible proof that sage grouse use the area. Now, however, the latest EO extends the distance beyond 275 meters to any area where there is defensible proof that the sage grouse do, in fact, use the expanded area.

Activities permitted or existing prior to Aug. 1, 2008 are exempt from the management strategy. Such activities include grazing allotments, utility ROWs, subdivision plats, mine plans, drilling and spacing units, and oil and gas units among others. In addition, activities on private lands are not subject to state or federal agency review or approval. Only state- or federally-owned lands are subject to this management strategy. Figure 38 also depicts landownership located within the Greybull River watershed boundaries.

Any proposed land uses and/or activities within the core areas are authorized on a case-by-case basis only when the project proposals demonstrate the activity will avoid negative impacts to the Greater sage-grouse. New projects within state or federal lands which require permitting are required to consult with the WGFD.

A key aspect regarding the establishment of core areas is the inclusion of leks which are open areas in the sagebrush-covered landscape. During the springtime breeding season, male sage grouse gather together in leks to perform colorful, sunrise courtship displays in front of females who gather on the outer perimeter of the leks. Most leks are included in core areas and are representative of nearby nesting habitat. As noted in the 2015 EO, a four-mile radius around an active lek is indicative of approximately 80 percent of nesting females associated within their particular lek of breeding and warrants protection.

Within the watershed there are 45 known occupied leks as depicted on Figure 38. Of those 45 leks, 42 are located within the sage grouse core area including 28 on federal land, 10 on private land and four on state land. Three other lek areas are located within the watershed but outside the sage grouse core area including one on federal land and two on private property.

Any activity or land use proposed within core areas must adhere to the limitations detailed in the EO. Such impacts are limited to five percent surface disturbance of suitable habitat per an average of 640 acres over the proposed assessment area. In addition, in core areas there is no surface occupancy allowed within 0.6 miles of an active lek. In non-core areas, this stipulation is within one-quarter of a mile with seasonal restrictions within two miles of a lek.

## 2.3 ANTHROPROGENIC SYSTEMS

### 2.3.1 Land Use and Ownership

This section provides a summary of land uses, land ownership and land management within the Greybull River watershed. The watershed is located within the Bighorn Basin in north-central Wyoming and includes portions of Big Horn and Park Counties.

Land ownership in the watershed boundary is depicted on Figure 39. As shown in Table 13, private landowners control nearly 28 percent of the watershed, while over 63 percent of the watershed is owned and maintained by federal agencies such as the U.S. Forest Service and the Bureau of Land Management. The remaining portion of over nine percent is owned by the state.

**Table 13. Land Ownership Distribution**

| Ownership | Acres | Percentage of Watershed |
|---|---|---|
| Private | 281,216.1 | 27.7 |
| State | 92,874.3 | 9.2 |
| Bureau of Reclamation | 342.4 | 0.03 |
| Bureau of Land Management | 366,726.9 | 36.2 |
| U.S. Forest Service | 272,721.6 | 26.9 |
| Water | 109.6 | 0.01 |

The private landowner area within the watershed is mostly rural in nature. The three largest population centers of the watershed total approximately 2,500 people (U.S. Census, 2017). The latest U.S. Census estimates for these communities include:

- Greybull: population of 1,872 with a $46,193 median household income
- Burlington: population of 344 with a $47,250 median household income
- Meeteetse: population of 327 with a $45,341 median household income.

## ***LAND USES***

Historical land use of the watershed closely resembles current land use. This includes water storage, agricultural uses/livestock grazing, industrial development, recreation, limited transportation uses and a wide variety of wildlife habitat. Water storage land use is described in further detail in Section 2.3.4 below, Water Storage.

### *Utilities and Transportation*

Within the watershed's boundary is infrastructure for power systems, utilities and railroads. The lone railroad, Burlington Northern Sante Fe (BNSF), located within the watershed is situated on the extreme eastern boundary and passes through the community of Greybull. Figure 40 depicts the locations for the electrical transmission lines and the BNSF Railroad. There are no commercial power generating systems or commercial wind turbines within the watershed (NREX, 2017).

As shown on Figure 40, there are only four primary paved transportation routes within the watershed. Those routes include:

- State Highway 120, which bisects the community of Meeteetse, is oriented in a north-south direction in the western portion of the watershed;
- Highway 14 extends west from the community of Greybull and intersects with Highway 16/20 near the community of Burlington. These highways are oriented in a west-east direction and connect the eastern portion of the watershed to the western portion of the watershed;
- County Road 40 (Greybull River Road) orients west-east and connects the communities of Burlington and Meeteetse via State Highway 120; and
- County Road 30, which bisects the community of Burlington, orients eastward from Burlington where it crosses the Greybull River and eventually connects to the town of Basin situated outside of the watershed's easternmost boundary.

### *Agricultural / Livestock Uses*

Agriculture is the primary economic and cultural influence for the population located within the watershed. It is the predominant land use within the privately-owned watershed area and includes livestock and crop production. For Park County which is roughly the central portion of the watershed, livestock production is the major industry which also includes crop production of hay and grain utilized as winter feed for the livestock (MCD, 2017). Similarly, the livestock production of beef cattle and sheep is also a major industry in Big Horn County, located in the eastern portion of the watershed. Along the valley floors of both the Greybull River and Dry Creek, there is the annual production of many irrigated crops such as malt barley, sugar beets, oats, hay and dry beans among others (BHC, 2017).

The U.S. Census of Agriculture releases its statistics every five years. The 2017 statistics were not available at the time of this report thus the 2012 figures were the latest available. Table 14 depicts the acreage devoted to both cropland and pastureland in each county plus the market value for the counties' crops and livestock sales over a period of ten years. It should be noted this table accounts for the entirety of both counties and

not simply the watershed area. However, the figures in the table do reflect the agriculture uses and subsequent economic trends across the watershed area.

The latest government statistics reveal the amount of land devoted to crop production in both Park and Big Horn County has dropped over a period of ten years. These ten-year reductions represent 12.9 and 24.3 percent for Park and Big Horn County (USDA, 2018a).

It should also be noted that over the same ten-year period, the average size farm (acres) has tended to decrease with a 40 percent reduction in farm size in Big Horn County and nearly 20 percent reduction in size in Park County. This indicates a potential land use shift towards smaller farms and sub-dividing of land for more residential or "hobby farm" uses.

**Table 14: Agricultural Land Uses**

| Farms | Park County | | | Big Horn County | | |
|---|---|---|---|---|---|---|
| | 2012 | 2007 | 2002 | 2012 | 2007 | 2002 |
| Number of farms | 860 | 782 | 627 | 627 | 621 | 441 |
| Land in farms (acres) | 813,152 | 881,736 | 810,302 | 302,555 | 438,033 | 411,782 |
| Avg. size of farm (ac.) | 946 | 1,128 | 1,140 | 483 | 705 | 822 |
| # of farms 1-9 ac. | 102 | 64 | 42 | 58 | 28 | 14 |
| # of farms 10-49 ac. | 220 | 217 | 202 | 143 | 147 | 85 |
| # of farms 50-69 ac. | 70 | 56 | 39 | 30 | 29 | 18 |
| # of farms 70-99 ac. | 49 | 49 | 26 | 40 | 59 | 40 |
| # of farms 100-139 ac. | 58 | 74 | 28 | 54 | 34 | 17 |
| # of farms 140-179 ac. | 60 | 42 | 33 | 41 | 50 | 26 |
| # of farms 180-219 ac. | 30 | 13 | 26 | 34 | 38 | 23 |
| # of farms 220-259 ac. | 22 | 21 | 11 | 7 | 19 | 11 |
| # of farms 260-499 ac. | 87 | 74 | 82 | 53 | 71 | 76 |
| # of farms 500-999 ac. | 63 | 60 | 66 | 82 | 64 | 50 |
| # of farms 1,000-1,999 ac. | 40 | 43 | 34 | 61 | 48 | 46 |
| # of farms >2,000 ac. | 59 | 69 | 38 | 24 | 34 | 35 |

Source: USDA, this data is compiled every five years; though the site was accessed in 2018, the latest data through 2017 is not available

### *Industrial Uses*

Oil and gas production within the Greybull River watershed area is predominantly located in the centrally-located Oregon Basin field located north of Meeteetse. The majority of the 20 fields located within the watershed are, in fact, situated in the western half of the watershed. There are two fields, Greybull and

Greybull West, located on the eastern portion of the watershed (NREX, 2017). There are over 1,000 producing oil and gas wells within the watershed with 60 percent of those located within the Oregon Basin field. In addition, there are nearly 600 plugged and abandoned oil and gas wells within the watershed with most also in the Oregon Basin field. Figure 40 depicts the locations for primary transmission lines and crude oil and natural gas wells.

Mining and mining interests occur within the watershed boundary. There are seven active mining permits within the watershed including three near Meeteetse, three southwest of Burlington and another located on the southeastern edge of the watershed's boundary. In addition, there are 10 active gravel pit permits located throughout the watershed. Those seven permit locations are shown on Figure 40. Table 15 provides details of the permitted operations. All the active mines and pits are less than 20 acres in size and are not likely to impose significant water quality impacts to the watershed. Although not actively mined within the watershed, there is potential for future mining because of known reserves of bentonite, coal, helium, metals and sulfur (NREX, 2017).

**Table 15: Active Mine/Gravel Permits**

| Company/Permit Holder | Type of Permit | Mine/Pit Name | Size (Ac.) | Status |
|---|---|---|---|---|
| Lewis Construction, LC | Limited Mine Operation | n/a | 15 | Limited Mine Operation |
| Nicholson Dirt Contracting | Limited Mine Operation | n/a | 10 | Limited Mine Operation |
| Lamax Construction, Inc. | Limited Mine Operation | Adella Marcus | 15 | Limited Mine Operation |
| B&D Construction, Inc. | Limited Mine Operation | n/a | 3 | Limited Mine Operation |
| Kobbe Construction | Limited Mine Operation | Kobbe | 3 | Limited Mine Operation |
| John's Excavation | Limited Mine Operation | Deromedi, John | 5 | Limited Mine Operation |
| Calvin Michaels | Limited Mine Operation | Neves | 10 | Limited Mine Operation |
| Rocking JR Ranch, Inc. | Limited Mine Operation | Rocking JR Ranch | 10 | Limited Mine Operation |
| Frost Rock Products Co. | Limited Mine Operation | Peterson | 1 | Limited Mine Operation |
| Leigh Rach, LLC | Limited Mine Operation | Smith | 4 | Limited Mine Operation |
| Greybull Valley Irrigation District | Small Mine | n/a | 18 | Small Mine |
| Park County | Sand and Gravel pit | Eagles Pass | n/a | Active Pit |
| Big Horn County | Sand and Gravel pit | Table Mountain SE | n/a | Active Pit |
| Big Horn County | Sand and Gravel pit | Table Mountain SE | n/a | Active Pit |
| Park County | Sand and Gravel pit | Lower Greybull | n/a | Active Pit |
| Big Horn County | Sand and Gravel pit | Basin | n/a | Active Pit |
| Big Horn County | Sand and Gravel pit | Emblem Cemetery | n/a | Active Pit |
| Big Horn County | Sand and Gravel pit | Greybull Cemetery | n/a | Active Pit |
| Park County | Sand and Gravel pit | Webster | n/a | Active Pit |

| Company/Permit Holder | Type of Permit | Mine/Pit Name | Size (Ac.) | Status |
|---|---|---|---|---|
| Park County | Sand and Gravel pit | Renner | n/a | Active Pit |
| Park County | Sand and Gravel pit | Larsen May | n/a | Active Pit |
| Park County | Sand and Gravel pit | New YU Bench | n/a | Active Pit |
| Big Horn County | Sand and Gravel pit | Cody | n/a | Active Pit |

Source: NREX, 2017

Timber production also occurs in the western portions of the watershed most notably in an area near the Timber Creek/West Fork Timber Creek drainages, and in several stretches along and near the upper portions of the Wood River drainage. These production areas all lie within the Shoshone National Forest under the administration of the U.S. Forest Service. Figure 40 depicts the known timber production areas (NREX, 2017).

***Recreation***

There are many recreational opportunities for residents and visitors alike within and near the watershed. These range from hunting, boating, fishing, camping, hiking, all-terrain vehicle (ATV) use in back-country areas and year-round sight-seeing of the area's many natural wonders. Though there are no national or state parks located within the watershed, there is one notable national park nearby. Highway 14/16 runs west from Greybull through the watershed and is eventually one of the main traffic connectors to the east entrance of Yellowstone National Park. This entrance is located 117 miles west of Greybull.

Hunting by residents and non-residents alike occurs throughout the watershed for big game animals, trophy game animals, small game animals, upland game birds and waterfowl. The big game includes antelope, deer, elk, moose and bighorn sheep. Trophy game in the watershed includes black bear, grey wolf and mountain lion. Small game hunters stalk rabbits, fox and squirrels. According to the WGFD, upland game birds can include grouse, partridge, pheasant, ptarmigan, quail, wild turkey and some migratory birds (WGFD, 2017b).

### 2.3.2 Land Management

Because a majority of the land within the watershed is federally owned (over 63 percent), land management is a very important issue regarding grazing, recreation, cultural resources, easements and environmental protection. Complicating the issue is the rural nature of the watershed's culture and its inherent connections to ranching, agriculture, hunting, and fishing among other recreational and even industrial concerns. This section focuses on the management of the land and the agencies authorized to conduct such actions.

#### 2.3.2.1 Grazing

To regulate the use of public lands for grazing, plus limit the use of a specific geographic area or grazing allotment, the U.S. Congress passed the Taylor Grazing Act of 1934. As a result, ranchers were allowed a specific number of livestock for a specific season of use. Subsequent surveys by the federal government led to the construction of allotment boundary fences, the development of a number of off-site water projects aimed at improving livestock distribution, and also led to the reduction of the number of grazing permits (SE, 2017). Such lands within the watershed study area include those managed by both the BLM and USFS. Table 16 provides requirements and process comparisons between those two federal agencies.

### *BLM Administered Land Within Wyoming*

One of the many BLM objectives is to authorize and manage livestock grazing on the land it administers under the principles of multiple use and sustained yield. The Wyoming BLM State Director is responsible for the guidelines and standards necessary to ensure healthy rangelands and livestock grazing management on approximately 17 million acres within Wyoming (BLM, 2018a). Such guidelines and standards are in place to achieve the four fundamentals of healthy rangeland and include:

- Properly functioning watersheds;
- The proper cycling of water, nutrients and energy;
- The water quality meets the state's standards; and
- The protection of the habitat for special status species.

Within Wyoming, the BLM has established six standards to ensure healthy rangelands and livestock grazing management including (BLM, 2018b):

- **Standard 1:** Within the potential of the ecological site (soil type, landform, climate, and geology), soils are stable and allow for water infiltration to provide for optimal plant growth and minimal surface runoff;
- **Standard 2:** Riparian and wetland vegetation has structural, age, and species diversity characteristic of the stage of channel succession and is resilient and capable of recovering from natural and human disturbance in order to provide forage and cover, capture sediment, dissipate energy, and provide for groundwater recharge;
- **Standard 3:** Upland vegetation on each ecological site consists of plant communities appropriate to the site which are resilient, diverse, and able to recover from natural and human disturbance;
- **Standard 4:** Rangelands can sustain viable populations and a diversity of native plant and animal species appropriate to the habitat. Habitats that support or could support threatened, endangered, species of special concern, or sensitive species will be maintained or enhanced;
- **Standard 5:** Water quality meets State standards; and
- **Standard 6:** Air quality meets State standards.

The BLM accomplishes the implementation of its standards and guidelines by reviewing individual allotments based on the current allotment categorization and prioritization process. If an allotment's review meets each of the six standards listed above, then no further action is necessary. If all those standards are not met, then further review and rationale is necessary. In addition, if the review finds livestock grazing practices are not being met then corrective actions must be developed and implemented.

BLM's policy requires the agency to prioritize and direct resources to lands which provide the greatest potential for improvement and the public benefit. Accordingly, grazing leases are divided into three categories (SE, 2017):

- **Maintain:** this includes large blocks of public lands where resources are typically near or at the desired condition;
- **Improve:** this includes large blocks of public lands where resources are far below the desired condition and current management is insufficient to meet resource objectives; and
- **Custodial:** this includes small, isolated parcels of land where resources are near the desired condition; typically, these include lease renewals, billings and transfers.

### *BLM Land Within the Watershed*

The Greybull River watershed study area supports all or portions of 103 grazing allotments on BLM administered land totaling over 537,000 acres. Table 17 and Figure 41 depict these allotments. Often these allotments are adjacent to or encompass private land where they serve as summer and early fall ranges for those adjacent ranches. Allotments range in size from over 32,000 acres for the Pitchfork allotment to less than four acres for the Allen Basin allotment.

### *USFS Administered Land Within Wyoming*

The U.S. Forest Service has supported controlled livestock grazing since the early days of the agency. By definition, USFS permitted grazing is the use of rangeland resources by livestock. Grazing permittees are individuals or organizations such as Grazing Associations who have acquired the privilege to graze livestock on National Forest or National Grasslands. Currently, the USFS objectives for the range management program are (USFS, 2018):

- To manage range vegetation to protect basic soil and water resources, provide for ecological diversity, improve or maintain environmental quality, and meet public needs for interrelated resource uses.
- To integrate management of range vegetation with other resource programs to achieve multiple use objectives contained in Forest land and resource management plans.
- To provide for livestock forage, wildlife food and habitat, outdoor recreation, and other resource values dependent on range vegetation.
- To contribute to the economic and social well-being of people by providing opportunities for economic diversity and by promoting stability for communities that depends on range resources for their livelihood.
- To provide expertise on range ecology, botany, and management of grazing animals.

### *USFS Land Within the Watershed Study Area*

The Greybull River watershed study area supports all or portions of 24 grazing allotments on USFS administered land totaling nearly 159,000 acres all within the Shoshone National Forest. Table 18 and Figure 41 depict these allotments. Similar to BLM allotments, these are often adjacent to or encompass private land where they serve as summer and early fall ranges for those adjacent ranches. These allotments range in

size from over 36,000 acres for the Greybull allotment to less than one acre for three separate allotments including the Washakie Needles, Community and Nine Mile allotments.

### *Prescribed Grazing*

Regarding grazing practices on federal, state or private land within the watershed study area, the USDA Natural Resources Conservation Service (NRCS) defines prescribed grazing in its Code 528 as "*managing the harvest of vegetation with grazing and/or browsing animals"* (USDA, 2012). This grazing practice is applied as part of a conservation land management system whose guidelines include:

- Improve or maintain desired species composition and vigor of plant communities.
- Improve or maintain quantity and quality of forage for grazing and browsing animals' health and productivity.
- Improve or maintain surface and/or subsurface water quality and quantity.
- Improve or maintain riparian and watershed function.
- Reduce accelerated soil erosion and maintain or improve soil condition.
- Improve or maintain the quantity and quality of food and/or cover available for wildlife.
- Manage fine fuel loads to achieve desired conditions.

These conservation practices can enhance grazing distribution and even optimize range conditions. Typically, such practices are used in coordination with a variety of BMPs such as prescribed fire, application of chemicals, salting and herding, fencing, plus water storage and water quality improvements.

On federal lands within the watershed study area, either the managing agency or the Wyoming NRCS assists the producer with the development of the preferred grazing plan. If the federal agency develops the plan, then the agency's specific guidelines plus Code 528 are both utilized. If the NRCS develops the plan, then the appropriate federal agency needs to review and approve that particular plan. In addition, according to the Wyoming state NRCS office, Wyoming provides payment for grazing on federal land (WYNRCS, 2018).

Within the watershed area, the NRCS office in Greybull is responsible for land in Big Horn County while the Powell NRCS office is responsible for the land in Park County. On private lands within the watershed, once a landowner enrolls into a contract with the NRCS, the NRCS will then assist the producer by developing a grazing plan which utilizes those same Code 528 standards. The landowner then assumes the responsibility to carry out the grazing plan accordingly. If a landowner does not adhere to a contracted grazing plan, then the landowner is subject to repayment of any funding that may have been given to them through the entire contract.

### *NRCS Network Effects Diagrams*

To achieve the desired purposes of conservation practices, the NRCS prepares Network Effects Diagrams (NEDs) or BMPs (conservation practices). These NEDs are essentially 'flow charts' of direct, indirect and cumulative effects resulting from BMPs. The result of NEDs is the depiction of the potential positive and negative outcomes of practice installation. They present a useful reference point for the next step of

conservation practice, plus serve as a communication tool with NRCS partners and the public at large (NRCS, 2018d). Figure 42 (NRCS, 2018e) depicts the flow chart for prescribed grazing utilized by the NRCS. The chart shows some of the direct and indirect benefits associated with prescribed grazing including:

- Direct Effects:
    - Increased control of livestock grazing, feeding and watering locations;
    - Increased manure distribution;
    - Decreased soil erosion and compaction;
    - Decreased equipment time and labor; and
    - Increased plant productivity and maintenance;
- Indirect Effects:
    - Increased soil quality;
    - Decreased amounts of contaminants, pathogens, sediments to receiving waters;
    - Increased livestock production and health;
    - Increased recreational opportunities; and
    - Decreased amounts of greenhouse gases and particulates.

#### 2.3.2.2 Ecological Sites

An important entity within federally-managed lands are areas referred to as ecological sites. The BLM defines such sites as *"an area of land with specific physical characteristics that differs from other areas both in its ability to produce distinctive kinds and amounts of vegetation and in its response to management"* (BLM, 2018b). The NRCS definition of an ecological site is *"a distinctive kind of land with specific characteristics that differs from other kinds of land in its ability to produce a distinctive kind and amount of vegetation".*

According to the Interagency Ecological Site Handbook for Rangelands, an ecological site is a conceptual division of the landscape that is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances.

This handbook provides a standardized method to be utilized by the BLM, USFS, and NRCS to define, delineate, and describe terrestrial ecological sites on rangelands (BLM, 2013). This includes the implementation of the standards and guidelines regarding grazing allotments administered by those agencies. Ecological Sites provide a consistent framework for classifying and describing rangeland, and forestland soils and vegetation; thereby delineating land units that share similar capabilities to respond to management activities or disturbance. Prescribed grazing plans take these ecological site descriptions into account during the plan's development whether on federal or private land.

Ecological Site Descriptions (ESDs) are reports that provide detailed information about a particular kind of land - a distinctive Ecological Site. ESDs provide land managers the information needed for evaluating the land as to suitability for various land-uses, capability to respond to different management activities or disturbance processes, and ability to sustain productivity over the long term. ESD information is presented in four major sections including (NRCS, 2018c):

- Site Characteristics - physiographic, climate, soil, and water features;
- Plant Communities – plant species, vegetation states, and ecological dynamics;
- Site Interpretations – management alternatives for the site and its related resources;
- Supporting Information – relevant literature, information and data sources

***Ecological Sites Within the Watershed Study Area***

Within the watershed any ecological site enhancement modifies the area to improve and/or increase the area's habitat for both animals and plants while at the same time with the protection of human health and the surrounding environment. There are a number of ways to accomplish such enhancements including:

- The restoration and/or protection of wetland/riparian areas;
- The control of invasive species (both plant and animal);
- Maintaining native vegetation;
- Planting native vegetation;
- The improvement of soil quality; and
- The stabilization of erosive soils.

The benefits of such enhancement practices can include:

- Enhanced fish and wildlife habitat;
- Potential flood attenuation;
- Potential groundwater recharge;
- Streambank and/or shoreline stabilization;
- Water quality improvement;
- Plan diversity; and
- Improved soil health.

As seen on Figures 43 and 44, each county within the watershed has a vast array of ecological site descriptions. The figures depict nearly 50 ecological category descriptions located within the watershed study area. As noted earlier, prescribed grazing plans take these ecological site descriptions into account during the plan's development whether on federal, state or private land.

#### 2.3.2.3 Easements

Whenever access across the lands of others is necessary, then easements, rights-of-way (ROW) or special-use permits will be required. This is the case whether the land is owned by the federal government, state, county, or is privately held. Some easements or ROW may be temporary in nature such as a haul road required for construction. Others could be permanent which is often the case on private lands.

Within both Park and Big Horn counties, the scope of the project would determine the required ROW or permits from those counties. For example, a ROW and/or permit may not be required if access is temporary in nature and ground disturbance isn't anticipated. The county may simply need to be notified of all the temporary activity to be performed. However, county ROW and/or a permit would be required if there will be permanent construction of roads, installation of utilities, work done in a flood plain, etc.

The Wyoming Board of Land Commissioners (WBLC) regulates activities on state-owned lands including the granting of ROW. Wyoming Title 36-10-105 allows the WBLC to grant ROW "for public utility facilities constructed by and under the authority of the United States" over all lands owned by the state.

Federally owned land may include the need for a special use permit from the USFS or the ROW from the BLM. For example, the GVID has a lease with BLM for the Roach Gulch Reservoir and the upstream face of the Greybull Dam. Any potential water project in the area may require a modification of the lease regarding any easement or ROW concerns (AECOM, 2014).

Regarding access to land within the Dry Creek watershed, it should be noted the Bench Canal Company which manages the Bench Canal irrigation system does not have easements described by metes and bounds. The end result is the ROW exists where the widths and extents are determined by what's necessary for ditch maintenance (SCE, 2016).

***Conservation Easements***

There are known conservation easements within the Greybull River watershed study area as depicted on Figure 45 and Table 19. The table depicts the acreage breakdown within the watershed and shows the Nature Conservancy is by far the largest easement holder with over 15,000 acres or approximately 85% of all the watershed's conservation easements.

Such easements can be voluntarily donated or sold by the landowner. These conservation easements are a legal restriction placed on a piece of property in order to protect its associated resources. It is a binding agreement which limits certain types of uses or can prevent development from taking place on the land while the land remains in private hands. Essentially, the easement protects the land for future generations. Some easements enable the landowner to qualify for tax benefits in compliance with Internal Revenue Service rules (NC, 2018).

**Table 19: Conservation Easements within the Greybull River Watershed Area**

| Easement Holder | Sum Acres |
|---|---|
| NRCS | 27.7 |
| The Nature Conservancy | 15,436.6 |
| Wyoming Stockgrower's Agricultural Land Trust | 2,735.7 |
| **Total:** | 18,200.0 |

The USDA's National Resource Conservation Service (NRCS) offers at least two programs which provide financial and/or technical assistance regarding easements and their associated conservation efforts. Both programs are utilized by various landowners within the watershed.

*Agricultural Conservation Easement Program (ACEP)*

The NRCS can provide financial and technical assistance to help conserve agricultural lands and wetlands through its ACEP. This program can assist American Indian tribes, state and local governments, and non-governmental organizations protect both working agricultural lands and also limit the uses of non-agricultural lands (NRCS, 2018). Some of those improvements as the result of easements include:

- Curb carbon losses and possibly increase carbon sequestration, especially on highly erodible cropland;
- Reduce soil erosion;
- Improve soil quality, thus contributing to high water infiltration rates and less runoff; and
- Increase plant and animal diversity.
- Improve water quality.

The ACEP includes a 'Wetlands Reserve Easements' component which helps restore, protect and even enhance enrolled wetlands (NRCS, 2018a). Some of those wetlands improvements include:

- More habitat for fish and wildlife that includes threatened and endangered species;
- Higher water quality due to the wetland's filtering of sediments and chemicals;
- Less flooding from wetlands acting as small reservoirs catching runoff water from farm fields;
- Higher groundwater recharge rates in nearby shallow aquifers;
- More biological diversity within the wetland and nearby areas;
- New educational, scientific and recreational activities for local schools and recreationists such as birders and hikers; and
- Ecologically important open space protected for several decades or more (NRCS, 2018a).

*Healthy Forests Reserve Program (HFRP)*

This program assists private landowners to restore, enhance and protect forested land through easements and financial aid. These conservation efforts help:

- The recovery of endangered and threatened species under the Endangered Species Act;
- Improve plant and animal biodiversity; and
- Enhance carbon sequestration (NRCS, 2018b).

### *Cultural Resources in Greybull Watershed*

According to the National Preservation Institute, the term "cultural resource" is not defined in the National Environmental Protection Act (NEPA) or any other Federal law (NPI, 2017). However, there are several laws and executive orders that deal with the kinds of resources that are cultural in character including:

- *NEPA, and the Council on Environmental Quality regulations*, require that agencies consider the effects of their actions on all aspects of the **"human environment."** Humans relate to their environment through their culture, so the cultural aspects of the environment — for example, cultural uses of the natural environment, the built environment, and human social institutions —must be considered in NEPA analyses;
- *National Historic Preservation Act (NHPA)* sets forth government policy and procedures regarding "historic properties" — that is, districts, sites, buildings, structures, and objects included in or eligible for the National Register of Historic Places. Section 106 of NHPA requires that Federal agencies consider the effects of their actions on such properties, following regulations issued by the Advisory Council on Historic Preservation (36 CFR 800);
- *Native American Graves Protection and Repatriation Act (NAGPRA)* requires Federal agencies and federally assisted museums to return "Native American cultural items" to the Federally recognized Indian tribes or Native Hawaiian groups with which they are associated; and
- *The American Indian Religious Freedom Act (AIRFA)* states the U.S. Government will respect and protect the rights of Indian tribes to the free exercise of their traditional religions; the courts have interpreted this as requiring agencies to consider the effects of their actions on traditional religious practices.

According to the Environmental Protection Agency's (EPA) Cultural Resources Management manual, there are at least 30 different federal laws and 28 federal regulations, guidelines and Executive Orders containing provisions requiring the protection of cultural resources (EPA, 2013).

Any proposed project taking place on federal lands or which utilize federal funds or require federal permitting must be preceded by a cultural resource inventory and review in compliance with Section 106 of the NHPA, the Wyoming Antiquities Act of 1966 and the Wyoming Environmental Quality Act of 1973 (SHPO, 2017). There are three classes of cultural resource inventories including (BLM, 2004):

- Class I - existing information inventory: a study of published and unpublished documents, records, files, registers, and other sources, resulting in analysis and synthesis of all reasonably available data.

Class I inventories encompass prehistoric, historic, and ethnological/sociological elements, and are in large part chronicles of past land uses. They may have major relevance to current land use decisions;

- Class II - probabilistic field survey: a statistically based sample survey designed to help characterize the probable density, diversity, and distribution of archaeological properties in a large area by interpreting the results of surveying limited and discontinuous portions of the target area; and
- Class III - intensive field survey: a continuous, intensive survey of an entire target area, aimed at locating and recording all archaeological properties that have surface indications, by walking close-interval parallel transects until the area has been thoroughly examined. Class III methods vary geographically, conforming to the prevailing standards for the region involved.

#### 2.3.2.4 Cultural Resources within the Greybull River Watershed Study Area

The National Park Service (NPS) maintains the official list of the national Register of Historic Places. Locally, this register is administered by the Wyoming State Historical Preservation Office (SHPO) located in Cheyenne. This registry is part of a national program which coordinates and supports the public and private efforts to identify, evaluate and protect America's historic and archeological resources.

This study scope of work did not require a cultural resource survey but requested the identification of any cultural resources which may exist within the study area. Within the watershed, there have been over 78,000 acres inventoried for cultural resources. To date, nearly 2,400 cultural resource sites have been recorded within the watershed's boundaries and more than 600 of those sites are known to be eligible for the National Register of Historic Sites (SHPO, 2017). Figure 46 shows the results of the inventoried areas based on the density of sites eligible for the National Register.

***Historic Sites Within the Watershed***

According to the NPS website, there are at least five listings on the Register of Historic Places located within the watershed as described below (SHPO, 2017) and depicted in Figure 46 and Table 20. A brief description of each site is provided below.

**Table 20: Historic Sites within Greybull River Watershed**

| NPS Ref # | Historic Name | Other Known Name(s) | NPS Listing Date | Location | Owner |
|---|---|---|---|---|---|
| 75001900 | Bridger Immigrant Road at the Dry Creek Crossing | n/a | 1/17/1975 | Appx. 29 miles west of Greybull on Hwy 14 | State |
| 87000780 | US Post Office—Greybull Main | n/a | 5/22/1987 | 401 Greybull Ave., in Greybull | Federal |
| 87001548 | Anderson Lodge | n/a | 9/14/1987 | Greybull Ranger District, Shoshone National Forest near Meeteetse | Federal |
| 90001388 | First National Bank of Meeteetse | Bank Museum; Old Bank Building | 9/5/1990 | 1033 Park Ave., in Meeteetse | Local |
| 09001110 | Carey Block | Hurst Block; First State Bank; Greybull Hotel | 12/18/2009 | 602 Greybull Ave., in Greybull | Private |

NPS, 2017a

The Bridger Immigrant Road at the Dry Creek Crossing

This 425-mile long road originated near Casper and was established by Jim Bridger in 1864 to reach the gold fields of western Montana. The wagon road was formed primarily by the shod hoofs of oxen, mule or horse teams and imprinted by the iron-banded wheels of the heavily-loaded wagons (SHPO, 2017). The Dry Creek crossing is located approximately 29 miles west of Greybull on Hwy 14. It was listed on the national Register in 1975 (#75001900).

**Image 20: The Bridger Immigrant Road at the Dry Creek Crossing**

*Photo courtesy of Wayne Cummings*

The Main U.S. Post Office in Greybull

This post office is located in the heart of Greybull and is one of 12 Wyoming post offices designated as a historic site. The building represents a continuum of federally constructed post offices allocated to the state between 1900-1941. The small, single-purpose Greybull post office began occupancy in 1939. It was listed on the national Register in 1987 (#87000780).

Each of those 12 post offices exhibited a variety of styles and sizes yet maintained a common demeanor representative of the federal presence. These variations often reflected the economic, political and governmental context of each community. The Greybull post office is considered exceptional in the category of arts due to its New Deal art murals on its walls (SHPO, 2017). Today, the 79-year-old building continues to serve as the area's main post office.

**Image 21: The Main U.S. Post Office in Greybull**

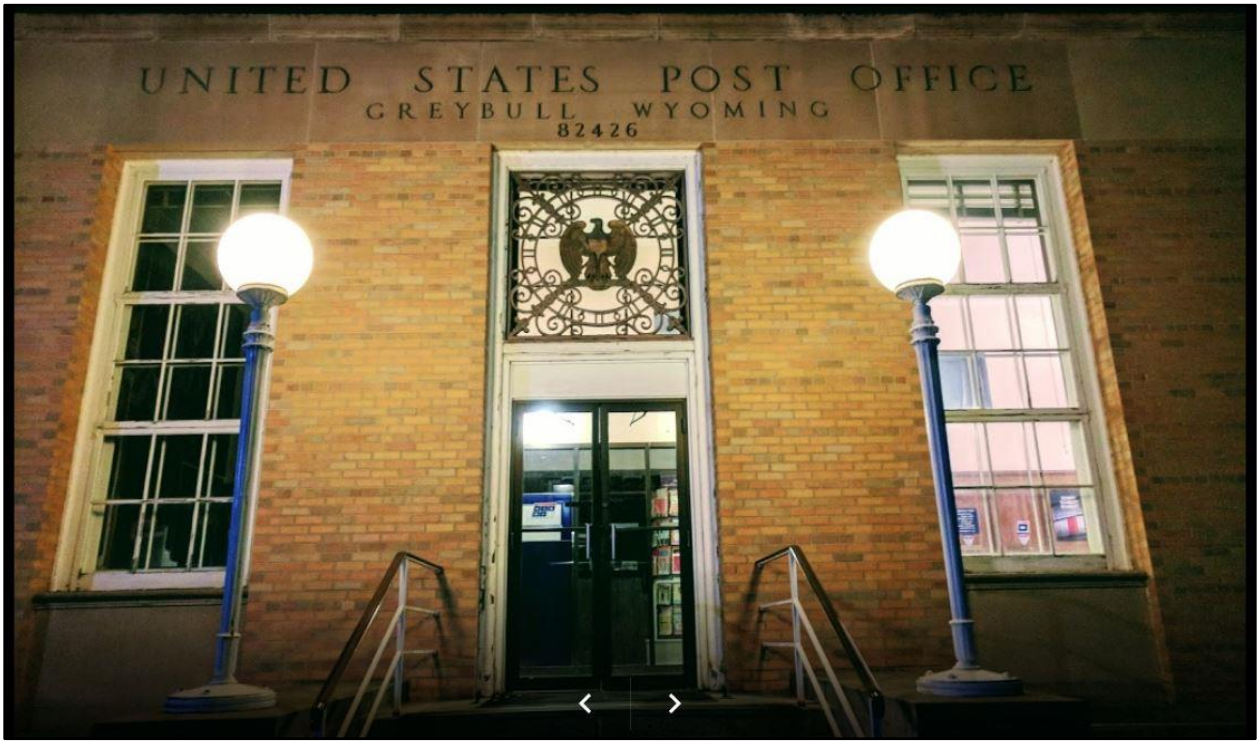



*Photo courtesy of Emily Young (United States Postal Service)*

The Anderson Lodge

This site is located approximately 29 miles west of Meeteetse within the Greybull Ranger District in the Shoshone National Forest. The site consists of a 2-story, multi-room log cabin lodge, plus a single-room log cabin, an outhouse, two small log foot bridges leading to the outhouse, a developed spring and a pole corral which is attached to the lodge. The site is considered important due to its association with the national conservation movement in the late 1800s and ensuing development of the U.S. Forest Service. The lodge was built in 1890 and used as an artist's studio including A.A. Anderson who was an artist and rancher in the

area. Anderson was instrumental in the development and management of the first national Forest Reserves from 1901-1906 (SHPO, 2017). Specifically, in 1902 President Theodore Roosevelt appointed Anderson as Special Superintendent of the Yellowstone Forest Reserve which later became known as the Shoshone National Forest (OWSA, 2017). The lodge was listed on the national Register in 1987 (#87001548).

**Image 22: The Anderson Lodge**

*Photo courtesy of Wyoming State Historical Preservation Office*

The First National Bank of Meeteetse

Built in 1901, this 2-story building is considered the cornerstone of Meeteetse's early downtown commercial district. This development led to Meeteetse becoming a leading center of trade and commerce within the Bighorn Basin. The originator was the banking firm of Hogg, Cheeseman, McDonald and Company Bankers whose investments solidified the town's hold on the local and regional commercial market (SHPO, 2017). Today it remains a focal point for the community serving as a museum filled with artifacts which help tell the story of the bank, its founders and employees. It was listed on the national Register in 1990 (#90001388).

**Image 23: The First National Bank of Meeteetse**

*Photo courtesy of Beau Johnston*

The Carey Block in Greybull

The Carey Block occupies the NW corner of the intersection of Greybull Avenue and N. Sixth Street. The original 2-story portion of the Block is a concrete reinforced building with brick-clad piers built in 1916. This structure represents the transformation of downtown Greybull at the beginning of the major oil boom in the Bighorn Basin. A single-story wing was added in 1933 which housed an auto dealership (SHPO, 2017). It was listed on the national Register in 2009 (#09001110).

**Image 24: The Carey Block in Greybull**

*Photo courtesy of U.S. National Park Service/Wyoming State Archives (Kennedy Neg. 129)*

### *Historic/Scenic Trails Within the Watershed*

The Bridger Trail is the lone historic trail within the watershed. As noted earlier, the Bridger Immigrant Road was established by Jim Bridger in 1864 for easier access to the gold and silver fields of southwestern Montana. This road basically followed the original Bridger Trail as shown on Figure 46.

The trail enters the southeast side of the watershed boundary approximately two miles due west of the town of Basin. It meanders for nearly 27 miles in a northwest direction before exiting approximately eight miles northwest of the town of Burlington. The trail's crossings include one of the watershed's Historic Sites at the Bridger Immigrant Road Dry Creek Crossing.

The trail as a whole is not listed in the National Register of Historic Places though two segments of the trail located outside the watershed boundary are listed as Historic Sites. One segment is located in Hot Springs County northwest of the town of Lysite and southeast of Thermopolis. The other segment is in Fremont County north of Lysite (SHPO, 2017).

The location of the trail was no accident. Bridger purposely built the trail on the west side of the Bighorn Mountains to provide a safer and quicker route to the gold fields as opposed to the Bozeman Trail located on the east side of the Bighorns. Bridger's trail was used by the prospectors and miners as a way to escape any interaction with the Plains Indians often found along the Bozeman Trail. Many historians consider the trail as the genesis of western transportation routes and helped foster early settlement in the area which to this point existed without a system of roads (SHPO, 2017).

**Image 25: The Bridger Trail**

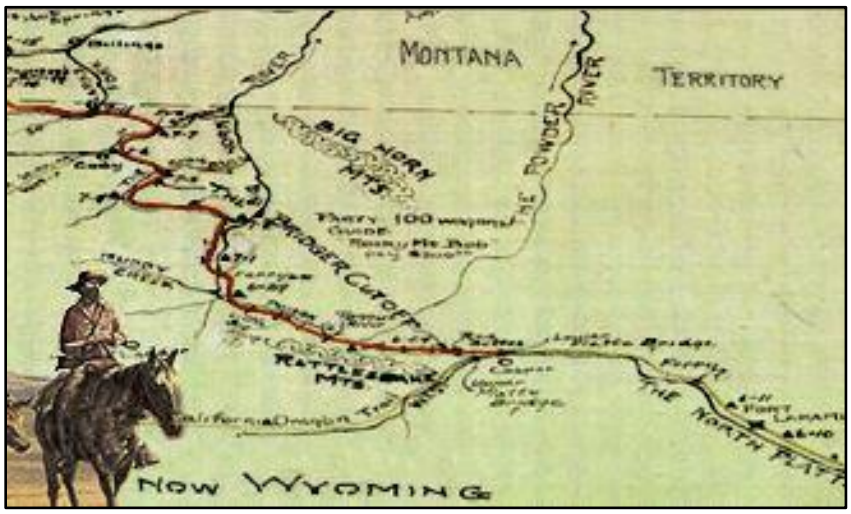



*Photo courtesy of Wyoming State Historical Preservation Office*

### 2.3.3 Agricultural Water Use

The total irrigated acreage serviced by GVID is approximately 72,700 acres in both Park and Big Horn Counties (see Figure 40). However, the watershed contains approximately 97,000 acres permitted for irrigation. The equates to over 24,000 acres permitted for irrigation which are not in operation. According to previous investigations, the watershed operates as a water-short system with an annual average shortage of 22,900 ac-ft. (AECOM, 2017) Should the watershed's permitted but non-irrigated land be brought into production, the watershed's already water-short status would be further compromised.

The primary agricultural production within the watershed varies from Big Horn County in the eastern portion to Park County in the west. In the lower elevations of Big Horn County, the major cash crops include sugar beets and malt barley though other crops such as alfalfa hay, beans, grass hay, alfalfa seed, feed barley, native grass and corn are also produced. The largest land user of the county, however, remains the livestock industry which raises primarily cattle and sheep (SBHCD, 2012). Within the higher elevations of Park County, livestock production prevails as the major industry though this production does include the irrigation of land for winter feed such as hay, alfalfa, grass and grain (MCD, 2017).

Within the watershed, the predominant agricultural water use is irrigation though some stock watering also exists. The dominant irrigation method continues to be flood irrigation although the center-pivot irrigation method is growing popularity and emerging as a viable alternative due to the ability to procure installation

funding through the Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP). This program provides financial incentives for the agricultural producer to make conservation work for them.

Much of the watershed, including a majority of the irrigated land, is defined as semi-arid. Such relatively dry land makes the allocation and storage of surface water resources a vital concern for the watershed's community as a whole and the agricultural community in particular. During the irrigation season the task of managing these resources falls to the State Engineer's Office (SEO), Greybull Valley Irrigation District (GVID) and local irrigation ditch riders.

The SEO administers the annual reports submitted by the state's divisional hydrographers and compiles an annual statewide Hydrographer's Report. The SEO has divided the state into four separate water divisions and each division is then divided into various districts. The Greybull River watershed is located within Division 3 and is comprised of Districts 8 and 16 (see Figures 47 and 48). Within the watershed, District 8 is, for the most part, the eastern half of the watershed study area while District 16 is the western half. Those reports include various hydrographic statistics including diversion amounts, reservoir capacities, etc. Further diversion and hydrographic discussion follow later in this section.

The GVID was organized as an irrigation district in 1920 and supplies stored water from three existing off-channel reservoirs which include the Upper Sunshine, the Lower Sunshine and the Roach Gulch reservoirs. The sole purpose of the GVID is the operation and maintenance of those three reservoirs plus their associated diversions and supply canals (SCE, 2011). When combined, the three reservoirs total approximately 144,955 ac-ft of storage capacity. Irrigation water is then distributed throughout the watershed to irrigated land served by 60 headgate structures (AECOM, 2017). The reservoirs are not managed to support river leveling efforts for flooding events.

The capacity of the three reservoirs is committed to the irrigation users within the watershed with the exception of a 5,000 ac-ft minimum pool in the Upper Sunshine which is reserved for a fishery. Though this pool can be used as a last resort, a restocking fee is required to be paid to the WGFD should the storage drop below the minimum. This 1996 agreement between GVID and WGFD states the fee will be paid by GVID should the storage drop below the minimum. This fish restocking fee amounts to $5,000 for each invasion of the minimum pool. Such invasions occurred in August 2001 and again in May 2002 (AECOM, 2017).

The watershed features a network of ditches and canals constructed and managed by various entities including Irrigation Districts and private owners. Water diversion structures and associated infrastructure convey water from the natural rivers and streams to cultivated lands and meadows throughout the area. Though flood irrigation is the predominant method of irrigation within the watershed, there is an increasing number of center pivots being installed.

Most of the water users are served by the combination of the Bench and Farmers Canals which were initially developed late in the 19th century. Irrigators using these systems consume approximately 75 percent of the storage water managed by the GVID. Combined, the Bench and Farmers Canal systems have water rights

of approximately 470 cubic feet per second (cfs). (Anderson, 2010) These irrigation entities are discussed in more detail later in this section.

#### 2.3.3.1 Surface Water Rights

Surface water rights play a pivotal role in the allocation of irrigation water. In Wyoming, as in most western states, water law is based on the 'doctrine of prior appropriation.' In other words, the first person to put the water to beneficial use has the first right. During periods of limited water supply, those with the first rights are entitled first. Those with latter rights may be denied water during such times when there are water shortages.

According the Wyoming SEO e-permit web site, there are nearly 1,100 surface water rights permits within the Greybull River watershed. Of those, 495 are permitted for various irrigation purposes. Table 21 depicts those permits.

**Table 21: Greybull River Watershed Irrigation Surface Water Rights**

| Water Right Status | Big Horn County | Park County | Total |
|---|---|---|---|
| Fully adjudicated | 197 | 202 | 399 |
| Complete | 27 | 25 | 52 |
| Partially adjudicated | 8 | 2 | 10 |
| Cancelled | 0 | 0 | 0 |
| No status given | 25 | 9 | 34 |
| **Total** | **257** | **238** | **495** |

Source: Wyoming SEO e-permit web site, 2018

#### 2.3.3.2 Irrigation Infrastructure

The watershed's surface water is the principal source for irrigation which includes 115 diversions associated with water rights in the Greybull River watershed. (see Figure 49). As noted in Sec. 2.1.6, nearly all (99 percent) of the irrigation features in both the Greybull River and Dry Creek watersheds are canals or ditches. This equates to 523 of the 526 total miles of canals, ditches, pipelines, etc. The highest concentration of canals/ditches is located around Burlington, Otto, and Emblem in the east-central portion of the watershed.

Within the watershed there are several operating irrigation entities including the Farmers Canal Company (FCC), the Bench Canal Company (BCC), and the owners/operators of the Keystone, Jimmerfield, Smith and Avent ditches. Each of these operations is located in the eastern half or lower-most portions of the watershed. The majority of other irrigation structures are privately owned and beyond the scope of work for inventory

Since 1982 there have been more than a dozen previous studies conducted for the WWDC for various irrigation-related aspects of the Greybull River watershed. Each these reports is publicly available on the WWDC website: http://library.wrds.uwyo.edu/wwdcrept/wwdcrept.html

Some of the more recent studies include:

- Greybull Valley Irrigation District Storage Enlargement, Level II, Phase I by AECOM, 2017; This study documented the development and screening evaluation of water storage alternatives for GVID. This included the evaluation of expansion of the three major storage reservoirs plus two new storage reservoir alternatives. The study concluded the best alternative was expansion of the Lower Sunshine Reservoir. Currently, AECOM is conducting the Level II, Phase II study for this project.
- Bench Canal Company Master Plan, Level I Study by Sage Civil Engineering, 2016; This study completed an inventory and assessment of the canal system including enhanced GIS work. The recommendations included the need to improve ROW, replace/update its infrastructure, pursue funding options and create a sinking fund to assure sustainability of the system.
- Greybull Valley Irrigation District Hydropower Level II Study by AECOM, 2014; This study evaluated the feasibility of developing hydropower at the outlet works of GVID's Upper Sunshine and Roach Gulch Reservoirs. The study recommended not to pursue hydropower development at the Upper Sunshine Reservoir. However, the study did state there is potential to pursue such efforts for the Roach Gulch facility.
- Keystone and Farmers Canal Master Plan, Level I Study by Sage Civil Engineering, 2011; This study inventoried and assessed the facilities owned by the Keystone, Jimmerfield, Smith, and Avent Canals, and the Farmers Canal Company and included GIS work on the various components of the systems. The recommendations included rehab of the Farmers/Bench Screen and Pearce Diversion plus cleaning the McKinney reservoir.
- Greybull Valley Rehabilitation and GIS Level II Study by Sage Civil Engineering, 2010; This study created a GIS base for GVID's system for potential future projects and/or commitments. It's summary stated the district's ongoing hydropower and rehabilitation projects were feasible to pursue.
- Greybull Valley Rehabilitation/Upper Sunshine Diversion Level II Study by Anderson Consulting Engineers, Inc., 2010; This study evaluated the rehabilitation/replacement needs associated with the existing diversion dam and headgate facilities. In 2012 the diversion dam and facilities were replaced at a cost of nearly $4M. The remaining canal entities were advised to form a single entity eligible for WWDC funding or enter into an agreement with GVID in order for GVID to become a sponsor for their projects.

## MAJOR DIVERSIONS IN THE WATERSHED

There are three major water storage diversions within the watershed. Each individual diversion feeds the three off-channel storage reservoirs mentioned earlier (Upper Sunshine, Lower Sunshine, and Roach Gulch reservoirs). Together these three reservoirs store the irrigation water managed by the GVID.

The three major diversions discussed below are monitored by the SEO. The average annual diversion amounts for the past five years for those major diversions are depicted in Table 22. Under normal conditions GVID typically supplies stored water from April until the second week of October which offsets shortfalls from live streamflow. GVID also uses the Roach Gulch Reservoir to smooth out diurnal fluctuations in river discharge in addition to allocating the reservoir's stored water (AECOM, 2017).

**Table 22: Average Annual Diversion Totals**

| Year | Major Diversion Canal Totals in Acre-Feet | | |
|---|---|---|---|
| | Upper Sunshine Canal (Upper Sunshine Reservoir) | Wood River Canal (Lower Sunshine Reservoir) | Lead Canal* (Roach Gulch Reservoir) |
| Water Year 2017 (Oct. 2016-Sept. 2017) | 32,500 | 28,400 | 114,000 |
| Water Year 2016 (Oct. 2015-Sept. 2016) | 26,400 | 14,000 | 140,000 |
| Water Year 2015 (Oct. 2014-Sept. 2015) | 12,500 | 12,700 | 120,000 |
| Water Year 2014 (Oct. 2013-Sept. 2014) | 73,100 | 38,700 | 116,000 |
| Water Year 2013 (Oct. 2012-Sept. 2013) | 14,800 | 16,600 | 87,600 |

Source: Wyoming SEO Annual Hydrographer's Reports (2013-2017) and the District 8 office personnel
* These figures include releases from the Upper and Lower Sunshine Reservoirs for storage in the Roach Gulch Reservoir

### *Upper Sunshine Diversion*

In 1939 the Greybull Valley/Upper Sunshine Diversion was constructed on the Greybull River in the western portion of the watershed (see Figure 49). This structure redirects water from the Greybull River into the Upper Sunshine Supply Ditch which outfalls into the Upper Sunshine Reservoir located approximately six miles downstream via Sunshine Creek. Approximately two miles downstream of the Upper Sunshine Reservoir the water feeds into the Lower Sunshine Reservoir via Sunshine Creek. Though reported to have a diversion capacity of 900 cubic feet per second (cfs), the design specifications indicate a capacity of 640 to 750 cfs at a depth of 6 to 6.5 feet. (Anderson, 2010) However, according to the GVID, this diversion was replaced in 2012 at a cost of nearly $4,000,000. Image 19 below was taken in June 2018 and depicts this new structure.

**Image 26: Upper Sunshine Diversion**

*Photo courtesy of Wayne Cummings*

### *Wood River Diversion*

In 1972 a second major diversion was constructed. But this particular diversion was constructed along the Wood River. This diversion redirects water into the Sunshine Basin Ditch and approximately 4.5 miles downstream the water outfalls into the Lower Sunshine Reservoir (see Figure 49). Each of these first two major diversions are located west of Meeteetse at elevations over 6,600 feet above sea level. Image 20 below was taken in June 2018.

**Image 27: Wood River Diversion**

*Photo courtesy of Wayne Cummings*

### *Sheets Flat Diversion*

The third major storage diversion is located approximately 21 miles downstream of the Lower Sunshine and along the Greybull River. This Sheets Flat Diversion redirects water into the Lead Canal and eventually outfalls into the Greybull Valley Reservoir commonly referred to as the Roach Gulch Reservoir (see Figure 49). Built in 1999, this diversion is located at an elevation of approximately 5,000 feet above sea level. Image 21 below was taken in June 2018.

**Image 28: Sheets Flat Diversion**

*Photos courtesy of Wayne Cummings*

### *Additional Major Diversion Structures*

In addition to the three major diversions discussed in the previous section, there are several other diversions which serve most of the irrigated acreage within the watershed. The largest of the remaining diversions is one on the Greybull River which services both the Farmers Canal Company and the Bench Canal Company (see Figure 49 – Irrigation Infrastructure). These two private companies serve many of the watershed's irrigators within the eastern portion of the watershed. These same two companies share the first mile of the diverted canal before another diversion reroutes the water into two separate canals for the two companies. From this second diversion the northward-flowing canal and lateral system serves the Bench Canal irrigators while the eastward-flowing canal and its lateral system serves the Farmers Canal irrigators.

Several miles upstream along the Greybull River from the above-mentioned diversion, are four more diversions serving the Keystone, Avent, Smith and Jimmerfield ditches. Each of these is individually privately owned.

#### 2.3.3.3 Irrigation Entities and Infrastructure

As noted earlier, there are 115 diversions within the Greybull River watershed study area. Many of those are small, private structures typically maintained by a lone owner. In addition to those structures, there are over 500 miles of irrigation laterals, canals and/or ditches most of which are in disrepair. Nearly all of those irrigation laterals, canals and/or ditches plus their associated infrastructure are privately held. Throughout the watershed, all these privately-held irrigation entities pose a problem for each irrigator with regard to funding for infrastructure improvement.

Within the watershed the consensus among the irrigation owners and stakeholders is the current condition of the watershed's irrigation infrastructure, for the most part, needs improvement. It's been well documented for decades through various studies and observations that nearly all those diversions, irrigating canals and laterals shown on Figure 49 are in need of upgrade and/or replacement. In order to receive WWDC funding for improvements, the irrigation entity involved must not be privately owned. This administrative 'roadblock' eliminates the privately-owned entities such as the Farmer Canal Company (FCC), Bench Canal Company (BCC) and the Keystone, Jimmerfiled, Smith and Avent Ditches from such funding.

According to WWDC Operating Criteria (Ch. 3), "The project sponsor shall be a public entity that can legally receive state funds…". This prevents the FCC or BCC from receiving state funds. Compounding the situation is the fact the FCC or BCC cannot form their own public irrigation district because both are already located within the boundary of another irrigation district, namely the GVID (SCE, 2016); the primary option for public entity formation is to create a watershed improvement district (WID). As such, the owners of these entities are responsible for the maintenance and operations of their particular system including the initial diversion structure on the Greybull River plus their respective supply canals and/or laterals.

The GVID, on the other hand, is eligible for WWDC funding for necessary rehabilitation improvements. Some of those improvement recommendations for structures throughout the watershed including the privately-owned structures have been on the books for decades.

##### *Farmers Canal Company (FCC)*

The FCC is privately owned and supplies irrigation water to the agricultural users along the Greybull River in the northeastern portion of the watershed (refer to Figure 49 for FCC managed infrastructure). It services approximately 24,000 acres.

Though the FCC users have direct-flow rights from the Greybull River, some water is stored in the three GVID reservoirs (SCE, 2016). Thus, the Greybull and Wood Rivers are used primarily as conveyances for GVID to transport stored water to various canals and ditches within the watershed including the Farmers Canal.

Beginning at a large diversion structure on the Greybull River approximately seven miles southwest of Burlington (see Figure 49), the early section of the canal is shared by the FCC with the Bench Canal Company (BCC) for approximately one mile. Both the FCC and BCC share operations and maintenance costs for this

initial portion of the canal including the diversion structure at the Greybull river. Approximately one mile downstream from the river diversion another large diversion structure splits the flow in two. From there, the flow eastward feeds the FCC users while the flow northward feeds the BCC users. From the second diversion, a series of laterals orient to the east to serve the FCC users. The operation totals approximately 65 miles of open ditch (SCE, 2011). This configuration means the BCC, FCC and GVID are heavily interconnected (SCE, 2016). On a typical day during irrigation season, the FCC users place their orders by phone by 8:00 am to the GVID secretary. Water request orders are adjusted daily.

A WWDC Irrigation Master Plan Study was completed for the FCC and Keystone Canal in 2011 and the following is a brief summary of the inventory and recommended improvements from this report (SCG, 2011). This particular project was unique because there were three sponsors including the GVID, the FCC and the four Keystone-portion entities. It should be noted, privately-owned entities can receive a waiver for Level I projects but cannot co-sponsor any projects beyond a Level I. This 2011 project was tasked to inventory the irrigation infrastructure of the sponsors and recommend rehabilitation options.

The subsequent 13-point plan for the Farmers Canal included the following improvements with the recommended year of completion. Cost estimates for each improvement are also provided in the 2011 report.

1. Farmers/Bench Canal Screen (2012); Install a screen to trap and remove debris from irrigation water. The screen conceptual design is 160-feet long and design for a flow of 650 cf. The estimated cost (in 2011 dollars) is approximately $791,700.
2. Pearce Diversion (2013); This diversion is in need of replacement to improve hydraulics and ease of operation. The stop logs are all different lengths making adjustments difficult. The estimated 2011 costs is approximately $187,561.90.
3. Bank Diversion (2013); The issues here are similar to the Pearce Diversion. Because both are main control structures they are key to the importance of the operations. The estimated 2011 costs is approximately $183,564.50.
4. McNiven Diversion (2014); Two gates are missing forcing the majority of the flow through two openings. Operation and functionality can be improved at a 2011 estimated cost of $183,564.50.
5. McKinney Reservoir Cleaning (2015); It was estimated that approximately 350,000 cubic yards of material must be removed from the reservoir at a cost between $1-$2/cubic yard or approximately $882,320.00.
6. McNiven Lateral (2017); This open lateral to pipeline conversion project was chosen with a 100-year design life. The eventual cost estimate did not include water gain realized by piping the laterals. The approximate cost is $97,304.73.
7. Town Lateral (2021); The is an open lateral to pipeline conversion. Approximate cost is $313,750.00.
8. Gould Lateral (2022); The is an open lateral to pipeline conversion. Approximate cost is $606,670.00.
9. JFW Lateral (2024); The is an open lateral to pipeline conversion. Approximate cost is $328,670.00.

10. Perkins Lateral (2026); The is an open lateral to pipeline conversion. Approximate cost is $1,530,700.00.
11. Bank-Bahr Lateral (2028); The is an open lateral to pipeline conversion. Approximate cost is $1,080,850.00.
12. Pearce Lateral (2031); The is an open lateral to pipeline conversion. Approximate cost is $1,257,400.00; and
13. Tucker Lateral (2034): The is an open lateral to pipeline conversion. Approximate cost is $209,600.00.

### *Bench Canal Company (BCC)*

The BCC supplies water to agricultural users located in the northern portion of the watershed on the Emblem Bench within the Dry Creek drainage basin (see Figure 49). Much like the FCC, the BCC is a privately-owned entity governed by a three-member board and services approximately 15,000 acres. This private ownership creates the same 'roadblock' as the FCC with regard to state funding for potential water projects. Like the FCC, the situation is compounded by the fact the BCC cannot form its own public irrigation district because it too is located within the boundary of the GVID. However, the BCC is currently pursuing development of a WID to empower themselves to apply for additional funding. Like the FCC, BCC users have direct-flow rights from the Greybull River and water storage is available in the three GVID reservoirs (SCE, 2016). During a typical day during irrigation season, the BCC users place their orders by phone by 8:00 am to the GVID secretary. Water request orders are adjusted daily.

From the diversion which splits the flow for the respective BCC and FCC users, the Bench Canal continues to the north and then east for approximately eight miles before it ends within the Dry Creek drainage. The Bench Canal carries water out of the Greybull watershed and irrigation runoff is then carried into the Dry Creek watershed. Although the water is carried across watershed, the discharge of the Greybull River and Dry Creek are both to the Bighorn River and the waters ultimately remain in the Bighorn Basin Watershed. A network of various laterals along the canal divides the Emblem Bench and diverts the water to the BCC users. This operation totals approximately 60 miles of pipelines and open, unlined channels. It should be noted, however, the pipelines only make up approximately 1.2 miles leaving over 58 miles of open channels.

The Bench Canal Company Master Plan, Level I Study conducted for the WWDC in 2016 focused on the inventory and assessment of the canal system (SCE, 2016). The work utilized GIS work to accomplish much of the tasks. With regard to the BCC infrastructure, of the 197 structures inventoried in 2016, 92 were recommended to be replaced or rehabilitated within 14 years. Some of the report's results included:

- The mapping of approximately 1,200 separate features;
- The mapping of approximately 60 miles of canals and laterals;
- Conditions of the structures were rated on a scale from 1 to 5 (5 being the worst);
- Open channels were rated on scales of 1 to 3 for breach risk and evidence of seepage;
- Visual inspections included excessive moss growth or other damage;

This report noted the BCC had completed a number of rehabilitation tasks but also noted those efforts were mostly the result of emergency repairs. And though some previous recommendations were completed, much of the system has maintained operation by simply pouring concrete over existing structures or using rock to stabilize channels and/or drops. After careful review, the report provided the BCC with the following Prioritization Plan including the recommendation of these projects and their schedules:

1) Bench Canal Lining Alternatives (2017-2018): The instability of the Bench Canal's bank at select locations posed the greatest risk to safety and continued operation of the system. The projected 2017 cost was $554,214.
2) North Lateral Structure S-NL-0050/Road 9 Crossing Reconstruction (2017-2018): This structure requires a narrowing of the road from 25 feet to 15 feet with substantial drop-offs into the lateral on either side. This is unsafe and has been the site of previous accidents. The projected cost for 2017 was $192,580.
3) Ramp Flume Modifications – Structure S-SL-0110 (2017-2018): The existing, non-functioning Montana Flume was slated to be replaced during the 2015-16 off season. This comes after the installation of a ramp flume five years earlier. The projected cost for 2017 was $192,580.
4) North Lateral Structure S-NL-0160 Reconstruction (2018-2019): This structure is unable to control the water and lacks functionality as delivery water cannot be prevented from spilling into the North Lateral Spill. Upgrading will reduce operations costs and seepage losses. The projected cost for 2018 was $159,944.
5) South Lateral Open Ditch-to-Pipe Conversion (2022-2028): Nearly all of BCC's 60 miles of water delivery system is open ditch. Delivery laterals compose 45 of those 60 miles and all have potential to convert to pipe. The South Lateral was chosen to be the first conversion because nearly half of the system's 137 control structures are located along this lateral. The 2022 estimated cost for conversion ranged from $6.1M to $7.2M.
6) Hi-Line Lateral Open Ditch-to-Pipe Conversion (2038-2045): Nearly all of BCC's 60 miles of water delivery system is open ditch. Delivery laterals compose 45 of those 60 miles and all have potential to convert to pipe. The Hi-Line Lateral was chosen next because it exhibited the poorest stability and contained the poorest (instable) soils. The 2038 estimated cost ranged from $10M to $10.7M.

**Bench Canal Rehabilitation Project, Level II, (NE, 1991)**

This Bench Canal study dates back to 1991 and described how "most of the canal facility is about 70 years old and almost half of the concrete structures are severely deteriorating". The study listed five rehabilitation projects which would be "critical" for the operation of the system. Those five include:

1. South Lateral Divider Structure;
2. North Lateral Divider Structure;
3. Dry Creek – "42" Laterals Divider/Wasteway Structure;
4. South-Highline Laterals Divider Structure; and
5. Mayland Drop Structure, South Lateral.

To date, several of these structures have been replaced though two of them (the Dry Creek and Mayland structures) do not appear to have been replaced (SCE, 2016).

***Keystone, Jimmerfield, Smith and Avent ditches***

A WWDC Irrigation Master Plan Study was completed for the FCC and Keystone Canal (SCG, 2011) in 2011 and the following is a brief summary of the inventory and recommended improvements from this report. This particular project was unique because there were three sponsors including the GVID, the FCC and the four Keystone-portion entities. It should be noted, privately-owned entities can receive a waiver for Level I projects but cannot co-sponsor any projects beyond a Level I. This 2011 project was tasked to inventory the irrigation infrastructure of the sponsors and recommend rehabilitation options.

The diversions for these four ditches are located upstream from the FCC/BCC diversion structure along an approximately five-mile section on the Greybull River. Each is privately owned, and each has its own diversion on the river (see Figure 49). Combined they service over 3,700 acres. The Keystone Ditch provides water for flood irrigation via pumps while the Jimmerfield and Smith ditches each provides flood irrigation via a gravity-flow system. The Avent Ditch supplies a large number of acres via a pump with a center pivot (SCE, 2011).

The recommendations for the four Keystone area ditches included the need to resolve the organizational challenges facing the four separate owners in order to allow progress beyond the Level I status. The report also provided analysis for the four ditches to combine their four separate diversions off the Greybull River into a single, cost-effective pipeline. No known movement has been made to date on these recommendations.

***Privately Owned Infrastructure***

Upstream from the private irrigation companies discussed previously are many more individual landowners who are not members of an irrigation company yet utilize irrigation on their land located mostly within the western portions of the watershed study area. Like their counterparts in the eastern portion of the watershed, these irrigators are not included in any public entity thus not eligible for public funding from the WWDC. Common maintenance activities such as headgate repair due to flooding and/or erosion, dredging for sediment/debris removal or controlled burning for vegetation removal can each be expensive and/or time-consuming activities. Should a landowner repair infrastructure within a ditch shared by another landowner, the onus of collecting repayment can be very difficult. These difficulties could be eliminated with the formation of a WID. This watershed improvement district would be a public entity and eligible for public funds to help pay for expensive and much-needed improvement and repair to the watershed's privately-held irrigation infrastructure.

### 2.3.4 Domestic, Municipal and Industrial Water

Potable water, also known as drinking water, is water that is safe to drink or use for food preparation without risk of health problems. For the purposes of this study, Public Water Systems (PWS) as designated by the Environmental Protection Agency (EPA) are the only potable water systems identified and described within this section. A PWS is an entity that provides water for human consumption through constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days a year.

#### 2.3.4.1 Public Water Systems

The entities within or near the watershed meeting one of these criteria are listed in Table 23 and include systems in the towns of Burlington, Meeteetse and Greybull. Figures 50 through 52 provide the locations of key infrastructure for the PWS listed below.

**Table 23 – Public Water Systems in Greybull River Watershed**

| Entity | PWS Number | Surface Water Source | System Capacity (gal/day) | Treatment Method |
|---|---|---|---|---|
| Burlington, Town of | WY5601098 | Two groundwater wells | 245,000 | Chlorination |
| Meeteetse, Town of | WY5600035 | Lower Sunshine Reservoir, Toe Drain | 576,000 | Microfiltration and chlorination (700,000 gal treated water storage capacity) |
| Greybull, Town of [1] | WY5600022 | Three groundwater wells | 1,500,000 | Chlorination (1,720,000 gal treated water storage capacity) |

[1] Greybull is located outside the Greybull River and Dry Creek HUC 10 boundary, but is near the confluence of both the Greybull River and Dry Creek with the Bighorn River. As a result the Greybull water distribution system is discussed in this study

***Town of Burlington***

The Town of Burlington PWS serves 332 people through 130 service connections within Burlington and 14 connections outside the Town. The water source is two groundwater wells drilled approximately 48 feet into the shallow alluvial aquifer in the upper Willwood Formation. The appropriation for each well is 85 gpm. The groundwater is chlorinated at the well house prior to conveyance to the two storage tanks in the system. Water is stored in two, 250-thousand-gallon (k-gal) tanks and then distributed to the system (Figure 50). The total treated water storage capacity is 400,000 gal with unknown peak day use or annual usage volume (WWDC, 2016). Water consumption per service connection is not metered although each well maintains a master meter to document total production to fulfill documentation requirements associated with the State Engineer's Office (WSEO, 2017).

***Town of Meeteetse***

The Town of Meeteetse potable water system serves 327 people through 230 service connections within the Town and 12 connections outside the Town. Historically, the Town obtained its water from an intake on the Wood River and Lower Sunshine Reservoir as raw water sources, but these two sources are inactive. Currently, the water source for the Town is an infiltration gallery at the toe of the Lower Sunshine Reservoir dam. A pump house near the dam provides hydraulic head necessary to convey water to the Meeteetse treatment plant. The raw water is treated by microfiltration and then chlorination prior to distribution to the system. The total treated water storage is 700,000 gallons. The golf course storage tank holds approximately 200 k-gal while the Meeteetse storage tank holds approximately 500 k-gal (Figure 51). The approximate peak

day use is 150,000 gal and the estimated yearly water use is 24 million gallons (MG) (WWDC, 2016). The system does not include individual meters on service connections.

In 2015, a Level I Master Plan Study was completed for the Town of Meeteetse (Gores, 2015). Recommendations from this study included:

To remain in sound operating condition, Meeteetse needs to make some updating to the system. These updating needs include:

1. Replacing obsolete and nonfunctional equipment in the water treatment plant,
2. Replacing the 40-year-old control system with a current day SCADA system that allows monitoring and control of the plant, both tanks, and the Antelope Hills pump station,
3. Resolving the confined space and control deficiencies in the vault at the main tank,
4. Security fence the 200,000-gallon tank and improve its access road,
5. Loop the water line to the WYDOT shop,
6. Loop some dead end lines and install two additional fire hydrants,
7. Eventually eliminate meter pits,
8. Replace the Highway 290 asbestos cement water transmission line when WYDOT next reconstructs this roadway, and
9. Modify the approach to the 500,000-gallon tank.

The study also recommended that with regard to addressing financial accounting of the system, it is recommended that and appropriate portion of the bonds and insurance cost associated with the water system be allocates to the water system expenditures, rather than having it as a general fund expense.

In Spring of 2017, high velocity flows in the Wood River caused riverbed erosion and scour that exposed an 80-foot length of 16-inch steel encasement pipe which houses an 8-inch PVC treated water transmission pipe associated with the Meeteetse water distribution system. The existing utility was trenched two feet into the river bed and then backfilled with flowable fill. The exposed casing and transmission pipe was susceptible to freezing during the 2017 to 2018 winter. The Town applied and obtained Federal Emergency Management Agency (FEMA) funding to resolve the issue. A design engineer and contractor implemented a temporary fix in 2017 to prevent pipe freeze and designed a permanent solution that involves horizontal boring ten feet below the riverbed within the existing utility easement between new valve vaults. The permanent solution will be implemented once the scope of work is approved by appropriate agencies and water levels in the Wood River allow such work to take place.

### *Town of Greybull*

Although outside the study area, the Town of Greybull water system is included in this section due to the proximity of the system to the confluence of both the Greybull River and Dry Creek with the Bighorn River. The Town of Greybull potable water system serves 3,200 people through 1,049 service connections within Greybull and 442 connections outside the Town. The water source is the Big Horn Regional (BHR) water system. The BHR water system delivers water to users throughout the Bighorn Basin and utilizes

groundwater as the source. The area surrounding Greybull is supplied by three wells drilled into the Madison Formation near Shell, WY. These wells are located up the Shell Valley to the east of Greybull and outside the watershed study area. The groundwater is chlorinated prior to distribution to the system. The total treated water storage capacity of the Greybull system is 1.72 MG through six tanks ranging in size from 10 k-gal to 1 million gallons (MG). The peak day use is 1.5 MG and annual usage volume of 217.8 MG (WWDC, 2018b). Water consumption per service connection is metered throughout the system (Figure 52).

#### 2.3.4.2 Groundwater Wells

Throughout the study area residents utilize groundwater as a potable water, irrigation and stock water source. These systems utilizing groundwater do not meet the qualifying criteria for a PWS and are often individual wells serving one landowner. There are 694 wells listed through the State Engineer's Office (SEO) e-Permit site with 380 wells within the study area categorized as Domestic (DOM) or Domestic/Stock (DOM/STK). In addition, 185 wells within the study area are categorized as Irrigation (IRR) or Stock (STK) (WSEO, 2017). Note that many of the wells overlap regarding designation as domestic and/or irrigation and stock use. The state defines domestic use of water as household use and watering of lawns and gardens for noncommercial family use where the area to be irrigated does not exceed one acre. The term 'stock' is defined as the normal watering of livestock. If feedlot operations are involved, the use should be designated as Miscellaneous. All well locations are depicted in Figure 53, while Figure 54 depicts potable wells (DOM or DOM/STK) and Figure 55 depicts non-potable wells (IRR or STK) and have a permit status of either completed, fully adjudicated or partially adjudicated.

The following series of tables depict information which was located on the SEO database and include:

- Groundwater well types;
- Groundwater well depths;
- Static water level depths in feet; and
- Groundwater well yields in gallons per minute.

**Table 24. SEO Permitted Well Types**

| Well Type | Quantity | Percentage |
|---|---|---|
| Domestic (DOM) | 217 | 31.3 |
| Stock (STK)* | 171 | 24.6 |
| Domestic/Stock (DOM;STK) | 163 | 23.5 |
| Miscellaneous (MIS) | 57 | 8.2 |
| Monitor Wells (MON) | 43 | 6.2 |
| Irrigation (IRR) ** | 14 | 2.0 |
| Industrial (IND)*** | 13 | 1.9 |
| Test Wells | 6 | 0.9 |
| Others | 10 | 1.4 |
| **Total** | **694** | **100** |

Source: Wyoming SEO, 2017
* Includes MIS/STK
**Includes IRR/MIS and IRR/STK
***Includes DOM/IND and IND/MIS

**Table 25: Groundwater Well Depths**

| Well Depth (ft.) | Quantity | Percentage |
|---|---|---|
| -1* | 28 | 4 |
| 0 to 50 | 401 | 57.8 |
| 50.1 to 100 | 101 | 14.6 |
| 101-200 | 100 | 14.4 |
| 201-300 | 27 | 3.9 |
| 301-400 | 18 | 2.6 |
| 401-600 | 9 | 1.3 |
| 601-815 | 9 | 1.3 |
| >816 | 1 | 0.1 |
| **Total** | **694** | |

Source: Wyoming SEO, 2017
*unknown or no data available

**Table 26: Groundwater Well Static Water Level Depths**

| Static Water Level (ft.) | Quantity | Percentage |
|---|---|---|
| 0 to 50 | 524 (75.5 %) | 75.5 |
| 51-100 | 51 (7.3%) | 7.3 |
| 101-200 | 33 (4.8%) | 4.8 |
| 201-300 | 14 (2%) | 2.0 |
| >300 | 3 (0.4%) | 0.4 |
| -1 to -7* | 69 (9.9%) | 9.9 |
| **Total** | **694** | |

Source: Wyoming SEO, 2017
*unknown or no data available

**Table 27: Groundwater Well Yield**

| Well Yield (gpm) | Quantity |
|---|---|
| 0 to 10 | 292 |
| 11-20 | 124 |
| 21-30 | 250 |
| 31-50 | 5 |
| 51-100 | 8 |
| 101-200 | 5 |
| 201-400 | 2 |
| 401-600 | 2 |
| 601-800 | 3 |
| 801-1000 | 1 |
| >1000 | 2 |
| **Total** | **694** |

Source: Wyoming SEO, 2017

In the summer of 2017, several landowners located near the Greybull River in the northwestern portion of the Town of Meeteetse experienced dry wells. As shown in Table 25, over 72 percent of the permitted wells are drilled to 100 feet or less. This indicates a majority of the watershed's permitted wells are completed in Quaternary or surficial formations near ground surface. Because these wells are typically less than 100 feet deep, those groundwater wells are likely influenced by river flow and irrigation uses. From conversations with

landowners, groundwater recharge observed during the events occurred very slowly. Issues of wells going dry have not historically been a problem in the area and last year was the first time that owners in the area have experienced this problem. It should also be noted that several of the land owners in the area have also observed a decrease in irrigation pond water volume where the ponds are naturally being filled by groundwater surfacing and recharged through groundwater. The issues of dry domestic wells and the observance of dry or reduced pond volumes highly indicate a groundwater recharge concern in the area.

#### 2.3.4.3 Industrial, Mining and Municipal-Industrial Water Use

In Wyoming, all water demands associated with industrial facilities, oil and gas production fields, mining operations and coal bed natural gas (CBNG) operations are all considered industrial water uses. This includes surface water in addition to groundwater usage. At the time of this report there were no CBNG operations within the Greybull River watershed. The state also defines "wastes" as sewage, industrial waste and all other liquid, gaseous, solid, radioactive, or other substances which may pollute any waters of the state (WDEQ, 2013). For these reasons, facilities must receive state surface water rights permits to use/store industrial water and/or sewage.

##### *2.3.4.3.1 Industrial Surface Water*

All water demands and withdrawals from surface water rights associated with industrial operations and facilities within the watershed are considered industrial surface water use.

***Industrial***

Within the Greybull River watershed there are four surface water rights permitted to supply industrial water use which are not directly associated with municipalities. Some of those permitted details include:

- Each permit is related to oil and gas operations in Park County;
- Three permits are storage reservoirs with a combined available capacity of 1.88 ac-ft. The source for one of those permits is Oil Patch Draw which is a tributary of the Oregon Coulee which in turn is a tributary of Dry Creek. Another is sourced from Cathodic Draw which is a tributary of Rawhide Creek which in turn is a tributary of the Greybull River. Finally, the third is sourced from the Short Fork of Meeteetse Creek which is a tributary of Meeteetse Creek which in turn is a tributary of the Greybull River; and
- The fourth permit is a diversion ditch with a headgate rate of 0.5 cfs and sourced directly from the Greybull River.

***Mining***

According to the SEO records, there are no surface water rights currently permitted for mining operations within the watershed.

### *Municipal/Industrial*

Municipal sewage operations are considered industrial because of the potential to pollute Wyoming waters. There are two surface water rights permits for sewage operations within the watershed. Both are for the towns of Burlington and Meeteetse. Those permit details include:

- The Burlington sewage lagoon is a three-cell facility totaling 10.10 ac-ft. It's located within the Beck-Allen Canal drainage which is a tributary of Farmer's Canal which in turn is a tributary of the Greybull River;
- The Meeteetse sewage lagoon is also a 3-cell facility totaling 55.85 ac-ft. It's located within the Rodeo Draw drainage which is a tributary of Mail Carrier Gulch which in turn is a tributary of the Greybull River.

#### *2.3.4.3.2 Industrial Groundwater*

Within the Greybull River watershed, the water usage from permitted wells which are associated with self-supplied industrial facilities and operations is considered groundwater usage. At the time of this report, there were 12 active groundwater wells permitted to supply industrial uses. Each is related to an oil and gas operation and are located in the vicinity of the oil and gas fields as shown on Figure 40. The permitted yields for those groundwater wells range from 350 to 7,262 gpm. However, those permitted rates are the maximum sustainable rate each well can be pumped and may not be indicative of actual water used though SEO records indicate one well did use over 61 million barrels of water in 2014.

### *Produced Water*

The Wyoming Pollutant Discharge Elimination System (WYPDES) program administers the National Pollutant Discharge Elimination System (NPDES) permit program which is under the auspices of the Environmental Protection Agency (EPA). Operators of any point source discharge are required to obtain a WYPDES discharge permit from the Wyoming Department of Environmental Quality (WDEQ). As defined by the WDEQ, a point source means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation or vessel or other floating craft, from which pollutants are or may be discharged (WDEQ, 2013).

One of the byproducts of oil and gas production is a produced water discharge. As defined by the WDEQ, "produced water means underground water which surfaces through oil and/or gas wells" (WDEQ, 2015). This water is comprised of water from the underground formation, the additional water injected into the underground formation for gas extraction, plus any chemicals added during the extraction and/or production processes. It is difficult to quantify water produced from the oil and gas production facilities; generally produced water increases as an oil field matures. Produced water created by production facilities tend to be a byproduct of or an obstacle to the extraction process. Often little attention is paid to quantities withdrawn (MWH, 2010). The Oregon Basin field currently is permitted to discharge 15,000 barrels per day (approximately one cfs) to Dry Creek. This is permitted through the WY Department of Environmental Quality Air division to control air quality related to hydrogen sulfur emissions. The volume of water discharged to the

creek is limited by the sulfide limits for air quality. Currently, private entities are looking to modify their treatment process to further reduce the sulfide and would allow additional waters to be discharged to Dry Creek. The current estimate by the private entity is that they would be able to increase discharge to Dry Creek from on tank battery location to 100,000 barrels per day (nearly 7 cfs). Overall, it is estimated after full development that the flow to Dry Creek could be from 350,000 to 500,000 barrels per day (22 to 33 cfs). In addition, the Pitchfork oil field by Meeteetse would increase from approximately 10 barrels per day to 100,000 barrels per day. The Spring Creek oil fields in the Carter mountains would also have an increase to 150,000 barrels per day which is discharged through a piped outfall near Meeteetse. If this technology is approved and implemented available water will increase in areas of the watershed with repeated water shortages.

Surface discharge is a method that is an economic driver for private entities rather than reinjection of produced water back into the aquifer which is expensive and creates concerns for groundwater degradation. The increase of water to Dry Creek would be considered a public benefit to both wildlife and agricultural use. This additional water would likely modify portions of the creek from ephemeral to perennial and create wetland and aquatic habitat opportunities. Specifically, several landowners have expressed interest in this and have supplied beneficial use letters to the State in support.

According to WDEQ, there are 21 active WYPDES effluent outfall permits within the Greybull River watershed which are summarized in Table 28 and depicted in Figure 56. Three permits are for the discharge from water treatment or sanitary wastewater facilities, one is for a Concentrated Animal Feeding Operation (CAFO), while the remaining 17 are for discharges from oil and gas operations. Four of the oil and gas operations are permitted for two effluent outfalls while the remaining 17 are permitted for a single outfall.

#### 2.3.4.4 Water Storage

Surface water storage in a water-short system such as the Greybull River watershed remains a critical issue for municipal, industrial, domestic and agricultural users. Within this watershed community is the need to address annual water shortages, seasonal storage fluctuations and the requirements necessary to benefit fisheries and wildlife habitat. Compounding these problems are the ever-increasing demands for water use, the aging irrigation infrastructure yielding irrigation inefficiencies, and the frequent periods of drought among other reasons. This section outlines the current water storage aspects of the watershed.

##### *2.3.4.4.1 Reservoirs*

According to the National Inventory of Dams (NID), the Greybull River watershed contains 20 reservoirs with a total maximum storage capacity of approximately 200,000 acre-feet (ac-ft), while the Dry Creek watershed contains six reservoirs with an approximate storage volume of 4,000 ac-ft (USACE, 2017). Seven of those reservoirs are off-channel impoundments including the Upper Sunshine Reservoir, the Lower Sunshine Reservoir, the Roach Gulch Reservoir, and the Bench, Harrington, Fairview and Wardell reservoirs.

Most of the Greybull River watershed storage is retained in Upper Sunshine Reservoir, the Lower Sunshine Reservoir and Roach Gulch Reservoir (AECOM, 2017). As noted earlier, these three reservoirs are off channel impoundments owned by the GVID and primarily provide irrigation water from April through the first weeks of October. However, the reservoirs provide secondary benefits to fish and wildlife, recreation and

limited flood attenuation. Table 29 depicts the capacity percentages of these three reservoirs since 2012 and illustrates the differences between the 'good' water years such as 2017 and water-short years such as 2013.

**Table 29: Major Reservoir Capacities by Year**

| Reservoir | 2012* | | 2013* | | 2014* | | 2015* | | 2016* | | 2017* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ac-Ft | % Capacity | Ac-Ft | % Capacity | Ac-Ft | % Capacity | Ac-Ft | % Capacity | Ac-Ft | % Capacity | Ac-Ft | % Capacity |
| Upper Sunshine | 13,065 | 24.7 | 9,462 | 17.9 | 46,547 | 86.9 | 38,013 | 71 | 28668 | 53.6 | 46,657 | 87.2 |
| Lower Sunshine | 7,294 | 12.4 | 5,129 | 8.7 | 48,519 | 86.1 | 36,715 | 65.1 | 35,547 | 63.1 | 47,637 | 84.5 |
| Roach Gulch | 0 | 0 | 5,464 | 16.5 | 17,493 | 53.4 | 9,027 | 27.6 | 8,814 | 26.9 | 21,009 | 64.2 |

Sources: Wyoming SEO Hydrographer's Reports 2012-2017
*As of Sept. 30

The Sage Creek impoundment is the largest reservoir in the Dry Creek watershed and is owned by Cody OAR Locks Ranch. It accounts for nearly 2,800 ac-ft of storage with the primary purpose being irrigation. The dam is briefly discussed later in this section.

Those 26 dams within the Greybull River and Dry Creek watersheds are listed in Table 30 with attributes such as owner, height, storage, associated river, watershed and hazard designation. The location of the dams within the two watersheds are shown on Figure 57 – National Inventory of Dams.

Reservoirs that do not fall under the jurisdiction of the Wyoming State Engineer's Office (WSEO) are not included in the database. The SEO criteria for jurisdiction includes any dam at least 20-feet high with a capacity to store at least 50 ac-ft of water. (WSEO, 2018a)

As depicted in Table 30, the three largest reservoirs within the watershed study area have all been given the state's designation of 'High Hazard' and are described further below. Those three reservoirs are given the designation 'High Hazard' because a failure of those dams would likely result in the loss of life. High Hazard dam owners are required to file Emergency Action Plans through the SEO Safety of Dams Division though all dam owners are highly encouraged to file such a plan (WSEO, 2018a). According to the SEO, those hazard designations include:

- High: failure would likely result in the loss of life;
- Significant: in the event of failure the loss of the dam is significant though the loss of life is unlikely;
- Low: failure would be the loss of the dam but not the loss of life.

### *Upper Sunshine Reservoir*

Upper Sunshine Reservoir is a homogenous earth dam (HEK) constructed in 1942 with the primary purpose of construction being irrigation water. Its source is the Greybull River. The dam is 160 feet high and 1,150 feet long. The storage is 65,100 ac-ft. according to the NID; however, the Greybull Valley Irrigation District Storage Enlargement – Level II Report (AECOM, 2017) indicates a maximum reservoir capacity of 53,520 ac-ft. As noted in Sec. 2.3.3, a minimum pool of 5,000 acre-foot is reserved as a fishery.

The reservoir consists of a submerged intake structure with controls for intake located at the dam crest, a concrete incased conduit, and a 60-inch steel outlet pipe structure. Water is diverted from the Greybull River at the beginning of the season and the reservoir is filled to full capacity. Once capacity is met, the diversion is closed. There have been several comments during this study about utilizing the reservoir for river leveling during flooding, but the operations of the Upper (and Lower) Reservoir is strictly for irrigation storage and the GVID do not operate for river leveling.

The SEO is the regulatory agency for the dam and conducts inspections of each dam every five years. The Upper Sunshine dam was last inspected on July 8, 2016. This latest SEO inspection report included the following:

- There are no cracks, slides, slumps, settlement or other on the crest upstream or downstream slopes;
- There is no upstream slope erosion from wave action;
- There are no flows of water or wet areas above the toe of the dam;
- There is no flowing water, sand boils or boggy areas at or below the toe of the dam;
- There is no released water undercutting the outlet or eroding the embankment;
- Conditions do not warrant an inspection by an engineer;
- There is no excessively cracked, spalled or displaced concrete; and
- There is no evidence the dam has been overtopped.

### *Lower Sunshine Reservoir*

Lower Sunshine Reservoir is a core earth dam (IEK) constructed in 1972 with benefits being hydroelectric potential, irrigation water storage, fish and wildlife and recreation. Its source is Sunshine Creek but it is also supplied by a diversion from the Wood River. The dam is 162 feet high and 1,660 feet long. The storage is 71,800 ac-ft. according to the NID; however, the Greybull Valley Irrigation District Storage Enlargement – Level II, Phase I Report (AECOM, 2017) indicates a maximum reservoir capacity of 56,380 ac-ft. The reservoir consists of a submerged intake, a concrete incased conduit, and a 60-inch steel outlet pipe structure. The intake controls are in a structure at the toe of the dam with the outlet controls.

The 2017 report by AECOM documented the water storage alternatives for the GVID. The study investigated several options of additional storage including enlargement of the three current GVID reservoirs plus the development of two new reservoirs. In its conclusion, the study verified the annual water shortage of the system was 22,900 ac-ft. It also concluded there is additional water available in the watershed and expansion of the Lower Sunshine Reservoir was the best alternative to accomplish additional storage.

In its 2017 study, AECOM confirmed the seepage through the dam foundation and abutments is very high which has been a historic concern of the SEO. There is potential for internal erosion or a piping mode of failure along the embankment / foundation contact on the right abutment (AECOM, 2017). Raising the dam to increase reservoir storage would likely require remediation of the right abutment wall including erection of a concrete cut-off wall and possibly grouting of voids. Investigations including drilling, sampling, and in-situ testing would need to take place to determine the extent of the required remediation effort (AECOM, 2017).

Currently, AECOM is conducting a subsequent Level II, Phase II study regarding expansion of the Lower Sunshine Reservoir. The project's final report is due to be released in the fall of 2019. This Phase II study is expanding on the results and recommendations of the Phase I work and includes among other objectives:

- Further geotechnical investigation to aid in refining project costs;
- Further investigations on the existing dam appurtenances;
- Refine the target storage volume for enlargement;
- Determine the permitting aspects for the enlargement project.

The SEO is the regulatory agency for the dam at the Lower Sunshine Reservoir. It was last inspected on July 8, 2016 and is inspected at least once every five years. The latest SEO inspection report included the following:

- There is brush on the crest/downstream slope which inhibits visual inspection of the entire surface;
- There are trees growing on the downstream slope of the embankment;
- There are no cracks, slides, slumps, settlement or other on the crest of the upstream/downstream slopes;
- There is no upstream slope erosion from wave action;
- There are no flows of water or wet areas above the toe of the dam;
- There is no flowing water, sand boils or boggy areas at or below the toe of the dam;
- There is no released water undercutting the outlet or eroding the embankment;
- Conditions do not warrant an inspection by an engineer;
- There is no excessively cracked, spalled or displaced concrete; and
- There is no evidence the dam has been overtopped.

### *Roach Gulch Reservoir*

Roach Gulch Reservoir is a core earth dam (IEK) constructed in 2000 with benefits being irrigation and recreation. Its source is the Greybull River via the Greybull Valley Diversion and Canal. The dam is 157 feet high and 1,798 feet long. The storage is 53,200 ac-ft. according to the NID website; however, the Greybull Valley Irrigation District Storage Enlargement – Level II Report (AECOM, 2017) indicates a maximum reservoir capacity of 33,170 ac-ft. The reservoir consists of a submerged intake, a concrete encased conduit, and a 60-inch steel outlet pipe structure. The intake controls are in a structure at the toe of the dam with the outlet controls.

The Roach Gulf Reservoir and dam site include a multitude of hydraulic and structural issues. The dam shows seepage along both the left and right abutment ranging in magnitude from two to ten gpm. The reservoir site also exhibits landslides and abutment movement. The extent of geotechnical problems at Roach

Gulch is such that AECOM, and their heritage company URS, have implemented inclinometers in the area to observe movement and document findings in annual reports (AECOM, 2017).

The SEO is the regulatory agency for the dam and it was last inspected on Aug. 14, 2014. It is inspected at least once every five years. The latest inspection report included the following:

- There are eroded gullies on the downstream slope;
- There are no cracks, slides, slumps, settlement or other on the crest of the upstream/downstream slopes;
- There is no upstream slope erosion from wave action;
- There are no flows of water or wet areas above the toe of the dam;
- There are boggy areas at or below the toe of the dam;
- The spillway channel exhibits no significant erosion, backcutting or deterioration;
- There is no released water undercutting the outlet or eroding the embankment;
- Conditions do not warrant an inspection by an engineer;
- There is no excessively cracked, spalled or displaced concrete; and
- There is no evidence the dam has been overtopped.

***Sage Creek Reservoir***

Similar to other Dry Creek watershed dams, the Sage Creek dam has a 'Low Hazard' ranking from the SEO. Sage Creek Reservoir is a homogeneous earth dam (HEK) constructed in 1982 with irrigation as its primary purpose. Its source is Sage Creek. The dam is 28 feet high and 1,400 feet long. The storage is 2,785 ac-ft. according to the NID website making it the largest of the Dry Creek reservoirs.

The SEO is the regulatory agency for the dam. It was last inspected on June 18, 2014. The latest inspection report included the following:

- There is brush on the crest/downstream slope which inhibits visual inspection of the entire surface;
- There are no cracks, slides, slumps, settlement or other on the crest of the upstream/downstream slopes;
- There is no upstream slope erosion from wave action;
- There are rodent holes on the upstream/downstream slope;
- There are no flows of water or wet areas above the toe of the dam;
- There are boggy areas at or below the toe of the dam;
- The outlet control/gate is missing;
- The spillway channel exhibits no significant erosion, backcutting or deterioration;

- There is no released water undercutting the outlet or eroding the embankment;
- Conditions do not warrant an inspection by an engineer;
- There is no excessively cracked, spalled or displaced concrete; and
- There is no evidence the dam has been overtopped.

#### *2.3.4.4.2 Upland Water Storage*

Upland water storage can provide increased benefit to the watershed community. This storage can affect seasonal water fluctuations which in turn can affect water quality, water availability, stream channel stability, flooding impacts, and the habitat for both the fisheries and terrestrial wildlife. In addition to the reservoirs described earlier, the upland water storage capabilities include but are not limited to springs, stock reservoirs, tanks, ponds and stock wells. It should be noted there are no natural lakes of significant size within the watershed.

Natural water features also provide sources for livestock and wildlife and are found throughout the watershed as depicted on Figure 7 while Figure 58 depicts the locations of permitted and/or developed water sources specific to irrigation and stock usage. As noted earlier, many of these SEO wells are utilized for irrigation and domestic uses. Still, whether seasonally or year-round, it is assumed many of the natural water features within the watershed remain viable water sources for both livestock and wildlife.

In addition to the reservoirs discussed in the previous section, there are numerous stock reservoirs and ponds located throughout the watershed. Many are utilized on a regular basis by both livestock and wildlife in the area while many others have essentially been abandoned due to a variety of circumstances. Each reservoir or pond's level of functionality is determined by various factors such as sediment build-up and often times erosion of the dam itself whether man-made or natural. In addition, many of the watershed's natural ponds can be determined by the availability of water whether from an intermittent or perennial stream and/or the season's rainfall or snowfall. Images 22 through 25 depict the various kinds of stock ponds and natural water storage features found throughout the watershed.

**Image 29: Perennial Stock Pond Located Four Miles SE of Lower Sunshine Reservoir**

***(observe the nearly full pond even late in the summer)***

Photo courtesy of Google Earth

**Image 30: Intermittent Stock Pond Located Seven Miles SW of Greybull**

***(note the earth dam across the stream channel and the near complete evaporation of the pond with only a small, green algae pond remaining)***

Photo courtesy of Google Earth

**Image 31: Mountain Lake Located Seven Miles East of Francs Peak**

***(this lake is located high in the foothills of the Absaroka Range at an elevation of 8553 ft. above sea level)***

Photo courtesy of Google Earth

**Image 32: Swamp/Marsh Area Located Along the Greybull River 14 Miles SW of Burlington**

***(note the green, highly vegetated marsh area in the middle of the image yet adjacent to an area of alkali soil)***

Photo courtesy of Google Earth

Inventory of these features was completed using aerial imagery and data from the National Hydrography Dataset (NHD). The results are shown on Figure 58 and Table 31. The categories were developed utilizing the perennial and/or intermittent nature of both natural and man-made stock ponds, plus other natural features such as swampy areas or ice masses.

**Table 31: Upland Water Storage Features**

| Category | Count |
|---|---|
| Ice Mass | 11 |
| Intermittent Industrial Pond | 4 |
| Intermittent Pond | 328 |
| Intermittent Reservoir | 8 |
| Intermittent Stock Pond | 375 |
| Perennial Industrial Pond | 21 |
| Perennial Pond | 131 |
| Perennial Reservoir | 15 |
| Perennial Stock Pond | 130 |
| Swamp/Marsh | 13 |
| Unknown | 8 |
| **Total** | **1044** |

As shown on Figure 53, there are at least 171 wells permitted for Stock use while another 163 wells are permitted for stock and/or domestic use. Stock tanks are often the reason for many of the watershed's permitted groundwater wells. These tanks, much like stock reservoirs, are utilized by both livestock and wildlife in the area.

Springs and seeps are the result of groundwater discharging naturally. Typically, this occurs when the land surface intersects with the groundwater table as shown in Figure 7 (USGS Mapped Springs and Seeps). The amount of flow from a spring can vary widely depending upon several factors including:

- Evapotranspiration and evaporation at the site of the spring itself;
- Drought conditions causing a depletion of the storage; and
- Recharge from seasonal snowfall and/or rainfall.

According to data acquired from the USGS/BLM, there are 32 known springs/seeps in the watershed. It is assumed that many more exist which remain unmapped.

# 3. REHABILITATION AND MANAGEMENT PLAN

This section presents the findings from the public outreach, discussions with land management agencies, and review of findings from Section 2 (Inventory and Evaluation). The rehabilitation and management strategies described in this section are intended to improve the watershed condition and function of the watershed which includes benefits to wildlife, livestock, and the environment. This section is divided into rehabilitation topics that are tangent projects that a landowner or public entity could pursue for funding and management topics that focuses on the potential for an over-arching management agency for the entire watershed. This study will be useful as a tool to identify the costs, permitting and funding logistics to complete a project and these topics are discussed in more detail in the following sections.

Several improvements are specific to landowners and are based on the landowner's outreach and input. On the other hand, some of the rehabilitation opportunities were identified based on recurring themes from stakeholders through surveys, conversations and comments during public meetings. The larger-scale issues are based on the survey results and include:

- Aging irrigation infrastructure
- Water storage; and
- Stream stability

Fortunately, this watershed is in relatively good condition, good functionality and has benefited from numerous WWDC-sponsored studies throughout the years. Typically, a watershed study is completed prior to any additional studies, but in the case of this watershed study, multiple irrigation studies have been completed and the area is currently exploring the potential to expand storage at the Lower Sunshine Reservoir. Because these efforts have been completed in previous studies and include costs, prioritization, funding, etc., rehabilitation projects related to larger irrigation entities and specifics to the expansion of the Lower Sunshine Reservoir are not included in this section. The one exception to this is the stabilization of the Hi-Line canal. Failure of this particular canal could cause catastrophic damage and economic loss if not prioritized for repair.

## 3.1 REHABILITATION TOPICS

In this section, each rehabilitation topic discusses the general overview of the issue, presents a conceptual design to remedy the issue and identifies the expected entities that will need to be involved for permitting and coordination. In Appendix A, one-sheet pages are provided for each topic for ease of use for a stakeholder interested in a particular topic. These one-sheet pages also include estimated costs, permitting contacts, and funding contacts.

### 3.1.1 Watershed-wide Rehabilitation Topics

Identification of watershed-wide issues were primarily a function of summarizing public comments, survey responses, and agency input. The intent of the topics introduced in this section is to provide unit costs, conceptual design and permitting considerations for those landowners that may be interested in pursuing

rehabilitation related to these topics. Watershed rehabilitation topics include: stream stabilization, water storage and irrigation infrastructure.

#### 3.1.1.1 Stream Stabilization

Streambank erosion is a common issue along the larger rivers of the watershed, particularly the Greybull and Wood Rivers, resulting in thousands of dollars of damage due to land loss and destruction of infrastructure. Lateral stream migration is normal for all streams, although certain stream types exhibit more lateral movement than others. Lateral movement allows streams to regulate its gradient by becoming more or less sinuous. This allows the channel to maintain its ability to transport its sediment load, which is a requirement of a stable stream. Rosgen "D" stream types (much of the Greybull and Wood Rivers, see Figure 11 for watershed Rosgen classifications) have characteristically high bank erosion rates. These stream types have a high sediment supply and aggradation due to sediment deposition which cause the channel to adjust its channel planform frequently. (Rosgen, 1996)

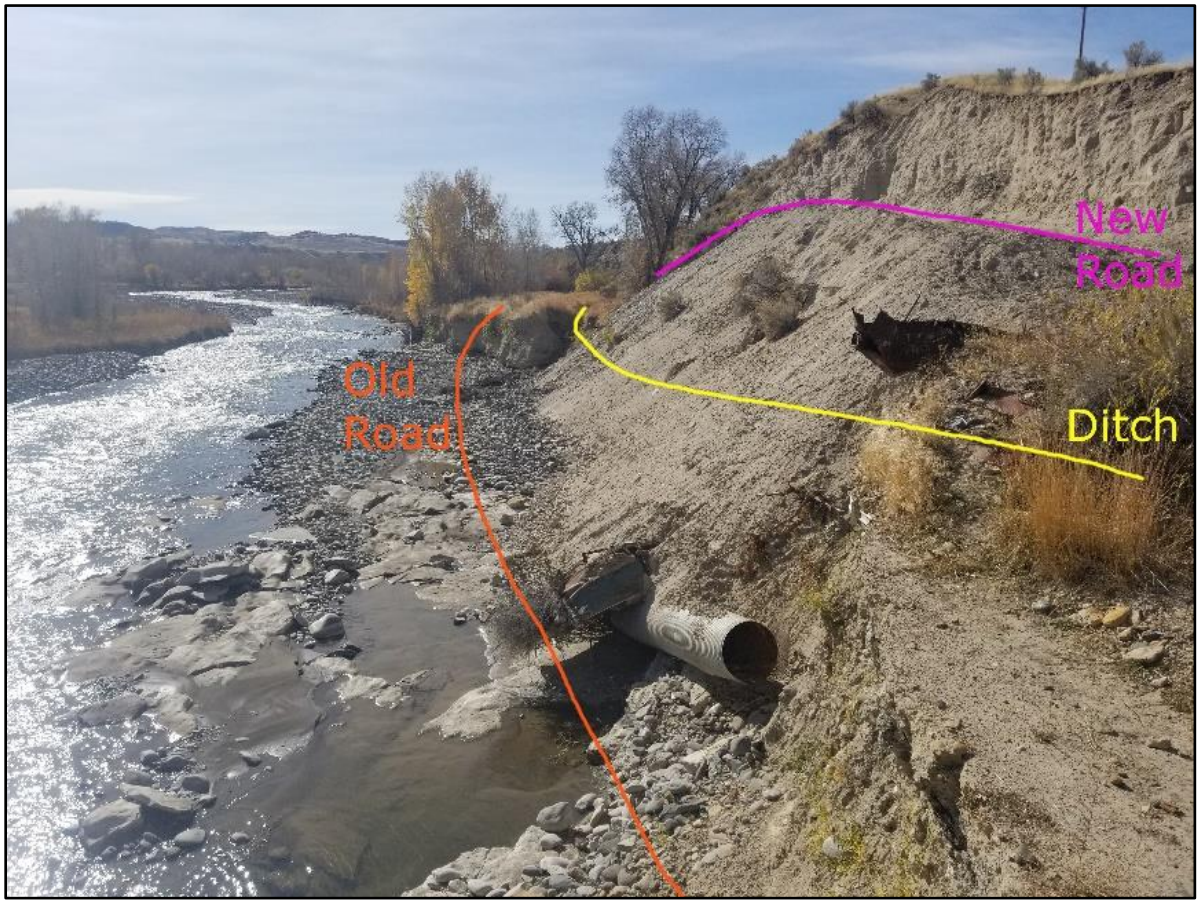
During this study, erosion and flooding became a recurring theme which may have been more pronounced due to the "wetter" years occurring over the past three years (see Table 6) and the subsequent damage due to higher flows. Landowners reported that typically a head gate or diversion structure would need to be replaced about every ten years due to erosion and flooding, but they are now finding that damage is occurring at more frequent intervals.

Field visits noted road damage on a bridge crossing the Greybull river (Road 4EU off Hwy 290) due to channel migration (Image 26), irrigation diversion damage and flooding from Wood River across roadways. (This location is planned for repair through the WY DOT and is not included as a rehabilitation project in this report but demonstrates the damage stream migration can create.) Dry Creek also has issues with flooding and erosion, but this is likely to occur near the confluence of the Bighorn River during the spring when flowing ice dams the river.

**Image 33. Road 4EU Damage Due to Streambank Migration and Erosion**.

In some cases, the Greybull River has migrated extensively, disrupting road and irrigation infrastructure (Image 27) and home structures. One landowner reported a loss of three feet of river bank in the direction of their home and are working to manage further erosion.

**Image 34. Road and Irrigation Damage.**



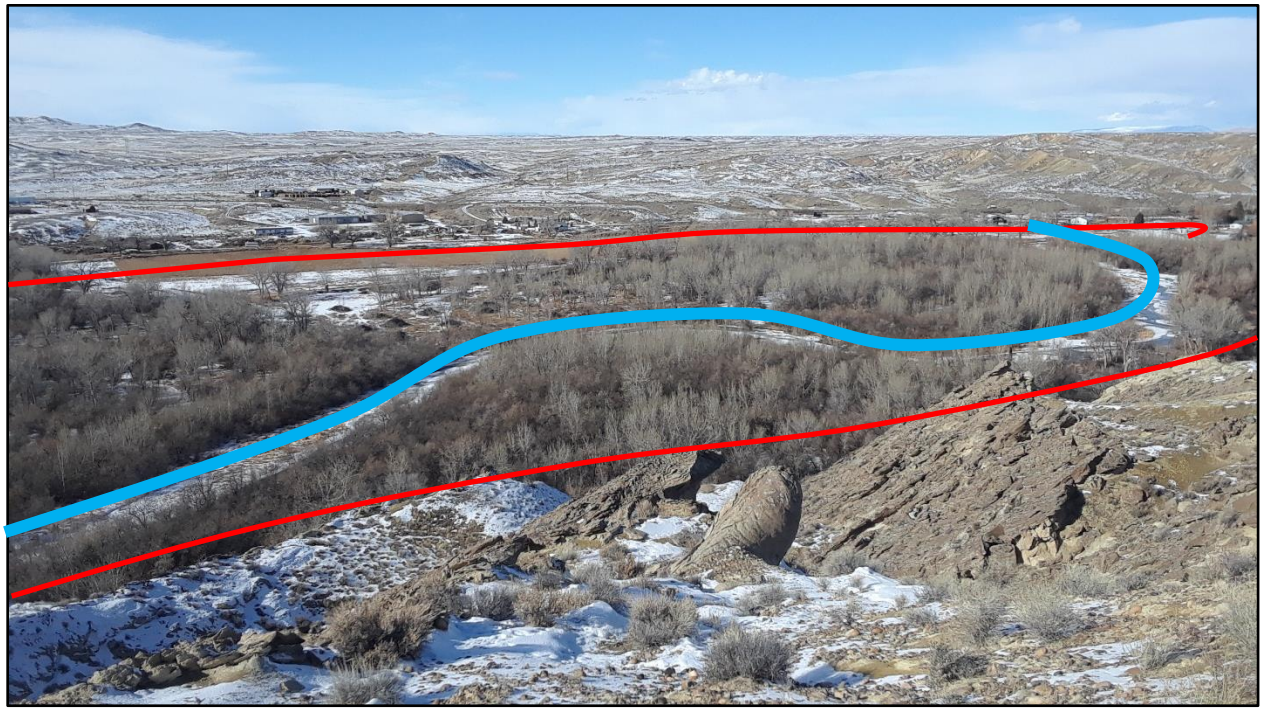

The numerous events that were reported or observed during the course of this study indicate this is a concern throughout the watershed. The following conceptual design is a general discussion on developing streambank stabilization in areas that are identified to have high enough value for protection against erosion.

*Conceptual Design*

Several case studies have shown that attempting to confine a stream results in more damage than if the stream was left alone. In addition, the costs of confining a channel the size of the Greybull or Wood Rivers would be prohibitively high and would diminish the river's watershed function (wetland habitat, sediment deposition in floodplain, etc.). Streambank stabilization on rivers the size of the Greybull and Wood Rivers is costly and should be reserved for circumstances when high-value land or infrastructure is in jeopardy. Future design considerations should site structures out of historical floodplains and channels. Image 28 shows a picture of the Greybull River with approximate extents of historic channel migration (in red) and the current river channel (in blue). Appropriate design would exclude the area within the red boundary for large-scale

infrastructure with the understanding that the river is likely to migrate across this full width at some point in time.

**Image 35: Greybull Historic Migration Pathway**



Certain streambank characteristics provide indication of bank stability. These characteristics include bank steepness, evidence of previous erosion, vegetative bank protection, and bank material composition. Meander bends are naturally unstable due to the non-uniform and non-symmetrical flow conditions that result in increased velocities and shear stress (ODOT, 2014).

For instances that bank stabilization is required, such as the bridge crossing in Image 26, a successful bank treatment requires that an engineer be consulted to design the bank stabilization treatment for the specific location in the watershed. The dimensions of the bank treatment and size of materials used depend on the expected flows and velocity of the river at the specific project location. The land manager should consider downstream and upstream effects of the bank stabilization project. An improperly designed streambank stabilization project can direct stream energy toward another bank downstream, potentially creating more erosion or flooding. An example of this is from a landowner in the lower portion of the watershed where modifications to the Greybull River by landowners across the river have inadvertently created increased velocities against the opposite streambank. Over a one-year period, erosion has eliminated over six-lineal feet of land and caused costs for new fencing to protect cattle (see the red-dashed line indicating previous bank location in Image 29).

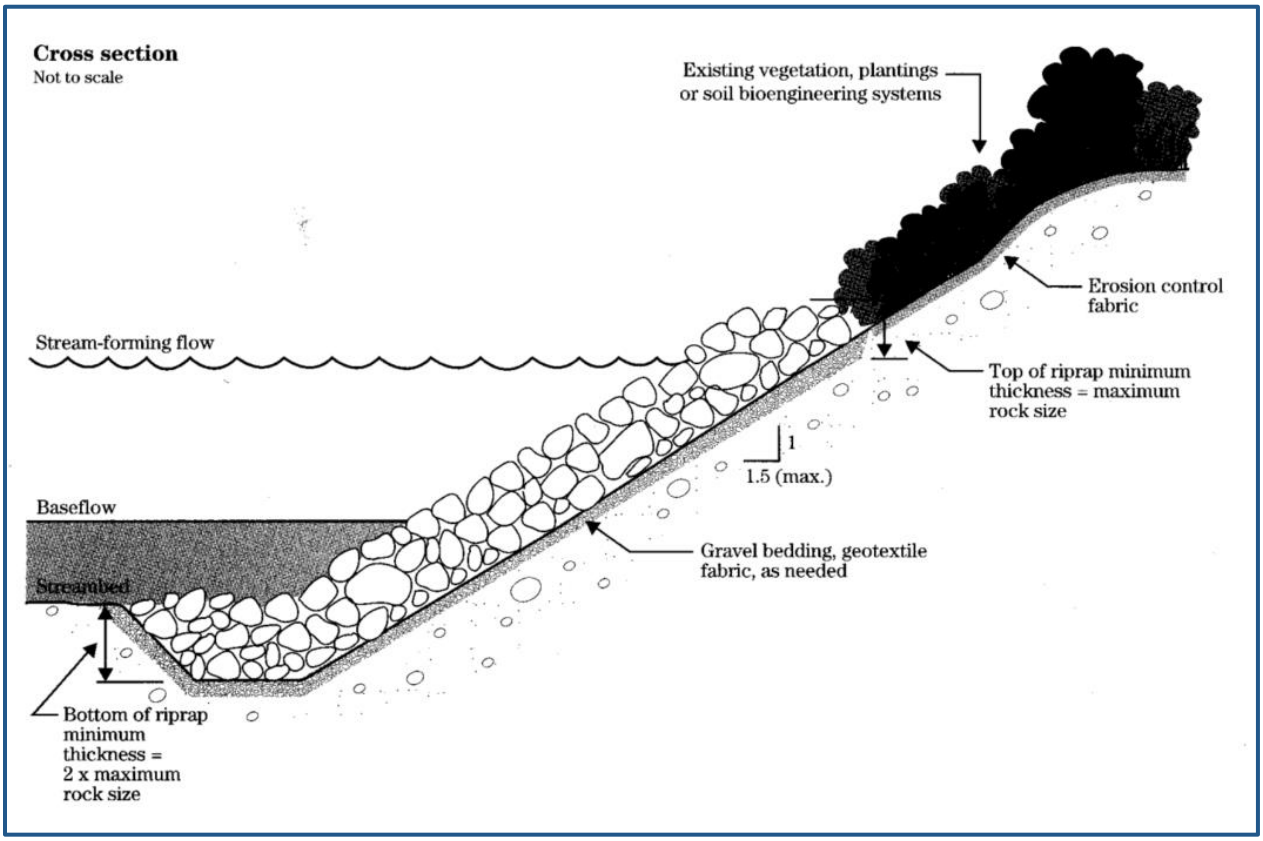
**Image 36: Over 6-feet of bank loss due to adjacent landowner river modifications.**

One commonly known streambank stabilization technique is the rock riprap revetment. The concept is simple and intuitive in that the subject bank is protected with a layer of large rock, however, several factors must be considered to properly design a rock riprap revetment. Design considerations include:

- bank slope,
- stream velocity,
- shear stress,
- toe trench depth,
- layer thickness, and
- length of threatened streambank.

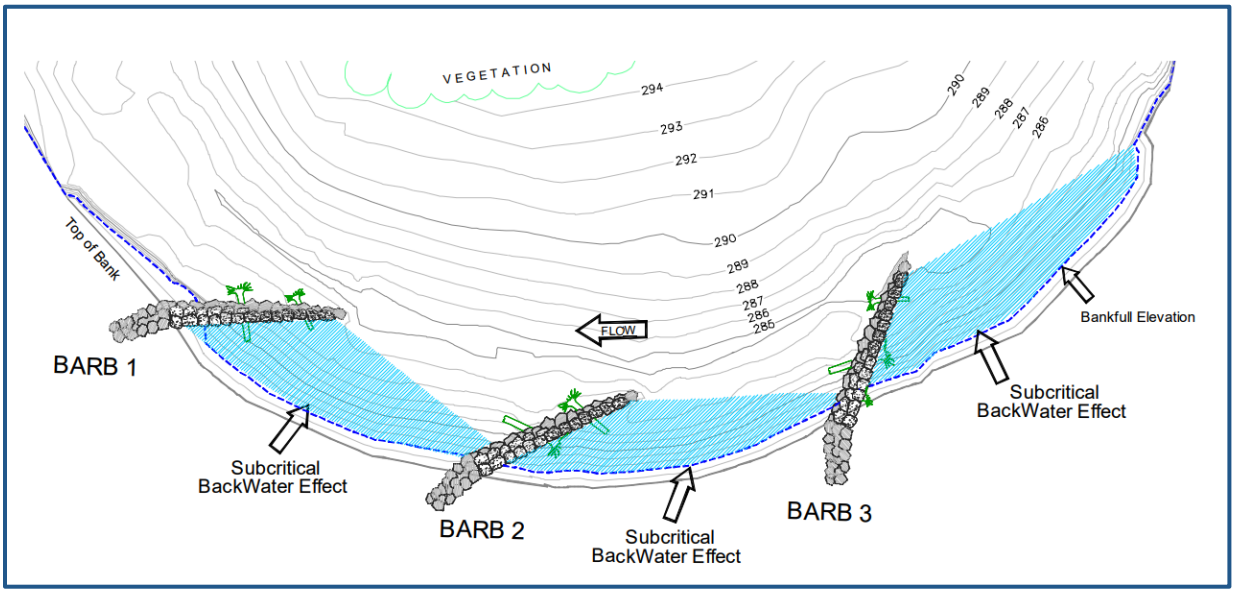
The design may also require a riprap backing of a geotextile or granular filter blanket to prevent the migration of fine soil through the voids in the riprap. Image 30 provides a cross-section example of a riprap revetment design. Large rivers, such as Greybull, that have steep banks and high stream velocity are likely to require very large riprap gravel or boulders which may prove to be cost prohibitive to landowners.

**Image 37: Riprap revetment design cross section**




A less commonly known technique is the use of stream barbs, also known as bendway weirs. This technique commonly uses rocks or logs to create two or more low sills that projects out from a streambank's thalweg (low points in the river) to redirect the stream flow away from an eroding bank, normally on the outside of a meander bend. This design makes use of weir hydraulics which causes flow to be redirected perpendicular to the barb centerline axis as it passes over the barb. By orienting the barbs upstream, streamflow is directed towards the channel centerline. Reducing near-bank velocities allows riparian vegetation to establish, further stabilizing the streambank (Image 31). Stream barbs are not recommended for use in degrading or laterally unstable channels (ODOT, 2014 and NRCS, 2013).

**Image 38: Stream barb near-bank velocity reduction (NRCS, 2013)**




One low cost option, and preventative measure, to protect streambanks is to leave riparian buffers intact. Roots of riparian vegetation help hold the bank together and vegetation increases roughness which decreases stream energy. If no riparian buffer exists, planting riparian species such as willow, cottonwood, box elder, and chokecherry can be a low-cost option to protect streambanks that have a low to moderate risk of erosion. The streambank should be assessed prior to planting to determine if this treatment will be effective. Factors that would deem this treatment ineffective would be streambanks that are too tall for vegetative roots to stabilize the slope or a streambank that is at too high of risk of erosion such that the vegetation would not have time to establish before the bank and vegetation is washed away.

*Permits*

A Section 404 permit and/or 401 water quality certifications may be necessary for implementation of a streambank stabilization project. A 404 permit is needed for most projects that places fill material into waters of the United States or perform dredging within the waters of the United States. The Section 404 permit is administered by the U.S. Army Corps of Engineers. The permit requires the applicant to consider alternatives that are less damaging to the aquatic environment and to determine if the nation's waters will be significantly degraded due to project implementation.

There are two types of 404 permits; the individual permit and the general permit. Upon application, the Corps will decide which type of permit is appropriate. Individual permits are issued to a single entity to authorize specific activities and are reviewed by the Corps. General permits are issued to the public at large to authorize specific activities that have minimal environmental impacts. There are currently 52 activities that the Corps covers under a nationwide general permit including most streambank stabilization activities. Two activities are covered under a regional general permit in Wyoming: construction and modification of boat ramps and fish habitat enhancement and restoration. Some streambank stabilization activities including stream barbs (sills) and rock riprap revetments are covered under the fish habitat and restoration general permit of the Corps.

*Estimated Costs*

The estimated cost to install streambank stabilization was developed for two scenarios: low-flow and high-flow rivers. Due to the variance in need for the length of streambank that needs to be stabilized, costs are present per 100 lineal foot (lf) of stream.

The high-flow estimated cost is based on a riprap revetment design and is $26,270 / 100 lf (2018 USD) of streambank. Reviewing flows from last spring and previous years, it was assumed that the flow velocity would be seven feet per second (fps) with velocities potentially increasing to 10 fps during very wet years. It was assumed a depth of six feet and a 2:1 bank slope for placement purposes. As shown on Image 30 (Revetment cross-section image), it was estimated that a 2.5-foot toe would be required. These estimates create a 16-foot long section of riprap to be placed perpendicular to the streambank. The size of riprap for the estimated velocities is D50 riprap size (NRCS Class II riprap), equating to 14-inch diameter rock. Cost consideration for material sourcing was based on a quarry located in Granit Canyon near Cheyenne and Laramie (370-mile travel distance). Differences in costs are highly dependent on the velocity of the river and the required riprap sizes needed to prevent the river from washing/eroding the riprap revetment away. Additional costs include permit application, surveying, site clearing and revegetation needs. Table 32 provides a breakdown of costs as outlined in Section C of the contract scope of services.

**Table 32: Riprap Revetment Opinion of Probable Cost per 100 LF**

| | | | | |
|---|---|---|---|---|
| Preparation of Final Design and Specifications | | | 380 | |
| Permitting and Mitigation | | | $ 1,250 | |
| Legal Fees | | | $ - | |
| Acquisition of Access and Rights of Way | | | $ 625 | |
| | | Pre-Construction Costs | | $ 2,255 |
| Cost of Project Components | | | | |
| 1 | PROJECT SURVEY AND LAYOUT | | $ 2,750 | |
| 2 | EROSION AND SEDIMENT CONTROL | | $ 15,780 | |
| 3 | SITE CLEARING | | $ 413 | |
| 4 | LANDSCAPING | | $ 42 | |
| | | Total Component Costs | | $ 18,985 |
| Construction Engineering Costs | | | $ 1,898 | |
| | | Component and Engineering Costs | | $ 20,883 |
| Contingency | | | $ 3,132 | |
| | | Total Construction Costs | | $ 24,015 |
| | | **Total Project Cost** | | **$ 26,270** |

Lesser flowing rivers would require smaller riprap or may be able to implement the geotextile fabric and revegetation to stabilize the bank, Image 32 shows and example of willow and fabric placement.

**Image 39: Willow Stake Planting for Streambank Stabilization**

The low-flow estimated cost is based on a riprap revetment design and is $20,399 / 100 lf (2018 USD) of streambank. Costs include permitting applications for Section 404 permitting, surveying, engineering design, placement of fabric and willows along six-feet of bank perpendicular to the streambank. Table 33 provides a breakdown of costs as outlined in Section C of the contract scope of services.

| Table 33: Revegetation Bank Stabilization Opinion of Probable Cost per 100 linear feet | | | |
|---|---|---|---|
| Preparation of Final Design and Specifications | | $ 3,160 | |
| Permitting and Mitigation | | $ 625 | |
| Legal Fees | | $ - | |
| Acquisition of Access and Rights of Way | | $ 625 | |
| | Pre-Construction Costs | | $ 4,410 |
| Cost of Project Components | | | |
| 1 | PROJECT SURVEY AND LAYOUT | $ 2,750 | |
| 2 | EROSION AND SEDIMENT CONTROL | $ 7,054 | |
| 3 | SITE CLEARING | $ 2,794 | |
| 4 | LANDSCAPING | $ 42 | |
| | Total Component Costs | | $ 12,640 |
| Construction Engineering Costs | | $ 1,264 | |
| | Component and Engineering Costs | | $ 13,904 |
| Contingency | | $ 2,086 | |
| | Total Construction Costs | | $ 15,989 |
| | **Total Project Cost** | | **$ 20,399** |

3.1.1.2 Water Storage

Many of the survey responses indicated an interest to increase water storage. Only one person in particular was interested in a small-scale pond on their property and this is described in the stakeholder specific rehabilitation topics. One finding from previous studies completed over the past ten years was a need for additional water storage in the area. A subsequent study, the Greybull Valley Irrigation District Storage Enlargement Level II Study was completed in 2017. This study looked at water availability and demand, alternatives analysis, permitting needs, and an economic analysis.

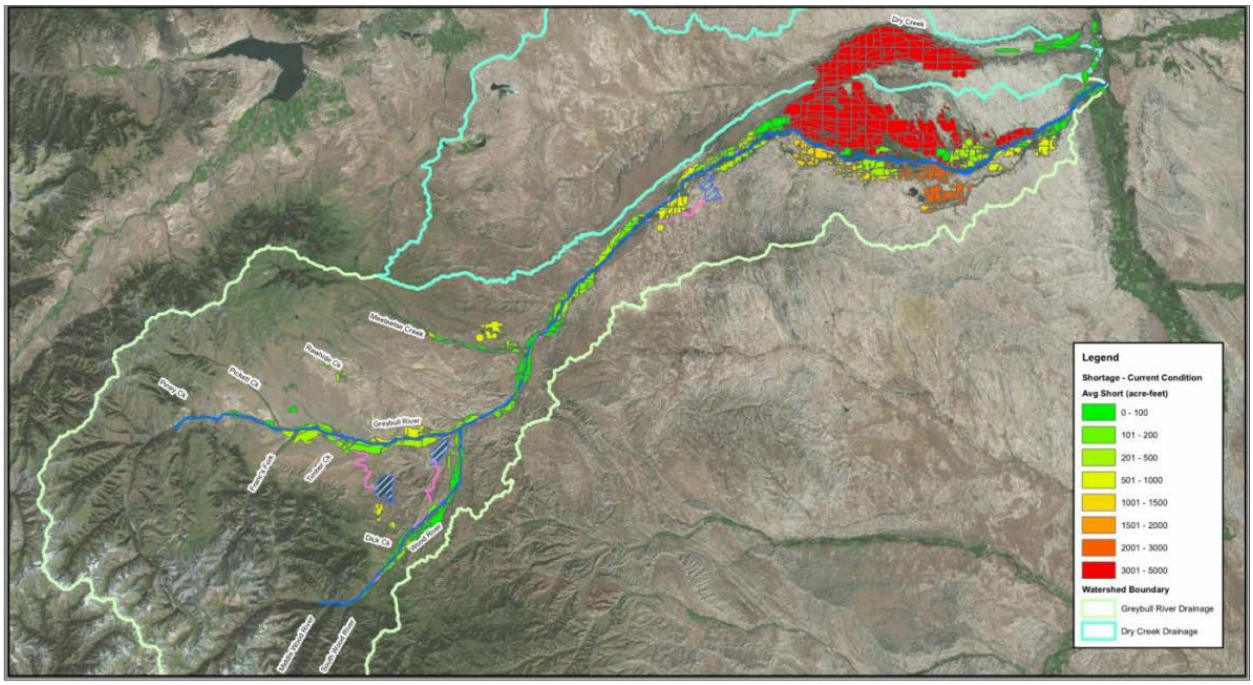
Results of this study found that the watershed operates as a water-short system, which is also verified by the hydrologic analysis completed for this study. The AECOM study further analyzed the watershed by reviewing water rights and water availability and concluded the watershed had available water that could be stored to reduce water shortages during the irrigation season. Three existing reservoirs and two new reservoirs were evaluated and screened based on logistics and technical practicality, cost, and biological and cultural constraint. The alternatives analysis identified the Lower Sunshine Reservoir as the preferred and best alternative to provide additional storage.

The proposed alternative will raise the Lower Sunshine Reservoir by five-feet which will create an additional 30,000 acre-feet of water storage. Economic analysis indicates the cost for expanding the reservoir to be between $1,500 and $3,000 per acre-feet ($15 to $85 million). Surveys were sent out as part of the 2017 study to gauge the public interest in water storage expansion; the survey resulted in approximately ten percent participation which makes it difficult to gauge public interest or willingness to pay. Currently this option

is being pursued and multiple public meetings have been held to determine interest and willingness to pay. As noted in Sec. 2.3.4.4, AECOM is conducting a subsequent Level II, Phase II study regarding expansion of the Lower Sunshine Reservoir. The project's final report is due to be released in the fall of 2019. This Phase II study is expanding on the results and recommendations of the Phase I work. Those itemized results and recommendations are outlined in Sec. 2.3.4.4. More information regarding costs, economic analysis, and alternatives reviewed can be found in the original report (*Greybull Valley Irrigation District Storage Enlargement, Level II, Phase 1 Study*, AECOM 2017).

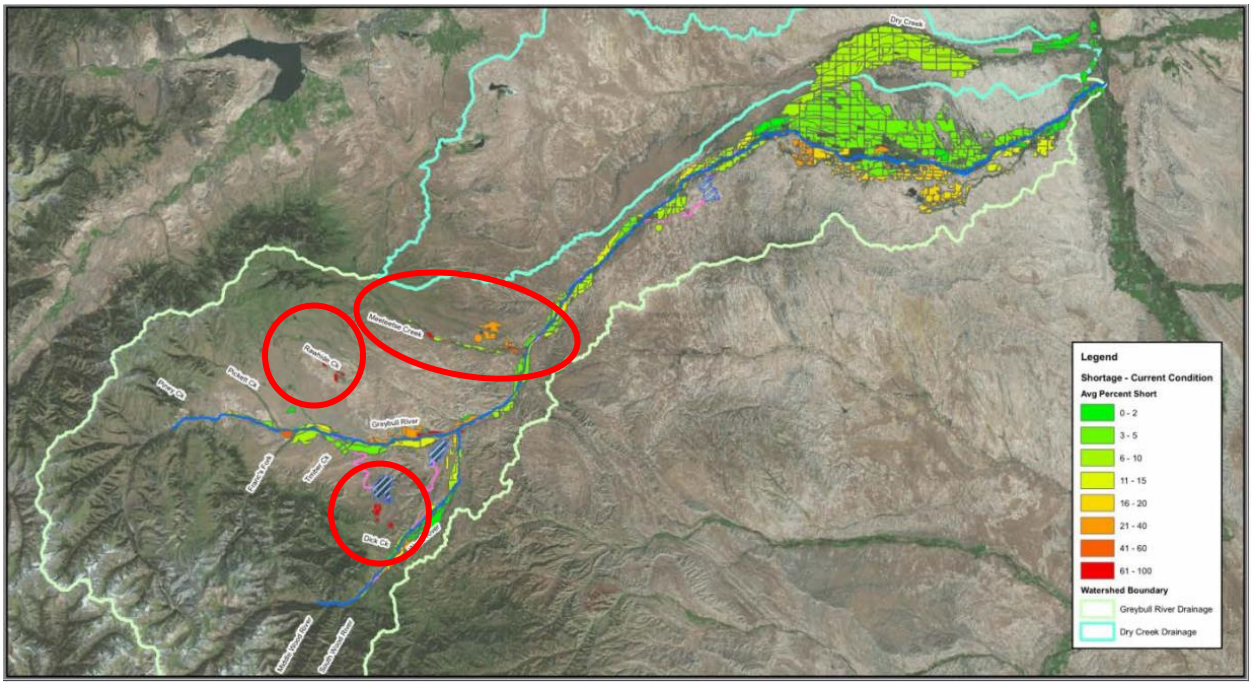
If the Lower Sunshine Reservoir is enlarged, this will primarily benefit water-users in the lower portion of the watershed, as shown on Image 33 from the AECOM report (Figure 2-6, AECOM, 2017), the largest volume of water shortages occurs in the lower basin. This figure shows that much of the lower watershed consistently have 3,000 to 5,000 acre-feet of water shortage while the upper portion of the watershed tends to have around100 to 500 acre-feet shortage on average. The public benefit on a watershed-wide analysis indicates providing additional storage in the Lower Sunshine Reservoir would alleviate the largest volume of water shortages in the lower portion of the watershed.

**Image 40: Average Annual Shortage by Diversion Structure Acre-Feet (reproduced from Figure 2-6, AECOM, 2017)**




However, comparison with the AECOM Figure 2-7 (reproduced as Image 34 below), shows the largest annual percent shortage often occurs along Meeteetse Creek, Rawhide Creek and south of the Upper Sunshine Reservoir, circled in red on the image. In these areas, the percent shortage is usually between 60 and 100 percent indicating although these areas do not use most of the water in the watershed, water shortages occur on a more frequent basis.

**Image 41: Average Annual Percent Shortage by Diversion Structure (Figure 2-7, AECOM, 2017)**




Feedback from public meetings also indicate a disparity of watershed management philosophy including equity of funding opportunities. Multiple comments have been made that mention a distinction of irrigation and even agricultural practices from a divide near Sheets Flat Bridge. Agricultural crops upstream of the bridge often include hay and wheat, while downstream consists of sugar beets, malt barley and beans resulting in a potential difference in water consumption needs. Additional comments in the upper watershed indicate a resentment towards water users in the lower watershed. Often, upper watershed landowners feel that the Greybull River is just a ditch serving the needs of downstream irrigators. Many stakeholders have expressed that the Greybull River watershed should serve everyone in the watershed and not just those in the downstream portions of the watershed.

Looking at the watershed in its entirety suggests there is a need for additional irrigation water storage in the upper watershed, although the extent of public benefit may be lesser than that of other storage opportunities downstream. Additional community feedback would be needed to determine interest prior to pursuing additional funding for feasibility studies. Many hurdles are present that would have to be overcome to develop storage in areas that could benefit landowners in the outlying areas of the watershed. Some of these hurdles include lack of a public entity to pursue funding, lower prioritization, competition for funding in regards to public benefit, and downstream senior water right conflicts that may preclude upstream storage potential.

#### 3.1.1.3 Irrigation

As illustrated in the Inventory and Evaluation Section, multiple master plan studies have been completed for the formal Irrigation District within the watershed. This was also reflected by numerous comments at public meetings and from survey results. Several comments included:

- Farmer's Canal is failing;

- 70 to 80 percent of the Bench Canal's infrastructure is failing; and
- Several unlined irrigation ditches up to eight miles long which lose nearly half their flow by the time the water reaches the fields.

The previous studies included infrastructure for the Bench Canal Company, Farmer's Canal Company and owners and operators of the Keystone, Jimmerfield, Smith and Avent Canals have also concluded a need to improve irrigation infrastructure. Because significant work has already been completed including prioritization, costs, permitting and funding options, these are not included in detail in this study. Refer to Section 2.3.3, Agricultural Water Use and existing reports for additional information.

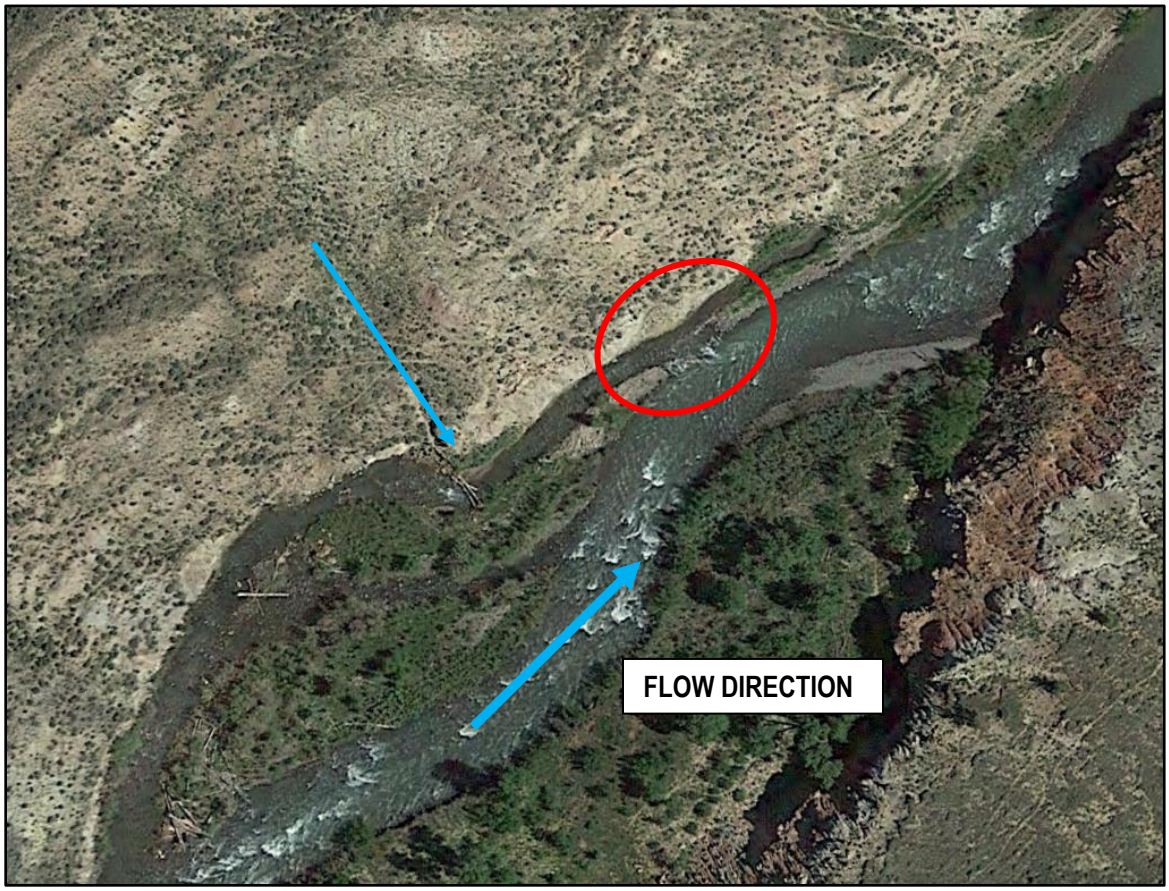
Of the items identified in the previous studies, repair of the Hi-Line ditch frequently came up in survey responses and discussion with landowners. Landowners have concern that the Hi-Line ditch is unstable and if this ditch fails, many agricultural producers will be without water and could be devastating to their livelihoods. In addition, there is concern that if the Hi-Line ditch fails, the water flowing out of the ditch will also cause significant damage. The Bench Canal Master Plan study has noted that this is one of four ditches that provide approximately 85 percent of water laterally. The BCC master plan also identified that this ditch exhibits the poorest stability. The Hi-Line ditch was also determined to have excessive erosion, higher ditch cleaning, weed control, and other maintenance costs (Sage, 2016). Cost in the study to replace the Hi-Line Ditch was estimated to be $522,245 or $90,367 per mile (2016 USD). The schedule for replacement of this canal is estimated to be between 2038 and 2045; however, due to the level of interest that this ditch has drawn during this watershed study regarding fear of failure, additional analysis of failure may be warranted to determine if this project needs a higher priority.

Regardless if the Hi-Line Ditch needs reprioritization or if the current schedule is adequate, most of the rehabilitation projects identified from the irrigation master planning studies will require funding. A majority of this funding can be obtained through Level III construction with the WWDC, but funding is only allowed to be provided to public entities. The BCC, FCC and other irrigation districts are not public entities and therefore, do not have an ability to apply for this funding. (The public entity requirement is waived for Level I Studies.) To obtain WWDC funding, two primary options for ID in the watershed are available; 1) become a public entity, or 2) ask for the GVID to sponsor the project. Benefits to each of these are discussed in more detail in Section 5, Funding Opportunities.

Currently, the BCC is exploring the benefits of becoming a Watershed Improvement District (WID) to become eligible for funding. The FCC and other private entities have not moved forward with either options to procure funds. With this delay in procuring funds, the infrastructure will continue to degrade.

Like the larger, private irrigation districts, there are numerous ditches, headgates and other infrastructure that is aging and in disrepair that are owned or shared by private landowners. Maintenance and repair often are undertaken by one landowner who then has the onus of obtaining repayment monies from other landowners who benefit from the same ditch. Many responses from stakeholders were focused on headgate and diversion structure damage due to flooding and erosion which can be addressed with streambank stabilization described previously. As shown in Image 35 below, many diversions can become nonfunctioning due to the river meandering away from the diversion so that water no longer flows into the diversion channel.

**Image 42: Nonfunctioning Diversion due to Channel Migration.**




The example above shows historical channel flow into the diversion (blue arrow) and also shows how the migration of the Greybull River has caused erosion effectively cutting of the channel. Preventative measures may include field surveys to identify areas at risk and areas of significant value to validate streambank stabilization. Repair costs can vary depending on the size of the ditch, flow and extent of channel migration. Permitting requirements for repair are similar to that of streambank stabilization due to the need to potentially place fill material into the river.

### 3.1.1.4 Russian Olive and Salt Cedar Removal

As noted earlier in Sec. 2.2.2, invasive species such as tamarisk (saltcedar) and Russian olive produce very negative impacts in Wyoming. Tamarisk is an aggressive colonizer which outcompetes and can even replace native willows, cottonwoods and other species. Russian olives are similar and add increased water consumption. After fire, each species sprouts vigorously and usually gains the upper hand over native species. The LANDFIRE dataset classifies 8,636 acres in the watershed study area of introduced riparian forest and woodland, which is most-likely dominated by tamarisk and Russian olive (see Figure 27). Some of the benefits listed for removing the noxious plants include:

- Increased grazing capacity;
- Reduced irrigation maintenance;

- Water savings;
- Increased numbers and diversity of wildlife;
- Increased physical access;
- Reduced fire danger; and
- Enhanced property value.

There is funding available for landowners within the watershed who need assistance to remove the Russian olive/Saltcedar trees on their property. The NRCS offers the Environmental Quality Incentives Program (EQIP) to assist in the removal of either of these invasive species. Once the application is filled out and approved, the applicant is required to sign a contract and agree to implement the planned practices as scheduled.

EQUIP assists in the cost for one year for the mechanical removal of the trees (often a tree sheer attached to a tractor or timber axe on a skid steer) and assists for two years in the chemical treatment for removal. Herbicide chemical treatment typically applied include glyphosate products (Roundup), 2,4-D Amine, or imazapyr (Habitat) and is applied to the outer ring of cut stumps to assist in killing the roots of the tree. Removal and chemical treatment will often take several years of diligence from the landowner to fully eradicate the species.

According to the NRCS, EQIP pays 60 percent of the total cost while the landowner pays the remaining 40 percent. The NRCS determines the costs on an annual basis as a result of contractor costs, chemical costs, etc. Currently, the cost is $496/acre for heavily infested areas while land with a medium infestation will cost $275/acre. Those costs continue to decrease depending upon lower infestation rates. This includes the costs for both the one-year mechanical removal and subsequent chemical treatment for two years.

One of the requirements of the program is an agreement by the applicant to remove all those invasive trees on the landowner's property and not just a few (Allen, 2018). To review EQIP, landowners can call either of the two NRCS offices serving the watershed in Powell (307.754.9301) or Greybull (307.765.2483), or visit the NRCS EQIP website at:
https://www.nrcs.usda.gov/wps/portal/nrcs/main/wy/programs/financial/eqip/

After those initial two years of chemical treatment, the landowner must continue to apply chemicals at his/her own expense to prevent the plants from reemerging. The local Weed & Pest Control offices offer some assistance for those chemical purchases. The Big Horn County Weed & Pest Control offers landowners a 50% cost share for those chemicals while the Park County office offers a 25 percent cost share.

Another funding opportunity for landowners or even communities within the watershed is the Wyoming Wildlife & Natural Resource Trust. The purpose of this program is to enhance and conserve wildlife habitat and natural resource values such as removal of Russian olive/saltcedar trees. Typically, this program offers assistance on a matching-funds basis but that basis can be amended during the application review process (Budd, 2018). Interested applicants can call 307.777.8024 for more information or review the program online at: http://wwnrt.wyo.gov/

### 3.1.2 Specific Rehabilitation Topics

#### 3.1.2.1 Fish Passage

As previously described in Section 2, a fish passage barrier is anything that limits the up- or down-stream movement of fish. Sometimes, like the Sheets Flat Diversion, the fish barrier is intentional to protect native species. Natural barriers can include waterfalls or beaver dams and since these are considered a natural process to the watershed, improvement or rehabilitation to natural processes is not included. On the other hand, anthropogenic barriers, which are primarily diversion structures, can be improved by developing fish passages for upstream movement or "fish friendly" diversion options for downstream movement of fish. Typically, the majority of barriers documented in this watershed are smaller diversion structures that also end up diverting fish into the irrigation ditches and are thus lost to the river system. During the inventory process and from outreach, it was discovered that the GVID is coordinating with the WGFD and Trout Unlimited to remedy the fish barrier located at the diversion on Wood River. Communication occurred with Nick Scribner (WYGF Statewide Fish Passage Coordinator) in November 2017 and during this conversation, Nick communicated that they were commencing the design stage for the fish passage. Since then, during a Wyoming Water Association tour of the GVID, it was discovered that progress has been made on the design and surveying is anticipated to begin Summer 2018. Although the design is intended to mimic the fish ladder located at the Upper Sunshine diversion, conceptual details, costs and permitting are included here as a reference tool for potential fish passage needs that may be identified in the future.

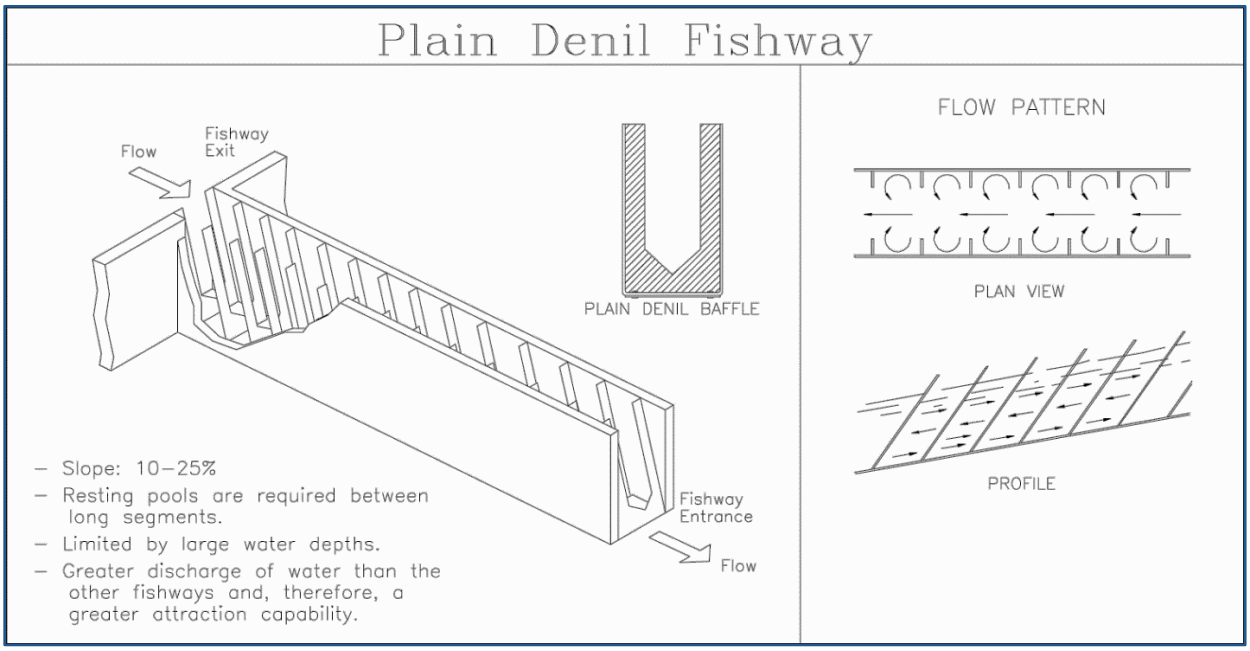
##### *3.1.2.1.1 Wood River Fish Ladder*

The Wood River provides important habitat for native Yellowstone cutthroat trout; however, fish passage is currently impeded by a dam that diverts water to the Lower Sunshine Reservoir. The dam was constructed in conjunction with the reservoir in 1972.

*Conceptual Design*

There are two types of fish ladders that are viable to be used at the Wood River location, or similar river in the watershed, to allow for upstream passage and are the Denil and vertical slot fishways. A Denil fishway (Image 36) uses a series of closely placed baffles positioned at an angle of 45 degrees to the fishway floor. Denil fishways are designed to be highly turbulent with high energy dissipation. The high flow associated with Denil fishways reduces sediment deposition within the fishway and attracts fish to the entrance. Reducing sediment deposition aids in less maintenance requirements for a functioning ladder. One drawback to the Denil fishway is that water velocities increase with depth and can eventually exceed fish swimming speeds. This type of fish ladder may not be the best option for situations where a wide range of water depth must be conveyed through the structure. (Katopodis, 1992). The new fish ladder on the Wood River is anticipated to be designed as a Denil fishway. The other conceptual designs presented are provided as a resource if, in the future, additional fish barriers are identified where fish passage becomes a priority.

**Image 43: Conceptual Design Denil Fishway**




A second option is the vertical slot fishway (Image 37) which use baffles that have a vertical slot towards the middle that the fish swim through. The baffles create a series of pools where the fish can rest while climbing the ladder. The main advantage of the vertical slot fishway is its ability to handle large variations in water level since the water velocity through the slot is maintained. The main disadvantage of the vertical slot fishway is that fish attraction is poor when the vertical slot at the downstream end is drowned by tailwater. Vertical slot fishways are also typically costlier to construct than Denil fishways (Katopodis, 1992).

**Image 44: Example vertical slot fishway**

A third option for fish passage is a bypass channel, which provide a more natural path for fish to migrate past the dam. Bypass channels are often more visually pleasing than fish ladders as well. Some design variables to consider are flow depth and velocity, upstream flow control, fish attraction, and the range of river flows. Some disadvantages to bypass channels are that they often take up more space and are less stable than the concrete fish ladders. More maintenance may be required, especially if the channel is not designed properly.

For all options, an engineer will ultimately be needed to design the fish ladder to ensure maintenance of structural integrity of the dam and to ensure effectiveness of the ladder in conjunction of the dam operation. Design considerations include height of the dam or passage to be navigated, length and slope of the fish passage, flow volume and velocity, access or easement considerations, water level/depth variation for fish attraction at the entrance of the passage, and costs.

*Permits*

Work activity for construction of a fish ladder is required to be authorized under Wyoming's Regional General Permit for Fish Habitat and Restoration (#11 Ladders). The applicant will need to perform the notification

procedure outlined in WY Regional General Permit 8202-06. The applicant will need to obtain a letter from the Wyoming Game and Fish Department (WGFD) stating that they have reviewed the design and concur with the proposed habitat improvement. It is recommended that the work be performed in the fall when stream flows are low. The time needed to perform the work is estimated to be from one week to several weeks. The Army Corps of Engineers and the WGFD should be notified several months in advance. Additional federal and state permitting considerations are provided in Section 4 (Permitting).

Because the Wood River dam is located on private property, an access agreement and potential easement would be needed for construction and maintenance. The estimated costs below assume some costs for procuring easements and access for future fish passage projects.

*Estimated Costs*

The estimated cost to install a Denil fishway is $160,000 (2018 USD). This cost includes upfront costs for final design and specifications, permitting and procurement for easements. The total upfront design and permitting fees is estimated at $47,720 (2018 USD). Construction phase costs were developed based on a few assumptions which are described below. Table 34 provides a table breakdown of costs as outlined in Section C of the contract scope of services. The cost estimate for the Denil fishway assumes a ten percent slope with an assumed height of ten feet and length of 100 feet. Costs include consideration for surveying, erosion and sediment control measures during construction, protective fencing, and concrete construction of the fish ladder. The estimated cost did not consider NEPA compliance, construction of roads or other access needs, excavated material disposal, or extensive revegetation needs (some revegetation is included).

| Table 34 Denil Fishway Opinion of Probable Cost | | | |
|---|---|---|---|
| Preparation of Final Design and Specifications | | $ 32,720 | |
| Permitting and Mitigation | | $ 6,250 | |
| Legal Fees | | $ 6,250 | |
| Acquisition of Access and Rights of Way | | $ 2,500 | |
| Pre-Construction Costs | | | $ 47,720 |
| Cost of Project Components | | | |
| 1 | PROJECT SURVEY AND LAYOUT | $ 5,500 | |
| 2 | EROSION AND SEDIMENT CONTROL | $ 8,944 | |
| 3 | SITE CLEARING | $ 3,123 | |
| 4 | EARTHWORK | $ 5,270 | |
| 5 | RETAINING WALLS | $ 45,293 | |
| 6 | FENCING | $ 12,619 | |
| 7 | LANDSCAPING | $ 1,051 | |
| Total Component Costs | | | $ 81,799 |
| Construction Engineering Costs | | $ 16,360 | |
| Component and Engineering Costs | | | $ 98,159 |
| Contingency | | $ 14,724 | |
| Total Construction Costs | | | $ 112,882 |
| **Total Project Cost** | | | **$ 160,602** |

As a high-level estimate when looking at potential future locations where a fish passage may be needed, the cost of the fish ladder should be based on a cost per vertical foot of dam height. In comparison to the cost estimate developed for this study, construction costs equate to $16,000 per vertical foot. As additional guidance, the Connecticut River Watershed Council completed a study of construction costs of fish ladders and have estimated the cost to construct a Denil fishway to be approximately $20,000 per vertical foot (CRWC, 2018).

*3.1.2.1.2 Fish Passage Maintenance*

The Upper Sunshine Reservoir was constructed in 1939 with a diversion dam on the Greybull River to divert water into the feeder canal. This dam acted as a barrier to fish migration, blocking over 100 miles of upstream fish habitat to downstream fish populations for nearly 80 years. The dam was replaced in 2012 and a fish ladder was incorporated into the design. Native Yellowstone cutthroat trout populations could once again migrate upstream to access spawning tributaries and the cold waters of the Shoshone National Forest (Kidston, 2012). During site visits, it was noticed that the existing fish ladder had sediment accumulation in the ladder.

Sediment that has accumulated at the top of the fish ladder can impede fish passage, as shown in Images 38 and 39. It is thought that some of the sediment accumulated when the dam operators were learning how

to adjust the new inflatable weir properly. The Greybull River transports high amounts of sediment, resulting in large deposits as flows recede. Proper dam operation can mitigate, but not eliminate sediment deposits around the fish ladder. Routine maintenance for sediment removal is necessary to maintain fish passage. During a Wyoming Water Association tour of the GVID in June 2018, it was observed that this specific fish ladder had been cleaned of sediment in the Spring. This was the first time in five years which is estimated to be an adequate time-frame for maintenance activities.

**Image 45 Sediment Accumulation at top of fish ladder**

**Image 46 Sediment in upper gate of fish ladder**

*Maintenance Activities*

To repair fish passage through the fish ladder and based on the level of sediment accumulated, the sediment may need to be removed by heavy equipment. A small excavator and a dump truck for hauling the material should be sufficient and is the basis for the routine maintenance estimated costs. Other maintenance options could include a hydro-excavator to collect the sediment and "mechanically transport" the sediment downstream of the diversion dam but would also require consultation with Army Corps of Engineers. The work should be performed in the fall when flows are low and fish are no longer spawning. The time needed to perform the work is estimated to be a week.

*Permits*

A land access agreement will be needed to perform the work on the north side of the river. The work activity should be authorized under Wyoming's Regional General Permit for Fish Habitat and Restoration (#14 Bedform). The applicant will need to perform the notification procedure outlined in WY Regional General Permit 8202-06. The applicant will need to obtain a letter from the Wyoming Game and Fish Department (WGFD) stating that they have reviewed the design and concur with the proposed habitat improvement. The Army Corps of Engineers and the WGFD should be notified several months in advance.

*Estimated Maintenance Costs*

The estimated cost to mechanically removed sediment buildup is $2,838 (2018 USD). This cost includes upfront costs for permitting and coordination to gain access to private property. Table 35 provides a breakdown of costs. Project components are primarily based on equipment costs which may be deferred if the managing company (i.e., GVID or other irrigation entity) already owns appropriate equipment. Some revegetation costs are also considered due to inherent damage of large equipment on the adjacent land.

**Table 35: Fish Ladder Sediment Removal at Sunshine Diversion Opinion of Probable Cost**

| | | | |
|---|---|---|---|
| Preparation of Final Design and Specifications | | $ 322 | |
| Permitting and Mitigation | | $ 476 | |
| | Pre-Construction Costs | | $ 798 |
| Cost of Project Components | | | |
| 1 | SEDIMENT REMOVAL | $ 1,269 | |
| 2 | MOBILIZATION/DEMOBILIZATION | $ 190 | |
| 3 | TRAFFIC CONTROL | $ 25 | |
| 4 | REVEGETATION | $ 127 | |
| | Total Component Costs | | $ 1,612 |
| Construction Engineering Costs | | $ 161 | |
| | Component and Engineering Costs | | $ 1,773 |
| Contingency | | $ 266 | |
| | Total Construction Costs | | $ 2,039 |
| | **Total Project Cost** | | **$ 2,838** |

#### 3.1.2.2 7K Ranch Concrete Lining

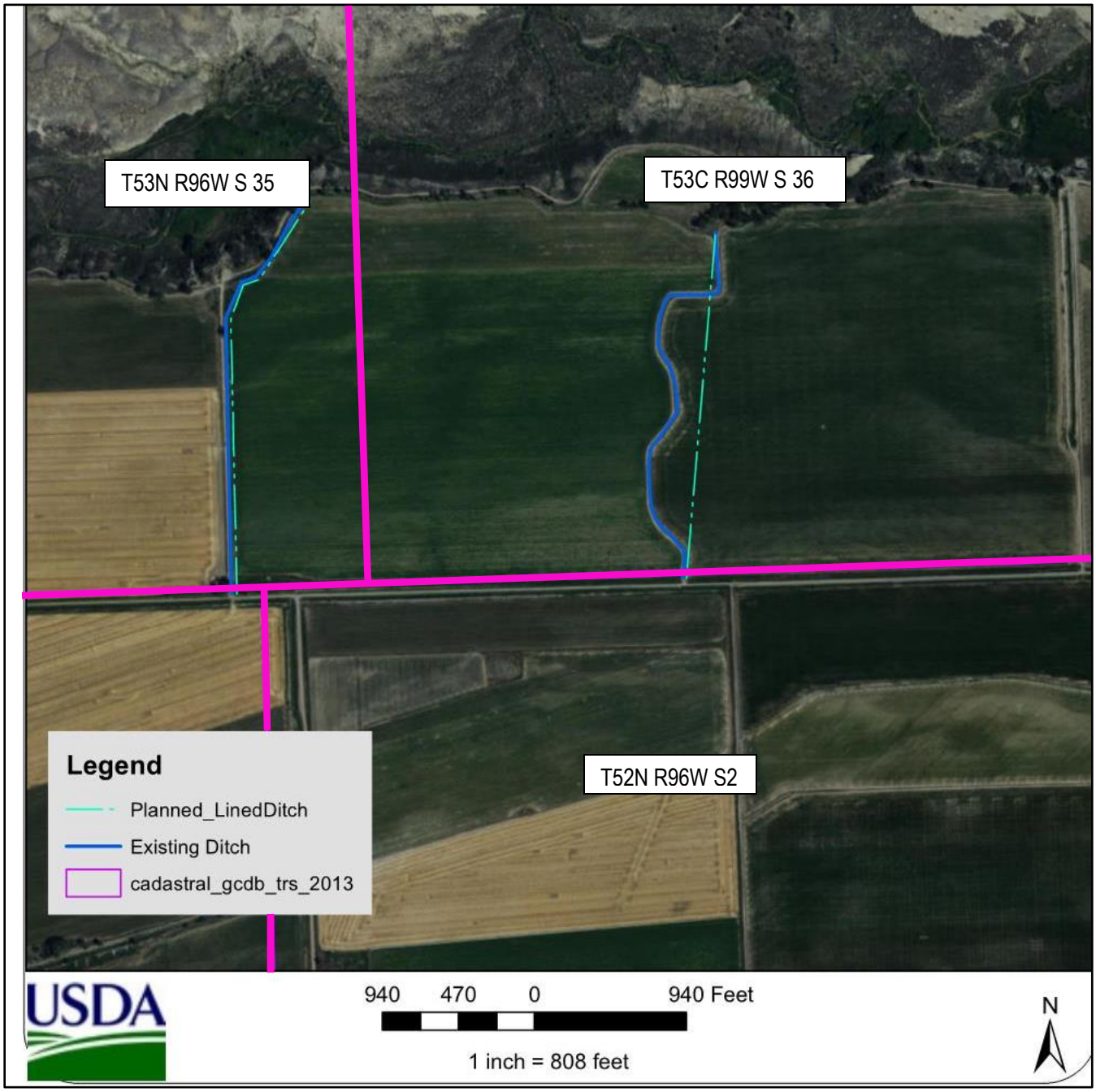
The BCC irrigation infrastructure delivers water to approximately 15,000 acres via 54 miles of canal by transporting water from the Greybull River to the Emblem Bench area. Prior Greybull water rights require that direct-flow quantities be supplemented by water in Upper and Lower Sunshine reservoirs to meet crop water needs throughout the growing season.

At one of the more distal portions of the Bench Canal irrigation infrastructure are two irrigation canals which flow to the north and discharge into Dry Creek. These canals are currently constructed with earthen banks.

During the process of this study, Dave Neves, 7K Ranch Inc., made contact and expressed continued interest to convert those two irrigation canals from dirt canals to concrete-lined, straightened irrigation channels. After conversions with Neves, the total length of these canals was determined to be approximately 4,050 linear feet. Image 40 below shows the current alignment of irrigation canals and proposed re-alignment of lined irrigation canals. Figure 59 depicts the location of the 7K Ranch area within the watershed.

Those irrigation canals distribute water to fields operated by the 7K Ranch. In 2017 the 7K ranch applied for funding from NRCS to reroute and line the two irrigation canals with concrete. Though the application was determined to meet the objectives for the EQIP 2014 program, it was not funded because other area applications proved to convey greater public benefits than the 7K Ranch proposal (Neves, 2017). The 7K Ranch opted to have the NRCS retain the application and to consider “changes that will help improve my chances of receiving future funding.”

**Image 47: 7K Ranch Proposed Concrete Channel Alignment**




Lining irrigation canals with concrete or another substrate offers a multitude of benefits when compared to earthen-lined channels. Such concrete lining provides several benefits including:

- Improved conveyance of irrigation water;
- Prevention of water-logging the land;
- Maintaining consistent water quality;

- Erosion prevention, and
- Reduced water loss (NRCS, 2011).

In order to complete an accurate design and cost estimate for lining any irrigation canals, the inlet, the canal cross section, discharge structures and soil characteristics all need to be identified. According to Wyoming conservation practice standards, concrete-lined canals are limited to:

- Bottom widths not greater than 6 feet;
- Flow capacities equal to or less than 100 cubic feet per second (cfs), and
- Design velocities equal to or less than 15 feet per second (fps) (NRCS, 2011).

The design proposed by Neves includes a channel with a 12-inch wide base, 56-inch wide top and an 18-inch depth. Utilizing those measurements, the flow is estimated at six cfs. All of those characteristics satisfy the conservation practice standards. Using this information, a conceptual design cross section and details for the inlet and outlet transition sections from the existing dirt-lined ditch were developed and are depicted in Figure 60.

Analysis of the average terrain slope from the upgradient, south end to the discharge located at the north end of the canal sections indicate an average slope of about 0.004 ft per ft or 0.4 percent. Using the approximate existing dimensions of the ditches, a simple concrete ditch was conceptually designed that could meet the design flows given the average slope. To minimize the excavation and re-grading work on the existing ditch, which will not be re-aligned, and to provide approximately six-inches of freeboard, a 1.25 horizontal to 1 vertical (1.25H:1V) side-slope was selected. For conceptual design and cost estimating purposes, it is assumed there is no need for structural re-bar because geotechnical testing for swelling/collapsing soils are likely to be negative.

The conceptual design was kept simple using 6-inch thick concrete with a heavy-duty, welded wire fabric (e.g., 6x6-W5.5xW5.5). This helps prevent concrete cracking over time. In addition, the inlet and outlet of this ditch will require a concrete headwall / cutoff wall with a burial depth of four feet to ensure the location is below the frost line. This prevents frost jacking over time. The inlet transition section will have a 20-foot-long section of gravel bedding to help capture sediment prior to the concrete headwall / cutoff wall. This helps to minimize maintenance in the channel. Similarly, the outlet transition back to the native ditch will have a ten-foot long section lined with gravel before transitioning back to native soil. This helps energy reduction and prevents erosion.

The calculations were completed assuming rough concrete joints which yield a Manning's roughness coefficient of n = 0.17 and ensures the flow would continue at a minimum slope of 0.002 percent. However, rough joints are not recommended for placement of concrete on very flat ditches. Thus, it is recommended to use a wet mix concrete and steel forms for a lesser roughness coefficient of n = 0.13 along those flat sections of the ditch. It may be possible to decrease the cross-sectional area of the ditch, which would conserve concrete usage during the final engineering design, if more detailed survey information is available regarding the existing cross section and slope of the ditch. For this conceptual design, however, it was

assumed that any cross-sectional savings would be offset by additional earthwork required to infill, compact and re-grade those portions of the western north-south ditch which are not proposed for straightening.

There are potential concerns to consider before advancing to any additional engineering. It must be understood this conceptual design assumes there are no swelling or collapsing soils in the area. In addition, it is assumed the existing soils are either free-draining sandy soil or normally consolidated fine grain soils. A geotechnical investigation should be performed to validate these assumptions or alter the design accordingly. Concrete-lined ditches constructed on poor soils can rise due to swelling soils or frost jacking. Similarly, the concrete can settle and crack over time due to settlement or consolidation of soils. Final engineering design should take all this into consideration.

*Estimated Costs*

The estimated cost to convert the 7K ranch unlined ditches to concrete is $150,229 (2018 USD). This cost includes additional design considerations including the potential for geotechnical investigation, a small amount of upfront costs for SEO notification (see permitting below) and any coordination to gain access to adjacent private property for construction needs. Table 36 provides a breakdown of costs.

**Table 36: 7K Ranch Concrete Ditch Lining Opinion of Probable Cost**

| | | | |
|---|---|---|---|
| Preparation of Final Design and Specifications | | $ 10,914 | |
| Permitting and Mitigation | | $ 625 | |
| Legal Fees | | $ - | |
| Acquisition of Access and Rights of Way | | $ 625 | |
| Pre-Construction Costs | | | $ 12,164 |
| Cost of Project Components | | | |
| 1 | PROJECT SURVEY AND LAYOUT | $ 2,750 | |
| 2 | EROSION AND SEDIMENT CONTROL | $ - | |
| 3 | SITE CLEARING | $ - | |
| 4 | EARTHWORK | $ 7,872 | |
| 5 | RETAINING WALLS | $ 98,520 | |
| 6 | FENCING | $ - | |
| 7 | LANDSCAPING | $ - | |
| Total Component Costs | | | $ 109,142 |
| Construction Engineering Costs | | $ 10,914 | |
| Component and Engineering Costs | | | $ 120,056 |
| Contingency | | $ 18,008 | |
| Total Construction Costs | | | $ 138,064 |
| **Total Project Cost** | | | **$ 150,229** |

*Permitting*

The intent of this project is to conserve water utilizing the concrete liner. This intent does not alter the hydraulic properties of the ditch such as enlargement or expansion. With this in mind the conceptual design does not include changing any hydraulic properties of the ditch. Because of the initial intent and lack of altering the canal's hydraulic properties, the SEO would not require a permit. SEO will still need to be notified of the work to be performed so that SEO can modify the details of the water rights permit already in place (WSEO, 2018b).

Within Big Horn County the project may require a Development Permit depending upon the scope of the project. The county's Land Planning department would need to be notified ahead of time to determine any permit requirement (Muckley, 2018).

#### 3.1.2.3 German Ditch Conversion to Pipe

The German Ditch irrigation infrastructure delivers water from its diversion on the Greybull River to eight landowners and their 1,820 acres located south of the Greybull River. Currently, the ditch is constructed utilizing earthen banks. During this study, interest by Mr. Candee to convert certain sections of the German Ditch from un-lined earthen sections to a piped structure came to attention of the SBHCD and the NRCS.

Candee, who is one of the landowners utilizing the ditch, proposed converting five miles of the earthen ditch into a ditch utilizing PVC pipe with a capability of providing water at the current rate of 26 cfs. Figure 59 depicts the general location of this particular area within the watershed while Figure 61 depicts an expanded view of this German Ditch system.

A brief cost estimate from NRCS using a pipe calculator and an NRCS pay calculator indicated a cost of nearly $2,000,000. This proposed pipeline would serve multiple landowners but would also cross BLM-owned land. Such a crossing introduces probable permitting concerns which are discussed later in this section.

Another long-term objective proposed by Mr. Candee was to eventually adapt the irrigation system to a center pivot (or similar) type system rather than the existing flood irrigation practices currently used. This would reduce water losses even further.

Though no official application for funding or design has occurred, Mr. Candee's proposed project is appropriate for inclusion in this study. He notes the current unlined ditches lose large amounts of water for several reasons including:

- Evaporation;
- Absorption into the ground;
- Disrepair from gopher and other rodent activity, and
- Water consumption from vegetation within and near the ditches.

As noted in the previous section, lining earthen irrigation canals with a pipeline offers a multitude of benefits including:

- Improved conveyance of irrigation water;

- Prevention of water-logging the land;
- Maintaining consistent water quality;
- Erosion prevention, and
- Reduced water loss (NRCS, 2011).

Approximately 1.5 miles downstream of the initial Greybull River diversion is a diversion which feeds the Maller Ditch which itself trends to the northeast. The proposed pipeline would begin construction just below this diversion and continue downstream. From this diversion the German Ditch continues its path to the southeast and approximately 1.35 miles downstream is a second diversion feeding an unnamed ditch. Beyond this diversion the German Ditch continues its path before outfalling into the Willow Creek drainage. Figure 61 depicts the area of all these particular ditches. Further design considerations are discussed below.

*Design Considerations*

In order to complete an accurate design and cost estimate for lining any irrigation canals, the inlet, the canal cross section, discharge structures and soil characteristics all need to be identified. However, for this report a conceptual design was developed and includes cross sections and details for the inlet transition, individual landowner diversions and for the pipe outlet to discharge into Willow Creek.

It's important to note the average channel slopes of this canal system vary significantly. For example, the initial 1.5-mile section off the Greybull River is relatively flat with an approximate 0.15 percent slope [S = 0.0015 foot per foot (ft/ft)]. Conversely, beginning at the Maller Ditch diversion, the slope steepens and averages about 1.1 percent (S = 0.011 ft/ft) downstream to the diversion of the unnamed ditch. Beyond the unnamed ditch diversion the slope of the remaining section down to the last farm then becomes relatively flat again and averages about 0.16 percent (S = 0.00167 ft/ft). Even further downstream the German Ditch then steepens again prior to its outfall into the Willow Creek drainage. Figure 61 depicts the general alignment of this system.

The reasoning to begin construction at the Maller Ditch diversion was chosen because it will allow for an easier transition from the current open ditch configuration to the proposed pipeline-lined ditch. This first and steeper section of the pipeline would utilize 24-inch PVC to convey the water beginning at the Maller Ditch diversion and continuing downstream to the diversion of the unnamed ditch. Because this steeper section features some tortuosity, this section of pipe will likely not follow the existing alignment of the ditch in order to minimize the use of bends which would create turbulence and settling points for sand and silt. Regarding those bends, it is recommended to primarily use 11.25-degree and 22.5-degree bends along the alignment with gated T-sections at each irrigated field which can then tie into the existing PVC piping system to divert water for the flood irrigation.

At the unnamed ditch diversion, the proposal is to then convert the 24-inch pipeline to a 36-inch PVC pipeline. This would allow for a more open-channel flow yielding a slower flow velocity. But this also introduces the probability of sediment build-up over time. As shown on Figure 61, the 36-inch pipeline would continue for several miles before its outlet transition back to the ditch's current native earthen-banks configuration.

The inlet and outlet of the piped irrigation line will require a concrete headwall / cutoff wall with a burial depth of at least four feet to ensure its location below the frost line. This prevents frost jacking over time. The inlet transition section at the Maller Ditch diversion will have a flume section converging into a concrete headwall/cutoff wall with the PVC pipe cast inside. Further downstream the outlet transition back to the native ditch will have a gated headwall followed by ten-foot long section lined with gravel before transitioning back to native soil. The ditch cross section and inlet/outlet details are shown on Figure 61.

With further and more detailed survey information in relation to existing ditch cross section and slope, the possibility exists to decrease the cross-sectional area (e.g., diameter of the pipe) which would save on construction costs during the final engineering design. For this conceptual design, however, it was assumed that any cross-sectional savings would be offset by additional earthwork required to infill, compact and re-grade the western north-south ditch that will not be straightened.

There are some potential considerations that should be addressed with this pipeline conversion project including:

- Straightening the ditch will not be straightforward as the terrain has already been adjusted to ensure gravity flow. A survey of the terrain and routing options need to be considered and reviewed with participating landowners to determine if a different path is preferential to following the existing ditch;
- Outreach should occur to the other landowners to gain an understanding of their interest in this project and potential willingness to pay if funding options are pursued. This will also include an agreement for maintenance (sediment flushing) and repair activities for the proposed pipeline. Legal documentation, such as a memorandum of understanding, among landowners may be warranted to aid in reimbursement fees, and
- This design assumes there are no swelling or collapsing soils in the area of design. In addition, it assumes the existing soils are either free draining sandy soil or normally consolidated fine grain soils. A geotechnical investigation should be performed to validate these assumptions or alter the design accordingly. Final engineering design should take further investigative results into consideration and provide appropriate details for pipe bedding material, if needed.

*Estimated Costs*

The estimated cost to convert the German Ditch to a piped system is $1,777,112 (2018 USD). This cost includes additional design considerations, permitting, legal and rights of way acquisition for BLM, SEO and potentially the USFWS and WGFD (see permitting below). Prices for piping were obtained from Conetec. Additional costs include surveying, excavation and grading, and other labor activities related to installment of the pipe. Table 37 below provides a breakdown of costs.

| Table 37: German Ditch PVC Pipe Conversion Opinion of Probable Cost | | | |
|---|---|---|---|
| Preparation of Final Design and Specifications | | $ 129,573 | |
| Permitting and Mitigation | | $ 3,750 | |
| Legal Fees | | $ 1,563 | |
| Acquisition of Access and Rights of Way | | $ 3,125 | |
| Pre-Construction Costs | | | $ 138,011 |
| Cost of Project Components | | | |
| 1 | PROJECT SURVEY AND LAYOUT | $ 8,250 | |
| 2 | EROSION AND SEDIMENT CONTROL | $ - | |
| 3 | SITE CLEARING | $ - | |
| 4 | EARTHWORK | $ 33,563 | |
| 5 | RETAINING WALLS | $ - | |
| 6 | FENCING | $ - | |
| 7 | IRRIGATION PIPING | $ 1,253,920 | |
| Total Component Costs | | | $ 1,295,733 |
| Construction Engineering Costs | | $ 129,573 | |
| Component and Engineering Costs | | | $ 1,425,306 |
| Contingency | | $ 213,796 | |
| Total Construction Costs | | | $ 1,639,102 |
| **Total Project Cost** | | | **$ 1,777,112** |

*Permitting*

This project involves BLM land and may require consultation with the USFWS and WGFD. The agencies will evaluate the environmental and related social and economic effects of the proposed actions. These agencies also provide opportunities for public review and comment on their evaluations. Evaluation of the Cultural Resources may also be involved.

Communication with the BLM office in Worland indicated an Environmental Assessment could be necessary depending upon the scope of the project. At the very least the project will require a ROW from BLM. There may already be a ROW since the ditch currently crosses BLM land, but if the alignment of the pipe route deviates from this, a new ROW may to be acquired.

Another possible hurdle may be the need to receive a waiver which would essentially circumvent the Ditches and Canal Act. Briefly, this act prevents the alteration of ditches or canals which cross public property. The BLM noted, however, this particular project would likely receive such a waiver because the ditch itself is not being altered. Plus, as BLM stated, the project would enhance the environmental aspects of the ditch through the subsequent water conservation (BLM, 2018c).

Communication with USACE revealed most of these types of projects are exempt from USACE permitting because they are typically maintenance of existing irrigation ditches (Little, 2018). However, the specific scope of the project could change such an exemption. For example, if the ditch intersects streams or groundwater then the wetlands in those areas would typically receive hydrology from natural resources and bring permitting into the picture. Regardless, consultation with USACE during project design is highly recommended.

The intent of this project is to change the means of conveyance of an open ditch to a pipeline. Typically, this kind of project also changes the location of the lands to receive water, i.e., from flood irrigation to pivot. Such a change requires a petition for change of use to the Wyoming SEO. Depending upon the status of the water rights involved, the petition would go before either the Surface Water Division of SEO or the SEO Board of Control. In addition, the petition must be accompanied by a newly-developed map of the area and certified by a Wyoming licensed Engineer or Surveyor. (WSEO, 2018b).

Once again, the scope and specific tasks of the project would determine what, if any, WDEQ permits would be required. For example, if the ditch is artificial, i.e., was never an existing stream or streambed, then a 401 Certification from WDEQ would most likely not be required. If, however, the ditch was originally a natural stream then a Small Construction Permit may be required from WDEQ. In addition, if the project warranted a 404 Permit from USACE then a 401 Certification would be required from WDEQ (WDEQ, 2018b).

Within Big Horn County the project would most likely require a Development Permit depending upon the scope of the project. The county's Land Planning department would need to be notified ahead of time to determine any permit requirement (Muckley, 2018).

#### 3.1.2.4 Stock Water Reservoir on Horse Creek

Another project proposed by one of the stakeholders involves construction of a SW-4 stock water reservoir for Mr. Ventling's ranching operations on Horse Creek which is located in the upper reaches of the Meeteetse Creek drainage. Mr. Ventling has several parcels of land in this drainage. A more reliable supply of water during times of drought could help provide stability to his ranching operations and allow more growth. Currently, a spring on the property is primarily used for watering. During spring runoff, Horse Creek is also utilized.

The area selected for the dam is located at the intersection of three parcels on Mr. Ventling's property and one parcel of BLM land as shown in Figure 63. Consideration for existing water rights was not included in the design consideration. Volume modifications for storage capacity provided in the conceptual design may need to be modified based on water availability.

*Design Considerations*

A conceptual design for the Horse Creek stock pond was developed using the State Engineer of Wyoming's guidelines for SW-4 Stock Water Reservoirs specific to a homogenous earth-fill dam. The design was completed using topography obtained from the USGS. The dam design as shown on Figure 63 consists of the following features:

- Dam footprint over-excavation of 18 inches to remove any loose surficial materials including deleterious materials and/or small rodent holes. This provides a firm foundation for the embankment.
- The total height of the dam is designed at 20 feet from the dam crest to the lowest point on the downstream slope
- The dam upstream slope is designed at a 2.5 horizontal to 1 vertical (2.5H:1V); the downstream slope is at 2.75H:1V. The crest of the dam is 16 feet wide.
- A key trench will extend below the native grade at least eight feet or deeper as directed by the engineer to extend through higher permeability layers (i.e., alluvial deposits). It will be backfilled with a low permeability soil or native coarse-grained soil mixed with bentonite to achieve a maximum permeability of 1 x $10^{-6}$ centimeters per second (cm/s).
- The outlet pipe selected was an 18-inch CMP Pipe of sewer grade quality with a gate valve buried into the embankment.
- The primary spillway has been designed into the right abutment with a channel depth of three feet and a bottom width of 12-feet containing side slopes at 2H:1V. The spillway sizing was based on a conservative Rational Method analysis for the approximate 512-acre basin upstream from the dam using a 100-year rainfall event.

The top six inches (approximately) of the over-excavation will be set aside explicitly as topsoil for revegetation. The dam embankment material will consist of generally lower permeability soils ideally ranging from $10^{-5}$ cm/s to $10^{-6}$ cm/s to help retain water. The fill material will need to contain sufficient sandy or gravely material content which provides a higher angle of repose for stability and better erosion resistance when compared to fine-grained soils. The recommended embankment soil types will need to generally consist of clayey sand, clayey sand with gravel, silty sand, sandy silt, sandy silt with gravel, sandy lean clay, and sandy lean clay with gravel. Compaction should be completed using a Sheepsfoot roller with three full passes for each 6-inch loose lift to achieve minimum compaction of at least 95 percent of a standard proctor.

The bottom five feet of the reservoir stage-storage curve is reserved for dead storage with the ability to capture about 0.90 acre-feet of sedimentation over time prior to reaching the invert of the outlet pipe. The total storage up to the spillway crest elevation is 13.8 acre-feet inclusive of the dead storage. The elevation is about 12.9 ac-ft when excluding dead storage.

There are several potential concerns that should be considered with this proposed project prior to advancing the engineering design further. Those concerns include:

- The dam was designed with the assumption that an in-stream reservoir would be permitted. If, after consultation with agencies, an in-stream permit is not allowed then additional routing, permitting and design consideration will be needed for an off-stream reservoir requiring those same additional routing, permitting and design considerations.
- The dam was designed without completion of any geotechnical engineering evaluations for the dam's foundation or for potential borrow areas.
- The flatter slope on the right abutment leads to a longer dam crest length and correspondingly larger embankment volume resulting in a less than optimal water storage-to-embankment volume ratio.

- Water right permitting including change-of-use or the need to obtain sufficient quantity for senior water rights need to be completed prior to any final design or other permitting applications.
- Depending upon seniority of water rights in Horse Creek to appropriate water for a stock reservoir, the outlet may need to be changed to a drop inlet structure with stop-logs to regulate the reservoir elevation and ensure the dam does not impound water and decrease the flows downstream for those senior water rights holders.

*Estimated Costs*

The estimated cost to construct the stock water reservoir on Horse Creek is $227,129 (2018 USD). This cost includes additional engineering, geotechnical investigation, surveying, permitting, legal and rights of way acquisition for BLM, SEO and potentially the USFWS and WGFD (see permitting below). Table 38 provides a breakdown of costs. Several additional cost considerations for final design include:

- The dam was sized to maximize the volume of storage while still staying under the 20-foot maximum height requirement for an SW-4 stock reservoir. Thus, it may be possible to reduce the height and corresponding storage volume in the reservoir accordingly if less water or a lower cost dam is needed. The dam as laid out however, minimizes the unit cost per unit volume of water stored in the dam as 51 percent (i.e., 6.6 acre-feet) of the 12.9 acre-feet of effective water storage between the top of dead storage and the spillway crest occurs in the top three feet.
- The dam as currently designed has riprap along the upstream slope as this is expected to be subject to erosion from regular winds that come from the northwest. This riprap was assumed to be imported in from Montana as no source of durable riprap exists close to the site. However, due to small size of the dam and if suitable alluvial gravels including cobbles and small boulders exist nearby, it may be possible to screen larger rock with a grizzly screen either within the dam footprint during over-excavation or from the borrow area(s) in order to provide this rock locally at a lower cost.
- No riprap or other erosion controls were designed or costed for the emergency spillway as it was envisioned to be revegetated and at a shallow slope near the critical velocity until well downstream of the dam on the right abutment. However, cattle activity around a water hole can be detrimental to vegetation and this may likely require some type of erosion control system capable of withstanding heavy animal activity during final design.

| Table 38: Horse Creek Stock Pond Dam Opinion of Probable Cost | | | |
|---|---|---|---|
| Preparation of Final Design and Specifications | | $ 50,000 | |
| Permitting and Mitigation | | $ 10,000 | |
| Legal Fees | | $ 1,250 | |
| Acquisition of Access and Rights of Way | | $ 1,563 | |
| Pre-Construction Costs | | | $ 62,813 |
| Cost of Project Components | | | |
| 1 | PROJECT SURVEY AND LAYOUT | $ 5,500 | |
| 2 | EARTHWORK | $ 112,934 | |
| 3 | OUTLET PIPE | $ 11,460 | |
| Total Component Costs | | | $ 129,894 |
| Construction Engineering Costs | | $ 12,989 | |
| Component and Engineering Costs | | | $ 142,884 |
| Contingency | | $ 21,433 | |
| Total Construction Costs | | | $ 164,316 |
| **Total Project Cost** | | | **$ 227,129** |

*Permitting*

Because this project is located on private land, there would be no federal permits or ROW required. However, during construction if access to the property would involve any federally-owned land, then a ROW would be required. That same scenario is in place regarding state land. Any access would require a state ROW.

Communication with the USACE indicated construction of stock ponds built solely for purposes of watering livestock more often than not fall within agricultural exemptions and don't require a permit (Little, 2018). However, there are some factors which would bring USACE regulation into play including:

- Construction on a perennial stream;
- If the purpose of the pond includes habitat enhancement such as a recreational fish pond or for migratory birds.

If the final details of the project include construction of a dam on Horse Creek and/or involve existing wetlands, then permits from both USACE and WDEQ would most likely be required. If the final details include construction of an -off-channel reservoir then permitting requirements from both USACE and WDEQ may be less. Prior to any construction, consultation with USACE and WDEQ is highly recommended.

A permit will be required from SEO before commencing construction of any reservoir or dam. Maps and/or plans must be submitted with the permit application. This includes specific requirements for dam height, reservoir storage capacity and mapping specifics among other permit requirements.

Within Park County the project would most likely require a Development Permit depending upon the scope of the project. The county's Land Planning department would need to be notified ahead of time to determine any permit requirement (Muckley, 2018).

## 3.2 MANAGEMENT TOPICS

Throughout the process of this study, numerous comments have been made regarding the need of repairs on infrastructure, the inability to procure funding for repairs, and a need for management. Several comments include the following:

> *"Expanding Lower Sunshine doesn't help those upstream"*
>
> *"Can landowners combine together to apply for funding?"*
>
> *"Doesn't it seem we need to form more districts, and God forbid, more taxes to help fix things?"*
>
> *"Why not take Bench and Farmer's Canal and put them into a district?"*
>
> *"We need to get everyone together and work together to solve these problems."*

Irrigation districts, such as the BCC and FCC are struggling to secure funding due to not being a public entity. Smaller, private owners also struggle to secure funding and gain cooperation from neighboring landowners to make repairs. Some of the additional issues for private landowners, such as the 7K Ranch project described previously, are that projects do not benefit enough compared to other projects submitted for funding. This issue becomes a recurring problem when the funds from NRCS and the Small Water Project Program (SWPP) of the WWDC are repeatedly awarded to higher prioritized projects.

Funding also becomes an issue when it comes to rehabilitation projects that are aimed at improving or protecting the watershed, such as Russian olive removal or stream stabilization. Often, funding opportunities focus on water development and economic improvement options (i.e., conversion to sprinkler irrigation) which again preclude opportunities for smaller, obscure projects to be funded. Many times, those types of projects are ineligible for certain types of funding or are considered lower priorities by some agencies. For example, the SWPP may consider environmental enhancement and flood control projects to be of a lower priority than other small projects. Projects chosen for funding through the SWPP must be able to demonstrate a public benefit.

Additionally, funding amounts from individual sources are often so small that the project owner, whether it be an irrigation district or private, has the onus of finding additional funding or financing a project on his or her own, which is oftentimes beyond their means. For example, conversion of a dirt lined ditch to concrete provides much benefit to the watershed by increasing irrigation efficiencies by reducing water loss. However, the cost to install 4,000 linear feet is estimated at nearly $150,000. This project may be eligible for certain funding, but NRCS will only fund a portion of project costs, typically up to 75 percent and the SWPP only funds up to $35,000 for individual projects. Although any amount of funding is beneficial, in many instances, the remaining amount of money required would likely be prohibitive for a project to be completed.

One option to remedy the concerns of stakeholders and to assist in creating funds and organization for project prioritization is to create a Watershed Improvement District (WID). This option is currently being pursued by

the BCC to become eligible for state funding. The next section briefly describes the function and process of becoming a WID and following sections describe the general concepts, strengths, weaknesses, opportunities and threats (SWOT) of creating a Greybull River WID.

### 3.2.1 Watershed Improvement Districts

The purpose of a WID is to provide prevention and control of erosion, floodwater and sediment damages; storage and conservation development; utilization and water disposal; preserve and protect land and water resources; health, safety and welfare of public; and for agricultural purposes. The 2018 Wyoming Statues, Title 41-Water, Chapter 8–Watershed Improvement Districts describes the definitions, purposes, establishment, board of director authority, assessment, and other processes of a functioning WID. The following provides a high-level overview of the processes and functions of a WID. A copy of the statue is provided in the project notebook and can also be accessed through the link below.

http://www.wyoleg.gov/StateStatutes/StatutesDownload

Other laws that apply to WIDs include the Special Districts Election Act (22-29-101), Bond Elections (22-21-103) and Auditing Requirements [16-4-121 (f) & 9-1-504 (iii)]. WIDs can be considered a subdivision of CDs, but CDs are not responsible for administration or management of a WID; CDs act more as consulting and advisory for WIDs.

***WID Creation Process***

If the creation of WID is desired by landowners within the watershed, the general process, as defined by the above reference statues, is as follows:

- a petition is developed for WID creation by the landowners;
- a hearing is held by the Conservation District(s);
- a referendum vote is completed by the landowners included in the proposed WID; and
- the Conservation District(s) declare final approval/denial.

The petition to form a WID needs to be signed by not less than 25 percent of the landowners owning at least 25 percent of the assessed valuation of property within the area proposed to be established as a WID. The petition must include the proposed boundaries, the acreage involved, the proposed name, the reason for creation and a description of who will pay. The WID boundary can cross other boundaries including conservation districts or irrigation districts.

If a petition is developed that adheres to these criteria, the CD(s) will then have a hearing to determine whether there is a need for the creation of the WID in the interest of public health, safety and welfare. Public hearings need to be held during development of the proposed boundaries and naming convention of the WID and this needs to be held within 45 to 90 days after the petition has been filed. In addition, if the Board of Supervisors receives protests signed by a minimum of 35 percent of assessed valuation of property, then the petition will fail.

If the CD(s) determine that there is a need for the WID based on the public hearing, then there will be a referendum vote by qualified landowners within proposed WID boundaries. If "at least a majority of the votes cast in the referendum, which affirmative votes represent a majority of the acreage contained in the proposed WID, favor creation of the WID", then the CDs can determine that the WID would be "administratively practicable and feasible" and they can declare the WID created.

***WID Authority***

A WID is operated by a board of directors consisting of five landowners within the WID boundaries. The Board of Directors are elected by the WID landowners on an annual basis and have at least the titles of chairman, secretary and treasurer. The Board of Directors do not receive a salary but can receive expenses for meeting and travel to perform their duties. The Board of Directors are under the supervision of the Conservation District Board of Supervisors. At a minimum the Board of Directors are required to file an annual report including financial statement, O&M activities for the preceding year and O&M activities planned for the present year, plus hold quarterly meetings of which one to be an inspection tour.

The WID has the authority to levy and collect assessments for projects identified within the district boundaries. Projects are approved or rejected through a hearing where three appraisers are appointed to identify costs and proportion assessments to those that accrue the benefit of the project. A hearing is conducted for the projects. The WID also has the power of eminent domain and has the ability to borrow money, issue bonds and apply liens.

WIDs can be dissolved if determined necessary. Dissolving a district can be completed in three ways:

1. Petition signed by 25 percent of voters owning at least 25 percent of the land within the district;
2. By resolution of the Board of Directors indicating dissolving is in the best interest of the inhabitants of that district; and
3. By resolution from county commissioners when the WID has failed to elect a Board of Directors, the WID territory is uninhabited, or if the county commissioners determine it is in the best interest of the people.

The process has been completed numerous times within Wyoming and several existing WIDs were contacted and interviewed to determine the hurdles, benefits and historical knowledge of this process. Those findings are presented in the next section where the SWOT of creating a Greybull WID is discussed.

### 3.2.2 Greybull River WID

Many of the watershed-wide issues that have been identified in the study fall under the purposes of a WID, including prevention of erosion, floodwater damage, storage development, and agricultural purposes. Also described in the rehabilitation section, there is a hurdle to obtain funding for many of the projects, either due to large project cost estimates, lower prioritization or ineligibility. Forming a WID in the Greybull River watershed could help to alleviate some of these hindrances.

The concept of forming a WID is not new to the area. Discussions with the former GVID General Manger (Tom Laidlaw, January 2018) indicate that this had been discussed by the GVID Board member several years

ago. In general, the GVID is open to the possibility of becoming a WID with the BCC; it appears some of the irrigation districts are also open to the idea. Loren Smith, Superintendent Water Division III, has expressed through email communications that formation of a WID would likely have less expenses and a lower level of effort, as compared to developing a single irrigation district for the watershed.

The issues faced by the Greybull River Watershed are common themes in other areas where smaller un-organized ditches are looking for funding from WWDC. Some examples of successful WID formation include the Nowood WID, Cottonwood/Grass Creek WID and the Red Lane WID. For each of these entities, there was a strong interest by the landowners to create a WID. Interest and participation is a key component in the successful development of a WID and a lot of effort is needed by the stakeholders in the area to gain interest and participation. Conversations with the conservation districts associated with the above mentioned WID and Greybull River watershed stakeholders have helped to identify a Strengths, Weaknesses, Opportunities and Threats (SWOT) outline to further assess the viability of developing a WID in the Greybull River Watershed. The next section presents these topics.

### ***Greybull River WID SWOT***

In order to help determine if it is reasonable to continue to pursue development of a Greybull River WID, a SWOT was developed to help identify the concerns that are likely to be brought up during public engagement, as well as the strengths and opportunities that can be used to continue to educate landowner during continued community outreach. Table 39 provides a summary of the SWOT topics discussed in more detail below.

#### *Strengths*

There are many strengths that can be leveraged by a WID. Most significant is the ability to acquire funds that are not available to private entities, specifically WWDC funding. There is also the ability to have financial flexibility through various mechanisms including borrowing money, assessment to landowners receiving benefits, levying taxes and enforcing liens. The WID can use this authority to structure and plan for prioritized needs in the area and can allow for pro-active maintenance rather than reactive rehab for failing infrastructure, flood events or watershed improvement opportunities. The funds leveraged by the WID can also be used for many additional projects that are not typically covered by state or federal funds. For example, if the watershed determines the invasive Russian olive tree needs to be eradicated, finances can be raised and allocated to this project. On the other hand, if a large ditch is determined to need upgrades to pipe for efficiency purposes, the WID can also apply to the WWDC for larger grants/funding. The options for funding multiple projects increase with a WID and reserve funds can be created.

In addition, there is the ability and intent of the WID to assign and apportion benefits, assessment, and project costs to specific landowners across the watershed. For instance, this means that if a project only benefits users off the Hi-Line Canal, these users will be the primary benefactors and thus will be apportioned the assessment costs.

The WID also provides organization and structure to the un-organized groups, individual landowners and other outlying stakeholders that are not currently benefiting from some of the existing entities (FCC, BCC, GVID, etc.). As clarification, un-organized groups do not indicate the groups are not functioning, but that they

are not official organizational entities. The WID also has legal rights to enforce payment and cooperation within the district which is a great strength when compared to landowner comments regarding their struggle to recoup maintenance costs from neighboring ditch users for work performed. The WID has the power to enforce liens and, if needed, has the power of eminent domain. Landowners still retain their water rights.

Finally, there is great strength in the ability of the landowners to vote for the Board of Directors of the watershed. Members are up for re-election every four years, with members staggered with elections occurring on an annual basis. This allows a level of democratic control over the representation on the Board of Directors; if stakeholders in the WID do not feel one of the five directors are fairly representing the district, there is the ability to vote the member out. This is different from the existing irrigation districts where the board members are often selected without elections and equitable representation may not always be present.

*Weaknesses*

Although there are many benefits to a WID, there are some potential weaknesses to a WID that need to be considered. Even though the district has the ability to fund and prioritize large and small projects, there is a potential for small voices to be lost. The best mitigation for this is to continue to promote public outreach and input during the quarterly WID meetings.

Not all smaller entities within the WID boundary would need to be dissolved to create a WID. This has potential to cause certain issues. For instance, an existing irrigation district within the WID would be applying assessments to landowners and both entities would be eligible to pursue funding opportunities. This could create political strife and increase competition to secure funding. The logistics of which entities would dissolve or remain after the creation of a WID would need to be evaluated prior to completion of the petition.

There is also a weakness in developing the correct and equitable determination of who will benefit from a specific project and what the magnitude of those benefit may be. There may be contention with the decisions made through the statutory process of having three appraisers assess each project. This process may be cumbersome or expensive and is also likely to require a longer-term timeline in order to conduct public hearings, issue bonds, apply for funding, etc. to get a project started. All of these potential weaknesses will need to be addressed during community outreach when trying to determine the level of interest in the area for developing a Greybull River WID.

*Opportunities*

Opportunities are different from strengths in that they are not necessarily an inherent aspect of the WID, but have potential to enhance the function of the area through the WID. The biggest opportunity for a WID is the ability to organize and prioritize projects across the watershed. Both large and small projects would have more opportunities for funding, both internally and externally. Additionally, there is an opportunity to complete similar projects (e.g., ditch dredging) concurrently meaning a potential for costs savings, such as mobilization costs, economies of scale opportunities, and a reduction of competition for funding applications.

With a WID, there is also potential for sharing technical expertise, tricks-of-the-trade, and other information between landowners across the watershed. The WID can be a great opportunity for education and outreach within the boundaries.

*Threats*

Threats are concerns that will need to be addressed during initial public meetings and coordination with other entities within the proposed WID boundary. These items are not inherent to the process of becoming a WID but may slow or stop the process altogether if not addressed or negotiated. Threats that cannot be resolved may result in an alternate boundary for the WID. Additionally threats may arise as interests and demographics within the WID change. One of the largest threats is the perceived challenge to dissolve existing entities to create a single, large entity. Some existing entities may not be willing or interested in giving up local authority. This can be addressed through negotiations and communication, but ultimately may not be able to be resolved. If areas are not interested, there is the option to modify WID boundaries.

Another threat is the requirement that 25 percent of landowners representing at least 25 percent of the property within the WID need to have an interest and sign the petition. This may be a hurdle if landowners with significant acreage are not willing to participate. This issue can also be resolved through public communication to gauge interest and resolve concerns or interested parties can develop an appropriate boundary that continued to provide benefit to the watershed but excludes certain areas. It should be noted that in some instances, it may be difficult if a landowner wants to be excluded; the landowner has the onus of proving no benefit from the WID in order to be removed from a WID that has been formed.

A similar threat is the changing demographics of landowners in the watershed. Many comments from the survey mentioned that property is being subdivided and water usage is changing (ex., less agriculture, more residential gardens, etc.). Additionally, many respondents and landowners that reached out during this study tended to be newer property owners, often coming from out-of-state or out of the region. This brings in differing perspectives on how the watershed should be managed. Although different perspectives can be a positive thing, it is identified as a threat because of a potential conflict between generational stakeholders and new landowners. Again, continued communication and appropriate representation on the WID Board of Directors can help to alleviate this threat.

The perspective from some of the other WIDs in the area indicate the cost to create and operate a WID was more than was originally expected. The extent of costs would include engineering and legal fees during the petition process and would also include annual assessment costs, election costs and additional legal cost related to operating the WID. These costs would vary depending on the size of the WID boundary and are not included in this report; however, gaining a reasonable estimate of operating costs during the petition and public outreach phase is suggested.

Finally, there has been a change in the Wyoming legislature's attitude regarding the number of special districts being created to obtain funding. The Executive Director of the Wyoming Association of Conservation Districts has indicated the legislature is questioning the process although there is no information regarding any WID petition being denied due to a concern of too many special districts. Changing legislative attitudes should be monitored and decision-makers should be included in discussions from the beginning to help guide the best path forward.

***Greybull River WID Next Steps***

Throughout this process, the creation of a larger management district has become the primary need to maintaining a functioning watershed. Feedback from public meetings, comments and a history of GVID exploring this option also points to a general interest and consensus that a Greybull River WID is warranted. However, it should be noted that public participation for this study was not as high as would have been preferred to appropriately gauge feasibility of pursing this option. It is recommended that the sponsors of this study, the MCD and SBHCD, continue to gauge interest in this potential. It may even be reasonable to consider a Level II Feasibility Study with the WWDC. A Level II Feasibility Study could complete a majority of the petition process: public outreach and meetings, development of proposed WID boundaries and acreage involved, identify the proposed name, develop language for the reason for creation and a description of who will pay and benefit. The logistics and ability for WWDC to fund this type of study will need to be further discussed and assessed through the WWDO application process.

# 4. PERMITTING

Nearly every water project will need some sort of permit whether the project is maintenance-oriented, repair or replacement of existing infrastructure, or the formation of a new storage reservoir. Most often, location determines the permitting process for areas administered by the BLM, USFS, Bureau of Reclamation, the state of Wyoming, either Park or Big Horn Counties or privately held land. The permitting process can be as complicated as the BLM requiring a full Environmental Impact Statement (EIS) or as simple as a routine water-rights application to Wyoming's SEO. The Rehabilitation and Management Section touches on the most likely permits needed for those projects identified but may not be all inclusive since the conceptual design does not fully scope all details. This section outlines the potential permits, processes and/or requirements for federal land plus state and county requirements. Table 40 provides a summary of agencies involved with the permitting processes while Table 41 provides a summary of the rehabilitation projects and identifies each likely or potentially applicable permit or regulation that may need to be considered.

## 4.1 FEDERAL PERMITTING/REGULATIONS

### 4.1.1 NEPA Process

The National Environmental Policy Act (NEPA) was signed into law in 1970 and requires federal agencies to assess the environmental effects of their proposed actions prior to making decisions. Such actions could include the federal funding of a project, federal approval for a project or simply projects proposed on federal land. These actions also include:

- Making decisions on permit applications;
- Adopting federal land management actions; and
- Constructing highways and other publicly-owned facilities.

Using the NEPA process, the agencies evaluate the environmental and related social/economic effects of the proposed actions. These agencies also provide opportunities for public review and comment on their evaluations. More specific information can be found at:

https://www.epa.gov/nepa/national-environmental-policy-act-review-process

### 4.1.2 USACE Section 404 Permit

According to the EPA, Section 404 of the Clean Water Act establishes a program which regulates the discharge of dredged and/or fill material into the waters of the U.S., including wetlands. Activities in waters regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports) and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States, unless the activity is exempt such as certain farming or forestry activities (EPA, 2018). Section 404 requirements include activity involving construction in a jurisdictional wetland or waters of the U.S., including intermittent streams.

The basic premise of the program is that no discharge of dredged or fill material may be permitted if: (1) a practicable alternative exists that is less damaging to the aquatic environment or (2) the nation's waters would

be significantly degraded. In other words, when you apply for a permit, you must first show that steps have been taken to avoid impacts to wetlands, streams and other aquatic resources; that potential impacts have been minimized; and that compensation will be provided for all remaining unavoidable impacts.

Proposed activities are regulated through a permit review process. An individual permit is required for potentially significant impacts. Individual permits are reviewed by the USACE which evaluates applications under a public interest review, as well as the environmental criteria set forth in the CWA Section 404(b)(1) Guidelines, regulations promulgated by EPA. Some states have assumed this permitting authority and regulate these activities.

For most discharges that will have only minimal adverse effects, a general permit may be suitable. General permits are issued on a nationwide, regional, or state basis for categories of activities. The general permit process eliminates individual review and allows certain activities to proceed with little or no delay, provided that the general or specific conditions for the general permit are met. There are general conditions the prospective permittee must comply with to quality for permit authorization. Some of those conditions relevant to the Greybull River watershed include but are not limited to the following activities.

**For Nationwide Permit (NWP) 13 – Bank Stabilization**

- No material is placed in excess of the minimum needed for erosion protection;
- The activity is no more than 500 feet in length along the bank, unless the district engineer waives this criterion by making a written determination concluding that the discharge will result in no more than minimal adverse environmental effects (an exception is for bulkheads—the district engineer cannot issue a waiver for a bulkhead that is greater than 1,000 feet in length along the bank);
- The activity will not exceed an average of one cubic yard per running foot, as measured along the length of the treated bank, below the plane of the ordinary high-water mark or the high tide line, unless the district engineer waives this criterion by making a written determination concluding that the discharge will result in no more than minimal adverse environmental effects;
- The activity does not involve discharges of dredged or fill material into special aquatic sites, unless the district engineer waives this criterion by making a written determination concluding that the discharge will result in no more than minimal adverse environmental effects;
- No material is of a type, or is placed in any location, or in any manner, that will impair surface water flow into or out of any waters of the United States;
- No material is placed in a manner that will be eroded by normal or expected high flows (properly anchored native trees and treetops may be used in low energy areas);
- Native plants appropriate for current site conditions, including salinity, must be used for bioengineering or vegetative bank stabilization;
- The activity is not a stream channelization activity; and
- The activity must be properly maintained, which may require repairing it after severe storms or erosion events. This NWP authorizes those maintenance and repair activities if they require authorization. rehabilitation

**For Nationwide Permit 45 – Repair of Uplands Damaged by Discrete Events**

This NWP authorizes discharges of dredged or fill material, including dredging or excavation, into all waters of the United States for activities associated with the restoration of upland areas damaged by storms, floods, or other discrete events. This NWP authorizes bank stabilization to protect the restored uplands. The restoration of the damaged areas, including any bank stabilization, must not exceed the contours, or ordinary high-water mark, that existed before the damage occurred. The district engineer retains the right to determine the extent of the pre-existing conditions and the extent of any restoration work authorized by this NWP. The work must commence, or be under contract to commence, within two years of the date of damage, unless this condition is waived in writing by the district engineer. This NWP cannot be used to reclaim lands lost to normal erosion processes over an extended period.

This NWP does not authorize beach restoration or nourishment.

Minor dredging is limited to the amount necessary to restore the damaged upland area and should not significantly alter the pre-existing bottom contours of the waterbody.

**Notification:** The permittee must submit a pre-construction notification to the district engineer (general condition 32) within 12 months of the date of the damage; for major storms, floods, or other discrete events, the district engineer may waive the 12-month limit for submitting a pre-construction notification if the permittee can demonstrate funding, contract, or other similar delays. The pre-construction notification must include documentation, such as a recent topographic survey or photographs, to justify the extent of the proposed restoration.

**Note:** The uplands themselves that are lost as a result of a storm, flood, or other discrete event can be replaced without a section 404 permit, if the uplands are restored to the ordinary high-water mark (in non-tidal waters) or high tide line (in tidal waters). (See also 33 CFR 328.5.) This NWP authorizes discharges of dredged or fill material into waters of the United States associated with the restoration of uplands.

**For Nationwide Permit General Conditions**

To qualify for NWP authorization, the prospective permittee must comply with the following general conditions, as applicable, in addition to any regional or case-specific conditions imposed by the division engineer or district engineer. Prospective permittees should contact the appropriate Corps district office to determine if regional conditions have been imposed on an NWP. Some of those general conditions include but not limited to:

- Navigation;
- Aquatic Life Movements;
- Spawning Areas
- Migratory Bird Breeding Areas
- Suitable Material
- Water Supply Intakes
- Adverse Effects from Impoundments
- Management of Water Flows
- Fills Within 100-Year Floodplains
- Soil Erosion and Sediment Controls
- Removal of Temporary Fills
- Proper Maintenance
- Single and Complete Project
- Wild and Scenic Rivers

- Endangered Species
- Migratory Birds and Bald and Golden Eagles.
- Historic Properties
- Discovery of Previously Unknown Remains and Artifacts
- Designated Critical Resource Waters
- Mitigation
- Safety of Impoundment Structures
- Water Quality
- Regional and Case-By-Case Conditions (this includes Blue and Red Ribbon Trout Streams and Native Species Status 1, 2, and 3 Streams)
- Activities Affecting Structures or Works Built by the United States
- Pre-Construction Notification

For more information visit: http://www.nwo.usace.army.mil/Missions/Regulatory-Program/Wyoming/

Contact information in Wyoming:
Kevin Little
U.S. Army Corps of Engineers
Wyoming Regulatory Office
2232 Dell Range Blvd, Suite 210
Cheyenne, Wyoming 82009
307-772-2300 x3

### 4.1.3 BLM Permitting

The BLM will be the lead agency if any potential project is located on BLM administered land. The agency will direct and manage the preparation of all documentation relating to any environmental issues such as the development of an EA or EIS. In addition, the BLM will manage all NEPA requirements. The proposed project would have to comply with the applicable BLM resource management and requirements including protections for sage grouse, and other sensitive animal and plant species.

Once the BLM initiates the NEPA process, the applicant agrees to pay all costs of the EIS/EA and must also sign a 'Cost Collection Agreement.' This agreement obligates the applicant to pay for all BLM costs associated with the NEPA process. In addition, potential projects on BLM land usually involve the USACE acting as a Cooperating Federal Agency.

Potential project applicants must also submit a right-of-way application with the BLM. This particular application must include a thorough project description, plus a summary of alternatives investigated detailing the reasoning for their elimination. For more information visit: https://www.blm.gov/wyoming

The Greybull River is the boundary for BLM field office jurisdiction. The area to the north of the river is managed by the Cody field office while south of the river is managed by the Worland office. Those contact specifics include:

**Cody Field Office**
R. Cade Powell
*Field Manager*
1002 Blackburn Street
Cody, WY 82414
Phone: 307-578-5900
Fax: 307-578-5939
E-mail: Cody_WYMail@blm.gov

**Worland Field Office**

John Elliot
*Field Manager*
101 South 23rd Street
Worland, WY 82401

Phone: 307-347-5100
Fax: 307-347-5228
E-mail: Worland_WYMail@blm.gov

### 4.1.4 USFS Permitting

Similar to the BLM, the United States Forest Service (USFS) will be the lead agency for any proposed project on USFS-administered land. Initially, the applicant will need to submit a Special Use Permit application to the USFS. This process is very similar to the BLM right-of-way process. Also, like the BLM, as lead agency the USFS will initiate the NEPA process, if necessary, and will also be responsible for subsequent NEPA compliance often in conjunction with the USACE. Much like the BLM, the applicant is responsible for all NEPA compliance costs, plus the costs of any required EA/EIS. It should be noted that agency expenses related to applications are the responsibility of the applicant. This includes the agency expenses as a result of any contracted consultant or third-party entities. In this situation, the applicant cannot direct the work of that third party. Those tasks are still directed by the USFS or any of the lead federal agencies involved. For more information: https://www.fs.fed.us/managing-land

### 4.1.5 USFWS Consultation

Section 7 of the Endangered Species Act requires federal agencies to consult with the U.S. Fish & Wildlife Service (USFWS) when the actions of a proposed project may affect threatened or endangered species. Initially, the lead agency such as the BLM will prepare a biological assessment to determine potential effects on any threatened or endangered species, or any critical habitats within the area. The USFWS must then either approve the assessment or require the proposed project to formulate appropriate mitigation measures to the project's scope, location and methods.

### 4.1.6 Other Permitting Requirements

Fish and Wildlife Coordination Act

This act requires federal agencies to consult with the USFWS, and the fish and wildlife agencies of States where the "waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted or otherwise controlled or modified" by the actions of an agency under a federal permit or license. Typically, this is done via the preparation of a Fish & Wildlife Coordination Act Report documenting the analysis of potential consequences to fish and wildlife resources as a result of the proposed project. Such a report would include mitigation measures approved by the USFWS. These mitigations could include compensation as a result of project-caused losses of wildlife resources.

Migratory Bird Treaty Act

This Act applies to any federal actions which would adversely affect a migratory bird or its eggs, young or nest. The Act requires there should be no taking of migratory birds including its eggs or nest but also the interference with nesting which could cause nest failure. It should be noted some agencies apply this Act to

all species, while others focus on sensitive species and raptors. Another note of interest is the fact that the Act is an older law which does not specify mitigation of impacts and how those impacts should be avoided.

Golden and Bald Eagle Protection Act

This Act specifically protects both eagle species. It prohibits the barter, purchase, take, possession, offer to sell or sale of, export or import, barter, transport of either eagle species. This includes any dead or alive bird, plus any part, egg or nest unless specifically authorized by the project's approved permit. Such permit authorization may be issued for the non-purposeful take as a result from disturbances, next removal or other project-related activities. Such permit specifics may be required if either species is located in the vicinity of a project.

National Historic Preservation Act

Section 106 of this Act requires federal agencies to account for the effects of their actions or undertakings on historic properties. It also requires the agency to afford the Advisory Council on Historic preservation a reasonable opportunity to comment on permit applications. In addition, the Act also requires the agency to consult with the state's historical preservation office, plus any tribal representatives, local groups and other government entities which could be impacted. In these instances, the agency would be required to identify and evaluate the National Register eligibility of cultural resources within a project's area, plus determine how a project would impact such resources then seek any necessary mitigation measures to avoid and/or minimize those impacts to the resources in question. Section 2.3.2 of this report details the cultural resource aspects within the watershed's boundaries.

## 4.2 STATE PERMITTING/REGULATIONS

### 4.2.1 Wyoming State Engineer's Office Surface Water Storage/Groundwater Permits

The water rights system of appropriation is administered by the WSEO. Before any diversion or storage of surface water is made, the applicant must complete a filing and receive the ensuing permit for any of the approved beneficial uses outlined in the application. When an existing ditch will be utilized for reservoir storage then an enlargement permit would be required. Regarding groundwater applications, the WSEO will review the potential for interference impacts to existing wells or surface water rights in the vicinity of the proposed well.

Forms S.W.3 and/or S.W.4 are required if a proposed stock reservoir will be constructed in an ephemeral stream or an existing draw. If the proposal is to develop surface water or groundwater sources serving any potential water management or land use practices, then the project sponsor(s) must obtain water rights permits and associated appropriations.

In addition, there are potential water projects which would require water rights permitting or review by the WSEO including:

- Construction of small reservoirs serving stock and other water uses;
- New installation or repair of water measurement devices/structures;
- Repair, construction and rehabilitation of diversion/headgate facilities;

- Diverting water through ditches or pipelines;
- Water storage in reservoir;
- Enlargement to existing ditch or storage facilities;
- In-stream flow purposes;
- Temporary industrial water hauls;
- Weather modification;
- Construction or rehabilitation of stock water facilities such as tanks, troughs and conveyances; and
- Spring developments or installation of new wells for stock watering.

The WSEO has developed the state's approval process for regulating dam safety. Any proposed dam must be approved by the WSEO if the proposed structure is greater than 20-feet high or will impound more than 50 ac-ft of water. For new dam proposals, the applicant must provide for review design drawings and documentation to support the construction. For existing dams, the applicant must also supply for review the plans and specifications for the alteration, modification or repair of a dam. In addition, any proposed diversion system capable of carrying more than 50 cfs must also receive approval by the WSEO.

If an applicant proposes to drill a new well or develop a spring, then a permit and appropriation must be received from the WSEO. In such a case, if the total yield or flow of the spring is 25 gpm or less and the beneficial use is stock/domestic, then the water source can be appropriated as groundwater. However, if the flow of a spring exceeds 25 gpm, then the water source would be treated as surface water.

Access agreements must be obtained from current landowners if an applicant does not own the land. In such a case, the applicant must hire a licensed Wyoming well driller and pump installer for well completion. For more information, contact the SEO Surface Water Division at 307.777.6475 or visit:

http://seo.wyo.gov/surface-water

### 4.2.2 WDEQ Permitting

The Wyoming Department of Environmental Quality (WDEQ) administers the National Pollution Discharge Elimination System (NPDES) permit and the associated Section 401 certification under the Clean Water Act. This certification ensures the authorized activities meet the state's water quality standard and do not degrade the water quality.

As noted in Section 2.3.4, operators of any point source discharge are required to obtain a WYPDES discharge permit from the WDEQ. As defined by the WDEQ, a point source means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation or vessel or other floating craft, from which pollutants are or may be discharged (WDEQ, 2013). For more information, call the Lander Field Office at 307.332.3144 or visit the state web site at: http://deq.wyoming.gov/

### 4.2.3 Wyoming Game and Fish Department

Proposed water projects falling under the requirements of NEPA, the Fish & Wildlife Coordination Act and other federal and state permitting actions and/or approvals would be required to consult with the WGFD. This includes any potential impacts to the core habitats of the greater sage-grouse in accordance with State of Wyoming Executive Orders 2015-4 and 2017-2. In these cases, the project would need to be assessed utilizing the WGFD's Density Disturbance Calculation Tool (DDCT). The WGFD would then make mitigation recommendations for concerns relating to the sage grouse, other wildlife or fishery resources. Occasionally, a Memorandum of Understanding (MOU) is developed between the WGFD, the WWDC and project sponsors regarding any proposed mitigation procedures. Some proposed projects on private land may not be required to consult with the WGFD but consultation is highly recommended. For more information, call the Cody Field Office at 307.527.7125 or visit: https://wgfd.wyo.gov/Regional-Offices/Cody-Region

### 4.2.4 Wyoming State Historical Preservation Office

As noted earlier, the Wyoming SHPO is consulted by federal agencies, state agencies and private consultants when the significance of cultural resources are potentially affected by any ground disturbing activities. When proposing any water project, early contact with the SHPO should be made to determine any possible concerns as a result of the project. For more information, call 307.777.7697 or visit: http://wyoshpo.state.wy.us/

### 4.2.5 Wyoming Board of Land Commissioners

The Wyoming Board of Land Commissioners is responsible for regulating all activities on state-owned land including the granting of rights-of-way. This regulation is accomplished through the State Lands and Investment Board. The proposed construction of any reservoir, road, utility, ditch or facility on state or school land must have a right-of-way. This is a requirement detailed in the *"Rules and Regulations Governing the Issuance of Rights of Way"* (W.S. 36-20 and 36-202). For more information, call the Lander Field Office at 307.332.7209 or visit: http://lands.wyo.gov/boards/sblc

## 4.3 COUNTY PERMITS

Within both Park and Big Horn counties, the scope of the project and the scope of the tasks to be performed would determine the required permits from those counties. For example, a permit may not be required if access is temporary in nature on established roads and/or ground disturbance isn't anticipated. The county may simply need to be notified of all the temporary activity to be performed. However, county permit(s) would be required if there will be permanent construction of roads, installation of utilities, work done in a flood plain, other ground disturbance, etc.

For more information in Big Horn County, call 307.568.2424 or visit:

http://www.bighorncountywy.gov/departments/land-planning/planning-zoning

For Park County, call 307.527.8540 in Cody, or 307.754.8540 in Powell; or visit:

http://www.parkcounty.us/planningandzoning/planandzone.html

# 5. FUNDING OPPORTUNITIES

The ability to pay for the projects identified and described in Section 3 is a critical component of successful planning, implementation and perhaps operation of individual projects or groups of projects. Therefore, the identification of specific sources of funding which are applicable and appropriate to those projects is key to moving forward with the items included in this watershed study. The projects and issues discussed in Section 3 cover a wide variety of watershed improvements including, but not limited to streambank stabilization; small and larger scale water storage ponds or reservoirs; rehabilitation of irrigation infrastructure; ditch lining or conversion to closed pipe; fish passage construction and maintenance and the potential formation of a Watershed Improvement District. A variety of funding sources and opportunities are available that may address the specific components of these watershed improvement projects. Those opportunities include full or partial grants, loans and other forms of support.

This section of the report provides an overview of the grant, loan and other support programs offered by local, state and federal agencies that may be available to fund projects in the Greybull River watershed. Website addresses for each program are provided and should be consulted for additional details on program requirements. The information presented here was obtained from several sources, including documents (noted below) that address multiple funding sources; additional website research; and review of other program documents. Several documents provided useful information, although not all the programs included in these documents are applicable to the projects identified for the Greybull River watershed. Larger or more significant applicable sources have been included in this section of the report, but the discussion is not intended to provide an exhaustive list of all potential funding sources. Additionally, it is important to note that some programs may change over time, or be eliminated, and new programs may become available.

- **Water Management & Conservation Assistance Programs 2014 Directory, Fifth Edition (WWDC).** WWDC has compiled information about local, state and federal agencies and other organizations that provide educational, technical, financial, planning and policy assistance to water users and the public in pursuing voluntary water management and conservation implementation. The document can be found at http://wwdc.state.wy.us/wconsprog/2014WtrMgntConsDirectory.html
- **Habitat Extension Bulletin available through the Wyoming Game and Fish Department (WGFD).** A variety of extension bulletins are available to assist with planning. Bulletin 50 provides information on cost-share programs and grants available through a number of different agencies and organizations for fisheries and wildlife habitat projects. That bulletin can be found at https://wgfd.wyo.gov/WGFD/media/content/PDF/Habitat/Extension%20Bulletins/B50-Fisheries-and-Wildlife-Habitat-Cost-Sharing-Programs-and-Grants.pdf.
- **River Restoration & Fish Passage Funding Sources and Contacts available through the Wyoming Game and Fish Department (WGFD).** This document provides information about a large number of funding sources that address Wyoming Water Strategy Initiatives 9 (River Restoration) and 10 (Collaborative Fish Passage). The document is organized by type of eligible entity and can be found at https://wgfd.wyo.gov/WGFD/media/content/PDF/Habitat/Aquatic%20Habitat/Funding_Sources.pdf.

The programs discussed in the following sections of this chapter are also summarized in Tables 42 through 46.

## 5.1 LOCAL AGENCIES / FUNDING OPPORTUNITIES

Table 42 provides contact information for local agencies and for the local offices of state or federal agencies that are available to provide additional information about specific funding sources or programs, assist in preparation of certain applications or provide other pertinent information or assistance.

**Table 42: Local Agency / Local Office Contact Information**

| Agency/Entity | Phone |
|---|---|
| South Big Horn Conservation District (SBHCD) | (307) 765-2483 |
| Meeteetse Conservation District (MCD) | (307) 868-2484 |
| | |
| Big Horn County Weed and Pest Control District | (307) 765-2855 |
| Park County Weed and Pest Control District | (307) 754-4521 |
| | |
| Wyoming Game & Fish Dept. (Cody regional office) | (307) 527-7125 |
| Wyoming Game & Fish Dept. (Lander regional office) | (307) 332-2688 |
| | |
| USDA Greybull Service Center (Farm Service Agency, NRCS and SBHCD) | (307) 765-2663 |
| USDA Riverton Service Center (Rural Development Area Office) | (307) 856-7524 |
| USDA Powell Service Center (NRCS) | (307) 754-9411 |
| | |
| BLM Wind River/Bighorn Basin District | (307) 347-5100 |

### 5.1.1 Local Weed and Pest Control Districts

Both the Big Horn County Weed and Pest Control District and the Park County Weed and Pest Control District offer cost-share programs aimed at controlling specific species of weeds or pests. District websites provide additional information:

https://www.bhcountyweedandpest.com/cost-share-programs

and

https://parkcountyweeds.org/programs/cost-share/.

Table 43 provides contact information for local county contact and brief program descriptions.

## 5.2 STATE FUNDING SOURCES

Multiple state funding sources are available for the projects identified in Section 3. Table 44 provides a summary of the agencies, programs, websites and contact information for the programs described below.

### 5.2.1 Wyoming Water Development Commission (WWDC)

The Wyoming Water Development Commission provides grant and loan funding for water supply reconnaissance (Level I), feasibility studies (Level II) and construction projects (Level III). Funding for studies and construction projects comes from mineral taxes. All planning studies and construction projects must be approved for funding by the Wyoming Legislature. Applicants must be public entities such as municipalities, irrigation districts, service and improvement districts, or joint powers boards. Projects must address water supply, transmission, or storage.

**Small Water Project Program:** The purpose of the WWDC SWPP is to participate with land management agencies and sponsoring entities in providing incentives for improving watershed condition and function. Projects eligible for SWPP grant funding assistance include the construction or rehabilitation of the following:

- Small reservoirs,
- Wells,
- Solar platforms,
- Pipelines and conveyance facilities,
- Springs,
- Wetland developments,
- Environmental projects,
- Irrigation works,
- Windmills,
- Rural community fire suppression systems, and
- Recreational projects.

Activities should improve watershed condition and function and provide benefit for wildlife, livestock and the environment. Projects may provide improved water quality, riparian habitat, habitat for fish and wildlife and address environmental concerns by providing water supplies to support plant and animal species or serve to improve natural resource conditions.

Under the SWPP, WWDC offers 50 percent grants up to $35,000 for eligible projects that provide adequate public benefit, improve watershed health and meet program definitions. 2018 legislation removed the cap on total project cost within the SWPP. Applications are evaluated on specific priorities; projects that have completed all necessary design, permitting, and funding requirements prior to application will be classified as “Shovel Ready”, and may be considered as a funding priority. The SWPP has broad eligibility, including Conservation Districts, Watershed Improvement Districts, Water Conservancy Districts, Irrigation Districts, municipalities and other approved assessment districts. Additional information on the SWPP, including the “Small Water Project Program 101 Slide Show” can be found at http://wwdc.state.wy.us/small_water_projects/small_water_project.html.

**Other programs:** Information on the following programs was obtained from the current Operating Criteria document, adopted in October 2017 and available at http://wwdc.state.wy.us/opcrit/final_opcrit.html.

- **New Development Program:** The New Development Program provides an opportunity for sponsors to develop water supplies for existing and anticipated future needs to ensure that lack of water supply will not inhibit economic growth. The program encourages water development through state or local partnerships. The sponsor can complete a water supply project with state funding assistance. If a project is developed to meet the needs of the sponsor alone, the sponsor owns the project and its revenues. However, if there is an opportunity to sell water for other purposes, the sponsor and state share in the revenues from the sale in proportion to the grant/loan mix.
- **Rehabilitation Program:** The purpose of the Rehabilitation Program is to provide funding assistance for the improvement of water projects completed and in use for at least fifteen years. Rehabilitation projects are initiated by an application from a project sponsor. If the application is approved, the project is usually assigned a Level II status and can proceed through construction if it is determined the project is technically and economically feasible. The project sponsor must be willing and capable of financially supporting a portion of the project development costs plus all operation and maintenance costs. The Rehabilitation Program serves to assist project sponsors in keeping existing water supplies effective and viable, thereby preserving their use for the future. Rehabilitation projects can improve an existing municipal or rural domestic water supply system or an agricultural storage facility or conveyance system. The projects serve to ensure dam safety; decrease operation, maintenance, and replacement costs; and/or provide a more efficient means of using existing water supplies.

For New Development and Rehabilitation projects, the project sponsor shall be a public entity that can legally receive state funds, incur debt, generate revenues to repay a state loan, hold title and grant a minimum of a parity position mortgage on the existing water system and improvements appurtenant to the project or provide other adequate security for the anticipated state construction loan.

The WWDC shall determine if the sponsor should be required to pay a portion of the Level I or Level II study costs incurred to develop the recommended alternative needed to secure funding for Level III construction. Typically, the WWDC is the lead agency in developing Level I and Level II reports. The Commission solely funds the studies to ensure the reports are unbiased and performed in such a manner as to determine whether the state should invest in the project. This procedure was also established because the project is better served if the sponsor uses its financial resources to fund its share of the project or to service the debt associated with the construction loan. However, in those exceptional cases where the sponsor assumes the role of lead agency in Level I and Level II studies, it shall share in the costs of those studies. If through the Level II process, a groundwater well is developed to be used as the water source for a Level III project, the sponsor shall share in the cost of the well.

Financial Plan – Grant Loan Mix:

1. The maximum grant shall be seventy-five percent (75%) for proposed Level III projects. To obtain the maximum grant, the sponsors must demonstrate to the WWDC that the maximum grant is warranted due to severe financial hardship.

2. The typical grant shall be sixty-seven percent (67%) for proposed Level III projects. To obtain the typical grant, the sponsors must demonstrate to the WWDC that they have taken steps or are willing to take steps to make their water supply systems financially self-supporting.
3. The WWDC may provide lesser grant amounts for proposed Level III projects that do not qualify for 1 or 2, above.

Financial Plan – Terms of the Loans:

1. Statutory guidelines establish a minimum rate of four percent (4%) for program loans. The current rate is 4 percent but may be increased by the Legislature.
2. The term of the loans cannot exceed fifty years after substantial completion of the project. Further, the term of the loan shall never exceed the economic life of the project. The sponsor's method of loan repayment (water rates, taxes, bonds, etc.) shall also be considered in establishing the term of the loan.
3. The statutes allow the WWDC to recommend that the payment of interest and principal be deferred up to five years after substantial completion of the project. In addition, the WWDC can recommend that the accrual of interest also be deferred during the term of the payment deferral. In no event can the combined deferment and term of the loan exceed fifty years.

Examples of ineligible projects:

*Environmental Enhancement* – Although the feasibility of providing or rehabilitating environmental improvements shall be considered on all program projects, the program does not have the resources to pursue projects that solely serve environmental enhancement purposes.

*Flood Control* – Projects that deal solely with flood control are essential in many parts of the state. There are active federal funding programs that serve this purpose. Therefore, sponsors are encouraged to seek funding from these alternate sources.

*Erosion Control* – While improvements to natural streams are sometimes necessary to keep existing water supplies viable, these improvements are typically performed through private or federal funding and should not be funded under the WWDC program.

**Dam and Reservoir Program:** Proposed new dams with storage capacity of 2,000-acre feet or more and proposed expansions of existing dams of 1,000-acre feet or more qualify for the Dam and Reservoir Program. Dams and reservoirs typically provide opportunities for many potential uses. While water supply and use shall be emphasized in the development of reservoir operating plans; recreation, environmental enhancement, flood control, erosion control and hydropower opportunities should be explored as secondary purposes.

**Water Resource Planning:** The WWDC serves as the water-planning agency for the State of Wyoming. Because the issues facing water development in the West are complex, the scope of the WWDC's planning efforts is not as closely defined as the New Development, Rehabilitation, and Dam and Reservoir Programs. Planning efforts include River Basin Plans, Watershed Studies, Master Plan and certain research activities.

**Groundwater Grant Program:** The primary purpose of the program is to inventory the available groundwater resources in the state. The program also serves to assist communities in the development of efficient water supplies. Authorized entities, including cities, towns and special districts, are eligible to receive up to $400,000 in grant funds and are required to provide 25 percent of the total project costs in local matching funds.

### 5.2.2 Wyoming Department of Environmental Quality (WDEQ)

The Water Quality Division of the Wyoming Department of Environmental Quality (WDEQ) consists of three sections: 1) Groundwater Protection, 2) Watershed Management, and 3) Water and Wastewater. To promote the specific missions of the Division, WDEQ offer the following grant and loan programs:

**Clean Water Act Section 319 funds:** This competitive grant program applies to projects that prevent or reduce nonpoint source pollution in surface and ground water. Applicable projects include those that focus on watershed restoration, watershed protection, monitoring/ assessment or planning or technical assistance. This program has broad eligibility and offers reimbursement grants of up to $400,000 for projects of up to four years. At least 40 percent of total project costs must be a non-federal or in-kind services match. Proposals are ranked on specific priorities developed by WDEQ. More information on program eligibility, grant terms and the application process can be found at http://deq.wyoming.gov/wqd/non-point-source/resources/grant-resources/.

**Clean Water Act Section 205(j) funds:** Funds are available for projects focused on water quality management planning and assessment, particularity for identified impaired waterbodies. Funding is competitive, and funds are awarded as reimbursement grants. Eligible entities include cities, towns, counties and conservation districts. At least 25 percent of the total project costs must be a non-federal or in-kind services match. More information on program eligibility, grant terms and the application process can be found at http://deq.wyoming.gov/wqd/non-point-source/resources/grant-resources/.

**Clean Water State Revolving Loan fund:** These loans apply to projects focused on sanitary sewer treatment and collection, storm water control, landfill water pollution control, and other water pollution control projects. State Revolving Fund (SRF) loans are normally offered at a 2.5 percent interest rate, with terms of up to 20 years. SRF loans do not require any matching funds and can even serve as matching funds for various grant programs such as the Wyoming Water Development Commission. Loan applicants must show that they can repay the loan and must adhere to specific federal and state procurement requirements. Additionally, the project must be listed on the current year's CWSRF Intended Use Plan (IUP), which is updated annually. This program has broad eligibility. Additional information on program eligibility, loan terms and the application process can be found at http://deq.wyoming.gov/wqd/state-revolving-loan-fund/.

**Drinking Water State Revolving Loan fund:** These loans apply to projects focused on drinking water systems, including source, treatment plant, storage tank, and transmission and distribution line projects. State Revolving Fund (SRF) loans are normally offered at a 2.5 percent interest rate, with terms of up to 20 years. SRF loans do not require any matching funds and can even serve as matching funds for various grant programs such as the Wyoming Water Development Commission. Loan applicants must show that they can repay the loan and must adhere to specific federal and state procurement requirements. Additionally, the

project must be listed on the current year's DWSRF Intended Use Plan (IUP), which is updated annually. This program has broad eligibility. Additional information on program eligibility, loan terms and the application process can be found at http://deq.wyoming.gov/wqd/state-revolving-loan-fund/.

### 5.2.3 Wyoming Department of Agriculture (WDA)

The mission state of the Wyoming Department of Agriculture follows: "The Wyoming Department of Agriculture is dedicated to the promotion and enhancement of Wyoming's agriculture, natural resources and contribution to Wyoming quality of life." The WDA assists the citizens of Wyoming to live safe and healthy lives, promote and preserve the agricultural community, be responsible stewards of natural resources, and achieve integrity in the marketplace. The WDA is comprised of six sections: 1) Administrative Services, 2) Analytical Services (Chemistry & Microbiology Laboratories), 3) Consumer Health Services, 4) Natural Resources & Policy, 5) Technical Services, and 6) Wyoming State Fair. The WDA offers the following programs:

**Water Quality Grant Program:** Grant funding is available to Conservation Districts for watershed planning efforts focused specifically on listed, impaired/ threatened water on the 303 (d) list. Up to $20,000 is available per project; applicants can apply for more than one project. Applications are evaluated on specific criteria, including the relevant pollutant of concern. Upon approval of an application, the Conservation District must submit a "Yearly Plan of Work" for each year of the project in order to release funding. Projects must have a 30 percent match, which can be cash or in-kind services. Federal funds, such as Clean Water Act Section 319 grant funds, can also be used as match. Additional application information can be found at http://agriculture.wy.gov/divisions/nrp/conservation-districts/funding-resources/water-quality.

**Rangeland Health Assessment Program:** Grant funding is available to qualified governmental agencies, including Conservation Districts, for projects that help build relationships on the ground, which includes bringing permitees together with land management agency personnel for the coordination of obtaining joint cooperative rangeland health assessment data. Up to $20,000 is available per project; applicants can apply for more than one project. Applications are evaluated on specific priorities, including timing and urgency for the project. Upon approval of an application, the applicant must submit a "Yearly Plan of Work" for each year of the project in order to release funding. Projects must have a 30 percent match, which can be cash, in-kind services or other agency contributions or grants. Additional application information can be found at http://agriculture.wy.gov/divisions/nrp/rangeland-health.

**Wyoming Office of State Lands and Investments (OSLI)**

The Office of State Lands and Investments (OSLI) is the administrative arm of the State Board of Land Commissioners and the State Loan and Investment Board. It is the statutory responsibility of the Office of State Lands & Investments to carry out the policy directives and decisions of these two Boards.

The organizational structure of Office of State Lands & Investments consists of the Office of the Director and four divisions: 1) Administrative Services Division, 2) Trust Land Management Division, 3) Field Service Division, and 4) Wyoming State Forestry. Collectively, these divisions serve the trust beneficiaries including Wyoming's school children and state institutions; numerous clients in agriculture, mineral, timber, transportation, communication, public utility, recreation, tourism and other Wyoming industries; local

government entities; state and federal agencies; and the resident and non-resident general public The OSLI offers the following loan programs:

*Farm Loan Program*

The Farm Loan program awards loans to:

- Purchase lands used principally for raising agricultural products, livestock, or dairying;
- Purchase livestock, fertilizers, and equipment calculated to maintain or increase the earning capacity of the borrower's agricultural operation;
- Purchase, construct, or install improvements calculated to maintain or increase the earning capacity of the borrower's agricultural operation;
- Liquidate debts of the borrower incurred in the furtherance of the borrower's agricultural operation; or
- Enhance or restore livestock numbers in the state pursuant to W. S. § 11 - 34 - 113 (j).

Information on program eligibility, loan terms and the application process can be found at http://lands.wyo.gov/grantsloans then click on 'Farm Loans' on the left side menu

*Small Water Development Project Loan Program*

The OSLI defines a "small water development project" as a project for development and use of water upon agricultural lands in Wyoming for agricultural purposes. Water development projects may include projects to convert dry land into irrigated land as well as projects which will lead to more efficient use of water and/or increased crop or forage production. Single loans or a combination of loans made to a single agricultural enterprise shall not exceed an outstanding principal balance of $150,000.00, regardless of the identity of the applicants. The term of the loan shall not exceed 40 years and may be for a shorter term as determined by financial strength, repayment ability, security, and other factors.

*Joint Powers Act Loan Program*

The Joint Powers Act (JPA) program awards loans for capital construction projects of local governmental entities (including special districts). Information on program eligibility, loan terms and the application process can be found at:
http://lands.wyo.gov/grantsloans then click on 'Joint Powers Act Loan Program' on the left side menu

*Hydro-Power Development Project Loans*

The Hydro-Power Development Project (Hydro) program awards loans to finance the construction of hydro-power development projects. Information on program eligibility, loan terms and the application process can be found at:
http://lands.wyo.gov/grantsloans then click on 'Hydro Power Loan Program' on the left side menu

### 5.2.4 Wyoming Game and Fish Department (WGFD)

The Wyoming Game and Fish Department (WGFD) may offer technical and funding assistance to help landowners, conservation groups, institutions, land managers, government agencies, industry, and non-profit organizations develop or maintain water sources for fish and wildlife. Assistance may also be provided for protecting or improving riparian areas/wetlands, restoring streams, and upgrading irrigation infrastructure in a manner that provides improved fish passage or diversion screening. Funding opportunities include the following:

*Habitat Trust Fund*

Funds are reimbursable grants that can be used for acquisition, maintenance or improvement of wildlife habitat; or for the promotion of human understanding and enjoyment of the fish and wildlife resource (habitat or information and education projects). Funds can be used for internal projects or paid as grants to an outside entity. These grants have broad eligibility; however, all proposals require a WGFD sponsor. Project proposals will be prioritized for funding by Department staff. No cost-share is required but is strongly recommended.

*Fish Passage Grants*

Funds are reimbursable grants that can be used for creating or improving upstream or downstream passage of all life stages of fish in Wyoming waterways and for screening diversions. Examples include developing fishways or fish ladders, assisting with the replacement of traditional push-up diversion dams with more fish-friendly options, and installing various screening technologies to keep fish from becoming entrained into irrigation ditches. These grants have broad eligibility; however, all proposals require a WGFD sponsor. Project proposals will be prioritized for funding by Department staff. No cost-share is required but is strongly recommended.

The WGFD website is https://wgfd.wyo.gov/.

### 5.2.5 Wyoming Wildlife and Natural Resource Trust (WWNRT)

The Wildlife and Natural Resource Trust, created in 2005, is an independent state agency governed by a nine-member citizen board appointed by the Governor. Funded by interest earned on a permanent account, donations, and legislative appropriation, the purpose of the program is to enhance and conserve wildlife habitat and natural resource values throughout the state. That focus includes improvement and maintenance of aquatic habitats, including wetland creation or enhancement, stream restoration, water management or other methods. Any project designed to improve wildlife habitat or natural resource values is eligible for funding.

Grant funding is available for large and small-scale projects; however, projects greater than $200,000 are subject to legislative approval. Grants will not fund salaries, acquisition of real property or purchase of water rights. Eligible entities include non-profit and governmental organizations, including special districts. Projects are required to provide public benefits. No matching funds are required. Additional information on project eligibility and the application process can be found at: https://sites.google.com/a/wyo.gov/wwnrt/how-to-apply.

## 5.3 FEDERAL FUNDING SOURCES

Multiple federal funding sources are available for the projects identified in Section 3. Table 45 provides a summary of the agencies, programs, websites and contact information for the programs described below.

### 5.3.1 Bureau of Reclamation (Reclamation)

Through WaterSMART, Reclamation will continue to work cooperatively with states, tribes, and local entities as they plan for and implement actions to increase water supply through investments to modernize existing infrastructure and provide attention to local water conflicts. Applicable grant programs include:

*WaterSMART Water and Energy Efficiency Grants (formerly Challenge Grants)*

Reclamation provides grant funding for projects that conserve and use water more efficiently; increase the production of hydropower; mitigate conflict risk in areas at a high risk of future water conflict; and accomplish other benefits that contribute to water supply reliability in the western United States. Projects are selected through a competitive process and the focus is on projects that can be completed within two or three years. Reclamation provides funding in two funding groups: Funding Group I provides up to $300,000 in Federal funding per project, for smaller on-the-ground projects that can be completed within two years; Funding Group II provides up to $1 million in funding for larger, phased, on-the-ground projects that may take up to three years to complete. Water and Energy Efficiency Grants are awarded through a west-wide competitive process that requires a minimum 50% cost share by the recipient, either in cash or as in-kind contributions. Eligible entities include irrigation and water districts, tribes, states and other entities with water or power delivery authority. Information on this program can be found at https://www.usbr.gov/watersmart/weeg/index.html.

*WaterSMART Small-Scale Water Efficiency Projects*

Reclamation provides up to $75,000 in grant funding for small water efficiency improvements that have been identified through previous planning efforts. Projects eligible for funding include installation of flow measurement or automation in a specific part of a water delivery system, lining of a section of a canal to address seepage, or other similar projects that are limited in scope. Grants require a 50% cost share by the recipient either in cash or as in-kind services. Irrigation and water districts, tribes, states and other entities with water or power delivery authority are eligible entities. Information on this program can be found at https://www.usbr.gov/watersmart/swep/index.html.

*Water Conservation Field Services Program*

This program provides grants of up to $100,000 per project through local competitions within a specific region. Eligible activities include developing and updating water conservation plans, engineering design of water management improvements, and demonstrating conservation technologies. Financial assistance provided through this program requires a minimum 50% cost share by the recipient. There is broad eligibility for this funding.

Funding opportunity announcements for WaterSMART grants and the WCFSP can be found at https://www.grants.gov/.

### 5.3.2 US Army Corps of Engineers (USACE)

The U.S. Army Corps of Engineers (USACE) is authorized to provide technical assistance to local communities, States and federally recognized Indian Tribes in support of their efforts to alleviate flooding impacts, reduce erosion and otherwise plan for the wise and prudent use of the nation's water and related land resources. They also have authority to construct certain water resources related projects and respond to water resource needs.

*Planning Assistance to States*

This program provides for assistance in preparation of plans for the development, utilization and conservation of water and related land resources. USACE provides technical planning assistance in all areas related to water resources development such as bank stabilization, sedimentation, water conservation, ecosystem and watershed planning and water quality. Assistance is limited to $500,000 per state and studies are cost-shared on a 50-50 basis with a non-federal sponsor such as a state, public entity or an Indian Tribe. Study sponsors have the option of providing in-kind services up to 100 percent of their share of the study cost. States, local governments, other non-Federal entities and eligible Native American Indian tribes are eligible for this program. Requests for assistance should be in the form of a letter to the USACE. Additional information is available at http://www.nae.usace.army.mil/Missions/Public-Services/Planning-Assistance-to-States/.

*Flood Plain Management Services*

This program provides technical services and planning guidance for support and promotion of effective flood plain management. Flood and flood plain data are developed and interpreted with assistance and guidance provided in the form of "Special Studies" on all aspects of flood plain management planning. All services are provided free of charge to local, regional, state or non-federal public agencies. Federal agencies and private entities have to cover 100% of costs. This program is open to state, regional and local governments and Native American Indian tribes. Requests for assistance should be in the form of a letter to the USACE. See http://www.nae.usace.army.mil/Missions/Public-Services/Flood-Plain-Management-Services/ for more information.

*Ecosystem Restoration*

The purpose of USACE ecosystem restoration activities is to restore significant ecosystem function, structure and dynamic process that have been degraded. The following programs are available:

- Aquatic Ecosystem Restoration: This effort is for restoration of historic habitat conditions to benefit fish and wildlife resources. This is primarily to provide structural or operational changes to improve the environment such a river channel reconnection, wetland creation or improving water quality. Project costs for non-Federal entities are 35% of total project costs. Requests for assistance should be in the form of a letter to the USACE. See http://www.nae.usace.army.mil/Missions/Public-Services/Continuing-Authorities-Program/Section-206/ for more information.
- Project Modification for Improvement of Environment: The purpose of this program is to modify structures or operation of previously constructed water resources projects to improve environmental quality, especially fish and wildlife values. A study, at federal expense, is initiated followed by a

feasibility plan that is cost-shared 25% by the sponsor. Requests for assistance should be in the form of a letter to the USACE. See http://www.nae.usace.army.mil/Missions/Public-Services/Ecosystem-Restoration-Authorities/ for more information.

*Flood Damage Reduction Projects*

This program provides structural and non-structural projects to reduce damages caused by flooding and focuses on solving local flood problems in urban areas, towns and villages. The Corps works with the project sponsor to define the flood problem, evaluate solutions, select a plan, develop the design and construct a project. A feasibility study is conducted to identify potential projects with the first $100,000 of the cost. Any cost above this amount is cost-shared 50-50 with the sponsor in the form of cash and in-kind services. Construction lands, easements, rights-of-way, relocations and disposal and 50 percent of the projects costs are the sponsor's responsibility. Operation and maintenance and a maximum of 50 percent of total project cost are the sponsor's responsibility.

### 5.3.3 Bureau of Land Management (BLM)

The BLM's *Riparian Habitat Management Program* offers the opportunity to coordinate with outside interests on riparian improvement projects. The goal of BLM's riparian-wetland management is to maintain, restore, improve, protect, and expand these areas so they are in proper functioning condition for their productivity, biological diversity and sustainability. The overall objective is to achieve an advanced ecological status, except where resource management objectives, including proper functioning condition, would require an earlier successional stage. The goal includes aggressive riparian-wetland information, inventory, training, and research programs as well as improving the partnerships and cooperative management processes.

Partnerships have been available for riparian improvement projects and for research into riparian issues. Funding is available on an annual basis subject to budget allocations from Congress. All submitted cooperative projects compete for the funds available in the riparian program. See https://www.blm.gov/programs/natural-resources/wetlands-and-riparian-health for more information.

### 5.3.4 USDA Natural Resources Conservation Service (NRCS)

NRCS offers voluntary programs to eligible landowners and agricultural producers to provide financial and technical assistance to help manage natural resources in a sustainable manner. Through these programs the agency approves contracts to provide financial assistance to help plan and implement conservation practices that address natural resource concerns or opportunities to help save energy, improve soil, water, plant, air, animal and related resources on agricultural lands and non-industrial private forest land. Financial assistance programs include the following:

*Agricultural Management Assistance (AMA)*

This helps agricultural producers use conservation to manage risk and solve natural resource issues through natural resources conservation. Producers receive conservation technical and financial assistance to construct or improve water management or irrigation structures, plant trees for windbreaks or, in order to improve water quality and mitigate risk, diversify their operation and conservation practices including soil

erosion control, integrated pest management or transition to organic farming. Persons or legal entities cannot receive more than $50,000 in AMA program payments per fiscal year. See https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/ama/?cid=stelprdb1242818 for more information.

*Conservation Stewardship Program (CSP)*

This helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resources concerns. Participants earn CSP payments for conservation performance—the higher the performance, the higher the payment. See https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/ for more information.

*Environmental Quality Incentives Program (EQIP)*

This program provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation or improved or created wildlife habitat. See: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/ for more information.

*Conservation Innovation Grants (CIG)*

These are competitive grants that drive public and private sector innovation in resource conservation. CIG uses EQIP funds to award competitive grants to non-Federal governmental or nongovernmental organizations, American Indian Tribes, or individuals. Producers involved in CIG funded projects must be EQIP eligible. A CIG funding notice is announced each year. Funds for single- or multi-year projects, not to exceed three years, will be awarded through a nationwide competitive grants process. Projects may be watershed-based, regional, multi-state, or nationwide in scope. The natural resource concerns eligible for funding through CIG are identified in the funding announcement and may change annually. See https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/ for more information.

*Emergency Watershed Protection (EWP) Program*

Congress established this program to respond to emergencies created by natural disasters. The EWP Program offers technical and financial assistance to help local communities such as cities, counties and towns relieve imminent hazards to life and property caused by floods, fires, windstorms, and other natural occurrences that impair a watershed. The EWP Program consists of two options: EWP Program – Recovery and EWP – Floodplain Easement (FPE). See https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/ewp/ for more information.

More information about each of the programs described above can be found at https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/. Additionally, NRCS also offers a number of technical assistance and landscape planning programs available to a broad array of entities. Information about all of the NRCS programs can be found at https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/.

### 5.3.5 Environmental Protection Agency (EPA)

The Healthy Watersheds Consortium (HWC) is a partnership between the U.S. Endowment for Forestry and Communities, the U.S. Environmental Protection Agency, and the USDA Natural Resources Conservation Service. The goal of the *Healthy Watersheds Consortium Grant Program* is to "accelerate strategic protection of healthy, freshwater ecosystems and their watersheds", with primary focus on prevention of deterioration in the watershed by:

- Developing funding mechanisms, plans, or other strategies to implement large-scale watershed protection, source water protection, green infrastructure, or related landscape conservation objectives;
- Building the sustainable organizational infrastructure, social support, and long-term funding commitments necessary to implement large-scale protection of healthy watersheds; and
- Supporting innovative or catalytic projects that may accelerate funding for or implementation of watershed protection efforts, or broadly advance this field of practice.

Awards will be considered in the following three categories. These categories are not rigid; they merely reflect our approach to watershed protection.

1. **Watershed Action Projects** are specific projects that fulfill components of an established plan or guiding document, such as leveraging funding to protect a particular property. These projects will typically leverage a Healthy Watersheds Consortium award many times for maximum results and should be part of a broader watershed strategy developed at the HUC 8 scale or larger. Applicants may seek additional funding for new projects in the same watershed in future award cycles ($50,000 - $250,000 award size).
2. **Building Watershed Protection Capacity** awards grow the organizational capacity needed for large-scale, long-term healthy watershed protection. Applicants must identify existing or proposed funding or strategies to be tapped with increased capacity for project implementation. How will increased capacity allow your organization to secure the funding or implement a strategy needed to accelerate long-term watershed protection? (maximum $150,000/year).
3. **Advancing the State of Practice** —Awards for new or experimental technologies, methods, financing strategies, or approaches to incentivize watershed protection which can be scaled to a broader level. Training projects that relate to gathering or exchanging information to advance the state of practice are eligible. Proposals must include a plan for scaling projects and disseminating information to relevant users and must include a demonstrated need from end users, via letters of support ($50,000 - $200,000 award size).

Eligible entities include not-for-profit 501(c)(3) organizations, for-profit companies, tribes, intertribal consortia, interstates, state, and local government agencies including water utilities and wastewater facilities, and colleges and universities are eligible for funding. Public/private partnerships are particularly desirable. Unincorporated individuals and federal agencies are not eligible.

Applicants should provide at least 25 percent of the total project cost, which may include cash donations or in-kind contributions from third-parties and allowable costs incurred by the applicant during the project. The Endowment may decrease the matching requirement to as low as 10% if the applicant can demonstrate in writing that financial circumstances are constrained to such an extent that fulfilling the matching funds' requirement would impose undue hardship.

Additional information on this program, eligible projects and the application process is provided at https://www.epa.gov/hwp/healthy-watersheds-consortium-grants-hwcg.

### 5.3.6 USDA Farm Service Agency (FSA)

The Farm Service Agency (FSA) administers the following programs:

*Conservation Reserve Program (CRP)*

A voluntary land conservation program for agricultural producers to help safeguard environmentally sensitive land. In exchange for a yearly rental payment, farmers enrolled in the program agree to remove environmentally-sensitive land from agricultural production and plant species that will improve environmental health and quality. Contracts for land enrolled in CRP are 10-15 years in length. The long-term goal of the program is to re-establish valuable land cover to help improve water quality, prevent soil erosion, and reduce loss of wildlife habitat. Farmers must meet certain requirements to be eligible for CRP enrollment. More information is available at https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index and https://www.fsa.usda.gov/state-offices/Wyoming/programs/index.

*Conservation Reserve Enhancement Program (CREP)*

As a part of the Conservation Reserve Program (CRP), CREP targets high-priority conservation concerns identified by a State, and federal funds are supplemented with non-federal funds to address those concerns. In exchange for removing environmentally sensitive land from production and establishing permanent resource conserving plant species, farmers and ranchers are paid an annual rental rate along with other federal and state incentives as applicable per each CREP agreement. Participation is voluntary, and the contract period is typically 10 to 15 years. More information is available at https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-enhancement/index.

*Emergency Conservation Program (ECP)*

This program is aimed at helping farmers and ranchers repair damage to farmlands caused by natural disasters and to help put in place methods for water conservation during severe drought. The ECP provides ranchers and farmers with funding and assistance to repair the damaged farmland or to install methods for water conservation. Funding for ECP is determined by Congress. Up to 75 percent of the cost to implement emergency conservation practices can be provided, however the final amount is determined by the committee reviewing the application. Qualified limited resource producers may earn up to 90 percent cost-share. The FSA County Committee is able to approve applications up to $50,000 while $50,001 to $100,000 requires state committee approval. Amounts over $100,000 require the approval of the national FSA office. The FSA

County Committee inspects the damage to determine if land is eligible for ECP. More information is available at https://www.fsa.usda.gov/programs-and-services/conservation-programs/emergency-conservation/index and https://www.fsa.usda.gov/state-offices/Wyoming/programs/index.

*Farmable Wetlands Program (FWP)*

This program is designed to restore previously farmed wetlands and wetland buffer to improve both vegetation and water flow. FWP is a voluntary program to restore up to one million acres of farmable wetlands and associated buffers. Participants must agree to restore the wetlands, establish plant cover, and to not use enrolled land for commercial purposes. Plant cover may include plants that are partially submerged or specific types of trees. Restrictions apply to the land and amount of acreage that can be enrolled. Landowners who take part in the FWP receive an annual rental payment for their enrolled acres. FSA also provides cost-sharing and other incentives to help offset the costs associated with putting these practices in place. Further information about the program, including rental payment information, other eligibility and maintenance criteria, and land requirements can be found at https://www.fsa.usda.gov/programs-and-services/conservation-programs/farmable-wetlands/index.

### 5.3.7 US Fish and Wildlife Service (USFWS)

*Partners for Fish and Wildlife Program (PFW)*

The Partners for Fish and Wildlife Program serves as the primary tool for conservation delivery on privately owned land for the USFWS. The Program provides technical and financial assistance to private landowners and tribes on a voluntary basis to help meet the habitat needs of federal trust species and conservation partner designated species of interest. The program targets habitats that are in need of restoration or enhancement such as riparian areas, streams, wetlands and grassland. Field biologists work one-on-one with landowners and partners to plan and implement a variety of projects including grazing lands management, sage steppe enhancement, stream habitat improvement and fish passage, invasive species removal and wetland establishment. Any privately-owned land is potentially eligible for restoration. Most participants are individual private landowners. For purposes of this program, "privately-owned" means land not owned by a State or the Federal Government. More information can be found at https://www.fws.gov/partners/.

*Wildlife and Sport Fish Restoration Program (WSFR)*

The Wildlife and Sport Fish Restoration Program (WSFR) works with states, insular areas and the District of Columbia to conserve, protect, and enhance fish, wildlife, their habitats, and the hunting, sport fishing and recreational boating opportunities they provide. The WSFR Program provides oversight and/or administrative support for the following grant programs: Wildlife Restoration Grant Program, Sport Fish Restoration Grant Program, Boating Infrastructure Grant Program, State Wildlife Grant Program, Landowner Incentive Program; Tribal Wildlife Grant Program, and Tribal Landowner Incentive Grant Program. Each of those grant programs has a specific focus, eligibility requirements, funding opportunities and application procedures. Information can be found at https://wsfrprograms.fws.gov/Subpages/GrantPrograms/GrantProgramsIndex.htm.

*Cooperative Endangered Species Conservation Fund/Section 6 Grants*

The Cooperative Endangered Species Conservation Fund (section 6 of the ESA) provides grants to States and Territories to participate in a wide array of voluntary conservation projects for candidate, proposed, and listed species. The program provides funding to states and territories for species and habitat conservation actions on non-federal lands. Grant programs include: Conservation Grants, Habitat Conservation Planning Assistance Grants, Habitat Conservation Planning Land Acquisition Grants and Recovery Land Acquisition Grants. States and territories must contribute a minimum non-federal match of 25% of the estimated program costs of approved projects, or 10% when two or more States or Territories implement a joint project. Participation in these programs is only available to State agencies that have a current cooperative agreement with the Secretary of the Interior. However, individuals or groups (for example land conservancies, cities, counties, community organizations, or conservation organizations) may work with a State agency that has a cooperative agreement on conservation efforts that are mutually beneficial, as a subgrantee. More information can be found at https://www.fws.gov/endangered/grants/index.html.

*North American Wetlands Conservation Act (NAWCA) Grant Program*

This grant program promotes long term conservation of wetlands ecosystems and the waterfowl, migratory birds, fish and wildlife that depend upon such habitat. Conservation actions supported are acquisition, enhancement and restoration of wetlands and wetlands associated habitat. This program encourages voluntary, public private partnerships. Public or private, profit or nonprofit entities or individuals establishing public/private sector partnerships are eligible. This program offers standard grants (larger projects) and a small grants option for projects less than $100,000. Cost share partners must at least match grant funds with non-federal monies. https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php.

Information of all of the above programs, plus other grant programs offered by the USFWS, can be found at https://www.fws.gov/grants/programs.html. Two additional USFWS programs are described below.

*National Fish Habitat Partnerships*

NFHAP is a national investment strategy to maximize the impact of conservation dollars on the ground. Under NFHAP, Federal, State, Tribal, and privately-raised funds are leveraged through regional partnerships to address the nation's biggest fish habitat challenges. The U.S. Fish and Wildlife Service is a key partner in implementing the National Fish Habitat Partnership, along with States, Tribes, other Federal agencies, conservation organizations, and industry. The Service is a natural collaborator with NFHAP because habitat protection and restoration are central elements of the Service's mission. Through Fish Habitat Partnerships (FHPs), organized around important aquatic habitat and species, Service employees provide NFHAP with leadership and technical expertise, from local restoration projects to regional FHP development and national administration.

Projects eligible for grant funding must protect, restore, or enhance fish and aquatic habitats or otherwise directly support habitat related priorities; every project must be identified in the Fisheries Operational Needs System (FONS). Individual awards range from approximately $1,000 to $300,000. NFHP funds are delivered through local FHPs; those in Wyoming include the Western Native Trout Initiative, Desert Fish and the Great Plains Fish Habitat Partnerships (each with their own eligibility requirements). Project proposals should be

submitted through the U.S Fish and Wildlife Service Conservation Office in Lander. More information can be found at https://www.fws.gov/fisheries/whatwedo/nfhap/nfhap.html and https://www.fws.gov/mountain-prairie/fisheries/landerFWCO.php.

*National Fish Passage Program*

The National Fish Passage Program (NFPP) is a voluntary program that provides direct technical assistance and financial assistance in the form of cooperative agreements to partners to provide fish (and other aquatic organisms) passage and restore aquatic connectivity for the benefit of federal trust resources. The NFPP is delivered through more than 65 Fisheries and Aquatic Conservation (FAC) Field Offices across all States and territories. FAC staff coordinates with project partners, stakeholders and other Service programs to identify and collaboratively implement projects within Regional priority areas. Eligible entities include, but are not limited to, state and federal agencies, private lands, tribes, local municipalities, and non-governmental organizations. Project proposals must be submitted through U.S. Fish and Wildlife Service Conservation Office in Lander. This program has cost sharing or matching requirements. More information can be found at https://www.fws.gov/fisheries/fish-passage.html
and https://www.fws.gov/mountain-prairie/fisheries/landerFWCO.php.

### 5.3.8 Other Funding Sources

Numerous private organizations offer grants or other financial assistance for projects with specific focus. The three documents listed at the beginning of this chapter which identify multiple funding sources also include examples of private organizations that may have applicable financial assistance programs. Some of these organization offer a local chapter or have a local presence in Wyoming.

Potentially relevant organizations include Ducks Unlimited (https://www.ducks.org/) and Trout Unlimited (https://www.tu.org/). Both of those organizations have offered various grant opportunities in recent years; local offices may be contacted for information about current grant programs (http://www.ducks.org/Wyoming and http://wyomingtu.org/).

The National Fish and Wildlife Foundation (NFWF) is another potential source of grant funding. NFWF provides funding on a competitive basis to projects that sustain, restore, and enhance our nation's fish, wildlife, and plants and their habitats. A list of conservation programs that offer funding is available at http://www.nfwf.org/whatwedo/programs/Pages/home.aspx.

### 5.3.9 Summary of Funding Sources and Opportunities

Tables 43 through 45 provide summaries of the local, state and federal funding opportunities discussed in this chapter. These tables identify specific funding programs administered by individual agencies and provide website and contact information. In addition, Table 46 provides an overview of the identified topics in Section 3 and identifies the potential funding sources that may be applicable to each.

# 6. SUMMARY

This section presents the summary and conclusions of this Level I Greybull River Watershed study and relate to the watershed improvements presented in the Rehabilitation and Management Plan discussed in Section 3. Those potential improvements include management strategies related to irrigation potential, livestock and wildlife watering, rangeland health and general stream health. Fortunately, the watershed is in relatively good condition with good functionality and has benefited from numerous WWDC-sponsored studies throughout the years.

This watershed study presents a holistic appraisal of the current condition of the Greybull River watershed which spans over one million acres and encompasses the watersheds of both the Greybull River and Dry Creek. The study looked at potential water improvement projects to restore, maintain and enhance a healthy watershed function and upgrade necessary irrigation infrastructure.

The watershed's existing conditions were inventoried and evaluated in Section 2 of this report. This included relatively intensive descriptions of:

- The physical systems including climate, topography, geology, soils, groundwater and surface water;
- The biological systems including fish, wildlife, landcover, wildlife habitat plus sensitive, endangered and threatened species;
- The anthropogenic systems including land use and ownership, land management, agricultural water use, municipal, industrial and domestic water use, plus water storage.

In addition, the datasets and reports evaluated have been incorporated into a GIS dataset and digital library. These have been provided electronically to the WWDC and both of the study's sponsors, the South Big Horn Conservation District and the Meeteetse Conservation District. This information can be utilized for future planning and implementation improvements which have been outlined earlier in this report.

Included in this study are rehabilitation topics that are tangent projects that a landowner or public entity could pursue for funding and management topics that focuses on the potential for an over-arching management agency for the entire watershed. This study will be useful as a tool to identify the costs, permitting and funding logistics to complete a project. It should be noted, however, not every possible project was identified during the study's development.

A series of public meetings, surveys, field visits, and dozens of emails and phone calls were conducted during the course of this study to gauge the public's sentiment and to listen to specific suggestions on watershed improvement needs and opportunities. As a result of public input and information gathered during the study, several specific conclusions are listed below.

Identification of watershed-wide issues were primarily a function of summarizing public comments, survey responses, and agency input. Those rehabilitation topics include:

- Stream stabilization: Streambank erosion is a common issue along the larger rivers of the watershed, particularly the Greybull and Wood Rivers, resulting in significant damage due to land loss and destruction of infrastructure.
- Water storage: Public input indicated an interest to increase water storage. As noted earlier, there is a current study underway to potentially expand the Lower Sunshine Reservoir.
- Irrigation: As illustrated in the Inventory and Evaluation Section, multiple master plan studies have been completed for the formal Irrigation District within the watershed. Of the items identified in the previous studies, repair of the Hi-Line ditch frequently came up in survey responses and discussion with landowners. This was also reflected by numerous comments at public meetings and from survey results. Several comments included:
    - Farmer's Canal is failing;
    - 70 to 80 percent of the Bench Canal's infrastructure is failing; and
    - Several unlined irrigation ditches up to eight miles long which lose nearly half their flow by the time the water reaches the fields.
- Russian olive and Saltcedar tree removal: Invasive species such as tamarisk (saltcedar) and Russian olive produce negative impacts throughout Wyoming including the Greybull River watershed study area. There is funding available for landowners within the watershed who need assistance to remove the Russian olive/Saltcedar trees on their property.

In addition to the watershed-wide rehabilitation topics, there were several specific rehabilitation topics investigated as a result of public input and previous studies. Those included:

- Fish passage construction and maintenance
- Ditch conversion to concrete channel
- Ditch conversion to piped infrastructure
- Privately-owned stock ponds

More significantly, the watershed may benefit from creating a WID to aid in financial procurement, project prioritization and organization for those private owners that do not currently fall under an existing irrigation ditch. Although there are several weaknesses and threats to creating WID, the strengths and opportunities far outweigh any negative perceptions. It is recommended stakeholders in the area continue to engage the public to gain a better understanding of concerns and interest in creating a WID. Funding opportunity for a Level II feasibility study through the WWDC may be available to assess the interest, WID boundary and willingness to pay from landowners in the region. This opportunity would need discussion from a sponsor (i.e., MCD, SBHCD, GVID) and staff at the WWDO prior to spending money on application fees.

# 7. REFERENCES


AECOM, 2017. *Final Report: Greybull Valley Irrigation District Storage Enlargement, Level II, Phase I Study*, prepared for the Wyoming Water Development Commission, March 2017.

AECOM, 2014. *Final Report: Greybull Valley Irrigation; Hydropower Level II Study*, prepared for the Wyoming Water Development Commission, January 2014.

Blackstone, D.L., Jr., 1963, *Development of geologic structures in central Rocky Mountains*, in Childs, O.E., and Beebe, B.W., eds., *Backbone of the Americas-Tectonic history from pole to pole*: Tulsa, Ok., American Association of Petroleum Geologists Memoir, p. 160-179.

Anderson, 2010. *Final Report for Greybull Valley Rehabilitation/Upper Sunshine Diversion, Level II Study*, prepared for the Wyoming Water Development Commission, June 2010.

Audubon, 2017. Audubon: Guide to North American Birds. Website accessed 8-14-17. https://www.audubon.org/field-guide/bird/mountain-plover

Beaugh, Corey J. *E.Coli Distribution and Streambed Processes of the Greybull River, WY.* A Thesis submitted to the University of Wyoming in partial fulfillment of the requirements for the degree of Master of Science in Rangeland Ecology / Watershed Management. Laramie, Wyoming. August 2012.

BHC, 2017. Big Horn County (BHC), *Big Horn County Land Use Plan*, website accessed Nov. 2017; http://www.bighorncountywy.gov/departments/land-planning/land-use-plan

Biederman J A, Somor A J, Harpold A A, Gutmann E D, Breshears D D, Troch P A, Gochis D J, Scott R L, Meddens A J H and Brooks P D 2015. Recent tree die-off has little effect on streamflow in contrast to expected increases from historical studies: Muted streamflow responses to tree die-off. *Water Resource. Res.* 51 9775–89.

Blackstone, D.L., Jr., 1963, *Development of geologic structures in central Rocky Mountains*, in Childs, O.E., and Beebe, B.W., eds., *Backbone of the Americas-Tectonic history from pole to pole*: Tulsa, Ok., American Association of Petroleum Geologists Memoir, p. 160-179.

BLM, 2018a. Wyoming Rangeland Management and Grazing. Website accessed May 2018. https://www.blm.gov/programs/natural-resources/rangeland-and-grazing/rangeland-health/wyoming

BLM, 2018b. Wyoming Standards for Healthy Public Rangelands; website accessed May 2018; https://www.blm.gov/documents/wyoming/public-room/guidebook/standards-healthy-rangelands-and-guidelines-livestock

BLM, 2018c. Phone conversation with Holly Elliot, NEPA advisor, Worland BLM office; Aug. 13, 2018.

BLM, 2013. U. S. Bureau of Land Management; Interagency Ecological Site Handbook for Rangelands; January 2013; website accessed May 2018; https://www.blm.gov/sites/blm.gov/files/uploads/Media_Library_BLM_Policy_Handbook_H-1734-1.pdf

BLM, 2004. U. S. Bureau of Land Management (BLM) Manual 8100: The Foundations for Managing Cultural Resources. Revised Dec. 2004.

Boon, S., 2012. Snow accumulation following forest disturbance. *Ecohydrology*. 5 279–85.

Brown A E, Zhang L, McMahon T A, Western A W and Vertessy R A 2005. A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation. *J. Hydrol.* 31028–61.

Bray, TJ 1996. *Changes in Channel Morphology and Riparian Mosaics on the Bighorn River, Wyoming*, MS Thesis, University of Wyoming, December 1996.

Budd, 2018. Phone conversation with Bob Budd, Executive Director, Wyoming Wildlife & Natural Resources Trust, Aug. 8, 2018.

Buechling, Arne, and Rodemaker, Eli, 2010. *Land Cover Classification and Mapping in the Bighorn Basin, Wyoming*, Wyoming Game and Fish Commission, Authorization Number: 6SC04006955.

CNHP, 2005. Colorado Natural Heritage Program. 2005. Ecological System Descriptions and Viability Guidelines for Colorado. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

CRWC, 2018. Connecticut River Watershed Council; construction costs; website accessed Aug. 1, 2018; http://www.edc.uri.edu/restoration/html/tech_sci/socio/costs.htm#fish

CSFS, 2017. Colorado State Forest Service, 2017. Product Use to Prevent Mountain Pine Beetle. Quick Guide Series ID 2010-1. Website accessed Sept. 2017. https://static.colostate.edu/client-files/csfs/pdfs/Web__Revision_June6_MPB_Prev_Products_QG.pdf

DOWL, 2015. *Final Report: South Big Horn County Rural Water District Expansion – Level II Study*, prepared for the WWDC.

EO, 2015. Greater Sage-Grouse Core Area Protection: Executive Order 2015-4 (replaces 2011-5 and 2013-3). Signed by WY Gov. Matt Mead, July 29, 2015.

EPA, 2018. U.S. Environmental Protection Agency; website accessed June 2018; https://www.epa.gov/cwa-404/section-404-permit-program

EPA, 2013. (U.S. Environmental Protection Agency), *Cultural Resources: Management for EPA Personnel*, 2013.

Everman, B. W. and U. O. Cox. 1896. A report upon the fishes of the Missouri River basin. Report of the U.S. Commissioner of Fish and Fisheries for 1894:325–429. Government Printing Office, Washington, D.C.

Finley, 2016. Judson Byrd. *Late Holocene Geoarchaeology in the Bighorn Basin, Wyoming*. Stones, Bones and Profiles: Exploring Archaeological Context, Early American Hunters-Gatherers, and Bison. 10.5876/9781607324539.c009.

Finn, Thomas M., 2010. *Petroleum Systems and Geologic Assessment of Oil and Gas in the Bighorn Basin Province, Wyoming and Montana*, United States Geological Survey (USGS), Ch. 6.

GEI Consultants, Inc. 1994. *Greybull Valley Dam and Reservoir Level II Phase V Final Conceptual Design Report*, prepared for the Wyoming Water Development Commission and the Greybull Valley Irrigation District.

Gibson, Ken, and Negron, Jose F. (USFS foresters), 2007. Fire and Bark Beetle Interactions. Derived from a presentation to the Western Bark Beetle Research Group Symposium, Society of American Foresters Conference. Portland OR. Oct. 2007.

Gores, 2015. Meeteetse Master Plan, Level I Study; funded by the WWDC, James & Gores Associates, August, 2015.

Hewett, D.F., 1926. *Geology and Oiland Coal Resources of the Oregon Basin, Meeteetse, and Grass Creek Basin Quanrangles, Wyoming*, USGS.

Hibbert A. R., 1971. Increases in stream flow after converting chaparral to grass. Water Resources Bulletin, 8: 71-80.

Hibbert A. R., Davis EA, Knipe OD (1982) Water yield changes resulting from treatment of Arizona chaparral. Gen. Tech. Rept. PSW-58, Berkeley, CA: USDA Forest Service, Pacific Southwest Forest and Rang Expt Stn 382-389.

Jost G, Weiler M, Gluns D R and Alila Y 2007. The influence of forest and topography on snow accumulation and melt at the watershed-scale. *J. Hydrol.* 347 101–15.

Katopodis, Chris, 1992. Introduction to Fishway Design. Freshwater Institute, Central and Arctic Region. Department of Fisheries and Oceans. Winnipeg, Manitoba, Canada.

Kidston, Martin. April 12, 2012. *Friendly to Fish; Greybull river flows through new dam*. Billings Gazette. Billings, Montana.

Kent, R. 1975. Fish populations in tributaries to the upper Nowood Creek and evaluation of Yellowstone cutthroat trout planted in Little Canyon Creek. Wyoming Game and Fish Department Administrative Report, Cheyenne.

Knick, Steven T., and Schueck, Linda, 2002. SAGEMAP: A Web-baes Spatial Dataset for Sage Grouse and Sagebrush Steppe Management in the Intermountain West. U.S. Geological Survey (USGS). Website accessed 8-11-17: https://pubs.usgs.gov/fs/2002/0124/fs12402.pdf

Kruse, C. G. 1998. Influence of nonnative trout and geomorphology on distributions of indigenous trout in the Yellowstone River drainage, Wyoming. Doctoral dissertation. University of Wyoming, Laramie.

Leatherman, D.A., Aguayo, I., and Mehall, T.M. 2011. Mountain Pine Beetle. Colorado State University. Fact Sheet #5.528. Sept. 2011.

Marston, RA, and JE Anderson 1991. *Watersheds and Vegetation of the Greater Yellowstone Ecosystem*. Conservation Biology, Vol.5: 338-346.

Little, 2018. Email correspondence with Kevin Little, USACE office in Cheyenne. Aug. 10, 2018

MCD, 2017. Meeteetse Conservation District (MCD); *Land Use Management and Resource Conservation Plan*, website accessed Nov. 2017; https://meeteetse-conservewy.net/publications-reports/lum-rcp/

Moberly, R.M., 1960, Morrison, *Cloverly, and Sykes Mountain Formations, northern Bighorn Basin, Wyoming and Montana*: USGS Bulletin, v. 71, no. 8, p. 1137–1176.

Muckley, 2018. Phone conversation with Stephanie Muckley, Big Horn County Land Planning department, Aug. 8, 2018.

Munn, Larry C., and Arneson, Christopher S, 1998. *Soils of Wyoming: A Digital Statewide Map at 1:500,000-Scale*, University of Wyoming, Agriculture Experiment Station.

MWH, 2010.b Report: Wind-Bighorn Basin Plan Update. Prepared for the Wyoming Water Development Commission. Prepared by MWH Americas, Inc. May 2010.

MWH, 2010a. *Wind-Bighorn Basin Plan: Task 4B – Spreadsheet Model and Hydrologic Database,* Technical Memorandum prepared for Wyoming Water Development Commission, May 2010.

MWH, 2003. *Wind/Bighorn River Basin Plan: Task 3B/3C – Spreadsheet Model Development and Calibration,* Technical Memorandum prepared for Wyoming Water Development Commission, January 2003.

NC, 2018. The Nature Conservancy; website accessed May 2018: https://www.nature.org/en-us/about-us/who-we-are/how-we-work/private-lands-conservation/

NE, 1991. *Bench Canal Rehabilitation Project, Level II*, prepared for the Wyoming Water Development Commission. Nov. 1991.

Nelson, 1991. Nelson Engineering: Bench Canal Rehabilitation Project, Level II; conducted for the WWDC; Nov. 1991.

Neves, Dave. November 2, 2017. Personal Communication. 7K Ranch Owner.

NPI, 2017. National Preservation Institute. Website accessed oct. 2017. https://www.npi.org/nepa

NPS, 2017. National Park Service: Forest Health: Bark Beetles and Fire. Website accessed Sept. 2017. https://www.nps.gov/romo/planyourvisit/upload/forest_health.pdf

NPS, 2017a. National Park Service website accessed Oct. 2017. https://www.nps.gov/subjects/nationalregister/index.htm

NPS, 2017b. National Park Service website accessed Nov. 2017. https://irma.nps.gov/Stats/Reports/Park/YELL

NRCS, 2018a. USDA Natural Resources Conservation Service; website accessed May 2018; https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/acep/

NRCS, 2018b. USDA Natural Resources Conservation Service; website accessed May 2018; https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/forests/

NRCS, 2018c. USDA Natural Resources Conservation Service: Ecological Site Descriptions; website accessed May 2018; https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/

NRCS, 2018d. USDA Natural Resources Conservation Service, website accessed June 2018; https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/ncps/

NRCS, 2018e. USDA Natural Resources Conservation Service, website accessed June 2018; https://www.nrcs.usda.gov/wps/portal/nrcs/site/national/home/

NRCS, 2011. Natural Resources Conservation Service Conservation Practice Standard: Irrigation Ditch Lining. Natural Resources Conservation Service. Wyoming. December 2011.

NREX, 2017. Natural Resource and Energy Explorer; website accessed Nov. 2017 http://nrex.wyo.gov/map

ODOT, 2014. Hydraulics Design Manual. Engineering and Asset Management Unit, Geo-environmental Section. Oregon Department of Transportation

OWSA, 2017. Office of Wyoming State Archaeologists, website accessed Dec. 2017; http://wyoarchaeo.state.wy.us/index.php/learn/wyoming-archaeology-awareness-month/project-a-day/63-september-8-anderson-lodge

Paige, Ginger, and Zygmunt, Jennifer, 2017. The Science Behind Wildfire Effects on Water Quality, Erosion. Living with Wildfires in Wyoming. PDF accessed on line, Sept. 2017. http://www.uwyo.edu/barnbackyard/_files/documents/resources/wildfire2013/waterqualityerosion2013wywildfire.pdf

Pappas, Gregory S., 2013. Bark Beetles in Western North America: An annotated Bibliography for Natural Resource Managers. University of Wyoming, 2013.

Pierce, William G., 1997. *Geologic Map of the Cody 1$^{o}$ x 2$^{o}$ Quadrangle, Northwestern Wyoming*.

Plafcan, M., Cassidy E.W., and Smalley, M.L. (1993) *Water Resources of Big Horn County, Wyoming*. U.S. Geological Survey. Chyenne, WY.

PT, 2018. Powell Tribune: *Meeteetse-area ferrets succeeding*; website accessed Oct. 2018: http://www.powelltribune.com/stories/meeteetse-area-ferrets-succeeding,16243

Pugh E T and Small E E 2013. The impact of beetle-induced conifer death on stand-scale canopy snow interception. *Hydrol. Res.* 44 644–57.

Pugh, E.T., and Gordon, E.S. 2012. A conceptual model of water yield effects from beetle-induced tree death in snow-dominated lodgepole pine forests. *Hydrological Processes*. Doi: 10.1002/hyp.9312.

RESPEC Consulting and Services, 2013. *E. coli Total Maximum Daily Loads for the Big Horn River Watershed*. Prepared for Wyoming Department of Environmental Quality, Cheyenne, WY.

Rice, et al., 2012. Climate Change on the Shoshone National Forest, Wyoming: A Synthesis of Past Climate, Climate Projections, and Ecosystem Implications. USDA Forest Service, Rocky Mountain Research Station.

Robinove, Charles J., Langford, Russell H. USGS, 1956. *Sedimentation and Chemical Quality of Surface Waters in the Wind River Basin*, Wyoming. USGS, Water-Supply Paper 1373.

Robinove, C.J. and Langford, R.H, 1963. *Geology and Ground-Water Resources of the Greybull River-Dry Creek Area, Wyoming*. U.S. Geological Survey, United States Government Printing Office, Washington D. C.

Rosgen, Dave, 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, CO.

Sawyer, H, and M. J. Kauffman. 2011. Stopover ecology of a migratory ungulate. Journal of Animal Ecology 80:1078-1087.

SBHCD, 2012. Natural Resource and Land Use Plan, 2012-2017, South Big Horn Conservation District.

SCE, 2016. Bench Canal Company Master Plan, Level I Study. Submitted to WWDC by Sage Civil Engineering, January 2016.

SCE, 2011. Final Report: Keystone and Farmers Canal Master Plan, Level I Study. Submitted to WWDC by Sage Civil Engineering, December 2011.

Scribner, Nick. November 14, 2017. Personal Communication. Statewide Passage Coordinator, Wyoming Game and Fish.

SE, 2017. Bear River Watershed – Level I Study; produced by Sunrise Engineering for the Wyoming Water Development Commission, WWDC website accessed Oct. 2017: http://library.wrds.uwyo.edu/wwdcrept/wwdcrept.html

SHPO, 2017. Wyoming State Historical Preservation Office. Telephone and email correspondence with Mary Hopkins, Wyoming State Historic Preservation Officer. Oct. 6, 2017.

Smedes, Harry W., Prostka, Harold J., 1972. *Stratigraphic Framework of the Absaroka Volcanic Supergroup in the Yellowstone National Park Region*, USGS, the Geology of Yellowstone National Park.

Somor A 2010. Quantifying streamflow change following bark beetle outbreak in multiple central Colorado catchments. *M.S. Thesis*. The University of Arizona.

Stednick J D and Jensen R 200.7 Effects of pine beetle infestations on water yield and water quality at the watershed scale in northern Colorado Technical report to CWRRI, Project 2007CO153B.

USACE, 2017. United States Army Corps of Engineers (USACE). National Inventory of Dams. Electronic document, website accessed Oct. 2017. http://nid.usace.army.mil/cm_apex/f?p=838:4:0::NO

U.S. Census, 2017. United States Census Bureau. Website accessed Oct. 2017. https://www.census.gov/programs-surveys/popproj/data/datasets.html

USDA, 2018. U.S. Dept. of Agriculture, Census of Agriculture website accessed May 2018. https://www.nass.usda.gov/AgCensus/

USDA, 2017, NRCS website. https://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/%20website%20accessed%20July%202017./

USDA, 2012. Natural Resources Conservation Service, Prescribed Grazing: practice code 528 PDF released Aug. 2012; Wyoming office.

USDA, 2011. USDA/Agricultural Research Service. (2011, July 12). E. coli can survive in streambed sediments for months. *ScienceDaily*.

USFWS, 2017. U.S. Fish and Wildlife Service, IPaC Information for Planning and Consultation, Website accessed Sept. 2017. https://ecos.fws.gov/ipac/

USFWS, 2015. U.S. Fish and Wildlife Service, *Historic Conservation Campaign Protects Greater Sage-Grouse*, United States Fish and Wildlife Service press release, Sept. 22, 2015.

USFS, 2018. Why does the Forest Service permit livestock grazing on National Forest System lands? Website accessed May 2018; https://www.fs.fed.us/rangeland-management/grazing/allowgrazing.shtml

USFS, 2017. U.S. Forest Service, U.S. Forest Service Manual; https://www.fs.fed.us/im/directives/dughtml/fsm_1000.html,%20website%20accessed%20Sept.%202017.

USFS, 2017a. U.S. Forest Service: Bark Beetle Epidemic. https://www.fs.usda.gov/detail/shoshone/landmanagement/?cid=STELPRDB5358725.%20Website%20accessed%20Sept.%202017.

USFS, 2011. What to Know: Mountain Pine Beetle Fact Sheet. Wyoming, 2011.

USGS, 2017. United States Geological Survey website; Madison Aquifer https://water.usgs.gov/ogw/karst/aquifers/madison/index,%20website%20accessed%20Aug.%202017.

USGS, 2017a. United States Geological Survey website accessed Sept. 2017; https://water.usgs.gov/GIS/huc_name.html#Region10

USGS, 2017b. National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed [December 2017] https://waterdata.usgs.gov/nwis/

USGS, 2013.Wildfire Briefing Sheet. Oct. 2013.

UW/CSU, 2013. Cheatgrass Management Handbook: Managing an invasive annual grass in the Rocky Mountain region, University of Wyoming/Colorado State University, August, 2013.

Varhola A, Coops N C, Weiler M and Moore R D 2010. Forest canopy effects on snow accumulation and ablation: an integrative review of empirical results. *J. Hydrol.* 392 219–33.

WDEQ, 2018a. Wyoming Surface Water Quality Standards; Ch. 1, Sec. 2(b). Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, WY.

WDEQ, 2018b. Phone conversation with Eric Hargett, Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, WY, Aug. 17, 2018.

WDEQ, 2016. Wyoming's 2014 Integrated 305(b) and 303(d) Report. Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, WY.

WDEQ, 2015. Wyoming Department of Environmental Quality, Wyoming Surface Water Quality Standards: Chapter 2: *Permit Regulations for Discharges to Wyoming Surface Waters*, Water Quality Division. Revised 2015.

WDEQ, 2013a. Chapter 1: Wyoming Surface Water Quality Standards. Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, WY.

WDEQ, 2013b. Wyoming Surface Water Classification List. Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, WY.

WDEQ, 2013(1). Livestock/Wildlife Best Management Practice Manual. Water Quality Division. Cheyenne, WY.

WDEQ, 2013(2). Urban Best Management Practice Manual. Water Quality Division. Cheyenne, WY.

WDEQ, 2006. Wyoming Department of Environmental Quality, *Wyoming's 2006 305(b) State Water Quality Assessment Report*.

WGFD, 2017. Wyoming State Wildlife Action Plan. https://wgfd.wyo.gov/Habitat/Habitat-Plans/Wyoming-State-Wildlife-Action-Plan

WGFD, 2017a. Wyoming Game and Fish Department web site access Oct. 2017. https://wgfd.wyo.gov/Fishing-and-Boating/Instream-Flow-XStream-Angler

WGFD, 2017b. The 2017 Upland Game Bird and Small Game Hunting Seasons; brochure. Wyoming Game and Fish Department publication. Website access Nov. 2017; https://wgfd.wyo.gov/Regulations/Regulation-PDFs/REGULATIONS_CH11_BROCHURE.pdf

WGFD, 2017c. Water Management Unit Plan and Stream Prioritization; WGFD. Website accessed Nov. 2017 https://wgfd.wyo.gov/WGFD/media/content/PDF/Fishing/ISF_WATERMGMTPLAN.pdf

WGFD, 2017d. Basin Management Plan; Greybull River (2GR), Wyoming Game and Fish Department, Fish Division. 2017.

WGFD, 2017e. Wyoming Game and Fish Department web site; accessed Oct.-Dec. 2017. https://wgfd.wyo.gov/Habitat/Habitat-Plans/Habitat-Priority-Areas

WGFD, 2017f. Wyoming Game and Fish Department. Phone conversations and email exchanges with several WGFD staff members. Dec. 2017.

WGFD, 2017g. Basin Management Plan; Dry Creek (2DC), Wyoming Game and Fish Department, Fish Division. 2017.

WGFD, 2017h. Mountain Plover; Wyoming Species Account, Wyoming Game and Fish Department. 2017.

WGFD, 2015. Wyoming Game and Fish Department: Strategic Habitat Plan; 2015. https://wgfd.wyo.gov/Habitat/Habitat-Plans/Strategic-Habitat-Plan

WGFD, 2015a. Standardized Definitions for Seasonal Wildlife Ranges. Revised Nov. 2015. https://wgfd.wyo.gov/Habitat/Sage-Grouse-Management

WGFD, 2005. Wyoming Game and Fish Department, Fish Division, Administrative Report; *Wood River Drainage Instream Flow Studies: Development of Instream Flow Water Right Recommendations for 4 Wood River Segments and Dick Creek*, May 2005.

WGFD, 2004. Wyoming Game and Fish Department, Fish Division, Administrative Report; *Greybull River Instream Flow Studies*, Feb. 2004.

WGFD, 2003. Wyoming Game and Fish Department, Fish Division, Administrative Report; *Instream Flow Studies on Pickett Creek, a Greybull River Tributary*, June 2003.

WNDD, 2017. Wyoming Natural Diversity Database, website accessed Sept. 2017. https://www.uwyo.edu/wyndd/

WRCC, 2017. Western Regional Climate Center. Website accessed Oct. 2017. https://wrcc.dri.edu/

WRDS, 2017. Wyoming Water Resources Data System and Wyoming State Climate Office. Website accessed Oct. 2017. http://www.wrds.uwyo.edu/sco/wyoclimate.html

WSEO, 2018a, State Engineer's Office Division III Diversion Data, 2018, District 8 and 16 Annual Hydrographer Reports, accessed [December 2018] https://sites.google.com/a/wyo.gov/seo/agency-divisions/division-iii---riverton/hydrographers-annual-reports

WSEO, 2018b. Two phone conversation with Cheryl Wright, Wyoming SEO office, regarding permit requirements for existing irrigation ditch improvements, Aug. 7 and Aug. 9, 2018.

WSEO, 2017. Wyoming State Engineer's Office. ePermit - Water Right Database. Electronic document, website accessed Oct. 2017

WSEO, 1974. State Engineer's Manual of Regulations and Instructions, Part II. Wyoming State Engineer's Office (WSEO). 1974

WSFD, 2017. Forest Health Management: Wyoming Forest Health Topics Overview. https://docs.google.com/presentation/d/17RSUg6ENtnobeWUa6GOlg6r8DqkCUOm53mx9YAlfaeg/pub?start=true&loop=true&delayms=10000&slide=id.gf3fad8786_0_12. Website accessed Sept. 2017.

WSFD, 2010. Wyoming State Forestry Division, Wyoming Statewide Forest Resource Strategy: Providing Long-Term Strategies to Manage Priority Landscapes. Wyoming State Forestry Division; Office of State Lands and Investments. 2010.

WSGS, 2017. Wyoming State Geological Survey website accessed Aug. 2017. http://www.wsgs.wyo.gov/wyoming-geology/geologic-history

WWDC, 2018a, Instream Flow, accessed [January 2018] http://wwdc.state.wy.us/instream_flows/instream_flows.html

WWDC, 2018b. Public Water System Survey, submitted Feb. 22, 2018 to the WWDC; website accessed October, 2018; http://wwdc.state.wy.us/watsys/responses/5600022C.html

WWDC, 2016. Wyoming Water Development Commission. 2016. Public Water System Survey. Electronic document, website accessed Oct. 2017 http://wwdc.state.wy.us/watsys/responses/5601098C.html

http://wwdc.state.wy.us/watsys/responses/5600035C.html

http://wwdc.state.wy.us/watsys/responses/5600022C.html

WyGISC. 2014. Simplified Land Cover (Vegetation) Type Descriptions. University of Wyoming, Laramie, Wyoming.

WYNRCS, 2018. Wyoming payment discussion; website accessed May 2018: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/wy/technical/stc/minutes/?cid=nrcs142p2_026803

Zafft, D. J. and T. C. Annear 1992. Assessment of stream fishery impacts and instream flow recommendations related to the Greybull Valley Project. Administrative Report. Wyoming Game and Fish Department, Fish Division, Cheyenne.

Zelt, Ronald B., Boughton, Greg, Miller, Kirk A., Mason, Jon P., Giankos, Laura M., 1999. *Environmental Setting of the Yellowstone River Basin, Montana, North Dakota, and Wyoming*. USGS, Water Resources Investigation Report 98-4269.

# TABLES

**Draft Report: Greybull River Watershed Level I Study**

**Prepared for the Wyoming Water Development Commission** Nov. 16, 2018

***Prepared by Woodard & Curran***

**Table 4**

**WDEQ Stream Classifications**

| River/Stream | Stream Classification |
|---|---|
| Dry Creek (below Hwy 32) | 2ABww |
| Dry Creek (between Hwy 32 and Hwy 120) | 3B |
| Dry Creek (above Hwy 120) | 2AB |
| South Lateral | 4A |
| Red Point Creek | 3B |
| N. Fork Dry Creek | 3B |
| Oregon Coulee | 3B |
| Coal Mine GL | 3B |
| Wiley Lk | 2AB |
| S. Fork Dry Creek | 3B |
| Greybull River | 2AB |
| Dorsey Creek | 3B |
| McKenny Creek | 3B |
| Sandstone Reservoir | 3B |
| McGee GL | 3B |
| Spring Creek | 3B |
| Rodeo Creek | 3B |
| Rose Creek | 3B |
| Paradise Creek | 3B |
| Farmers Canal | 4A |
| Beck-Allen Canal | 4A |
| Bench Canal | 4A |
| Wardel Reservoir | 2ABww |
| Venus Creek | 1 |
| Willow Creek | 2AB |
| Meeteetse Creek | 2AB |
| Timber Creek | 2AB |
| Francs Creek | 2AB |
| Pickett Creek | 2AB |
| Iron Creek | 4B |
| Rawhide Creek (upper 14.8 miles) | 2B |
| Rawhide Creek (lower 14 miles) | 2C |
| Anderson Creek | 1 |
| Wood River | 2AB |
| Sunshine Creek | 2AB |
| Middle Fork Wood River | 2AB |
| South Fork Wood River | 2AB |
| Sunshine Reservoir | 2AB |
| East Fork Wood River | 3B |

Source: WDEQ, 2013a

## Table 6: Stream Gauge Dry, Average, Wet Designations

| Watershed | USGS Site No. | Station Name | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Greybull | 06276500 | Greybull River at Meeteetse, WY | Avg | Wet | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Avg | Dry | Dry | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Wet | Wet | Wet | Avg | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Wet | Avg | Wet |
| Greybull | 06274500 | near Pitchfork, WY | Avg | Wet | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Avg | Dry | Dry | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Wet | Wet | Wet | Avg | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Wet | Avg | Wet |
| Greybull | 06274800 | Wood River Near Kirwin, WY | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Avg | Dry | Dry | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Wet | Wet | Wet | Avg | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Avg | Avg | Wet | Wet | Avg | Avg | Avg | Wet | Avg | Wet |
| Greybull | 06274810 | Wood River at Kirwin, WY | Avg | Wet | Wet | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Avg | Dry | Dry | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Wet | Avg | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Avg | Avg | Wet | Wet | Avg | Avg | Avg | Wet | Avg | Wet |
| Greybull | 06275000 | Wood River at Sunshine, WY | Wet | Wet | Avg | Avg | Dry | Avg | Avg | Avg | Avg | Dry | Wet | Avg | Dry | Avg | Avg | Dry | Dry | Dry | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Wet | Wet | Wet | Avg | Dry | Dry | Avg | Dry | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Wet |
| Greybull | 06275500 | Wood River near Meeteetse, WY | Avg | Wet | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Avg | Dry | Dry | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Wet | Wet | Wet | Avg | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Wet | Avg | Wet |
| Greybull | 06277500 | Greybull River near Basin, WY | Avg | Wet | Wet | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Avg | Dry | Dry | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Wet | Wet | Avg | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Wet | Avg | Wet |
| Dry Creek | 06277950 | Dry Creek near Greybull, WY | Avg | Avg | Wet | Wet | Avg | Wet | Avg | Avg | Avg | Avg | Avg | Avg | Dry | Wet | Avg | Avg | Dry | Avg | Avg | Avg | Avg | Dry | Wet | Avg | Wet | Avg | Wet | Wet | Avg | Dry | Dry | Dry | Dry | Dry | Avg | Dry | Avg | Wet | Avg | Avg | Avg | Wet | Wet | Dry | Avg |
| Dry Creek | 06278000 | Dry Creek at Greybull, WY | Avg | Wet | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Avg | Dry | Dry | Avg | Avg | Avg | Avg | Avg | Avg | Wet | Wet | Wet | Wet | Avg | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Avg | Avg | Avg | Wet | Avg | Avg | Avg | Wet | Avg | Wet |

| Legend | |
|---|---|
| Dry | Dry Year |
| Avg | Average Year |
| Wet | Wet Year |

## Table 8
## Aquatic Species Observed Within the
## Greybull River Basin

| Common Name | Scientific Name | Status |
|---|---|---|
| **Fish** | | |
| Brook Trout | *Salvelinus fontinalis* | Nonnative |
| Black Bullhead | *Ameiurus melas* | NSS5 |
| Black Crappie | *Pomoxis nigromaculatus* | Nonnative |
| Bluegill | *Lepomis macrochirus* | Nonnative |
| Brown Trout | *Salmo trutta* | Nonnative |
| Channel Catfish | *Ictalurus punctatus* | NSS5 |
| Carp | *Cyprinus carpio* | Nonnative |
| Flathead Chub | *Platygobio gracilis* | **NSS4** |
| Flathead Minnow | *Pimephales promelas* | NSS7 |
| Fall Rainbow | *Oncorhynchus mykiss* | Nonnative |
| Golden Trout | *Oncorhynchus aguabonita* | Nonnative |
| Golden Shiner | *Notemigonus crysoleucas* | Nonnative |
| Lake Chub | *Couesius plumbeus* | NSS5 |
| Largemouth Bass | *Micropterus salmoides* | Nonnative |
| Longnose Dace | *Rhinichthys cataractae* | NSS7 |
| Longnose Sucker | *Catostomus catostomus* | NSS5 |
| Mountain Sucker | *Catostomus platyrhynchus* | NSS5 |
| Mountain Whitefish | *Prosopium williamsoni* | NSS4 |
| Shorthead Redhorse | *Moxostoma macrolepidotum* | NSS5 |
| Plains Killifish | *Fundulus zebrinus* | NSS4* |
| Rainbow Trout | *Oncorhynchus mykiss* | Nonnative |
| River Carpsucker | *Carpiodes carpio* | NSS5 |
| Sauger | *Sander canadense* | **NSS3** |
| Sand Shiner | *Notropis stramineus* | NSS7 |
| Splake | --- | Nonnative |
| Snake River Cutthroat | *Oncorhynchus clarkii* | NSS4 |

| Common Name | Scientific Name | Status |
|---|---|---|
| **Fish** | | |
| Stonecat | *Noturus flavus* | NSS5 |
| Walleye | *Sander vitreus* | Nonnative |
| White Crappie | *Pomoxis annularis* | Nonnative |
| White Sucker | *Catostomus commersoni* | NSS7 |
| Yellow Perch | *Perca flavescens* | Nonnative |
| Yellowstone Cutthroat | *Oncorhynchus clarkii* | **NSS3** |
| **Amphibians** | | |
| Boreal Chorus Frog | *Pseudacris maculata* | NSS5 |
| Western (Boreal) Toad | *Anaxyrus boreas boreas* | **NSS1** |
| Northern Leopard Frog | *Lithobates pipiens* | **NSS4** |
| Plains Spadefoot | *Spea bombifrons* | **NSS4** |
| Columbia Spotted Frog | *Rana luteiventris* | **NSS3** |
| Rocky Mountain Toad | *Anaxyrus woodhousii* | NSS5 |
| Western Tiger Salamander | *Ambystoma mavortium melanostictum* | **NSS4** |
| **Reptiles** | | |
| Bullsnake | *Pituophis catenifer sayi* | NSS5 |
| Eastern Yellow-bellied Racer | *Coluber constrictor flaviventris* | NSS5 |
| Greater Short-horned Lizard | *Phrynosoma hernandesi* | **NSS4** |
| Wandering Gartersnake | *Thamnophis elegans vagrans* | NSS5 |
| Northern Rubber Boa | *Charina bottae* | **NSS3** |
| Northern Sagebrush Lizard | *Sceloporus graciosus graciosus* | NSS5 |
| Plains Hog-nosed Snake | *Heterodon nasicus* | NSSU** |
| Pale Milksnake | *Lampropeltis triangulum multistriata* | **NSS3** |
| Prairie Rattlesnake | *Crotalus viridis* | **NSS4** |
| Eastern Spiny Softshell | *Apalone spinifera spinifera* | **NSS2** |

Source: WGFD, 2017d

**BOLD** indicates SGCN; *Native in Wyoming but not native in this watershed; ** Information is lacking to determine status

# Table 10: Fish Passage Barriers

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Greybull River | Arnold Ditch | Water is diverted to a N. channel by a rock spur. It then flows a 1/8 mile to a push-up dam which forces water 200 yards NE to a headgate/bypass. | Passable, Many Species | Push-up/Rock | Yes | The headgate is large (4'), so there is potential for entrainment. Passage could be an issue during low water, but it was not at this time. It would be difficult to screen the ditch at the headgate/bypass structure because of its distance from the river/ |
| Greybull River | Beck and Allen Ditch | The Beck & Allen Ditch diverts off the Farmers Canal, and is therefore not an a fish passage issue. | | | | |
| Greybull River | Bench Canal | This canal shares a common diversion with the Farmer Canal. For a complete description of that diversion see the profile for Farmer & Bench Diversion. | | | | |
| Greybull River | Croxall and Brown Diversion | **Data not collected/synthesized by WGFD.** | | | | |
| Greybull River | Butte Ditch | Water is diverted through an open ditch to the E. Diverted water travels a ¼ mile where it hits a headgate/by-pass structure. | Seasonally Passable, Many Species | | | If more water was left in the river during this time of year the diversion would not be a barrier. This is a seasonal barrier, and should be passable at higher flows. |
| Greybull River | Dodge Canal | | Passable, Many Species | Push-up/Rock | Yes | Passage is not likely a large issue with this ditch; however fish might be getting entrained. A proper fish screen could mitigate this issue. |
| Greybull River | Dyer Ditch | The river flows into a sandstone wall about 100' before the P.O.D. and bends to the N. Water leaves the river through an open ditch on the east side. | Passable, Many Species | Push-up/Rock | Yes | The diversion does not create a barrier at this time although during low flows it could be extended across the whole river. The open ditch carries diverted water to an unscreened headgate. The irrigator did not indicate seeing many fish in this ditch. |
| Greybull River | Farmer's Canal | This canal shares a common diversion with the Bench Canal. For a complete description of that diversion see the profile for Farmer & Bench Diversion. | | | | |
| Greybull River | German Ditch | The river channel divides with diverted water continuing E. through a headgate, & the rest dropping N. over a rip-rap diversion into the river channel. | Partially Passable, Salmonids | Other | No | This would likely be a low priority for mitigation.<br>The Farmer and Bench Canals point of diversion is only a mile upstream from here and it de-waters the river. The headgate is not screened so there is potential for entrainment. |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Greybull River | J.F.W. Canal | J.F.W. diverts from the Perkins, which diverts from the Beck & Allen, which diverts from the Farmer, which shares a common diversion with the Bench. | | | | |
| Greybull River | Pappapau Ditch | | Passable, Many Species | Push-up/Rock | Yes | Passage is not a yearlong issue at this diversion, but it is uncertain how the dam is manipulated during irrigation. It could potentially be changed to divert more water, and in doing so negatively affect passage. |
| Greybull River | Rocky Ditch Diversion | River divides into 2 channels above the point of diversion. An open ditch on the right channel takes water ¼ of a mile to a headgate/by-pass structure. | Passable, Many Species | | | There is no barrier associated with this ditch. The irrigator does not report seeing many fish in the ditch, but it's not screened leaving potential for entrainment. The headgate structure is located about ¼ of a mile downstream from the point of diversion. |
| Greybull River | Ruby Ditch Diversion | **Data not collected/synthesized by WGFD.** Ditch was not surveyed, but irrigator was contacted-See Notes. | | | | The ditch does not typically have an in-stream push-up dam to divert water. However, in the fall during low water years a push-up has been used. The irrigators have placed a Hog panel in front of the headgate in a horse-shoe shape. |
| Greybull River | Sandstone Ditch | Water is diverted by a push-up dam. The dam spans the width of the river & diverts all flows through a buried culvert into the ditch channel. | Not Passable | Earth | Yes | This diversion is a complete barrier to fish and without a screen it likely entrains fish. However, the river is has many diversions above it and 2 to 3 below it. These factors likely make it a low priority for mitigation. |
| Greybull River | T.L. Ditch | The river is flowing to the N. with water diverted off the west side through a headgate directly on the river at the point of diversion. | Passable, Many Species | | | The headgate is not screened so there is potential for fish to be entrained. The irrigator could not be contacted so no information on the number of fish in the ditch could be obtained. The diversion does not create a fish barrier. |
| Greybull River | Whitney Gleaver Ditch Diversion | | Passable, Many Species | Push-up/Rock | Yes | Passage is not a yearlong issue at this diversion, but it is uncertain how the dam is manipulated during irrigation. It could potentially be changed to divert more water, and in doing so negatively affect passage. |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Greybull River | Wilson McNally Ditch | Water is diverted off the right bank through an open ditch. From the P.O.D. water travels a ¼ of a mile to the headgate/ by-pass structure. | Passable, Many Species | | | There is no fish barrier at this diversion, so passage is not an issue. However, there is no screen at the headgate making entrainment a possibility. The irrigator does have problems with silt and there was some accumulation seen at the outlet. |
| Greybull River | Winkle and Benbrook Ditch Dive | The river runs N.E. with water diverted off the E. side through an open ditch. From here water travels a ¼ mile to the headgate/by-pass structure. | Seasonally Passable, Many Spec | | | |
| Meeteetse Creek | Joe Moss Ditch | Water is diverted out to the Cr. to the E. by a rock/rubble/board push-up dam. It is directed into an open ditch through a metal culvert controlled by a head-gate. | Passable, Salmonids | Other | No | The diversion is messy, but not a serious passage issue for trout. It is one of the largest ditches on the Cr. and is not screened, so there is potential for entrainment. It is therefore a moderate priority for mitigation. |
| Pickett Creek (Prev | Ashworth No. 2 Ditch | | Passable, Many Species | Push-up/Rock | Yes | Passage does not appear to be an issue at this ditch. However, because there is no screen on the head-gate and the high number of fish seen in the diverted channel entrainment is likely an issue for the little time it runs during the fall. |
| Wood River | Only Chance Ditch | **Data not collected/synthesized by WGFD.** | | | | |
| Greybull River | Fairview Canal | Water is diverted through an open channel on the right bank of the river. The headgate is 35 yards downstream from the point of diversion. | Passable, Many Species | | | The diversion does not create a permanent barrier and there is no in-stream structure to impede fish movements. The headgate does not have a screen which makes entrainment a possibility. |
| Greybull River | Jimmerfield Ditch | Water flowing NE is diverted by a small rock spur into an open ditch channel. It continues NE passed a spillway to a headgate/bypass structure. | Passable, Many Species | Other | No | The ditch does not create a barrier to passage. There is no screen on the headgate, so there is potential for entrainment. |
| Greybull River | Keystone Ditch Diversion | The River is diverted into an open ditch through a rock/gravel push-up dam. The headgate structure is located a ¼ mile from the point of diversion. | Passable, Many Species | Push-up/Rock | Yes | If the diversion is a barrier it is only seasonal. All fish could pass at the time of the survey. A lot of water is diverted out of the river at this diversion through an open ditch and the headgate is not screened so entrainment could be a possibility. |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Greybull River | Roach-Jimmerfield Ditch | This ditch now shares a common diversion with the Roach Gulch Supply Canal, and no longer diverts water directly off the river. | | | | |
| Greybull River | Snyder (Nichols) Ditch | Shares a common diversion with the Roach Gulch Supply Canal and is therefore not a fish passage issue. | | | | |
| Greybull River | Tatman - St Joe Diversion | Water is diverted off the right bank of the river through an open ditch. | Passable, Many Species | | | The diversion does not create a barrier for passage, but the headgate is not screened creating a possibility for entrainment. |
| Greybull River | Pitchfork ditch (also known as th | | Passable, Many Species | Push-up/Rock | Yes | Passage is not a yearlong issue at this diversion, but it is uncertain how the dam is manipulated during irrigation. It could potentially be changed to divert more water, and in doing so negatively affect passage. |
| Greybull River | Cheeseman Ditch Diversion | **Data not collected/synthesized by WGFD.** **BAGs location modified using ALLTOPO NAD 83** | | | | |
| Greybull River | Cockins Ditch Diversion | **Data not collected/synthesized by WGFD.** **BAGs location modified using ALLTOPO NAD 83** | | | | |
| Greybull River | Wood and Burnett Ditch | River flows E. into a concrete headgate structure which diverts water & causes the river to bend to the S. & drop over a narrow concrete diversion. | Partially Passable, Salmonids | Concrete | No | The diversion is a permanent barrier to most fish and without a screen it has potential to entrain fish. However, there are diversions upstream and downstream from this point, so during low water events the river is likely fragmented. |
| Franc's Fork | Pitchfork Rd. culvert | The rd. crossing used to consist of 2 culverts and an elevated concrete apron. The crossing was replaced in the fall of 2009. | Passable, Many Species | | | |
| Franc's Fork | Ashworth No. 3 | Cr. flows to the NE and is diverted to the E. by a rock/boulder push-up dam. The head-gate/by-pass structure is about 1/8 of a mile E. of the point of diversion. | Passable, Many Species | Push-up/Rock | Yes | The head-gate structure for this ditch has a by- pass channel back to the Cr. Entrainment in the ditch could be reduced by screening fish at the head-gate and directing them back to the Cr. through the by-pass. Passage was not an issue at this time. |
| Wood River | Wood River Supply ditch diverio | Talked to Mike May about access onto the Antler ranch on 10/15/09. Access was denied based on concerns involving structure maintenance, and issues with the WGFD not following through. | | | | |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Greybull River | Flanagan | The River is flowing in the N.E. direction as it bends to the E. it divides into 2 channels. Water is diverted out of the smaller of the two channels by a small push-up diversion. | Passable, Many Species | | | The push-up dam did not block the entire river channel, but if that became necessary during low flow years, passage would be possible in the channel to the south. There is no screen on the headgate, so there is potential for entrainment. |
| Greybull River | Young ditch diversion | The E. flowing river divides into 2 channels upstream from the P.O.D. Water exits from the S. channel through an open ditch. These flows can be blocked by stretching tarp material across the inlet. | Passable, Many Species | | | At the point of diversion there are more than two channels of the river, so even if the diverted channel was completely blocked fish could still have passage up the other channels. The ditch was not running during the survey. |
| Greybull River | Elk Ditch Diversion | A small rock instream push-up dam diverts water from a northern side channel of the Greybull R. The diverted water is directed into a ditch or a by- pass channel by a T-shaped concrete structure. | Passable, Many Species | | | The push-up dam only blocks 2/3 of the width of the side channel so passage is not an issue. Fish were seen at the mouth of the ditch and one was seen being diverted into the by-pass channel so entrainment is likely an issue. |
| Greybull River | Meyers Ditch No. 4 | Water divides into 2 channels about 400' upstream from the point of diversion. The smaller channel to the S. has water diverted off its southern side through an open ditch with no control structure. | Passable, Many Species | | | It does not appear that this diversion causes any passage issues. Fish could still move past the point of diversion in the northern channel of the river if a push-up dam were put in place in the southern channel. Entrainment might be an issue for fish. |
| West Timber Creek | Unknown diversion No. 2, Pitchfork Ranch | Water flowing to the N. enters a T-shaped concrete structure in the Cr. Water flows into the structure and either passes straight through and back into the Cr., or is diverted into a ditch to the W. | Seasonally Passable, Salmonids | Concrete | Yes | The structure is likely a barrier during irrigation season and a partial barrier at other times. It also has potential to entrain fish during the irrigation season because it blocks the width of the Cr., and the ditch outlet has no screen. |
| West Timber Creek | Unknown diversion No. 1, Pitchfork Ranch | Water flowing N. enters a T-shaped concrete structure with two outlets. Water either continues N. straight through the structure or it is diverted into a ditch through an outlet to the E. | Seasonally Passable, Many Spec | Concrete | Yes | The diversion is at least a partial barrier during the irrigation season, but does not create passage issues during other times of the year. Entrainment could also be a problem during irrigation because there is no screen at the point of diversion. |
| West Timber Creek | West Timber Creek Ditch | Water from the Pitchfork and Ashworth ditch No. 3 dump into the Cr. about 20' upstream from the diversion. This water and additional flows from Timber Cr. are then diverted to the east. | Seasonally Passable, Salmonids | Concrete | No | The 3' drop created by this diversion is likely a partial barrier year round, however when flows are blocked within the structure during irrigation it is probably a complete barrier. Entrainment is also a possibility. |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Greybull River | Co. Rd. 3NG Bridge | The river flows NE. under a concrete bridge with 3 piers. The majority of water goes between the southernmost piers slightly constricting flows. | Passable, Many Species | | | |
| Greybull River | Sunshine Supply Canal | Water flowing east is forced into a southern river channel by a large push- up dam. From here it is diverted to the south through two large head-gates set in a concrete diversion dam. | Not Passable | Concrete | No | Fish are likely being entrained in this ditch because the amount of water which is taken out of the river on a seasonal basis. A fish screen could help mitigate the # of fish lost down this canal. |
| Greybull River | Weller Ditch | The E. flowing river braids into 2 channels with water diverted out of the northernmost one by a push-up dam. The head-gate and by-pass channel are located 1/8 of a mile from the point of diversion. | Passable, Many Species | Push-up/Rock | Yes | It is uncertain to the number of fish entrained in this ditch, however because there is no screen it has potential to occur. |
| Greybull River | Jevon Ditch | Water is diverted out of the river to the N. by a rock/stream bed material push up diversion. | Passable, Many Species | Push-up/Rock | Yes | Passage is not a yearlong issue at this diversion, but it is uncertain how the dam is manipulated during irrigation. It could potentially be changed to divert more water, and in doing so negatively affect passage. Young of year trout were seen. |
| Pickett Creek | Trout Ditch Diversion | S. flowing Cr. enters an in-stream, T-shaped diversion structure. From here water either continues S. through the ditch head-gate or bends to the W. through a by-pass back to the stream channel. | Seasonally Passable, Salmonids | Concrete | No | Additional passage notes: Passage is more affected during irrigation when stacked 2x4's block the outlet, likely making it impossible for fish to pass upstream. Another passage factor to consider is the flows through this section of the Cr. |
| Rose Creek | Ashworth No. 1 | SE. flowing Cr. has a ditch travel directly through its channel from the W. and perpendicular to its flows. At this point the Cr is dammed and diverted using boards/tarp set in a concrete structure. | Seasonally Passable, Salmonids | Other | | Irrigator indicated that this Cr. goes underground near the base of the Mt. upstream from the point of diversion. He also indicated that this Cr. has brook trout. |
| Pickett Creek (Prev | Whitefish ditch | A push-up dam diverts water out a side channel on the W. channel of Pickett Cr. The Cr. is manipulated upstream of the diversion forcing water either in a W. or E. channel based on irrigating needs. | Passable, Many Species | Push-up/Rock | Yes | This ditch only runs for three weeks in the spring. It doesn't have a control structure so fish are likely being entrained down the open ditch, but the short running period likely makes this a low priority for mitigation. |
| Wood River | Hurlbet Ditch | Information gathered from District 16 Hydrographer-Commissioner notes. No access was granted. | | | | |
| Wood River | River ditch | Information gathered from District 16 Hydrographer-Commissioner notes. No access was granted. | | | | |
| Wood River | Brown and Hagberry ditch | The point of diversion was not visited, no access was granted by the landowner. Water is diverted off the west side of the River. | | | | |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Wood River | Davis Ditch Diversion | Not visited, no access granted. The JW Thomas ditch is less than a mile upstream and the Watson ditch is less than a mile downstream from this diversion. | | | | |
| Wood River | Cheese-mantle ditch | This ditch leaves the E. side of the River, and ties in with the Only Chance ditch. The Wilson ditch is less than a mile upstream and the Only Chance ditch is over a mile downstream from this point. | | | | |
| Wood River | Watson ditch | The ditch leaves the river on the west side. The Davis ditch is located less than a mile upstream and the Hurlbet ditch is over a mile downstream. | | | | |
| Wood River | Hagberry No. 2 & No. 3 | Only the head-gate for this system was surveyed, because no access was granted on the property with the point of diversion. The head-gate structure consists of a ditch outlet and a by-pass outlet. | | | | This diversion has a by-pass channel at the head- gate that takes water back to the River. A fish screen could be placed on the head-gate to by- pass fish back to the river. The by-pass channel reconnected with the river at the time of the survey. |
| Wood River | Hagberry No. 1 | Water is diverted out of the main river channel through an open ditch. The ditch cuts through a side channel where it diverts additional water. The side channel only has water during high water. | Passable, Many Species | | | The ditches trash screen has narrow enough openings that almost all fish would be washed over the screen into the by-pass channel. The by-pass channel was empty at the time of the survey, but water has to travel .5 miles to get back to the river. |
| Wood River | Wilson ditch | Water is diverted out of a side channel on the W. side of the river through an open ditch. About 100' downstream from the 1st point of diversion a push-up dam can be used to divert more water. | Passable, Many Species | Other | Yes | This is the only ditch the irrigator has seen fish in. There is a by-pass channel at the head-gate, creating a possibility for screening the ditch at that point. |
| Wood River | Cutshall's irrigation pump | A small open ditch on the SW side of the river diverts water about 300' to a settling pond. From here water is either pumped out through two small pumps or is by-passed back to the river. | Passable, Many Species | | | The diversion itself likely has very little impact on fish passage. However, the river channel just downstream from this point has been heavily manipulated (narrowing and deepening flows). Any entrained fish would more likely continue downstream. |
| Wood River | Renneberg pipeline No. 2 | An open ditch transports water out of a northern side channel of the river. The ditch carries water to a head-gate regulated buried pipe, and then to a settling pond with irrigation pumps. | Passable, Many Species | | | This ditch does run during spring spawning periods, but doesn't create a barrier for fish passage. The ditch only runs about 100 yards before spilling out into the settling pond. It may entrain some fish because there is no screen on the head-gate. |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Wood River | Loveland ditch | The River is forced into a man-made channel as it flows to the NE. The bank has been built up above the water level about 6' at the point of diversion. Water is diverted to the E. | Passable, Many Species | Push-up/Rock | Yes | It is uncertain to how often this ditch is used and how it appears when it is active. As it is now there are no problems with passage. There is no control structure so it is likely that fish could be entrained when the ditch is active. |
| Wood River | J.W. Thomas ditch | Location is based on data from Water district No. 16. | | | | |
| Wood River | Noon point rd. bridge | Free spanning, metal and concrete bridge over the Wood River. The concrete side pillars constrict the river flow, but not enough that it would inhibit fish passage. | Passable, Many Species | | | |
| Dick Creek | Dick Creek Ditch | This diversion has not been field investigated. The Creek is running to the northeast with the diverted water leaving to the north. | | | | |
| Dick Creek | Bowers Ditch | This diversion was not field investigated. Information comes from Water district No. 16 records. The ditch occurs on property owned by the Antler Ranch, and access was not granted. | | | | |
| Dick Creek | Belle Ditch | This ditch was not field investigated, because no access was granted. Information on this ditch was obtained from the Water district 16, and the Wyoming Water Rights Database. | | | | |
| Meeteetse Creek | Meeteetse Rim ditch | This ditch has not yet been field surveyed. Information was obtained from Water district No. 16 records. | | | | |
| Meeteetse Creek | Winninger Pipeline | Water is diverted through a screw-type metal headgate backed by wooden planks and reinforced with two iron pilings. | Passable, Many Species | Other | No | There is no permanent barrier associated with this ditch. The hog panel screen is not meant for fish and would allow all fish into the headgate, so there is potential for entrainment. |
| Meeteetse Creek | Nina ditch | Cr. flows E. into a concrete headgate structure, which diverts water through a buried culvert. The Cr. bends to the S.E. after passing by the headgate and drops over two small diversion structures. | Seasonally Passable, Many Species | Other | No | The diversion might be a seasonal barrier if water levels are low enough, but the diversion as it is now is not a passage issue. There is no screen on the headgate so there is potential for entrainment. |
| Meeteetse Creek | Gordon No. 1 ditch | Determined during interview with the landowner that this ditch has been eliminated. | | | | |
| Rawhide Creek | Thomas ditch | This ditch has only preliminary data, and has not been field surveyed. It diverts water off the S. side of the Cr. and irrigates lands to the S.W. | | | | |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Rawhide Creek | Pearce No. 2 ditch | A rock/coble push-up dam forces water through a screwtype metal headgate on the right bank of the river. | Passable, Salmonids | Other | No | There are YSCs in this Cr. so it would be nice to have this ditch screened at some point. Passage could become a problem depending on how the push-up dam is engineered each year. The other issue with this Cr. system involves its flows. |
| Little Rawhide Creek | Pearce ditch | This ditch has only preliminary data, and has not yet been field surveyed. Information is based on an interview with the 91 Ranch manager. | | | | |
| Rawhide Creek | Pearce No. 3 ditch | Water is backed up by a concrete headwall causing flows to leave the Cr. through a headgate on the left bank. | Not Passable | Concrete | Yes | The diversion is a barrier and the headgate is not screened creating a potential for entrainment. However the flow regime of this system should be better understood before the barrier is fixed. |
| Rawhide Creek | Rawhide No. 2 ditch | A concrete chute with headwalls on each bank of the Cr. uses drop boards to back up water and divert flows through a headgate on the right bank of the Cr. | Not Passable | Concrete | No | The diversion is an upstream barrier to fish passage, and creates an insufficient flow barrier in the Cr. below it. The headgate is not screened so there is also potential for entrainment. |
| Meeteetse Creek | Hagen ditch | Cr. flows E. into a concrete headgate structure, which diverts water through a buried culvert. The Cr. bends to the S.E. after passing by the headgate and drops over a small concrete diversion. | Partially Passable, Salmonids | Concrete | No | The diversion is only a partial barrier, and therefore not a high priority. The headgate is not screened, so there is some potential for entrainment. |
| Meeteetse Creek | Gordon No. 2 ditch | Water is diverted into a short side channel with a 6' mouth. A screw-type metal headgate backed by sheet metal regulates flows into a buried culvert which dumps into an open ditch. | Seasonally Passable, Many Species | Push-up/Rock | Yes | The diversion is a low priority for mitigation, because it only causes a barrier during low water. The irrigator rarely sees trout in the ditch, and has seen fewer in recent years, however because it is not screened it has potential for entrainment. |
| No Name Creek | No Name Creek Falls, No. 1 | A natural waterfall on No Name Creek causes a complete barrier to passage. No measurements were taken of the waterfall. | Not Passable | | | Natural barrier--no recommendations |
| Canyon Creek | Wood River Rd. crossing, Canyo | Canyon Cr. goes under the Wood river road through a corrugated metal culvert. | Unknown | | | The culvert's downstream end is placed above the bed level creating a partial barrier. However, fixing this structure would provide minimal habitat because there is a natural barrier about 20 yards upstream from the crossing. |
| Canyon Creek | Canyon Creek, Natural Barrier N | A vertical cascade over some large boulders causes a barrier to fish passage. | Not Passable | | | This is a natural barrier and does not require treatment. |
| Little Rose Creek | Little Rose Creek, Falls No. 1 | A large waterfall over a rock outcrop creates a complete barrier to passage. | Not Passable | | | The waterfall is a natural barrier, therefore no treatment is recommended. |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Rose Creek | Rose Cr., Natural barrier No. 1 | The Creek cascades over some large boulders creating a significant drop. | Not Passable | | | This is a natural barrier, therefore no treatment is recommended. |
| Rose Creek | Rose Creek, Dry Section | The information for this barrier was collected from A. Croft's YSC CARA files and WHAM surveys. The location represents the upper part of the dry section. | Not Passable | | | This dry section of Rose Creek is not created by an upstream diversion. |
| Anderson Creek | Anderson Creek, Natural Barrier | The Cr. cascades through a series of boulders creating a barrier to upstream passage. Information was gathered from A. Croft's YSC CARA files, and Aderson Cr. WHAM surveys. | Not Passable | | | |
| Wood River | Wood River, Natural Barrier No. | A waterfall on the Wood River creates a complete barrier for fish moving upstream. | Not Passable | | | There is a barrier below this point which inhibits fish from traveling this far up the drainage. |
| Greybull River | Wyoming Ditch | North flowing river diverts water off the east side. Water is diverted into an open ditch which carries it about ¼ of a mile to a headgate/by-pass structure. | Passable, Many Species | | | There is no in-stream barrier, so upstream passage is not an issue. Limited entrainment does occur (see comments section), but beaver activity in the area would likely make screening the ditch complicated. |
| Greybull River | Dotterer Ditch | N. flowing river has water diverted off the E. side through a screw-type headgate set in a concrete structure. | Passable, Many Species | | | The ditch does not cause a passage barrier, but because the headgate is not screened fish do have potential to be entrained. However, because the headgate is right on the bank silting is a problem for the ditch. |
| Piney Creek | Pallette Ranch No. 1, Unknown | Water flows S. and is diverted off the right bank through an open ditch used during high water. A seasonal hand-made rock structure backs water up to Dhelp direct flows into the ditch. | Passable, Many Species | Push-up/Rock | Yes | The ditch is only used from the beginning of May or later to the end of June. The mouth of the ditch is only 2' wide, and the hand-made rock diversion dam is only seasonal. The set-up for the ditch make it a low priority. |
| Piney Creek | Pallette Ranch No. 1, Unknown | Seasonal hand-made diversion directs water into an open channel, which carries flows over a screen covered buried pipe. Water drops into the pipe Dwhich dumps it into a head-gate structure. | Passable, Many Species | Push-up/Rock | Yes | The diversion does not create a barrier to fish, and the entrance to the pipe is screened with expanded metal reducing the probability of adult trout being entrained. The only reason the ditch would have any priority is because it is on a YSC stream. |
| Greybull River | Borner and Harvey Ditch | River starts to bend to the NE with diverted water leaving through an open ditch on the left bank. The ditch carries water ¼ mile to a headgate/by-pass structure. | Passable, Many Species | | | The diversion does not create a permanent barrier to fish passage. There is no screen on the headgate so entrainment is a possibility. With a 24" headgate the ditch is not large and not likely a high priority. |

## Table 10: Fish Passage Barriers (cont.)

| Stream Name | Structure Name | Site Description | Passage Status | DamType | Dam Permanent (Yes/No) | Recommendations |
|---|---|---|---|---|---|---|
| Greybull River | Avent Ditch | River flows to the NE with water diverted off the left bank through an open ditch. The diverted channel flows one mile to the NE where connects with a headgate/by-pass structure. | Passable, Many Species | | Yes | diversion does not create a barrier, but without a screen on the headgate entrainment could be a possibility. The ditch meanders about one mile before reaching the headgate/ by-pass structure, and is not likely a great location for a screen and by-pass. |
| Greybull River | Smith Ditch | Water is diverted off the left bank of a N. channel of the Greybull River. A small rock/rubble push-up dam creates a riffle and directs flows toward the mouth of an open ditch. | Passable, Many Species | Push-up/Rock | Yes | The diversion does not create a permanent barrier to fish passage. However if water levels were low enough it is possible the N. channel of the river would have insubstantial flows to pass fish. The headgate structure is not screened. |
| Greybull River | Boone Ditch | Water is diverted off the right bank of the river through a headgate regulated culvert which dumps into an open ditch channel. | Passable, Many Species | | | There is no in-stream structure to impede passage. Entrainment could be a possibility at this headgate because it is not screened. It should be noted before considering the ditch for mitigation that the Roach Gulch supply canal diverts off the river. |
| Greybull River | Roach Gulch Lead Canal | Water flowing E. is backed up by an in-stream diversion dam that extends the width of the river. Water either continues downstream through a sluice- gate or is diverted into an open canal. | Not Passable | Concrete | No | The diversion is likely a complete upstream barrier to fish passage, and with the amount of water being diverted entrainment is a potential problem. The small dam which sits in front of the headgate would make it difficult for fish which have been entrained. |
| Greybull River | Farmers & Bench Common Dive | The River is diverted by steel panels set in a concrete diversion. Water can either be diverted through 3 open headgates or let back into the channel though a sluice-gate. | Seasonally Passable, Salmonids | Other | No | |
| Greybull River | McCune Ditch | An old headgate for this ditch was found. It does not appear that the system has been used for a while. The old point of diversion diverts out of an empty river channel. | | | | |
| Greybull River | U.S.G.S. Gaging Station, Greybu | A metal box structure extends the width of the River for a gaging station. The structure is anchored in concrete on each side of the river. | Passable, Many Species | | | |
| Timber Creek | Park County Road 4lx, Culvert C | Previous culvert crossing was replaced with a fish friendly bottom-less arch. | Passable, Many Species | | | |
| Francs Fork | Last Chance ditch | The structure is still under construction. Plans were reviewed by Lew Stahl, but the structure needs to be inventoried after completion. | | | | |

## Table 16: Grazing Permit Comparisons Between the USFS and BLM

| Requirement/ Process | USFS | BLM |
|---|---|---|
| Base Property Requirements | To qualify for a term grazing permit, an applicant must own base property to be permitted. Base Property is land and improvements owned and used by the permittee for a farm or ranch operation and specifically designated by him to qualify for a term grazing permit. | BLM requires an applicant to own or control base property. The base property is land capable of serving as a base of operation for livestock use. For the desert southwest, base property can be water. |
| Livestock Ownership Requirement | To qualify for a term grazing permit, an applicant must own livestock to be permitted. | BLM does not require ownership of the livestock, but does require proof of control, such as a lease. A surcharge is added for grazing livestock not owned by the permittee. |
| Permit Acquisition Process | Qualified applicants may be issued permits with term status through prior use, the grant process, purchase of base property or livestock with waiver, or interchange of permits with other agencies. | The preference for obtaining a permit can be acquired by purchasing or leasing base property from a current permittee, or by the current permittee transferring preference to a new base property owned or controlled by someone who wants to acquire a permit. |
| Permit Renewal Process | Issue new permits with term status to previous holders at the end of each term permit period, provided they continue to meet eligibility and qualifications. | The current permittee has preference for receiving a new permit when the old one expires. |
| Permit Leasing | Holders of grazing permits with term status shall not lease base property or permitted livestock to someone else and allow the lessee to use the grazing permit. | Grazing permit preference for obtaining a permit can be acquired by leasing base property from a current permittee. |

Ref: USFS, website accessed May 2018; https://www.fs.fed.us/rangeland-management/documents/grazing/BLMGrazingAdministrationRequirementsProcesses201708.pdf

***Notes:***

Base Property Requirements: BLM requires ownership or control of base property. For most of the west, the base property is land capable of serving as a base of operation for livestock use.

Livestock Ownership Requirement: BLM does not require ownership of the livestock but does require proof of control and adds a surcharge for grazing livestock not owned by the permittee (with some exceptions for descendants of the permittee). The amount of the surcharge varies by state because it is based on the private grazing land lease rate (determined by the National Agricultural Statistics Service).

Permit Acquisition Process: The BLM preference for obtaining a permit can be acquired by purchasing or leasing base property from a current permittee, or by the current permittee transferring preference to a new base property owned or controlled by someone who wants to acquire a permit. The person acquiring the preference through one of these two methods then applies for a permit, and BLM reviews if the new applicant qualifies in accordance with the regulations. If the applicant qualifies, a permit is issued. For vacant allotments, BLM has a list of criteria for selecting from amongst multiple applicants.

Permit Renewal Process: For permit renewals in the BLM, the current permittee has preference for receiving a new permit when the old one expires. Ideally, the current permittee applies for a new permit before the existing permit expires. Existing monitoring data and assessments are reviewed to ensure land health standards are being met. Changes from the old permit can be requested by the permittee, or BLM may propose adjustments based on changing land conditions. A National Environmental Policy Act document (categorical exclusion, environmental assessment, or environmental impact statement) is completed. Consultation with USFW is completed if the permit authorizes use on allotment(s) with T&E species habitat. The BLM issues a proposed decision, followed by a final decision. After the administrative review period during which the decision can be appealed for a hearing by an Administrative Law Judge, the renewed permit is issued.

## Table 17: BLM Grazing Allotments in Greybull River Watershed

| Allotment # | Allotment Name | Acres (GIS calculated) | Active Date |
|---|---|---|---|
| 00668 | Dorsey Creek | 18.4 | 1/1/1946 |
| 02519 | Newall Springs | 3619.4 | 1/1/1946 |
| 00683 | South Sleeper | 5006.1 | No data |
| 02522 | Kruger SEC 15 | 83.2 | No data |
| 01049 | Individual 1049 | 1206.8 | 1/1/1946 |
| 00527 | Blackstone | 822.6 | No data |
| 01020 | Mckinnie Reservoir | 1695.9 | 1/1/1946 |
| 00632 | Dick Creek | 1114.2 | 1/1/1946 |
| 00543 | Cannady Individual | 1266.7 | No data |
| 01051 | Greybull Group | 11979.6 | 1/1/1946 |
| 00668 | Dorsey Creek | 4443.5 | No data |
| 03092 | Peterson | 1092.7 | 1/1/1946 |
| 03094 | Dry Creek 3094 | 2136.2 | 1/1/1946 |
| 01047 | County Line | 956.6 | 1/1/1946 |
| 02806 | South Y U Bench | 2054.6 | 1/1/1946 |
| 02562 | Meeteetse-East | 2131.4 | No data |
| 02564 | Homestead/Avent | 7393.7 | 1/1/1946 |
| 01146 | Lewis | 60.6 | 1/1/1946 |
| 02545 | 91 Ranch | 31375.1 | 1/1/1946 |
| 01001 | Table Mountain | 20404.0 | 1/1/1946 |
| 03068 | Oregon Coulee | 5008.6 | 1/1/1946 |
| 00549 | Greybull Bend | 332.7 | No data |
| 03031 | Meeteetse Creek 3031 | 278.9 | 1/1/1946 |
| 00577 | South Basin | 2873.3 | No data |
| 00509 | New Burlington Group | 19162.6 | No data |
| 01085 | Individual 1085 | 248.6 | 1/1/1946 |
| 02502 | Armstrong | 1565.8 | 1/1/1946 |
| 01046 | Bench Canal | 677.7 | 1/1/1946 |
| 02563 | Larsen SEC 15 | 491.8 | No data |
| 00612 | South Tatman | 1966.7 | No data |
| 01073 | Sage Creek Group | 724.1 | 1/1/1946 |
| 00763 | Greybull Airport | 11.1 | 6/1/2017 |
| 03035 | Eagle Pass | 28231.2 | 1/1/1946 |
| 03091 | YU Bench - West | 11360.6 | 1/1/1946 |
| 00526 | Rimrock Basin | 35.7 | No data |
| 00618 | North Blacksone | 373.2 | No data |
| 03096 | Meeteetse Rim | 2672.6 | 1/1/1946 |
| 01048 | Dry Creek 1048 | 770.6 | 1/1/1946 |
| 03034 | Spring Creek | 2901.1 | 1/1/1946 |
| 02534 | Renner Section 15 | 194.5 | 1/1/1946 |
| 01069 | Peaks 1069 | 18124.7 | 1/1/1946 |
| 03112 | Stone Barn 15 | 8915.2 | 1/1/1946 |
| 03090 | YU Bench - East | 9129.3 | 1/1/1946 |

## Table 17: BLM Grazing Allotments in Greybull River Watershed

| Allotment # | Allotment Name | Acres (GIS calculated) | Active Date |
|---|---|---|---|
| 01062 | Dry Creek 1062 | 4219.9 | 1/1/1946 |
| 02544 | Tonopah Ridge | 4362.7 | 1/1/1946 |
| 03095 | Greybull River | 48.5 | 1/1/1946 |
| 01006 | Sand Draw | 19780.1 | 1/1/1946 |
| 03002 | Stonewall Creek | 1269.2 | 1/1/1946 |
| 00611 | Neves Individual | 74.3 | No data |
| 03065 | Trailing Pasture | 153.1 | 1/1/1946 |
| 00669 | Allen Basin | 3.9 | No data |
| 03009 | Keystone 3009 | 447.0 | 1/1/1946 |
| 03029 | Oregon Basin | 11545.4 | 1/1/1946 |
| 00515 | Upper Gooseberry | 2049.5 | No data |
| 03110 | Boundary Well | 564.9 | 1/1/1946 |
| 01012 | West River | 251.5 | 1/1/1946 |
| 03033 | Hogg (GCRA) | 684.4 | 1/1/1946 |
| 00627 | Rooster Creek | 1986.7 | No data |
| 01086 | Schlaf/Common | 3962.8 | 1/1/1946 |
| 00595 | Iron Creek | 1012.3 | No data |
| 02532 | Pitchfork | 511.4 | 1/1/1946 |
| 00578 | North Basin Group | 2037.2 | No data |
| 03079 | Red Cabin | 7674.5 | 1/1/1946 |
| 03067 | Red Point | 14548.2 | 1/1/1946 |
| 03098 | Rawhide | 1331.7 | 1/1/1946 |
| 01060 | East/West | 12731.3 | 1/1/1946 |
| 01059 | Thumper | 7619.9 | 1/1/1946 |
| 03102 | Bench | 10168.7 | 1/1/1946 |
| 03113 | Oilwell | 10236.8 | 1/1/1946 |
| 03071 | Wiley Rim | 5.6 | 1/1/1946 |
| 02504 | Carter Mountain | 8090.4 | 1/1/1946 |
| 00629 | Rankine | 95.4 | 1/1/1946 |
| 03080 | Sunshine Reservoir | 1079.9 | 1/1/1946 |
| 00674 | North Tatman | 10540.4 | No data |
| 00764 | Burlington Cemetary | 43.9 | 5/31/2017 |
| 00666 | Reclamation | 7249.0 | 1/1/1946 |
| 14243 | Dry Creek Wildlife | 241.2 | 1/1/1946 |
| 03048 | Hoodoo Base | 9659.9 | 1/1/1946 |
| 01002 | Whistle Creek | 95.6 | 1/1/1946 |
| 01074 | Keystone 1074 | 496.2 | 1/1/1946 |
| 03073 | Rimrock | 2351.8 | 1/1/1946 |
| 03039 | Palette | 10318.6 | 1/1/1946 |
| 00510 | Fernandez Blu-Jay | 6267.1 | No data |
| 02535 | Meeteetse Rim 2535 | 3446.7 | 1/1/1946 |
| 03052 | Lake | 6848.7 | 1/1/1946 |
| 03088 | Reclamation 15 | 2404.7 | 1/1/1946 |

## Table 17: BLM Grazing Allotments in Greybull River Watershed

| Allotment # | Allotment Name | Acres (GIS calculated) | Active Date |
|---|---|---|---|
| 02510 | Gould Individul | 447.4 | No data |
| 03010 | Osborn | 1997.4 | 1/1/1946 |
| 00766 | Wood River Ranger Station | 39.9 | 6/1/2017 |
| 02561 | Meeteetse Creek 2561 | 10836.1 | 1/1/1946 |
| 03069 | Lower YU Bench | 4526.5 | 1/1/1946 |
| 02532 | Pitchfork | 32789.8 | 1/1/1946 |
| 03107 | Turnell | 5934.8 | 1/1/1946 |
| 03104 | Lone Tree | 2330.9 | 1/1/1946 |
| 02511 | Gould North Individul | 1482.4 | 1/1/1946 |
| 02524 | Jack Creek | 1086.4 | 1/1/1946 |
| 02555 | Lawler SEC 15 | 1608.2 | No data |
| 02553 | Winniger | 4840.8 | 1/1/1946 |
| 03119 | Rush Creek | 5320.5 | 1/1/1946 |
| 00639 | Tatman-Snyder | 30042.3 | No data |
| 02523 | Kukla Section 15 | 8883.9 | 1/1/1946 |
| 03061 | Little Dry Creek | 17786.6 | 1/1/1946 |
| 02551 | Cottonwood | 3997.5 | 1/1/1946 |
| **Total: 103 allotments** | | **Total Acres: 537,374.3** | |

Source: BLM

## Table 18: USFS Grazing Allotments in Greybull River Watershed

| Allotment # | Allotment Name | Acres (GIS Calculated) | Status |
|---|---|---|---|
| 02076 | Piney | 14285.7 | Active |
| 02059 | Francs Peak | 14023.8 | Active |
| 04154 | Rock Creek | 42.0 | Active |
| 02055 | Cottonwood | 1.4 | Active |
| 02040 | Deer Creek | 4414.1 | Active |
| 02047 | Rennerberg | 1347.4 | Active |
| 02072 | Yellow Steer Creek | 19233.4 | Active |
| 02046 | Pickett Creek | 15533.8 | Active |
| 02066 | Twin Peaks | 4816.1 | Active |
| 02074 | Washakie Needles | 0.4 | Active |
| 02044 | Guard Station | 13218.6 | Active |
| 02049 | Sugarload/Three Peaks | 1.8 | Active |
| 02041 | Dick Creek | 9578.5 | Active |
| 04135 | Community | 0.1 | Active |
| 05195 | Nine Mile | 0.3 | Closed |
| 02051 | Wood River | 4046.4 | Active |
| 05198 | Washakie | 16.0 | Closed |
| 02042 | Gooseberry Creek | 1954.2 | Active |
| 04164 | Boulder Creek | 1.0 | Closed |
| 02043 | Greybull | 36474.1 | Active |
| 04131 | Belknap | 4.5 | Active |
| 02057 | East Fork | 10156.2 | Active |
| 02050 | Timber Creek | 9199.6 | Active |
| 02048 | Sage Creek On/Off | 281.9 | Active |
| **Total: 24 allotments** | | **Total Acres: 158,631.6** | |

Source: USFS

**Table 28 Surface Water Outfalls**

| Outfall ID | WY Permit # | Outfall | Permittee | Facility Name | PermitType | Permit Issued | Permit Expiration |
|---|---|---|---|---|---|---|---|
| 7821 | WY0022900 | 001 | Merit Energy Company | Oregon Basin Field - Battery #1 North | Oil Treaters | 3/9/2015 | 6/30/2020 |
| 8729 | WY0046175 | 001 | Meeteetse, Town of | Water Treatment Facility | Water Treatment Plant | 4/27/2016 | 6/30/2021 |
| 15380 | WY0034606 | 001 | Burlington, Town of | Burlington Wastewater Lagoon | Sanitary Wastewater | 8/26/2014 | 9/30/2019 |
| 1152 | WY0001902 | 001 | Merit Energy Company | Oregon Basin Field - Battery #1 South | Oil Treaters | 3/9/2015 | 6/30/2020 |
| 1352 | WY0020265 | 001 | BreitBurn Operating, LP | Sheep Point Field | Oil Treaters | 5/31/2016 | 10/31/2021 |
| 1151 | WY0001899 | 001 | Merit Energy Company | Oregon Basin Field - Battery #2 North | Oil Treaters | 3/9/2015 | 6/30/2020 |
| 1320 | WY0001911 | 001 | Merit Energy Company | Oregon Basin Field - Battery #3 South (formerly Oregon Basin Field - Battery #3-5 South) | Oil Treaters | 3/9/2015 | 6/30/2020 |
| 1138 | WY0000973 | 001 | BreitBurn Operating, LP | North Sunshine State 27 Battery | Oil Treaters | 3/31/2014 | 6/30/2019 |
| 1296 | WY0023248 | 001 | Legacy Reserves Operating, LP | Fourbear Unit, Battery #1 | Oil Treaters | 5/3/2017 | 6/30/2022 |
| 1225 | WY0002241 | 001 | Phoenix Production Company | Gwen Knapp Battery | Oil Treaters | 5/28/2013 | 7/31/2018 |
| 1468 | WY0027731 | 001 | BreitBurn Operating, LP | State 30 Lease 70-1284 | Oil Treaters | 7/15/2016 | 10/31/2021 |
| 1256 | WY0020044 | 001 | Meeteetse, Town of | Meeteetse Wastewater Lagoons | Sanitary Wastewater | 2/28/2013 | 6/30/2017 |
| 1456 | WY0026590 | 001 | Merit Energy Company | Pitchfork Unit | Oil Treaters | 5/15/2017 | 6/30/2022 |
| 24111 | WY0048739 | 001 | John Bullinger and Sons, Inc. | Bullinger Feedlot | CAFO | 6/1/2013 | 4/30/2018 |
| 25209 | WY0056359 | 001 | Terex Energy Corporation | Rawhide Oil Field | Oil Treaters | 9/21/2016 | 10/31/2021 |
| 62967 | WY0022900 | 002 | Merit Energy Company | Oregon Basin Field - Battery #1 North | Oil Treaters | 3/9/2015 | 6/30/2020 |
| 62960 | WY0001902 | 002 | Merit Energy Company | Oregon Basin Field - Battery #1 South | Oil Treaters | 3/9/2015 | 6/30/2020 |
| 58523 | WY0095559 | 001 | Principle Petroleum LLC | Rose Creek Field Principle Production Facility | Oil Treaters | 8/29/2014 | 7/31/2019 |
| 62952 | WY0001911 | 002 | Merit Energy Company | Oregon Basin Field - Battery #3 South (formerly Oregon Basin Field - Battery #3-5 South) | Oil Treaters | 3/9/2015 | 6/30/2020 |
| 62958 | WY0027197 | 002 | Merit Energy Company | Oregon Basin Field--Sidney Battery | Oil Treaters | 3/9/2015 | 6/30/2020 |
| 15103 | WY0027197 | 001 | Merit Energy Company | Oregon Basin Field--Sidney Battery | Oil Treaters | 3/9/2015 | 6/30/2020 |

## Table 30: National Inventory of Dams

| Name | Owner | River | Watershed | County | Year Completed | Year Inspected | Long. | Latitude | WY NID-ID | Height (ft) | Storage (ac-ft) | WSEO Hazard Ranking[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bench Canal | Bench Canal Co. | Greybull River | Dry Creek | Big Horn | 1969 | 6/14/2012 | -108.3192 | 44.4833 | WY01086 | 35 | 497 | Low |
| C. Thomsen (Custer Lake) | Glen E. Nielsen | Thomsen Draw | Dry Creek | Park | 1930 | 8/21/2013 | -108.9122 | 44.435 | WY01105 | 13 | 80 | Low |
| Larry's Last Chance | USDI BLM | Larry's Draw | Dry Creek | Big Horn | 1965 | 6/21/2012 | -108.3808 | 44.5883 | WY01735 | 25 | 60 | Low |
| Phipps NO. 1 | Walter Thomas Phipps | Kellerman Drain | Dry Creek | Big Horn | 1999 | 6/26/2014 | -108.2397 | 44.48972 | WY02225 | 15 | 95 | Low |
| Sage Creek | Cody OAR Lock Ranch | Sage Creek | Dry Creek | Park | 1982 | 6/18/2014 | -108.9314 | 44.40694 | WY01112 | 28 | 2785 | Low |
| Saver Detention | USDI BLM | Tributary Dry Creek | Dry Creek | Park | 1967 | 5/23/2013 | -108.625 | 44.441667 | WY01419 | 29 | 37 | Low |
| | | | | | | | | | | | | |
| Albert Wardell No. 1 | Sandstone Ditch Co. | Dorsey Creek | Greybull | Big Horn | 1973 | 7/7/2011 | -108.2631 | 44.34167 | WY01052 | 35 | 956 | Low |
| Corral | MC Land & Cattle Co. | Corral Draw (tributary Snyder Draw) | Greybull | Park | 1983 | 7/2/2014 | -108.9228 | 44.21028 | WY01602 | 52 | 1027 | Significant |
| Delbert Jones | Jones Bros. Enterpises | Greybull River (off stream) | Greybull | Big Horn | 1962 | 8/14/2014 | -108.2783 | 44.41306 | WY01034 | 21 | 166 | Low |
| Fairview Extension Dam | BLM | Wardell Draw | Greybull | Big Horn | - | 10/3/2011 | -108.3072 | 44.34833 | WY01162 | 20.1 | 1578 | Significant |
| Greybull Valley (1st enl.) - Roach Gulch | GVID | Red Clay Draw | Greybull | Park | 2000 | 8/14/2014 | -108.6125 | 44.3739 | WY02234 | 207 | 53200 | High |
| Harrington | BLM | Wardell Draw | Greybull | Big Horn | - | 10/3/2011 | -108.3156 | 44.35778 | WY01164 | 20 | 1503 | Significant |
| Horse Creek | Matt Wagner | Horse Creek | Greybull | Park | 1973 | 8/23/2013 | -109.0244 | 44.21944 | WY01703 | 29 | 51 | Low |
| Lake McKinney | John Bullinger & Sons | McKinney Creek (tributary of Greybull River) | Greybull | Big Horn | 1939 | 6/25/2012 | -108.235 | 44.42 | WY01163 | 26 | 550 | Low |
| Lower Sunshine | GVID | Sunshine Creek (off stream) | Greybull | Park | 1972 | 8/30/2011 | -108.9767 | 44.09945 | WY01096 | 162 | 71800 | High |
| Mackey | GVID | Mackey Gulch | Greybull | Park | 2000 | 5/20/2015 | -108.6394 | 44.33167 | WY02235 | 15 | 179 | Low |
| Renner Detention Dam No.2 | BLM | Renner Creek (Greybull River) | Greybull | - | - | 10/2/2011 | -108.5953 | 44.37333 | WY01826 | 24 | 51 | Low |
| Rush Creek | Matt Wagner | Horse Creek | Greybull | Park | 1973 | 8/23/2013 | -109.0317 | 44.20833 | WY01053 | 49 | 339 | Low |
| Sandstone Dam | BLM | Greybull River | Greybull | Big Horn | - | 10/3/2011 | -108.3021 | 44.36843 | WY01161 | 28 | 1185 | Low |
| Snyder | GVID | Unamed Gulch | Greybull | Park | 2000 | 8/23/2010 | -108.6647 | 44.32611 | WY02236 | 35 | 150 | Low |
| Snyder No. 1 | Jerry W. Snyder | Emblem DR, (tributary of Greybull River) | Greybull | Big Horn | 1995 | 6/25/2015 | -108.1544 | 44.47417 | WY01988 | 21 | 597 | Low |
| Snyder No. 2 | Jerry W. Snyder | Bangle Draw | Greybull | Big Horn | 1994 | 6/23/2011 | -108.1667 | 44.42833 | WY02096 | 21 | 120 | Low |
| Thayer No. 1 | Hunt Oil Co. | Greybull River (off Carter Mtn.) | Greybull | Park | 1935 | 6/13/2014 | -109.275 | 44.13445 | WY01909 | 13 | 69 | Low |
| Thomas | 91 Ranch | N. Rawhide Creek | Greybull | Park | 1949 | 8/29/2013 | -109.1903 | 44.22 | WY01159 | 56 | 1104 | Low |
| Upper Sunshine | GVID | Greybull River (off stream) | Greybull | Park | 1942 | 8/30/2011 | -109.0486 | 44.06028 | WY01097 | 160 | 65100 | High |
| White | Lee Adams | White Gulch | Greybull | Big Horn | 1914 | 6/13/2012 | -108.1817 | 44.38833 | WY01151 | 20 | 201 | Low |

Source: USACE, 2017

[1] WSEO, 2018

## Table 39: Greybull River WID SWOT

| Strengths | Opportunities | Weaknesses | Threats |
|---|---|---|---|
| Ability to acquire funds not available to private entities (ie WWDC funds); financial flexibility; additional funding options/ mechanisms; can borrow, levy taxes, enforce leins | Ability to organize and prioritize projects across the watershed | Small voices may get lost | Challenge to "dissolve" existing entitites and create a single, larger entity; existing entities not likely to want to give up local authority |
| Provides organization and structure to un-organized groups or individual landowners | Large and small scale projects would have more opportunities for funding (internal and external) | Longer-term process for issuing bonds for individual projects (hearings, appraisals, assessments, etc.) | Requires 25% landowner interest with 25% of boundary property and desire to create and be part of the WID. |
| Other legal rights: can acquire/ dispose of property; have power of eminent domain; construct/operate maintain structures | Potential for cost savings; economies of scale for regional projects | Determination of who benefits from a specific project and the magnitude of those benefits may be difficult (unclear and/or expensive to identify) | Changing demographics (new ownership vs. generational ownership) have different ideas of what future planning/ watershed activities should look like. |
| Ability to assign and apportion benefits and costs to specific landowners or areas across the watershed | Sharing of technical expertise among landowners across the watershed | Smaller entities within the WID could remain intact. Creates additional questions and complications with decision making and assessments. | Costs of creating and operating such an entity - time, legal requirements, election costs, annual assessments etc. |
| Board members are elected and are up for re-election every 4 years. Ability to vote out members that don't reflect landowner interest. | | | Change in legislative attitude towards the amount of special districts being created within Wyoming. |
| Landowners would be able to maintain control over water rights. | | | |

## Table 40: Summary of Permitting Agencies

| Agency | Applicable Permit/Regulations/Authority | Permit Requirements and/or Actions Generating a Need for Permit | Contact Information | Notes |
|---|---|---|---|---|
| **Federal Agencies** | | | | |
| U.S. Army Corps of Engineers (USACE) | ● Clean Water Act; Section 404 Individual Permit<br>● National Environmental Policy Act (NEPA); 40 CFR 1500.4 | ● Increased diversions yield in-stream flow;<br>● Reservoir enlargement/changes cause indirect effects of inundation to wetlands;<br>● Excavation of material from the existing reservoir pool for dam construction;<br>● Placement of fill into jurisdictional wetlands and surface waters. | Kevin Little<br>USACE<br>Omaha District, Cheyenne Regulatory Office<br>2232 Dell Range Blvd # 210<br>Cheyenne, WY 82009<br>(307) 772-2300<br>Kevin.C.Little@usace.army.mil | The USACE could:<br>● Be the lead federal agency for all alternatives for the project;<br>● Or a co-operating agency for the alternatives located on federal lands such as those managed by BLM. |
| U.S. Bureau of Land Management (BLM) | ● Big Horn Basin Sage-Grouse Management Plan and Final EIS;<br>● National Environmental Policy Act (NEPA); 40 CFR 1500.4<br>● Right-of-Way (ROW) Application or Amendment – Federal Land Policy and Management Act (1976); 43 CFR, part 2800. | ● Impacts to sensitive species and/or sage-grouse habitat;<br>● Construction of permanent facilities (embankment or spillway) and operation activity on BLM lands and easements. | John Elliot, Field Manager<br>BLM Worland Field Office<br>101 S. 23rd Street<br>Worland, WY 82401<br>(307) 347-5100<br>jelliot@blm.gov | The BLM could:<br>● Be the lead federal agency for the project;<br>● Or a co-operating agency with the USACE for the alternatives on federal lands managed by BLM. |

## Table 40: Summary of Permitting Agencies (cont.)

| Agency | Applicable Permit/Regulations/Authority | Permit Requirements and/or Actions Generating a Need for Permit | Contact Information | Notes |
|---|---|---|---|---|
| U.S. Fish and Wildlife Service (USFWS) | Endangered Species Act (ESA): Section 7 | Potential activity which could adversely affect Federally-listed, proposed, or candidate endangered species and/or their designated critical habitat. | Tyler Abbott, Field Supervisor<br>USFWS<br>Wyoming Ecological Services Field Office<br>5353 Yellowstone Rd, Suite 308A<br>Cheyenne, WY 82009<br>(307) 772-2374<br>tyler_abbott@fws.gov | ● Direct impacts on any federally listed species as a result of reservoir expansion actions or indirect impacts from downstream depletions would require Section 7 consultation;<br>● As part of the NEPA process, an ESA consultation would be done in accordance with Section 7. In such cases a Biological Assessment (BA) would be prepared by the USACE if adverse impacts to federally listed species are identified. Susequently, the USFWS would issue a Biological Opinion (BO) on the project's effects on these species and include required conservation measures to avoid jeopardizing the continued existence of an ESA protected species. |
| | ● Golden and Bald Eagle Protection Act;<br>● Migratory Bird Treaty Act (MBTA) | Potential federal activity which could affect a migratory bird or an active nest will require compliance. | Tyler Abbott, Field Supervisor<br>USFWS<br>Wyoming Ecological Services Field Office<br>5353 Yellowstone Rd, Suite 308A<br>Cheyenne, WY 82009<br>(307) 772-2374<br>tyler_abbott@fws.gov | Though no permit is required, the project plan/construction efforts must comply with the MBTA which includes avoiding habitat disturbance during construction. This could include surveying prior to construction to ensure no birds are present or simply avoiding disturbance activities during the nesting season. Any vegetation disturbance would be conducted from Sept.1-March 1 (non-breeding migratory season for migratory birds). In some cases this isn't feasible so field surveys for cavities and nests must be conducted prior to ground disturbance activities and/or vegetation removal during the breeding/nesting season. If active nests are present, any vegetation removal would be suspended until the young have fledged. In addition, any ground disturbance would also be suspended until an appropriate buffer (distance) in in place for the species of interest until those young have fledged. |

## Table 40: Summary of Permitting Agencies (cont.)

| Agency | Applicable Permit/Regulations/Authority | Permit Requirements and/or Actions Generating a Need for Permit | Contact Information | Notes |
|---|---|---|---|---|
| U.S. Fish and Wildlife Service (USFWS) | Fish and Wildlife Coordination Act (FWCA); 16 U.S.C. 661-667e | Fish and wildlife conservation must be considered with any water-supply project. | Tyler Abbott, Field Supervisor<br>USFWS<br>Wyoming Ecological Services Field Office<br>5353 Yellowstone Rd, Suite 308A<br>Cheyenne, WY 82009<br>(307) 772-2374<br>tyler_abbott@fws.gov | The FWCA requires a report of the Secretary of Interior be prepared for the project and would include any mitigation necessary regarding any possible adverse effects to fish and wildlife. This report is developed by the lead federal agency. In addition, FWCA consultation runs concurrently with the NEPA process. |
| **State Agencies** | | | | |
| Wyoming Department of Environmental Quality (WDEQ), Water Quality Division (WQD) | ● Clean Water Act; Section 401<br>● Wyoming Statutes (W.S.) 35-11-101 through 35- 11-1803 which include the Wyoming Environmental Quality Act | WDEQ certifies Section 404 permits issued by the USACE to construct or operate a facility. | Eric Hargett<br>401 Certification Coordinator<br>307-777-6701<br>eric.hargett@wyo.gov | ● The 401 Certification would run concurrently with the NEPA/404 process;<br>● Typically, the WDEQ provides a 401 Certification for a project before the USACE issues a 404 Permit;<br>● Often it is beneficial for the WDEQ to be a cooperating agency on any EIS. |
| Wyoming Game and Fish Department (WGFD) | ● State of Wyoming Executive Orders 2017-2 and 2015- 4.<br>● Consultation on wildlife issues (terrestrial and aquatic) plus mitigation for NEPA and other state and federal permits | WGFD reviews potential project impacts to greater sage-grouse using the Density Disturbance Calculation Tool then develops recommendations. | **WGFD Headquarters**<br>Scott Talbott, Director5400 Bishop Blvd.Cheyenne, WY 82006(307) 777-4600wgfdwebmaster@wyo.govAngela BruceHabitat Protection Coordinator307-777-4587Tom AnnearWater Management Program Coordinator307-777-4555<br><br>**Cody Regional WGFD Office**<br>2820 State Highway 120Cody, WY 82414307-527-7125 | Typically, the WGFD provides recommendations:<br>● For applicable state permits;<br>● For wildlife protection and mitigation to the lead federal agency for NEPA;<br>● For the Section 404 permit. |

## Table 40: Summary of Permitting Agencies (cont.)

| Agency | Applicable Permit/Regulations/Authority | Permit Requirements and/or Actions Generating a Need for Permit | Contact Information | Notes |
|---|---|---|---|---|
| Wyoming State Historic Preservation Office (SHPO) | National Historic Preservation Act (NHPA); Section 106 | NHPA requires federal agencies to take historic properties into account for project activities within federal lands or projects receiving federal funds. | Mary Hopkins<br>State Historic Preservation Officer<br>Barrett Building - 3rd Floor<br>2301 Central Avenue<br>Cheyenne, WY 82002<br>(307) 777-6311 | ● The lead federal agency initiates the required NEPA process including the Section 106 compliance and consultation with appropriate Indian tribes;<br>● The lead federal agency would prepare a letter describing eligibility and effects and seek concurrence from the Wyoming SHPO;<br>● The Wyoming SHPO must respond within 30 days regarding concurrence with determinations of eligibility and effects;<br>● Any potential impacts to cultural, historic and archeological resources would be documented in the subsequent EIS;<br>● Compliance with and the Programmatic Agreement between the BLM and SHPO. |
| Wyoming State Engineer's Office (SEO), Surface Water and Engineering Division | ● Ensures the safety and structural integrity of water storage facilities in Wyoming;<br>● Conducts site inspections of existing facilities;<br>● After review, approves/disapproves construction plans for new structures of rehabilitation of existing structure. W.S 41-3-307 through 41-3-318 | Construction of a new dam or enlargement of an existing dam. | **Wyoming SEO**<br>Surface Water and Engineering Division<br>122 West 25th Street<br>Herschler Building<br>1st Floor West<br>Cheyenne, WY 82002<br>307-777-6475<br><br>Safety of Dams Engineers<br>Mike Hand (307) 777-6153<br>Nathan Graves (307) 777-3500 | ● The Wyoming SEO must review and approve designs prior to construction of any dam modifications.<br>● The Wyoming SEO must satisfactorily observe and document all construction activities related to dam modifications. |
| | Administers Wyoming water rights which are issued for recognized beneficial uses including irrigation. | Adjudication or acquisition of new water rights | **Wyoming SEO**<br>Surface Water and Engineering Division<br>122 West 25th Street<br>Herschler Building<br>1st Floor West<br>Cheyenne, WY 82002<br>307-777-6475 | ● Any storage of new water would require submittal of an application;<br>● An application must also be submitted to increase diversions or construct new diversions. |

## Table 41: Summary of Rehabilitation Project Permit Needs

| Rehabilitation Topics | Permits/ROW/Consultation Required | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Federal* | | | | State of Wyoming | | | | | |
| | USACE Section 404 | BLM | USFS | USFWS | WSEO | WDEQ | WGFD | WSHPO | WY Board of Land | County |
| Stream Stabilization | Yes | Yes if on BLM land or access is through BLM land | Yes if on USFS land | Possibly if federal land is involved | Possibly | No | Possibly depending upon project and location | Possibly if federal land or funding is involved | Yes if location or access involves state land | Consult to determine if scope of project requires permit(s) |
| Water Storage | Yes | Yes if on BLM land or access is through BLM land | Yes if on USFS land | Possibly if federal land is involved | Yes | No | Probably | Possibly if federal land or funding is involved | Yes if location or access involves state land | Consult to determine if scope of project requires permit(s) |
| Irrigation | Possibly; consult with USACE | Yes if on BLM land or access is through BLM land | Yes if on USFS land | Possibly | Yes | Possibly | Possibly depending upon project and location | Possibly if federal land or funding is involved | Yes if location or access involves state land | Consult to determine if scope of project requires permit(s) |
| Russian olive or Saltcedar Tree Removal | Unlikely but need to consult depending upon location, project specifics | Yes if on BLM land or access is through BLM land | Yes if on USFS land | Possibly if federal land is involved | No | No | Possibly depending upon project and location | No | Yes if location or access involves state land | Consult to determine if scope of project requires permit(s) |
| Fish Passage | Yes | Yes if on BLM land or access is through BLM land | Yes if on USFS land | Possibly | Possibly | No | Yes | Possibly if federal land or funding is involved | Yes if location or access involves state land | Consult to determine if scope of project requires permit(s) |
| 7K Ranch Concrete Lining | No | No | No | No | No** | No | No | Possibly if federal funding is involved | No | No** |

| Rehabilitation Topics | Permits/ROW/Consultation Required | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Federal* | | | | State of Wyoming | | | | | |
| | USACE Section 404 | BLM | USFS | USFWS | WSEO | WDEQ | WGFD | WSHPO | WY Board of Land | County |
| German Ditch Conversion to Pipe | Unlikely but need to consult depending upon location, project specifics | Yes | No | Yes | Yes | No | Yes | Possibly if federal funding is involved | Yes, if location or access involves state land | Possibly; consult to determine if scope of project requires permit(s) |
| Private Stock Pond Development | Perhaps; need to consult depending upon location, project specifics | No | No | Unlikely but need to consult depending upon location, project specifics | Yes | Perhaps; need to consult depending upon location, project specifics | Possibly depending upon project and location | Possibly if federal funding is involved | Yes, if location or access involves state land | Possibly; consult to determine if scope of project requires permit(s) |

* The NEPA process, location and scope of a project may determine the extent of permits, ROW and/or consultation such as development of an EIS or compliance with the Golden and Bald Eagle Protection Act, etc.

**Yes if hydraulic properties of the ditch are changed such as expansion, enlargement, etc.

## Table 43: Local Entity Funding Sources

| Agency/ Entity | Program Name/ Focus | Website | Phone | E-mail |
|---|---|---|---|---|
| ***South Big Horn Conservation District*** | Liason; administrative and technical assistance; program coordination; partnering | www.sbhcd.org/ | (307) 765 - 2483 | sbhcd1@gmail.com |
| ***Meeteetse Conservation District*** | | https://meeteetse-conservewy.net/ | (307) 868 - 2484 | meeteetse@conservewy.net |
| | | | | |
| ***Big Horn County Weed and Pest Control District*** | Cost share programs for control of specific species of weeds and pests | https://www.bhcountyweedandpest.com/cost-share-programs | (307) 765 - 2855 | bhcwp@bhcweed.com |
| ***Park County Weed and Pest Control District*** | | https://parkcountyweeds.org/programs/cost-share/ | (307) 754 - 4521 | jshorb@parkcountyweeds.org |

## Table 44: State Entity Funding Sources

| Agency/ Entity | Program Name | Website | Contact Information | |
|---|---|---|---|---|
| ***Wyoming Water Development Commission (WWDC)*** | Small Water Project Program (SWPP) | http://wwdc.state.wy.us/small_water_projects/small_water_project.html | (307) 777-7626 | Jodie.Pavlicka@wyo.gov |
| | New Development Program | http://wwdc.state.wy.us/planning_program/planning_projects.html | | barry.lawrence@wyo.gov |
| | Rehabilitation Program | | | |
| | Water Resource Planning | | | |
| | Dam and Reservoir Program | http://wwdc.state.wy.us/dam_reservoir/dam_reservoir.html | | jason.mead@wyo.gov |
| | Groundwater Grant Program | http://wwdc.state.wy.us/groundwater_grant/groundwater_grant_projects.html | | kevin.boyce@wyo.gov |
| ***Office of State Lands and Investments (OSLI)*** | Farm Loan Program | http://lands.wyo.gov/grantsloans | (307) 777 - 6646 | shawn.king1@wyo.gov |
| | Small Water Development Projects Loans Program | | (307) 777 - 6373 | elizabeth.blackwell@wyo.gov |
| | Joint Powers Act Loan Program | | (307) 777 - 6645 | val.lewkowski@wyo.gov |
| | Hydro-Power Development Project Loan | | (307) 777 - 7309 | sheila.palmer1@wyo.gov |
| ***Wyoming Department of Environmental Quality, Water Quality Division*** | Watershed Protection - Nonpoint Source Program - Clean Water Act Section 319 Funds | deq.wyoming.gov/wqd/non-point-source/ | (307 )777 - 6080 | jennifer.zygmunt@wyo.gov |
| | Watershed Protection - Nonpoint Source Program - Section 205(j) Funds | | | |
| | Water and Wastewater Program - State Revolving Loan Fund: Clean Water State Revolving Fund | deq.wyoming.gov/wqd/state-revolving-loan-fund/ | (307) 777 - 6941 | bill.tillman@wyo.gov |
| | Water and Wastewater Program - State Revolving Loan Fund: Drinking Water State Revolving Fund | | | |
| ***Wyoming Game and Fish Department*** | Habitat Trust Fund | https://wgfd.wyo.gov/ | (307) 777-4600 | |
| | Fish Passage Grants | | | |
| ***Wyoming Wildlife and Natural Resources Trust (WWNRT)*** | Wyoming Wildlife and Natural Resources Trust Fund | http://wwnrt.wyo.gov/ | (307) 777 - 8024 | https://sites.google.com/a/wyo.gov/wwnrt/contact-us |
| ***Wyoming Department of Agriculture*** | Water Quality Grant Program | http://agriculture.wy.gov/divisions/nrp/conservation-districts/funding-resources/water-quality | (307) 777 - 6576 | chris.wichmann@wyo.gov |
| | Rangeland Health Assessments Program | http://agriculture.wy.gov/divisions/nrp/rangeland-health | | |

## Table 45: Federal Entity Funding Sources

| Agency/ Entity | Program Name | Website | Contact Information | |
|---|---|---|---|---|
| ***Bureau of Reclamation*** | WaterSMART: Water and Energy Efficiency Grants | https://www.usbr.gov/watersmart/weeg/index.html | (303) 445 - 2839 | jgerman@usbr.gov |
| | WaterSMART: Water Marketing Strategy Grants | https://www.usbr.gov/watersmart/watermarketing/index.html | (303) 445 - 2906 | aomorgan@usbr.gov |
| | WaterSMART: Small Scale Water Efficiency Projects Funding Opportunity | https://www.usbr.gov/watersmart/swep/index.html | (303) 445 -2764 | rgraber@usbr.gov |
| | Water Conservation Field Services Program | https://www.usbr.gov/waterconservation/ | (303) 445 - 2839 | jgerman@usbr.gov |
| ***US Army Corps of Engineers*** | Planning Assistance to States | http://www.nae.usace.army.mil/Missions/Public-Services/Planning-Assistance-to-States/ | (978) 318 - 8520 | Christopher Hatfield |
| | Floodplain Management Services | http://www.nae.usace.army.mil/Missions/Public-Services/Flood-Plain-Management-Services/ | | |
| | Ecosystem Restoration | http://www.nae.usace.army.mil/Missions/Public-Services/Ecosystem-Restoration-Authorities/ | (978) 318 - 8347 | Larry Oliver |
| | Flood Damamge Reduction | https://www.usace.army.mil/Media/News-Releases/News-Release-Article-View/Article/1546721/us-army-corps-of-engineers-releases-work-plan-for-fiscal-2018-civil-works-appro/ | (202) 761 - 7690 | Eugene.A.Pawlik@usace.army.mil |
| ***Bureau of Land Management*** | Riparian Habitat Management Program | https://www.blm.gov/programs/natural-resources/wetlands-and-riparian-health | (307) 775 - 6256 | blm_wy_state_office_wymail@blm.gov |
| ***USDA Natural Resource Conservation Service (NRCS)*** | Agricultural Management Assistance (AMA) | https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/ama/?cid=stelprdb1242818 | (307) 754 - 9301 ext. 116 | rory.karhu@wy.usda.gov |
| | Conservation Stewardship Program (CSP) | https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/ | | |
| | Environmental Quality Incentives Program (EQIP) | https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/ | | |
| | Conservation Innovation Grants (CIG) | https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/ | | nrcscig@wdc.usda.gov |
| | Emergency Watershed Protection Program (EWP) | https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/ewp/ | (202) 720 - 5795 | |

## Table 45: Federal Entity Funding Sources

| Agency/ Entity | Program Name | Website | Contact Information | |
|---|---|---|---|---|
| ***Environmental Protection Agency*** | Healthy Watersheds Consortium Grants (HWCG) | https://www.epa.gov/hwp/healthy-watersheds-consortium-grants-hwcg#healthywater | (864) 233 - 7646 | peter@usendowment.org |
| ***USDA Farm Service Agency*** | Conservation Reserve Program (CRP) | https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index | (307) 261 - 5081 | Cindy Hottel |
| | Conservation Reserve Enhancement Program (CREP) | https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-enhancement/index | | |
| | Emergency Conservation Program (ECP) | https://www.fsa.usda.gov/programs-and-services/conservation-programs/emergency-conservation/index | | |
| | Farmable Wetlands Program (FWP) | https://www.fsa.usda.gov/programs-and-services/conservation-programs/farmable-wetlands/index | | |
| ***US Fish and Wildlife Service*** | Partners for Fish and Wildlife Program (PFW) | https://www.fws.gov/partners/ | (307) 332 - 5897 | Mark_J_Hogan@fws.gov |
| | Wildlife and Sport Fish Restoration Program (WSFR) | https://wsfrprograms.fws.gov/Subpages/GrantPrograms/GrantProgramsIndex.htm | (307) 777 - 5345 | Carol Bybee |
| | Endangered Species Conservation | https://www.fws.gov/endangered/grants/ | | |
| | North American Wetlands Conservation Act Grant Program | https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php | | |
| | National Fish Habitat Partnerships (NFHP) | https://www.fws.gov/ | (307) 332-2159 | |
| | National Fish Passage Program (NFPP) | | | |

## Table 45: Federal Entity Funding Sources

| Agency/ Entity | Program Name | Website | Contact Information | |
|---|---|---|---|---|
| ***Environmental Protection Agency*** | Healthy Watersheds Consortium Grants (HWCG) | https://www.epa.gov/hwp/healthy-watersheds-consortium-grants-hwcg#healthywater | (864) 233 - 7646 | peter@usendowment.org |
| ***USDA Farm Service Agency*** | Conservation Reserve Program (CRP) | https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index | (307) 261 - 5081 | Cindy Hottel |
| | Conservation Reserve Enhancement Program (CREP) | https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-enhancement/index | | |
| | Emergency Conservation Program (ECP) | https://www.fsa.usda.gov/programs-and-services/conservation-programs/emergency-conservation/index | | |
| | Farmable Wetlands Program (FWP) | https://www.fsa.usda.gov/programs-and-services/conservation-programs/farmable-wetlands/index | | |
| ***US Fish and Wildlife Service*** | Partners for Fish and Wildlife Program (PFW) | https://www.fws.gov/partners/ | (307) 332 - 5897 | Mark_J_Hogan@fws.gov |
| | Wildlife and Sport Fish Restoration Program (WSFR) | https://wsfrprograms.fws.gov/Subpages/GrantPrograms/GrantProgramsIndex.htm | (307) 777 - 5345 | Carol Bybee |
| | Endangered Species Conservation | https://www.fws.gov/endangered/grants/ | | |
| | North American Wetlands Conservation Act Grant Program | https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php | | |
| | National Fish Habitat Partnerships (NFHP) | https://www.fws.gov/ | (307) 332-2159 | |
| | National Fish Passage Program (NFPP) | | | |

## Table 46: Project Funding Opportunities

| Agency/ Entity | Streambank Stabilization | Private Owner Storage Pond | Upland Watershed Storage | Irrigation Rehabilitation | Ditch conversion to concrete/ pipe | Fish Passage | WID Formation |
|---|---|---|---|---|---|---|---|
| *South Big Horn Conservation District* | | | | | | | |
| *Meeteetse Conservation District* | | | | | | | |
| *Big Horn County Weed and Pest Control District* | X** | X** | X** | X** | X** | | |
| *Park County Weed and Pest Control District* | X** | X** | X** | X** | X** | | |
| *WWDC Small Water Project Program (SWPP)** | | | | | | X | |
| *WWDC New Development Program** | | | X | | | | X |
| *WWDC Rehabilitation Program** | | | X | X | X | | |
| *WWDC Water Resource Planning** | | | X | X | X | X | |
| *WWDC Dam and Reservoir Program** | | | X | | | | |
| *WWDC Groundwater Grant Program** | | | | | | | |
| *OSLI Farm Loan Program* | | X | | | | | |
| *OSLI Small Water Development Projects Loans* | | X | | | | | |
| *OSLI Joint Powers Act Loan Program* | | | X | | | | |
| *OSLI Hydro-Power Development Project Loan* | | | X | | | | |
| *WDEQ Watershed Protection Section 319* | X | | | | | X | |
| *WDEQ Watershed Protection Section 205(j)* | | | | | | | |
| *WDEQ State Revolving Loan Fund: Clean Water* | | | | | | | |
| *WDEQ State Revolving Loan Fund: Drinking Water* | | | | | | | |
| *WGFD Habitat Trust Fund* | | | | | | X | |
| *WGFD Fish Passage Grants* | | | | | | X | |
| *Wyoming Wildlife & Natural Resources Trust Fund* | | | | | | X | |
| *WDA Water Quality Grant Program* | X | | | | | | |
| *WDA Rangeland Health Assessments Program* | | | | | | | X |
| *Reclamation WaterSMART: Water and Energy Efficiency Grants** | X | | X | X | X | | |
| *Reclamation WaterSMART: Water Marketing Strategy Grants** | | | | | | | |
| *Reclamation WaterSMART: Small Scale Water Efficiency Projects Funding Opportunity** | X | | | X | X | | |
| *Reclamation Water Conservation Field Services Program** | X*** | | X*** | X*** | X*** | | |
| *USACE Planning Assistance to States** | X | | X | X | X | | |
| *USACE Floodplain Management Services** | | | | | | | |
| *USACE Ecosystem Restoration** | | | | | | X | |
| *USACE Flood Damamge Reduction** | | | | | | | |
| *BLM Riparian Habitat Management Program* | | | | | | | |
| *NRCS Agricultural Management Assistance* | X | X | X | X | X | | |
| *NRCS Conservation Stewardship Program* | X | X | X | X | X | | |
| *NRCS Environmental Quality Incentives Program* | X | X | X | X | X | | |
| *NRCS Conservation Innovation Grants* | X | | X | X | X | | |
| *NRCS Emergency Watershed Protection* | X | | | | | | |
| *EPA Healthy Watersheds Consortium Grants** | X | | X | X | X | | |
| *FSA Conservation Reserve Program* | | | | | | | |
| *FSA Conservation Reserve Enhancement Program* | | | | | | | |
| *FSA Emergency Conservation Program* | X | X | X | X | X | | |
| *FSA Farmable Wetlands Program* | | | | | | | |

## Table 46: Project Funding Opportunities

| Agency/ Entity | Streambank Stabilization | Private Owner Storage Pond | Upland Watershed Storage | Irrigation Rehabilitation | Ditch conversion to concrete/ pipe | Fish Passage | WID Formation |
|---|---|---|---|---|---|---|---|
| *USFWS Partners for Fish and Wildlife Program* | X | | | | | X | |
| *USFWS Wildlife and Sport Fish Restoration Program* | | | | | | X | |
| *USFWS Endangered Species Conservation* | | | | | | | |
| *USFWS North American Wetlands Conservation Act Grant Program* | | | | | | | |
| *USFWS National Fish Habitat Partnerships* | | | | | | X | |
| *USFWS National Fish Passage Program* | | | | | | X | |
| *Ducks Unlimited* | | | | | | X | |
| *Trout Unlimited* | | | | | | X | |
| *National Fish and Wildlife Foundation* | | | | | | X | |

Note: X=yes depending upon the scope of the project

* Sponsor must be a public entity or Indian Tribe

** If the project includes removal/control of invasive species or control of pests

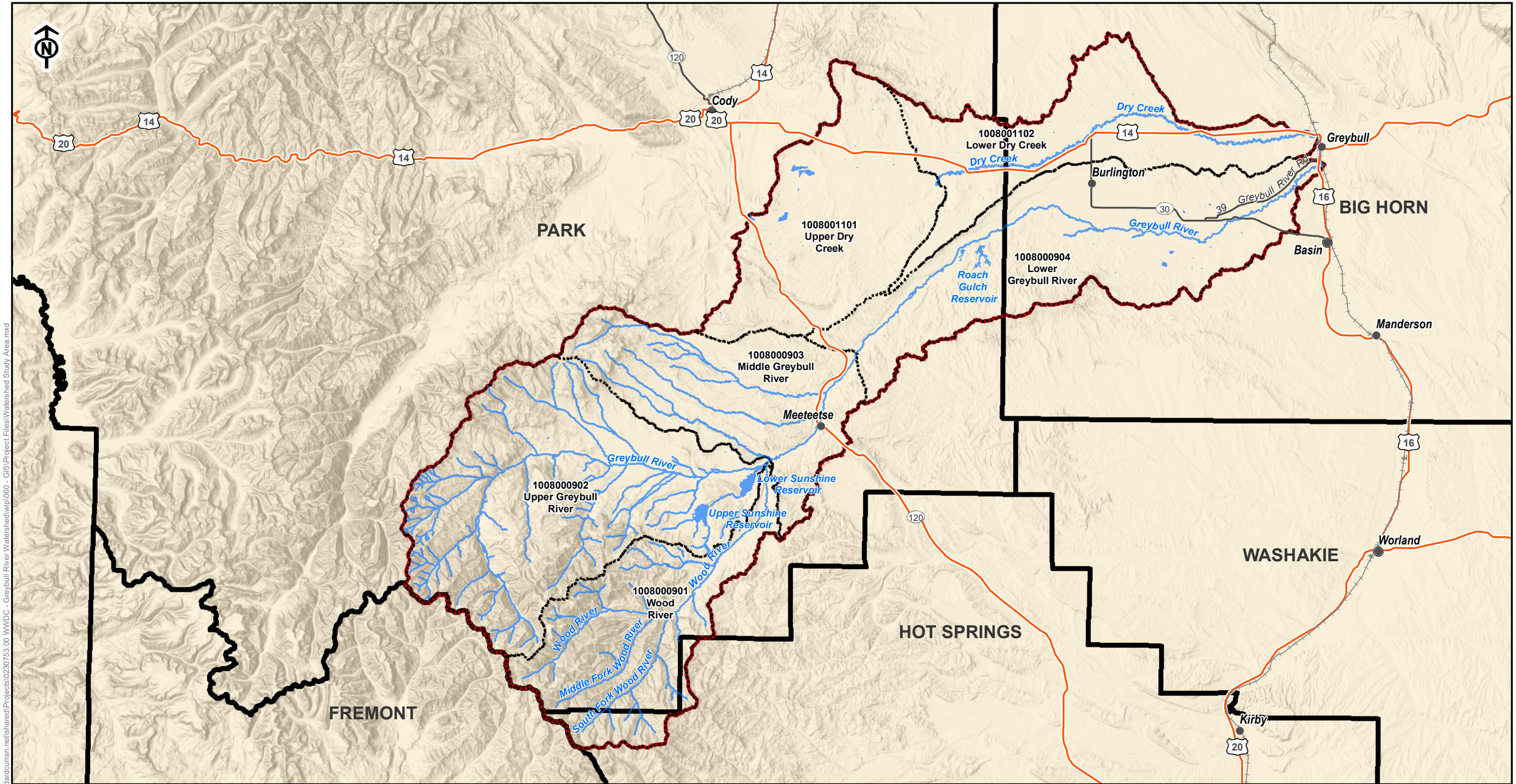
*** This program assists in funding the planning and design stages of the project

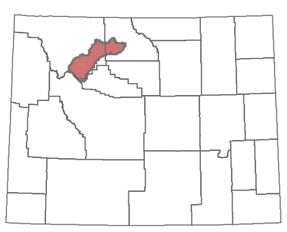
# FIGURES

**Final Report: Greybull River Watershed Level I Study**

**Prepared for the Wyoming Water Development Commission**
Nov.16, 2018

***Prepared by Woodard & Curran***



**LEGEND**

- Watershed Study Area
- City/Town
- Reservoir/Lake
- River/Stream
- Railroad
- Highway
- Major Road
- HUC10 Boundary

# Watershed Study Area

Greybull Watershed Study

*FIGURE 1*

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**LEGEND**

Watershed Study Area

PARK

FREMONT

HOT SPRINGS

WASHAKIE

BIG HORN

ABSAROKA RANGE

Cody

Meeteetse

Worland

Burlington

Otto

Greybull

Basin

Manderson

TABLE MOUNTAIN

YU BENCH

CARTER MOUNTAIN

Buffalo Bill Reservoir

Roach Gulch Reservoir

Lower Sunshine Reservoir

Upper Sunshine Reservoir

POWELL FLATS

Shoshone National Forest

0 5 10 20 30 40 50 Miles

# Watershed Study Area Topography

Greybull Watershed Study

*FIGURE 2*

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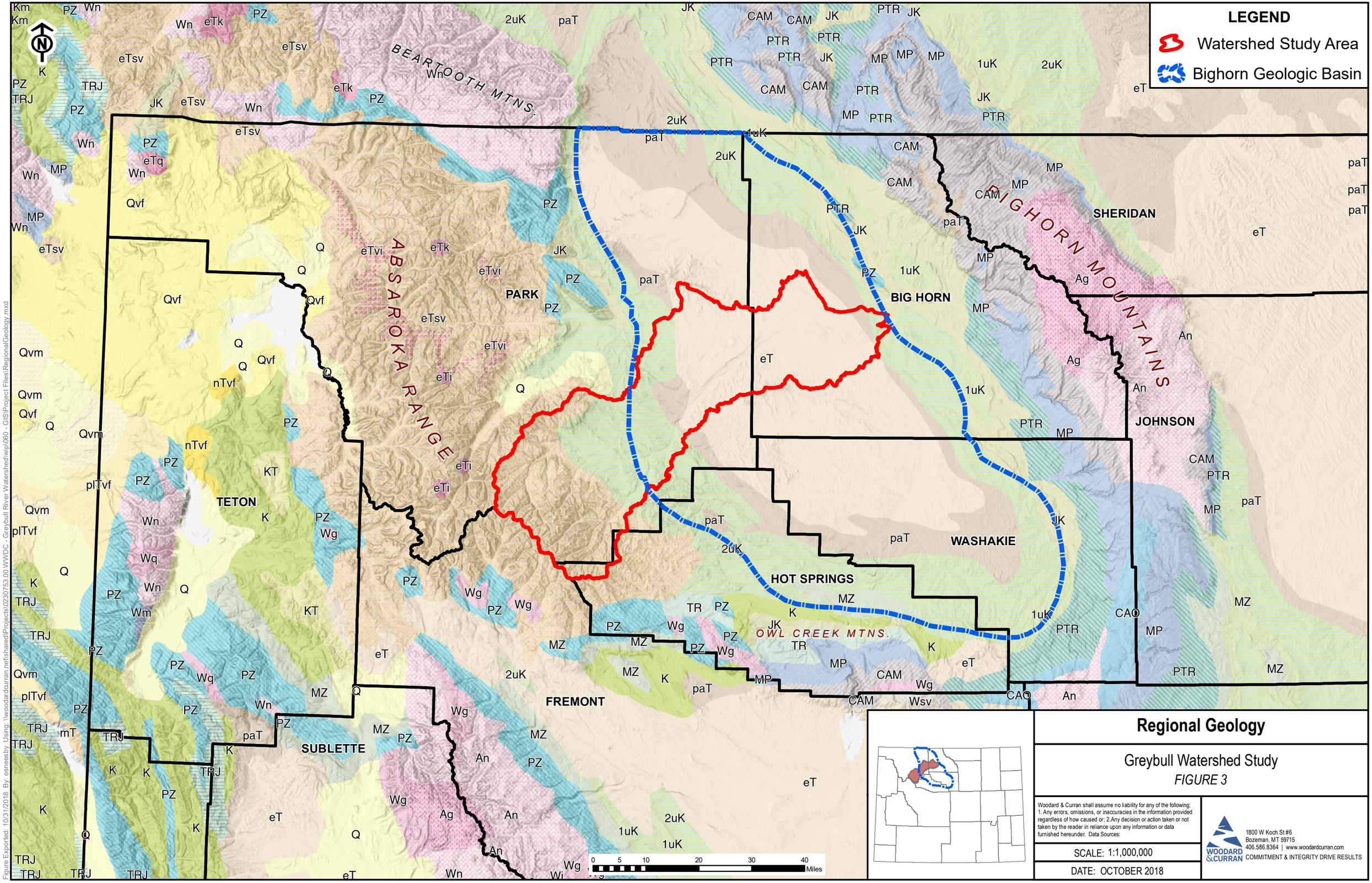


# Regional Geology

Greybull Watershed Study

*FIGURE 3*

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# Regional Geology Legend

**Geologic Unit - Max. Age/Min. Age (Rocktype), Lithology**

- 1uK - Upper Cretaceous (Sedimentary)
- 2uK - Upper Cretaceous (Sedimentary)
- Ag - Archean (Plutonic), Undivided granitic rocks
- An - Archean (Metamorphic and undivided crystalline), Undivided gneissic rocks
- CAM - Cambrian/Mississippian (Sedimentary)
- CAO - Cambrian/Ordovician (Sedimentary)
- JK - Jurassic/Cretaceous (Sedimentary)
- K - Cretaceous (Sedimentary)
- KT - Cretaceous/Tertiary (Sedimentary)
- MP - Mississippian/Permian (Sedimentary)
- MZ - Mesozoic (Sedimentary)
- PTR - Permian/Triassic (Sedimentary)
- PZ - Paleozoic (Sedimentary)
- Q - Quaternary (Sedimentary)
- Qvf - Quaternary (Volcanic), Felsic Rocks
- TR - Triassic (Sedimentary)
- TRJ - Triassic/Jurassic (Sedimentary)
- Wg - Late Archean (Plutonic), Undivided granitic rocks
- Wn - Late Archean (Metamorphic and undivided crystalline), Undivided gneissic rocks
- Wq - Late Archean (Plutonic), Granite
- Wsv - Late Archean (Volcanic), Interlayered sedimentary and volcanic rocks
- eT - Eocene (Sedimentary).
- eTi - Eocene (Plutonic), Intermediate Rocks
- eTk - Eocene (Plutonic), Alkaline Complex
- eTsv - Eocene (Volcanic), Interlayered sedimentary and volcanic rocks
- eTvi - Eocene (Volcanic), Intermediate Rocks
- nTvf - Neogene (Volcanic), Felsic rocks
- paT - Paleocene (Sedimentary).

## Regional Geology

Greybull Watershed Study

*FIGURE 3a - LEGEND*

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**LEGEND**

Watershed Study Area

PARK

BIG HORN

WASHAKIE

HOT SPRINGS

FREMONT

ABSAROKA RANGE

0 2.5 5 10 15 20 Miles

# Bedrock Geology

Greybull Watershed Study

*FIGURE 4*

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# Bedrock Geology Legend

- Qa - Alluvium and colluvium
- Qt - Gravel, pediment, and fan deposits
- Qg - Glacial deposits
- Qls - Landslide deposits
- Ti - Intrusive igneous rocks
- Twi - Absaroka Volcanic Supergroup: Thorofare Creek Group - Wiggins Formation
- Ts - Absaroka Volcanic Supergroup: Sunlight Group - Trout Peak Trachyandesite, Wapiti Formation, Crescent Hill Basalt, and Mount Wallace Formation
- Tt - Absaroka Volcanic Supergroup: Thorofare Creek Group - Tepee Trail Formation
- Ta - Absaroka Volcanic Supergroup: Thorofare Creek Group - Aycross Formation
- Tta - Tatman Formation
- Twl - Willwood Formation
- Tfu - Fort Union Formation
- Kl - Lance Formation
- Km - Meeteetse Formation
- Kmv - Mesaverde Formation (N) or Mesaverde Group (S)
- Kc - Cody Shale
- Kf - Frontier Formation
- Kft - Frontier Formation, and Mowry and Thermopolis Shales
- Kmt - Mowry and Thermopolis Shales
- Mm - Madison Group (TB), Madison Limestone or Group (N), or Madison Limestone (S)
- MD - Madison Limestone or Group, and Darby Formation, or Madison Group, and Three Forks and Jefferson Formations
- O_ - Bighorn Dolomite, Gallatin Limestone, and Gros Ventre Formation (TB); Bighorn Dolomite, Snowy Range Formation, Pilgrim Limestone, Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone (Y); Bighorn Dolomite, Gallatin Limestone, Gros Ventre Formation, and Flathead Sandstone (N), Whitewood Dolomite, and Winnipeg and Deadwood Formations (NE)
- Water

## Bedrock Geology

Greybull Watershed Study

*FIGURE 4a - LEGEND*

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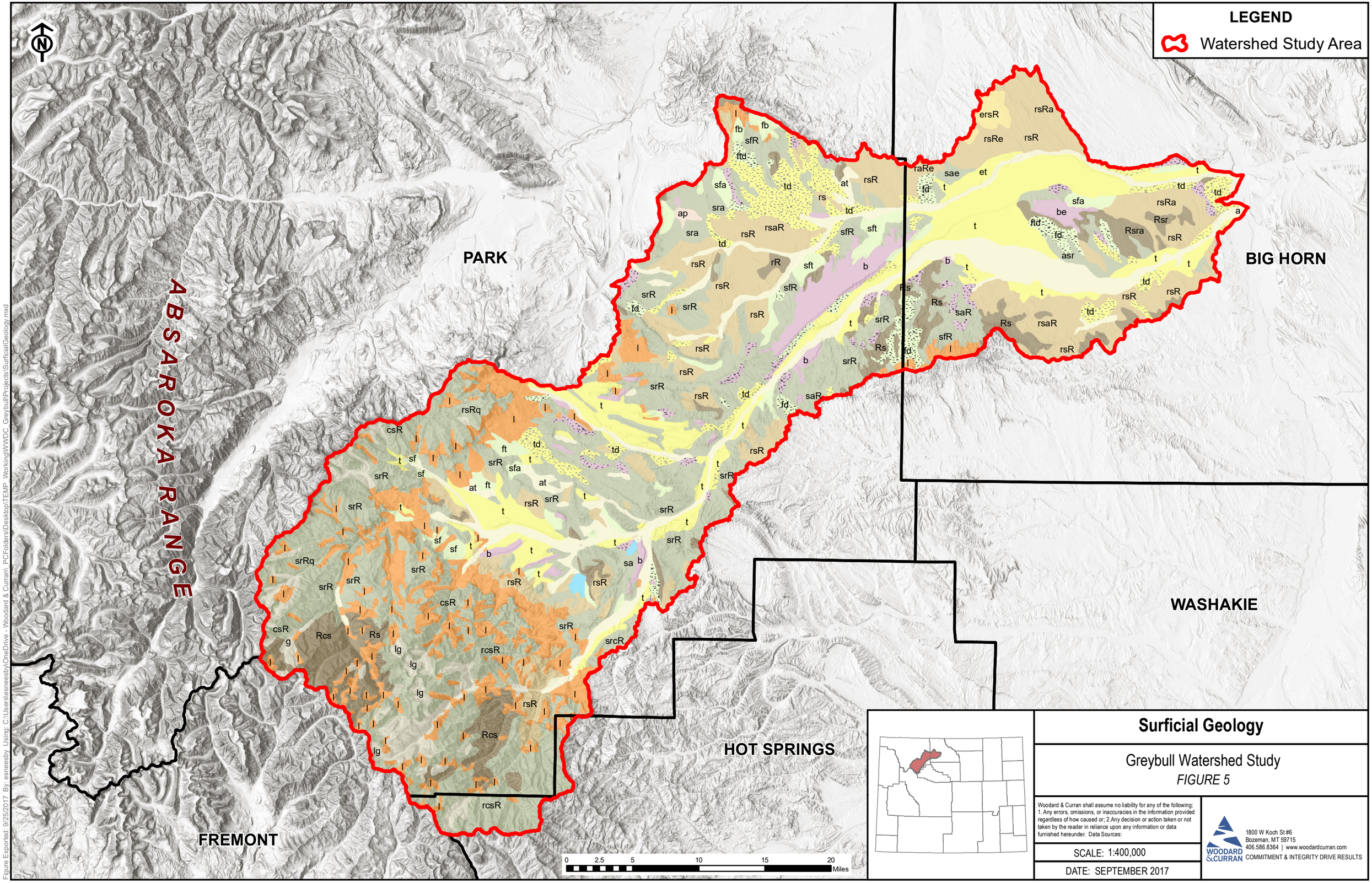


# Surficial Geology

Greybull Watershed Study

*FIGURE 5*

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## Surficial Geology Legend

- LAKE - Larger lakes and reservoirs
- Ri - Bedrock and glaciated bedrock including hot spring deposits and volcanic necks; mixed with scattered shallow deposits of eolian, grus, slopewash, colluvium, residuum, glacial, and alluvium.
- ai - Alluvium with scattered deposits of terrace, slopewash, eolian, residuum, grus and glacial
- bdi - Dissected bench with scattered deposits of residuum, slopewash, landslide, and eolian
- bi - Bench including eolian, slopewash, outwash, and bench and/or mesa
- ei - Eolian mixed with scattered deposits of residuum, alluvium, and slopewash
- fdi - Dissected alluvial fan and gradational fan deposits mixed with scattered deposits of slopewash and residuum
- fi - Alluvial fan and gradational fan deposits mixed with scattered deposits of slopewash, residuum, and eolian
- gi - Glacial deposits mixed with scattered deposits of slopewash, residuum, grus, alluvium, colluvium, landslide, and/or bedrock outcrops
- li - Landslide mixed with scattered deposits of slopewash, residuum, Tertiary landslides, and bedrock outcrops; landslides too small and numerous to show separately
- pea - Playa deposits mixed with scattered deposits of alluvium, eolian, and residuum; playa deposits too small to show separately
- ri -Residuum mixed with alluvium, eolian, slopewash, grus, and/or bedrock outcrops
- sci - Slopewash and colluvium mixed with scattered deposits of slopewash, residuum, grus, glacial, periglacial, alluvium, eolian, and/or bedrock outcrops
- tdi - Dissected terrace deposits mixing with alluvium, residuum, eolian, and slopewash
- ti - Terrace deposits mixed with scattered deposits of alluvium, residuum, eolian, slopewash, and outwash

**SURFICIAL GEOLOGY SUMMARY**

| Symbol | Description | Total Acres | Percent of Study Area Total Acreage |
|---|---|---|---|
| ai | Alluvium with scattered terrace, slope wash, eolian, residuum, grus, and glacial deposits | 78,963 | 7.8 |
| bdi | Dissected bench deposits, with scattered residuum, slope wash, landslide, and eolian deposits | 14,575 | 1.4 |
| bi | Bench deposits, including eolian, slope wash, outwash, and bench and/or mesa | 26,160 | 2.6 |
| ei | Eolian deposits mixed with scattered residuum, alluvium, and slope wash deposits | 4,488 | 0.4 |
| fdi | Dissected alluvial fan and gradational fan deposits mixed with scattered residuum and slope wash deposits | 18,658 | 1.8 |
| fi | Alluvial fan and gradational fan deposits mixed with scattered slope wash, residuum, and eolian deposits | 29,702 | 2.9 |
| gi | Glacial deposits mixed with scattered slope wash, residuum, grus, alluvium, colluvium, and landslide deposits, and/or bedrock outcrops | 28,602 | 2.8 |
| LAKE | Lake | 1,402 | 0.1 |
| li | Landslide deposits mixed with scattered residuum and slope wash deposits, Tertiary landslides, and bedrock outcrops; landslides too small and numerous to | 103,712 | 10.2 |
| pea | Playa deposits mixed with scattered alluvium, residuum, and eolian deposits; playa deposits too small to show separately | 1,065 | 0.1 |
| ri | Residuum mixed with alluvium, eolian, slope wash, and grus deposits, and/or bedrock outcrops | 150,689 | 14.9 |
| Ri | Bedrock and glaciated bedrock, including hot spring deposits and volcanic necks; mixed with scattered shallow eolian, grus, slope wash, colluvium, residuum, glacial, | 73,563 | 7.3 |
| sci | Slope wash and colluvium mixed with scattered slope wash, residuum, grus, glacial, periglacial, alluvium, and eolian deposits, and/or bedrock outcrops | 340,280 | 33.6 |
| tdi | Dissected terrace deposits mixing with alluvium, residuum, eolian, and slope wash deposits | 44,676 | 4.4 |
| ti | Terrace deposits mixed with scattered alluvium, residuum, eolian, slope wash, and outwash deposits | 97,455 | 9.6 |
| | Totals | 1,013,991 | 100.0 |

# Surficial Geology

Greybull Watershed Study

*FIGURE 5a - LEGEND*

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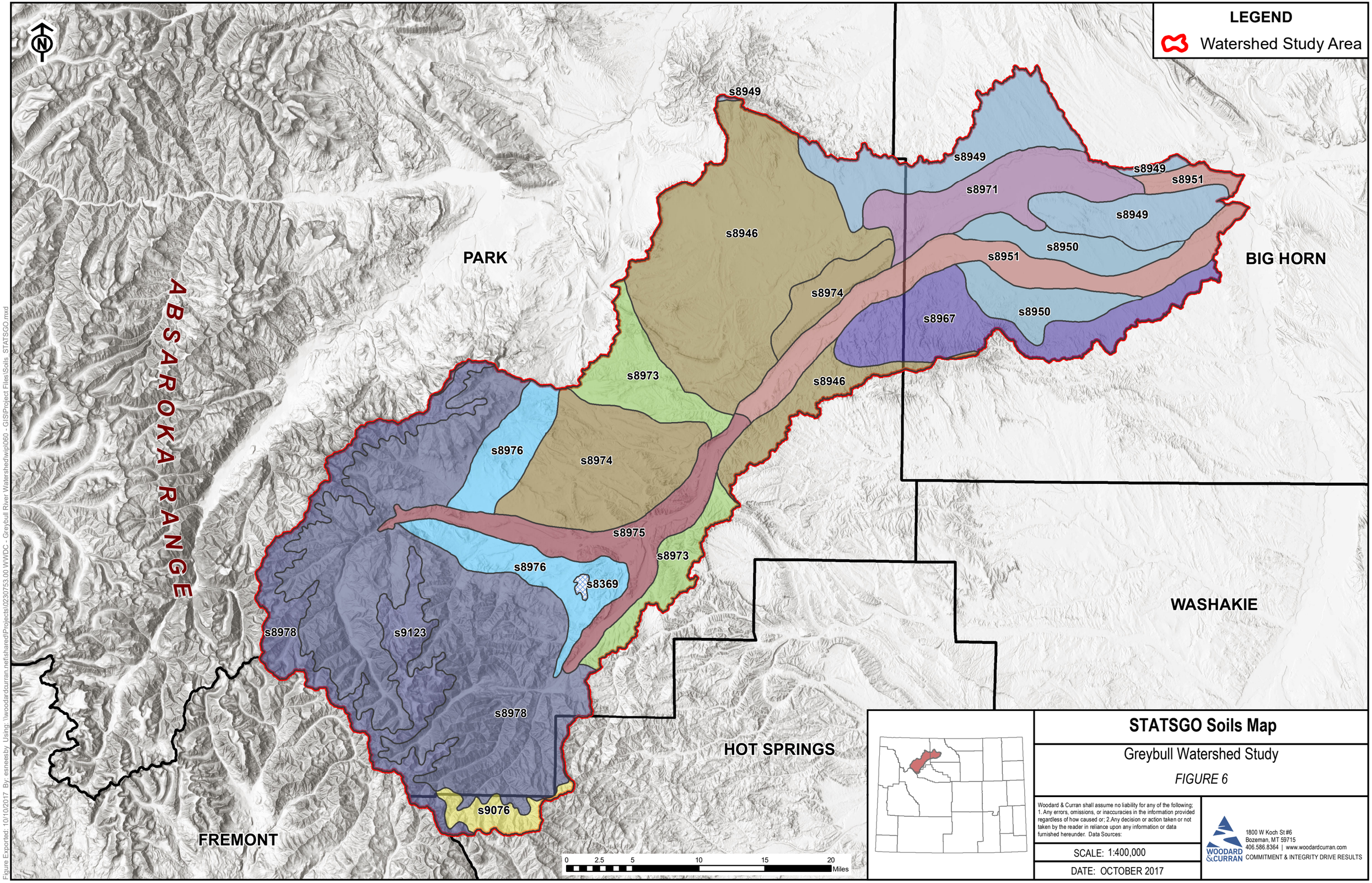


# STATSGO Soils Map

Greybull Watershed Study

*FIGURE 6*

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## STATSGO Soils Legend

- Rock outcrop-Nielsen-Hobacker-Clayburn-Blaine-Bachus (s8978)
- Rubble land-Rock outcrop-Cowood (s9123)
- Travson-Shingle-Rock outcrop-Midway-Keyner-Hiland-Bowbac (s8946)
- Water (s8369)
- Woosley-Starman-Rock outcrop-Mosroc-Fornor-Decross (s9076)
- Yamac-Evanston-Attewan (s8974)
- Yamac-Moyerson-Forelle-Diamondville-Delphill-Blazon-Blackhall-Alcova (s8973)
- Yamac-Vanda-Evanston-Alcova (s8975)
- Youngston-Rock outcrop-Persayo-Neiber (s8967)
- Youngston-Sharland-Garland (s8971)
- Youngston-Uffens-Stutzman-Lostwells-Apron (s8950)
- Youngston-Willwood-Sharland-Preatorson-Lostwells-Garland-Apron (s8951)
- Youngston-Worland-Persayo-Oceanet-Greybull (s8949)
- Zillman-Evanston-Delphill-Crago-Brownsto-Blazon-Blackhall (s8976)

# STATSGO Soils Map

Greybull Watershed Study

*FIGURE 6a - LEGEND*

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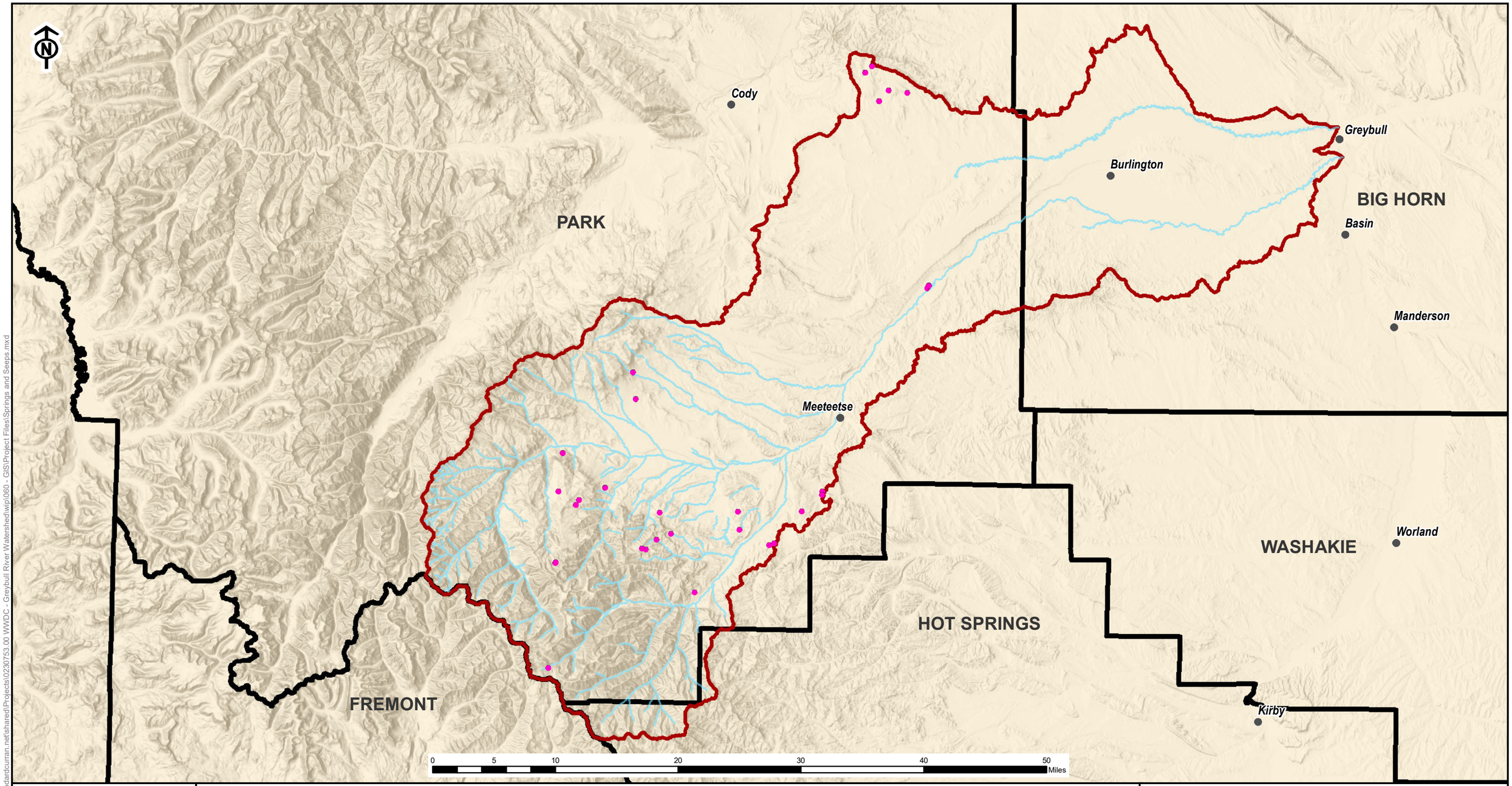


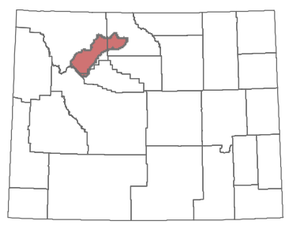

**LEGEND**

- Watershed Study Area
- Spring/Seep

# USGS Mapped Springs/Seeps

Greybull Watershed Study

*FIGURE 7*

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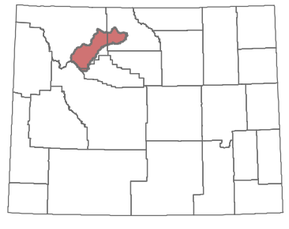
Cody
Greybull
Burlington
Basin
Manderson
Meeteetse
Worland
Kirby
PARK
BIG HORN
WASHAKIE
HOT SPRINGS
FREMONT
0 5 10 20 30 40 50 Miles



## LEGEND

- Watershed Study Area
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream Gauge

# Stream Types and Stream Gauge Locations

Greybull Watershed Study

*FIGURE 8*

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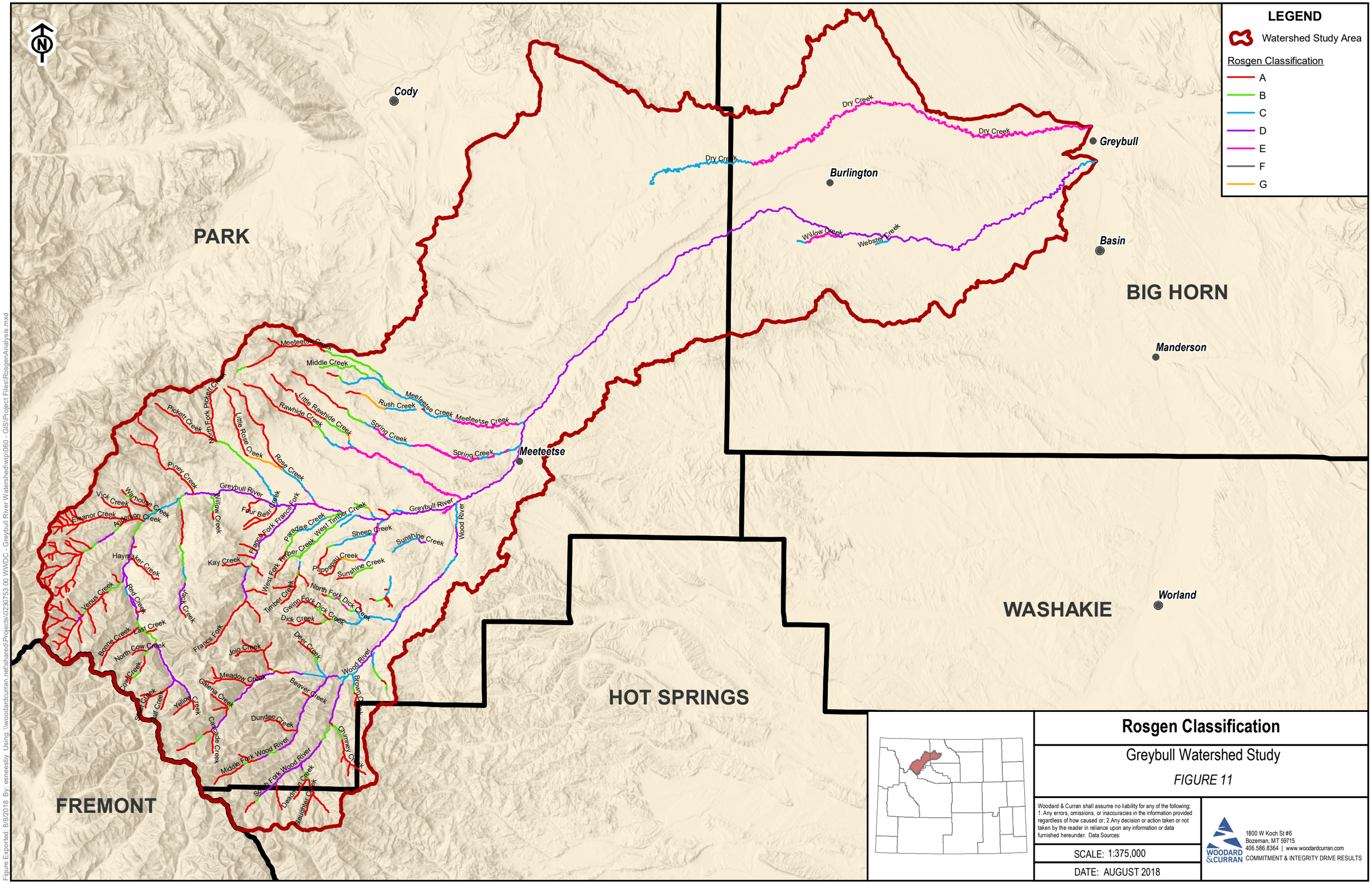


## Rosgen Classification

Greybull Watershed Study

*FIGURE 11*

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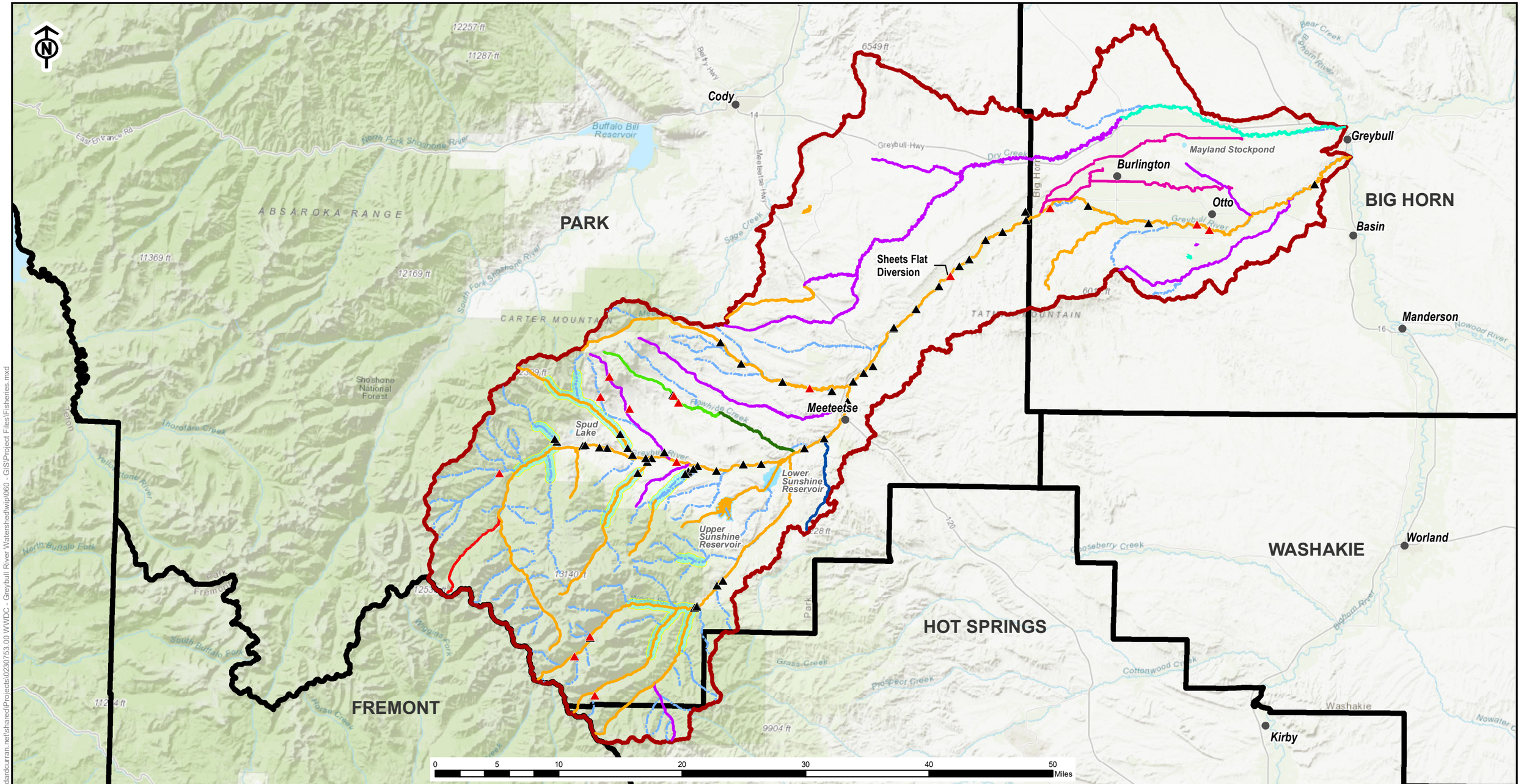


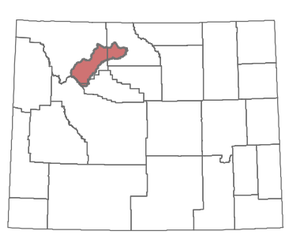

**LEGEND**

- Watershed Study Area
- Instream Flow

Fish Passage Barrier
- Passable
- Not Passable or Partially Passable

Classified Stream/River
- 1
- 2AB
- 2ABww
- 2B
- 2C
- 3B
- 4A
- 4B
- Other Major Stream/River (Not classified)

Classified Lake/Reservoir
- 2AB
- 2ABww
- 3B

# Fisheries

## Greybull Watershed Study

*FIGURE 12*

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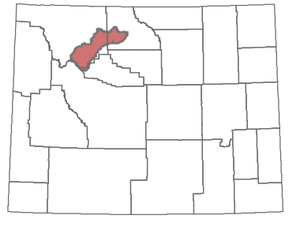
Cody
Greybull
Burlington
BIG HORN
PARK
Basin
Sheets Flat Bridge
Manderson
Meeteetse
Worland
WASHAKIE
HOT SPRINGS
FREMONT
Kirby
0 5 10 20 30 40 50 Miles



## LEGEND

- Watershed Study Area
- Perennial Stream
- Category 4A Impaired Stream (WDEQ, 2014)

# Impaired Streams

Greybull Watershed Study

*FIGURE 13*

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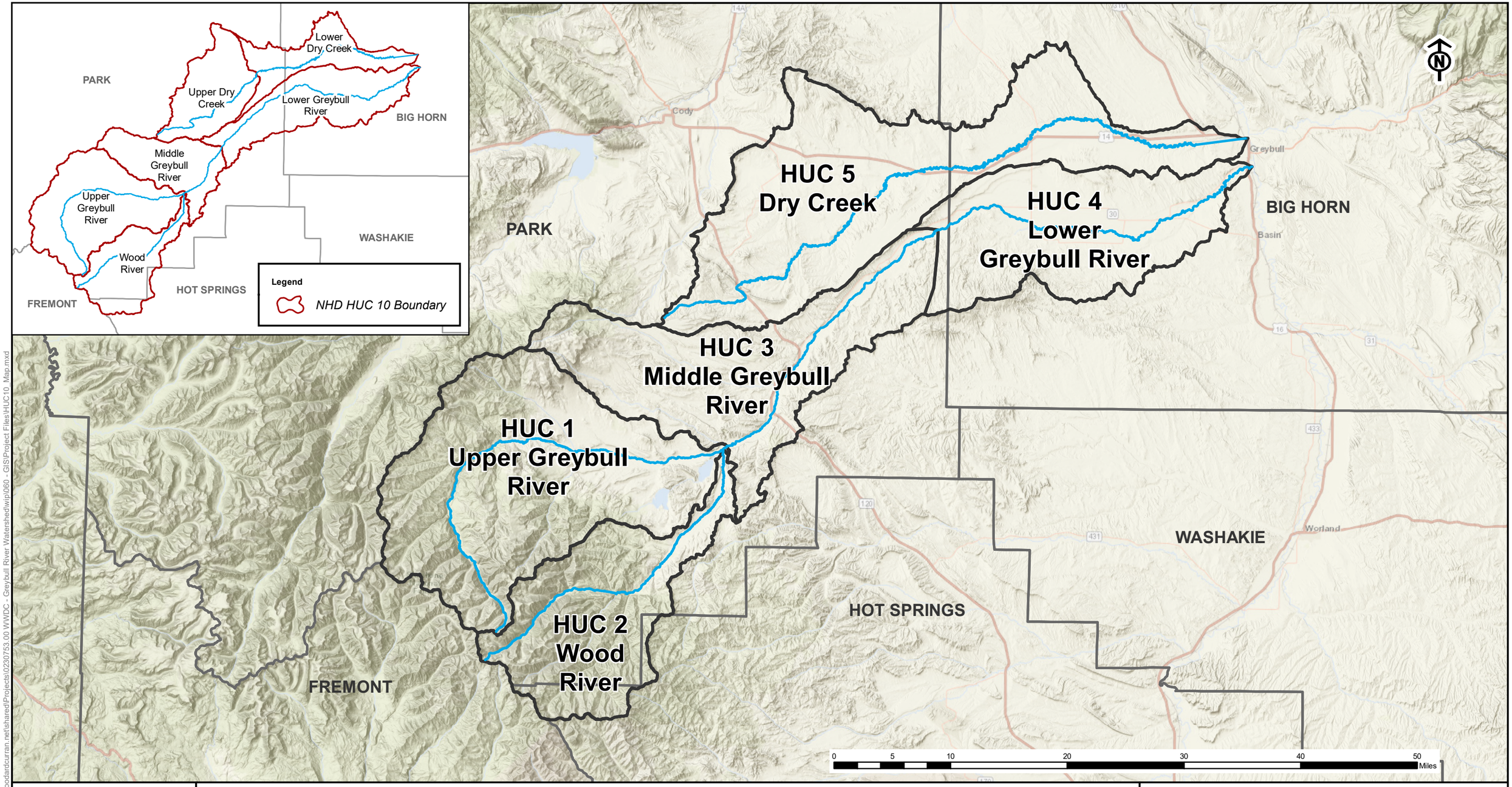


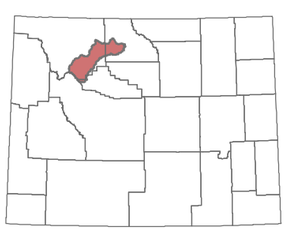

## Legend

Main Reaches

Hydrologic Unit Codes

# 10-digit Hydrologic Unit Codes (HUC-10s)

Greybull Watershed Study

*FIGURE 14*

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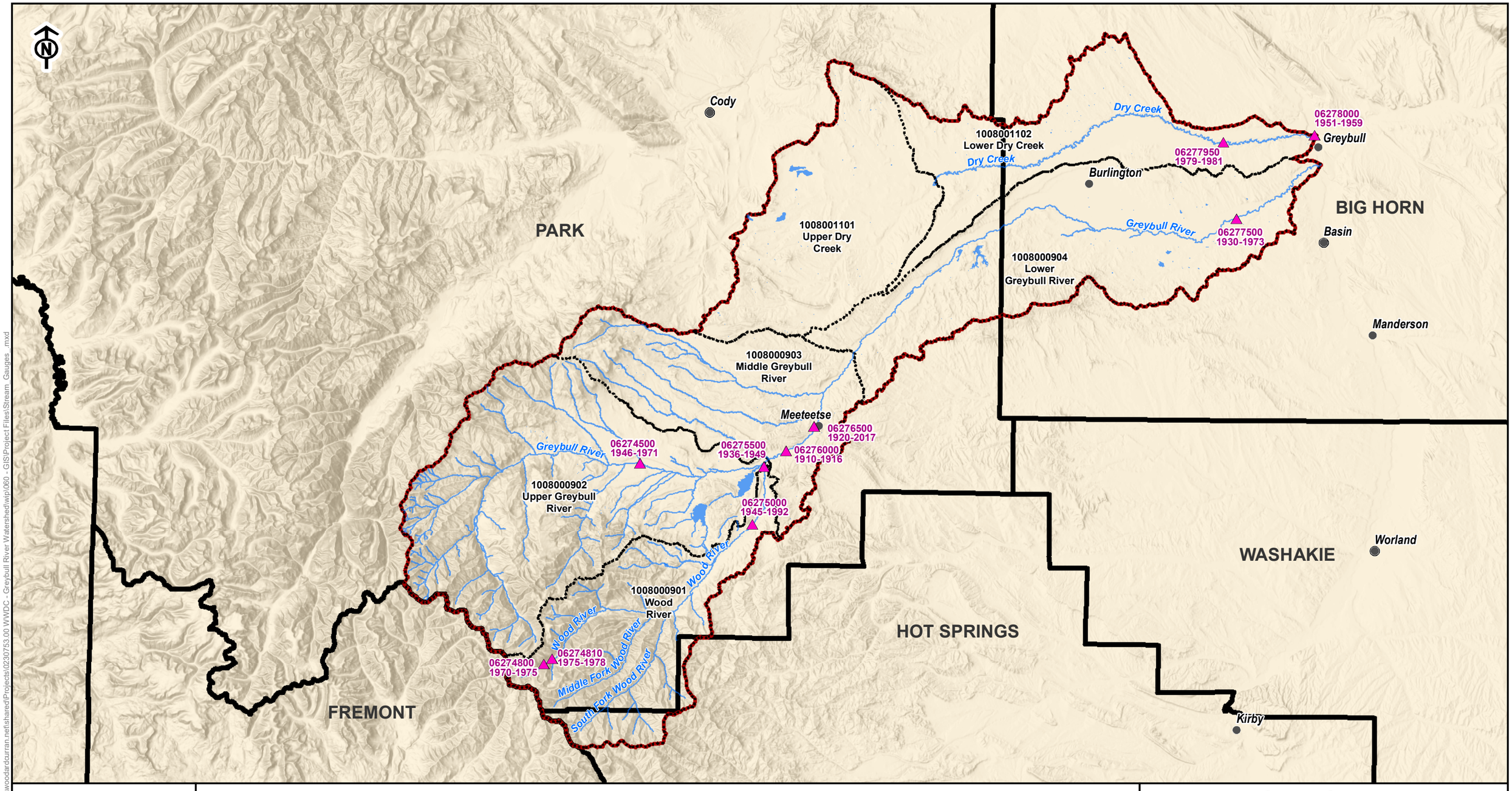


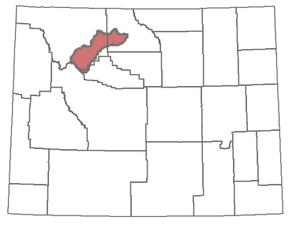

**LEGEND**

Watershed Study Area | Reservoir/Lake | HUC10 Boundary

City/Town | River/Stream | Stream Gauges

# Stream Gauges

Greybull Watershed Study

*FIGURE 15*

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HUC 5
Dry Available: 20691
Avg. Available: 19155
Wet Available: 17661

HUC 4
Dry Available: 43841
Avg. Available: 88863
Wet Available: 173469

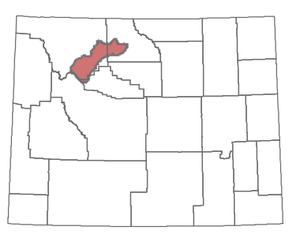
HUC 3
Dry Available: 36533
Avg. Available: 67016
Wet Available: 139734

HUC 1
Dry Available: 22799
Avg. Available: 70784
Wet Available: 157733

HUC 2
Dry Available: 48389
Avg. Available: 79767
Wet Available: 116124

Cody
Greybull
Basin
Worland
14
16
31
433
120
431

0 5 10 20 30 40 50 Miles



## Legend

All Reaches

Hydrologic Unit Codes (HUCs)

# Annual Available Flow (ac-ft) for All Reaches in HUC

Greybull Watershed Study

*FIGURE 20*

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HUC 5
Dry Shortage: 0
Avg. Shortage: 0
Wet Shortage: 0

HUC 4
Dry Shortage: 60322
Avg. Shortage: 10080
Wet Shortage: 92

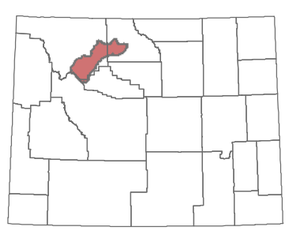
HUC 3
Dry Shortage: 12469
Avg. Shortage: 7456
Wet Shortage: 6381

HUC 1
Dry Shortage: 2848
Avg. Shortage: 1079
Wet Shortage: 344

HUC 2
Dry Shortage: 161
Avg. Shortage: 0
Wet Shortage: 0

Cody
Greybull
Basin
Worland
14
30
16
31
433
120
431

0 5 10 20 30 40 50 Miles



## Legend

All Reaches

Hydrologic Unit Codes (HUCs)

# Annual Shortages (ac-ft) for All Reaches in HUC

Greybull Watershed Study

*FIGURE 21*

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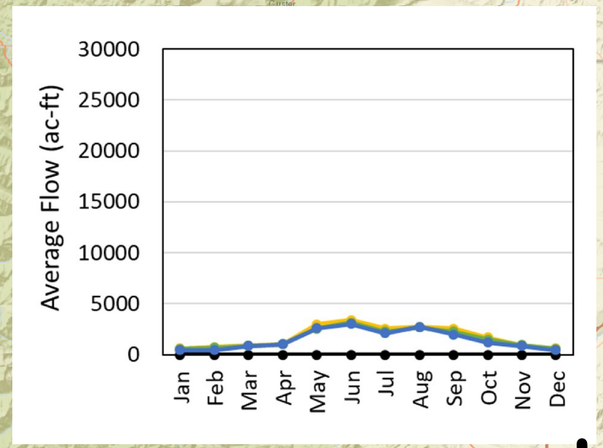


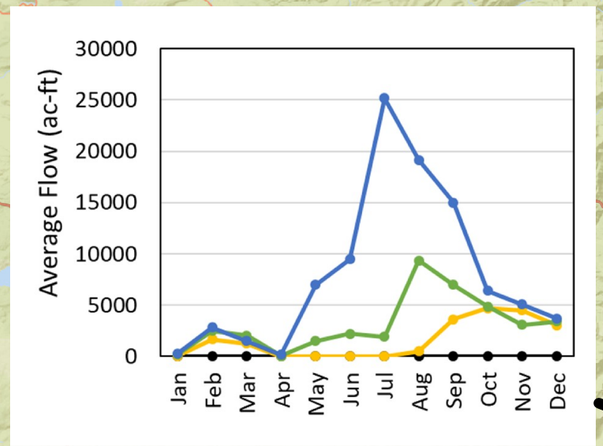


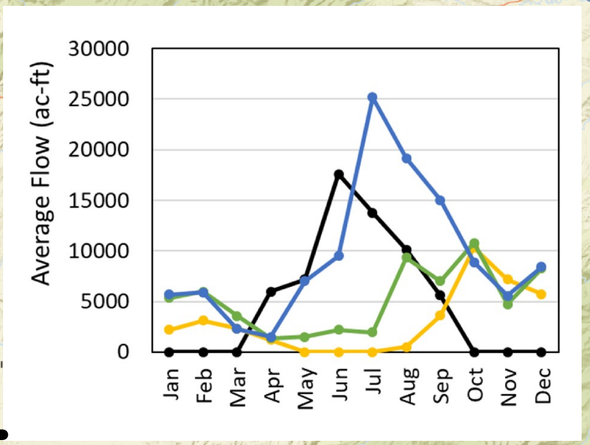


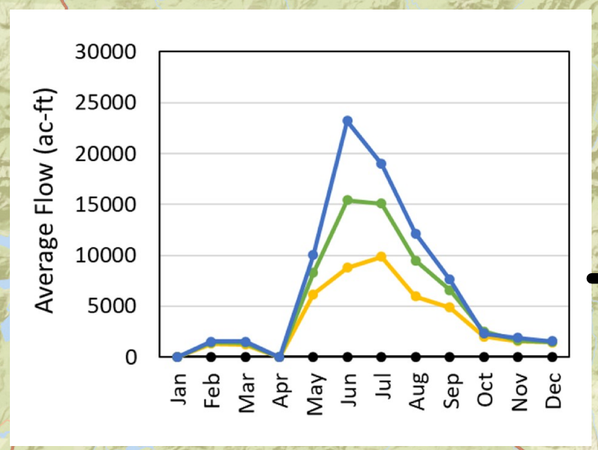


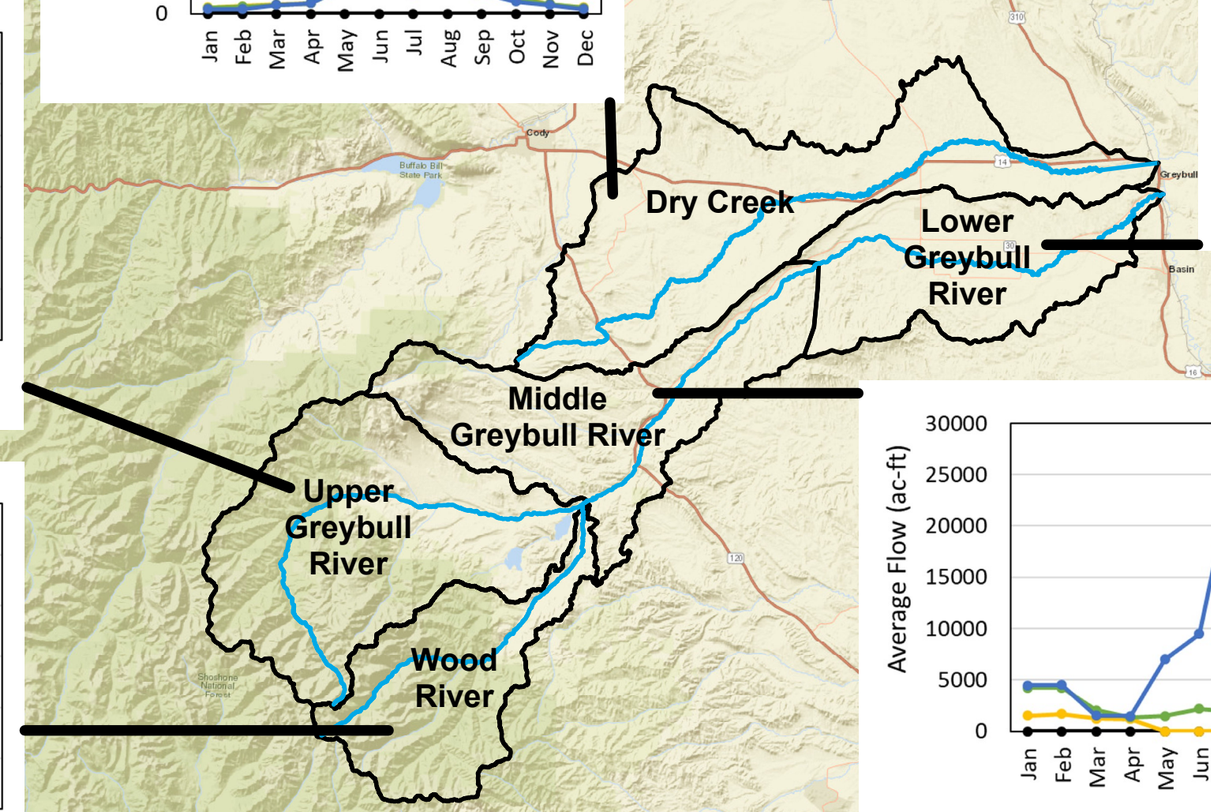


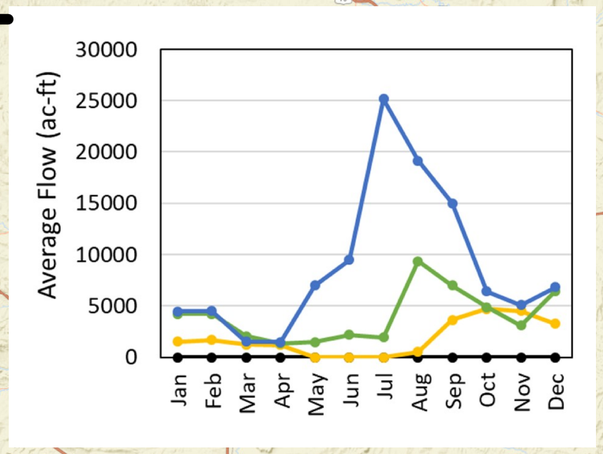


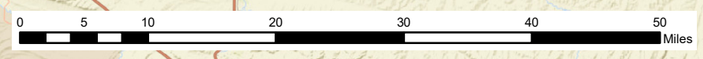


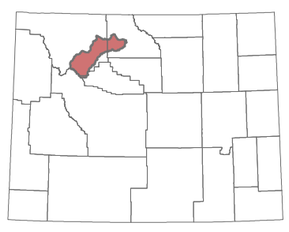

## Legend

- Main Reaches
- Hydrologic Unit Codes
- Shortage: Dry
- Available: Dry
- Available: Avg
- Available: Wet

# Hydrographs of HUC's Main Reaches

Greybull Watershed Study

*FIGURE 22*

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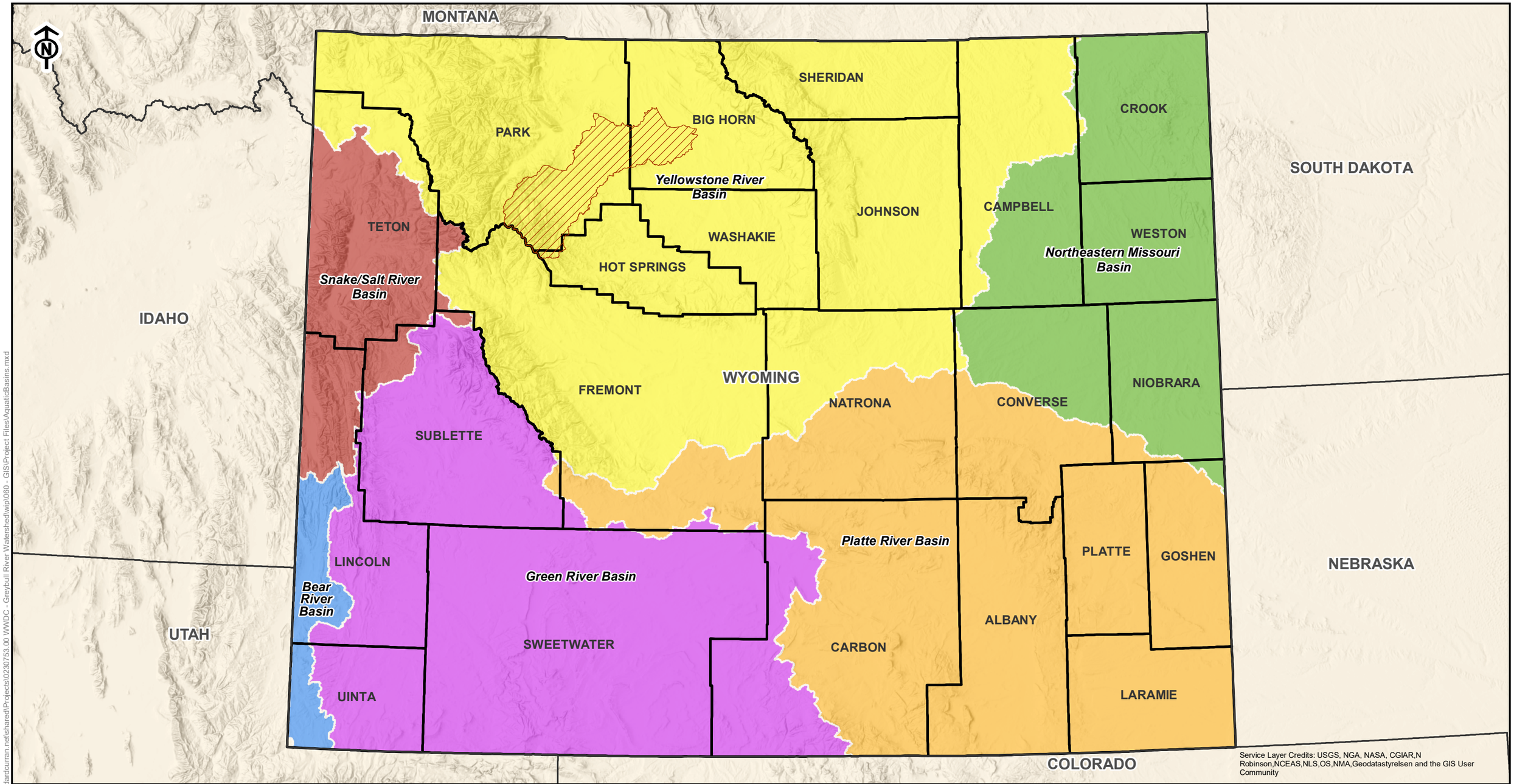


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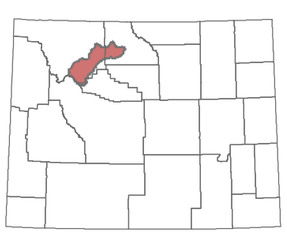

## LEGEND

- Watershed Study Area
- Bear River Basin
- Green River Basin
- Northeastern Missouri Basin
- Platte River Basin
- Snake/Salt River Basin
- Yellowstone River Basin

0 5 10 20 30 40 50 Miles

# State-wide Aquatic Basins

Greybull Watershed Study

*FIGURE 24*

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PARK

BIG HORN

WASHAKIE

HOT SPRINGS

FREMONT

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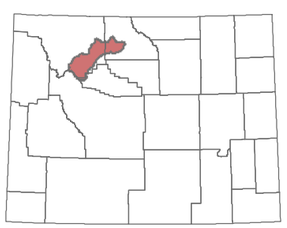

## LEGEND

Watershed Study Area

Canopy Type

- Closed tree canopy
- Open tree canopy
- Sparse tree canopy
- Herbaceous - grassland
- Herbaceous - shrub-steppe
- No Dominant Lifeform
- Shrubland
- Dwarf-shrubland
- Sparsely vegetated
- Non-vegetated

0 5 10 20 30 40 50 Miles

# Canopy Types

## Greybull Watershed Study

*FIGURE 25*

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SCALE: 1 " = 7 miles

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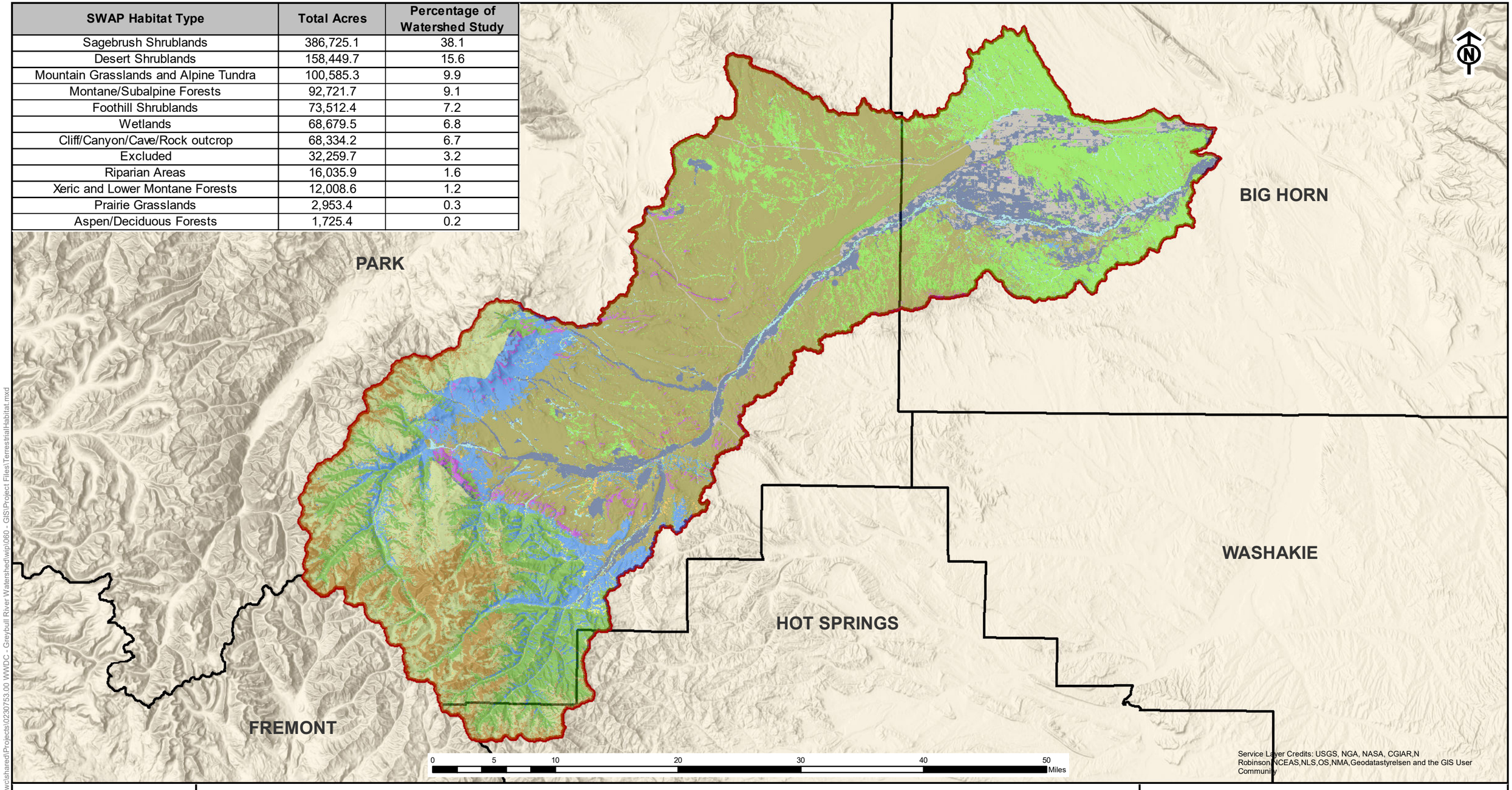
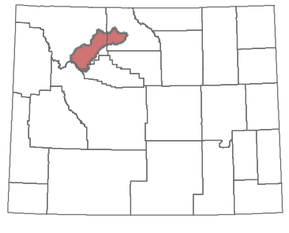
| SWAP Habitat Type | Total Acres | Percentage of Watershed Study |
|---|---|---|
| Sagebrush Shrublands | 386,725.1 | 38.1 |
| Desert Shrublands | 158,449.7 | 15.6 |
| Mountain Grasslands and Alpine Tundra | 100,585.3 | 9.9 |
| Montane/Subalpine Forests | 92,721.7 | 9.1 |
| Foothill Shrublands | 73,512.4 | 7.2 |
| Wetlands | 68,679.5 | 6.8 |
| Cliff/Canyon/Cave/Rock outcrop | 68,334.2 | 6.7 |
| Excluded | 32,259.7 | 3.2 |
| Riparian Areas | 16,035.9 | 1.6 |
| Xeric and Lower Montane Forests | 12,008.6 | 1.2 |
| Prairie Grasslands | 2,953.4 | 0.3 |
| Aspen/Deciduous Forests | 1,725.4 | 0.2 |



## LEGEND

Watershed Study Area

**Terrestrial Habitat Types (State Wildlife Action Plan, 2017)**

- Aspen/Deciduous Forests
- Cliff/Canyon/Cave/Rock outcrop
- Desert Shrublands
- Excluded
- Foothill Shrublands
- Montane/Subalpine Forests
- Mountain Grasslands and Alpine Tundra
- Prairie Grasslands
- Riparian Areas
- Sagebrush Shrublands
- Wetlands
- Xeric and Lower Montane Forests

# SWAP Terrestrial Habitat Types

Greybull Watershed Study

*FIGURE 26*

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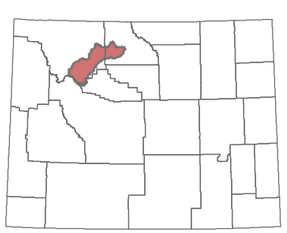
Cody
Greybull
Burlington
PARK
BIG HORN
Basin
Manderson
Meeteetse
Worland
WASHAKIE
HOT SPRINGS
Kirby
FREMONT
0 5 10 20 30 40 50
Miles
Service Layer Credits: USGS, NGA, NASA, CGIAR,N Robinson,NCEAS,NLS,OS,NMA,Geodatastyrelsen and the GIS User Community



## LEGEND

- Watershed Study Area
- Introduced Upland Vegetation-Perennial Grassland and Forbland
- Introduced Upland Vegetation-Annual and Biennial Forbland
- Introduced Upland Vegetation-Annual Grassland
- Introduced Riparian Forest and Woodland

# Introduced Vegetation

Greybull Watershed Study

*FIGURE 27*

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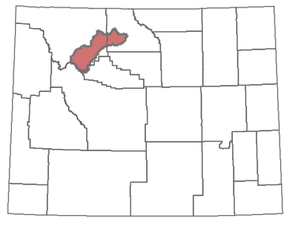
Cody
Greybull
Burlington
PARK
BIG HORN
Basin
Manderson
Meeteetse
Worland
WASHAKIE
HOT SPRINGS
Kirby
FREMONT
0 5 10 20 30 40 50 Miles
Service Layer Credits: USGS, NGA, NASA, CGIAR,N Robinson,NCEAS,NLS,OS,NMA,Geodatastyrelsen and the GIS User Community



## LEGEND

Watershed Study Area

**WETLAND TYPE**

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Riverine
- Freshwater Pond
- Lake

# Wetlands

Greybull Watershed Study

*FIGURE 28*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources: National Wetland Inventory

SCALE: 1 " = 7 miles

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PARK

BIG HORN

FREMONT

HOT SPRINGS

WASHAKIE

Cody

Meeteetse

Burlington

HWY 30
Bridge

Greybull River Rd

Greybull

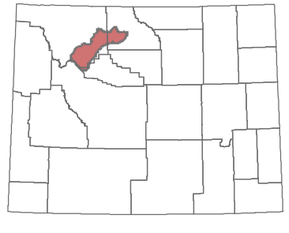
Basin

Manderson

Worland

Kirby

0 5 10 20 30 40 50
Miles



## LEGEND

- Watershed Study Area
- Aquatic Enhancement Habitat Priorities
- Aquatic Crucial Habitat Priorities

# Aquatic Crucial and Enhancement Habitat Priorities

Greybull Watershed Study

*FIGURE 29*

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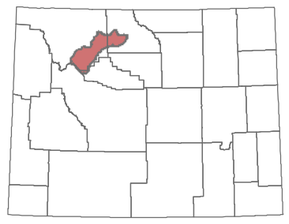
Cody
Greybull
Burlington
BIG HORN
PARK
Basin
Meeteetse
Manderson
Worland
WASHAKIE
HOT SPRINGS
FREMONT
Kirby
0 5 10 20 30 40 50 Miles



## LEGEND

- Watershed Study Area
- Terrestrial Crucial Habitat Priorities
- Terrestrial Enhancement Habitat Priorities

# Terrestrial Crucial and Enhancement Habitat Priorities

Greybull Watershed Study

*FIGURE 30*

Woodard & Curran shall assume no liability for any of the following: 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2. Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

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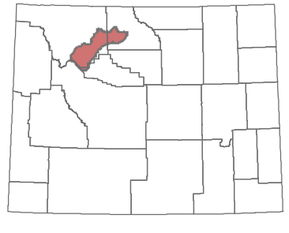
Cody
Greybull
Burlington
BIG HORN
PARK
Basin
Meeteetse
Manderson
Worland
WASHAKIE
HOT SPRINGS
FREMONT
Kirby
0 5 10 20 30 40 50 Miles



## LEGEND

- Watershed Study Area
- Combined Enhancement Habitat Priorities
- Combined Crucial Habitat Priorities

# Combined Crucial and Enhancement Habitat Priorities

Greybull Watershed Study

*FIGURE 31*

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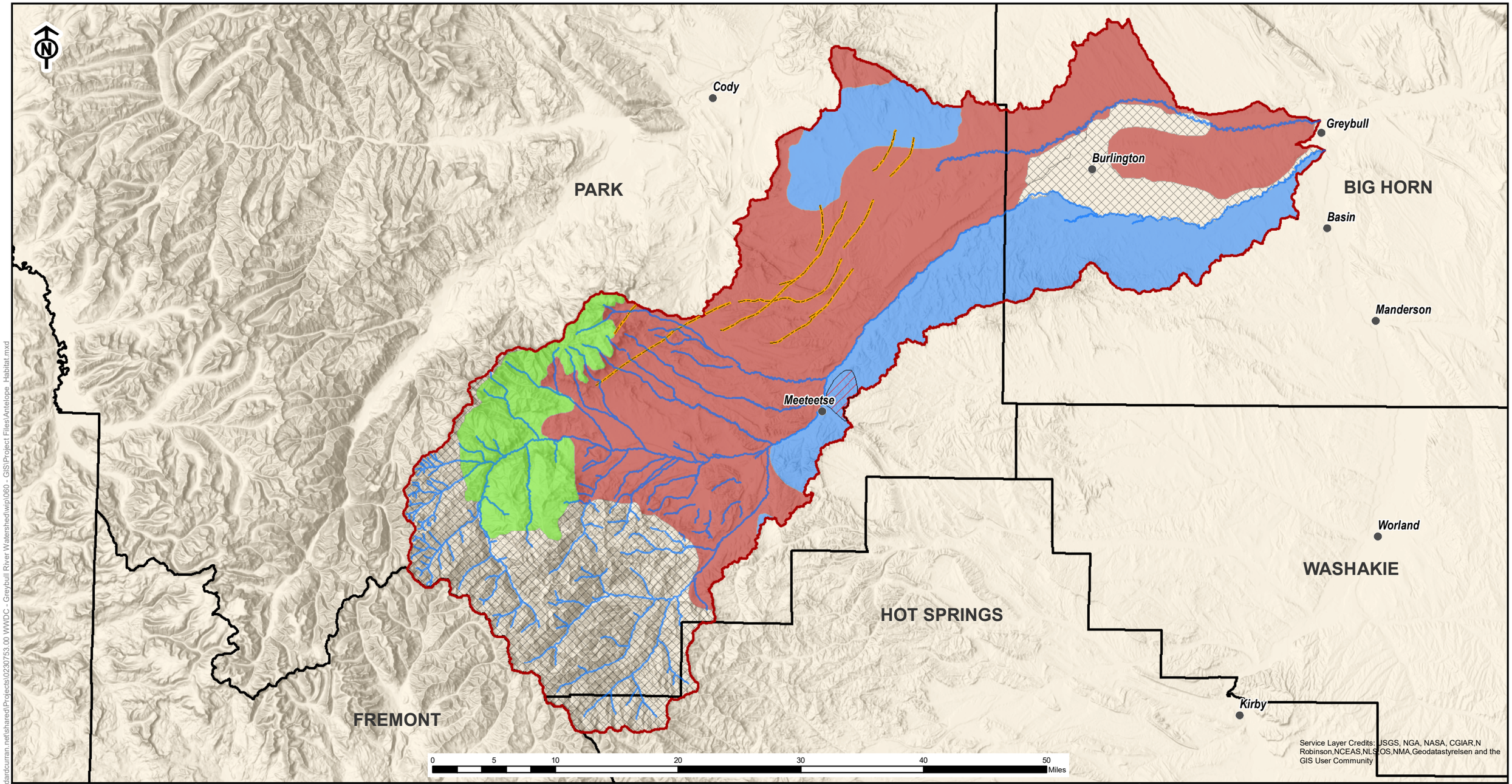


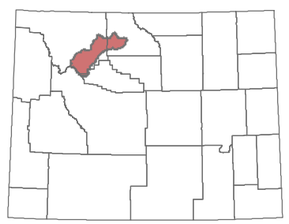

## LEGEND

- Watershed Study Area
- Antelope Migration Routes
- Antelope Crucial Range

**Antelope Seasonal Range**

Range Description

- Winter/Year Long
- Does not contain enough animals to be important habitat or habitat is of limited importance.
- Spring/Summer/Fall
- Year Long. May leave under severe conditions

# Antelope Habitat

Greybull Watershed Study

*FIGURE 32*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

SCALE: 1 " = 7 miles

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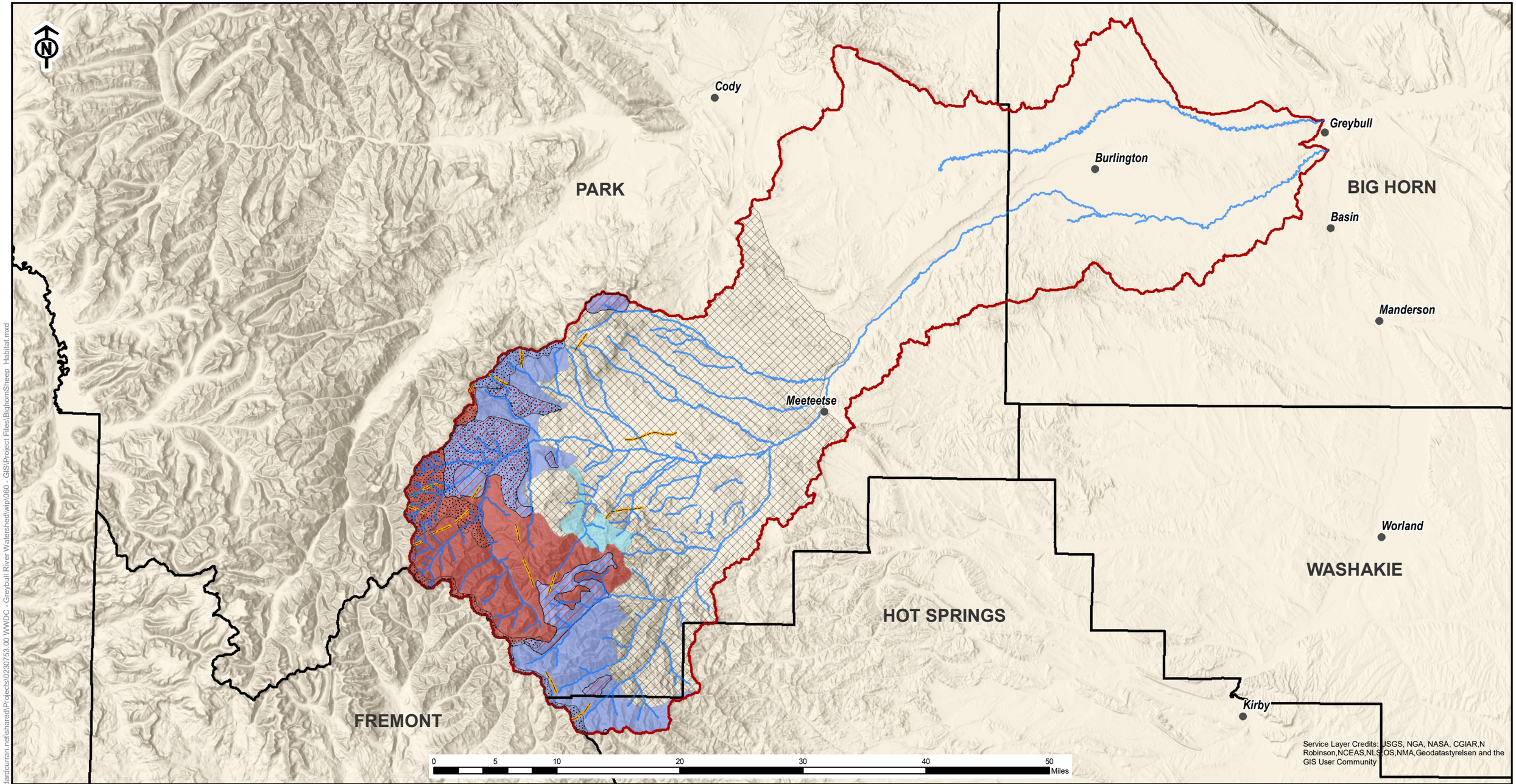


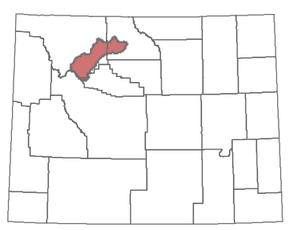

## LEGEND

- Watershed Study Area
- Bighorn Sheep Migration Routes
- Bighorn Sheep Crucial Range
- Bighorn Sheep Parturition Area

**Bighorn Sheep Seasonal Range**

Range Description

- Winter/Year Long
- Does not contain enough animals to be important habitat or habitat is of limited importance.
- Winter
- Year Long. May leave under severe conditions

# Bighorn Sheep Habitat

Greybull Watershed Study

*FIGURE 33*

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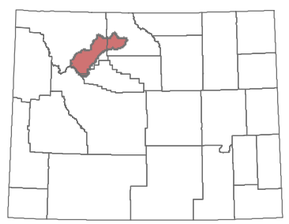
Cody
Greybull
Burlington
Basin
Manderson
Meeteetse
Worland
Kirby
PARK
BIG HORN
WASHAKIE
HOT SPRINGS
FREMONT
0 5 10 20 30 40 50 Miles
Service Layer Credits: USGS, NGA, NASA, CGIAR,N Robinson,NCEAS,NLS,OS,NMA,Geodatastyrelsen and the GIS User Community



## LEGEND

- Watershed Study Area
- Elk Migration Routes
- Elk Crucial Range
- Elk Parturition Area

**Elk Seasonal Range**

Range Description

- Winter/Year Long
- Winter
- Does not contain enough animals to be important habitat or habitat is of limited importance.
- Year Long. May leave under severe conditions

# Elk Habitat

Greybull Watershed Study

*FIGURE 34*

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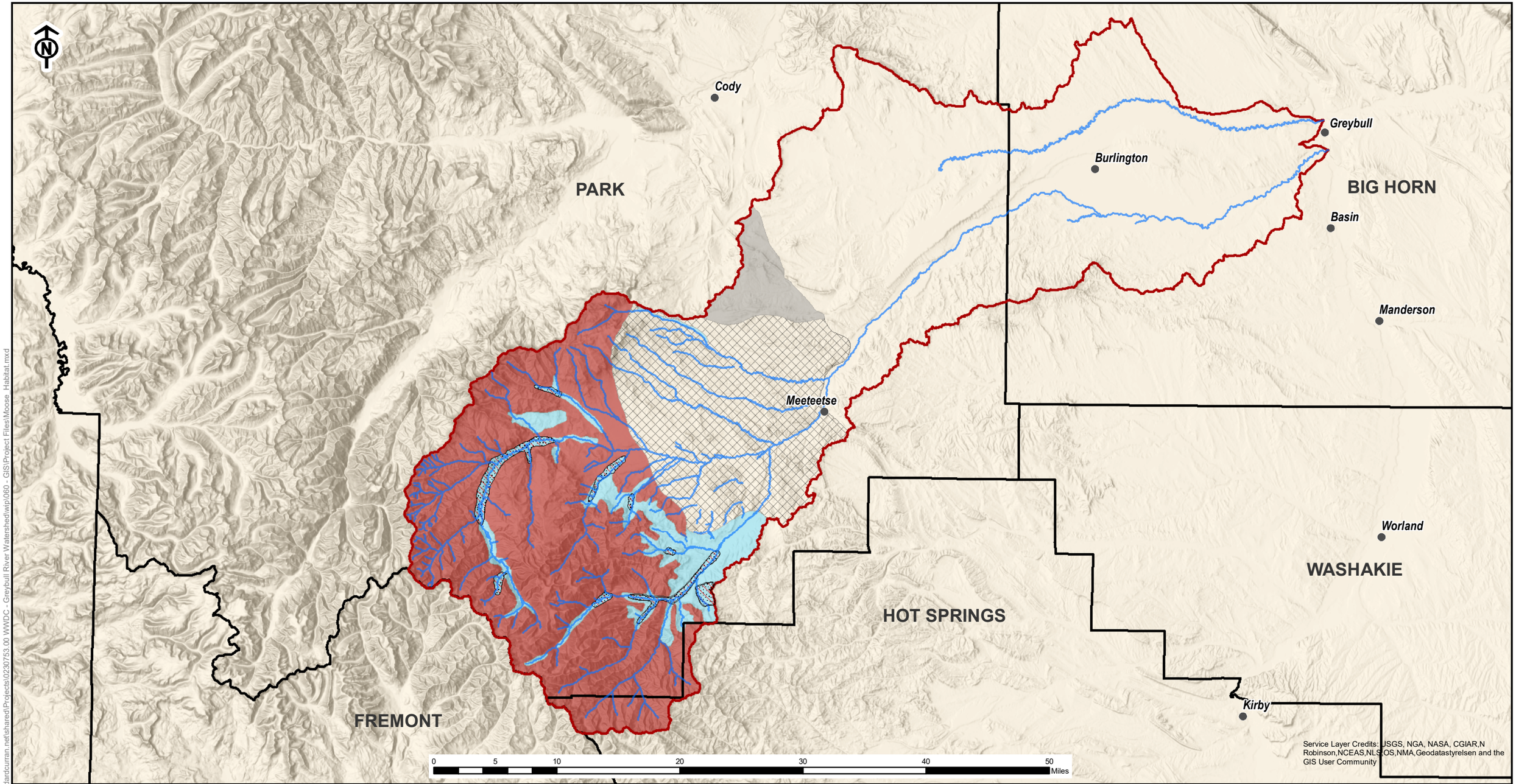


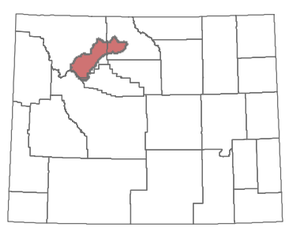

## LEGEND

- Watershed Study Area
- Moose Crucial Range
- Moose_ParturitionArea

**Moose Seasonal Range**

Range Description

- Winter
- Does not contain enough animals to be important habitat or habitat is of limited importance.
- Undetermined/Undocumented
- Year Long. May leave under severe conditions

# Moose Habitat

Greybull Watershed Study

*FIGURE 35*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

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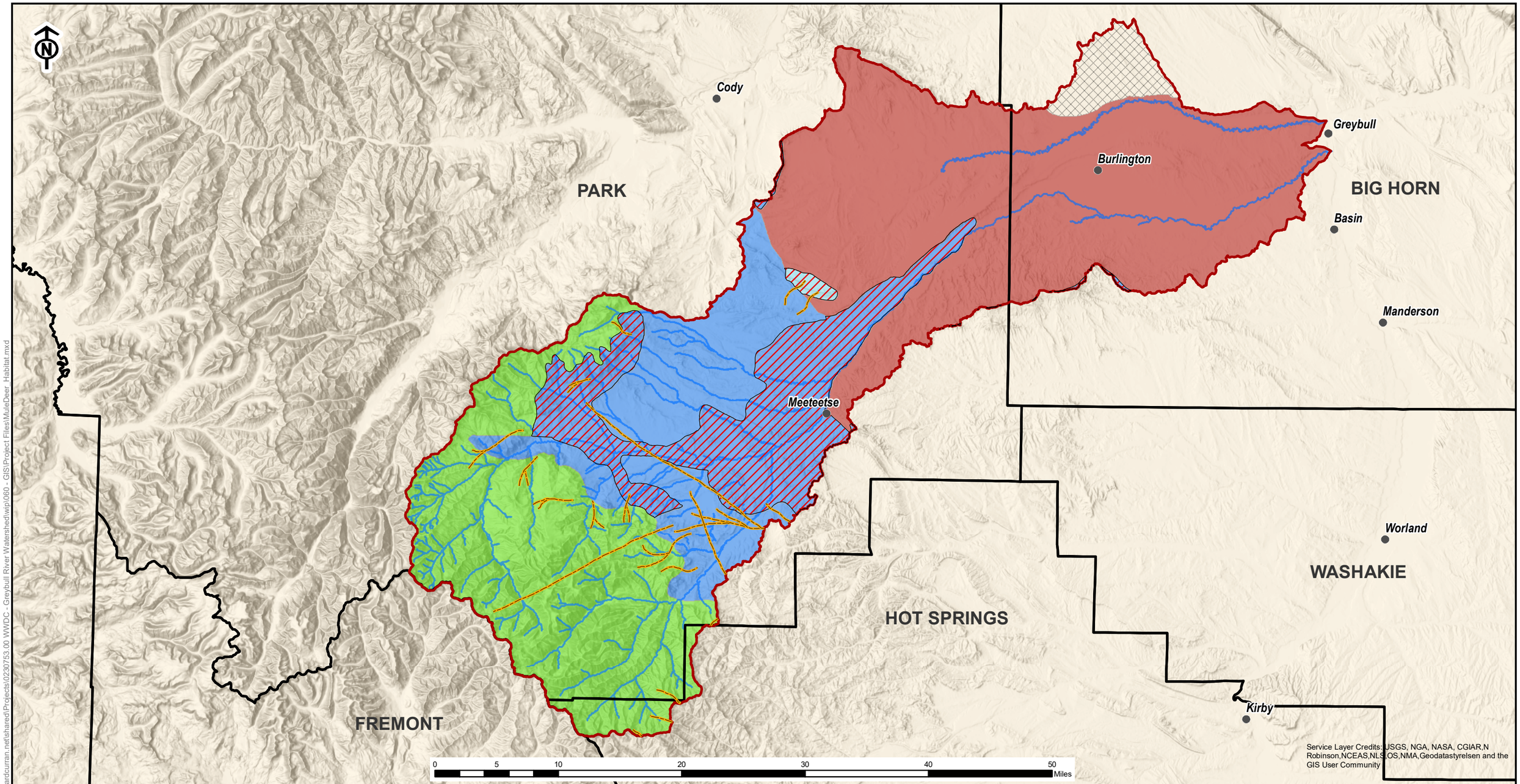


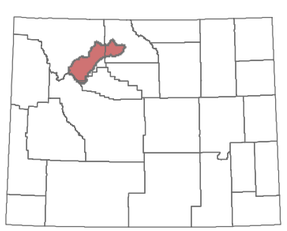

## LEGEND

- Watershed Study Area
- Mule Deer Migration Routes
- Mule Deer Crucial Range

**Mule Deer Seasonal Range**

Range Description

- Winter
- Winter/Year Long
- Does not contain enough animals to be important habitat or habitat is of limited importance.
- Spring/Summer/Fall
- Year Long

# Mule Deer Habitat

Greybull Watershed Study

*FIGURE 36*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

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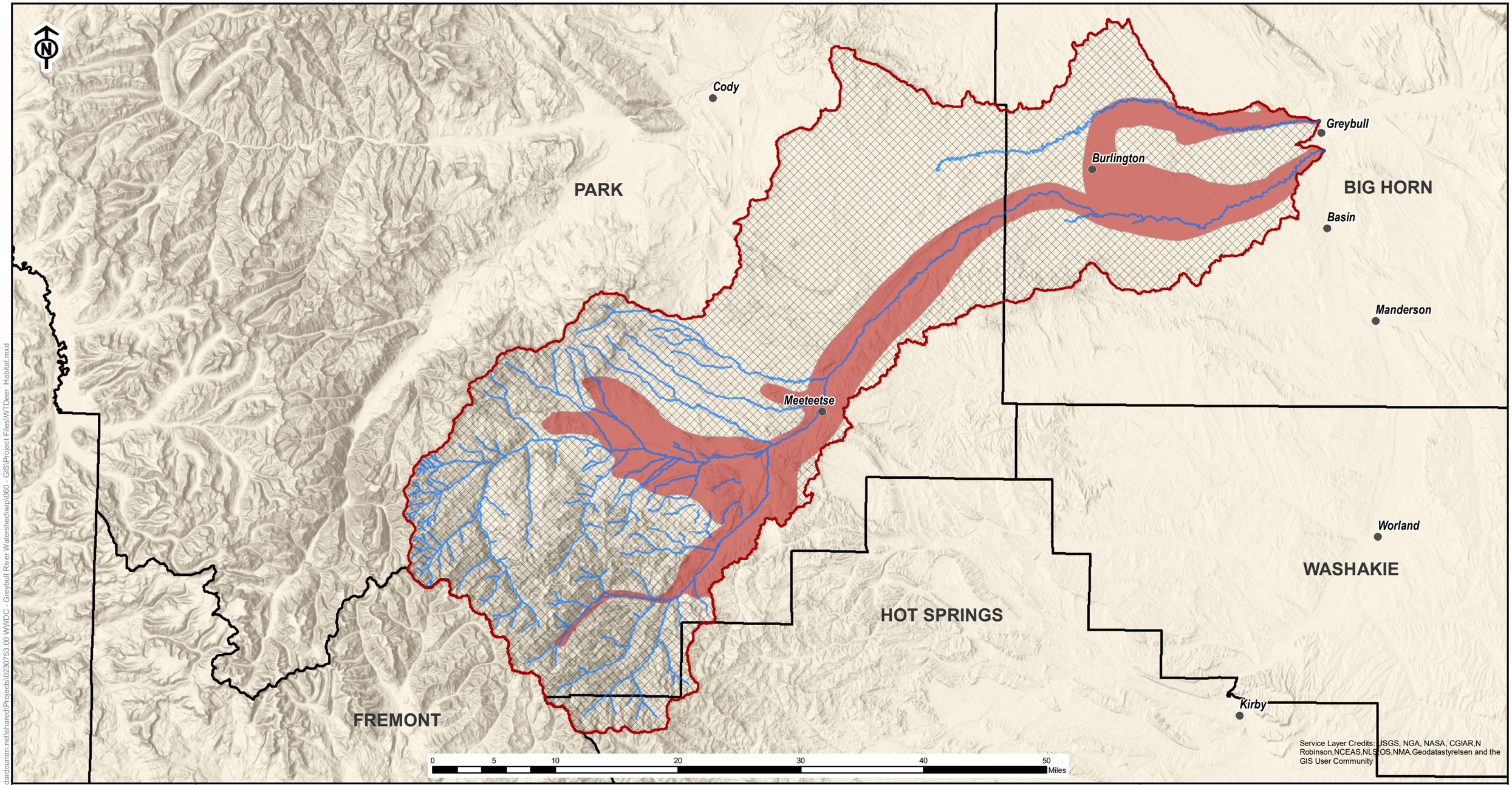


## LEGEND

Watershed Study Area

**White-tailed Deer Seasonal Range**

Range Description

Does not contain enough animals to be important habitat or habitat is of limited importance.

Year Long. May leave under severe conditions

# White-tailed Deer Habitat

Greybull Watershed Study

*FIGURE 37*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

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PARK

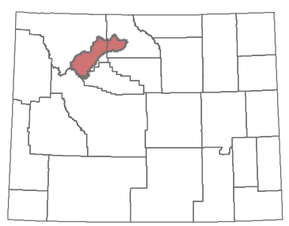
BIG HORN

HOT SPRINGS

WASHAKIE

FREMONT

Service Layer Credits: USGS, NGA, NASA, CGIAR,N Robinson,NCEAS,NLS,OS,NMA,Geodatastyrelsen and the GIS User Community



## LEGEND

- Sage Grouse Lek (2016) (within Watershed Study Area)
- Sage Grouse Core Area (within Watershed Study Area) - 316,525 acres
- Watershed Study Area

**Surface Ownership**

- Federal
- State
- Private

0 5 10 20 30 40 50 Miles

# Sage Grouse Core Areas and Lek Locations

Greybull Watershed Study

*FIGURE 38*

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Bureau of Reclamation (Surface Owner)

PARK

FREMONT

HOT SPRINGS

WASHAKIE

BIG HORN

Greybull

Burlington

Otto

Bench Canal Reservoir

Greybull River Rd

Wiley Lake

Roach Gulch Reservoir

Harrington Reservoir

Fairview Reservoir

Thomas Reservoir

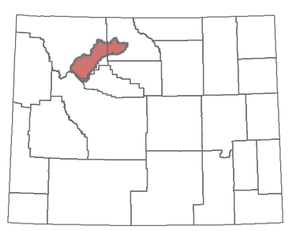
Corral Reservoir

Meeteetse

Lower Sunshine Reservoir

Sunshine Reservoir

0 5 10 20 30 40 50 Miles



## LEGEND

- Watershed Study Area
- Storage Reservoirs
- Transmission Line

Surface Ownership

- Bureau of Land Management
- Bureau of Reclamation
- Forest Service
- Private
- State

# Land Ownership

Greybull Watershed Study

*FIGURE 39*

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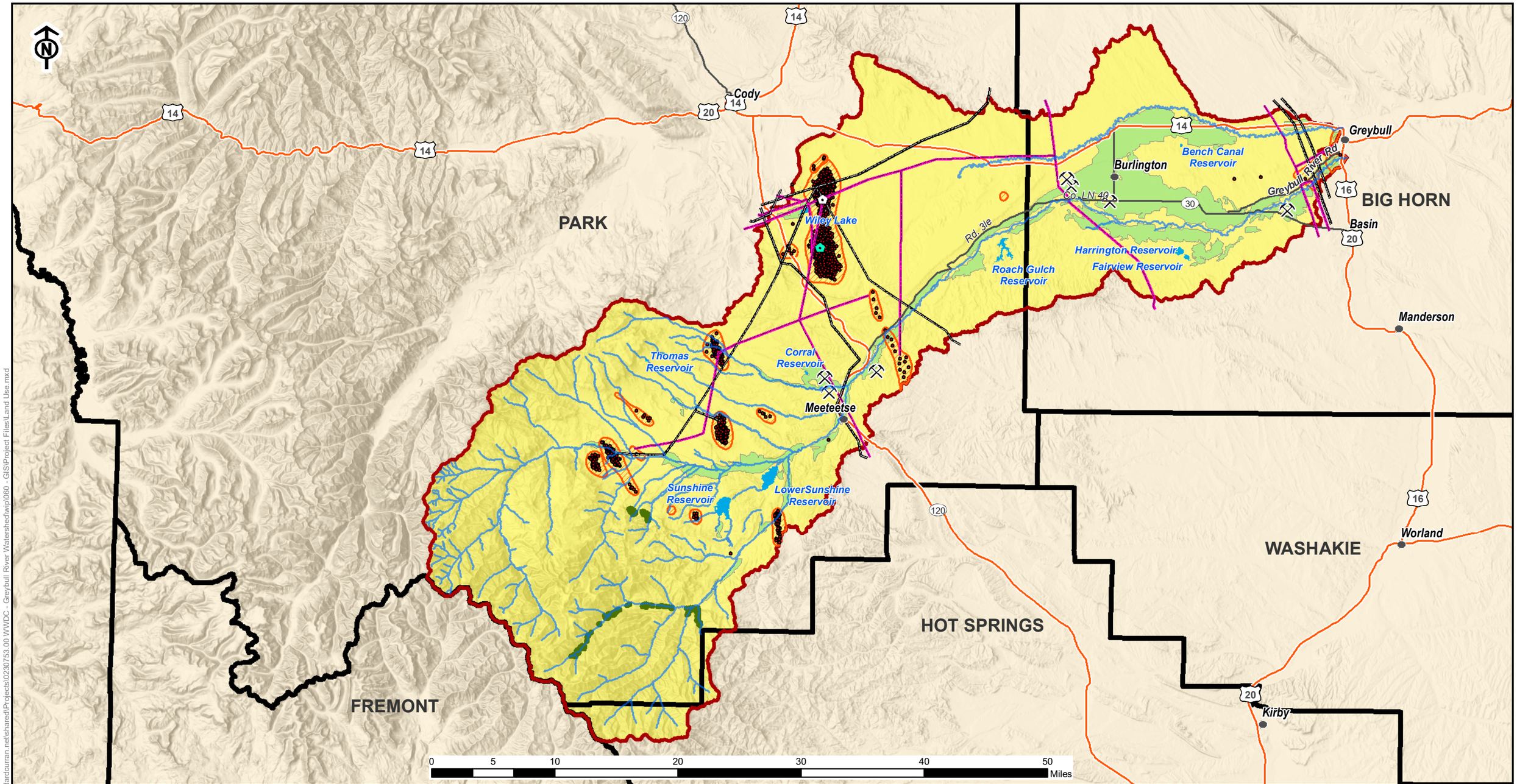


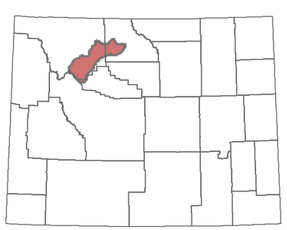

## LEGEND

- Watershed Study Area
- Storage Reservoir
- Irrigated Cropland
- Non-Agricultural/Grazing
- Active Mine Permit
- Timber Harvesting
- Active Oil and Gas Well
- Oil and Gas Field
- Oil Pipeline
- Gas Pipeline
- Active Gas Processing Plant
- Abandoned Gas Processing Plant

# Land Use

Greybull Watershed Study

*FIGURE 40*

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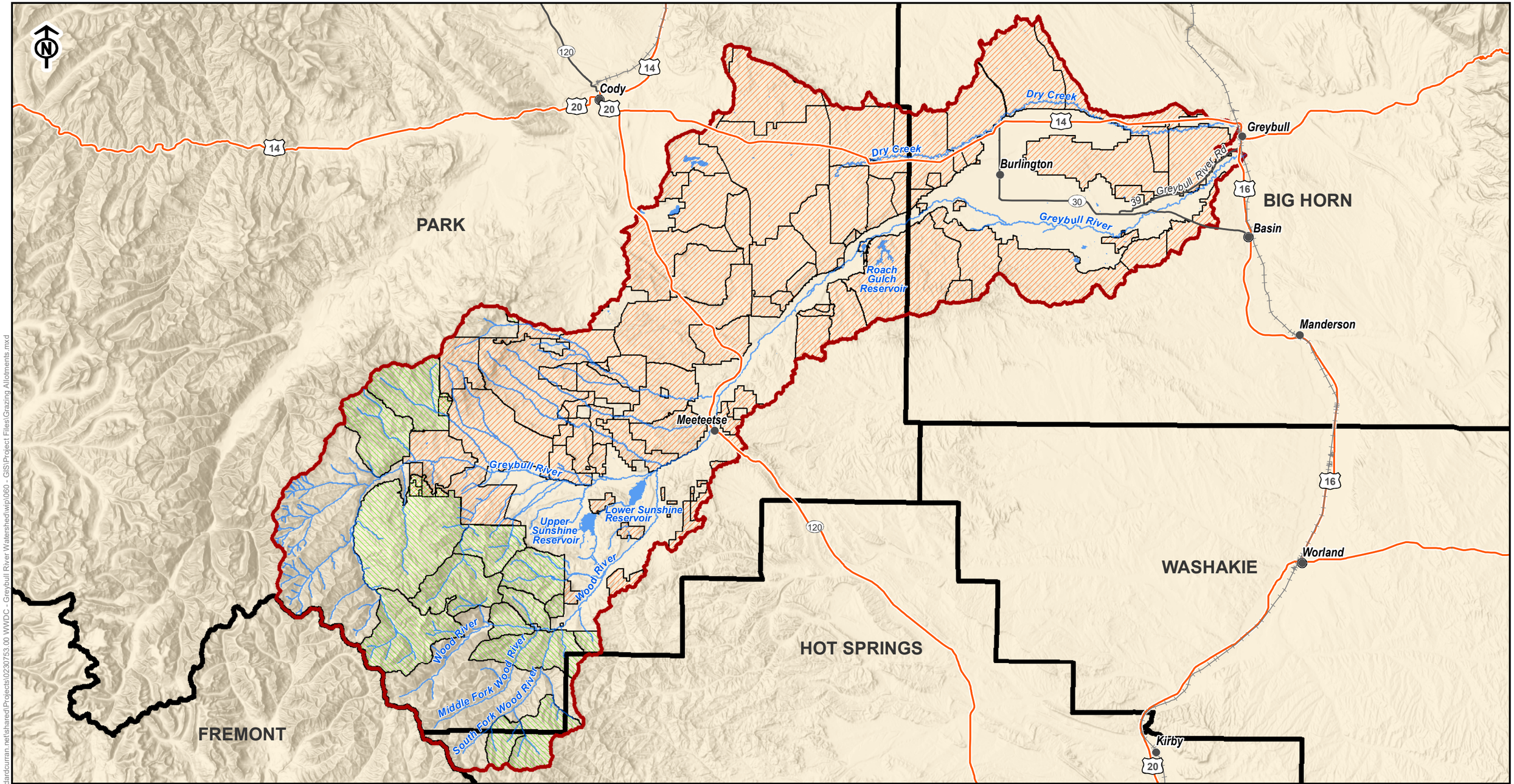


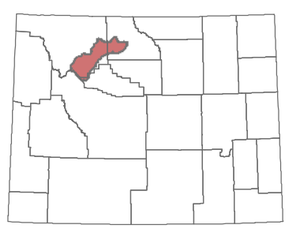

**LEGEND**

- Watershed Study Area
- City/Town
- Reservoir/Lake
- River/Stream
- Railroad
- Highway
- Major Road
- U.S. Forest Service Grazing Allotment
- Bureau of Land Management Grazing Allotment

0 5 10 20 30 40 50 Miles

# Grazing Allotments

Greybull Watershed Study

*FIGURE 41*

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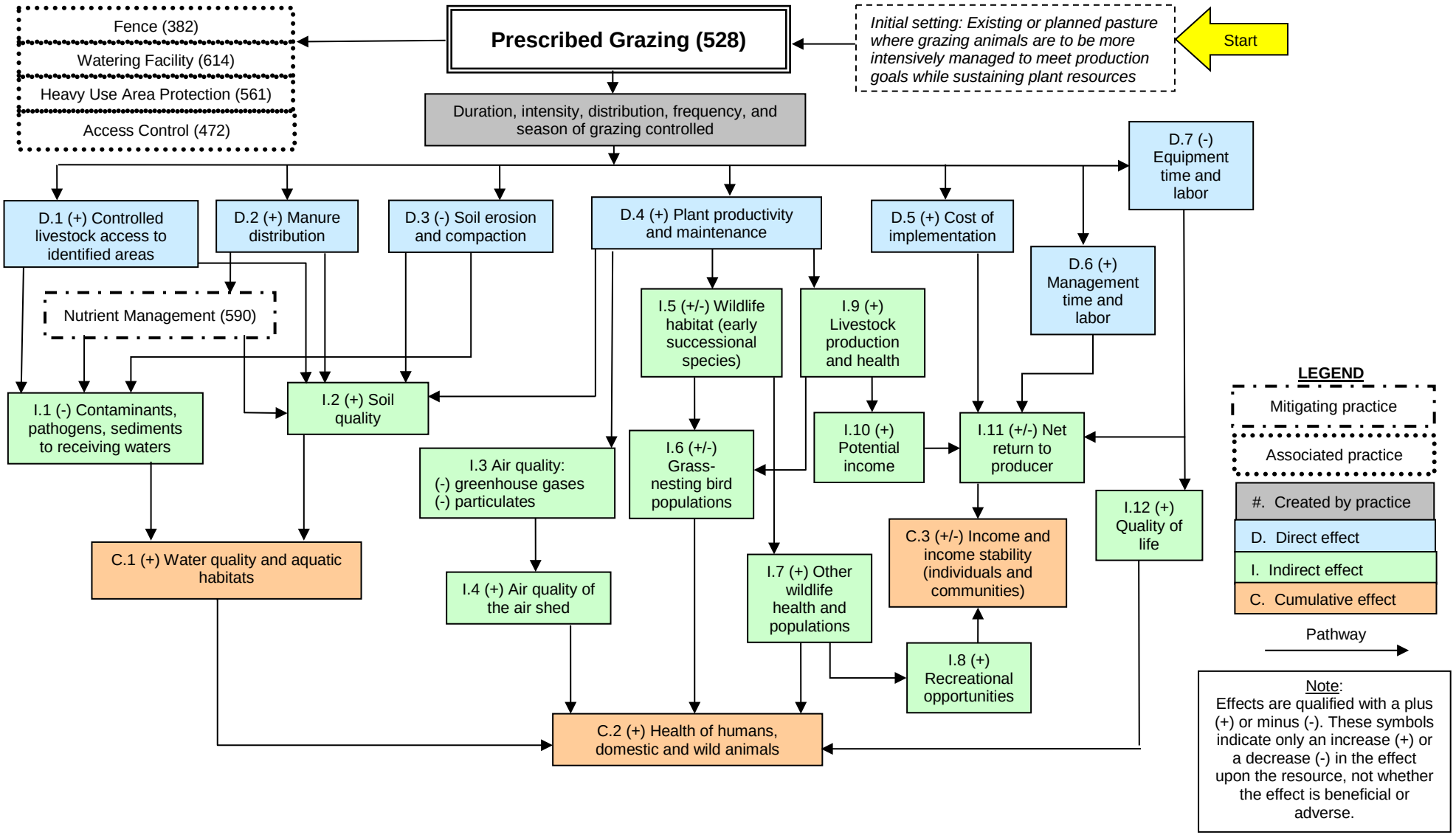
**Figure 42:**

# NRCS CONSERVATION PRACTICE EFFECTS - NETWORK DIAGRAM

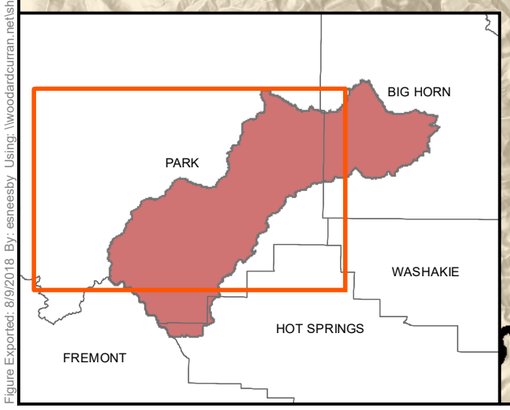
August 2017



## LEGEND

- Clayey (Cy) 10-14 East Precipitation Zone
- Clayey (Cy) 5-9 Big Horn Basin Precipitat
- Droughty (Dr) LRU 43B-A
- Droughty (Dr) LRU 43B-D
- Droughty Steep (DrStp) LRU 43B-A
- Droughty Steep (DrStp) LRU 43B-D
- Gravelly (Gr) 10-14 East Precipitation Zone
- Gravelly (Gr) 5-9 Big Horn Basin Precipitat
- Limy (Ly) LRU 43B-A
- Loamy (Lo) LRU 43B-A
- Loamy (Lo) LRU 43B-D
- Loamy (Ly) 10-14 East Precipitation Zone
- Loamy (Ly) 5-9 Big Horn Basin Precipitat
- Loamy (Ly) LRU D: 10-14 Mesic Big Horn
- Loamy Calcareous Big Horn Basin Mesic, 7-12 (1
- Loamy Steep (LoStp) LRU 43B-A
- Loamy Steep (LoStp) LRU 43B-D
- Lowland (LL) 10-14 East Precipitation Zone
- Lowland (LL) 5-9 Big Horn Basin Precipitat
- Overflow (Ov) LRU 43B-A
- Overflow (Ov) LRU 43B-D
- Overflow (Ov) 10-14 East Precipitation Zone
- Overflow 10-14 Mesic Big Horn Basin
- Riparian Meadow (RM) LRU 43B-Y
- Saline Lowland (SL) 5-9 Big Horn Basin Precipitat
- Saline Lowland (SL) 10-14 East Precipitation Zone
- Saline Lowland, drained (SLdr) 10-14 East Precipitation Zone
- Saline Subirrigated (Sb) LRU 43B-Y
- Saline Subirrigated (SS) 5-9 Big Horn Basin Precipitat
- Saline Upland (SU) 10-14 East Precipitation Zone
- Saline Upland (SU) 5-9 Big Horn Basin Precipitat
- Sandy (Sy) LRU 43B-A
- Sandy (Sy) 10-14 East Precipitation Zone
- Sandy (Sy) 5-9 Big Horn Basin Precipitat
- Sandy (Sy) 5-9 Mesic Big Horn Basin
- Shallow Clayey (SwCy) 10-14 East Precipitation Zone
- Shallow Droughty (SwDr) LRU 43B-A
- Shallow Droughty (SwDr) LRU 43B-D
- Shallow Limy (SwLy) 15-19 p.z.
- Shallow Limy Droughty (SwLyDr) LRU 43B-A
- Shallow Loamy (SwLy) 10-14 East Precipitation Zone
- Shallow Loamy (SwLy) 5-9 Big Horn Basin Precipitat
- Shallow Sandy (SwSy) 10-14 East Precipitation Zone
- Shallow To Gravel 5-9 Mesic Big Horn Basin
- Subirrigated (Sb) LRU 43B-Y
- Thin Loamy (TLo) LRU 43B-A
- Thin Loamy (TLo) LRU 43B-C
- Very Shallow (VSw) LRU 43B-A
- Wet Meadow (WM) LRU 43B-Y
- Not rated or not available

PARK
BIG HORN
HOT SPRINGS
Cody
Meeteetse
Dry Creek
Roach Gulch Reservoir
Lower Sunshine Reservoir
Upper Sunshine Reservoir
Greybull River
Wood River
120
14
20




# Ecological Site Descriptions - Park County

Greybull Watershed Study

*FIGURE 43*

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SCALE: 1:275,000

DATE: AUGUST 2018

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## LEGEND

- <all other values>
- Coarse Upland (CU) 5-9 Big Horn Basin Precipitat
- Loamy (Ly) 10-14 East Precipitation Zone
- Loamy (Ly) 5-9 Big Horn Basin Precipitat
- Lowland (LL) 5-9 Big Horn Basin Precipitat
- Saline Lowland (SL) 5-9 Big Horn Basin Precipitat
- Saline Lowland (SL) 10-14 East Precipitation Zone
- Saline Subirrigated (SS) 5-9 Big Horn Basin Precipitat
- Saline Upland (SU) 5-9 Big Horn Basin Precipitat
- Sandy (Sy) 5-9 Big Horn Basin Precipitat
- Shale (Sh) 5-9 Big Horn Basin Precipitat
- Shallow Sandy (SwSy) 5-9 Big Horn Basin Precipitat
- Very Shallow (VS) 10-14 East Precipitation Zone
- Wetland (WL) 5-9 Big Horn Basin Precipitat
- Not rated or not available

BIG HORN

PARK

Dry Creek

Dry Creek

Greybull River

Greybull River Rd

Burlington

Greybull

Basin

Roach Gulch Reservoir

14

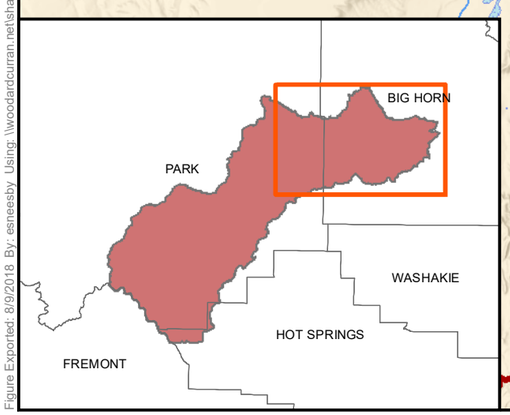
16

30

39

30

20




# Ecological Site Descriptions - Big Horn County

Greybull Watershed Study

*FIGURE 44*

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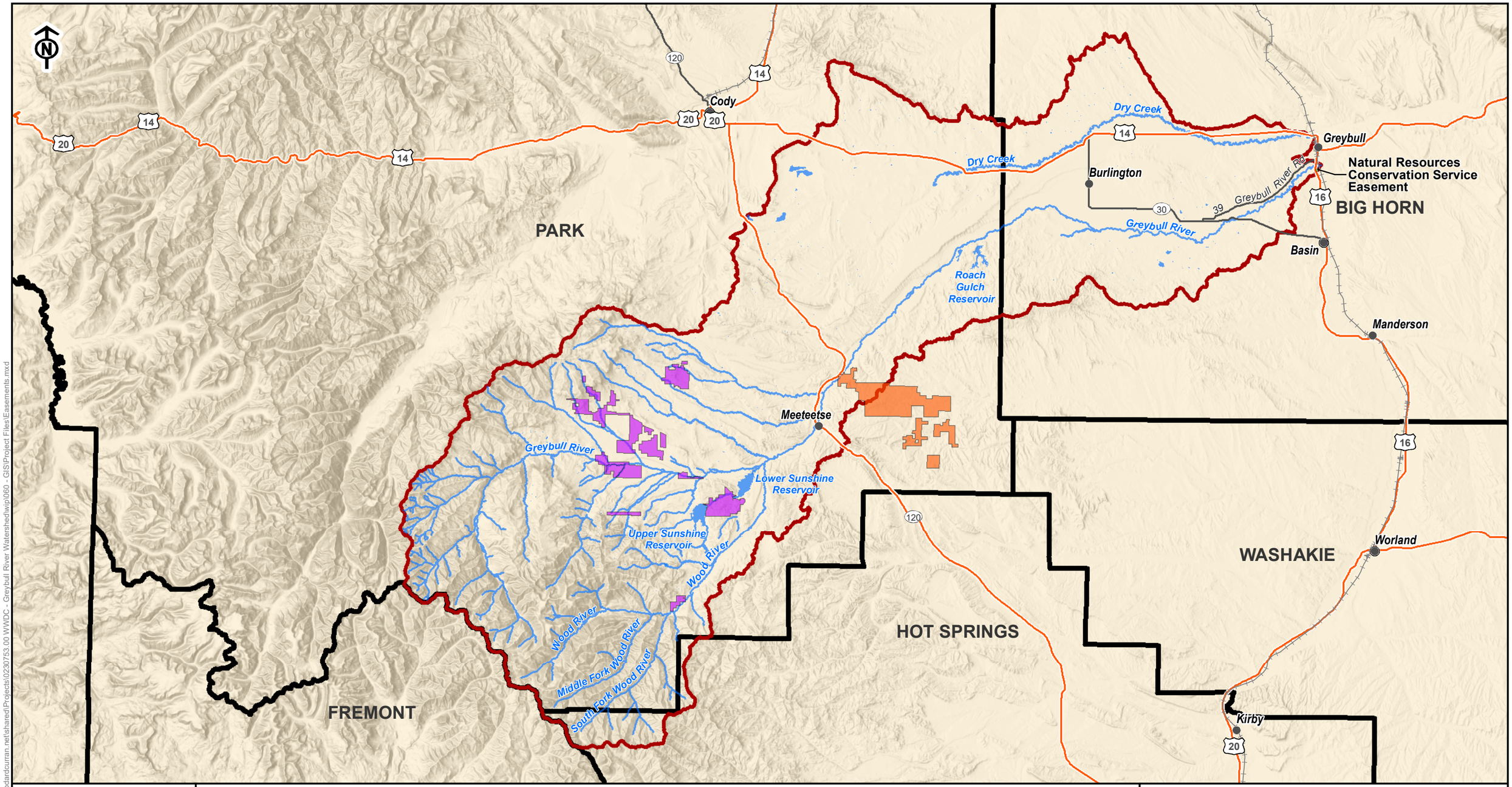


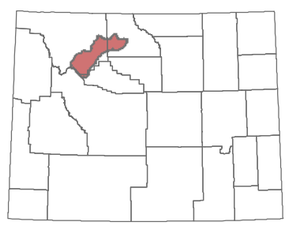

**LEGEND**

- Watershed Study Area
- City/Town

Conservation Easement Holder

- The Nature Conservancy
- Natural Resources Conservation Service
- Wyoming Stockgrowers Agricultural Land Trust

- Reservoir/Lake
- River/Stream
- Railroad
- Highway
- Major Road

# Conservation Easements

Greybull Watershed Study

*FIGURE 45*

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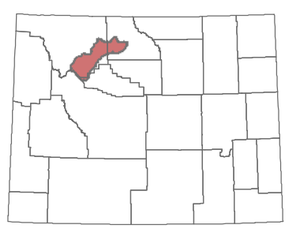
Cody
PARK
Bridger Immigrant
Road-Dry Creek
Crossing
Burlington
Greybull
Carey Block
US Post Office
Greybull Main
BIG HORN
Basin
BRIDGER TRAIL
Manderson
Meeteetse
First National Bank
of Meeteetse
Anderson Lodge
WASHAKIE
Worland
HOT SPRINGS
FREMONT
Kirby
0 5 10 20 30 40 50 Miles



**LEGEND**

- Watershed Study Area
- National Register Historic Places
- Bridger Trail

Number of Cultural Sites
Eligible for Inclusion on the
National Register of Historic Places

- 1-5
- 5-10
- 10-15
- >15

# Cultural Resources

Greybull Watershed Study
*FIGURE 46*

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MONTANA

SOUTH DAKOTA

IDAHO

NEBRASKA

UTAH

COLORADO

PARK

BIG HORN

SHERIDAN

CROOK

TETON

JOHNSON

CAMPBELL

WESTON

WASHAKIE

HOT SPRINGS

DIVISION 2

DIVISION 3

WYOMING

FREMONT

NATRONA

CONVERSE

NIOBRARA

SUBLETTE

LINCOLN

DIVISION 4

DIVISION 1

PLATTE

GOSHEN

SWEETWATER

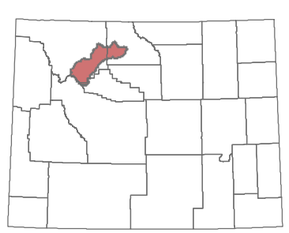
CARBON

ALBANY

UINTA

LARAMIE

Service Layer Credits: USGS, NGA, NASA, CGIAR,N Robinson,NCEAS,NLS,OS,NMA,Geodatastyrelsen and the GIS User Community



## LEGEND

Watershed Study Area

SEO DIVISION

- Division 1
- Division 2
- Division 3
- Division 4

0 5 10 20 30 40 50 Miles

# State Engineer's Office (SEO) Divisions

Greybull Watershed Study

*FIGURE 47*

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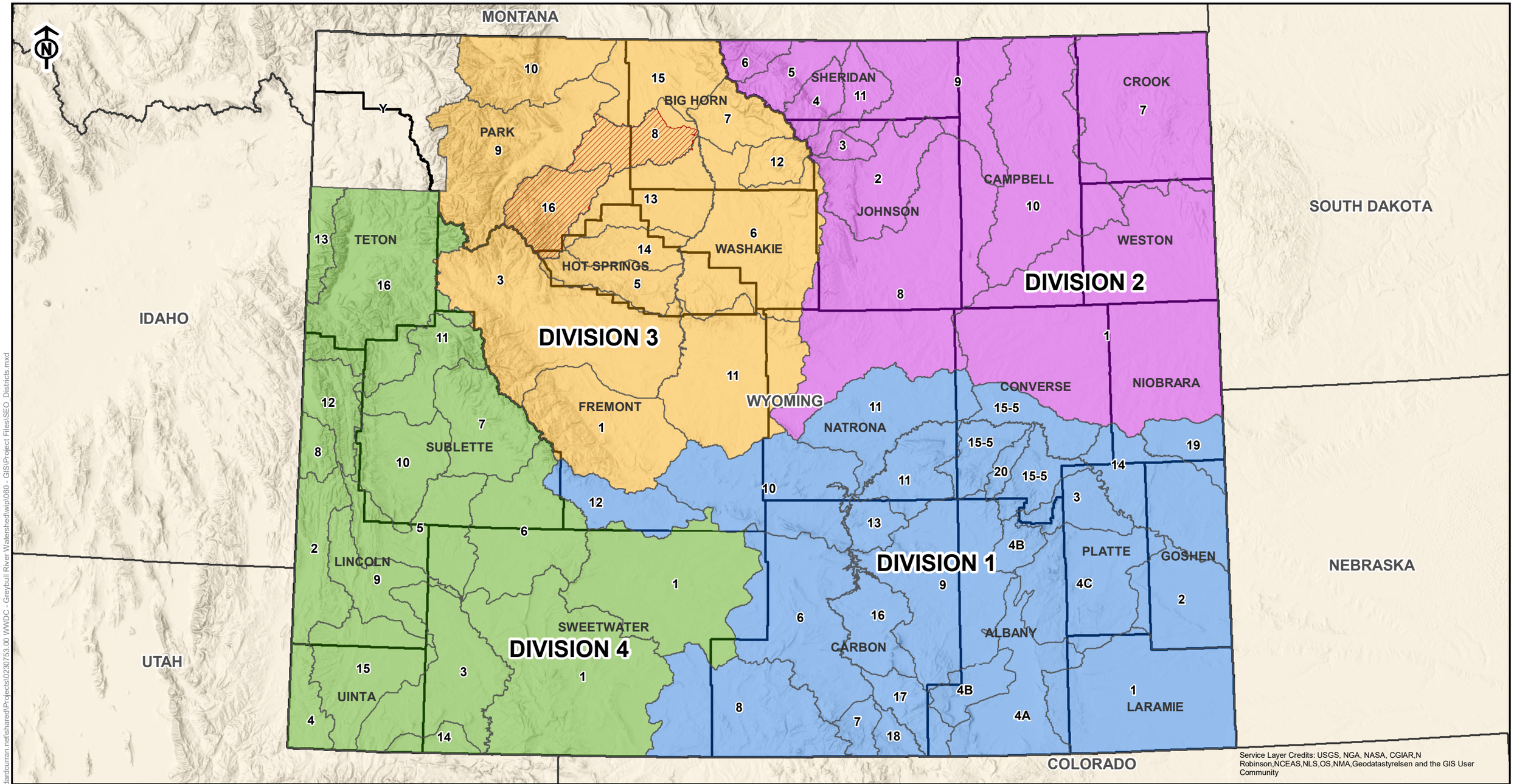


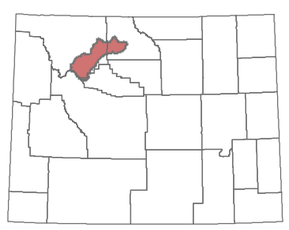

## LEGEND

- Watershed Study Area
- SEO Divisions
  - Division 1
  - Division 2
  - Division 3
  - Division 4
- SEO Districts

0 5 10 20 30 40 50 Miles

# State Engineer's Office (SEO) Districts

Greybull Watershed Study

*FIGURE 48*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

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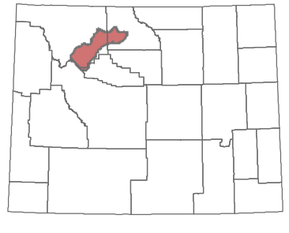
Cody
PARK
Wiley Lake
Thomas Reservoir
Corral Reservoir
Greybull River
Sheets Flat Diversion
Lead Canal
Roach Gulch Reservoir
Burlington
Dry Creek
Bench Canal Reservoir
Greybull
Dry Creek
Greybull River
BIG HORN
Basin
Harrington Reservoir
Fairview Reservoir
Manderson
Meeteetse
Upper Sunshine Diversion
Greybull River
Sunshine Supply Ditch
Upper Sunshine Reservoir
Lower Sunshine Reservoir
Sunshine Basin Ditch
Stonewall Crk
Wood River
Wood River Diversion
Wood River
WASHAKIE
Worland
HOT SPRINGS
FREMONT
Kirby



## LEGEND

- Watershed Study Area
- Storage Reservoir
- Farmers Irrigation System
- Keystone Irrigation System
- Bench Canal Irrigation System
- Diversion Point
- Primary Diversion Point
- Primary Diversion Canal/Ditch

# Irrigation Infrastructure

Greybull Watershed Study

*FIGURE 49*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

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**LEGEND**

- City/Town
- Storage Tank
- Well
- Major Road

0 1,000 2,000 4,000 Feet

# Municipal Water System Key Infrastructure
# Burlington, WY

## Greybull Watershed Study

*FIGURE 50*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

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**LEGEND**

- City/Town
- Storage Tank
- Lower Sunshine Reservoir Dam Toe
- Meeteetse Water Treatment Plant
- Highway
- River/Stream
- Reservoir/Lake

0 0.5 1 2 Miles

# Municipal Water System Key Infrastructure
# Meeteetse, WY

## Greybull Watershed Study

*FIGURE 51*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

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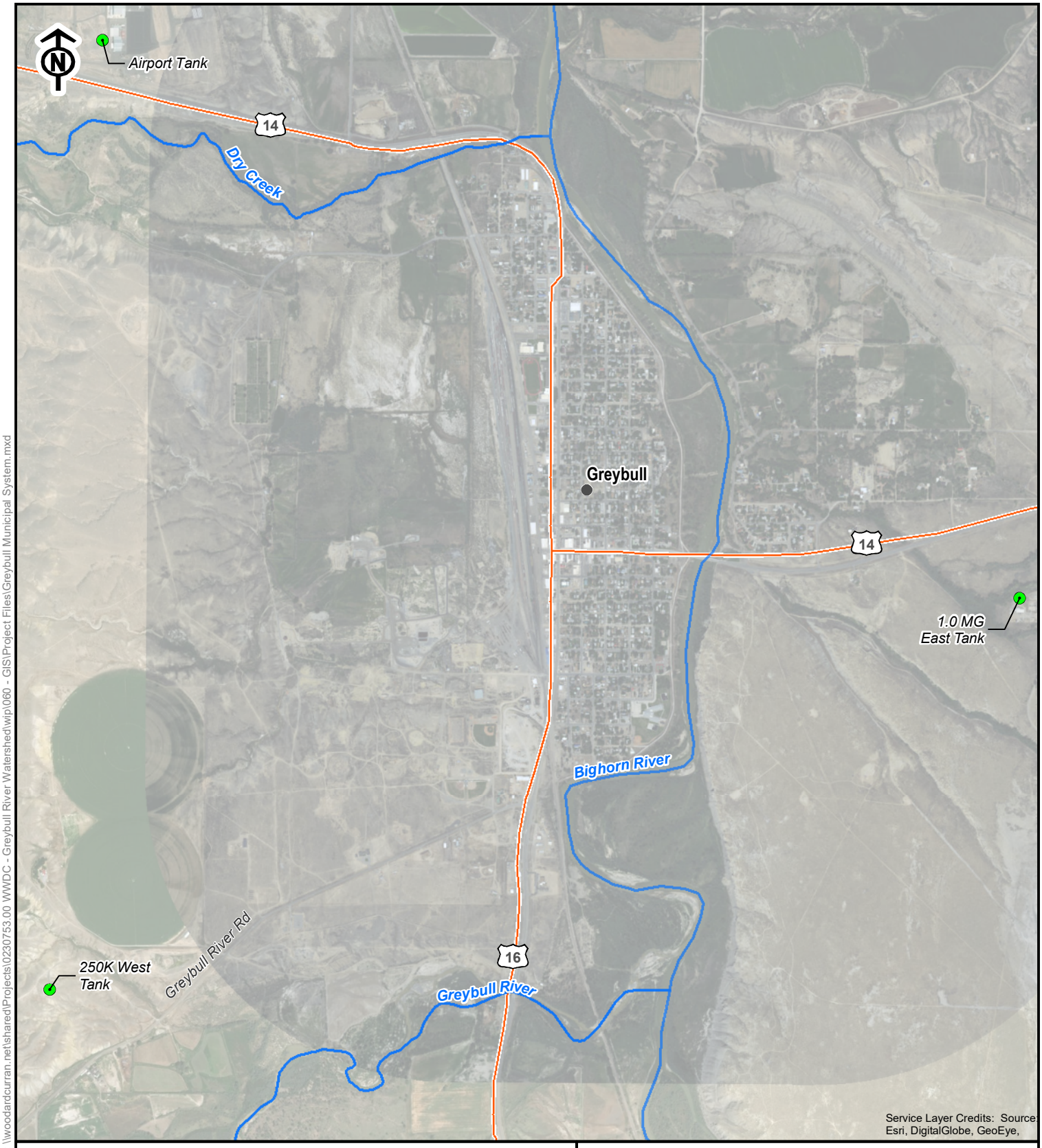


**LEGEND**

- City/Town
- Storage Tank
- River/Stream
- Highway

0 0.25 0.5 0.75 1 Miles

# Municipal Water System Key Infrastructure
# Greybull, WY

## Greybull Watershed Study

*FIGURE 52*

Woodard & Curran shall assume no liability for any of the following; 1. Any errors, omissions, or inaccuracies in the information provided regardless of how caused or; 2.Any decision or action taken or not taken by the reader in reliance upon any information or data furnished hereunder. Data Sources:

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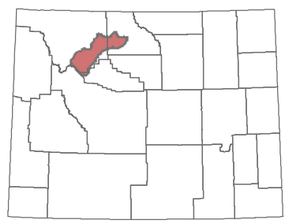
Cody
Greybull
Burlington
PARK
BIG HORN
Basin
Manderson
Meeteetse
WASHAKIE
Worland
HOT SPRINGS
FREMONT
Kirby
0 5 10 20 30 40 50
Miles



## LEGEND

- Watershed Study Area
- Permitted Well (varying uses)

# Permitted Wells

Greybull Watershed Study

*FIGURE 53*

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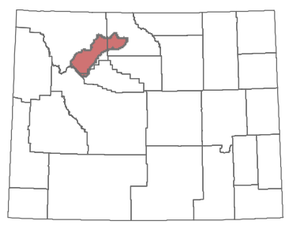
Cody
Greybull
Burlington
Basin
Manderson
Meeteetse
Worland
Kirby
PARK
BIG HORN
WASHAKIE
HOT SPRINGS
FREMONT
0 5 10 20 30 40 50
Miles



**LEGEND**

Watershed Study Area

SEO Permitted Well
Permitted Use:
- Domestic Use

# Potable Water Supplies

Greybull Watershed Study
*FIGURE 54*

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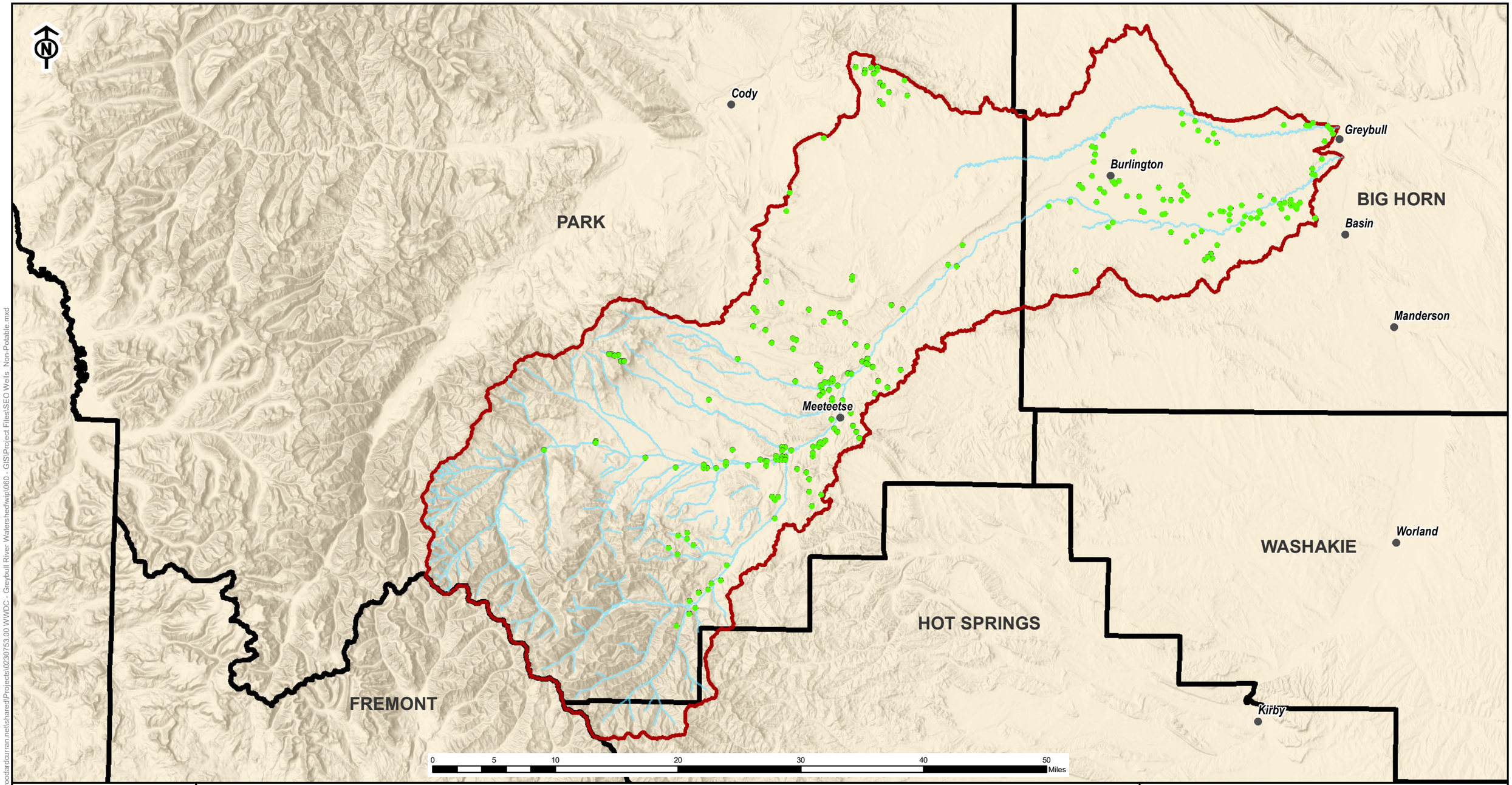


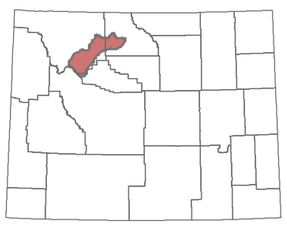

**LEGEND**

Watershed Study Area

SEO Permitted Well

Permitted Use:

- Irrigation or Stock

# Non-Potable Water Supplies

Greybull Watershed Study

*FIGURE 55*

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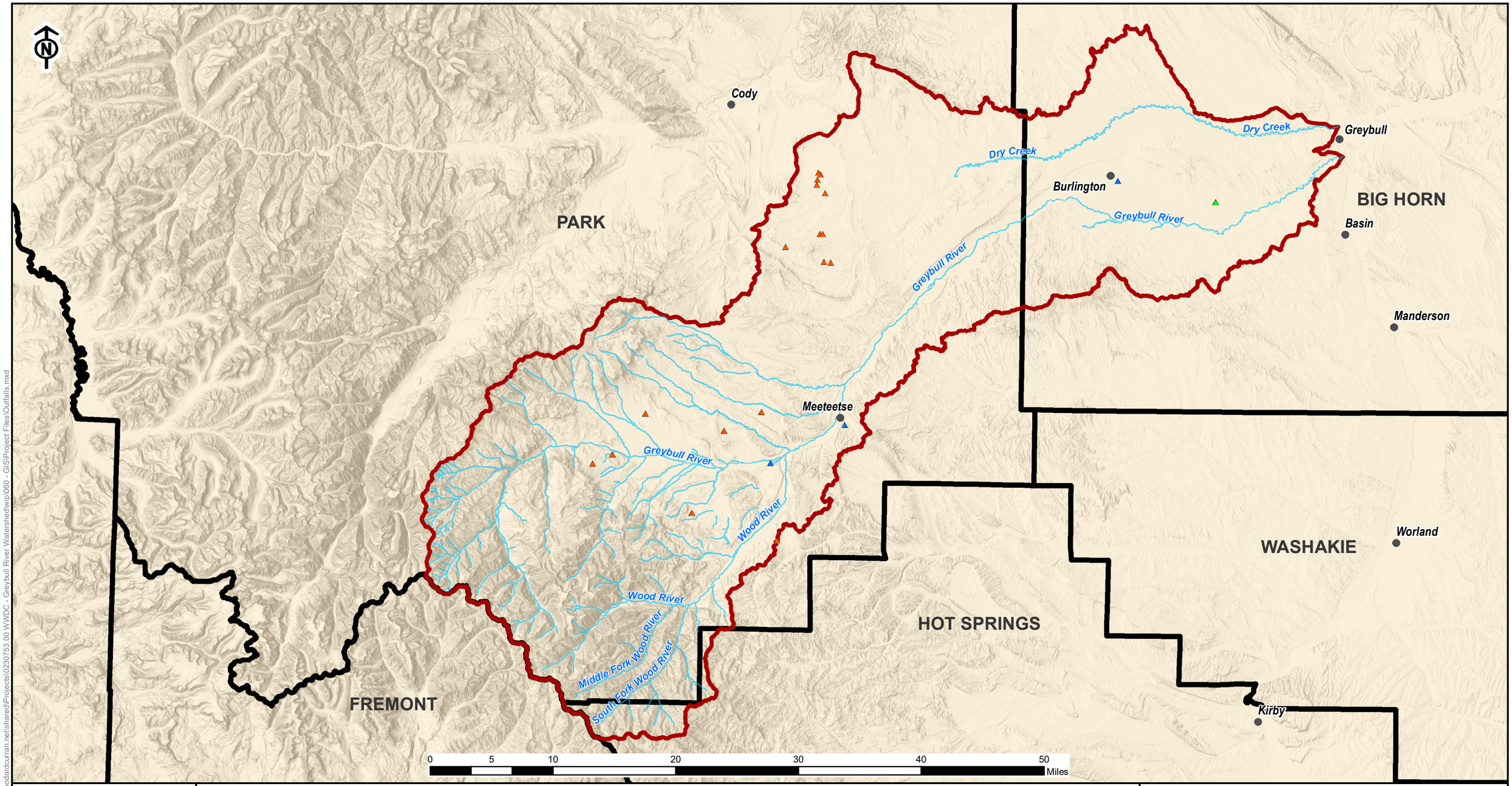


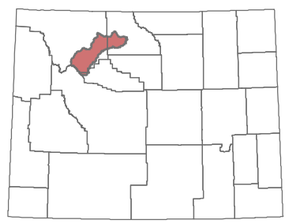

## LEGEND

Watershed Study Area

**WYPDES Effluent Outfalls**

- Sanitary Wastewater or Water Treatment Plant
- CAFO
- Oil Treaters

# WYPDES Effluent Outfalls

Greybull Watershed Study

*FIGURE 56*

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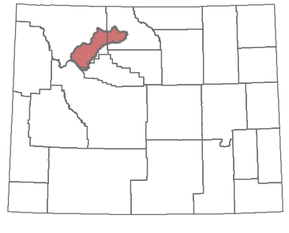
Cody
Greybull
Burlington
Basin
Manderson
Meeteetse
Worland
Kirby
PARK
BIG HORN
WASHAKIE
HOT SPRINGS
FREMONT
WILEY
SAGE CREEK
Wiley Lake
PHIPPS NO.1
BENCH CANAL
Bench Canal Reservoir
SNYDER NO. 1
BOULDER LANE
SNYDER NO. 2
LAKE MCKINNEY
DELBERT JONES
WHITE
GREYBULL VALLEY
RENNER DETENTION DAM NO. 2
Harrington Reservoir
Fairview Reservoir
HARRINGTON
FAIRVIEW EXTENSION
ALBERT WARDELL NO. 1
MACKEY
SNYDER
Roach Gulch Reservoir
FOSTER NO.1 DAM 1A
FOSTER NO. 3
Thomas Reservoir
THOMAS
RUSH CREEK
Corral Reservoir
CORRAL
HORSE CREEK
THAYER NO. 1
LOWER SUNSHINE
Upper Sunshine Reservoir
UPPER SUNSHINE
LowerSunshine Reservoir
0 5 10 20 30 40 50 Miles



## LEGEND

- Watershed Study Area
- Storage Reservoir
- ▲ Dam (National Inventory of Dams)

# Dams and Storage Reservoirs

Greybull Watershed Study

*FIGURE 57*

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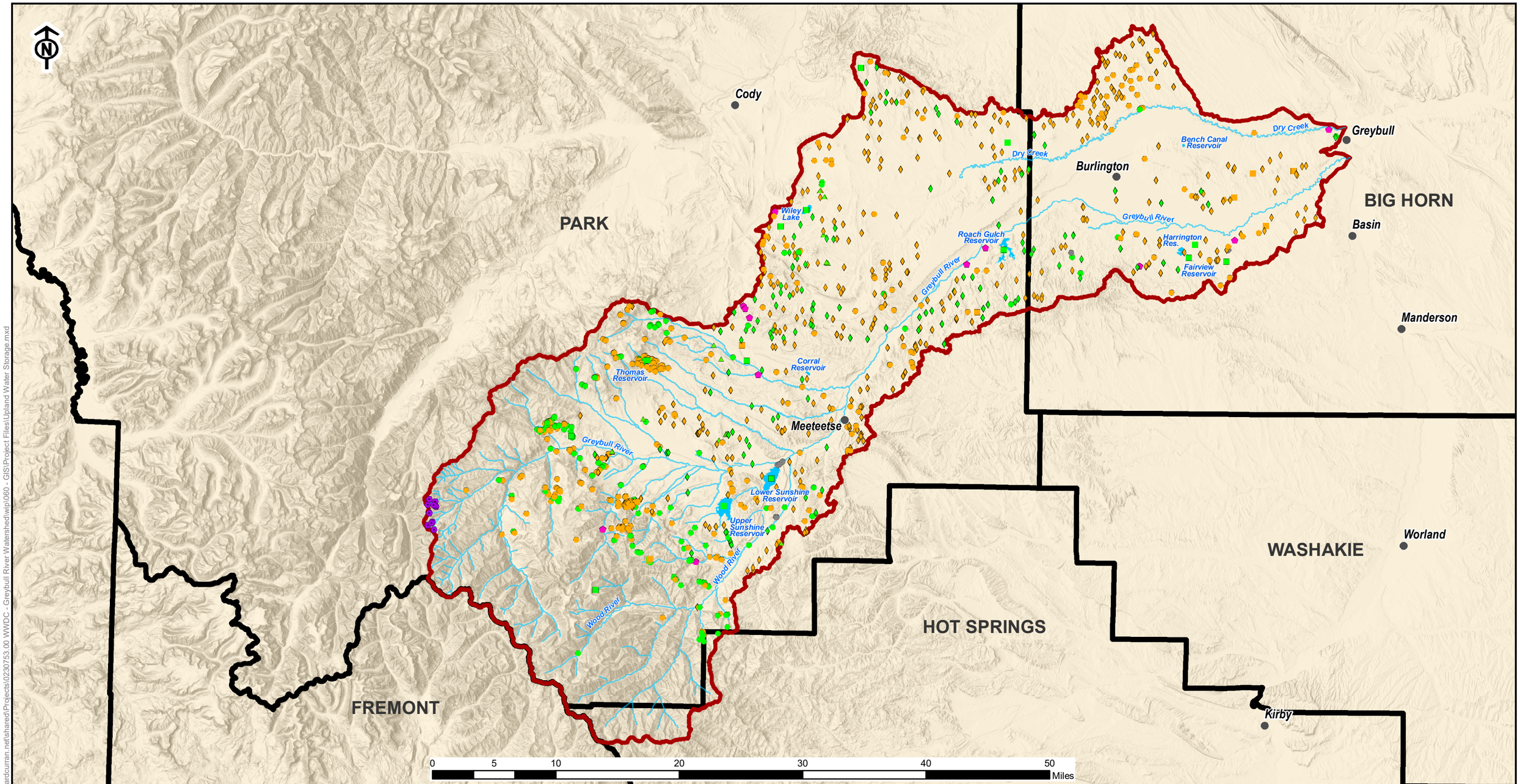
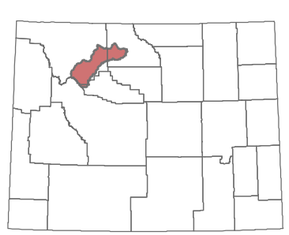
Figure Exported: 7/23/2018 By: esneesby Using: \\woodardcurran.net\shared\Projects\0230753.00 WWDC - Greybull River Watershed\wip\060 - GIS\Project Files\Dams and Storage Reservoirs.mxd



## LEGEND

- Watershed Study Area
- Intermittent Industrial Pond
- Intermittent Pond
- Intermittent Reservoir
- Intermittent Stock Pond
- Perennial Industrial Pond
- Perennial Pond
- Perennial Reservoir
- Perennial Stock Pond
- Ice Mass
- Swamp/Marsh
- Unknown

# Upland Water Storage

## Greybull Watershed Study

*FIGURE 58*

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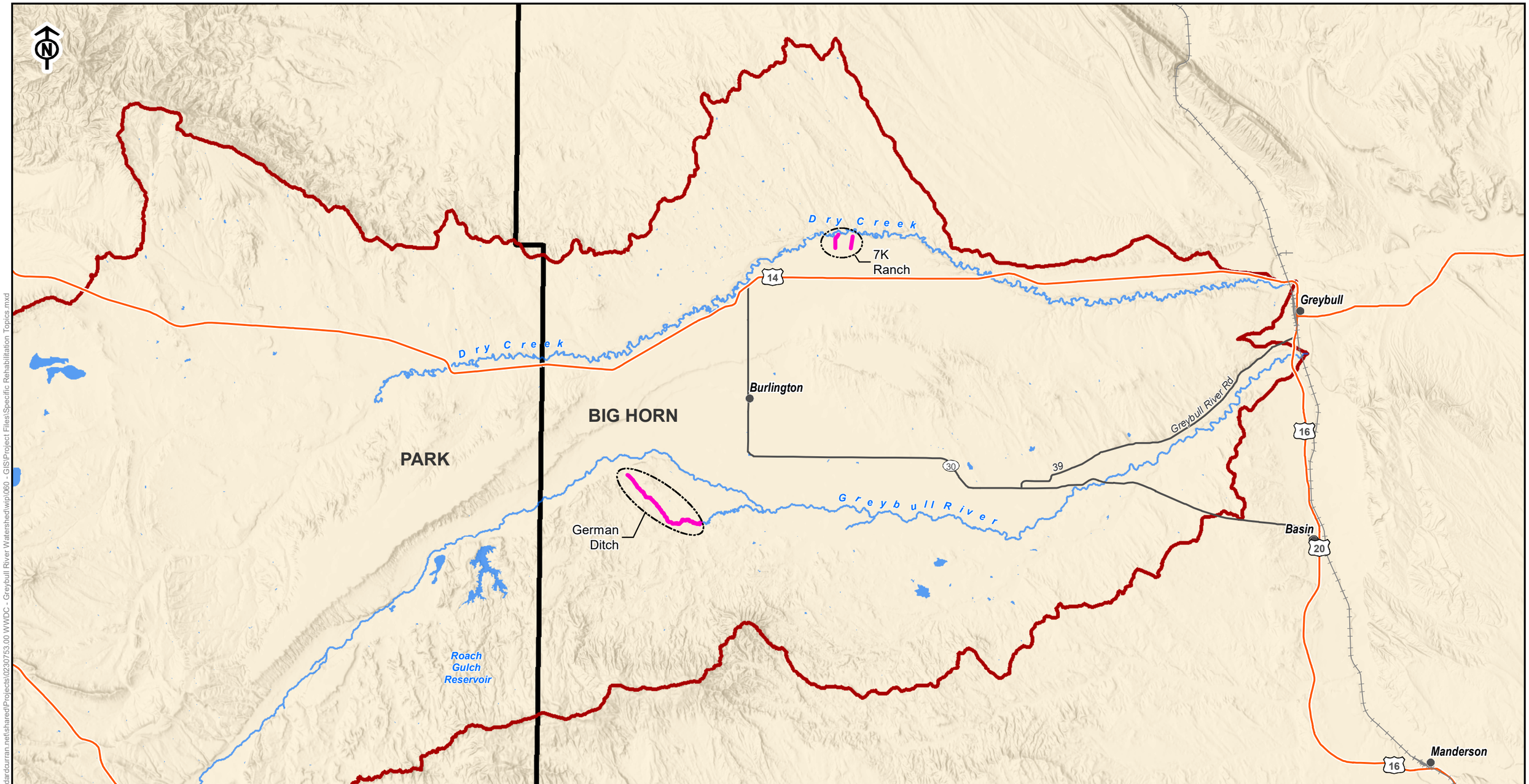


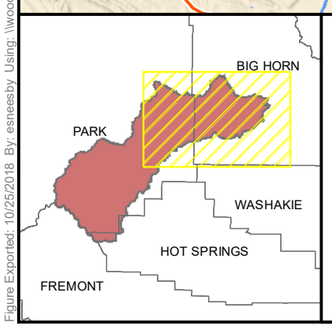


**LEGEND**

- Watershed Study Area
- City/Town
- Reservoir/Lake
- River/Stream
- Railroad
- Highway
- Major Road
- Specific Rehabilitation Topics

# Specific Rehabilitation Topics

Greybull Watershed Study

*FIGURE 59*

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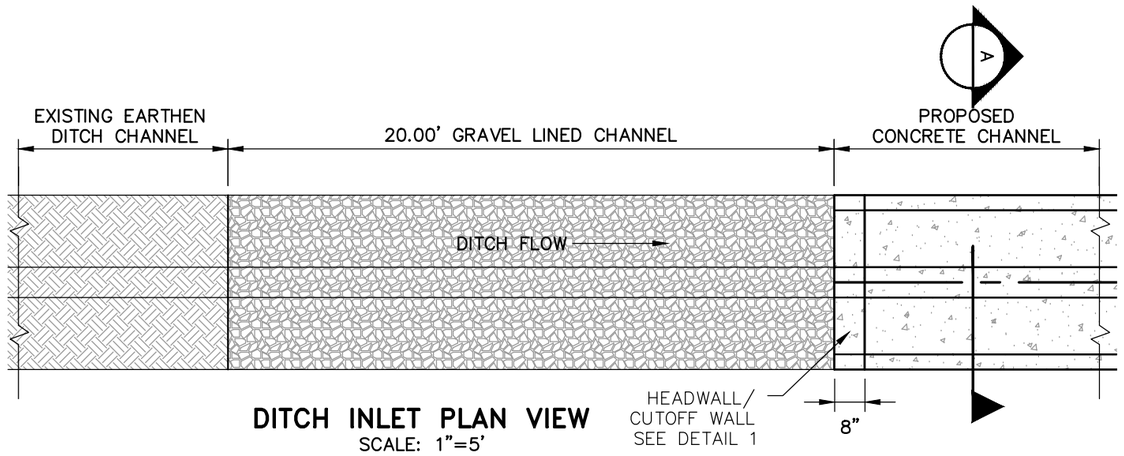
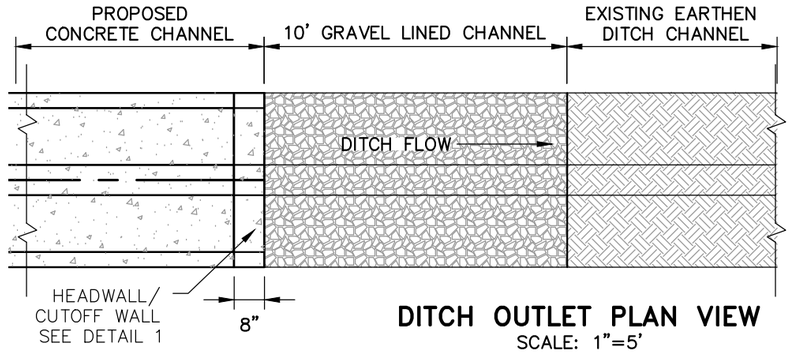
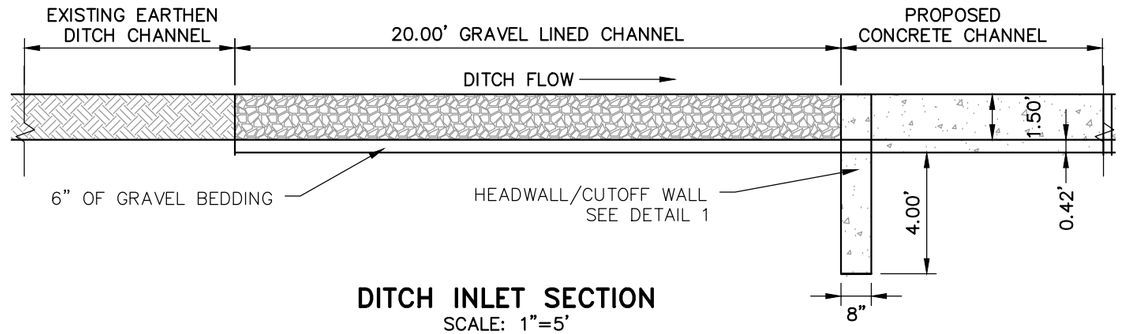
Figure Exported: 10/25/2018 By: esneesby Using: \\woodardcurran.net\shared\Projects\0230753.00 WWDC - Greybull River Watershed\wip\060 - GIS\Project Files\Specific Rehabilitation Topics.mxd



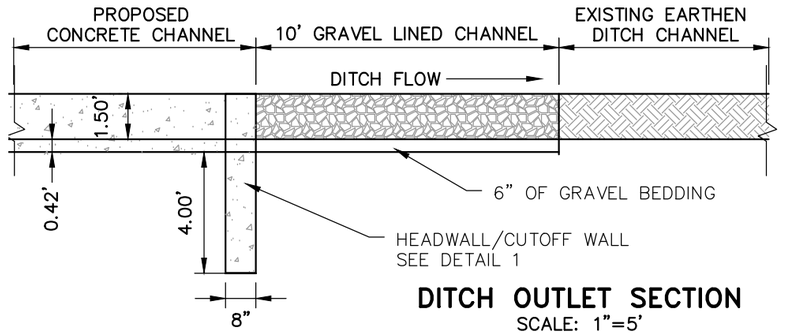

**DITCH INLET PLAN VIEW**
SCALE: 1"=5'



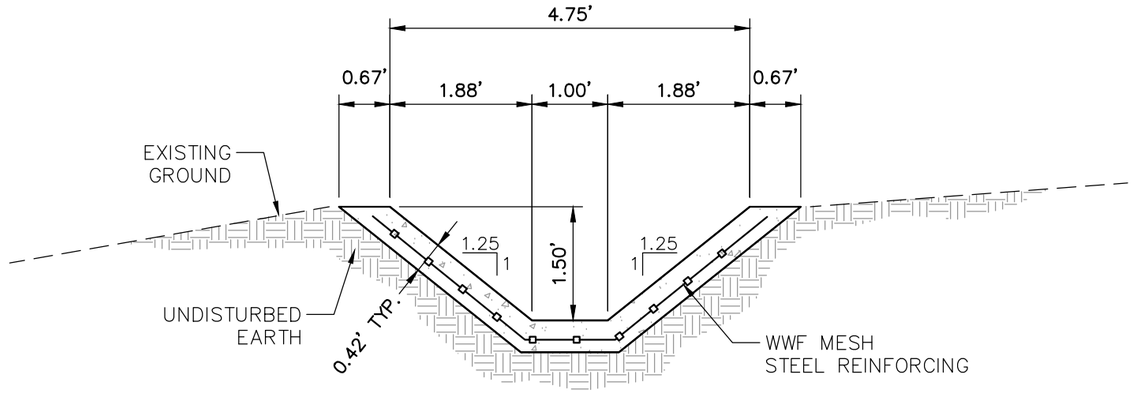

**DITCH OUTLET PLAN VIEW**
SCALE: 1"=5'



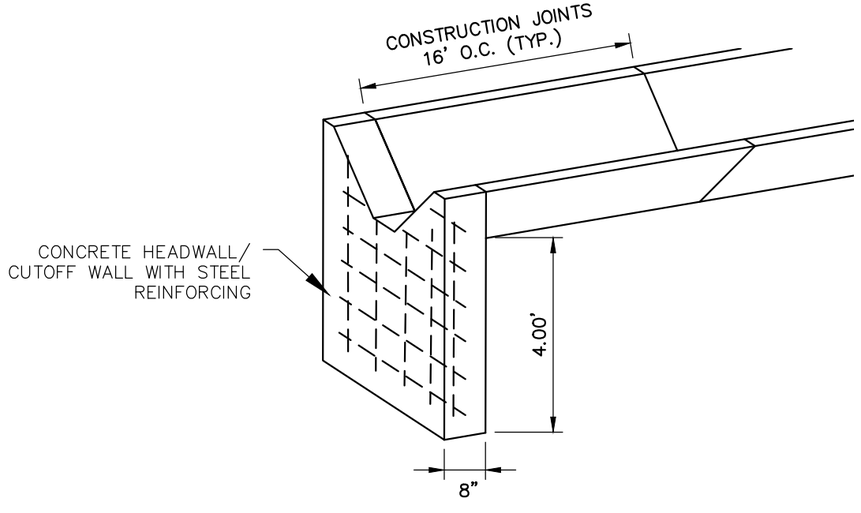

**DITCH INLET SECTION**
SCALE: 1"=5'




**DITCH OUTLET SECTION**
SCALE: 1"=5'




**SECTION** A / –
SCALE: 1"=2'




**HEADWALL/CUTOFF WALL DETAIL** 1 / –
NOT TO SCALE

PRELIMINARY- NOT FOR CONSTRUCTION

CONCEPTUAL DESIGN FOR THE 7K RANCH CONCRETE LINED DITCH

DESIGNED BY: EJ
DRAWN BY: MM
CHECKED BY: EJ
0230753.00-C-SKETCH 101*.dwg

WYOMING WATER DEVELOPMENT COMMISSION

GREYBULL RIVER WATERSHED REHABILITATION PROJECT

JOB NO: 0230753.00
DATE: 7/26/2018
SCALE: AS NOTED

FIGURE 60

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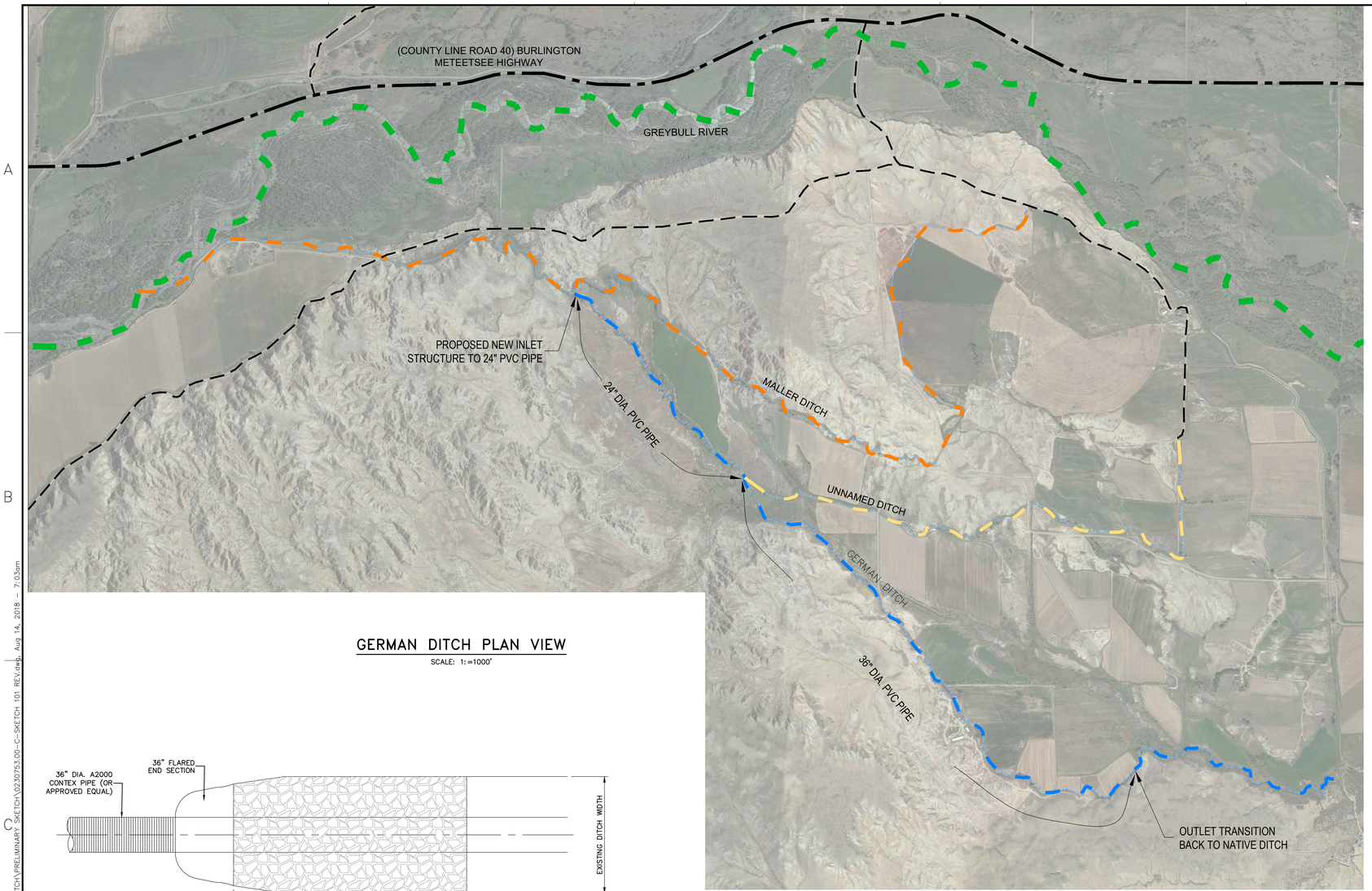
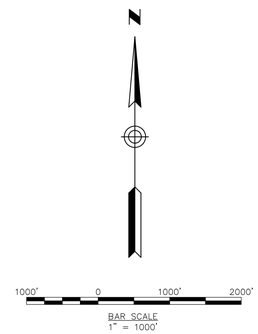
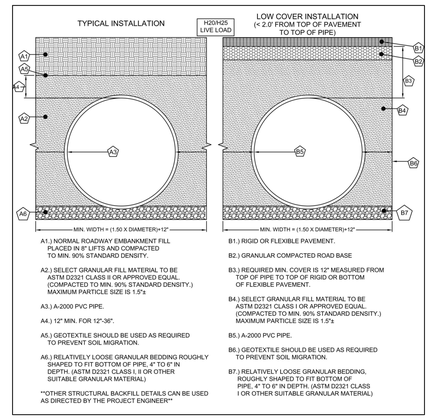
\\woodardcurran.net\shared\Projects\0230753.00 WWDC – Greybull River Watershed\wip\Drawings\Civil\7K RANCH DITCH_PRELIMINARY SKETCH\0230753.00-C-SKETCH 101.dwg, Aug 14, 2018 – 7:08am



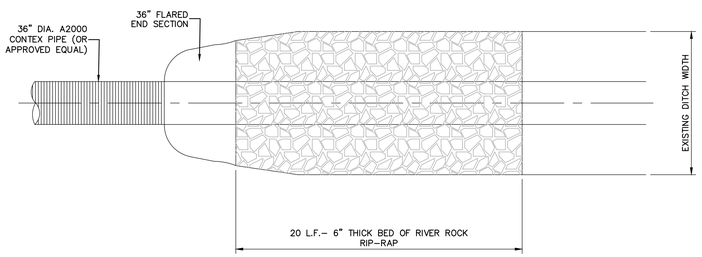

## GERMAN DITCH PLAN VIEW

SCALE: 1:=1000'



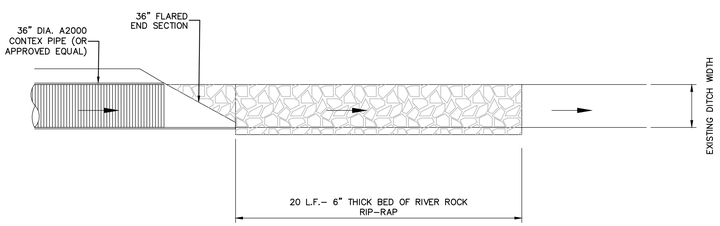




## TYPICAL PIPE INSTALLATION SPECIFICATIONS



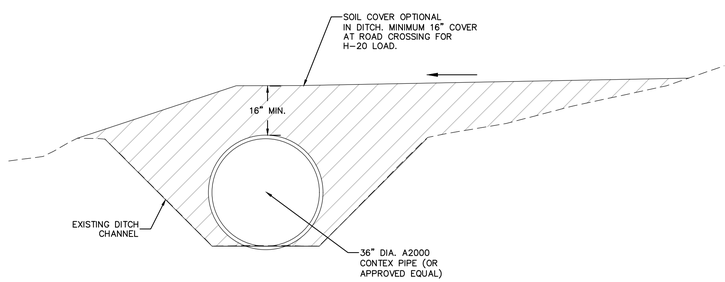

## PLAN VIEW– TYPICAL PIPE INLET/OUTLET DETAIL

SCALE: 1"=5'




## SECTION – TYPICAL PIPE INLET/OUTLET DETAIL

SCALE: 1"=5'




## SECTION– TYPICAL PIPE INSTALLATION

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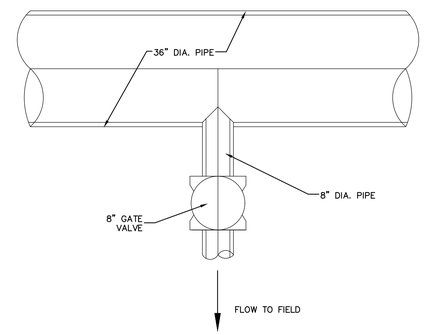


## PLAN– TYPICAL FIELD OUTLET DETAIL

SCALE: 1"=2'

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| REV. | DESCRIPTION | DATE |
|---|---|---|
| 1 | CONCEPTUAL DESIGN | 8/10/18 |

DESIGNED BY: EJ | CHECKED BY: EJ
DRAWN BY: MAM | 02307533.00-C-SKETCH 101.dwg

CONCEPTUAL DESIGN FOR
PVC LINING GERMAN DITCH

WYOMING WATER DEVELOPMENT COMMISSION

GREYBULL RIVER WATERSHED REHABILITATION PROJECT

JOB NO.:02300753.00
DATE: 8/3/2018
SCALE: 1"=1000'
SHEET: 1 OF 1

FIGURE 61

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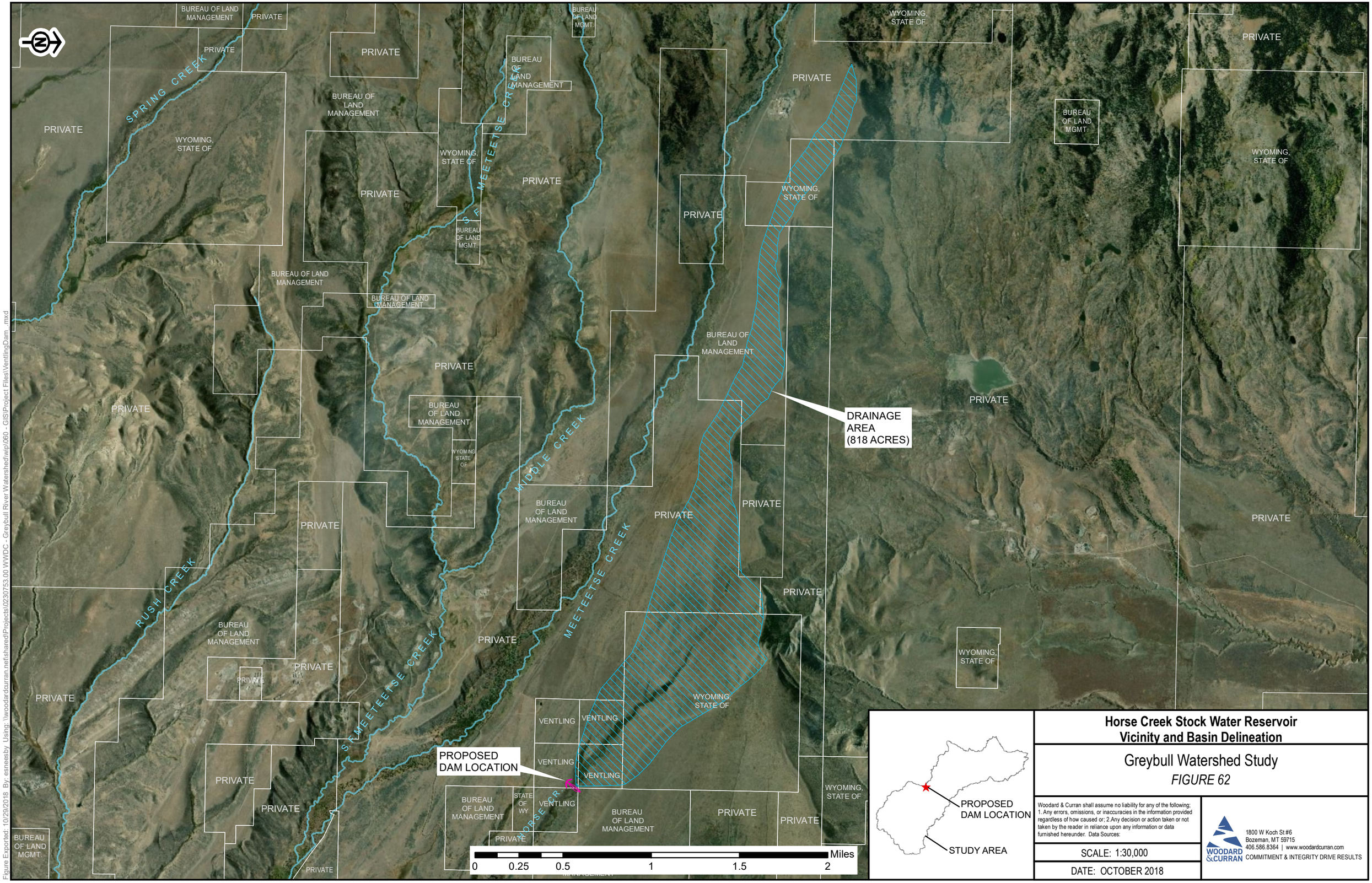


# Horse Creek Stock Water Reservoir Vicinity and Basin Delineation

## Greybull Watershed Study

*FIGURE 62*

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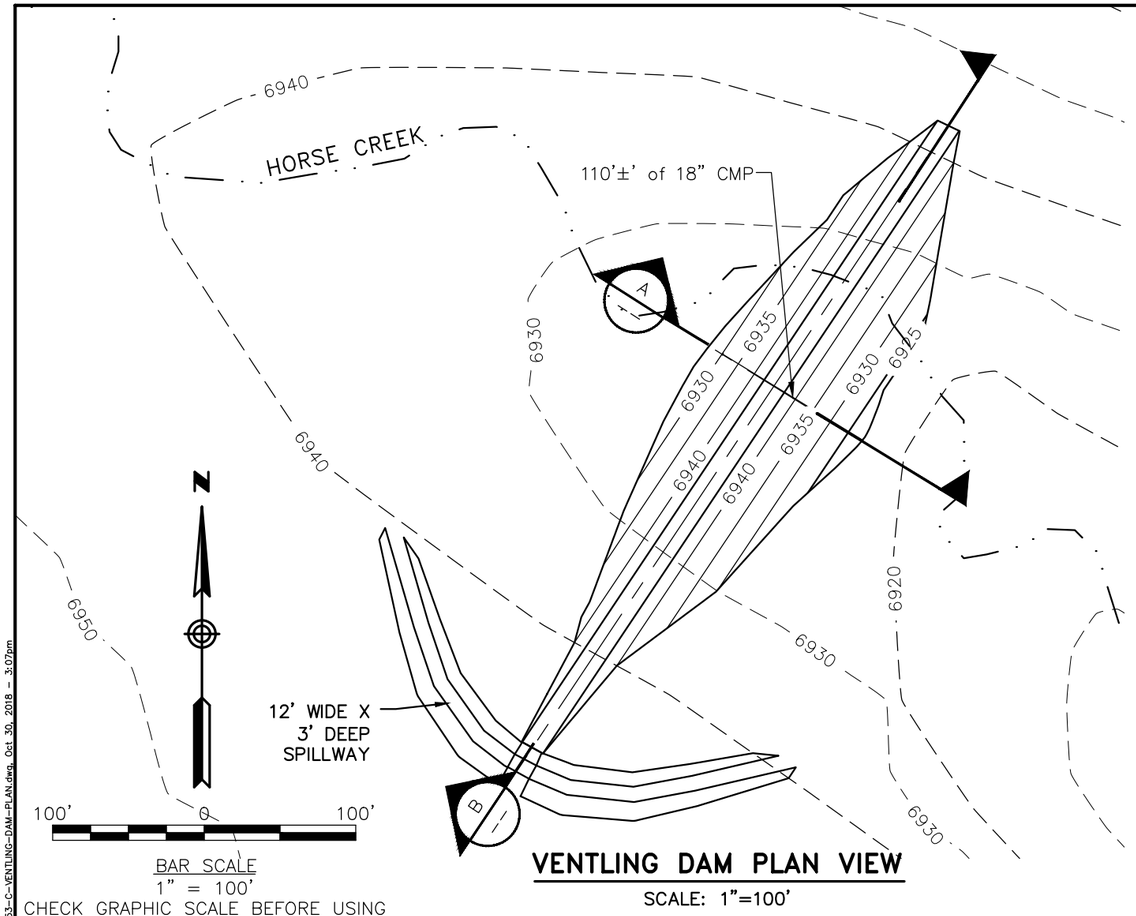
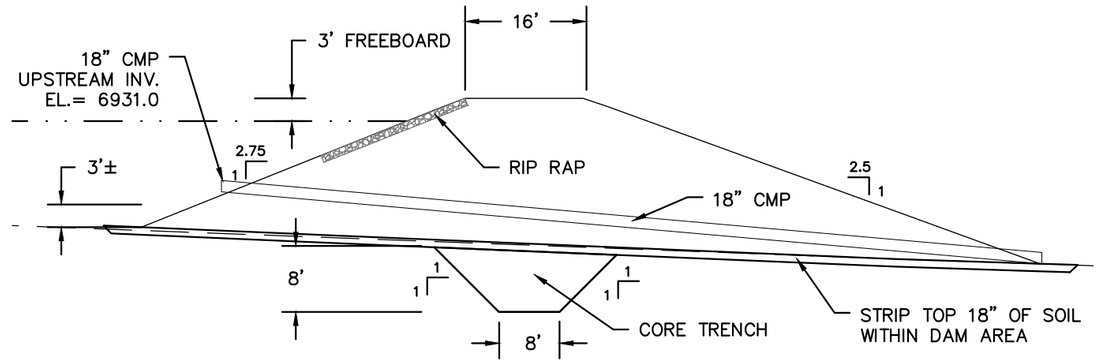
Figure Exported: 10/29/2018 By: esneesby Using: \\woodardcurran.net\shared\Projects\0230753.00 WWDC - Greybull River Watershed\wip\060 - GIS\Project Files\VentlingDam_.mxd




## VENTLING DAM PLAN VIEW

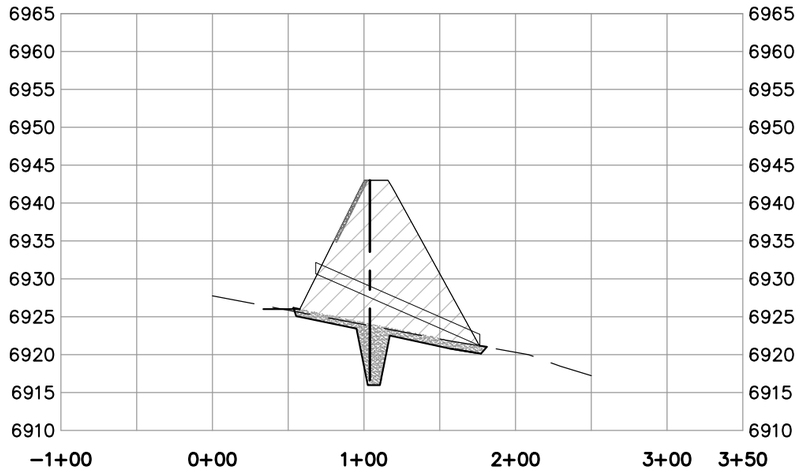
SCALE: 1"=100'

| STAGE STORAGE INFORMATION | | |
|---|---|---|
| ELEVATION | VOLUME (ACRE-FEET) | COMMENT |
| 6926 | 0.0 | DEAD STORAGE |
| 6927 | 0.0 | DEAD STORAGE |
| 6928 | 0.1 | DEAD STORAGE |
| 6929 | 0.3 | DEAD STORAGE |
| 6930 | 0.5 | DEAD STORAGE |
| 6931 | 0.9 | TOP OF DEAD STORAGE |
| 6932 | 1.4 | |
| 6933 | 2.1 | |
| 6934 | 3.1 | |
| 6935 | 4.2 | |
| 6936 | 5.5 | |
| 6937 | 7.2 | |
| 6938 | 9.1 | |
| 6939 | 11.3 | |
| 6940 | 13.8 | SPILLWAY CREST ELEVATION |
| 6941 | 16.6 | |
| 6942 | 19.8 | |
| 6943 | 21.5 | TOP OF DAM |

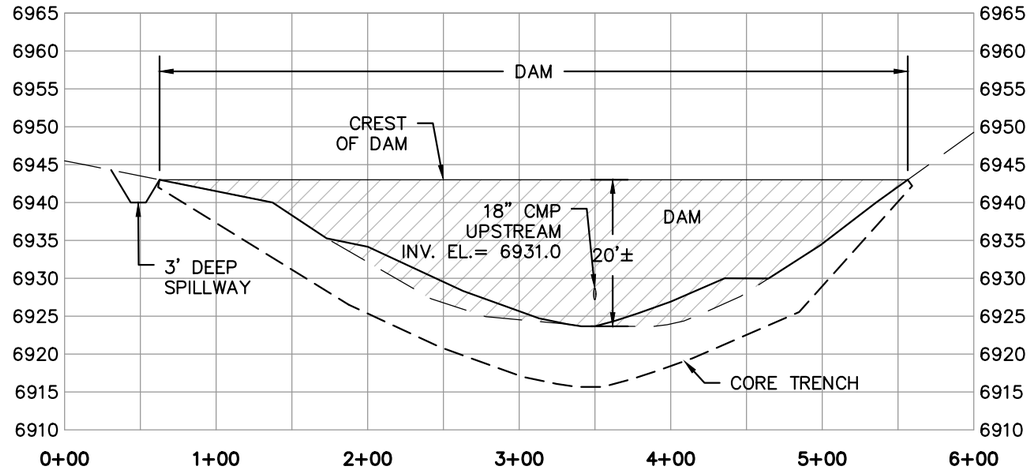



## SECTION A–A VENTLING DAM

SCALE: 1"=20'




SECTION A–A
HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 20'




SECTION B–B
HORIZONTAL SCALE: 1" = 100'
VERTICAL SCALE: 1" = 20'

PRELIMINARY-
NOT FOR CONSTRUCTION

PRELIMINARY PLAN FOR THE
HORSE CREEK STOCK POND

WYOMING WATER
DEVELOPMENT COMMISSION

GREYBULL RIVER WATERSHED
REHABILITATION PROJECT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DESIGNED BY: EJ
DRAWN BY: MAM
CHECKED BY: EJ
0230753-C-VENTLING-DAM-*.dwg

JOB NO: 0230753.00
DATE: 8/7/2018
SCALE: 1"=20'

FIGURE 63


\\woodardcurron.net\shares\Projects\0230753.00 WWDC – Greybull River Watershed\wip\Drawings\Civil\VENTLING DAM\0230753-C-VENTLING-DAM-PLAN.dwg, Oct 30, 2018 – 3:07pm

# APPENDIX A:
# GIS Data References and Sources

## Appendix A: GIS Data Sources

### Appendix A: GIS Data References and Sources

#### Cadastral
- Public Land Survey System
- State Engineer Office Districts
- Cities and Town
- Counties

#### Climate
- Weather Stations
- Weather Station Data

#### Cultural
- Bridger Trail
- Cultural Resources
- National Register of Historic Places

#### Wildlife
- Big Game Crucial Ranges
- Big Game Migration Routes
- Big Game Seasonal Ranges
- Aquatic Basins
- Aquatic Crucial Habitat
- Aquatic Enhancement Habitat
- Fish Passage Barriers
- Crucial Stream Corridors
- Sage Grouse Core Areas
- Instream Flow
- SWAP Habitat Types (vector)
- Terrestrial Crucial Habitat

#### Groundwater
- Aquifers
- Springs and Seeps

#### Land
- Conservation Easements
- Grazing Allotments
- Agricultural Land Use
- Surface Management
- Surface Ownership

#### Land Cover
- Land Cover
- Land Cover (USGS Gap Analysis)
- LANDFIRE
- LANDFIRE Canopy
- National Wetlands Inventory
- Ecological Sites

#### Modeling
- Diversion Node Numbers
- HUC 10
- HUC 10 (revised)
- HUC 10 w/ modeling results
- Creeks and Rivers (modeled)
- Primary Streams
- Stream Gauges (modeling use)

#### Rehabilitation
- Rehabilitation Area (Polygon)
- Rehabilitation Area (Line)
- Rehabilitation Area (Point)
- Water Shortage Areas

#### Surface Water
- WDEQ Assessed Streams (2014)
- GVID Reservoirs
- HUC 12 Watershed Boundaries
- HUC 10 Watershed Boundaries
- HUC 8 Watershed Boundaries
- HUC 6 Watershed Boundaries
- FEMA National Flood Layer
- National Hydrology Dataset
- Project Area (HUC 8 merge)
- Stream Gauges
- Upland Water Shortage

#### Infrastructure
- Minor Highways (ESRI dataset)
- Big Horn County Roads
- Park County Roads
- Railroads
- Electrical Transmission Lines
- Pipelines

## Appendix A (cont.)

### Appendix A: GIS Data References and Sources

#### Geology

- Geologic Basins
- Bedrock Geology
- Surface Geology

#### Geomorphology

- Rosgen Streams
- SSURGO Soils
- STATSGO Soils
- Elevation Contours

#### Natural Resources

- Gas Processing Plants
- Active Mine Permits
- Oil and Gas Fields
- Oil and Gas Wells (Active)
- Timber Harvesting

#### Miscellaneous Raster Data

- Crop Types
- Land Cover (USGS Gap Analysis)
- PRISM 30-year Annual Precipitation
- SWAP Habitat Data

#### Water Use

- Municipal Systems
- Water Wells (SEO)
- Storage Reservoirs

#### Water Use - Agricultural

- Irrigated Land
- Headgates
- Points of Diversion
- Service Areas

#### The data listed was sourced from the following agencies and organizations:

- *The Nature Conservancy*
- *U.S. Geological Survey (USGS)*
- *U.S. Forest Service (USFS)*
- *U.S. Department of Agriculture (USDA)*
- *U.S. Fish and Wildlife Service (FWS)*
- *U.S. Environmental Protection Agency (EPA)*
- *U.S. Bureau of Land Management (BLM)*
- *U.S. Army Corps of Engineers*
- *USDA Natural Resources Conservation Service (NRCS)*
- *Wyoming Water Development Office (WWDO)*
- *Wyoming Department of Environmental Quality (WDEQ)*
- *Wyoming State Engineer's Office (SEO)*
- *Wyoming Game and Fish Department (WGFD)*
- *Wyoming State Geological Survey (WSGS)*
- *Wyoming Geographic Information Science Center (WyGISC)*
- *Wyoming State Geological Survey (WSGS)*
- *Wyoming Oil and Gas Conservation Commission (WOGCC)*
- *Wyoming Water Resources Data System (WRDS)*
- *Wyoming State Historic Preservation Office (SHPO)*
- *National Park Service (NPS)*
- *Big Horn County*
- *Park County*
- *Greybull Valley Irrigation District*

# APPENDIX B:

## Geologic Descriptions

# 1. GEOLOGIC DESCRIPTIONS

## 1.1 TRIASSIC SYSTEM - CHUGWATER GROUP

The thickness of this group ranges from 700 to1100 feet and is not exposed, i.e., does not crop out in the area. Its composition includes siltstone, red sandy shale with red sandstone, gypsum, sandstone and limestone (Hewett, 1926). The brick-red color of the various rock layers is the result of oxidation of the iron minerals within. The formation is interrupted in many areas by high-quality gypsum veins.

## 1.2 JURASSIC SYSTEM - MORRISON FORMATION

The thickness of this formation ranges from 150 to 580 feet and does not crop out in the area. Composition includes sandstone at the lower levels with red or gray shale on the upper portions (Hewett, 1926). Mudstone, siltstone and limestone are also prevalent and includes a fertile source of dinosaur fossils in the green siltstone beds and lower sandstones. These two layers are relics of the rivers and floodplains of the Jurassic period.

## 1.3 LOWER CRETACEOUS SYSTEMS

*Cloverly Formation*

The Cloverly Formation is the basal portion of the Lower Cretaceous System and ranges from 210 to 385 feet in thickness and consists of interbedded claystone, variegated shale, sandstone and some minor amounts of conglomerate. The middle portion is comprised of claystone and variegated shale yet interbedded with thin sandstone beds which accumulated in floodplain, fluvial and lacustrine environments. Moberly (1960) referred to this portion as Little Sheep Mudstone and Himes Members. Very fine to medium-grained sandstone overlay these units and are referred to as the Greybull Sandstone Member. The upper portion of this formation consists of finely laminated siltstone and shale with some minor thin sandstone beds which accumulated in tidal flats (Finn, 2010).

*Thermopolis Shale*

This unit consists of 125 to 230 feet of siltstones and marine shales. It represents continued deposition during sea-level rise in the early Cretaceous. It includes layers of dark-gray to black shale which is interbedded with thin layers of bentonite, sandy claystone and siltstone (Finn, 2010).

*Muddy Sandstone*

This very fine to medium-grained sandstone unit is interbedded with minor amounts of carbonaceous shale, siltstone, shale and coal of the Albina Age. It was deposited in fluvial, marginal marine and estuarine environments with thickness ranging from 7-125 feet (Finn, 2010).

*Mowry Shale*

This shale is the basal portion of the Upper Cretaceous System and consists of two distinct units. The lower portion ranges from 160 to 400 feet in thickness and consists of soft fissile clay-rich shale similar to the Thermopolis. The upper portion ranges from 240 to400 feet in thickness. It consists of hard brittle siliceous

shale with numerous gray to tan bentonite beds throughout. Fine-grained sandstones occur in both the middle and upper portions of this unit. These sands have produced oil on the east side of the basin (Finn, 2010).

## 1.4 UPPER CRETACEOUS SYSTEM

*Frontier Formation*

This unit consists of bentonite, gray shale, siltstone and gray sandstone which accumulated in a marine or marginal marine environment. Many of the sandstones are continuous for tens of miles. But areas are also truncated due to erosion, most likely by marine flooding surfaces (Finn, 2010). According to Robinove (1963), its thickness varies from 424 to 465 feet.

*Cody Shale*

This shale is composed of siltstone, sandstone and marine shale deposited during a major marine transgressive-regressive cycle. Its thickness ranges from 1700 to 3800 feet depending upon the area of the watershed being considered. The main part is composed of marine shale with increasing amounts of interbedded sandstone in the upper portion. Many of the upper sandstones are traceable over many miles, almost blanket-like. The limited outcrop descriptions include fine to medium-grained sandstones with a variety of bedding features (Finn, 2010).

*Mesaverde Formation*

This formation is composed of basal regressive, marginal marine sandstone and is overlain by interbedded non-marine carbonaceous shale, shale, siltstone and coal. The lower member conformably overlies and interfingers with the Cody Shale. It consists of very fine to medium-grained sandstone, carbonaceous shale, siltstone, shale and coal. Its western limit is generally 400 to 500 feet thick. The middle portion consists of interbedded siltstone, shale, carbonaceous shale, sandstone and coal deposited in fluvial environments. According to outcrop studies, it is considered to be fluvial in origin throughout most of the watershed.

*Meeteetse Formation*

The Meeteetse Formation, is an intertonguing marine, marginal marine and non-marine strata. According to Hewitt, the thickness of this formation in the western portion of the watershed varies from 660 to 1,360 feet thick. It consists of very fine to medium-grained sandstone, siltstone, shale, carbonaceous shale and coal which accumulated in poorly drained coastal environments.

*Lance Formation*

This uppermost portion of the Cretaceous rocks in the Bighorn Basin consists of interbedded shale and sandstone with some conglomerate though some coal is found locally. Deposited by fluvial systems, the sandstones are fine- to coarse-grained and locally conglomeratic. The Laramide orogeny and initial partitioning of the Rocky Mountain foreland basin is indicated by the Lance Formation thickness patterns in the basin. It ranges from less than 500 feet in the southeastern portion of the watershed to 1,500-1,800 feet near the basin trough adjacent to and east of the Oregon Basin fault (Finn, 2010).

## 1.5 TERTIARY SYSTEMS

*Fort Union Formation*

This formation consists of sandstone, siltstone, conglomeratic sandstone, conglomerate, carbonaceous shale and coal. This formation contains economic deposits of coal, uranium and coalbed methane throughout various areas of the state of Wyoming. The sandstones are described as very fine to coarse-grained and represent a variety of fluvial deposits. In contrast, the finer grained and carbonaceous deposits represent lacustrine and swamp deposits. Its thickness indicates continued subsidence of the basin trough during the Laramide orogeny. This is reflected in the present-day structural configuration of the watershed. Generally, the formation is less than 1,000 feet thick around the basin's margins where it outcrops. Here it overlies unconformably the Lance Formation and other locally older Upper Cretaceous rocks. In the north portion of the basin it thins locally yet thickens to more than 7,500 feet in the structurally deepest central portion of the basin (Finn, 2010).

*Willwood and Tatman Formations*

The Willwood and Tatman Formations (undivided) strata are assigned to represent the lowermost Eocene in the Bighorn Basin. Its comprised of variegated shales, sandstones and conglomerates. Exposures in the southern part of the basin exhibit a thickness of nearly 2,400 feet. The lower Eocene Tatman Formation overlies and in part interfingers with the Willwood. Only the south-central portion of the basin contain the Tatman as isolated, erosional remnants. It consists of fine-grained sandstone and carbonaceous shale which accumulated in lakes and swamps. Its thickness ranges up to 900 feet. Together, these formations have a reported 5,000 feet of thickness in the subsurface along the deep axis of the basin. In addition, the combined thickness of the Fort Union and lower Eocene rocks ranges from less than 1,000 feet around the basin's margins to more than 13,000 feet near the basin's axis. This combination is a reflection of today's present structure of the Bighorn Basin (Finn, 2010).

## 1.6 QUATERNARY (SURFICIAL) SYSTEMS

Terraces or formations of four ages occur in the watershed including two high, gravel-covered terraces, and two wider, more thickly-graveled lower terraces (Hewitt, 1926).

Of the two higher terraces in the western and northern portions of the watershed, the Meeteetse Rim is the largest whose remnants form a chain nearly 20-miles long beginning northwest of the town of Meeteetse. These remnants are essentially flat, treeless surfaces and uniformly underlain by a layer of coarse gravel and boulders 10-50 feet thick. At nearly 6,500 feet above sea level, the Cottonwood Terrace is the highest formation with only three remnants remaining. The gravel which underlies this terrace is largely dark lava with reddish and gray quartzite (Hewitt, 1926).

The two lower terraces in the central and eastern portion of the watershed are more level and wider, and very extensive in the valleys. The Sunshine Terrace is the higher of the two and is well developed along the Wood and Greybull Rivers. Typically, this terrace is covered with 8-15 feet of gravel. The Greybull Terrace is the lowest formation and constitutes the floor of the valleys in this area of the watershed. The gravel layer which

covers the terrace is rarely thicker than 10 feet which in turn is covered by soil sometimes reaching a thickness of five feet (Hewitt, 1926).

# 2. SOIL DESCRIPTIONS

## 2.1 ROCK OUTCROP-NIELSEN-HOBACKER-CLAYBURN-BLAINE-BACHUS (S8978)

This group of soils is the most abundant group (over 230,000 acres) in the watershed occupying nearly 23 percent of the watershed's total area and is found in the westernmost mountainous areas. The group's descriptions include:

- Rock outcrop and Eutrocryepts soils typically found on 15 to 80 percent mountain slopes composed of well drained colluvium derived from acidic volcanic breccia and includes cobbly and very cobbly sandy loam; annual mean precipitation of 22-61 inches at elevations ranging from 8,960-12,560 feet;
- Nielsen series is typically found on 5 to 70 percent slopes composed of shallow, well drained soils formed in residuum and colluvium from sandstone, quartzite and felsic volcanic rocks these soils are on ridges and mountain side-slopes between 5,500-8,500 feet; annual mean precipitation of 20 inches
- Hobacker series consists of very deep, well drained soils formed in alluvium and colluvium on alluvial fans and stream terraces typically on slopes 0 to 30 percent; this gravelly and cobbly alluvium or colluvium is found at 5,800-9,000 feet; annual mean precipitation of 20 inches
- Clayburn series consists of very deep, well drained soils that formed in glacial drift, colluvium or alluvium derived mainly from shale, sandstone and andesite with some basalt; typically found on plateaus, hills and mountain slopes from 2 to 65 percent at 6,500-11,000 feet; annual mean precipitation of 30 inches
- Blaine series consists of moderately deep, well drained soils that formed in colluvium and residuum derived from igneous rock, conglomerate, hard shale or sandstone and are on escarpments, hills, ridges, cuestas and mountain slopes. The slopes range from 0 to 60 percent at elevations ranging from 4,000-7,500 feet; annual mean precipitation of 17 inches and
- Bachus series consists of moderately deep, well drained soils that formed in slope alluvium weathered from quartzitic sandstone typically found on anticlines along mountain fronts and have slopes of 2 to 25 percent at elevations of 6,800-9,000 feet; annual mean precipitation of approximately 20 inches.

## 2.2 TRAVSON-SHINGLE-ROCK OUTCROP-MIDWAY-KEYNER-HILAND-BOWBAC (S8946)

This centrally-located group of soils occupies nearly 17 percent of the watershed's area totaling over 170,000 acres. Its descriptions include:

- Travson series consists of somewhat excessively drained soils that are shallow to hard sandstone on ridges and dipslopes; formed in residuum on slopes ranging from 10 to 60 percent at elevations of 4,200-6,500 feet; annual mean precipitation of 10-14 inches with over half falling April-May;
- Shingle series consists of well drained soils that are very shallow or shallow to bedrock formed in residuum and colluvium derived from interbedded shale and sandstone or in alluvium from mudstone; located on bedrock-controlled hillslopes and ridges on slopes 0 to 80 percent on elevations of 3,800-6,500 feet; mean annual precipitation of 13 inches;

- Rock outcrop consists of a protruding rock formation exposed on the surface which can be covered by a thin layer of soil, gravel, etc.;
- Midway series consists of shallow, well drained soils formed in residuum and slope alluvium from calcareous platy, clayey shale; found on ridge crests, mesas, plains, and hills in shale bedrock uplands on slopes from 0 to 40 percent; mean annual precipitation is about 13 inches;
- Keyner series consists of very deep, well drained soils formed in moderately coarse sediments weathered from calcareous, sodic sandstone interbedded with shale; located on relict alluvial terraces and fans on slopes typically 0 to 15 percent on elevations of 3,800-6,500 feet; mean annual precipitation is about 12 inches;
- Hiland series consists of very deep, well drained soils formed in alluvium or eolian deposits on relict surfaces consisting of terraces, fans, fan remnants pediments, ridges, hills and stabilized dunes; the permeability is moderate on slopes from 0 to 20 percent on elevations of 3,800-6,300 feet; average annual precipitation is about 12 inches; and
- Bowbac series consists of moderately deep, well drained soils formed in alluvium, eolian deposits or residuum derived primarily from argillaceous sandstone; occupy alluvial fans, terraces, dissected fan remnants, fan piedmonts, hillslopes, pediments, plateaus, ridges and buttes on slopes 0 to 15 percent and both simple and complex on elevations of 3,500-6,500 feet; mean annual precipitation is about 13 inches.

## 2.3 YAMAC-EVANSTON-ATTEWAN (S8974)

As depicted on Figure 5, this group of soils is dominant in two portions of the watershed and occupies nearly 84,000 acres or 8.25% of the watershed's area. Those descriptions include:

- Yamac consists of well drained alluvium derived from sedimentary rock on alluvial fans with slopes 0 to 6 percent.; elevations range from 5,400-6,700 feet with a mean annual precipitation of 10-19 inches;
- Evanston series consists of very deep, well drained soils formed in alluvium weathered from quartzite, sandstone and shale; located on alluvial fans, hills, hillslopes, ridges, and terraces of sedimentary plains and uplands on slopes 0 to 65 percent on elevations of 3,800-8,200 feet; mean annual precipitation is about 13 inches; and
- Attewan series consists of very deep, well drained soils that formed in alluvium and glacial outwash 20 to 40 inches deep over very gravelly loamy sand or sand; found on outwash terraces, stream terraces, eskers, and alluvial fans on slopes 0 to 8 percent on elevations of 3,800-6,500 feet; mean annual precipitation is about 12 inches.

## 2.4 YOUNGSTON-WORLAND-PERSAYO-OCEANET-GREYBULL (S8949)

As depicted on Figure 5, this group of soils is dominant in three eastern portions of the watershed within the Dry Creek drainage. They occupy nearly 80,000 acres or just under 8% of the watershed's area. Those descriptions include:

- Youngston series consists of very deep, well drained soils formed in stratified alluvium from mixed sources found on recent alluvial terraces, fans, and fan aprons on slopes 0 to 10 percent on elevations of 3,700-6,300 feet; mean annual precipitation is about seven inches;
- Worland series consists of well drained soils of moderately deep to calcareous sandstone formed in residuum and colluvial slopewash weathered from the underlying bedrock; located on hill footslopes, backslopes, and ridge shoulders and summits or crests on slopes 0 to 35 percent and both simple and complex; elevations range from 3,800-6,300 feet; mean annual precipitation is about seven inches
- Persayo series consists of shallow, well drained soils formed in slope alluvium or colluvium over residuum derived from soft sedimentary bedrock; located on hills, basin floor remnants, fan remnants, dipslopes, scarp slopes and escarpments on slopes 0 to 65 percent on elevations of 4,000-6,200 feet; mean annual precipitation is about eight inches;
- Oceanet series consists of well drained soils that are shallow and very shallow to soft, calcareous sandstone formed in residuum and local alluvium weathered from the underlying bedrock; located on low rolling and steep hillslopes and summits on complex slopes from 0 to 60 percent on elevations of 4,800-6,500 feet; mean annual precipitation is about seven inches; and
- Greybull series consists of well drained soils moderately deep to shale, and formed in residuum and colluvial slopewash derived from soft, calcareous shale; located on shale bedrock controlled uplands and rolling hills on simple and complex slopes of 0 to 50 percent at elevations of 3,800-6,700 feet; mean annual precipitation is about seven inches.

## 2.5 RUBBLE LAND-ROCK OUTCROP-COWOOD (S9123)

As depicted on Figure 5, this group of soils is located in the western, mountainous portion of the watershed. It occupies over 73,000 acres or about 7% of the watershed's area. Those descriptions include:

- Rubble land/rock outcrop includes areas of 90-percent or more stones/boulders; typically found on 15 to 70 percent slopes and practically no soil is exposed; areas of exposed hard bedrock and colluvium derived from acidic volcanic breccia and very gravelly loam;
- Cowood series consists of shallow, well drained soils formed in colluvium or slide deposits over residuum derived from mixed rock sources and located are on mountains, escarpments, ridges, hills and landslides on slopes are 0 to 75 percent; elevations range from 5,000-9,200 feet with a mean annual precipitation of about 30 inches.

## 2.6 YOUNGSTON-WILLWOOD-SHARLAND-PREATORSON-LOSTWELLS-GARLAND-APRON (S8951)

As depicted on Figure 5, this group of soils is located along a narrow band in the central portion of the watershed plus a smaller area in the easternmost portion. They occupy over 63,000 acres or about 6% of the watershed's area. Those descriptions include:

- Youngston series consists of very deep, well drained soils formed in stratified alluvium from mixed sources found on recent alluvial terraces, fans, and fan aprons on slopes 0 to 10 percent on elevations of 3,700-6,300 feet; mean annual precipitation is about seven inches;

- Willwood series consists of gray, calcareous, single grained, very cobbly sand with gray, calcareous, very gravelly loamy sand located on edges of old terrace or fan surfaces or at the margins of floodplains and recent terraces on slopes 0 to 6 percent; elevations range from 3,800-5,200 feet with an average annual precipitation of about seven inches;
- Sharland series consists of very deep, well drained soils formed in alluvium on alluvial fans, pediment surfaces and terraces on slopes 0 to 10 percent; elevations range from 3,800-5,200 feet with an average annual precipitation is about seven inches;
- Preatorson series consists of very deep, well drained soils on alluvial fans and stream terraces formed in alluvium from basalt on slopes 0 to 30 percent; elevations range from 3,800-5,200 feet with an average annual precipitation is about seven inches;
- Lostwells series consists of very deep, well drained soils formed in alluvium on alluvial terraces and floodplains on slopes of 0 to 10 percent; elevations range from 3,800-6,300 feet with a mean annual precipitation is about seven inches;
- Garland series consists of very deep, well drained, medium or moderately fine textured soils underlain by gravel, cobbles, and sand; located on terraces and alluvial fans with of 0 to 10 percent; elevations range from 3,800-5,200 feet with a mean annual precipitation is about six inches; and
- Apron series consists of very deep, well drained soils formed in alluvium or slope alluvium from calcareous sandstone interbedded with shale; located on fan aprons, alluvial fans, fan remnants and stream terraces with slopes 0 to 15 percent; elevations range from 3,900-5,600 feet with a mean annual precipitation of about 7.5 inches.

## 2.7 YOUNGSTON-ROCK OUTCROP-PERSAYO-NEIBER (S8967

As depicted on Figure 5, this group of soils is located along a narrow band in the southeastern portion of the watershed. It occupies nearly 58,000 acres or about 5.7% of the watershed's area. Those descriptions include:

- Youngston series consists of very deep, well drained soils formed in stratified alluvium from mixed sources found on recent alluvial terraces, fans, and fan aprons on slopes 0 to 10 percent on elevations of 3,700-6,300 feet; mean annual precipitation is about seven inches;
- Rock outcrop consists of a protruding rock formation exposed on the surface which can be covered by a thin layer of soil, gravel, etc.;
- Persayo series consists of shallow, well drained soils formed in slope alluvium or colluvium over residuum derived from soft sedimentary bedrock; located on hills, basin floor remnants, fan remnants, dipslopes, scarp slopes and escarpments on slopes 0 to 65 percent on elevations of 4,000-6,200 feet; mean annual precipitation is about eight inches; and
- Neiber series consists of moderately deep, well drained soils formed in material from soft, calcareous sandstone interbedded with shale; located on upland backslopes and footslopes and have slopes of 3 to 30 percent; elevations range from 4,000-5,500 feet with a mean annual precipitation of about eight inches.

## 2.8 ZILLMAN-EVANSTON-DELPHILL-CRAGO-BROWNSTO-BLAZON-BLACKHALL (S8976)

As depicted on Figure 5, this group of soils is dominant in two areas in the foothills of the Absoraka Mountain range in the western portion of the watershed. It occupies over 55,000 acres or about 5.5% of the watershed's area. Those descriptions include:

- Zillman series consists of deep, well drained soils on mountain slopes, terraces, and upper fan aprons formed in slope alluvium and sediments of mixed origin with slopes 2 to 65 percent; the elevation ranges from 6,500-7,800 feet with a mean annual precipitation of about 13 inches;
- Evanston series consists of very deep, well drained soils that formed in alluvium weathered from quartzite, sandstone and shale located on alluvial fans, hills, hillslopes, ridges, and terraces of sedimentary plains and uplands with slopes 0 to 65 percent; the elevation ranges from 6,500-7,800 feet with a mean annual precipitation of about 13 inches;
- Delphill series consists of well drained soils that are moderately deep to bedrock formed in residual materials modified by slopewash alluvium and are on benches, pediments, ridges, and rolling uplands with slopes from 2 to 45 percent; the elevation ranges from 5,500-8,000 feet with a mean annual precipitation of about 12 inches;
- Crago series consists of very deep, well drained soils that formed in alluvium or colluvium derived mainly from limestone or basal conglomerate located on alluvial fans, fan remnants, stream terraces, escarpments, hills and mountain slopes with slopes from 0 to 75 percent; the elevation ranges from 5,500-8,000 feet with a mean annual precipitation of about 12 inches;
- Brownsto series consists of very deep, well drained soils formed in alluvium, colluvium, and glacial outwash on alluvial fans, hills, hillslopes, outwash fans, and terraces with slopes from 0 to 75 percent; the elevation ranges from 6,000-7,800 feet with a mean annual precipitation of about 12 inches;
- Blazon series consists of well drained soils that are shallow to shale, and formed in slope alluvium over residuum derived from shale interbedded with sandstone, loamstone, and siltstone. They are located on pediments, hillslopes, plateaus and ridges with slopes range 0 to 60 percent; the elevation ranges from 5,300-8,400 feet with a mean annual precipitation of about 12 inches; and
- Blackhall series consists of very shallow and shallow, well drained soils that formed in material weathered from sandstone, and is located on hills and ridges with slopes from 3 to 65 percent; the elevation ranges from 4,200-7,800 feet with a mean annual precipitation of about 12 inches.

## 2.9 YAMAC-MOYERSON-FORELLE-DIAMONDVILLE-DELPHILL-BLAZON-BLACKHALL-ALCOVA (S8973)

As depicted on Figure 5, this group of soils is dominant in two areas in the central and western portions of the watershed. It occupies nearly 50,000 acres or about 5% of the watershed's area. Those descriptions include:

- Yamac consists of well drained alluvium derived from sedimentary rock on alluvial fans with slopes 0 to 6 percent.; elevations range from 5,400-6,700 feet with a mean annual precipitation of 10-19 inches;
- Moyerson series consists of well drained soils that are shallow to soft bedrock and formed in residuum and colluvial slopewash derived from soft shale and siltstone. These soils are on upland

hills, ridges, and dissected plateaus with slopes 2 to 65 percent; the elevation ranges from 5,600-7,800 feet with a mean annual precipitation of about 12 inches;

- Forelle series consists of very deep, well drained soils on fan aprons, fan piedmonts, hillslopes, and hill toeslope positions formed in alluvium and slope alluvium derived from sedimentary rocks, primarily shale. Slopes are typically simple and range from 0 to 30 percent; elevations range from 5,300-7,800 feet with a mean annual precipitation of about 12 inches;
- Diamondville series consists of moderately deep, well drained soils that formed in alluvium and residuum weathered from calcareous loamstone and sandstone, and located on fan remnants, plateaus, hills and ridges of cold intermountain basins with slopes of 0 to 15 percent; the elevations range from 4,600-7,500 feet with the mean annual precipitation of 10 to 15 inches;
- Delphill series consists of well drained soils that are moderately deep to bedrock formed in residual materials modified by slopewash alluvium and are on benches, pediments, ridges, and rolling uplands with slopes from 2 to 45 percent; the elevation ranges from 5,500-8,000 feet with a mean annual precipitation of about 12 inches;
- Blazon series consists of well drained soils that are shallow to shale, and formed in slope alluvium over residuum derived from shale interbedded with sandstone, loamstone, and siltstone. They are located on pediments, hillslopes, plateaus and ridges with slopes range 0 to 60 percent; the elevation ranges from 5,300-8,400 feet with a mean annual precipitation of about 12 inches; and
- Blackhall series consists of very shallow and shallow, well drained soils that formed in material weathered from sandstone, and are located on hills and ridges with slopes from 3 to 65 percent; the elevation ranges from 4,200-7,800 feet with a mean annual precipitation of about 12 inches; and
- Alcova series consists of very deep, well drained soils formed in old, calcareous alluvium derived from mixed sources located on relict terraces, pediments, and dissected fan aprons. Slopes are simple and complex ranging from 0 to 15 percent; elevation ranges from 5,100-7,800 feet and the mean annual precipitation is about 12 inches.

## 2.10 YOUNGSTON-SHARLAND-GARLAND (S8971)

As depicted on Figure 5, this group of soils is dominant in the eastern portion of the watershed in the Dry Creek drainage. It occupies nearly 48,000 acres or about 5% of the watershed's area. Those descriptions include:

- Youngston series consists of very deep, well drained soils formed in stratified alluvium from mixed sources found on recent alluvial terraces, fans, and fan aprons on slopes 0 to 10 percent on elevations of 3,700-6,300 feet; mean annual precipitation is about seven inches;
- Sharland series consists of very deep, well drained soils that formed in alluvium, and located on alluvial fans, pediment surfaces and terraces with slopes 0 to 10 percent; elevations range from 3,800-5,200 feet with a mean annual precipitation of about seven inches; and
- Garland series consists of very deep, well drained, medium or moderately fine textured soils underlain by gravel, cobbles, and sand, and located on terraces and alluvial fans with slopes of 0 to 10 percent; elevations range from 3,800-5,200 feet with a mean annual precipitation of about six inches.

## 2.11 YAMAC-VANDA-EVANSTON-ALCOVA (S8975)

As depicted on Figure 5, this group of soils is dominant in western portion of the watershed along the Wood River and the upper reaches of the Greybull River. It occupies nearly 48,000 acres or about 5% of the watershed's area. Those descriptions include:

- Yamac consists of well drained alluvium derived from sedimentary rock on alluvial fans with slopes 0 to 6 percent.; elevations range from 5,400-6,700 feet with a mean annual precipitation of 10-19 inches;
- Vanda series consists of very deep, well drained soils that formed in alluvium derived mainly from semi-consolidated sedimentary bedrock or from glaciolacustrine or glaciofluvial deposits. These soils are on alluvial fans, lake plains, sedimentary plains, drainageways, and stream terraces with slopes 0 to 15 percent; elevations range from 4,500-5,500 feet with a mean annual precipitation of about 12 inches;
- Evanston series consists of very deep, well drained soils that formed in alluvium weathered from quartzite, sandstone and shale located on alluvial fans, hills, hillslopes, ridges, and terraces of sedimentary plains and uplands with slopes 0 to 65 percent; the elevation ranges from 6,500-7,800 feet with a mean annual precipitation of about 13 inches; and
- Alcova series consists of very deep, well drained soils formed in old, calcareous alluvium derived from mixed sources located on relict terraces, pediments, and dissected fan aprons. Slopes are simple and complex ranging from 0 to 15 percent; elevation ranges from 5,100-7,800 feet with a mean annual precipitation of about 12 inches.

## 2.12 YOUNGSTON-UFFENS-STUTZMAN-LOSTWELLS-APRON (S8950)

As depicted on Figure 5, this group of soils is dominant in two portions of the watershed along the final reaches of Greybull River in the eastern part of the watershed. It occupies nearly 43,000 acres or about 4% of the watershed's area. Those descriptions include:

- Youngston series consists of very deep, well drained soils formed in stratified alluvium from mixed sources found on recent alluvial terraces, fans, and fan aprons on slopes 0 to 10 percent on elevations of 3,600- 6,300 feet with a mean annual precipitation of about seven inches;
- Uffens series consists of very deep, well drained soils that formed in deltaic and alluvial sediments derived from mixed parent materials located on terraces and fans with slopes of 0 to 12 percent; elevations range from 3,800-6,400 feet with a mean annual precipitation of about eight inches;
- Stutzman series consists of deep, well drained soils that formed in calcareous, fine textured alluvium located on alluvial fans, terraces, and valley bottoms with slopes of 0 to 10 percent; elevations range from 3,800- 5,500 feet with a mean annual precipitation of about six inches;
- Lostwells series consists of very deep, well drained soils formed in alluvium on alluvial terraces and floodplains on slopes of 0 to 10 percent; elevations range from 3,800-6,300 feet with a mean annual precipitation of about seven inches; and
- Apron series consists of very deep, well drained soils formed in alluvium or slope alluvium from calcareous sandstone interbedded with shale, and located on fan aprons, alluvial fans, fan remnants

and stream terraces with slopes 0 to 15 percent; elevations of 3,900-5,600 feet and a mean annual precipitation of 7.5 inches.

## 2.13 WOOSLEY-STARMAN-ROCK OUTCROP-MOSROC-FORNOR-DECROSS (S9076)

As depicted on Figure 5, this group of soils is dominant in a relatively small area in the southernmost section of the watershed. It occupies over 11,000 acres or about 1% of the watershed's area. Those descriptions include:

- Woosley series consists of well drained soils that are moderately deep to limestone formed in residuum, alluvial, and colluvial slopewash weathered from the underlying rock. Woosley soils are on mountain footslope, toeslope, and backslope positions with slopes 2 to 30 percent; elevations range from 6,500-9,000 feet with a mean annual precipitation of about 20 inches;
- Starman series consists of very shallow and shallow, well drained soils formed in slope alluvium or colluvium over residuum from calcareous sedimentary rock located on mountain slopes, hills, and ridges with slopes 0 to 70 percent; elevations range from 5,900-9,200 feet with a mean annual precipitation of about 18 inches;
- Rock outcrop
- Mosroc series consists of well drained soils that are shallow to granitic bedrock formed in weathered material derived dominantly from granite on mountain ridges and hillslopes with slopes 1 to 15 percent; elevations range from 7,000-8,500 feet with a mean annual precipitation of about 12 inches;
- Fornor series consists of very deep, well drained soils that formed in glacial drift on moraines, terraces, and till plains with slopes of 2 to 30 percent; elevations range from 6,800-8,400 feet with a mean annual precipitation is 17 inches; and
- Decross series consists of very deep, well drained soils formed in alluvium from limestone located on relict alluvial fans, fan aprons, mountain slopes, and pediment toeslopes with slopes of 0 to 60 percent; elevations range from 5,600-9,000 feet with a mean annual precipitation of about 20 inches.