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FINAL

Thunder Basin Watershed Management Plan

Level 1 Watershed Study
Volume I

Submitted to:
Wyoming Water Development Commission

Prepared by:
Olsson Associates

In Association With:
ESCO Associates, Inc.
Wester Wetstein Associates
Steady Stream Hydrology, Inc.

November 2009

OLSSON ASSOCIATES

Olsson Project No. 008-1217

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Thunder Basin Watershed Management Plan

Level I Watershed Study

WWDC Contract Number 055C0293618

November 30, 2009

I hereby certify that this report was prepared by us or under our direct supervision and that we are duly Licensed Professional Geologists and Engineers under the laws of the State of Wyoming.

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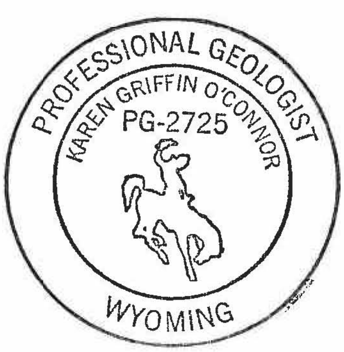

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1.0 Introduction

Olsson Associates (Olsson) prepared the Thunder Basin Watershed Management Plan for the Wyoming Water Development Commission in accordance with Contract No. 055C0293618. The plan was prepared in association with ESCO Associates (ESCO) of Boulder, Colorado, Steady Stream Hydrology, Inc. of Sheridan, Wyoming, and Wester Westein & Associates (WWA) of Laramie, Wyoming. The plan was prepared on behalf of the watershed landowners and the project sponsors including the Thunder Basin Grazing Association (TBGA), the Thunder Basin Grasslands Prairie Ecosystem Association and the four conservation districts that are represented in the Thunder Basin Watershed (Converse, Campbell, Weston and Niobrara).

1.1 Purpose and Scope

The purpose of this Watershed Management Plan is to describe Thunder Basin watershed in its current condition and to suggest resolutions for any water related issues and opportunities identified. Level I watershed studies include an extensive inventory and description of the watershed with scientific information on geology, hydrology, soils, climate, plant communities, wildlife habitat, infrastructure, and the geomorphic characteristics of the watershed stream system. The information gathered is intended to be used to develop proposed watershed improvements. Specific to this study, the project sponsors have requested an evaluation of surface and groundwater availability, the potential to develop upland livestock and wildlife water resources, and the potential to develop and enhance additional irrigation systems and water storage. Proposed projects are listed in the report and include cost estimates as well as information on project financing opportunities and project permitting considerations.

1.2 Project Geographic Information System (GIS)

The scientific information gathered as part of the Level I watershed study is compiled into a Geographic Information System (GIS) dataset. A list of the GIS layers developed for this project is provided in Data Summary 1.2-1 (In Appendix A). The GIS dataset is an electronic repository of the information gathered during the description and inventory phase of the project. The information includes mapped datasets on soil, geology, vegetation, wildlife, and infrastructure, that is represented in a series of layers that can be "turned on" or "turned off" electronically (See Figure 1.2-1). With the GIS datasets, the user has the opportunity to overlay a series of maps to discern patterns and/or site proposed projects. For example, the GIS maps were used by our hydrologists to differentiate the geomorphologic characteristics of the streams and to identify the potential impacts to wetlands and/or infrastructure at potential water storage sites.

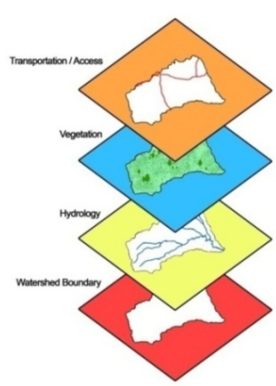


Figure 1.2-1 Geographic Information System Map Layer Illustration

Each map in this report contains a list of the data sources. The sources of information also are listed electronically in the metadata files for the layers. The major sources of data for the maps are as follows:

- Natural Resources Conservation Service (NRCS)
- U.S. Bureau of Land Management (BLM)
- U.S. Bureau of Reclamation
- U.S. Environmental Protection Agency (EPA)
- U.S. Department of Agriculture (USDA)
- U.S. Farm Service Agency (FSA)
- U.S. Forest Service (USFS)
- U.S. Fish and Wildlife Service (USFWS)
- U.S. Geological Survey (USGS)
- Wyoming Department of Environmental Quality (WDEQ)
- Wyoming Game and Fish Department (WGFD)
- Wyoming Geographic Information Science Center (WyGISC)
- Wyoming Oil and Gas Commission
- Wyoming State Engineer's Office (WSEO)
- Wyoming State Geological Survey (WSGS)
- Wyoming Water Development Commission (WWDC)

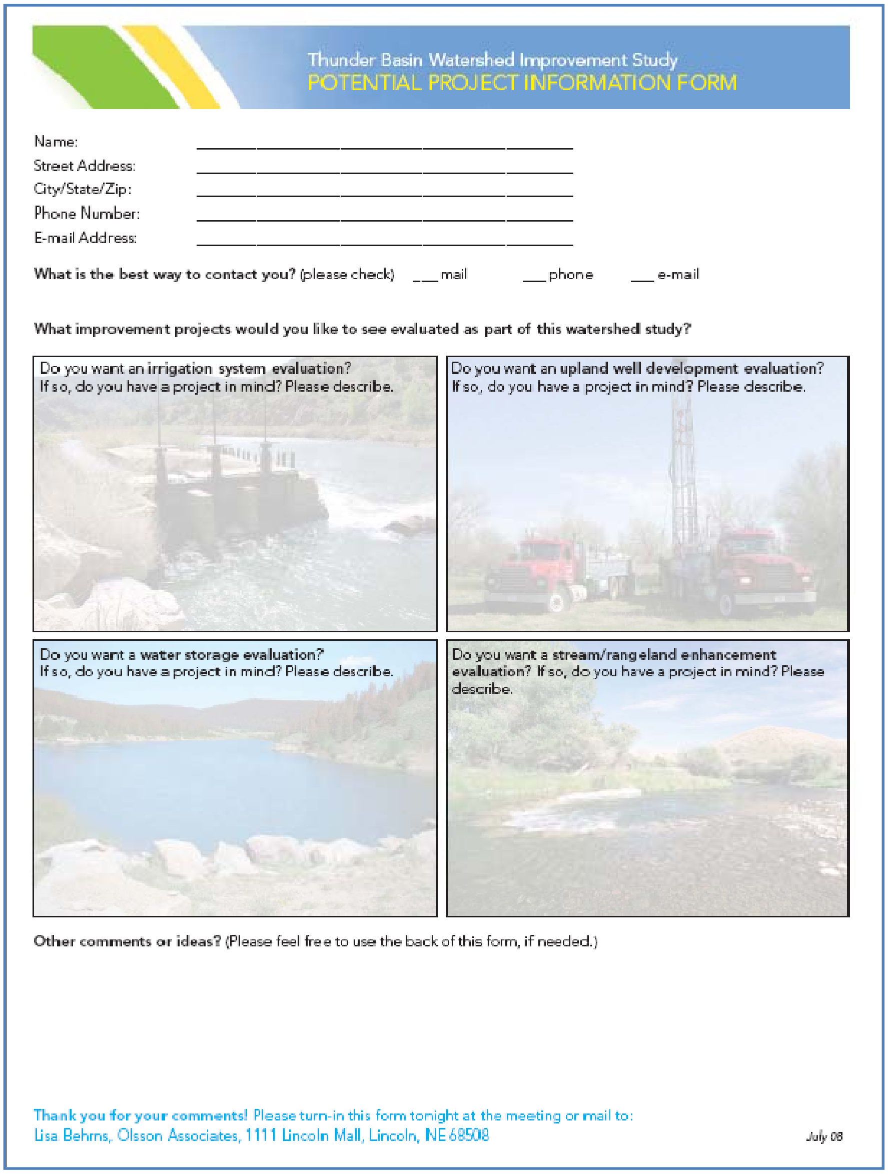
The information gathered for the Thunder Basin Watershed Study is presented in maps and datasets described throughout this report. The two-dimensional maps represent three-dimensional features and therefore the datasets were transformed using the Universal Transverse Mercator System (UTM), Zone 13 north. As specified in the contract, the GIS data is provided in electronic format using ArcGIS version 9.3 which is the current industry standard for GIS datasets.

1.3 Overview of Study Area Key Issues

Thunder Basin watershed lies in the northeast portion of Wyoming and includes the Upper Cheyenne River, Dry Fork Cheyenne River, and Antelope Creek which are the primary tributaries to the Cheyenne River System. The watershed is located in northeast Converse, southeast Campbell, southwest Weston and northwest Niobrara counties (Maps 1a-1e, Study Area Location). The watershed encompasses approximately 1.9 million acres of primarily grassland. The area has a robust livestock industry and is one of the world's largest producers of coal. Since early 2000, however, the area has been abnormally dry and the drought conditions have exacerbated the need for additional water development and distribution.

The TBGA in conjunction with the four conservation districts (Converse, Campbell, Weston, and Niobrara), the BLM, NRCS, WWDC and other government agencies, have been promoting watershed improvement projects and best management practices across the area. With the extended drought conditions and the prospect of additional project support through the WWDC, the TBGA and the conservation districts decided to promote the completion of this Level 1 study in order to provide a comprehensive, multidisciplinary watershed management plan that will identify and begin to address the key issues facing the area. The intent was to produce a watershed management plan that would take into account the landowners' requests for future project improvements and also provide a comprehensive understanding of the current conditions of the watershed so that projects that will benefit a multitude of landowners and recreational visitors could be coordinated across the area.

In order to solicit landowner involvement and input, this project began with a series of bimonthly project meetings where information was solicited on specific project initiatives including irrigation system upgrades, upland water development (wells), surface water storage, stream, and rangeland enhancements. Figure 1.3-1 depicts the project meeting information request forms sent to landowners across the project area. Responses from the request for information were compiled into a project database.



Thunder Basin Watershed Improvement Study
POTENTIAL PROJECT INFORMATION FORM

Name: ________________
Street Address: ________________
City/State/Zip: ________________
Phone Number: ________________
E-mail Address: ________________

What is the best way to contact you? (please check) ___ mail ___ phone ___ e-mail

What improvement projects would you like to see evaluated as part of this watershed study?

Do you want an **irrigation system evaluation?** If so, do you have a project in mind? Please describe.

Do you want an **upland well development evaluation?** If so, do you have a project in mind? Please describe.

Do you want a **water storage evaluation?** If so, do you have a project in mind? Please describe.

Do you want a **stream/rangeland enhancement evaluation?** If so, do you have a project in mind? Please describe.

Other comments or ideas? (Please feel free to use the back of this form, if needed.)

Thank you for your comments! Please turn-in this form tonight at the meeting or mail to:
Lisa Behrns, Olsson Associates, 1111 Lincoln Mall, Lincoln, NE 68508

July 08

Figure 1.3-1 Landowner Request for Information Form

Approximately 20 percent of the landowners across Thunder Basin responded to the request for information. Seven landowners had no specific projects for evaluation; however, they asked to be kept informed of the project status. Two of the landowners had ranches outside of the watershed boundary and were not evaluated as part of this project. Of the remaining 10 responses, six requested irrigation system evaluations, eight requested information on well development opportunities, four requested information on water storage sites and six were interested in stream and rangeland enhancements. Landowners that requested evaluation and granted site access were visited by the project team. Specific issues raised at project meetings during the site visits and in written responses included:

- *Irrigation Systems* – Less than 1 percent of Thunder Basin is irrigated and spreader dike systems are used as the standard for water distribution throughout Thunder Basin. There were several requests to upgrade spreader dike systems.
- *Groundwater Well Development* – Additional stock and wildlife water supplies are needed throughout the basin to enhance range conditions and habitat restoration. Solar wells were requested with pipelines, as needed, to reduce the distance cattle must travel to water.
- *Water Storage Sites* – The majority of landowners are not interested in medium to large reservoirs, however, most are interested in small stock watering ponds that can supply water to an area consistently throughout the year.
- *Stream Erosion* – There are specific areas along Black Thunder Creek, Cheyenne River and Owl Creek where stream erosion is an issue.
- *Rangeland/Riparian Conservation* – Questions arose about what grasses would perform best in specific soil types with minimal precipitation. Also, the riparian areas along the Cheyenne River and Black Thunder Creek were mentioned with questions raised about what is causing the large number of dead cottonwoods.

With these specific key issues identified, the project team began a comprehensive evaluation of the watershed. The first stage of the study involved compiling a description and inventory of Thunder Basin, as is described in the next section of this report.

2.0 Watershed Description

The following section provides a description of the natural environmental features and resources of the Thunder Basin watershed. References are noted throughout the text and are listed in Section 9.0 to afford the reader sources of additional information on the specific topics discussed in this document.

2.1 Natural Environment

2.1.1 Basin Description

Thunder Basin watershed lies within the geologic structural basin called the Powder River Basin which is part of the Missouri Plateau of the Great Plains (Trimble, 1980). The region is characterized by rolling uplands that have been dissected by tributaries of the Missouri River system. Thunder Basin lies within the south central portion of the Powder River Basin, which is bounded on its margins by upturned rocks or mountainous masses rising from the plains. On the east, the Powder River Basin is bounded by the Black Hills. On the south, the Powder River Basin is bounded by the Casper arch, the Laramie Mountains, and the Hartville Uplift (Macke 1993). To the north and northeast, the terrain of the Powder River Basin merges with, and cannot be distinguished from, the remainder of the Missouri Plateau (Keefer 1974).

Specifically, the Thunder Basin watershed consists of a dissected, rolling upland plain with low to moderate relief, broken by buttes, mesas, hills, and ridges. Elevations range from 3,690 feet to 6,310 feet above mean sea level across Thunder Basin with the highest elevations to the west and lowest to the east following the drainage pattern of the Cheyenne River and its tributaries (Map 2, Ground Elevation Map). The present-day landforms of the semiarid region have been shaped mostly by the action of water, even though precipitation is low and evaporation greatly exceeds precipitation. Erosion-resistant clinker, produced by the natural burning of coal beds, caps many hills and ridges within Thunder Basin with a characteristic broken, red brick colored rock. The drainages dissecting Thunder Basin are incised, typically are ephemeral or intermittent, and do not naturally provide permanent or year-round sources of water along the entirety of their reaches. Augmenting surface precipitation runoff are springs and seeps that are fed by groundwater from shallow aquifers (BLM, 2003).

2.1.2 Climate

2.1.2.1 Climate Overview

The climate of the Thunder Basin watershed can be classified as semiarid, steppe in the Kőppen climate classification system. The climate of Thunder Basin watershed is influenced by several nearby and distant mountain ranges including the Absaroka and Wind River mountains approximately 200 miles to the west, the Bighorn Mountains approximately 50 miles to the northwest and the Laramie Mountains approximately 50 miles to the south. The Black Hills, about 25 miles to the east in western South Dakota, also influence the watershed. Moisture from the Pacific Ocean transported by westerly winds is primarily blocked by the Absaroka and Wind River mountains through autumn, winter and spring. During the summer months thunderstorms that develop on the eastern slope of the Bighorn and Laramie mountains can affect the watershed. During the winter months, Thunder Basin watershed is exposed to cold air masses that migrate down from western and central Canada. Periods of extreme cold air can persist for several days in the watershed. Down slope flow conditions, air moving from higher elevation to lower elevation from the Bighorn Mountains, Laramie Mountains, and Black Hills, can warm the air and reduce humidity levels.

2.1.2.2 Drought Conditions in Wyoming

The U.S Drought Monitor and the U.S. Drought Monitor maps for Wyoming use a scale referred to as the U.S. Monitor Intensity Scale. The scale is based on the combination of individual drought indices. The definition for each level of the scale, ranging from D0 to D4, is identified on the U.S. Drought Monitor maps. In October 2008, the southern portions of the watershed were near drought intensity D0, defined as abnormally dry conditions. The 2008 map identified the northern portion of the watershed as not affected by drought conditions; however, caution should be used in interpreting drought conditions for specific points on the U.S. Drought Monitor map. The U.S. Drought Monitor maps are prepared across the entire country and specific locations can experience different drought conditions than identified on the generalized maps. Specific weather station data from Thunder Basin is provided in the next section. It is interesting to note that in October 2008, according to the U.S. Climate Prediction Center, drought conditions were not expected to occur during the period between October 16, 2008 and January, 2009. The prediction held to be true and drought conditions have diminished in the area. The current U.S. Drought Monitor map for Wyoming does not indicate drought conditions anywhere in the state.

2.1.2.3 Weather Stations and Historic Precipitation Records

Map 3, Weather Stations, identifies 10 weather stations within relative proximity to the Thunder Basin watershed. Of those, only the Dull Center weather station continues to operate. The time period covered by each weather station is listed next to each weather station in Table 2.1.2-1 (Western Regional Climate Center, 2008). Precipitation records for each of the listed weather stations can be found in Appendix B. The precipitation record for Dull Center is listed in Figure 2.1.2-1. At Dull Center, the average annual precipitation is 12.8 inches per year. Historical records indicate mean annual snowfall from the 10 weather station locations varies from 19.5 inches at the Clareton 16 SW weather station to 61.2 inches at the Ross weather station. The period and extent of time covered for each weather station varies considerably and therefore it may be inaccurate to conclude that the range of mean annual snowfall values is due to spatial variation.

Table 2.1.2-1 – Precipitation Weather Stations Near Thunder Basin Watershed

Precipitation Station	Beginning Year	Ending Year
New Castle 14W	1948	1958
Hampshire 3 SW	1921	1955
Clareton 16 SW	1948	1957
Rochelle 3 E	1927	2002
Dull Center 1 SE	1926	On going
Bill 10 NE	1948	1958
Bill	1948	1978
Bill 12 W	1948	1957
Verse 8 NW	1940	1959
Ross	1938	1961

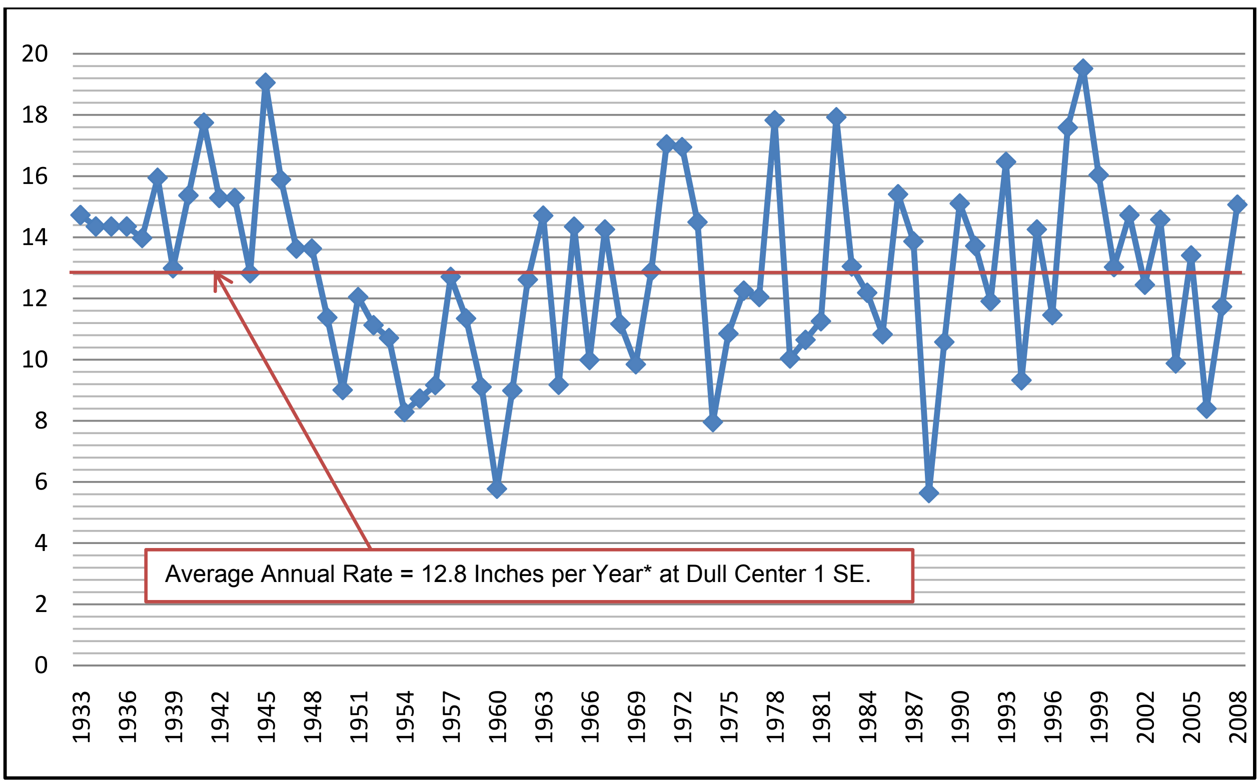


Figure 2.1.2-1 Precipitation for Dull Center, Wyoming in inches per year.

Based on Dull Center, Wyoming, climate data collected between 1926 and 2009, monthly mean maximum temperatures reach the low 70s in July and August. Monthly mean minimum temperatures drop into the mid 20s during December and January.

2.1.2.4 Precipitation Zones

Isohyetals of mean annual precipitation for the entire state of Wyoming are shown in Figure 2.1.2-2. According to Figure 2.1.2-2 the vast majority of Thunder Basin watershed lies in an area that receives less than 14 inches of precipitation per year. This matches precipitation values indicated by the weather station data at Dull Center.

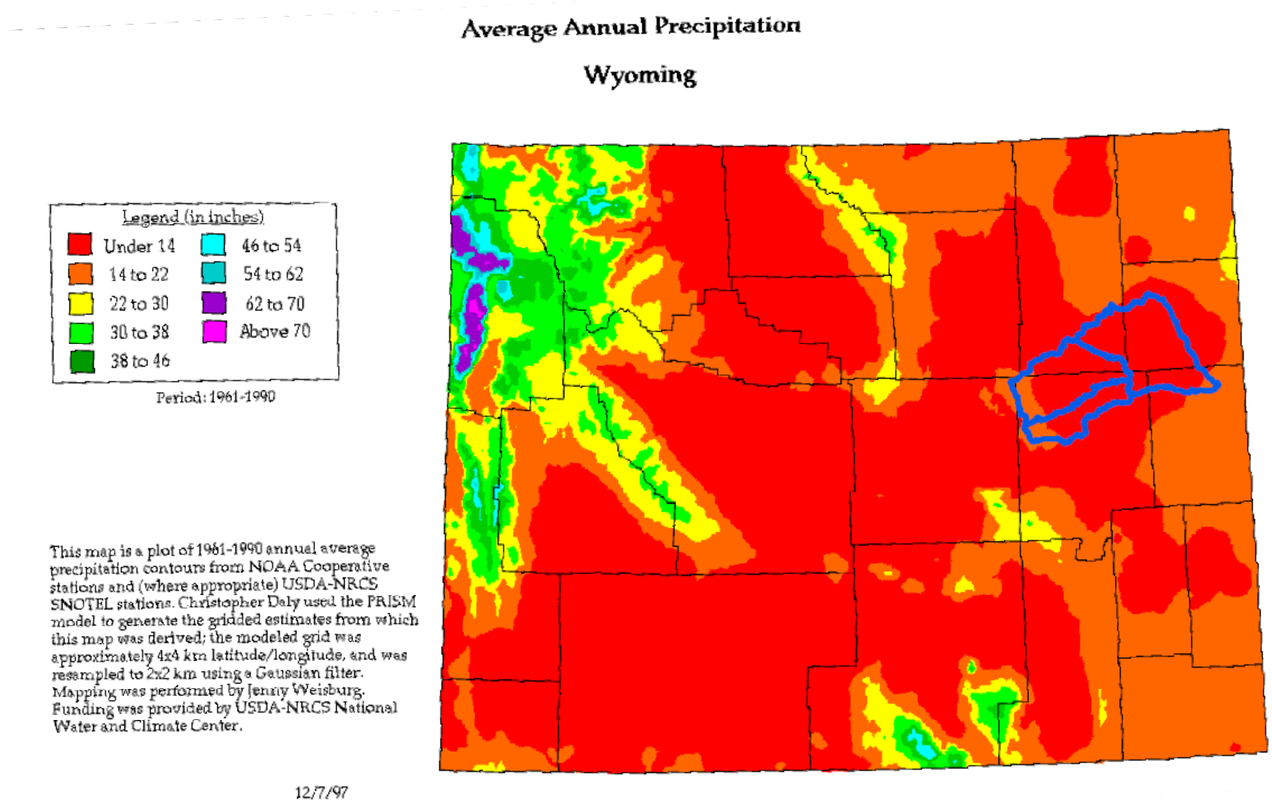


Figure 2.1.2-2 Average Annual Precipitation of Wyoming with Thunder Basin Watershed and the three subbasins in blue.

2.1.3 Vegetation and Land Cover

2.1.3.1 Overview

Vegetation of the Thunder Basin Watershed typically receives from 12 inches to 14 inches of annual precipitation on average, though portions average as little as 10 inches, and as much as 15 inches (WRCC 2008). Beyond these averages, periodic declines in moisture delivery are responsible for conditions of severe stress. Through periods of near average or greater moisture availability, mid-grasses are visually and physically dominant. Shortgrass cover, primarily blue grama (*Bouteloua gracilis*) is minimal during these times but upon return of severe moisture stress and the decline of mid-grass cover, the shortgrass cover can become visually dominant.

A representation of generalized vegetation conditions of Wyoming including the study area has been made using satellite spectral imaging data by the Wyoming Gap Analysis Program (www.wygisc.uwyo.edu/wbn/gap.html). This Land Cover/Vegetation map is presented in Map 4. A more detailed evaluation of potential natural vegetation and the dynamics of plant communities necessary to understand the way they exist on the ground is available by using the soils-based description of ecological sites that has been completed by the NRCS. Ecological sites of the project area are depicted on Map 5.

The bulk of upland vegetation is comprised of plant communities in which grasses are predominant, biologically, and visually. In addition, especially in the uplands of the north-central, south central and far west portions, the grass component is joined by a substantial presence of big sagebrush (*Artemisia tridentata*, mostly subspecies *wyomingensis*). Shrub abundance varies both in response to substrates but also in response to range condition. Stress in the form of drought, or long-duration grazing, can encourage the establishment of shrubs, as grass competition is lessened. Based on state and transition model information presented in the NRCS Ecological Site Descriptions (ESDs), most ecological sites of the Thunder Basin area can be expected to come to experience greater shrub cover as the effects of stress, such as over-grazing, compound. It is important to note that grazing effects are likely not responsible for the presence of sagebrush in all cases. Extended drought is also an effective stressor. Some evidence also supports the view that sagebrush (and even abundant sagebrush) is a natural plant community component and not a vestige of stress, with abundance proportional to precipitation and snow cover (WGFD 2009).

Using a conceptual model of vegetational change -- known in ecological and range science as plant succession, USFS 2007 found that less than 10 percent of the Thunder Basin National Grassland area (comprising approximately two-thirds of the study area) had proceeded to the oldest ("late seral") stage in which big sagebrush was highly abundant. Slightly more than one-third, on average, was in a less-developed intermediate stage with moderate shrub presence. Slightly more than one-half of the area was deemed to be in a relatively young stage, to intermediate stage, with comparatively little shrub presence. The latter areas may include areas from which sagebrush had been cleared by fires -- with or without human involvement -- or otherwise removed in cultivation or active range management. Regarding the latter, the history of homesteading and range improvement in the area has left scattered small areas of old or "go-back" fields that often after cultivation were planted to crested wheatgrass (*Agropyron desertorum*). Typically, these areas subsequently have been invaded by native species, sometimes including big sagebrush.

Of the upland grassland and shrub-steppe vegetation, USFS 2007 identifies the following major plant community segregates:

- Artemisia tridentata (Wyoming big sage)/ Bouteoua gracilis (blue grama) – Pascopyrum smithii (western wheatgrass).
- Artemisia tridentata / Pascopyrum smithii
- Bouteloua gracilis – Carex filifolia (threadleaf sedge)
- Hesperostipa comata (needle-and-thread) - Bouteloua gracilis

Besides the species included in the above community names, grasses including Junegrass (*Koeleria macrantha*) and various bunch bluegrasses (now collectively referable to *Poa secunda*, with common names including Sandberg bluegrass, Canby bluegrass, big bluegrass, and alkali bluegrass), as well as the grass-likes threadleaf sedge (*Carex filifolia*) and needleleaf sedge (*Carex duriuscula*) are common. On sandier sites, silver sagebrush (*Artemisia cana*) and Spanish bayonet (*Yucca glauca*) may be common. Perennial forbs are numerous but not usually abundant and such species as cowboy's delight (scarlet globemallow, *Sphaeralcea coccinea*), American vetch (*Vicia americana*), scarlet gaura (*Gaura coccinea*), Hood's phlox (*Phlox hoodii*), and silverleaf scurfpea (*Psoralidium argophyllum*) are commonly present. Numerous annual plants are present, though highly variable in abundance depending on the moisture pattern of a given year. These plants include native species such as Indian plantain (*Plantago patagonica*), narrowleaf collomia (*Collomia linearis*), false pennyroyal (*Hedeoma hispida* and *H. drummondii*), and six-weeks fescue (*Vulpia octoflora*) in addition to non-native species such as allysum (mostly *Allysum desertorum*), Japanese brome (*Bromus japonicus*) and cheatgrass (downy brome, *Bromus tectorum*). The latter two species are winter annual plants that typically germinate in late summer and fall. They are often sufficiently abundant to compete with, and significantly reduce, the productivity of the native perennial species. This competitive advantage apparently is mediated by their early establishment and pre-emptive use of moisture and perhaps nutrient resources during the early growing season. Although palatable during early growing season, their presence in the plant community is regarded as a negative because of limited later season palatability, added fire hazard, and displacement of perennial plants.

Minor plant community components of the basin area include localized areas (Map 4, Land Cover/Vegetation) of ponderosa pine (*Pinus ponderosa / Pseudoroegneria spicata*) woodland (as well as salt-affected sites that support greasewood (*Sarcobatus vermiculatus*/ *Pascopyrum smithii - Bouteloua gracilis*) or desert sub-shrubs such as Gardner saltbush (*Artiplex gardneri*) or Birdsfoot sage (*Artemisia pedatifida*).

2.1.3.2 Targeted Vegetation

Vegetational components that have particular importance with respect to water resources of the Thunder Basin Water Management Area include the phreatophytic Russian olive (*Elaeagnus angustifolia*) and salt cedar (*Tamarix chinensis*), both of which are listed noxious weeds in Wyoming. These non-native shrubs / small trees are known to access stored moisture at great depth and to transpire large amounts, diminishing both groundwater availability and stream flows. Areas densely infested with salt cedar may be capable of removing from the soil (and losing through leaves and stems) 2.1 cubic meters per square meter per year (Horton and Campbell 1974). This rate translates to approximately 6.9 acre feet per acre per year.

Salt cedar is capable of establishing, far from known occurrences, in areas with only the slightest moisture accumulation. The USFS (2007) states that salt cedar is established in the Cow Creek and Red Hills areas and has recently begun to appear on Antelope Creek and the Cheyenne River, as well as certain tributaries.

Russian olive has been present in the basin for decades, having survived from early farmstead plantings as isolated trees. This plant in other western U.S. drainage basins has exhibited a period of benign presence followed by a rapid radiation -- perhaps as a result of natural selection-based adjustment to the environmental particulars of the region. From available evidence, it would appear that a stage of rapid radiation has not begun in the study area. On-going control of both salt cedar and Russian olive by the Thunder Basin Grazing Association may have been effective in controlling the onset of rapid expansionof young Russian olive or salt cedar on Antelope Creek and the Cheyenne River.

If allowed to proceed, new establishment of stands of Russian olive and salt cedar can produce dense thickets. This will, in turn, increase phreatophytic depletion of massive amounts of shallow groundwater (with direct connection to surface water). Besides the loss of water, the dense thickets can be expected to shade out and out-compete previously existing riparian species, including the native cottonwoods (*Populus deltoides*) and willows (*Salix* spp.). There also has been speculation that the federally listed threatened species Ute Ladies-tresses

(*Spiranthes diluvialis* ; isolated occurrences documented in Converse, Goshen, Laramie and Niobrara Counties.) could be affected as thickets of woody species develop (Bonnie Hiedel, Wyoming Natural Diversity Database as cited in USFS, 2007).

Other noxious weeds present in the study area include Canada thistle (*Cirsium arvense*), Russian knapweed (*Centaurea repens*), spotted knapweed (*Centaurea maculosa*), hoary cress (*Cardaria* spp), Dalmation toadflax (*Linaria genistifolia* ssp. *dalmatica*), burdock (*Arctium minus*), houndstongue (*Cynoglossum officinale*), and leafy spurge (*Euphorbia esula*). The most abundant and the one most typical of moisture accumulation sites is Canada thistle. To the extent that any of these noxious weeds displace diverse native plant communities to form extensive monocultures, they may not only diminish livestock and wildlife forage values, but they may negatively influence watershed function.

2.1.4 Soils

Soil surveys have been completed across the entire Thunder Basin and are available online by the NRCS (http://SoilDataMart.nrcs.usda.gov/). Map 6 illustrates the STATSGO (STATe Soil GeOgraphic) Soil Survey as prepared by the NRCS and Table 2.1.4-1 lists the acreages associated with each soil type. Additionally, the SSURGO (Soil SURvey GeOgraphic) Soil Survey data is incorporated in the GIS dataset included electronically with this report. The SSURGO Soil Survey map is too detailed to show at the scale of the maps in this report.

Table 2.1.4-1 Thunder Basin Watershed STATSGO Soil Types

Soil Type	Acres	Percent
Draknab-Clarkelen (s9067)	125,671	7%
Orpha-Dwyer (s9069)	3,967	0%
Renohill-Cushman-Cambria (s9001)	3,089	0%
Rock outcrop-Redsun-Hazton (s9171)	11,771	1%
Shingle-Hiland (s9073)	305,699	16%
Shingle-Samday-Hiland (s9072)	84,305	4%
Taluce-Shingle-Cushman (s8932)	217,277	11%
Tassel-Hiland-Bowbac (s9071)	203,143	11%
Tassel-Shingle-Rock outcrop (s9075)	158,516	8%
Theedle-Kishona-Cambria (s9643)	747	0%
Turnercrest-Forkwood-Cushman (s8933)	2	0%
Turnercrest-Terro-Tassel (s8987)	255,154	13%
Ulm-Renohill (s9074)	186,876	10%
Ulm-Renohill-Forkwood-Cushman-Bidman (s9003)	45,927	2%
Ustic Torriorthents-Hiland-Bowbac (s9068)	69,115	4%
Wibaux-Shingle-Badland (s9642)	53,291	3%
Wibaux-Shingle-Rock outcrop (s9070)	59,892	3%
Wibaux-Teckla-Bidman (s9629)	65,885	3%
Wibaux-Wags-Hilight (s9641)	49,644	3%
Total	**1,899,971**	**100%**

As stated in the dataset description for the NRCS SSURGO Soil Survey map, the data set is a digital soil survey and generally is the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. The information was prepared by digitizing maps, by compiling information onto a planimetric correct base and digitizing, or by revising digitized maps using remotely sensed and other information. The data set consists of a detailed, field verified inventory of soils and miscellaneous areas that normally occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The SSURGO Soil Survey map depicts information about the kinds and distribution of soils on the landscape. The soil map and data used in the SSURGO product were prepared by soil scientists as part of the National Cooperative Soil Survey.

Both the STATSGO and SSURGO Soil survey interpretations predict soil behavior for specified soil uses and under specified soil management practices. For the purposes of this study, they assist the planning of broad categories of land use such as cropland, rangeland, and pastureland. Soil survey interpretations also help plan specific management practices that are applied to specific soils, such as irrigation of cropland, or equipment use. Soil interpretations use soil properties and qualities that directly influence a specified use of the soil. These properties and qualities include: (1) site features, such as slope gradient; (2) individual horizon features, such as particle size; and, (3) characteristics that pertain to soil as a whole, such as depth to a restrictive layer. Data Summary 2.1.4-1 (In Appendix A) lists the specific soil properties and qualities available on the soil associations and specifies the report containing the tabular data.

As described in the Powder River Basin Oil and Gas Final Environmental Impact Statement, (BLM, 2003), soils within the Thunder Basin watershed have developed in residual material and alluvium in a climatic regime characterized by cold winters, warm summers, and low-to-moderate precipitation. The upland soils are derived from both residual material (derived from flat-lying, interbedded sandstone, siltstone, and shale) and stream alluvium. Valley soils have developed in unconsolidated stream sediments including silt, sand, and gravel.

Soils in the Thunder Basin watershed are generally low in organic matter and are alkaline (Lowry et al. 1986). Textures range from clay loams to sandy loams with varying amounts of gravel or coarser materials. Slopes range from nearly level to very steep with deeper soils found in the less steeply sloping areas. These soils support little crop agriculture except in irrigated valleys of perennial streams. Across Thunder Basin the predominant land use is rangeland and the vegetation developed on the soils is predominantly grass and shrubs.

2.1.5 Geology

The following five subsections (Surficial Units, Bedrock Units, Structural Features, Slope Stability and Seismotectonics) describe the overall geologic framework of the Thunder Basin watershed.

2.1.5.1 Surficial Units

Map 7 illustrates the surficial geology of the Thunder Basin watershed. Surficial deposits across the watershed are divided into three distinct types: 1) Bedrock, residuum and mined areas; 2) River Valley Deposits; and, 3) Upland Deposits. The important aspect of each of these deposits as it pertains to this watershed study is explained here.

Most of the surficial geologic material across Thunder Basin watershed is described in the Surficial Geology map as residuum with eolian and alluvium. Residuum refers to material eroded from bedrock and specifically, eolian refers to windblown deposits and alluvium to materials deposited by water. The residuum deposits are composed of fine clay, silt, and sand ranging up to coarse sands and gravels.

The red clinker deposits, found primarily in the central portion of the watershed, are significant to this watershed study in two distinct aspects: water storage and wildlife habitat. As described in the Powder River Basin Environmental Impact Statement (BLM, 2003):

> *"Generally, clinker consists of fractured rock on a base of porous ash. Semipermeable clay frequently underlies clinker formations (Heffern and Coates 1999). This structure allows clinker to absorb, store, and transfer large amounts of water. The quality of water from clinker aquifers is highly variable but in general, Total Dissolved Solids (TDS) values are lower for older formations (Heffern and Coates 1999). The irregular terrain of clinker formations provides a unique habitat for plant and animals species that would otherwise not survive on the treeless plain (Heffern and Coates 1999). Clinker is not considered a valuable agricultural soil and has a very poor revegetation potential".*

The clinker is resistant to erosion and therefore is found on elevated, exposed surfaces of the basin such as the Rochelle Hills. More information will be provided regarding clinker deposits in Section 2.1.6.3, Springs. The remaining exposed bedrock and mined areas are described in more detail in Sections 2.1.5.2, Bedrock Units.

The river valley deposits are significant to the watershed study because they represent a significant source of surface and groundwater. The deposits include combinations of alluvium, alluvial fan, alluvial terrace, and slopewash material that is typically coarser-grained than the eolian materials. The coarse-grained nature of the deposits provides for increased infiltration and recharge to alluvial aquifers described in more detail in Section 2.1.6.1, Alluvial Aquifers.

The upland deposits include a significant area west of the clinker deposits in the central portion of the watershed. The predominant component of these deposits is eolian, with scattered alluvium. Slopewash with colluvium is mapped along the steeper slopes in the western portion of the watershed.

2.1.5.2 Bedrock Units

The four shallow bedrock units that directly underlie the surficial deposits, or are exposed in isolated outcrops and along ridges/slopes of Thunder Basin (Map 8, Bedrock Geology), have played an important role in soil formation and other geomorphologic processes. The four shallow bedrock units from youngest to oldest include:

- Tertiary Wasatch Formation
- Tertiary Fort Union Formation; Lebo member
- Tertiary Fort Union Formation; Tullock member
- Cretaceous Lance Formation

The Wasatch Formation of Eocene age consists of fine- to coarse-grained, lenticular sandstone interbedded with shale and coal (Hodson, 1973). The sandstone units sandwiched between the thick coal beds are the primary aquifers of the Wasatch Formation. The formation is up to 1,600 feet thick (HKM, 2002).

The Fort Union Formation (Paleocene age) was deposited by northeastward-flowing river systems consisting of braided and meandering streams in the basin center that were fed by alluvial fans associated with uplift on the margins of the basin. The Fort Union ranges from 2,300 feet to 6,000 feet in thickness (Curry, 1971) and is subdivided into three members; 1) Tullock, 2) Lebo, and 3) Tongue River. The members consist of interbedded sandstones, siltstones, claystones, mudstones, carbonaceous shales, and rare limestones. The Lebo and Tullock members have thin coal beds (Curry, 1971).

The Cretaceous Lance Formation is also continental in origin with sandstones, siltstones and claystones. The Lance Formation is 1,600 feet to 3,000 feet in thickness in the southern portion of the Powder River Basin (Feathers et al, 1981). The Lance Formation is stratigraphically below and older than the Wasatch and Fort Union Formations (Brown, 1993).

2.1.5.3 Structural Features

Thunder Basin watershed lies within the northwest-southeast trending structural basin that was filled with sediments of continental origin eroded and transported from the surrounding uplifted margins (Brown, 1993). The Powder River Basin formed approximately 60 million years ago (Glass and Blackstone, 1996) during the Laramide Orogeny, which was the mountain-building event that formed the Rocky Mountains. The margins of the basin are asymmetrical with the western margin closer to the axis than the eastern margin. Rock layers dip gently several degrees throughout much of the basin, however, dips steepen significantly to the east and west of Thunder Basin along the margins of the Powder River Basin. A generalized geologic cross section across the Powder River Basin is shown in Figure 2.1.5-1. Note that this cross section is northwest of Thunder Basin but is indicative of the structural features within the study area.

The significance of the structural basin that defines this area of northeast Wyoming cannot be overstated. The tectonic events of the Laramide Orogeny affected the outcrop patterns which influenced soil development, aquifer and groundwater movement, and oil, gas, coal, and methane deposits, as well as the topographic relief of the area.

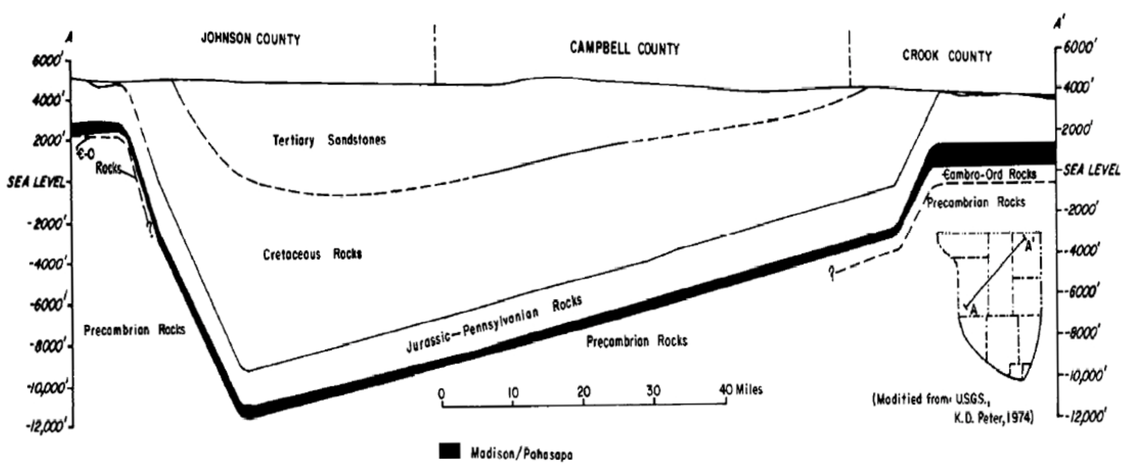


Figure Source: Wyoming State Engineer's Office, 1976

Figure 2.1.5-1 Generalized Cross Section across the Powder River Basin.

2.1.5.4 Slope Stability

According to the WSGS, landslides (often called mass wasting) occur when a slope becomes unstable. Rock falls, debris flows, slumps, and creep are all types of landslides. Landslides can cause considerable damage: they can cover or destroy roads, carry houses downslope, and temporarily block rivers with unstable earthen dams, which cause flash-flooding downstream when compromised. The WSGS has mapped more than 30,000 landslides in Wyoming, and maintains a database of these locations. Landslides of significant size or scale have not been mapped in the Thunder Basin Watershed. Although not mapped, there are known landslides in both the Red Hills and Rochelle Hills of Thunder Basin. A persistent landslide n the Rochelle Hills has permanently closed a section of Forest Service Road 933. As illustrated in Map 9 Landslides, landslides have been mapped to the northwest of the watershed in the steep slopes in southwest Campbell County.

The lack of WSGS mapped landslides within the Thunder Basin watershed does not relieve project sponsors from evaluating the hazards of slope instability on specific sites prior to project implementation. Small, localized, slope failures can occur along the banks of active channels. Slope instability increases during times of material saturation accompanying storm events when undercutting of stream banks is most intense. For this reason, watershed improvement projects should include site-specific geologic hazard analyses, including an evaluation of the site's susceptibility to landslides.

2.1.5.5 Seismotectonics

According to the WSGS, earthquakes happen in Wyoming every day, but are rarely strong enough to be felt. Most earthquakes occur in western Wyoming, particularly in the northwestern corner (Yellowstone National Park); however, earthquakes occur and are felt in the eastern half of the state, as well. For example, there have been 29 historic earthquakes recorded in Converse County with magnitudes greater than 3.0; five greater than 3.0 in Weston; seven greater than 2.5 in Campbell; and, eight greater than 3.0 in Niobrara County. The WSGS has published seismology characteristics for the entire Thunder Basin watershed that are published by county and are available on the WSGS Web site:
http://www.wrds.uwyo.edu/wrds/wsgs/hazards/quakes/seischar/seischar.html

Watershed improvement projects that involve significant disturbance or construction efforts should include site-specific geologic hazard analyses including a seismotectonic evaluation.

2.1.6 Groundwater

Groundwater in Thunder Basin flows within the interstitial pore spaces of shallow alluvial sediments described in the Surficial Units section of this report and within the rock materials described in the Bedrock Units section of this report. The following subsections provide more information on the quantity and quality of groundwater available in the two specific aquifer types, as well as from the springs that discharge groundwater to the surface. The physical properties such as hydraulic conductivity and transmissivity, as well as the chemical composition of the aquifer materials, are important to establish so that productive and high-quality groundwater wells can be proposed for watershed improvement projects.

2.1.6.1 Alluvial Aquifers

Alluvial aquifers occur in the stream-valley alluvium located along rivers and major drainages. Map 7 illustrates the location of the alluvial streambed deposits in Thunder Basin. Whitehead (1996) described the aquifer materials comprising the alluvial aquifers in the area as unconsolidated deposits of silt, sand, and gravel occurring in floodplains, stream terraces, and alluvial fans. In general, coarser materials occur within the Cheyenne River drainage and mostly-fine to medium-grained materials overlies the Tertiary Formations in the remaining portion of the basin (Hodson et al, 1973). The thickness of the alluvial deposits is not entirely known because of the variability inherent in alluvial depositional environments. For the entire Powder River Basin, the alluvial aquifers are generally less than 50 feet in thickness but can be as thick as 100 feet in some valleys west of Thunder Basin, along the margins of Powder River Basin (Hodson et al, 1973). Another report of groundwater characteristics describes the alluvial deposits as commonly 30 feet, with a maximum measured thickness of 100 feet (Wells, 1982).

At this time, the number of alluvial wells versus bedrock wells completed in the Thunder Basin is not known. However, estimates can be made based on well location, well completion depth, and well yield. Using Map 7, Surficial Geology and the well depths registered with the WSEO, there are 159 wells within the mapped extent of River Valley alluvium deposits with well depths of less than 50 feet. The well yield for the wells ranges up to 50 gallons per minute (gpm). This provides an estimate of the number of alluvial wells; however, until the state engineer's office requires well completion information that includes the geologic unit, an accurate count is not known.

Water quality of the aquifers within the Powder River Basin is described in Bartos and Ogle, 2002 and Rice et al, 2002. The authors subdivide the primary aquifers as shallow (200 feet to 500 feet) to deep (more than 500 feet). The shallow groundwater system exhibited a chemically dynamic system with localized flow consisting of groundwater with a mixed composition of ions. The shallow system was described as containing calcium, magnesium, and lesser amounts of sodium cations (positively charged ions), and bicarbonate or sulfate, as the dominant anions (negatively charged ions). The deeper system is chemically static and exhibits regional flow patterns, with sodium and bicarbonate as its dominant ions. Additional information on the water quality aspects of the bedrock aquifers is described below.

2.1.6.2 Bedrock Aquifers

The groundwater contained in the bedrock units of the Thunder Basin area has been studied and described by numerous authors. The bedrock aquifers are part of the Northern Great Plains aquifer system that has been described as, "an extensive sequence of aquifers and confining units arranged in a stack of layers that may be discontinuous locally but that functions regionally as an aquifer system" (BLM, 2003). In Thunder Basin, the aquifer system includes specifically the Tertiary aquifers exposed at the surface, as well as the deeper regional aquifers within older sedimentary rocks deposited during the Upper and Lower Cretaceous and Paleozoic (Whitehead, 1996). Data Summary 2.1.6-1 (in Appendix A) summarizes information on the bedrock aquifers. For the purposes of this report, the following major aquifer systems will not be discussed because they do not occur within the Thunder Basin watershed or are too deep and would be too costly to complete and maintain for livestock/wildlife and irrigation purposes:

- Middle Tertiary Aquifer (Arikaree Formation)
- Dakota Aquifer System (Newcastle, Fall River and Lakota Formations)
- Madison Aquifer System (Madison and various carbonate Formations)

The following summarizes information from Data Summary 2.1.6-1 (in Appendix A) on the well yield, general water quality, and water supply uses for the remaining bedrock aquifers within Thunder Basin:

- The **Wasatch Formation** yields generally less than 15 gpm with higher yields (up to 500 gpm) recorded. Some Wasatch wells flow under artesian conditions (HKM, 2002). The TDS content ranges from less than 200 milligrams per liter (mg/l) to greater than 8,000 mg/l (Hodson et al, 1973). Wells completed in the Wasatch Formation are used for municipal/public, domestic and stock water supplies.
- The **Fort Union Formation** yields generally 1 gpm to 60 gpm with higher yields recorded along with significant drawdown. Water quality is similar to the Wasatch Formation as these two units often are grouped into the Fort Union/Wasatch Aquifer System. Wells completed in the Fort Union Formation are used for municipal/public, domestic and stock water supplies.
- The **Lance Formation** is part of the Fox Hills/Lance Aquifer System. The Lance Formation yields up to 350 gpm but with large drawdowns. TDS content from outcrops north of Niobrara County range from 1,500 mg/l to 3,000 mg/l, with fluoride enrichment characteristic and high sodium and radionuclide content in specific areas especially near uranium mines. Wells completed in the Lance Formation are used for municipal/public, domestic and stock water supplies.

2.1.6.3 Springs

Map 10, Springs, illustrates the location of springs and seeps as mapped by the USGS. There are likely many more developed and undeveloped springs in the watershed that are not represented by the map. Additional mapping of the springs in Thunder Basin would provide a better understanding of the existing water resources of the watershed.

Springs represent a location where the groundwater table intersects the ground surface. In Thunder Basin this often occurs in association with clinker units. Clinker has an important role as an aquifer, in the storage and flow of water, and it also is the source of discharge for numerous springs in the watershed. Precipitation, in the form of both rainfall and snowmelt infiltrates the porous clinker units. The stored water is discharged slowly through springs, as well as streams, and aquifers which, in turn, help maintain flow in perennial streams (Heffern and Coates, 1999). Since many of the springs in Thunder Basin are associated with the clinker units, which are dependent on precipitation for recharge, it is not surprising that many of the landowners remarked that their springs have been drying up, or had experienced reduced flows, during the same period of extended drought conditions in the area.

2.1.7 Surface Water Hydrology

2.1.7.1 Hydrologic Regions and Stream Types

The Thunder Basin watershed is comprised of three main watersheds: the Antelope Creek, Dry Fork Cheyenne River, and the Upper Cheyenne River watersheds. The downstream limit of the study area is upstream of the Cheyenne River's confluence with Lance Creek (Map 1). Map 11, Watershed Hydrologic Features, shows a more detailed breakdown of watershed areas, along with their hydrologic unit codes (HUC). A listing of the hydrologic unit codes is included as Data Summary 2.1.7-1 in Appendix A.

The southwestern portion of the Thunder Basin watershed lies within the Eastern Basins and Eastern Plains Region and the northeastern portion of the watershed lies within the Central Basins and Northern Plains Region as designated by Miller (2003). These regions are shown in Map 11, Watershed Hydrologic Features. The Central Basins and Northern Plains Region includes the Bighorn Basin and the plains of northeastern Wyoming, the latter of which is representative of the study area. Miller describes these areas as semiarid to arid, characterized by grasslands, shrublands, and some open woodlands. Measured annual peak flows are characterized by large year-to-year variability since annual peak flows generally are caused by moderate, to very intense, localized convective rainstorms.

The Eastern Basins and Eastern Plains Region, inclusive of the southwest portion of the Thunder Basin watershed, is characterized by semiarid grasslands. Annual peak flows are generally larger than annual peak flows for the Central Basins and Northern Plains Region. Precipitation characteristics and the resulting variability in annual peak flows are similar in both of these regions.

The U.S. Army Corps of Engineers (USACE) (2000) defines different stream regimes as follows: A perennial stream has flowing water year-round during a typical year. The water table is located above the streambed for most of the year. Groundwater is the primary source of water for stream flow. Runoff from rainfall is a supplemental source of water for stream flow. An intermittent stream has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water. Runoff from rainfall is a supplemental source of water for stream flow. An ephemeral stream has flowing water only during, and for a short duration after, precipitation events in a typical year. Ephemeral streambeds are located above the water table year-round. Groundwater is not a source of water for the stream. Runoff from rainfall is the primary source of water for stream flow.

Based on the National Hydrography Dataset (NHD) dated December 31, 2005, within the study area, only the lower portion of the Cheyenne River, downstream of Snyder Creek, is considered to be a perennial stream. The larger tributaries are considered to be intermittent. They include Antelope Creek, Bates Creek, Bear Creek, Black Thunder Creek, and Cheyenne River above Snyder Creek, Dry Fork Cheyenne River, Hay Creek, Little Thunder Creek, Lodgepole Creek, North Fork Bear Creek, Porcupine Creek, Sand Creek, Snyder Creek, and Wildcat Creek. The remaining tributaries are considered to be ephemeral streams.

2.1.7.2 Existing Lakes and Reservoirs

There are no natural lakes of significant size in the Thunder Basin watershed. Wetlands and small areas with water do occur in the watershed, as shown in Map 12, National Wetlands Inventory Map, and described in Section 5.0.

According to the National Inventory of Dams (NID), there are 67 dams within the Thunder Basin study area. Map 13, National Inventory of Dams, shows the locations of the dams. The state engineer's office referred to the NID Web site upon being contacted regarding information about existing dams. The combined storage behind the identified dams is 19,741 acre-feet. The largest identified reservoir, Betty Reservoir, holds 2,029 acre-feet. The median reservoir size is 130 acre-feet. The dam inventory includes at least one dam that was known to have been breached. Dams that do not fall under the jurisdiction of the state engineer's office are not included in the database.

The study area contains numerous small impoundments and stock watering ponds, which are shown in Map 14, Stock/Wildlife Ponds. Approximately 194 stock ponds are represented in the map. These stock ponds represent permitted ponds with uses identified as stock ponds.

2.1.7.3 Gaging/Sampling Stations

Map 15, Gaging Stations and Streamflow/Sampling Sites, shows surface water gaging stations and sampling locations, as well as groundwater, spring, and lake/reservoir observation stations. Within the Thunder Basin Watershed, there are one active and six historic USGS streamflow gaging stations, as shown in Map 15. In addition, there are 17 miscellaneous sampling, streamflow sites, and/or temporary gages identified in the study area. Detailed information regarding these sites is available at http://waterdata.usgs.gov/wy/nwis/si.

USGS Gage 06364300, Porcupine Creek near Teckla, Wyoming, is on a tributary of Antelope Creek immediately upstream of a current mining operation. The reported drainage area is 78.6 square miles. The period of record for flow data is June 9, 2003 to July 31, 2006. Streamflow and water quality data for this gage can be found at the following Web site:
http://nwis.waterdata.usgs.gov/wy/nwis/inventory/?site_no=06364300&;

USGS Gage 06364700, Antelope Creek near Teckla, Wyoming, is approximately 1,700 feet downstream of Porcupine Creek's confluence with Antelope Creek. The reported drainage area is 959 square miles. The period of record for flow data is Sept. 8, 1977 to Sept. 30, 1981. Streamflow and water quality data for this gage can be found at the following Web site:
http://nwis.waterdata.usgs.gov/wy/nwis/inventory/?site_no=06364700&;

USGS Gage 06365300, Dry Fork Cheyenne River near Bill, Wyoming, is approximately 34 miles upstream of the confluence with the Cheyenne River. The drainage area is reported to be 128 square miles. The period of record for flow data is Nov.1, 1976 to Sept. 30, 1987. Streamflow and water quality data for this gage can be found at the following Web site:
http://nwis.waterdata.usgs.gov/wy/nwis/inventory/?site_no=06365300&;

USGS Gage 06365900, Cheyenne River near Dull Center, Wyoming, is the only active gage in the study area. It is about 1 mile downstream of the confluence of Antelope Creek and the Dry Fork of the Cheyenne River. The drainage area is reported to be 1,527 square miles. The period of record for flow data is April 1, 1976 to present, however the record is not continuous. Generally data is available for April 1976 to September 1981, October 1985 to September 1987, July 2004 to September 2005, and, October 2006 to present. There are no major reservoirs upstream of the gaging station other than Betty Reservoir, which should not significantly affect the flows at the gaging station. At least two mining operations are located upstream of the gage along Antelope Creek and its tributary. Streamflow and water quality data for this gage can be found at the following Web site:
http://nwis.waterdata.usgs.gov/wy/nwis/inventory/?site_no=06365900&

USGS Gage 06375600, Little Thunder Creek near Hampshire, Wyoming, is approximately 3 miles upstream of its confluence with Black Thunder Creek. The reported drainage area is 234 square miles. The period of record for flow data is Sept. 7, 1977 to Dec. 31, 1997. Streamflow and water quality data for this gage can be found at the following Web site: http://nwis.waterdata.usgs.gov/wy/nwis/inventory/?site_no=06375600&;

USGS Gage 06376300, Black Thunder Creek near Hampshire, Wyoming, is more than 6 miles upstream of its confluence with the Cheyenne River. The reported drainage area is 535 square miles. The period of record for flow data is Oct. 1, 1972 to Sept. 30, 1990. Streamflow and water quality data for this gage can be found at the following Web site:
http://nwis.waterdata.usgs.gov/wy/nwis/inventory/?site_no=06376300&;

USGS Gage 06378300, Lodgepole Creek near Hampshire, Wyoming, is approximately 8.4 miles upstream of its confluence with the Cheyenne River. The drainage area is approximately 348 square miles. The period of record for flow data is Sept. 7, 1977 to Sept. 30, 1981. Streamflow and water quality data for this gage can be found at the following Web site: http://nwis.waterdata.usgs.gov/wy/nwis/inventory/?site_no=06378300&

2.1.7.4 Stream Flow Characteristics

Most streams originating in the basins or plains areas of Wyoming are ephemeral, flowing only as a result of local snowmelt or intense rainstorms. Intense localized convective rainstorms can produce most of the total flow for any given year in these watersheds (Miller, 2003). As seen in Figure 2.1.7-1, most of the gages listed above show the majority of flow occurring between March and August with peaks generally occurring in May and March. Flows occurring in May account for a significant percentage of the annual flow at the following gages: 06364700 (50 percent), 06365900 (48 percent), 06375600 (59 percent), 06376300 (31 percent), and 0678300 (48 percent). The streamflow distributions reflect snowmelt and spring rainstorm events. The lower reaches of Dry Fork Cheyenne, Antelope Creek, and Upper Cheyenne maintain perennial flow from groundwater and springs, as discussed in Section 2.1.8.3.

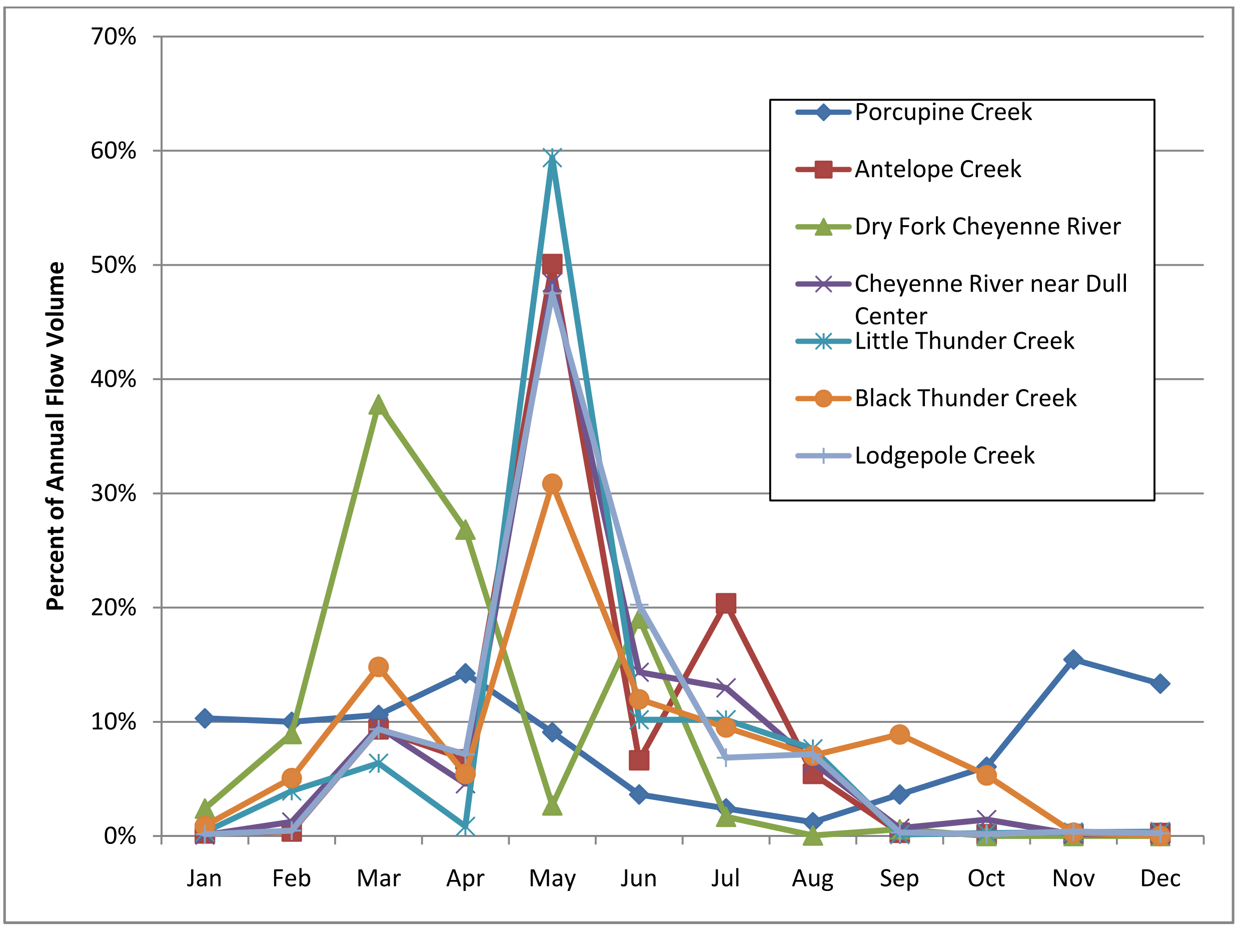


Figure 2.1.7-1 Average Flow Per Month for Rivers and Creeks in Thunder Basin

The annual distribution for Porcupine Creek near Teckla, Wyoming (USGS Gage 06364300), as seen in Figure 2.1.7-1, shows more consistent flows throughout the year, indicating base flows likely are more prevalent in the creek. Decreased flows June through October indicate either typical, drier conditions or less base flow due to pumping of wells. The period of record for this gage is short and occurred during the drought, so the data might not represent a typical year.

Cheyenne River near Dull Center (USGS Gage 06365900) has records starting in 1976 and carrying through to the present. Mean annual discharges, shown in cubic feet per second (cfs) in Figure 2.1.7-2 reflect the drought that has occurred after 2000, with very low flows for water years 2004 to 2006. The figures also include water year 1978, which was the wettest on record.

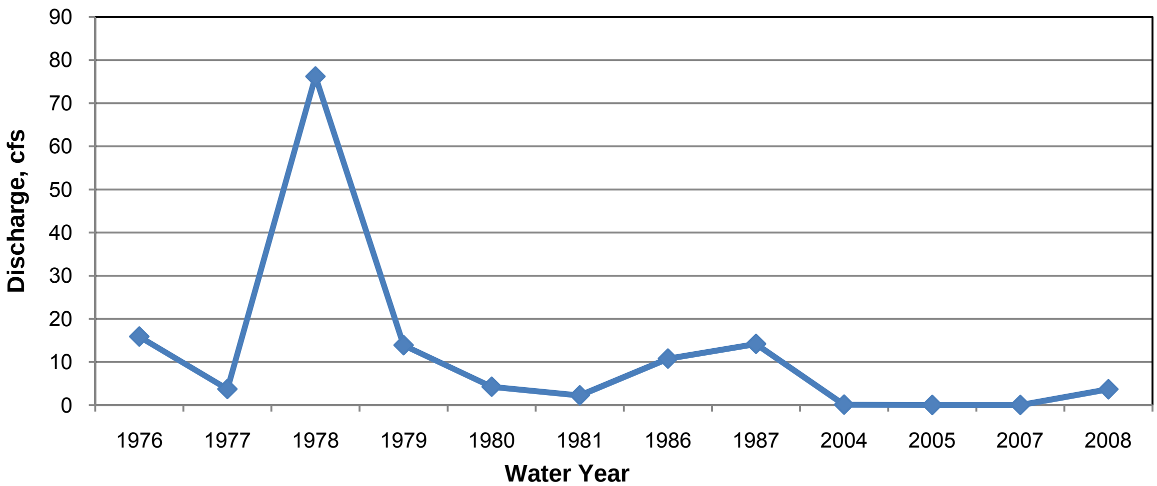


Figure 2.1.7-2 Mean Annual Discharge from Cheyenne River at Dull Center in CFS.

As seen from the previous sections, the data for this area, especially long-term data is limited, particularly on tributaries to the Cheyenne River. In areas where future projects are being considered, it is recommended that additional stream gages be installed to better understand the streamflow characteristics and quantities. Adding stream gages will enable better estimates of potential watershed yield and timing of flows.

2.1.8 Stream Geomorphology

The following section provides information on the stream geomorphology of Thunder Basin. Fluvial geomorphology is the study of how land is formed under the processes associated with running water. Over time, a natural stream channel at a given location establishes a cross section and planiform that reflect the quantity of water and the quantity and characteristics of sediment delivered to it from the drainage basin, as well as the imposed topography and local geologic conditions. Neither the water supplied (discharge) nor the quantity and distribution of sizes of the sediment load are delivered to the channel at a constant rate. All are subject to the variations of weather and climate, which dictate the magnitude, timing, and frequency of the range of flows and sediment, delivered to a given channel reach. Thus, the channel experiences varying sequences of low and high flows, depending on runoff from the drainage basin. Largely due to the varying runoff, the sediment supplied from the landscape and from sediments stored in, and adjacent to, the channel, varies as well (Emmett, Leopold, and Myrick, 1983).

Alluvial channels, like the ones in Thunder Basin, composed of sediments deposited by the river, are free to adjust their form, and to a lesser extent, their gradient. Because of this, over time, an alluvial river develops a cross section and shape reflecting the quantities of water and sediment and the sizes of sediment brought to it. While this form, in any given period responds to the variability of flow and sediment, observations of natural alluvial channels demonstrate that the channel, over time, develops a cross-sectional form reflecting an integration of these temporal variations. In general, channels have a cross-sectional area, width, and depth at bankfull discharge that is related to the range of flows capable of eroding and transporting the alluvial deposits constituting the channel boundaries. Bankfull discharge refers to the discharge when streamflow just begins to overtop the floodplain. The floodplain is defined as a relatively flat depositional surface, adjacent to the channel and constructed by the river in the present hydrologic regimen.

A variety of terms have been used to characterize stream and rivers flowing in alluvium, encompassing the concepts of adjustability and the tendency of a channel to develop a size and shape reflecting the range of flows and the quantity and characteristics of the sediment to which the channel is subjected. While erosion and deposition may take place, the channel neither aggrades (raises) nor degrades (lowers) its mean bed over time. The time scale is important because channel behavior may vary over different time scales, and over very long periods of geologic time, stable equilibrium is not maintained as the landscape is denuded or reduced in elevation. This is clearly evident by the existence of terraces, which, by definition, are abandoned floodplains from previous hydrologic regimes.

Many studies have generalized the observation that stream channels are larger where larger volumes of flow occur (Leopold, 1994). These concepts are fundamental to the discipline of fluvial geomorphology, as recorded by Leopold, Wolman, and Miller (1964), Emmett (1975), Schumm (1977), Dunne and Leopold (1978), Richards (1982), and Leopold (1994). Fluvial refers to rivers or features produced by river action. Geomorphology refers to that branch of both physiography and geology which deals with the form of the earth, the general configuration of its surface, and the changes that take place in the evolution of landforms. The adjustment of the channel size to the volume of through-flowing water was well-established by Leopold and Maddock (1953), in their concept of the hydraulic geometry of streams. Typically, the size of streams and rivers increases in the downstream direction, such that there is a relationship between drainage area at a given location and many channel size and streamflow parameters. Even so, the size of the stream channel is more directly related to discharge than drainage area (Emmett, 1975).

A variety of observations support the generalization that alluvial channels are adjustable and, over time, establish channel sizes and forms that are consonant with the flow and sediments available to them. In a given river reach, or length of stream, repeated measurements of cross sections of a channel reveal maintenance of the channel form as the river migrates across the valley floor (Leopold and Wolman, 1960).

It is commonly observed that many, if not most, alluvial rivers are subject to episodic floods; that is, the flow overtops the river banks and spills over the adjacent lands. Floodplains are formed by lateral movement of the channel and deposition of bars and by vertical accretion resulting from deposition of sediment by floods. To the extent that the adjacent land is the product of deposition by the existing river it is, by definition, a floodplain. The floodplain therefore is a flat area adjacent to the channel constructed by the river in the present hydrologic regimen. Deposits, and surfaces other than the floodplain, may exist on the valley floor. If they are alluvial, that is riverine in origin, they may constitute terraces (topographic surfaces) or terrace deposits laid down by the river under a different hydrologic regimen. Although there is some evidence to suggest that the bankfull stage, i.e., height of the floodplain, in many rivers corresponds to a discharge of constant frequency -- for example, every one to two years

(Wolman and Leopold, 1957; Emmett, 1975) variability is encountered among river sites in a given region and in different regions (Williams, 1978). Similarly, in some rivers, there is a close correspondence between flows during which much of the annual sediment load is transported (effective discharge) and the bankfull flow (Wolman and Miller, 1960).

Because many correlations have been demonstrated between discharge at the bankfull stage and channel features such as cross-sectional area, width, and depth, this discharge is sometimes referred to as the “channel forming” or “dominant discharge.”

Stream stability is morphologically defined as the ability of the stream to maintain, over time, its dimension, pattern, and profile, in such a manner that it is neither aggrading nor degrading and is able to transport without adverse consequence the flows and detritus of its watershed. Stable streams do, however, assume many combinations of dimension, pattern, profile, and materials within individual valley and geologic types. Due to the great diversity of these morphological features within rivers and streams, Rosgen (1994, 1996) developed a stream classification system by which to stratify and describe these various river types. The Rosgen Stream Classification System was utilized for this watershed study and is described in greater detail below.

2.1.8.1 Rosgen Classification System

The Rosgen Stream Classification System is a way of classifying and evaluating a stream system. The Rosgen system is widely accepted as the classification system of choice for watershed management activities. It is comprised of four levels, each being more detailed and site specific. Figure 2.1.8-1 shows the four inventory or assessment levels. Rosgen (2006) describes the following five objectives of this stream classification system:

- To predict a river’s behavior from its appearance, based on documentation of similar response from similar types for imposed conditions;
- To stratify empirical hydraulic and sediment relations by stream type by state (condition) to minimize variance;
- To provide a mechanism to extrapolate site-specific morphological data;
- To describe physical stream relations to complement biological inventory and assist in establishing potential and departure states; and
- To provide a consistent frame of reference for communicating stream morphology and condition among a variety of disciplines.

As part of the Thunder Basin watershed study a Level I Rosgen channel classification was completed. This basic level of stream classification is based on morphological characteristics that result from the integration of basin relief, landform, and valley morphology. This coarse-scale level uses dimension, pattern, and profile to make determinations. Level I criteria is typically determined from topographic maps, landform maps, and/or aerial topography. Table 2.1.8-1 shows the general stream type descriptions and delineative criteria for a Level I classification.

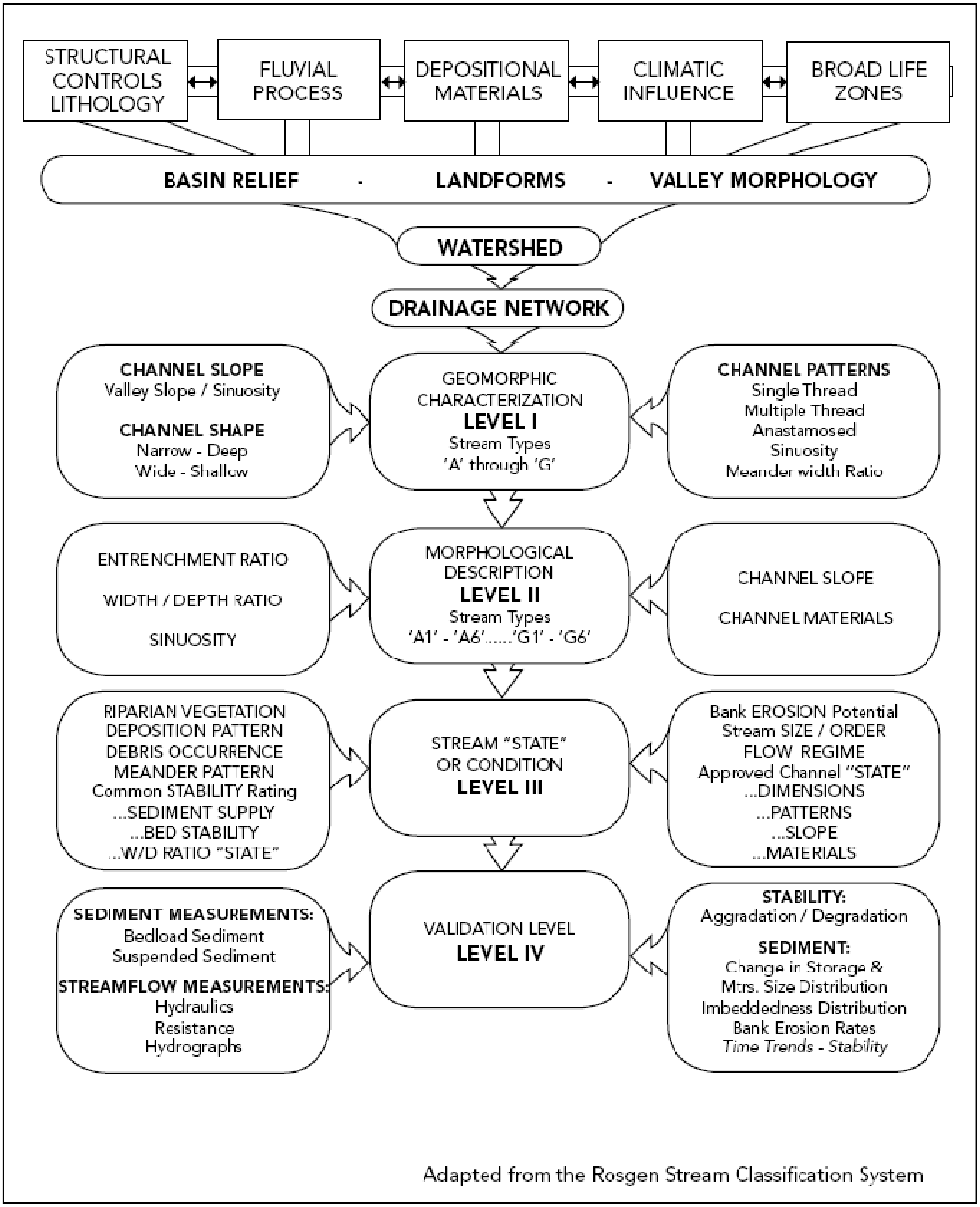


Figure 2.1.8-1 Rosgen Stream Classification System

Table 2.1.8-1 General Stream Type Descriptions

Stream Type	General Description	Entrenchment Ratio	Width to Depth Ratio	Sinuosity	Slope	Landform/Soils/Features
Aa+	Very steep, deply entrenched, debris transport, torrent streams.	<1.4	<12	1.0 to 1.1	>.10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0 to 1.2	.04 to .10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step/pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	.02 to .039	Moderate relief, colluvial deposition, and/or structural. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate w/scour pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodpolains.	>2.2	>12	>1.2	<.02	Broad valleys w/terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<.04	Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment, w/abundance of sediment supply. Convergence/divergence bed features, aggradational processes, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.	>2.2	Highly variable	Highly variable	<.005	Broad, low-gradient valleys with fine alluviium and/or Lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition w/well-vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high wash load sediment.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<.02	Broad valley/meadows. Alluvial materials with floodplains. Highly sinuous with stable, well-vegetated banks, Riffle/pool morphology with very low width/depth ratios.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	>12	>1.2	<.02	Entrenched in highly weathered material. Gentle gradients, with a high width/depth ratio. Meandering laterally unstable with ihgh bank erosion rates. Riffle/pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	.02 to .039	Gullies, step/pool morphology w/moderate slopes and low width/depth ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

Disturbances to the channel, such as accelerated bank erosion or sediment supplies, can lead to channel changes and eventually stream type changes, as well. For example, there were evolutionary channel changes observed where an E-typed channel originally was functioning at a higher base level that, over time, converted to a C, Gc, F, and now is a C-type channel at a lower base level.

2.1.8.2 Level 1 Classification Methods

For the Thunder Basin Level I Watershed Study, a Level I Rosgen channel classification was completed for the entire watershed. This Level I classification is intended to provide a general summary of the channel types (A through G and NDC – no distinct channel) present within the watershed. The classification was completed utilizing topographic maps and aerial photography (GoogleEarth) and limited field visits.

Level I stream classification is a general characterization of the stream within the watershed and is intended to be preliminary in nature. This level of classification makes use of readily available published information and relies on the experience of the observer. The first four delineative criteria for classification levels I and II are the same, but vary greatly in the intensity of required data. Level II stream classification requires field measurements of the entrenchment ratio, width-to-depth ratio, slope, and sinuosity by establishment of a cross section and longitudinal profile.

The following sequence of analysis was used in the Level I Stream Channel Classification:

- Map and identify the origin and character of landforms
- Overlay the drainage systems of interest
- Locate the terrace elevations to differentiate Pleistocene, Holocene, and Modern depositional features.

1) Overlay the river system on the fluvial landscape to get the following:

    - General channel slope (steep/flat)
    - Channel bed features (step/pool or riffle/pool)
    - Estimate of channel shape (general width/depth ratios categories – less than 12; 12 to 40; and more than 40)
    - Pattern and profile to show floodplain extent
    - Plan view pattern (single or multiple channels)
    - Confinement (entrenchment slight, moderate, entrenched) or lateral containment (yes or no)

2) Delineation of Valley Types and Landforms

    - Landforms (alluvial fans, glacial and/or fluvial terraces, floodplains, hanging valleys)
    - Valley Types I through X (see Rosgen, 1996)

2.1.8.3 Level I Classification Results

The results of the Level I Rosgen Stream Classification are graphically displayed on Map 16, Major Streams with Rosgen Classification, and summarized on Data Summaries 2.1.8-1 – 2.1.8-3 (in Appendix A) and Figure 2.1.8-2 as follows:

- Data Summary 2.1.8-1 – Level I Rosgen Stream Channel Classification Reach ID's
- Data Summary 2.1.8-2 - Level I Rosgen Stream Channel Classification Reach Information (6 pages)
- Data Summary 2.1.8-3 - Level I Rosgen Stream Channel Classification Channel Type Statistics by Watershed.
- Figure 2.1.8-2 - Level I Rosgen Stream Channel Classification Type Percentage and Count by Watershed.

The majority of the streams within the Thunder Basin Watershed Study area are ephemeral or intermittent in nature. These streams are flashy and respond to temporary runoff events caused by snowmelt and precipitation events. Spring runoff events typically occur from March to April with early summer rains prolonging the stream flow into summer. Flows decrease and cease typically in mid to late summer only flowing in response to thunderstorm events. All three of the main stems (Dry Fork Cheyenne, Antelope Creek, and Upper Cheyenne) typically maintain perennial flow from groundwater and springs. These flows vary with summer thunderstorms as well. The following subsections describe the results of the classification for each of the three watersheds.

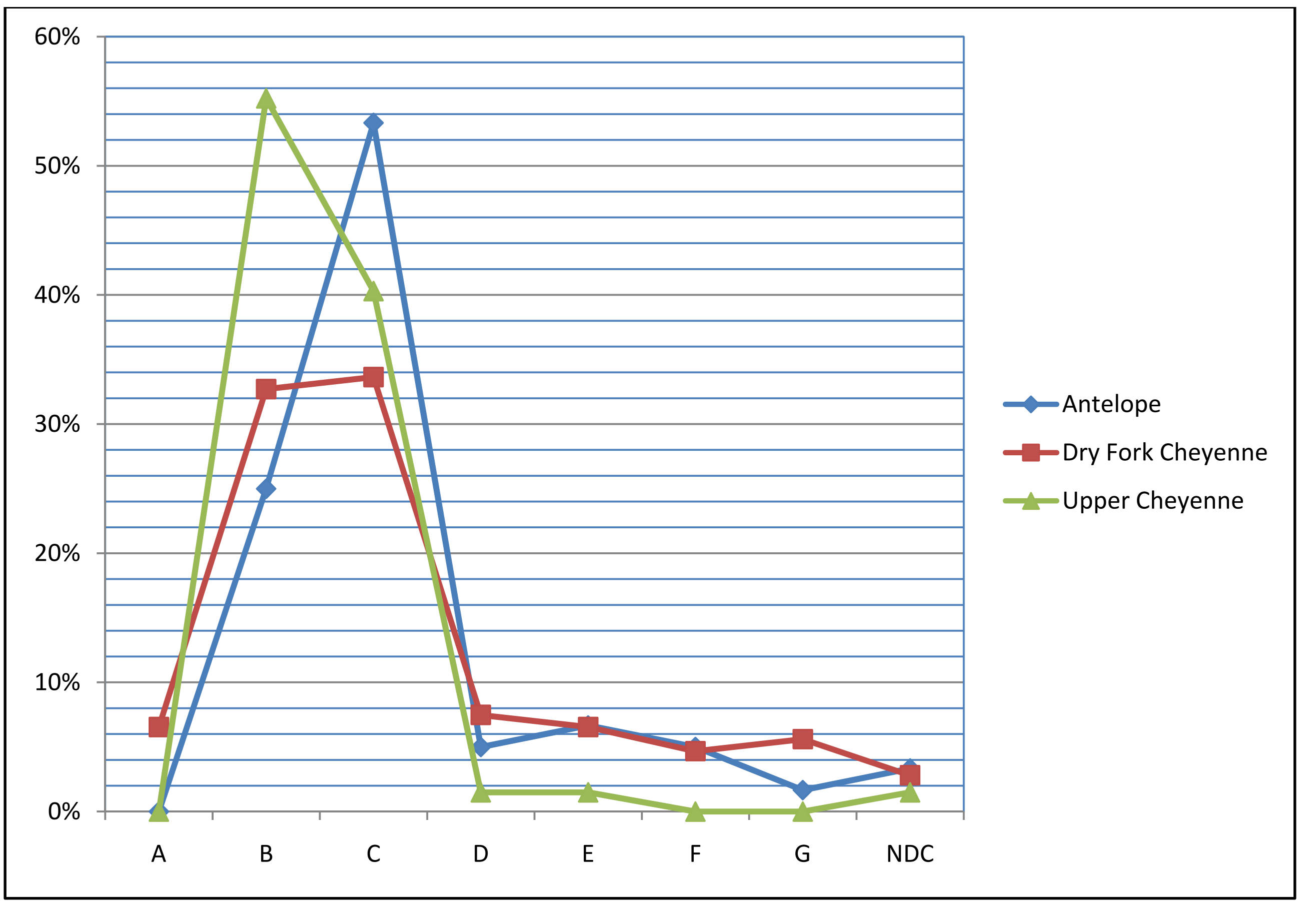


Figure 2.1.8-2 Level I Rosgen Stream Channel Classification Type Percentage by Watershed.

Dry Fork Cheyenne Watershed. Within the Dry Fork Cheyenne Watershed there were 107 individual reaches assessed. This included the North, South, and Middle Forks of the Dry Fork Cheyenne River. Tributaries that were classified included:

- Alta Creek
- Bad Creek
- Brown Springs Creek
- Brush Creek
- Duck Creek
- Dugout Creek
- Lake Creek
- Phillips Creek
- Skunk Creek
- Spring Creek
- Willow Creek
- Woody Creek

For the entire Dry Fork Watershed 6.5 % of the channels were Rosgen Type A, 32.7 % were Type B, 33.6% were Type C, 7.5% were Type D, 6.5% were type E, 4.7% were Type F, 5.6% were Type G, and 2.8% were areas of no defined channel (NDC). Within the Dry Fork Watershed the predominant B and C types were typically found along the valley bottoms and at the topographic break from the steep uplands onto the valley floor. C type channels are a single thread meandering channel with a well developed floodplain which is typical of the main stem of the Dry Fork. There were reaches observed where the geology was such that the valley became more confined and the channel slope would increase downstream with a decrease in floodplain area resulting in Type B channel reaches. This was observed near the confluence with Dugout Creek.

The majority of the Type A and Type G channels were observed in the upper reaches of the tributaries as expected. These steeper, more confined reaches are typically associated with Type A channels. The Type G channels, or gullies, are typical as well in the upper reaches where the slope breaks and the head cut features are formed along the slopes.

There were reaches with multiple channels that were identified as Type D channels. These areas were typically bounded by C or B types and typically occurred where there was previously a dam of some type (stock pond embankment, spreader dikes). The remaining E, F and NDC reaches were located within the watershed in lower percentages. The Type E channels were typically observed on broad flood plains where some extent of groundwater influence was likely. These E types are very narrow and deep with stable banks and vegetation with deep roots. These features typically develop in areas where groundwater is available for a longer duration during the growing season. Areas where there was NDC were backwater areas of embankments, playas, and areas within the channel affected by spreader dikes.

On two separate field visits the following sites were photographed and observed. Location #1 lies on the Dry Fork Cheyenne River between the confluence with Alta Creek and Dugout Creek.

Photo 1 - Dry Fork Cheyenne River between Alta Creek and Dugout Creek at flood stage.

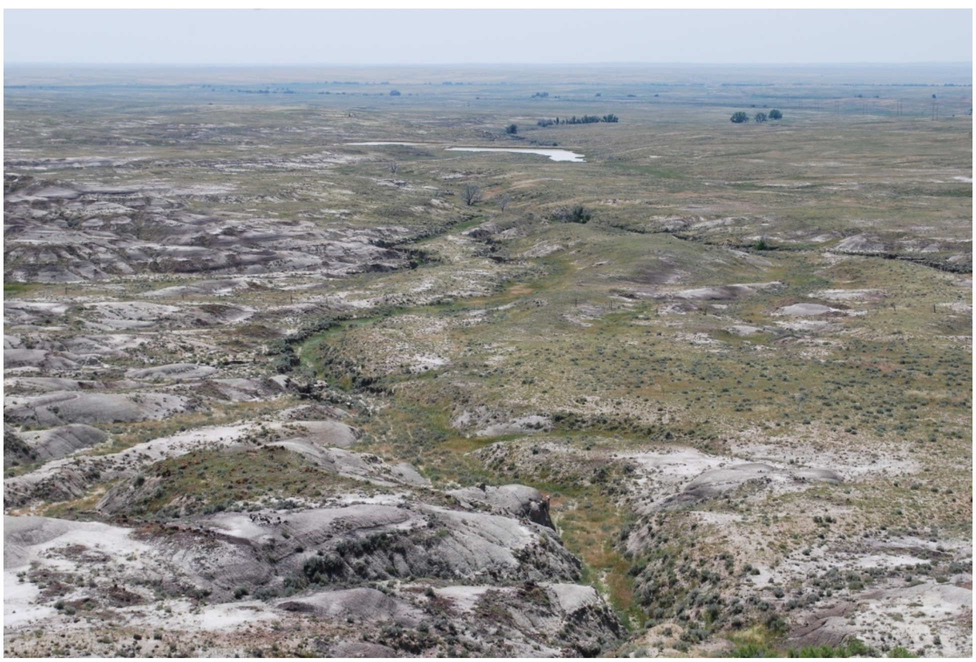


Photo 2 – Looking East at Woody Creek down to Cheyenne River (G Channel Type)

Photo 3 - Spreader Dikes on Woody Creek

Photo 3 is a spreader system on Woody creek with a diversion ditch from Woody Creek. The ditch was constructed under a Converse County Conservation District Project. Photo 4 shows Woody Creek at the Woody Creek Road culvert.

Photo 4 - Woody Creek Type B channel.

In Photo 5 the riparian area is well developed and maintaining stable stream banks. At this location there are upland water sources available for livestock on Forest Service Land.

Photo 5 - Woody Creek Type B Channel and healthy riparian area.

Photo 6 - Typical Type E Channel.

Photo 6 shows a typical swale feature resulting in an Type E channel in a small tributary to Bad Creek. These channels are typical of the flat valley bottoms.

Antelope Creek Watershed

Within the Antelope Creek Watershed there were 60 individual reaches assessed. This included the North Fork, South Fork and the main stem of Antelope Creek along with the following tributaries:

- Bates Creek
- Bear Creek
- Beckwith Creek
- Betty Supply Ditch
- Lonetree Creek
- M Creek
- Ninemile Creek
- Porcupine Creek
- Sand Creek
- Spring Creek
- Stinking Water Creek
- Wildcat Creek
- Wind Creek

For the entire Antelope Watershed 25% of the reaches were Type B channels, 53.3% were Type C channels, 5% were Type D channels, 6.7% were E Type Channels, 5% were F Type channels, 1.7% were G Type channels, and 3.3% were areas of NDC. As the percentages show the majority of channels were C and B types. The upper reaches of Sand Creek were an interesting area where at the upper end of the watershed the channel was classified as an E Type channel. This area was a flat surface at the head of the creek where a very high sinuosity channel had developed before a B type section on a steeper slope and then becoming a C Type channel for the remainder of Sand Creek.

Another interesting area within the Antelope Watershed was the Betty Supply Ditch. Although the ditch is not a natural channel it was classified and resulted in an F Type channel which is very typical for an irrigation ditch.

Antelope Creek at Phillips Road was evaluated during a field visit. As shown in Photo 7 below, the channel is a C Type channel, single thread, meandering channel with a well established flood plain. The reach within the area where the photo is taken is A-Ant-11-C. A Level II channel classification completed by the Wyoming DEQ (Hargett, 2007) classified this reach as a C5 Channel Type as well.

These photos show a very stable and well vegetated section of Antelope Creek at Phillips Road looking upstream and downstream.

Photo 7 - Antelope Creek at Phillips Road, C Type Channel.

Photo 8 - Antelope Creek at Phillips Road looking downstream.

Upper Cheyenne Watershed

Within the Upper Cheyenne Watershed there were 67 individual reaches assessed. This included the Cheyenne River along with the following tributaries:

- Black Thunder Creek
- Boggy Creek

- Coyote Creek
- Crooked Creek
- Frog Creek
- Hay Creek
- Horse Creek
- Keyton Creek
- Little Thunder Creek
- Lodgepole Creek
- Sevenmile Creek
- Sheep Creek
- Snyder Creek
- Wagonhound Creek

The Level I channel classification resulted in 55.2% B Type channels, 40.3% C Type channels, 1.5% D Type channels, and 1.5% with NDC. There were no A, F, and G Type channels identified.

As shown in Photo 9 below there are several reaches within the watershed where the Level I assessment results in a channel classification that is not accurate due to the complexity of channels existing within other channels at different base levels. Photo 9 shows the Cheyenne River at Woody Creek Road bridge where the Level I channel type is an F Type (D-Dry-25-F and D-Dry-23-F) when the actual site is a C Type channel within an F Type Channel.

Photo 9 - Cheyenne River at Woody Creek Road. Level I F Type classification.

Photo 10 - Upstream View of Lodgepole Creek at Grieve Road. Level I C Type classification.

Photo 11 - Downstream View of Lodgepole Creek at Grieve Road. Level I C Type classification.

Photo 12 - Keyton Creek Road (FS 937. Level I C Type classification.

Within the Black Thunder drainage there were three locations where the Wyoming DEQ (Hargett, 2007) completed a Level II Rosgen Stream Classification. From the upper most reach, DEQ site 164 identified the stream as a B4c Type and this Level I classification resulted in a B type classification as well at reach U-Blk-6-B. Farther down the creek at reach U-Bla-8-B the Level II classification also identified the reach (Site163) as a B4c which coincided with the Level I B Type classification.

Just below the confluence with Black Thunder Creek on the Cheyenne River the DEQ has a Level II classification site (Site 162) that is classified as a C4 channel type. This reach (U-Che-4b-C) was also classified as a Level I C Type channel. Another DEQ site (Site 159) is located just below the confluence with Antelope Creek. Site 159 was classified as a C5 channel type in the Level II and as a C Type channel (U-Che-3-C) in this Level I investigation.

Finally in the lowest reaches of the Upper Cheyenne River Watershed DEQ Site 161 classified the channel as an F4 channel type and the Level I classification resulted in a C Type classification (U-Che-11-C). This discrepancy is likely due to the onsite detail available in the Level II field assessment. From the aerial photo is appears that the area is only moderately entrenched. The DEQ report states that beaver activity in the area may have influenced the channel classification as well.

2.2 Land Uses and Management Activities

2.2.1 Land Ownership

Thunder Basin watershed is 1,899,993 acres primarily within the four counties, Weston, Campbell, Converse and Niobrara. The exact acreages in each county are listed in Table 2.2.1-1.

Table 2.2.1-1 Number of Acres per County in Thunder Basin Watershed

County	Acres	Percentage of Total Acres
Campbell	449,005	24%
Weston	478,690	25%
Niobrara	177,626	9%
Converse	792,126	42%
Natrona	2,546	Less than 1%
Total	**1,899,993**	

The majority of land in Thunder Basin is privately owned with the second largest landowner being the Federal Government. The distribution of land ownership is illustrated in Map 17 and listed in Table 2.2.1-2.

Table 2.2.1-2 Thunder Basin Landownership

Landowner		Acres	Percentage of Total Acres
Federal		459,544	24%
	Bankhead Jones	185,033	10%
	Bureau of Land Management	100,145	5%
	National Grasslands	174,366	9%
Private		1,308,682	69%
State		131,767	7%
Total		**1,899,993**	

2.2.2 Range Conditions

2.2.2.1 Grazing Allotments/Leases

Federal Grazing Allotments. The following data were obtained using GIS data for grazing allotments administered by the BLM in the Buffalo, Casper and New Castle Districts. BLM grazing allotments encompass approximately 27 percent (~521,100 acres) of the land within the Thunder Basin watershed (~1,900,00 acres), which includes the Antelope, Dry Fork of the Cheyenne and Upper Cheyenne watersheds (see Map 18 – Grazing Allotments). The BLM allotment numbers and names are provided on Table 2.2.2-1 – Listing of BLM Grazing Allotments. The BLM-administered allotments typically include intermingled private, state, and federally-administered lands used for grazing and are not currently administered through grazing agreements with Grazing Associations.

Under the Record of Decision and Approved Resource Management Plan for the Buffalo (BLM, 1985, revised 2001), Casper (BLM, 2007) and New Castle (BLM, 2000, revised 2008) Districts, livestock grazing permittees are required to implement management actions (e.g., grazing systems, land treatments, and range improvements) appropriate to the allotment category (i.e., "C" – Custodial, "M" – Maintain, or "I" – Improve). Grazing on BLM lands to meet these requirements is managed under the Standards for Healthy Rangelands and Guidelines for Livestock Grazing Management for the Public Lands Administered by the BLM in the State of Wyoming (BLM, 2007). Among the full suite of grazing management guidelines, those most applicable to this watershed study are summarized as follows:

- Ensure that conditions after grazing use will support infiltration, maintain soil moisture storage, stabilize soils, release sufficient water to maintain overall system function, and maintain soil permeability rates and other appropriate processes.
- Restore, maintain, or improve riparian plant communities to sustain adequate residual plant cover for sediment capture and groundwater recharge.
- Implement riparian improvements (e.g., instream structures, water troughs, etc.) to maintain or enhance appropriate stream channel morphology; develop springs, seeps, reservoirs, wells or other water development projects in a manner protective of watershed ecological and hydrological functions; and implement range improvements away from riparian areas to avoid conflicts in achieving or maintaining riparian function.
- Adopt management practices and implement range improvements that protect vegetative cover and thereby maintain, restore or enhance water quality.

A set of six standards have been established to meet the above guidelines (BLM, 2007). Each standard sets a specific objective, explains the function and importance of the objective, and provides indicators to assess the attainment of the objective. Implementation of appropriate range management practices and/or improvements is carried out under an activity or implementation plan, including allotment management plans (AMPs). AMPs have been completed for the following allotments in the Thunder Basin watershed (BLM, 2009):

Table 2.2.2-1 – Listing of BLM Grazing Allotments

Buffalo Field Office

- 02312 STUART, JAMES R.
- 02325 LINCH
- 12023 LAWVER
- 12036 WILLOW CREEK
- 12080 DRY CREEK RANCH I
- 12082 WILD HORSE CREEK
- 12231 HILIGHT
- 12235 MOORE, JAMES R
- 12236 BATES CREEK

Casper Field Office

- 00229 SAND CREEK
- 00236 TURNER FLATS
- 00284 NORTH STINKING WATER
- 00341 TWENTYMILE CREEK
- 00342 SKUNK CREEK
- 00345 TURNER DIVIDE
- 00369 SAWMILL CANYON
- 00372 DEATH CALL DRAW
- 00376 BOWMAN DRAW
- 00395 SOUTHWICK
- 00459 ANTELOPE CREEK
- 00460 SANDY DRAW
- 00471 HIGHLAND FLATS
- 00480 RED BUTTE
- 00482 HIGHLAND FLATS 2
- 00497 FARNSWORTH DRAW
- 10005 BONER
- 10059 LITTLE PINE RIDGE
- 10071 ALLEMAND
- 10087 COLE CREEK
- 10108 HENRY
- 10109 NORTH FORK
- 10113 HORNBUCKLE
- 10114 55 RANCH
- 10147 SMITH
- 10149 STAPLE THREE
- 10151 VALENTINE
- 10155 BOX CREEK
- 10161 SEVEN
- 10168 MONUMENT HILL
- 10172 COATES 2
- 31005 SALT CREEK
- 31006 ANTELOPE CREEK 2

New Castle Field Office

- 04044 SNYDER CREEK II
- 04051 ROCK CORRAL DRAW
- 04052 LITTLE ALKALI CREEK

- 04072 CLAYTON DRAW I
- 04073 CLAYTON DRAW II
- 04074 SNYDER CREEK I
- 04084 BOGGY CREEK I
- 04089 GRAHAM DRAW
- 04094 CHARLIES DRAW II
- 04102 CROOKED CREEK I
- 04104 LITTLE ALKALI CREEK
- 04118 LANCE CREEK IV
- 04120 SEVEN-MILE CREEK
- 04124 COUNT CREEK
- 04162 W BACON CREEK
- 04187 BAGGY CREEK
- 04188 CHARLIES DRAW I
- 04225 FRED DRAW II
- 04240 BOWEN FLAT
- 04247 SOUTH SNYDER CREEK
- 04258 RAVEN
- 04266 FATAL HOLLOW
- 04267 THREE-MILE BUTTE
- 04269 MULE CREEK JUNCTION
- 04284 HAY CREEK OIL FIELD
- 04288 PINEY DRAW II
- 04289 SNYDER CREEK III
- 04293 PINEY DRAW I
- 04294 COTTONWOOD CREEK
- 04302 CALF DRAW
- 04303 FRED DRAW I
- 04304 TRAIL CREEK
- 04314 SPRING CREEK I
- 04347 RHAY
- 04357 RAVEN WYOMING
- 04374 SNYDER CREEK IV
- 04401 AU7 RANCH
- 04408 BARREL DRAW
- 04414 WINDMILL DRAW
- 14001 WEST BULL CREEK I
- 14012 SNYDER CRK DRAINAGE

The following data were obtained using GIS data for grazing allotments administered by the U.S. Forest Service Douglas Ranger District. U.S. Forest Service grazing allotments encompass approximately 40 percent (~754,750 acres) of the land within the Thunder Basin watershed (~1,900,000 acres) (see Map 18 – Grazing Allotments). These grazing allotments are administered by the Forest Service through grazing agreements with the Thunder Basin Grazing Association and the Inyan Kara Grazing Association, who manage ~561,000 acres (~30 percent) and ~164,000 acres (~8 percent) within the Thunder Basin watershed respectively. Grazing agreements are grazing permits authorizing grazing associations to Grazing agreements are grazing permits authorizing grazing associations to conduct specified amounts of grazing on National Forest System lands for a period of ten years or less and include provisions for the association to issue grazing permits to their members 36 C.F.R. §222.3(c)(1). The grazing associations are responsible for administering issued permits in conformance with the appropriate law and regulations, allotment management plans, and rules of management (USDA, 1997). The 1985 Medicine Bow National Forest Land and Resource Management Plan direct resource use on the Thunder Basin National Grassland. This management plan was later revised in 2007 (USDA, 2007). Guidelines (to be applied on a grassland-wide scale) for the management of livestock grazing to maintain or improve riparian/woody draw areas includes the following:

- Avoid season-long grazing and activities, such as feeding, salting, herding, or water developments, which concentrate livestock in riparian/woody draw areas.
- Control the timing, duration, and intensity of grazing in riparian areas to promote establishment and development of woody species.

Two Environmental Impact Statements were done on areas within the Thunder Basin National Grassland, the Inyan Kara Analysis Area (USDA, 2008) and the Thunder Basin Analysis Area (USDA, 2007) to determine how existing resource conditions compare to the desired conditions outlined in the Thunder Basin National Grassland Land and Resource Management Plan (LRMP). The result would be the development of a management strategy to maintain or improve rangeland conditions which could be incorporated into individual AMPs. Area-wide design criteria established from the Environmental Impact Statements (EISs) include the following items that directly relate to this watershed study:

- Rotate livestock season of use in riparian areas to increase rush, sedge, shrub, and tree canopy cover.
- If the desired condition of a specific riparian area includes increasing willow cover or cottonwood density, livestock would be managed to improve riparian woody species.
- Manage livestock use through control of time/timing, and duration/frequency of use in riparian areas and wetlands to maintain or improve long-term stream health. Exclude livestock from riparian areas and wetlands that are not meeting or moving towards desired condition objectives where monitoring information shows continued livestock grazing would prevent attainment of those objectives. Grazing intensity or amount of forage utilization in uplands would be light to moderate in areas requiring an upward trend in vegetation, watershed, and/or soil health. Decrease livestock congregation in riparian areas and adjust livestock grazing distribution in areas of concern through appropriate analyzed management options.
- Keep stock tanks, salt supplements, and similar features out of the Water Influence Zone if practicable and out of riparian areas and wetlands always. Keep stock driveways out of water Influence Zone except to cross at designated points. Armor water gaps and designated stock crossings where needed and practicable.

State Grazing Leases. Most of the state lands within the Cheyenne River watershed are leased to private landowners for grazing. These leases are typically issued by the Board of Land Commissioners and administered by the Office of State Lands and Investments. Grazing management, practices and improvements on state lands are usually established and implemented by the lessee. Improvements are normally paid for and owned by the lessee with reimbursement by the new lessee upon transfer of the lease.

Grazing on Private Lands. Grazing practices on private lands are established by the landowner, often with technical assistance from the local NRCS staff and/or a range consultant. Range improvement projects implemented under an NRCS program follow the guidelines established in the plan of operations developed for the property and/or applicable NRCS technical guidelines as adapted for local conditions.

2.2.2.2 Ecological Site Descriptions

Practical potentials of grazing resources are best understood when landscape units with homogenous growing conditions such as precipitation, soils, slope, and geomorphic nature are identified and separated from each other. The USDA NRCS has accomplished this task for the Thunder Basin study area. These units known as Ecological Sites are included in the NRCS Electronic Field Office Technical Guides (eFOTGs) for Campbell, Converse, Niobrara, Natrona and Weston counties. These eFOTGs are available online at the following Web site: http://www.nrcs.usda.gov/technical/efotg/.

ESDs are grouped by precipitation zones; a total of 21 ecological sites are applicable for the Cheyenne River watershed (Map 5, Ecological Sites). As an example, a copy of the most prevalent ESD for the Thunder Basin watershed (MLRA 58B, Site Type: Rangeland, Site Name: Loamy (Ly) 10 inches to 14 inches Northern Plains Precipitation Zone) is included in Appendix

C – Ecological Site Description. The ESD addresses the full range of physiographic and climatic features, influencing water features, representative soil features, plant communities, wildlife interpretations, grazing interpretations, hydrology functions, recreational uses, and other information relevant to the site type. NRCS staff can assist in identifying the applicable ESDs to a given area; these ESDs can then be easily downloaded in pdf format from the previously cited Web site. The 21 ecological sites occurring within the study area are summarized by acreage in the Table 2.2.2-2.

Table 2.2.2-2. Ecological Sites within the Thunder Basin Watershed

Ecological Site Name	Approximate Acreage
SHALLOW LOAMY (10-14 SE)	5
SANDY (15-19 BL)	30
LOAMY (15-17 NP)	44
CLAYEY (15-19 BL)	59
SANDY (15-17 NP)	92
SHALLOW LOAMY (15-17 NP)	143
LOAMY (10-14 SE)	375
LOAMY (15-19 NP)	1,517
CLAYEY OVERFLOW (10-14 NP)	3,718
SALINE LOWLAND (10-14 NP)	4,652
VERY SHALLOW (10-14 NP)	6,298
SANDS (10-14 NP)	21,959
OVERFLOW (10-14 NP)	31,184
SALINE UPLAND (10-14 NP)	33,997
LOWLAND (10-14 NP)	56,762
SHALLOW CLAYEY (10-14 NP)	85,534
SHALLOW SANDY (10-14 NP)	104,022
CLAYEY (10-14 NP)	111,780
No Data	181,269
SANDY (10-14 NP)	221,203
SHALLOW LOAMY (10-14 NP)	291,454
LOAMY (10-14 NP)	742,549

The Thunder Basin watershed includes three precipitation zones: 10 inches to 14 inches; 15 inches to 17 inches; and 15 inches to 19 inches. These are shown in parentheses in the title of the ecological site. Ecological site descriptions can be used to compare what is growing on rangeland sites with what each is capable of supporting. Such comparison allows the relative health (ecological condition) of the range resource to be evaluated. Forage production of each site is closely related to the ecological condition of the site. Watershed values also are tied to the condition class. For example, areas with reduced ground cover have greater potential for limited infiltration and increased runoff; similarly, degraded sites may have soils with reduced organic content and consequently degraded soil structure, which likewise limits moisture infiltration and holding capacity.

Comparison of existing conditions to the historic “ideal” for a given ecological site facilitates a classification of range condition that expresses the degree to which the existing plant community reflects potential natural conditions. Four classes often have been used to make this categorization as follows: 76 percent to 100 percent; 51 percent to 75 percent; 26 percent to 50 percent; and 0 to 25 percent. In early years these categories were identified as excellent, good, fair and poor. More recently, the BLM has referred to these as seral, late seral, mid seral and early seral, respectively.

In the detailed analysis of range condition conducted by the U.S. Forest Service on the Thunder Basin National Grasslands (Thunder Basin Analysis Area Vegetation Management FEIS, USDA 2001), a similar evaluation of range condition using a seral stage model (Benkobi and Uresk 1995) was employed. A comparison was made of existing conditions to the desired conditions as set forth in the Thunder Basin Land and Resource Management Plan (USFS 2001). In the latter plan, it was not a given that all areas should ultimately come to qualify as late seral (the Benkobi and Uresk most advanced seral stage). Rather, a mix of seral stages with accompanying differences in species richness and structure among other things was targeted. Even though the goal of late seral was 10 percent to 25 percent, depending on the sub-area (and not 100 percent), the overall Thunder Basin Grassland rating was somewhat low (USDA 2007). It should be noted that the stated need in was to move acres from later intermediate to late seral; early and early intermediate acres were generally within the target. A more detailed analysis of range condition and specific range attributes can be found in USDA (2007).

2.2.2.3 Range Conditions

Well-distributed livestock water sources are critical to the implementation of grazing management control that works. Evaluations of range condition on a particular property can be used to identify areas that will benefit over a period of years from a plan to adjust exposure to grazing to the benefit of the more nutritious and productive species. However, such plans inevitably require that an area be possessed of water in close proximity to encourage livestock to stay rather than leave for water.

Fundamentals of science-based range management revolve around the health of individual range plants. The degree to which they are allowed access to their basic needs determines their over-all well-being and their ability to produce useable forage. That useable forage is at once the sought-after product and the means by which future plant production is enabled. Aerial parts of range plants are the means by which carbohydrates are produced. Some amount of this production must be reserved to enable construction of new photosynthetic parts (leaves and stems) in future years. Removal of the capacity to produce these carbohydrates by defoliation has been proven to diminish the capacity of range plants to renew growth in future seasons. Hence, the objective of range management is the balancing of grazing use (which can be one cause of defoliation) with the maintenance of the energy budget of the range plants. This balance is not usually possible in the form of adjusting only the number of animals continuously present on a pasture. Rather the balance is struck by limiting the exposure to any defoliation and leaving the plants and their photosynthetic parts at rest for planned periods. Length of rest from defoliation is important but the timing of the harvest is also highly influential in encouraging (or discouraging) long-term plant health depending on the plant species.

In as much as drainage ways are often the location of what water is available, livestock pressure in these portions of the landscape is disproportionately great. With dispersal of livestock watering sources to uplands, not only are riparian areas relieved from grazing and trampling pressure, but little used forage on remote uplands may be accessed by foraging animals.

Ultimately, improved health of perennial range plants with greater ground cover and average overall height will tend to enhance snow-catch in winter and reduce surface water runoff during melt out and rain events. The latter tends to enhance soil moisture infiltration which feeds back to improved plant growth and competitive hold by these plants, with better resistance to invasion of weeds. Enhanced soil moisture infiltration also increases the likelihood that moisture will pass through the soil and into groundwater and may support more continuous moisture supply to riparian and swale sites.

Range management in recent times has also come to incorporate concern with wildlife habitat conditions. Rested rangeland vegetation mosaics may enhance intact availability of forbs advantageous to many wildlife and greater plant height and cover offers improved habitat for native insect and arachnid populations that birds especially find necessary. The alternative water resource improvements presented in this report will achieve their highest and their most durable positive effects in conjunction with well-reasoned range management planning that directs and times livestock activities in accordance with range plant health.

2.2.3 Oil and Gas Production

The petroleum industry has been exploring for oil and gas in Wyoming for over 124 years. During that time, oil and gas production has become an important economical commodity in Thunder Basin. Nationally, Wyoming ranked 5th in production of crude oil and 2nd in natural gas production during 2007. Park County was the leading crude oil producer in 2007 followed by Campbell County. Sublette County was the largest natural gas producer and Campbell County was the second largest (Petroleum Association of Wyoming, 2009). Map 19 illustrates the distribution of oil and gas fields which cover the majority of the basin. Data Summary 2.2.3-1 (in Appendix A) lists the active oil and gas fields identified on Map 19. The locations of all active wells are available through the Wyoming Oil and Gas Conservation Commission:
http://wogcc.state.wy.us/

In the past 10 years, there has been a substantial increase in the number of Coal Bed Methane (CBM) wells in the area. According to the Final Environmental Impact Statement prepared to address the potential impacts of increased CBM development across the Powder River Basin (including Thunder Basin):

> *Development of oil and gas in the PRB is generally classified into two categories: CBM and non-CBM. Development of CBM resources began in the mid-1980s. With advancements in technology, development and production of CBM has been increasing substantially since the mid-1990s. In contrast, production of non-CBM resources was relatively stable from 1986 through 1991, but has been declining sharply since (BLM 2001). Overall, oil and gas development in the PRB, exclusive of CBM, is expected to decline slowly (BLM 2001).*

During the oil and gas production, a significant amount of water is produced during the CBM extraction process. Table 2.2.3-1 lists the amount of oil, gas, and water produced during oil and gas production across Wyoming with the four counties of the Thunder Basin watershed highlighted for emphasis (http://wogcc.state.wy.us/cfdocs/2008_stats.htm). The table lists data for the entire counties which extend well beyond the boundaries for the Thunder Basin Watershed study; however the data is useful for comparing the orders of magnitude of oil, gas and water. Based on the quantities of oil, gas and water presented in Table 2.2.3-1, it is clear that a significant amount of water is extracted from the deeper aquifers and either discharged to the surface or reinjected during CBM production.

The issue of how the increase in CBM production has impacted the groundwater and surface water supplies in Thunder Basin was a topic of discussion in several of the earlier Thunder

Basin project meetings. The impact of this withdrawal and subsequent release of water during production of the CBM was not the focus of this study. Several recent publications have been prepared in order to answer some of the signification issues related to increased CBM production the most comprehensive recent document is the USGS Water Resources Investigations Report 02-0-4045, 2002.

Table 2.2.3-1 2008 Oil and Gas Production Summary

2008 County Report with Percentage of State Total							
COUNTY	Wells	Total Year Oil/BBLS	% State Oil Total	Total Year Gas/MCF	% State Gas Total	Total Year Water/BBLS	% State Water Total
ALBANY	40	50,100	0.0009	6,323	0	4,880,109	0.002
BIG HORN	545	1,999,583	0.0378	2,780,483	0.0011	174,263,971	0.0713
CAMPBELL	16326	8,233,266	0.1555	166,660,822	0.0672	462,264,221	0.1892
CARBON	1883	1,671,728	0.0316	122,681,378	0.0495	84,818,466	0.0347
CONVERSE	1114	1,808,869	0.0342	8,882,537	0.0036	8,409,026	0.0034
CROOK	470	1,496,703	0.0283	42,025	0	27,069,454	0.0111
FREMONT	1452	3,183,909	0.0601	142,098,875	0.0573	181,689,903	0.0744
GOSHEN		0	0	0	0	0	0
HOT SPRINGS	758	3,107,987	0.0587	611,726	0.0002	225,231,458	0.0922
JOHNSON	3643	1,071,795	0.0202	313,213,156	0.1264	180,834,112	0.074
LARAMIE	115	473,284	0.0089	97,005	0	1,188,481	0.0005
LINCOLN	1580	819,973	0.0155	89,519,605	0.0361	1,228,149	0.0005
NATRONA	2218	4,327,376	0.0817	28,638,808	0.0116	314,962,320	0.1289
NIOBRARA	277	487,385	0.0092	1,882,485	0.0008	11,336,642	0.0046
PARK	1601	8,006,553	0.1513	13,698,981	0.0055	543,381,235	0.2224
SHERIDAN	3493	27,077	0.0005	68,380,477	0.0276	140,447,444	0.0575
SUBLETTE	4274	7,665,750	0.1448	1,143,671,272	0.4615	22,926,124	0.0094
SWEETWATER	3472	5,392,716	0.1019	240,855,499	0.0972	42,033,924	0.0172
UINTA	510	1,342,346	0.0254	130,355,216	0.0526	3,019,362	0.0012
WASHAKIE	401	774,850	0.0146	2,575,949	0.001	9,801,964	0.004
WESTON	1276	993,775	0.0188	1,688,699	0.0007	3,580,427	0.0015
	County Totals		**52,935,025**		**2,478,341,321**		**2,443,366,792**

Source: Barclay, N et al, 2008. Wyoming Oil and Gas Statistics

2.2.4 Mining and Mineral Resources

Map 20, Active Historic Coal Mines and Resource Potential, illustrates the coal mines and their mineral resource potential. Thunder Basin is the single largest source of coal mined in the United States, and contains one of the largest deposits of coal in the world. In 2007, the Powder River Basin alone produced 436 million tons of coal with most of the active coal mining in the Powder River Basin taking place in Thunder Basin along drainages of the Cheyenne River. The Black Thunder Coal Mine in Thunder Basin is the most productive coal mine in the United States. In 2006 this single mine produced 84 million metric tons of coal, more than any state except Wyoming, West Virginia, and Kentucky (E. Freme, 2007). One reason for the enormous quantities of coal extracted from the basin has to do with the composition of the coal. The mines in Thunder Basin produce low-sulphur, sub-bituminous coal suitable for power station fuel without any preparation except crushing. For example, Black Thunder coal has a heating value of 20.3MJ/kg, and the ash contents are around 5% while as-received moisture is 25–30%. The moisture content of some Powder River Basin coals increases their reactivity to the extent that spontaneous combustion can be a problem if they are not properly handled. Recent history of coal production listed by mine is available online at http://www.wma-minelife.com/coal/coalfrm/coalfrm1.htm.

2.2.5 Other Minerals

Map 21, Other Mine Sites and Mineral Potential, illustrates the location of a uranium mineral potential in the southwest portion of Thunder Basin. Currently there are two active uranium mines to the south of Thunder Basin (Rio Algom Mining Corp., and Power Resources, Inc).

2.2.6 Transportation and Energy Infrastructure

The main transportation routes across Thunder Basin are illustrated in Map 22, Major Roads and Railroads. Highway 59 is the main north/south route and east/west is Highway 450. Due to the high coal production rates in Thunder Basin, the north/south rail lines in central Thunder Basin have an extremely high volume of rail traffic. Maps 23 and 24, Major Pipelines, Major Electric Transmission Lines, respectively, provide information on the location of major pipelines and powerlines in Thunder Basin. Information on primary infrastructure such as dams and bridges will be used when siting water storage projects as discussed later in this report.

3.0 Watershed Inventory

3.1 Irrigation Inventory

3.1.1 Overview

Map 25 illustrates the irrigated lands and the irrigation point diversions in Thunder Basin. The following paragraphs discuss the irrigated agriculture of Thunder Basin including: the lands currently being irrigated; the current and potential future cropping pattern; and, the irrigation methods used.

Irrigated Lands Mapping. Maps that show irrigated lands overlain on topographic maps were obtained from the University of Wyoming. Color infrared (CIR) satellite imagery from 2002 was used to identify irrigated lands on an individual basis. Almost all of the irrigated lands in the watershed are located in the overbanks and flanking terraces along the streams and rivers in Thunder Basin.

To verify the actual irrigated acreages, Map 25, Irrigated Lands was digitally overlain on digital orthophoto quarter quadrangle (DOQQ) CIR photography flown in 2002, which is the latest available coverage suitable for this purpose. The red color on the CIR aerials indicates the presence of growing vegetation. When comparing the CIR aerials to the irrigated lands maps, areas where the vegetation was thriving and where it was sparse, were apparent. When looking at the CIR aerials, it was interesting to note that many of the irrigated areas shown on the irrigated lands maps did not appear to be irrigated when looking at the CIR aerials. The reduced area of irrigated lands on the CIR aerials would suggest that due to drought conditions, fewer crops and/or pastures are being planted and/or the vegetation is not thriving.

Soils. Most of the soils in Thunder Basin are not well suited to crop irrigation. As illustrated in Map 26, Irrigated Land Capability Classes, the irrigation classification for Thunder Basin indicates that the "best" soil for irrigated crop is identified as Irrigation Class III which can be described as soils that have severe limitations that reduce the choice of plants or require special conservation practices, or both. Understandably based on the available soil types in Thunder Basin, grass is the crop of choice as can be seen in the following section. Table 3.1.1-1 lists the irrigation capability of the soils in Thunder Basin. A Class I soil has the best qualities for irrigation while a Class VIII soil is the most restrictive type of soil to try and irrigate. This table summarizes data Map 26 and lists the percent of Thunder Basin within each irrigation class.

Table 3.1.1-1 Irrigation Class Distribution in Thunder Basin

Irrigation Capability	Acres	Percent
Class III	469,575	25%
Class IV	611,589	32%
Class VI	131,301	7%
Class VII	626,857	33%
Class VIII	46,595	2%
No Data	12,722	1%
Total	**1,885,918**	**100%**

Cropping Patterns. According to 2006 USDA data, the only crop grown in Thunder Basin is grass hay. Table 3.1.1-2 lists the cropping patterns in the active irrigated acres.

Table 3.1.1-2 Cropping Patterns in Thunder Basin Watershed

Sub-Basin Name	HUC	Crop (acres)						Total Active
		Alfalfa	Grass	Grain	Corn	Idle	Total	
Upper Cheyenne	10120103	0	6,357	0	0	914	7272	6357
Antelope Creek	10120101	0	1,199	0	0	51	1250	1199
Dry Fork Cheyenne	10120102	0	1,014	0	0	454	1468	1014
Total		0	8,570	0	0	1419	9990	8570

Irrigation Methods. Ninety nine percent of the irrigation in Thunder Basin is accomplished with surface water; only 1 percent of irrigation utilizes groundwater (Table 3.1.1-3).

Table 3.1.1-3 Primary Source of Irrigation Water in Thunder Basin

Sub-Basin Name	HUC	Primary Source of Water Supply		
		Groundwater	Surface Water	Total
Upper Cheyenne	10120103	127	7,145	7,272
Antelope Creek	10120101	0	1,250	1,250
Dry Fork Cheyenne	10120102	32	1,436	1,468
Total		**159**	**9831**	**9,990**

Flood irrigation is the most common form of irrigation in Thunder Basin. It also is the most cost - effective form of irrigation, since the capital outlay is only for diversion ditches and diversion structures. Irrigation ditches are relatively inexpensive to construct, and are inexpensive to maintain. The drawback to using flood irrigation is that most of the rivers and streams in Thunder Basin have inconsistent if any flow, making irrigation unreliable. In addition, the sediment delivered during these flash flood events cause a net loss of system storage and conveyance.

3.1.2 Irrigation System Descriptions

Most, if not all, of the irrigation systems in Thunder Basin watershed are small, privately owned systems. Many of them are dated systems, and in need of improvements and maintenance. These irrigation systems' service areas range from 10 acres to a few hundred acres. The following table breaks the irrigated lands into different irrigation classifications:

Table 3.1.2-1 Summary of Irrigated Lands by Irrigation Classification (in acres).

Sub-Basin Name	HUC	Irrigation Classification							
		A	B	C	Total ABC	S	H	E	Total
Upper Cheyenne	10120103	18	1,959	0	1,977	2,194	2,187	914	7,272
Antelope Creek	10120101	0	427	0	427	196	576	51	1,250
Dry Fork Cheyenne	10120102	0	119	0	119	763	132	454	1,468.00
Total		**18**	**2505**	**0**	**2523**	**3153**	**2895**	**1419**	**9,990**

The irrigation classifications are as follows:

A- Fully irrigated land
B- Partial service irrigation
S- Spreader dike irrigation
H- Minor beneficial use
E- Idle irrigation

Based on this classification system, essentially none of the land in the Thunder Basin Watershed would be considered fully irrigated, especially during a time of drought.

3.2 Groundwater Development Inventory

3.2.1 Groundwater Development Description

Based on the state engineer's July 2008 database, there are approximately 5,867 wells that are fully adjudicated/in good standing in the Thunder Basin watershed. The primary uses of the wells are listed in Table 3.2.1-1 and illustrated in Map 27, Groundwater Registered Wells Inventory Map. As listed in the table, CBM and stock wells are the most numerous water wells in the watershed.

Table 3.2.1-1 Registered Well Use in Thunder Basin

Well use	Registered Wells	Percentage of Total
CBM	1,350	30%
Stock	1,316	29%
Stock/CBM	912	20%
Other	591	13%
Domestic/Stock	156	3%
Domestic	80	2%
Industrial	117	3%
Total	**4,522**	**100%**

Maps 28, Groundwater Registered Well Yield, and Map 29, Groundwater Registered Well Depth, illustrate the well yields and completion depths of the registered wells in Thunder Basin. This information is useful in reviewing additional opportunities to install wells. A more detailed geologic evaluation would be needed before a well construction project could be initiated, but information on well-depth and yield can provide preliminary information on the productivity and installation costs of proposed new wells.

3.3 Water Storage Site Inventory

Development of additional surface water storage opportunities within the Thunder Basin study area was a key objective of this Level I study. Providing additional water for irrigation and livestock/wildlife watering were the highest priorities for the study sponsors. Potential recreational opportunities and improvement of the riparian corridors also were important considerations. To create additional storage, both storage needs and potentially available water must be evaluated. The following sections discuss the potentially available and projected water shortages, existing reservoirs, and previous water storage investigations.

3.3.1 Surface Water Availability and Shortages

Information developed for the Northeast Wyoming River Basins Plan Final Report (HKM, 2002a) provided the basis for evaluating water availability and shortages as it related to proposed water storage projects in the Thunder Basin study area. The Northeast Wyoming River Basins Model consists of four water accounting spreadsheets that represent four sub-basins within the area. They are the Beaver Creek Model, the Belle Fourche Model, the Cheyenne River Model, and the Red Creek Model. The Cheyenne River model includes the main stem Cheyenne River, along with 17 tributaries. The models were developed as a planning tool for the state of Wyoming and local water users to determine where available flows might be available for future development.

The following paragraphs summarize the model development, as described in the technical memorandum documenting the Northeast Wyoming River Basins Plan Spreadsheet Model Development and Calibration (HKM 2002b).

The models are intended to simulate water use and availability under existing conditions. Three models were developed, reflecting each of three hydrologic conditions: dry, normal, and wet year water supply. The spreadsheets each represent one calendar year of flows, on a monthly time step. The modelers relied on historical gage data from 1970 to 1999 to identify the hydrological conditions for each year in the study period. Streamflow, estimated actual diversions, full supply diversions, irrigation returns, and reservoir conditions are the basic input data to the models. For the reaches in the Cheyenne River model, the dry years ranged from 73% to 98% lower than the normal years, with an average of 85% lower than normal. The wet years ranged from 63% to 706% higher than normal years, with an average of 312% higher than normal.

The models do not explicitly account for water rights, appropriations, or compact allocations nor is the model operated based on these legal constraints. Further, the model does not associate supplemental reservoir releases to the appropriate water users. However, by calibrating the models to historical streamflows at gaged locations, the models can be used to generally represent existing operations. Theoretical maximum diversion requirements were calculated using the mapped acreage of irrigated lands and consumptive irrigation requirements (CIR) were provided by the Consumptive Use and Consumptive Irrigation Requirements – Wyoming (Pochop et al., 1992.) The models were calibrated by adjusting the estimated actual diversions and diversion demands as well as irrigation efficiencies, duration of irrigation, and irrigation return flows.

To mathematically represent the Cheyenne River sub-basin, the river system was divided into reaches based primarily upon the location of major tributary confluences. Each reach then was subdivided by identifying a series of individual nodes representing diversions, reservoirs, tributary confluences, gages, or other significant water resources features. Figure 3.3.1-1, Model Nodes and Reaches Schematic, shows the model elements for the Cheyenne River portion of the Northeast Wyoming Basins model.

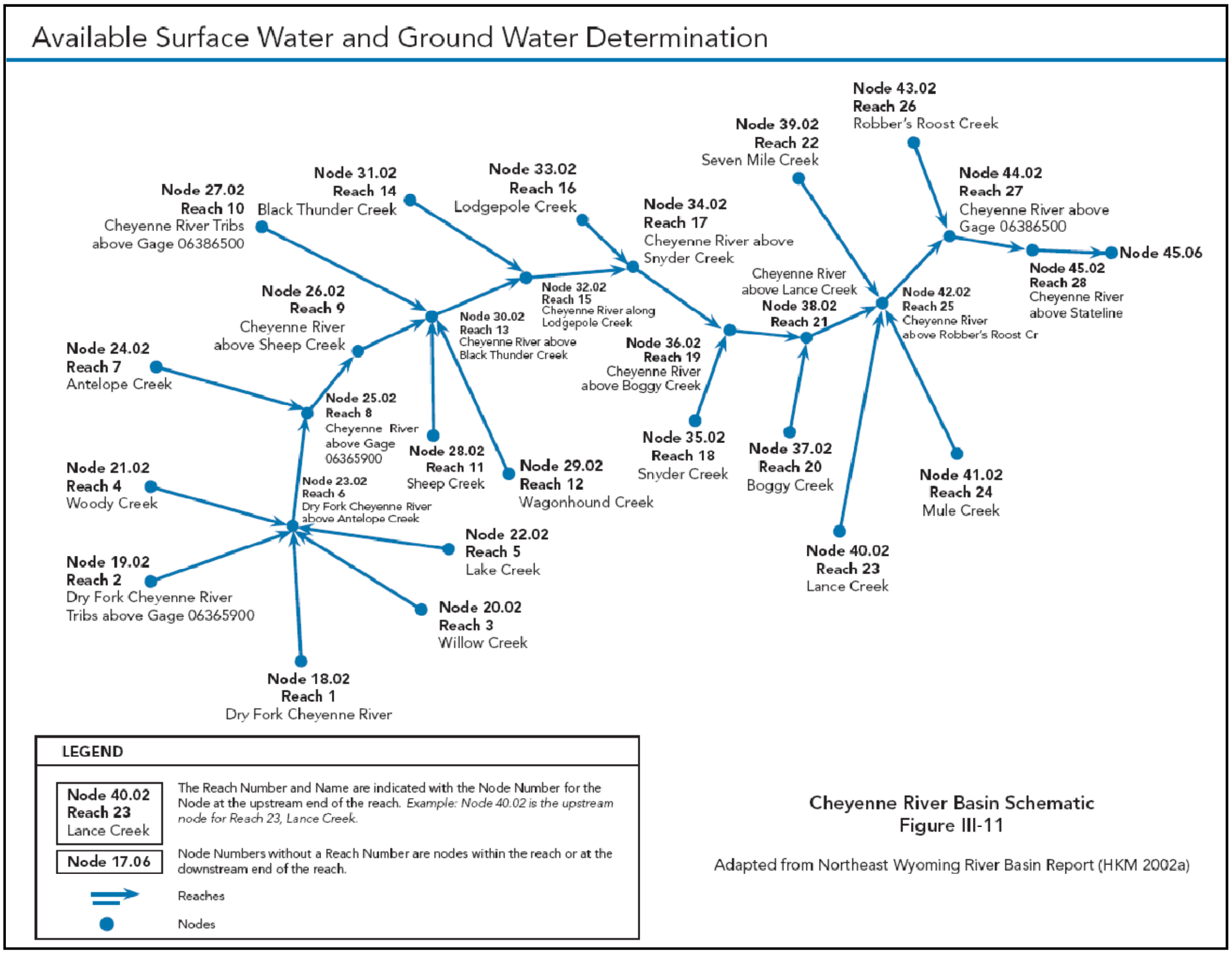


Figure 3.3.1-1 Cheyenne River Model Node Diagram (HKM, 2002a).

At each node, a water budget computation was completed to determine the amount of water that bypasses the node. At non-storage nodes, the difference between inflow, including upstream inflows, return flow, imports and basin gains, and outflows, including diversions, basin losses and exports, is the amount of flow available for the next node downstream. For storage nodes, an additional loss calculation for evaporation and the change in storage was evaluated. Also at storage nodes, any uncontrolled spill that occurs is added to the scheduled release to determine total outflow. Diverted amounts at diversion nodes are the minimum of demand (the full supply diversion at the structure) and physically available streamflow. The mass balance, or water budget calculations, is performed for all nodes in a reach.

"Available water" at a given reach terminus was defined as the minimum of the physically available flow at that point and the available flow at all downstream reaches (HKM, 2002c). Available flow was defined first at the most downstream point and then upstream availability was calculated in stream order. The calculations were made on a monthly basis, and annual water availability was computed as the sum of monthly values. Calculating the annual availability in this way yields a different result than applying the same logic to annual flows for each reach. The summation of monthly values is more accurate, since it reflects the constraints of downstream use on a monthly basis.

Tables III-16, III-17, and III-18 of the Northeast Basins report (HKM, 2002a) show the monthly and annual available water by model reach for the Cheyenne River basin. A summary showing the annual available water is depicted in Table 3.3.1-1. The annual available water in the Cheyenne River above Lance Creek, the eastern limit of the Thunder Basin is 1,515 acre-feet, 12,895 acre-feet, and 57,621 acre-feet for the dry, normal, and wet hydrologic conditions, respectively. These values represent the annual availability, as opposed to the sum of the monthly availability. Annual availability for normal year hydrologic conditions is shown in Map 30, Surface Water Availability. The model indicated shortages in many of the reaches. These reaches are highlighted in blue on Table 3.3.1-1.

Table 3.3.1-1 Annual Available Flow Data for Cheyenne River Basin for Dry, Normal, and Wet Year Hydrologic Conditions (acre-feet) as reported in Northeast Wyoming River Basins Report (HKM, 2000a)

Reach	Reach Name	Dry Year	Normal Year	Wet Year
1	Dry Fork Cheyenne River	24	244	1,967
2	Dry Fork Cheyenne River Tribs above Gage 06365900	44	183	1,341
3	Willow Creek	60	225	704
4	Woody Creek	2	8	13
5	Lake Creek	18	68	213
6	Dry Fork Cheyenne River Tribs above Antelope Cr	164	860	4,501
7	Antelope Creek	534	2,837	21,427
8	Cheyenne River above Gage 06365900	705	3,696	25,968
9	Cheyenne River above Sheep Cr	707	6,341	37,321
10	Cheyenne River Tribs above Gage 06386500	69	399	1,980
11	Sheep Creek	1	8	19
12	Wagonhound Creek	3	17	60
13	Cheyenne River above Black Thunder Cr	1,007	7,074	39,624
14	Black Thunder Creek	358	5,120	16,078
15	Cheyenne River above Lodgepole Cr	1,482	12,193	55,745
16	Lodgepole Creek	9	480	1,268
17	Cheyenne River above Snyder Cr	1,491	12,674	57,013
18	Snyder Creek	14	187	474
19	Cheyenne River above Boggy Cr	1,511	12,861	57,500
20	Boggy Creek	4	34	122
21	Cheyenne River above Lance Creek	1,515	12,895	57,621
22	Seven Mile Creek	2	29	65
23	Lance Creek	3,184	18,323	44,909
24	Mule Creek	6	33	80

Reach	Reach Name	Dry Year	Normal Year	Wet Year
25	Cheyenne River above Robbers' Roost Cr	4,706	31,280	102,675
26	Robbers' Roost Creek	8	47	138
27	Cheyenne River above Gage 06386500	4,742	31,328	103,270
28	Cheyenne River above Stateline	4,911	31,434	103,362
	Model indicates shortage in reach			
	1,000 acre-feet or more available in normal year (reaches within study area)			

The model has limitations, which should be considered when reviewing the model and its results. The most significant limitation is that the model does not account for diversions in accordance with Wyoming water law. Downstream senior rights are not given priority, which should result in an upstream junior right incurring a shortage. Though the model does not account for this occurrence, historical diversion data would reflect these actual operational conditions. If a Level II study of a particular storage project is to be undertaken, it is suggested that StateMod or similar model be developed so that water rights can be appropriately exercised and potential water availability can be more accurately estimated.

3.3.2 Existing Reservoirs

As discussed in Section 2.1.7.2, Map 13, (National Inventory of Dams), shows the locations of the study area's 67 dams in the NIDS. The combined storage behind the identified dams is 19,741 acre-feet. The largest identified reservoir, Betty Reservoir, holds 2,029 acre-feet. The median reservoir size is 130 acre-feet. Dams that do not fall under the jurisdiction of the state engineer's office are not included in the database. Data Summary 3.3.2-1 (in Appendix A) lists the dams with select relevant information. Map 14, Stock/Wildlife Ponds, shows the location of 194 stock ponds in the study area.

3.3.3 Previous Storage Site Investigations

The Northeast Wyoming River Basins Plan (HKM, 2002a) only identified one long-list future water use opportunity, the Antelope Creek Water System. Water produced by CBM development in the Powder River drainage would be collected and conveyed to Antelope Creek in the Cheyenne River drainage. Water would be stored and treated in Bell 1 Reservoir and Bell 2 Reservoir and discharged into Antelope Creek for irrigation use. The project was eliminated from further consideration in this report since the purpose of the project was disposal of water produced through CBM development and was not considered to be a water supply project.

Studies completed in 1939 and 1957 included potential water storage projects. The list of projects is in Table 3.3.3-1, along with available information about the project location and the source of the information. The intended storage for the structures varied in size from 100 acre-feet to 15,000 acre-feet. None of these projects were identified in the Northeast Wyoming River Basins Plan. A Level 2 study was completed in 1939 for a reservoir on Black Thunder Creek. The location of the reservoir is in the same general area as one of the proposed reservoirs described in Section 4.2. The project was deemed to have an unacceptable cost-to-benefit ratio.

Table 3.3.3-1 1939- 1957 Potential Water Storage Projects

Project Name / Water Source	Section, Township & Range / County	Storage, acre-feet	Water Uses	Flaw
Water Resources of the Missouri River Basin in Wyoming - Cheyenne River [1]				
Lake Berry / Lodgepole Creek	Sec 31, T 42 N, R 64 W / Weston	2,931	Agricultural	--- [5]
Proposed Black Thunder Creek Reservoir, Weston County, Wyoming [2]				
Black Thunder Creek Reservoir	Sec 2, T 42&43 N, R 67 W / Weston	1,058	Agricultural	Benefit/Cost
Cheyenne River Basin Water Resource Study [3]				
Lodgepole	Sec 32, T 42 N, R 64 W / Weston	450	Agricultural	---
Wildcat	Sec 17, T 42 N, R 65 W / Weston	200	Agricultural	---
Black Thunder	Sec 2, T 42 N, R 67 W / Weston	1,058	Agricultural	---
Dry Draw	Sec 3, T 42 N, R 69 W / Campbell	100	Agricultural	---
Dry Draw	Sec 22, T 43 N, R 69 W / Campbell	100	Agricultural	---
Burning Coal Bank Draw	Sec 14, T 43 N, R 70 W / Campbell	100	Agricultural	---
Dry Draw	Sec 36, T 41 N, R 68 W / Converse	200	Agricultural	---
Dry Lake	Sec 11, T 41 N, R 68 W / Weston	15,000	Agricultural	---
Wildcat	Sec 35, T 41 N, R 69 W / Converse	100	Agricultural	---
Antelope	Sec 31, T 41 N, R 70 W / Converse	8,000	Agricultural	---
Wind	Sec 10, T 40 N, R 75 W / Converse	135	Agricultural	---
Bear	Sec 15, T 38 N, R 74 W / Converse	350	Agricultural	---
Dry Fork	Sec 17, T 37 N, R 75 W / Converse	200	Agricultural	---
Draw/Dry Fork	Sec 33, T 37 N, R 75 W / Converse	200	Agricultural	---
Northeast Wyoming River Basins Plan Final Report [4]				
Antelope Creek Water System	T 40 N, R 71 W / Converse	772	Agricultural	Not water supply

Notes: For notes 1-4, the report title is listed above and the following information provides / Level / Author / Date / Report Location

[1] Level 1 / State Engineer's Office / 1939 / WWDO and State Library

[2] Level 2 / St Plan. BD & WPA / 1939 / WWDO

[3] Level 1 / Wyoming Natural Resources Board / 1957 / WWDO & WRDS

[4] Level 1 / HKM Engineering, Inc. / 2002

[5] Not available in document or unknown

3.4 Water Quality

3.4.1 Stream Classifications

Many of the streams in the Thunder Basin watershed have been classified for protection of one or more uses by the WDEQ. Streams within the study area have been classified as 2ABWW or 3B (WDEQ, 2001). The Water Quality Rules and Regulations, Chapter 1, Wyoming Surface Water Quality Standards defines these three classifications as follows:

"Class 2AB waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either "cold water" or "warm water" depending upon the predominance of cold water or warm water species present. All Class 2AB waters are designated as cold water game fisheries unless identified as a warm water game fishery by a "ww" notation in the "Wyoming Surface Water Classification List". Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are protected for that use. Class 2AB waters are also protected for non-game fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value uses.

Class 3B 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. Such characteristics will be a primary indicator used in identifying Class 3B waters."

Table 3.4-1 defines the uses that are protected for all of the WDEQ surface water classifications. Map 31, WDEQ Stream Classifications, shows the stream classifications within the study area. Table 3.4-2 lists the streams and their classifications. Antelope Creek and Black Thunder Creek are classified as 3B waters, for which designated protected uses include aquatic life other than fish, recreation, wildlife, agriculture, industry and scenic value. The Cheyenne River is categorized as Class 2ABWW waters, for which designated protected uses include drinking water, warm-water game fisheries, non-game fisheries, fish consumption and all uses protected for Class 3B waters.

Table 3.4-1 WDEQ Surface Water Classes and Use Designation

	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
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
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, ephemeral waters, wet meadows etc). For stormwaterpermitting, 401 Certification, and WQ assessment purposes, independently the actual uses on each particular water must be determined.

Table 3.4-2 Thunder Basin Stream Classifications

Stream Name	WDEQ Classification	
	2ABWW	3B
Antelope Creek		
Bacon Creek		
Bates Creek		
Bear Creek		
Black Thunder Creek		
Buck Creek		
Cheyenne River		
Dry Fork Cheyenne River		
Duck Creek		
Frog Creek		
Hay Creek		
Keyton Creek		
Little Thunder Creek (above North Prong)		
Little Thunder Creek (below North Prong)		
Lodgepole Creek		
Porcupine Creek		
Prairie Creek		
Rough Creek		
Sage Creek		
Sand Creek		
Snyder Creek		
Wildcat Creek		
Willow Creek		
Wind Creek		

3.4.2 Water Quality Assessment

Water quality in the Thunder Basin watershed was assessed in a recent study and documented in the report *Water Quality Conditions of Antelope Creek, Black Thunder Creek, and the Cheyenne River, 2002-2006* published by the WDEQ water control division (WDEQ/WCD) (Hargett, 2007). The stream assessments were conducted under Section 305(b) of the Clean Water Act (CWA) with the goal of evaluating the streams to determine whether they meet the goals of the CWA and support their uses as designated by WDEQ/WCD. The Water Quality Rules and Regulations of the WDEQ/WCD protect water quality for designated uses including drinking water, fisheries, aquatic life other than fish, fish consumption, agriculture, industry, recreation, and scenic value.

Stream assessments were performed by the WDEQ/WQD Watershed Management Section's Monitoring Program during 2003 and 2004. Collected data was combined with representative and valid data collected by other federal, state, and local entities as appropriate. Additional data was collected by the USGS from 2002 to 2006 WGFD in 2004 and 2005 and incorporated into the water quality assessment (Hargett, 2007).

The main findings of the study focused on suitability of the streams to support aquatic life. The study found that total dissolved iron levels were high and sometimes exceeded WDEQ criteria levels in the streams. The report also stated that historical episodes of down-cutting, widening, and lateral migration have occurred. It was thought that channel reaches of the Cheyenne River and tributaries are still adjusting their dimensions but that they are moving toward a more stable form (Hargett, 2007).

3.4.3 Suitability for Agricultural Use

Analysis of available water quality samples was conducted to gain a sense of whether the water is suitable for agricultural use, mainly irrigation and livestock watering. Water quality criteria were compiled from four sources to assess the suitability and is presented in Data Summary 3.4.3-1 (in Appendix A). It should be noted that the WDEQ criteria was obtained from Chapter eight of the Water Quality Rules and Regulations, which addresses standards for Wyoming groundwater. Chapter one, which addresses surface water standards, does not contain water quality standards for livestock or irrigation.

Water quality sampling data was obtained from the USGS Web site for the gages identified on Map 15, Gaging Stations and Streamflow/Sampling Sites. Twelve of the gage locations had only one or two sample events, whereas seven of the gage locations had 39 sample events to 97 sample events. Water quality data can be found for the gages at the following Web site: http://nwis.waterdata.usgs.gov/wy/nwis/qwdata.

Data Summary 3.4.3-2 (in Appendix A) shows a summary of the sampling results. Ranges of results were typically shown for gage locations that had numerous samples, while the gages with only one or two samples show the results for the one or two samples, as appropriate. Values that exceeded the criteria listed in Data Summary 3.4.3-1 (in Appendix A) are highlighted in red. If results were reported as a “less than” value that was greater than the criteria, the results were highlighted in blue. It is possible that the criterion was exceeded, but not enough information was provided to be certain. For example, mercury was often reported as less than 1.0 µg/L, but the criteria is 0.05 µg/L, less than the value reported. It is not known whether the criterion was exceeded. Sodium absorption ratio data was not available for any of the samples. The Niobrara Conservation District reported that high SAR water is known to have caused adverse affects in the Cheyenne River basin.

The water quality criteria exceeded most often were sulfate, specific conductance, and manganese. Exceeding the criteria does not necessarily indicate that water is unsuitable for livestock watering or agriculture. It does suggest that livestock and less tolerant plants might not be as productive as they would be with lower levels of the constituent.

3.4.4 Waters Requiring TMDLs

The Wyoming 2008 305(b) Integrated State Water Quality Assessment Report does not show any of the streams in the study area to be water bodies for which Total Maximum Daily Load (TMDL) determinations have been completed or are needed. The State’s 2006 303(d) List of Waters Requiring TMDLs did not identify any streams within the study as needing a TMDL determination.

3.4.5 WYPDES Permitted Discharges

Data obtained from the WDEQ/WCD shows that there are 529 Wyoming Pollution Discharge Elimination System (WYPDES) permitted discharges in the study area. The breakdown of permit types are 503 CBM permits, seven coal mine permits, three industrial permits, and 16 oil treatment permits. The locations of the outfalls are shown in Map 32, WYPDES Permitted Discharges. Available flow and water quality information for the outfalls was obtained from

WDEQ/WCD. The spreadsheet of information includes more than 72,000 flow and water quality sampling data points. Analysis of this information is beyond the scope of this project, however the data is available for analysis in a Level II study.

3.4.6 Thunder Basin Wetland Functions

Wetlands can provide many functions, including wildlife habitat, flood flow alteration, erosion control, sediment capture, nutrient transformation, groundwater recharge/ discharge, habitat for rare species, and recreational opportunities. An individual wetland may provide some but not all of these functions, depending on variables such as size, hydrologic regime, location in the landscape, connectivity to other wetlands, and surrounding land use. Thus for the Thunder Basin watershed, it is only possible to generalize about wetland functions, and not discuss the functions of individual wetlands.

The location of the Thunder Basin wetlands were mapped as part of the National Inventory of Wetlands (Map 12). Please note that at the time of this report production, the maps were available electronically for only a portion of the basin which explains why large areas of the map have no wetlands identified.

The Thunder Basin watershed primarily contains three general categories of wetlands:

- Riparian wetlands adjacent to stream channels
- Seep wetlands in areas where groundwater reaches the surface
- Wetlands associated with small impoundments such as cattle ponds

The functions most likely to be provided by each type of wetland are discussed below.

Riparian Wetlands. These wetlands are located along drainages throughout the watershed. Depending on their size and whether the stream is ephemeral, intermittent, or perennial, these wetlands are most likely to provide the functions of wildlife habitat, flood flow alteration, and streambank erosion control. Some of these wetlands may occur in cut-off oxbows of streams. Wetlands adjacent to streams can serve as corridors for movement of terrestrial wildlife, and particularly if they are associated with permanent bodies of water, serve as cover and food sources for aquatic organisms. Thus, they may provide recreational opportunities for hunting and fishing. In addition, wetlands adjacent to streams provide storage for out-of-bank flood flows. In these areas, flood waters will be slowed, and the lower flood velocity combined with the vegetative cover are likely to reduce erosion in and adjacent to stream channels. Wetlands along perennial streams will have a more diverse plant community, and may provide habitat for rare species such as Ute ladies'-tresses (*Spiranthes diluvialis*).

Seep Wetlands. These wetlands develop in places where ground water intersects with the land surface for at least part of the year. The wetlands in these areas may have a hydrologic regime that is temporary or relatively permanent. Depending on the season of the year and the duration of seepage, these wetlands may provide the functions of recharging or discharging ground water, or both. Recharging ground water may be important for maintaining the water table and thus supplying wells, while discharging ground water may be important for maintain the headwaters of streams, particularly perennial streams. Wetlands maintained by seeping ground water are often quite diverse due to their relative hydrologic stability compared to wetlands maintained exclusively by surface runoff, and thus also may provide habitat for rare species such as Ute ladies'-tresses.

Impoundment Wetlands. These wetlands are associated with small ponds, such as those created for cattle. These ponds may be on-line (in other words, impoundments of a channel) or off-line in which case the water may be maintained by pumping water. Depending on the size of the pond, the depth of the water, and the source of the water, the wetland may be a fringe around the margins or may be more extensive. In either case, the impounded basin allows for water to be detained for longer periods of time than is the case for most riparian or seep wetlands. Thus these wetlands can provide the function of improving water quality by trapping sediment and removing and transforming nutrients. In addition, they can provide a water source for wildlife during times when surface water is otherwise scarce. Even a small pond with a fringe wetland may provide resting habitat for migrating waterfowl. Their use for ranching activities usually limits plant diversity or suitable habitat for rare species.

4.0 Watershed Management and Rehabilitation Plan

The following subsections provide details on the proposed watershed improvement projects. The projects are subdivided into irrigation improvements, surface water storage and wildlife/livestock watering opportunities and other management practice improvements.

4.1. Irrigation Systems

Rehabilitation plans have been proposed for each of the ditches inventoried. The rehabilitation plans give the owners of these ditches an idea of what needs to be done to make these ditches function properly and efficiently.

The alternatives were based upon information obtained from project meetings and the evaluation of field inventory data. These alternatives provide the owners an overall assessment of conditions associated with the ditches and the associated hydraulic structures. They are not all-inclusive as the entire extent of each ditch was not examined. For the purposes of this Level I investigation, the rehabilitation plans offer potential solutions to the primary issues and problems associated with each system. The irrigators can use these plans as a "resource or wish list" from which they can select projects for future Small Water Project Program or Water Development Program Level II investigations and ultimately Level III design and construction, if they desire to follow through with WWDC funding. Alternatively, this information also will support application for Natural Resources Conservation Service and/or other funding, as appropriate.

The rehabilitation plans focus on:

- Rehabilitation/replacement of existing structures
- Enhanced delivery of water
- Reduction in annual operation and maintenance costs
- Improvement in ditch management and efficiency
- Economic practicality
- Physical feasibility

4.1.2 Ditch Rehabilitation Plans

Based upon the results of the field inventories, rehabilitation cost estimates were developed and are presented in Table 4.1.2-1, Proposed Irrigation Improvements. This table includes the general description of the improvements and the estimated cost of construction.

Table 4.1.2-1 Proposed Irrigation Improvements

Rehabilitation Item Number	Ranch Name	Description	Units	Quantity	Unit Cost	Total Cost
Cheyenne Watershed (Black Thunder Creek) Improvements						
1	Stroh	Repair/Replace Head gate and install diversion structure	LS	1	-	$15,000
2	Stroh	Re-grade ditch 1	FT	2481	$5/FT	$12,405
3	Stroh	Repair/Replace Siphon	LS	1	-	$10,000
4	Stroh	Re-grade ditch 2	FT	3174	$5/FT	$15,870
5	Stroh	Re-grade ditch 3	FT	1263	$5/FT	$6,315
Cheyenne Watershed (Cheyenne River) Improvements						
6	Harshbarger	Re-grade ditch	FT	1600	$5/FT	$8,000
7	Harshbarger	Re-grade ditch	FT	5165	$5/FT	$25,825
8	Harshbarger	Repair/Replace Headgate	LS	1	-	$5,000
Antelope Creek Watershed Improvements						
9	Turner	Construct Spreader dikes	FT	420	$35/FT	$14,700
Dry Fork Cheyenne Watershed Improvements						
10	Pellatz	Install new headgate	EA	1	5000	$5,000
11	Pellatz	Re-grade ditch 1	FT	7778	$5/FT	$38,890
12	Pellatz	Re-grade ditch 2	FT	4057	$5/FT	$20,285
13	Pellatz	Build new dike	FT	1000	$35/FT	$35,000

During the visit to the Stroh Ranch, we identified that aside from the dam on the ranch, there are existing irrigation ditches that are not being used (Map 35f). The Little Black Thunder runs through the ranch; however due to bank erosion and cutting, the river has dropped significantly in places. So even though there is water flowing in the river, it is not making its way into the irrigation ditches. Based on these observations and further engineering evaluations, we have proposed several upgrades to the ditch system including headgate repair/replacement, ditch repair and siphon repair/replacement. As part of the headgate repair/replacement an in channel diversion structure will be needed as well. The existing dam is not functioning and the channel has downcut. There appears to be opportunities for cross vane type structures to provide adequate head pressure for a new diversion and headgate.

Harshbargers' 4W ranch is on the Cheyenne River. A combination of ditches and pumps are used for irrigation (Map 35c). The Cheyenne River runs dry most of the year, with large flows occurring during rainfall events. Since the ditches are used only a few times a year, they are prone to vegetation overgrowth and deterioration. Based on the existing ditches, some improvements could be made. Table 4.1.2-1 lists several proposed improvements including ditch repair and headgate repair/replacement. The Harshbargers also would like to create a permanent dam in the river that backs up flow high enough to divert water into the ditches on a more permanent basis. See Section 4.2.3.3 for more information on different dam options for the Harshbargers' property. Another option may be to construct a series of cross vane type structures to provide an increase in head elevation for the diversion point.

Turner Ranch is on Bates Creek (Map 35h). The Turners are using spreader dikes to distribute flow from Bates Creek to the hay fields. Mr. Turner is interested in identifying more acreage where spreader dikes could provide irrigation. As listed in Table 4.2.1-1, and based on the field reconnaissance and aerial photo review, we have proposed 420 linear feet of spreader dike construction to augment hay field production.

On Don Pellatz ranch, the fields are terraced (36i). There is a diversion off the Woody Creek into an irrigation canal (Ditch 1) leading to the irrigated fields. Based on CIR aerial imagery, this setup appears to be effectively irrigating the terraced fields. After speaking with Mr. Pellatz and visiting his land, we have determined that the irrigation canal has eroded in areas. He also has no head gate on the canal, thus he cannot control the amount of water his fields receive. This is a problem when too much water sits on the field. There is the possibility of storing water to the north of his land with the construction of a dike/dam across the north side of his field. Further study would be necessary in order to evaluate the practicality of building a dike for storage purposes. He also has a second irrigation ditch (Ditch 2) that collects the excess water from the irrigated fields and feeds another field on the east side of Woody Creek Road. Currently this ditch is not as effective as Ditch 1. This ditch might be better served if a dike could be built to store water. Table 4.2.1-1 lists the described improvements for the ranch.

The Bell Ranch has fields suitable for irrigation along the Antelope River. He was interested in identifying places on his property where a dam might be constructed to provide reliable irrigation to his fields. Storage water locations on Bell's property are discussed in greater detail in the following section.

4.2 Surface Water Storage

4.2.1 Alternative Concepts for New Surface Water Storage

Due to the large study area, it was necessary to develop screening criteria and methods to identify locations where water would be available and needed. Four main surface water storage concepts were developed based on known needs and shortages, potential water availability, and property owner requests. They are described below. The evaluations are described in Sections 4.2.2-4.2.5.

Account III Multipurpose Storage (see Section 4.2.2) – Reservoirs that would meet the requirements for WWDC Account III funding were first investigated. New reservoirs would need to provide at least 2,000 acre-feet of storage to qualify for the funding mechanism. Expansion of existing reservoirs must provide an additional 1,000 acre-feet of storage to qualify for the funding. The primary function of the reservoirs would be to provide supplemental irrigation water for irrigated lands that could be served through gravity delivery of water. The storage sites would need to be located far enough downstream of the headwaters to be able to capture the necessary amount of available flow. Secondary functions of the reservoirs would be to provide water in an "environmental account" to release for streamflow enhancement at critical times of the year, and as a seasonal fishery and/or for recreation.

Property Owner Storage Evaluation Requests (see Section 4.2.3) – Through the public information process, property owners and stakeholders were asked for input regarding storage evaluations on their properties. These requests were evaluated.

Livestock / Wildlife Storage (see Section 4.2.3) – As a rule of thumb, cattle will graze up to a mile from a water source. Using this criterion, an analysis of the watershed was conducted to identify locations where additional water storage for livestock watering could be beneficial.

Supplemental Storage at Existing Breached Dam Locations (see Section 4.2.5) – The watershed was searched to locate breached dam locations as potential water storage locations. Locations where dams once existed served a useful purpose at some point in time. Rehabilitating a breached dam could be less expensive than constructing a new water storage dam. These water storage sites would be used for supplemental irrigation of nearby irrigated lands and/or livestock and wildlife watering.

4.2.2 Potential Account III Sites

4.2.2.1 Overview

To qualify for WWDC Account III funding, a new surface-water storage project must provide a minimum of 2,000 acre-feet of storage and an expansion of an existing surface water storage site must provide an additional 1,000 acre-feet of storage. This section describes the process used to locate the structures and their conceptual design. The conceptual designs were based on information gathered and developed through the various tasks of this project.

4.2.2.2 Alternative Reservoir Locations and Sizing

Available flow for the normal year hydrologic conditions by reach was obtained from the Northeast Wyoming River Basins Plan Final Report (HKM, 2002a). The information was evaluated to determine which tributaries could potentially have a minimum of 1,000 acre-feet available in a typical year. Table 3.3.1-1 shows the available flow data for the Cheyenne River basin. Annual available flows for Antelope Creek, Black Thunder Creek, and six of the listed Cheyenne River reaches within the study area show at least 1,000 acre-feet of available flow. The drainage areas at the downstream ends of the reaches were determined so that unit available flow could be determined in acre-feet per square mile of drainage area. Data Summary 4.2.2-1 (in Appendix A) lists the reaches, the monthly and annual available flows, and the unit available flows.

For expansion of existing reservoirs, each of the 67 dams identified in the NIDS and shown in Map 13, National Inventory of Dams, was evaluated to determine whether each dam has enough watershed area to yield a minimum of 1,000 acre-feet of available water based on the averages described in the preceding paragraph. Of the 67 dams, only one dam emerged as a potential site, "Peterson No. 1" located on Black Thunder Creek downstream of Dull Center Road and upstream of the confluence with the Cheyenne River. The site has nearly 560 square miles of watershed area, almost the entire Black Thunder Creek watershed, for which over 5,000 acre-feet is shown to be available in a normal year. The NIDS shows that the existing dam has a height of 20 feet and permitted storage of 246 acre-feet. Neither aerial photography nor USGS topographic maps show that there is an existing water body in the specified location.

The landowner listed for the dam was contacted and reported that there is an existing dam that is used to capture flows when available and to irrigate hay meadows downstream of the dam. A reconnaissance-level investigation of the dam site was completed. A dam at that location that could store a minimum of 1,000 acre-feet of water in addition to the existing 264 acre-feet would need to be at least 15 feet in height, and 3,500 feet in length. The surface area would cover approximately 220 acres. These estimates are based on topographic mapping with 20-foot contour intervals. The location of the dam is shown in Map 33, Potential Surface Water Storage

Sites. It is estimated that the cost to expand the dam to capture and store a minimum of 1,000 acre-feet would be approximately $6 to $7 million based on the average cost per acre-foot of stored water developed for new dams presented in the remainder of this section,

New water storage dams were located to capture as much of the available flow as possible with there still being irrigated lands downstream, and of the sites that could benefit from the supplemental water. In addition, the locations needed to be far enough downstream of each subwatershed that the available flow for the drainage area exceeded 2,000 acre-feet. Other factors in the potential locations of the storage sites included topography, geology, and upstream/downstream constraints, including mines, highways, buildings, and other infrastructure. Water storage sites were developed in four locations, one each in the Antelope Creek and Black Thunder sub-watersheds, and two along the Cheyenne River, termed “Cheyenne 1” and “Cheyenne 2.”

It should be noted that the sites were identified using available water data from the Northeast Wyoming River Basins model, which does not include a detailed accounting of diversions in accordance with Wyoming water law. For example, downstream senior rights are not given priority, which should result in an upstream junior right incurring a shortage. If a Level II study of a particular storage project is to be undertaken, it is recommended that StateMod or similar model be developed so that water rights can be appropriately exercised and potential water availability can be more accurately estimated.

Concentrations of salts and other constituents can increase due to evaporation of water within storage reservoirs. The effects of accumulation of salts and other water constituents on the watershed should be investigated if one of the storage site projects were to advance to the next level of study.

The four sites identified as viable sites for new water storage dams are shown in Map 33. Data Summary 4.2.2-2 (in Appendix A) presents a comprehensive summary of design parameters related to the four dam locations, as well as a wide array of relevant information collected and developed throughout the course of the project. Maps 34a-34d show the four locations with the dam centerlines and limits of storage volumes.

Each dam site was designed to have an environmental account (EA) pool, irrigation storage, and a useful life of at least 50 years. The initial goal was to provide useful life of at least 100 years, however, an estimation of the potential sedimentation rates indicated that a dam that would be able to store 100 years of sediment accumulation plus water would not be reasonable.

Sedimentation was estimated from Figure 27 of *Sediment Sources and Drainage Basin Characteristic in Upper Cheyenne River Basin* (Hadley and Schumm, 1961). It is included in this report as Figure 4.2.2-1, Sediment Yield in the Cheyenne River Basin. The U.S. Bureau of Reclamation has conducted sedimentation surveys on a number of its reservoirs. Reports obtained from the following Web site were reviewed. Annual sedimentation rates tended to be higher than those reported in Hadley and Schumm.
http://www.usbr.gov/pmts/sediment/projects/ReservoirSurveys/index.html

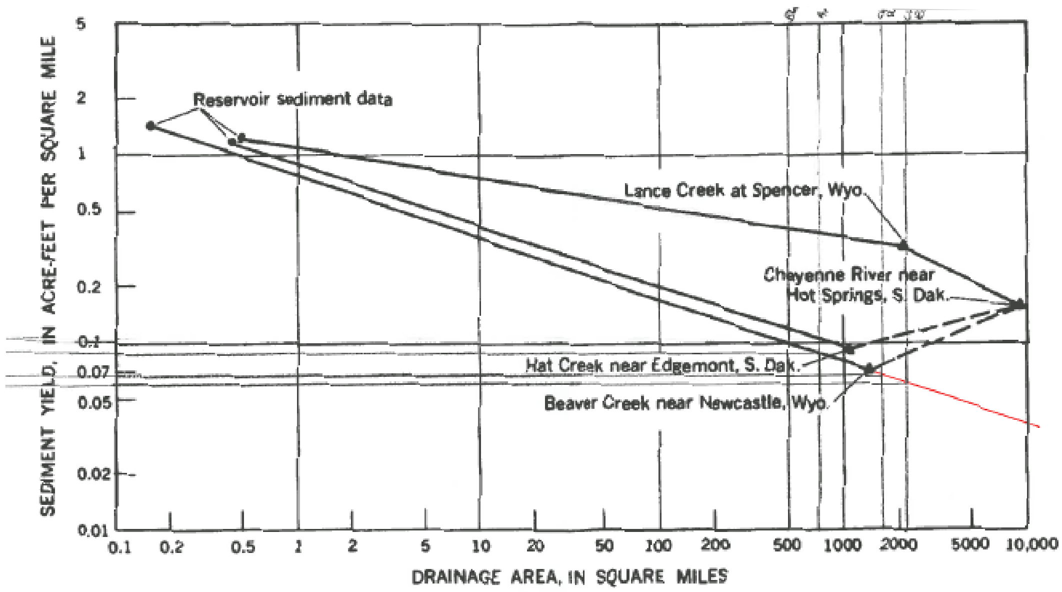


FIGURE 27.—Relations between sediment yield to 87 sediment-observation reservoirs and suspended sediment measured at gaging stations in the Cheyenne River basin.

Figure 4.2.2-1 Sediment Sources and Drainage Basin Characteristic in Upper Cheyenne River Basin (Hadley and Schumm, 1961).

Elevation and stage-storage information for each location was developed using USGS topographic maps with 20-foot contour intervals. Detailed topographic information will be needed if further analysis of dam sites is desired. The NRCS' Reservoir Operations Study Computer Program (RESOP) was used to estimate reservoir levels on a monthly basis. RESOP utilizes stage-storage relationships, monthly available flows, monthly average precipitation, monthly average evaporation, estimates of seepage, and beneficial use.

The EA pool volume was determined from the lowest average monthly water level determined with the RESOP model. Irrigation storage for each site was determined by modeling the reservoirs with and without irrigation. The initial estimate of irrigation was half of the volume of the lowest month's permanent pool. The volume of water available for irrigation was spread between May and August and the water available models were iterated to use the difference between the EA and the available water.

For Antelope and Cheyenne 1, the total storage was determined by the 50-year sediment accumulation volume. The total storage is slightly higher than the 50-year sedimentation volume because the spillway elevation was set to the nearest tenth of a foot, which added a small amount of volume. For Black Thunder and Cheyenne 2, the total storage was based on the RESOP analysis, which maximized the storage at each site. At the construction of the reservoirs, the total storage is greater than the EA pool plus the irrigation volume.

As the reservoir fills with sediment, the environmental account storage will decrease and the elevation of the irrigation storage pool will increase. Once the environmental account volume is filled with sediment, the irrigation storage pool will begin to fill with sediment and the volume available for irrigation will decrease. The water level management of each reservoir will change over time. After the design life of each reservoir is reached, it is anticipated that it could be full of sediment. It should be noted that a sediment capture rate of 100 percent was used. This rate might be overly conservative, but the sediment yield information greatly varied. Should a site advance to a Level II study, a more detailed analysis on sedimentation will be needed.

Table 4.2.2-2 summarizes the storage volumes and design life for each dam site. The EA pool, irrigation pool and 100-year water surface are shown on Maps 34a-34d.

Table 4.2.2-2 Summary of Potential Dam Site Storage and Design Life

Dam Site	EA Pool (acre feet)	Irrigation Storage (af)	Total Storage (af)	Sedimentation Rate (af/mi^2/yr)	50-Year Sedimentation Volume (af)	Total Storage Life (yr)
Antelope	384	1,334	3,509*	0.09	3,497	50
Black Thunder	703	2,156	2,897**	0.068	2,530	57
Cheyenne 1	966	3,663	5,840*	0.061	5,824	50
Cheyenne 2	2,952	5,563	8,575**	0.1	7,122	60

Notes: *Total storage was calculated to accommodate the 50-year sedimentation volume. Total storage volume is slightly higher since top of spillway was set to a tenth of a foot.

**Total storage was based on RESOP analysis that maximized water storage at the site. Not all water in excess of EA pool is available for irrigation.

4.2.2.3 Flood Hydrology and Spillway Sizing

A conceptual design of the dams, spillways, and outlet works was completed for the four potential dams. Each site was designed using the following typical criteria: earth dams with low level outlets, a 100-year flood control concrete spillway, an earth emergency spillway for one half of the Probable Maximum Flood (PMF), and a minimum design life of 50 years. The NRCS Water Resources Site Analysis Program (SITES 2005.1) was used to complete the conceptual design.

Conceptual Dam Safety Hazard Classification

According to the state engineer's office, the State of Wyoming does not explicitly define hazard classifications but does follow Federal Emergency Management Agency (FEMA) 333, *Federal Guidelines for Dam Safety* (FEMA, 1998). Three hazard classifications are defined in the document:

- *Low Hazard Potential:* Dams assigned the low hazard potential classification are those where failure or mis-operation results in no probable loss of human life and low economic and/or environmental losses. Losses are principally limited to the owner's property.
- *Significant Hazard Potential:* Dams assigned the significant hazard potential classification are those dams where failure or mis-operation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or can impact other concerns. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.

- *High Hazard Potential:* Dams assigned the high hazard potential classification are those where failure or mis-operation will probably cause loss of human life.

Due to their locations and surroundings, it is thought that the four sites would be classified as significant or low hazard potential dams.

Inflow Design Flood and Probable Maximum Flood Determination

Because the State of Wyoming's Safety of Dams Program information does not specify the design criteria for different dam sizes and classifications, the State of Colorado Dam Safety Rules were used as a guideline for determining the Inflow Design Flood (IDF) that would be required for design of the dams and spillways. Based on their sizes, the dams would be classified as small dams. For the purposes of this study, they were all considered to be significant hazard dams. Each site was evaluated with an IDF equal to one-half of the PMF, in accordance with State of Colorado guidelines.

The level of study for this project does not warrant the in-depth analysis necessary to determine the most accurate PMF for each dam site; therefore, the PMF peak flows for each site were determined based on correlations of drainage area versus peak flows from previous studies of dam sites in Wyoming, South Dakota, Montana, and Nebraska. This information was compiled for the Cottonwood/Grass Creek Watershed Management Plan (SEH, 2007).

The original data included 35 sites ranging in drainage area sizes from 3.1 square miles to 19,650 square miles. Outliers were determined and removed from the data set, along with sites that did not reflect typical Wyoming sites. From the remaining sites, correlation factors for both the whole data set and ranges of drainage areas were determined. The subset for drainage areas ranging from 65 square miles (mi^2) to 4,300 mi^2 yielded a correlation factor (R^2) value of 0.91.The following regression equation was determined based on these 14 sites and was used to determine the PMF flow for each of the four potential dam sites:

$$Q_{PMF} = 91.669(DA) + 87,375$$

Where: Q_{PMF} = Peak PMF discharge in cubic feet per second (cfs)
DA = Drainage area in mi^2

The Q_{PMF} and IDF values determined for each of the four sites is summarized in Table 4.2.2-3. The information is also included in Data Summary 4.2.2-1 (in Appendix A).

Table 4.2.2-3 Inflow Design Floods and Volumes for Potential Dam Sites

Dam Site	Drainage Area (mi^2)	Q_{PMF} (cfs)	IDF (½ Q_{PMF}) (cfs)	V_{PMF} (acre-feet)
Antelope	777	158,605	79,303	394,373
Black Thunder	506	133,753	66,876	240,715
Cheyenne 1	1,713	244,399	122,199	924,815
Cheyenne 2	2,335	301,417	150,708	1,277,344

The IDF values were used to calibrate the point rainfall input in the SITES 2005.1 program. It is important to note that should any of the potential dam sites be investigated further, a more detailed analysis of the IDF will be required.

IDF volumes were estimated using the same procedure for the same 14 dam sites. The following regression equation, which yielded an R^2 value of 0.82, was determined and used to determine IDF volumes for the four dam sites:

$$V_{PMF} = 567.77(DA) - 46{,}030$$

Where: V_{PMF} = PMF volume in acre-feet feet per second (cfs)
DA = Drainage area in mi^2

The V_{PMF} values determined for each of the four sites is summarized in Table 4.2.2-3. The information also is included in Table 4.2.2-2.

100-Year Flood Determination

The 100-year peak discharges were determined using USGS Water-Resources Investigations Report (WRIR) 03-4107 (Miller, 2003). The Black Thunder watershed is in Region 2 and the remaining sites are primarily in Region 3. The two equations that were used to determine the 100-year peak discharges are as follows:

$$\text{Region 2: } Q_{100} = 415(DA^{0.430})$$

$$\text{Region 3: } Q_{100} = 127(DA^{0.432})(Soil^{2.05})$$

Where: Q_{100} = 100-year peak discharge in cubic feet per second (cfs)
DA = Drainage area in mi^2
Soil = Mean basin soils hydrologic index

The time of concentration and runoff curve numbers were determined for each watershed and input into the SITES models developed for each dam site. The 100-year, 24-hour point rainfall values were obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 2 maps. A weighted average of rainfall depths over the entire watershed for each site was determined. The weighted average rainfall values were put into the SITES models. The times of concentration and runoff curve numbers were adjusted to calibrate the models to the 100-year peak discharges estimated from WRIR 03-4107. The 100-year peak discharges and weighted 100-year, 24-hour point rainfall values are summarized in Table 4.2.2-4.

Table 4.2.2-4 100-Year Design Inflows and Related Parameters for Potential Dam Sites

Dam Site	Drainage Area (mi^2)	Soil Index from USGS WRIR 03-4107	Q_{100} (cfs) from USGS WRIR 03-4107	100-Year, 24-Hour Point Rainfall (in) from NOAA Atlas II
Antelope 1	777	3	21,408	3.9
Black Thunder	506	N/A	6,037	3.5
Cheyenne 1	1,713	3	30,122	3.8
Cheyenne 2	2,335	3	34,435	3.7

4.2.2.4 Conceptual Dam and Appurtenances Design

Typical design parameters were applied to each dam site to complete the dam analysis. Each dam will have a low-level outlet pipe with a gate control to release irrigation flows. The conceptual 100-year flood control (principle) spillway was assumed to be a concrete chute with 7-foot foot vertical walls on each side. The length of the spillway was based on the elevation difference between the top of the (total) storage elevation and the valley flow-line elevation as determined from quadrangle topographic maps and a three horizontal to one vertical (3:1) slope between the top of the spillway and the valley floor elevations. The 100-year peak inflow was used to size the width of the spillway as determined by the following formula:

$$W = \frac{Q_{100}}{3H^{1.5}}$$

Where: W = Width of spillway in feet
Q_{100} = 100-year peak discharge in cfs
H = Height of spillway in feet

The earth embankments were assumed to have a top width of 14 feet with a 2 percent slope to the crown on either side. A 25-foot-wide wave berm is on the upstream side of the embankment, a 40-foot-wide berm is on the downstream side, and side slope ratios were assumed to be 3:1. The emergency spillway exit channels were assumed to be excavated out of native material. The lengths were determined by using a 3 percent slope from the emergency spillway crest to the flowline elevation. The bottom width and crest elevation were determined by iterations in SITES 2005.1 using the target IDF values. Typically, the materials excavated from the emergency spillway, if suitable, will be used in the construction of the embankment.

4.2.2.5 Discussion of Sites

Antelope Creek: The first potential location for a dam on Antelope Creek was downstream of the confluence with Porcupine Creek, approximately 10 miles downstream of the location proposed in this report. This location was near the centroid of the watershed and incorporated additional tributary area. The location, however, was immediately downstream of mining operations. The proposed location is approximately 1 mile upstream of current mining operations, but future conflicts could exist and need to be thoroughly investigated.

The Antelope Creek watershed has the lowest available water yield as compared to the other three potential locations. The total estimated volume was 3,509 acre-feet, with an irrigation volume of 1,334 acre-feet. The surface area at the principle spillway was estimated to be 311 acres. The design life was estimated to be 50 years. A conceptual cost estimate for the Antelope Creek dam site is included in Tables 4.2.2-5. Annual operation and maintenance costs for all of the structures was estimated to be 0.75% of the construction cost, based on Nebraska NRCS recommendations.

Table 4.2.2-5 Conceptual-Level Cost Estimate - Antelope Creek Site

DESCRIPTION OF ITEM	UNIT	UNIT PRICE	QUANTITY	COST ESTIMATE
Final Design and Specifications	LS	$775,000	1	$775,000
Permitting	LS	$95,000	1	$95,000
Mitigation	AC	$8,000	0.0	$0
Legal Fees	LS	$30,000	1	$30,000
Acquisition of Right-of-Way	LS	$185,000	1	$185,000
Total Non-Construction Costs				**$1,085,000**
Mobilization	LS	$360,000	1	$360,000
Dam	CY	$10	482,000	$4,820,000
Principal Spillway	LS	$980,000	1	$980,000
Outlet Works	LS	$55,000	1	$55,000
Construction Cost Subtotal #1				**$6,215,000**
Engineering Costs = CCS#1 x 10%				$621,500
Subtotal #2				$6,836,500
Contingency = Subtotal #2 x 15%				$1,025,475
Construction Cost Total				**$8,946,975**
Project Cost Total				**$10,031,975**
Less Level II/Phase III Costs				$870,100
Project Cost Used in Ability to Pay Analysis				**$9,161,875**
Anticipated Annual O&M Costs, 0.75% of Construction Cost				**$67,000**

Black Thunder: The Black Thunder watershed has the highest unit available water among the three watersheds under consideration for potential storage sites. The total estimated volume was 2,897 acre-feet, with an irrigation volume of 2,156 acre-feet. The surface area at the principle spillway was estimated to be 320 acres. The design life was estimated to be 56 years.

As can be seen in Map 34b, there are buildings that comprise the headquarters for a ranch approximately 1,700 feet upstream of the dam centerline. One of the buildings seen from aerial photography is close to the 100-year flood boundary. The landowner suggested moving the dam upstream of the ranch headquarters. This option was investigated, and an alternate dam centerline is shown in Map 34b. The site topography is not as favorable in this location, as indicated by the dam that is approximately 25 percent longer. It is likely the cost of the dam could be 25 percent to 50 percent higher than that of the original location. The 100-year flood boundary was estimated from the USGS topographic maps with 20-foot contours. Although it appears that the building closest to the 100-year flood boundary is outside of the boundary, more accurate information is needed to determine its actual elevation. It would be less expensive to move a building or two, if necessary, than to increase the size of the dam by as much as would be needed the alternate location. If desired, the feasibility of this location can be investigated. A conceptual cost estimate for the Black Thunder dam site is included in Table 4.2.2-6.

Table 4.2.2-6 Conceptual-Level Cost Estimate - Black Thunder Site

DESCRIPTION OF ITEM	UNIT	UNIT PRICE	QUANTITY	COST ESTIMATE
Final Design and Specifications	LS	$920,000	1	$920,000
Permitting	LS	$110,000	1	$110,000
Mitigation	AC	$8,000	1.9	$15,200
Legal Fees	LS	$35,000	1	$35,000
Acquisition of Right-of-Way	LS	$220,000	1	$220,000
Total Non-Construction Costs				**$1,300,200**
Mobilization	LS	$425,000	1	$425,000
Dam	CY	$10	662,000	$6,620,000
Principal Spillway	LS	$273,000	1	$273,000
Outlet Works	LS	$50,000	1	$50,000
Construction Cost Subtotal #1				**$7,368,000**
Engineering Costs = CCS#1 x 10%				$736,800
Subtotal #2				$8,104,800
Contingency = Subtotal #2 x 15%				$1,215,720
Construction Cost Total				**$10,620,720**
Project Cost Total				**$11,920,920**
Less Level II/Phase III Costs				$1,031,520
Project Cost Used in Ability to Pay Analysis				**$10,889,400**
Anticipated Annual O&M Costs, 0.75% of Construction Cost				**$80,000**

Cheyenne 1: This potential dam is upstream of Black Thunder Creek. There are irrigated lands between the dam and Black Thunder Creek that could benefit from supplemental irrigation. The total estimated volume was 5,840 acre-feet, with an irrigation volume of 3,663 acre-feet. The surface area at the principle spillway was estimated to be 527 acres. The design life was estimated to be 50 years. It is estimated that 19.5 acres of non-riverine wetlands could be affected by construction of the dam. It could prove difficult to mitigate this area of wetlands. A conceptual cost estimate for the Cheyenne 1 dam site is included in Table 4.2.2-7.

Table 4.2.2-7 Conceptual-Level Cost Estimate - Cheyenne 1 Site

DESCRIPTION OF ITEM	UNIT	UNIT PRICE	QUANTITY	COST ESTIMATE
Final Design and Specifications	LS	$1,615,000	1	$1,615,000
Permitting	LS	$195,000	1	$195,000
Mitigation	AC	$8,000	19.5	$156,000
Legal Fees	LS	$65,000	1	$65,000
Acquisition of Right-of-Way	LS	$390,000	1	$390,000
Total Non-Construction Costs				**$2,421,000**
Mobilization	LS	$735,000	1	$735,000
Dam	CY	$10	1,094,000	$10,940,000
Principal Spillway	LS	$1,190,000	1	$1,190,000
Outlet Works	LS	$50,000	1	$50,000
Construction Cost Subtotal #1				**$12,915,000**

DESCRIPTION OF ITEM	UNIT	UNIT PRICE	QUANTITY	COST ESTIMATE
Engineering Costs = CCS#1 x 10%				$1,291,500
Subtotal #2				$14,206,500
Contingency = Subtotal #2 x 15%				$2,130,975
Construction Cost Total				**$18,758,475**
Project Cost Total				**$21,179,475**
Less Level II/Phase III Costs				$1,808,100
Project Cost Used in Ability to Pay Analysis				**$19,371,375**
Anticipated Annual O&M Costs, 0.75% of Construction Cost				**$141,000**

Cheyenne 2: This potential dam location is the largest of the four. It is downstream of Black Thunder Creek. The total estimated volume was 8,575 acre-feet, with an irrigation volume of 3,663 acre-feet. The surface area at the principle spillway was estimated to be 764 acres. The design life of the dam was estimated to be 59 years based on the estimate of sedimentation. It is estimated that 13 acres of non-riverine wetlands could be affected by construction of the dam. Though not as many acres as Cheyenne 1, this wetlands area also could prove difficult to mitigate. A conceptual cost estimate for the Cheyenne 2 dam site is included in Table 4.2.2-8.

Table 4.2.2-8 Conceptual-Level Cost Estimate - Cheyenne 2 Site

DESCRIPTION OF ITEM	UNIT	UNIT PRICE	QUANTITY	COST ESTIMATE
Final Design and Specifications	LS	$1,245,000	1	$1,245,000
Permitting	LS	$150,000	1	$150,000
Mitigation	AC	$8,000	13.0	$104,000
Legal Fees	LS	$50,000	1	$50,000
Acquisition of Right-of-Way	LS	$300,000	1	$300,000
Total Non-Construction Costs				**$1,849,000**
Mobilization	LS	$575,000	1	$575,000
Dam	CY	$10	766,000	$7,660,000
Principal Spillway	LS	$1,680,000	1	$1,680,000
Outlet Works	LS	$60,000	1	$60,000
Construction Cost Subtotal #1				**$9,975,000**
Engineering Costs = CCS#1 x 10%				$997,500
Subtotal #2				$10,972,500
Contingency = Subtotal #2 x 15%				$1,645,875
Construction Cost Total				**$14,467,375**
Project Cost Total				**$16,316,375**
Less Level II/Phase III Costs				$1,396,500
Project Cost Used in Ability to Pay Analysis				**$14,919,875**
Anticipated Annual O&M Costs, 0.75% of Construction Cost				**$109,000**

All of the sites have the potential for development of recreation based on their storage areas at the principle spillway. The reservoirs levels, however, would fluctuate throughout the year due to irrigation. Public access to most of the sites is marginal, as most lack public roads. The Antelope Creek site has the best potential access, with Highway 59 crossing near the upstream end of the reservoir. The locations of the storage sites were compared to nearby irrigated lands or potentially irrigable lands to make a general assessment of the water delivery system that would be needed. Irrigated lands that could benefit from supplemental irrigation are located in close proximity to Cheyenne 1 and Black Thunder. Irrigated lands do not appear to be located in close proximity to the Antelope Creek or Cheyenne 2 sites.

4.2.2.6 Anticipated Geologic Conditions

The overall geologic conditions for the watershed were presented in Section 2.1.5. Maps 7 and 8 show the surficial and bedrock geology for the study area. In evaluating potential dam locations, the foremost concern from a geologic perspective was to avoid the clinker surficial geology, since it is unsuitable for a reservoir. The Antelope Creek site is underlain by the Lebo member of the Tertiary-age Fort Union Formation. The Black Thunder site is underlain by the Tullock member of the Tertiary-age Fort Union Formation. The Cheyenne 1 site is underlain by Quaternary-age alluvium and colluvium in the vicinity of the Cheyenne River channel and the Tullock member of the Tertiary-age Fort Union Formation outside of the river channel. The Cheyenne 2 site is also underlain by Quaternary-age alluvium and colluvium in the vicinity of the Cheyenne River and the Lance Formation outside of the river channel area. The Fort Union and Lance Formations consist primarily of shales, sandstones, and coal beds. Due to the general nature of the geologic mapping and the variability of conditions, site-specific studies must be conducted should one of the sites advance to a Level 2 study.

4.2.3 Property Owner Storage Evaluation Requests

During the course of the project, bi-monthly public meetings were held to solicit input from landowners within the study area. At the beginning of the project, landowners were sent information that included a potential project information form — upon which irrigation system, upland well development, stream/rangeland enhancements, and water storage assessments could be requested.

The following sections describe the surface water assessments that were requested, and the analyses conducted. Generally, the properties were evaluated for suitable storage locations.

4.2.3.1 Bell Property

The Bell Ranch property is within the Antelope Creek watershed, in which the average unit available water yield is 2.7 acre-feet per square mile, as shown in the Northeast Wyoming River Basins Report (HKM, 2002a). Aerial and topographic information was used to identify tributaries on which a dam could be constructed. During a site visit to the property, Mr. Bell identified a potential dam, which is shown in Map 35a, Bell Ranch. The tributary area for this area was 1.4 square miles. Based on the average available water yield of 2.7 acre-feet per mile, the annual available water was estimated to be 3.8 acre-feet, not taking into account evaporation and seepage. If a storage site with an average depth of 7 feet were available, the surface area would be less than 0.6 acres. With annual evaporation in the area of 30 inches, or 2.5 feet, approximately 1.5 acre-feet would be lost to evaporation. Seepage in these small structures can often reach 40 percent of the storage, which would approach 1.6 acre-feet. Most of the water would be lost to seepage and evaporation. It is evident that the benefit-to-cost ratio would be too low to justify the project. It is possible that more in-depth analysis of this location could show more available water yield, making the location more feasible.

4.2.3.2 Haefele Property

The Haefele Ranch also is within the Antelope Creek watershed, in which the average unit available water yield is 2.7 acre-feet per square mile. Tributaries on the property have watershed areas of 0.3-1.1 square miles. Based on the analysis for the Bell property above and the information available at this level of study, construction of a surface water dam would not meet acceptable cost-benefit ratios.

Sand Creek flows through and/or is next to the Haefele Ranch. A dam on Sand Creek in the vicinity of the Haefele's property has the potential to impound runoff from 278 square miles of watershed. Based on an average available water yield of 2.7 acre-feet per mile, the annual available water was estimated to be 751 acre-feet, not taking into account evaporation and seepage. Map 35b, Haefele Ranch, shows the location at which Sand Creek would be dammed. The dam itself would likely need to be approximately 2 miles long. This information was presented at the Jan. 21, 2009 public meeting. The Haefeles were present and commented that, although they would appreciate the supplemental water, they were not interested in constructing a dam on their property.

4.2.3.3 Harshbarger Property

The Harshbarger property is next to the Cheyenne River. It has a run-of-the-river type dam that is constructed by the property owner of materials pushed up with his own equipment. The location of the existing dam is shown in Map 35c, Harshbarger Ranch. The dam is washed out during every major flood event, necessitating reconstruction. The purpose of the dam is to back water up high enough to be diverted to the 87-acre "UNK's Field," as shown in Map 35c. The property owner requested that an improved dam and spillway be evaluated at a location approximately 3,000 feet downstream of the existing location. The objective of the project would be to back water up high enough that the existing canal can still be used to irrigate UNK's field. An additional benefit of the project would be sub-irrigation of the riparian area adjacent to the Cheyenne River. The structure would need to be able to withstand the high flows of the Cheyenne River in the spring without causing flooding problems upstream.

Major (retired) Harshbarger, the property owner, noted that under existing conditions, the water must be 6 feet to 8 feet deep near the entrance of the canal in order to be used. The bottom of the canal is believed to be approximately 4 feet above the bottom of the Cheyenne River. The downstream dam location would need to back water up 10 feet to 12 feet at the new dam in order to maintain a water elevation that would still make use of the existing canal. Map 35c shows an example location where the dam could be situated. Based on Cheyenne River channel elevations determined from the USGS topographic map, the elevations would appear to work for being able to back water up 10 feet to 12 feet. The north bank appears to be steep, which could be suitable for a dam, and there appears to be enough elevation difference between the top of bank and the channel bottom to construct a dam of the desired height. The bank on the south side is not as steep or well-defined. More refined elevation information is needed to determine whether a dam is feasible in this general area. A feasibility study is recommended to evaluate the viability of constructing a diversion dam downstream of the existing run-of-the-river dam.

Sherwin Dam on Piney Creek is on the Harshbarger property. It is shown in Map 35c. Sherwin Dam is a permitted dam included in the state's dam database. It has been breached. Major

Harshbarger noted that over the years sediment built up more than 20 feet deep behind the dam. The storage was listed in the database as 664 acre-feet, which is significant. Repair of the Sherwin Dam was discussed at the Jan. 21, 2009 public meeting, where the reception was neutral. The dam is located in the Cheyenne River watershed, which has an average unit available water yield of 4.0 acre-feet per square mile. The drainage area for the dam is 10.2 square miles, which would represent an annual available water yield of 40.8 acre-feet. A feasibility study is recommended to determine what would be needed to rehabilitate Sherwin Dam as a structurally sound reservoir. A more detailed analysis of water availability and water rights would determine whether the reservoir could be expanded and could qualify for Account III funding.

4.2.3.4 Moore Property

The Moore request was for water improvements for three general areas: (1) Township 40N, Range 75W, Sections 2, 3, and North ½ of Sec 11, (2) Township 41N, Range 75W, Sections 33 and 34, and (3) Township 40N, Range 77W, Sections 10, 11, 14, 15, and 22 (Maps 35d and 35e). These locations were examined to evaluate whether surface water storage would be feasible.

The first location listed above contains steep draws that are tributary to Wind Creek. The topography would provide good locations for dams due to the steep draws. The property is within the Antelope Creek watershed, with an average annual available flow of 2.7 acre-feet per square mile during normal hydrologic conditions. If a dam were constructed in the northeast quarter of Section 11 to capture approximately four Wind Creek tributaries, the watershed area would be just more than 1 square mile, resulting in an average of 2.7 acre-feet of available water per year. Similar to the information presented for the Bell and Haefele properties, the anticipated yield would be small and much of the water lost to evaporation and seepage. It is possible that more in-depth analysis of this location could show more available water yield, making the location more feasible.

The second location also is in the Antelope Creek watershed. Red Rock Draw flows through Section 33 and McNaughton flows through Section 34. The watershed area for Red Rock Draw is 8.7 square miles for a dam constructed in the southeast quarter of Section 32, immediately to the west of Section 33, as shown in Map 35d, Moore Ranch – East Property. The resulting average annual available water at this location would be 23.5 acre-feet. This amount of water, after seepage and evaporation losses, could be enough to support supplemental irrigation of some fields. The drawback is that it would not be located on the Moore property. The benefits to the adjacent landowner would need investigation. This location warrants further consideration and feasibility study is recommended. The watershed area for McNaughton Draw, for a dam located in the northeast quarter of Section 33, would be 1 square mile. This area is too small to support viable water storage.

The third location is near the western central boundary of the study area. The topography is primarily steep canyons, which could make good water storage sites. The South and North Forks of Wind Creek flow through the property. Watershed areas were delineated for dams located in the northwest quarter and southwest quarter of Section 11 on tributaries of Wind Creek and the northwest quarter of Section 14 on the South Fork of Wind Creek. The drainage areas were 1 square mile, eight-tenths of a square mile, and 1.1 square miles, respectively, which are too small to support viable water storage.

4.2.4 Livestock Watering Opportunities

Due to the large watershed, it was necessary to develop a screening method to determine where additional livestock watering is desirable or needed, in addition to the requests of property owners. As a rule of thumb, cattle will graze up to a mile from a water source. Map 36, Existing Livestock/Wildlife Watering Opportunities, shows the stock wells in the state engineer's office database and stock pond locations. Around each of these, circles with a 1-mile radius were drawn to indicate locations served by an existing water source. Areas outside of the circles indicate areas where additional water development could be useful. Areas not sufficiently served by an existing water source were evaluated for well development, as described in Section 4.4, and for rehabilitation of existing breached dams, as described below in Section 4.2.5.

4.2.5 Evaluation of Breached Dam Sites

A reconnaissance-level survey of the entire study area was conducted using aerial photography, topographic maps, and GIS surface water layers to identify locations where breached dams exist. Some of the dams are breached such that the former reservoir is empty, while others are apparently partially breached and still hold a smaller amount of water. Map 37, Breached Dam Locations, shows the locations of the identified breached dams, which are listed in Data Summary 4.2.2-3 (in Appendix A). One location, termed "Sherwin Dam" is included in the NIDS and is included in the list of jurisdictional dams of the state engineer's office. It is the only known breached dam in the watershed that is in the state database.

The estimated surface area behind each breached dam was estimated. Assuming an average depth of 5 feet, an estimate was made of how much storage could be gained. At Sherwin Dam, the actual volume was listed in the dams' database. There are 119 breached dam locations. The median pond size was 0.3 acres and the median estimated volume was 1.5 acre-feet. The total estimated volume was 1,096 acre-feet.

The preliminary results of a partial study of the watershed were presented at the project public meeting on Jan. 21, 2009. Attendees were asked whether any of the locations were desirable for rehabilitation. The TBGA annual meeting was to be held the same week and the same question was posted at the meeting. Other than storage evaluation requests described in Section 4.2.3, no feedback was received regarding which of the breached dam locations would be desirable to rehabilitate.

The breached dam locations were compared to the cattle ranges around the stock wells and stock ponds, as shown in Map 36, Existing Livestock/Wildlife Watering Opportunities. Six of the breached dam locations were outside of the circles that designated the ranges. Those six structures could be repaired to provide additional livestock / wildlife watering in areas not served by other water sources. 4.2.2-9 shows the locations and estimated conceptual-level costs to repair the structures, which were based on a typical cost per acre-foot of water. If there is interest in rehabilitating any of these structures, site visits must be made to gain a better sense of the extent of necessary rehabilitation. The locations of these six breached dams are highlighted in Map 37.

Table 4.2.2-9 Breached Dam Locations and Estimated Conceptual-level Costs to Repair

Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)	Unit Cost ($/ac-ft)	Total Cost ($)	Notes
36	76	23	22,678	0.52	5	113,390	2.6	$17,000	$44,252	Ponds still hold some water, depth reflects storage that could be added to the existing ponds if the dams were repaired.
37	76	21	6,224	0.14	5	31,120	0.7	$17,000	$20,000	
39	64	28	6,625	0.15	5	33,125	0.8	$17,000	$20,000	
39	71	21	8,671	0.20	5	43,355	1.0	$17,000	$20,000	
39	76	35	9,994	0.23	5	49,970	1.1	$17,000	$20,000	
46	66	20	11,719	0.27	5	58,595	1.3	$17,000	$22,868	

4.3 Groundwater Development

Shallow groundwater development is a viable source of water for wildlife/livestock in Thunder Basin. The information provided in Section 2.1.6 indicates that the shallow alluvial wells can produce up to 50 gpm, although the average flow ranges from 5 gpm to 10 gpm. Similarly, shallow bedrock wells completed in the Wasatch, Fort Union and Lance Formation can yield similar range of flow as the alluvial wells. Solar-powered well systems can be installed to pump water into either surface water ponds or storage tanks for livestock and wildlife watering. A lower-power pump would be desirable for use for this purpose. Based on the information on shallow well development in Thunder Basin, it is reasonable to assume the pump capacity at 5 gpm. The average annual hours of light in the area is approximately 4,400 hours (including cloud cover). The resulting annual pumping would be 3-4 acre-feet. To assess the viability of installing shallow wells at a particular location would require a site-specific evaluation by a groundwater professional and/or an experienced and capable well driller. Additionally, the locations of these systems would need to be identified by landowners to ensure that the locations are conducive to his or her range management practices.

4.4 Wildlife/Livestock Watering Opportunities

4.4.1 Existing/Planned/Proposed Watering Sites

The WWDC in conjunction with the Weston, Campbell, and Converse conservations districts has been working with members of the TBGA to develop new livestock/wildlife watering sites throughout Thunder Basin. Map 38 illustrates locations of 26 recently completed and ongoing projects in the watershed. The projects included items such as well installation, pipeline, solar well pump, and stock tanks.

4.4.2 Alternative New Watering Opportunities

The following subsections include information on additional sites that could be developed in a similar manner through the Small Water Project Program, Wyoming Water Development Program. These proposed projects were identified by landowners with the assistance of the TBGA sponsors through their attendance and involvement in the Thunder Basin Watershed Improvement project meetings. Each request was evaluated separately. Table 4.4.2-1 provides a list of the projects, the water source, types of proposed improvements and estimated costs. Other projects with similar parameters still exist throughout the watershed. The sites listed below provide a basis for evaluation upon which other sites could be assessed. For example, many of the SEO well sites listed on Map 27 are currently not producing. Along with the list of sites provided in Table 4.4.2-1, upland well developments would result in significant benefits to the watershed. Some benefits discussed with the ranch owners included:

- Healthy livestock with additional watering sites that minimize distance traveled per day to a clean water source

- Reduced soil erosion due to reduced distance livestock travel to water per day resulting in reduced sediment loading on streams
- Reduced impacts to sensitive riparian habitats
- Enhanced stream stability through stable vegetative cover
- Reduced expansion and establishment of non-native plants

Table 4.4.2-1 Upland Water Well Development Projects

Project Number	Ranch Name	Well Install	Solar System	Pipeline Length (feet)	Fencing (feet)	Site Prep	Stock Tanks	Estimated Cost
Antelope Creek Watershed Improvements								
1	Bell	2	1	0	0	2	2	$37,200
2	Haefele	1	0	0	5280	1	1	$33,940
3	Moore	3	3	15000	15000	3	6	$89,800
Upper Cheyenne Watershed Improvements								
4	Lynch	1	1	0	0	1	1	$15,600
5	Stroh	1	1	5000	10000	1	2	$57,900

4.4.2.1 Bell Ranch

Owners of Bell Ranch desire additional upland wildlife and livestock watering sites on their property. The addition of wells with stock tanks would allow for optimizing range management practices. Currently they have both artesian and pumped wells that tap into bedrock aquifers and yield 10 gpm (Map 35a). With the installation of two strategically placed wells, livestock could be rotated through a series of meadows and that would benefit the watershed. Based on existing well completion and yield information, conceptual cost estimates were developed for the installation of two new wells (Table 4.4.2-1).

4.4.2.2 Haefele Ranch

Owners of Haefele Ranch desire additional upland wildlife and livestock watering sites on their property. The addition of one well in the ‘highway’ field with stock tanks would allow for the Haefele’s to avoid season-long grazing and other activities in the riparian/woody draw areas by providing a watering source in the uplands consequently optimizing range management practices. Currently they have developed springs, artesian, and pumped wells (Map 35b). The request is for one new well and fencing. Based on existing well completion and yield information, conceptual cost estimates are presented in Table 4.4.2-1.

4.4.2.3 Lynch Ranch

Owners of Lynch Ranch desire additional upland wildlife and livestock watering sites on their property. The addition of a well with stock tanks would allow for optimizing range management practices. Wells on the ranch and surrounding property range in depth from 125 to 700 feet and have yields registered up to 10 gpm (Map 35g). The request is for one new solar well along a fenceline to provide water to two pastures. Based on existing well completion and yield information, conceptual cost estimates are presented in Table 4.4.2-1.

4.4.2.4 Moore Ranch

Owners of Moore Ranch desire additional upland wildlife and livestock watering sites on their property. The addition of wells with stock tanks would allow for optimizing range management practices. The areas of interest includes: 40N-75W Sec 2, 3, N1/2 Sec 11, 41N-75W Sec 33, 34, and 40N-77W Sec 10, 11, 14, 15, 22. The request is for three new solar wells and piping across to five pastures. Based on existing well completion and yield information, conceptual cost estimates are presented in Table 4.4.2-1.

4.4.2.5 Stroh Ranch

Owners of Stroh Ranch desire additional upland wildlife and livestock watering sites on their property. The addition of a well in the “mailbox pasture” with stock tanks would allow for optimizing range management practices. Wells on the ranch and surrounding property range in depth from 100 to 200 feet and have yields registered up to 10 gpm (Map 35f). The request is for one new solar well and piping to two pastures. Based on existing well completion and yield information, conceptual cost estimates are presented in Table 4.4.2-1.

4.5 Other Management Practice Improvements

4.5.1 Grazing Management

Management of grazing use that enhances the extent and height of ground cover can be expected to enhance the retention of snow and rain in a manner that encourages greater infiltration into the soil surface. Improved vigor of prairie vegetation including riparian vegetation will reduce vulnerability to invasion by weeds in general including salt cedar and Russian olive.

Beyond the water budget benefits, successful grazing management marshals the proper balance of grazing intensity and duration on a site so that long-term yield of forage is maximized. Higher ground cover and biomass production positively influences wildlife habitat value, water course stability, as well as soil stability and water quality.

4.5.2 Salt Cedar and Russian Olive Treatment

According to the Thunder Basin Area Analysis FEIS, invasion of Russian olive and salt cedar has been confronted well in the basin, at least on public lands. Continued resistance to invasion however is likely to be required. This may take the form of manual removal preferably followed by chemical treatment of remaining stump or root stub surfaces with Garlon®, Roundup® or Rodeo®. For large infestations should they come to exist, the tamarix leaf beetle (*Diorhabda elongata* ssp. *deserticola*) could be useful in diminishing the size of the problem, though as with most bio-control approaches it cannot be expected to eliminate salt cedar. TBGA administers a joint spray program in conjunction with the Thunder Basin Grasslands Prairie Ecosystem Association and for the past five years with the Nation Wild Turkey Federation on both private and public lands.

4.5.3 Noxious Weed Control

Other noxious weeds present in the study area include Canada thistle (*Cirsium arvense*), Russian knapweed (*Centaurea repens*), spotted knapweed (*Centaurea maculosa*), hoary cress (*Cardaria* spp), Dalmation toadflax (*Linaria genistifolia* ssp. *dalmatica*), burdock (*Arctium minus*), houndstongue (*Cynoglossum officinale*), and leafy spurge (*Euphorbia esula*). The most abundant and the one most typical of moisture accumulation sites is Canada thistle. Control of established Canada thistle may be accomplished via chemical control using systemic herbicides (for example Curtail®, Tordon® Milestone® or Transline®) at a time when translocation downward to the deep root mass can be accomplished (usually fall). Control via non-chemical means may be achieved by increasing the competitive strength of desirable forage or non-forage plants or in some cases by limiting the availability of soil nitrogen.

5.0 Cost Estimates

5.1 Irrigation System Cost Estimates

Table 4.1.2-1 presents the estimated costs for the recommended irrigation infrastructure rehabilitation measures. The estimates are based on prior experience by team members in the planning, design, costing, and construction oversight of similar project elements and personal communications with members of the TBGA. The costs are provided in cost per linear foot of ditch repair or spreader dike installation. Table 5.1-1 provides a summary of the costs and then calculates an annual cost per acre serviced over 20 years.

Table 5.1-1 Irrigation Cost Estimate with Cost per Acre Served

Rehabilitation Item Number	Description	Acres serviced	Revenue per acre	Rehabilitation cost	Cost per acre serviced	Annual cost per acre
Cheyenne Watershed (Black Thunder Creek) Improvements						
1	Replace Head gate and re-grade ditches	67	30	$53,275	$795	$53
2	Re-grade ditch 3	65	30	$6,315	$97	$7
Cheyenne Watershed (Cheyenne River) Improvements						
3	Replace Head gate and re-grade ditches	87	30	$38,825	$446	$30
Antelope Creek Watershed Improvements						
4	Construct Spreader dikes	19	30	$14,700	$774	$52
Dry Fork Cheyenne Watershed Improvements						
5	Install Headgate and re-grade ditch	70	30	$53,000	$757	$51
6	Build Dike and re-grade ditch	47	30	$55,285	$1,176	$79
Note: Annual cost per acre was determined using a 3% interest rate and calculated over a 20 year period.						

5.2 Surface Water Storage Sites Cost Estimates

5.2.1 Cost Estimates for Account III Storage Sites

Tables 4.2.2-5 through 4.2.2-8 present the costs for the Antelope Creek, Black Thunder Creek, Cheyenne River 1 and Cheyenne River 2 sites. Table 5.2.1-1 presents a summary of the costs and calculates the cost on an annual basis per acre-foot of irrigation storage water. In order of least to most expensive based on this measure, the four sites would be ranked as follows: Cheyenne 2, Black Thunder, Cheyenne 1, and Antelope Creek. Annual operation and maintenance costs for the reservoirs is anticipated to be 0.75% of the construction cost.

Table 5.2.1-1 Potential Dam Sites Cost Summary

Dam Site	Irrigation Storage, ac-ft	Cost, $	Annual Cost/ac-ft of storage
Antelope	1,334	$10,000,000	$150
Black Thunder	2,156	$11,900,000	$99
Cheyenne 1	3,663	$21,200,000	$116
Cheyenne 2	5,563	$16,300,000	$50

One site for expansion of an existing dam to store a minimum of 1,000 acre-feet was identified on Black Thunder Creek, as described in Section 4.2.2.2. The cost for this dam was estimated to be approximately $4 to $5 million.

5.2.2 Cost Estimates for Rehabilitated Breached Dams

Table 4.2.2-9 shows the estimated conceptual level costs of repairing the breached dams. The costs were based on a typical cost per acre-foot of water. Site visits must be conducted and more detailed analysis of needed repairs done, if there is interest in rehabilitating any of these structures. The visits would provide a better sense of the scope of necessary repairs.

5.3 Cost Estimates for Groundwater Well Development/Wildlife/Livestock Watering

Table 4.4.2-1 shows the estimated conceptual level costs for groundwater well/ wildlife and livestock watering projects. The costs were based on similar project cost estimates for Small Water Project and personal communications with members of the TBGA. Site visits must be conducted and more detailed analysis of the site-specific hydrogeology will need to be completed before the projects are implemented. The evaluations will provide additional detail on well completion depths and well yield estimates.

5.4 Cost Estimates for Other Management Practice Improvements

5.4.1 Grazing Management

Costs of implementation of changes in grazing management other than livestock watering (addressed above) vary from comparatively small (salting, planning, moving herds between paddocks) to comparatively large when the need for additional fencing is involved.

5.4.2 Salt Cedar and Russian Olive Control

Estimates by Hart (2004) of the cost of saving water that would otherwise be lost to transpiration of salt cedar (by removing the salt cedar) ranged from $16 to $111 per acre-foot. This represents an extremely cost-effective approach to increase of available water in a range watershed.

5.4.3 Noxious Weed Control

Costs of chemical herbicide application are variable depending on scale of infestation, distances to be traveled, and fuel costs. Relative to control of Canada thistle, costs for the chemicals mentioned above range from $16 to $26 per acre not including application (Jacobs et al. 2006). If it can be arranged to have grazing animals in place and focused on emergent thistle leaves in spring, followed by summer rest to strengthen desirable perennials, then Canada thislte can be controlled through herd management simultaneous with general range improvement.

6.0 Permits

The following discussion presents the regulatory issues for the types of projects that have been identified in sections 4.0 and 5.0. The purpose of this analysis is to characterize the potential environmental permitting issues. This includes the identification of environmental documentation, permits, agency clearances and approvals, and agency requirements necessary for implementation of the proposed actions and alternatives. The WWDC has requested that there be a semblance of consistency between the different watershed studies. This section, therefore, will be structured similar to the report prepared by Short Elliott Hendrickson Inc., 2007 (SEH 2007).

The National Environmental Policy Act (NEPA) applies to any federal action and compliance is the responsibility of the lead federal agency. Other federal environmental regulations are regulated by the following federal agencies: EPA, BLM, USFS, USACE, and/or the USFWS and may apply to the potential projects described in this plan. The State of Wyoming agencies which may have approval requirements include, but are not limited to, the WDEQ, WSEO, State Historic Preservation Officer, and the Board of Land Commissioners through the Office of State Lands and Investments.

The following discussions are based upon various assumptions about the potential actions within the study area. These assumptions may change as project planning progresses from this Level I Study. Ultimately, the applicability of the individual federal and state permits, clearances and approvals will depend upon sites selected and the potential implications at each of those sites.

6.1 NEPA Compliance and Documentation

NEPA requires federal agencies to assess the possible environmental consequences of projects which they propose to undertake, fund, or approve. NEPA applies to any of the proposed actions for which the project site is located on federal land, federal funds may be used, and/or when formal federal agency actions are necessary for the project to move forward. One of the primary intentions of the NEPA process is to avoid, minimize, and mitigate adverse environmental consequences of federal actions. NEPA requires analysis and documentation of potential adverse and beneficial effects of a proposed action and alternatives and mandates an open public involvement process.

For this project, it is likely that either BLM and/or USFS would be the lead federal agency(s) charged with ensuring compliance with NEPA and related environmental statutes. The BLM would be lead for those projects on lands under their administration, and the USFS would be the lead for projects located on National Forest Service lands. Map 17 illustrates land ownership across the study area. The USACE would likely be the lead federal agency on private lands where wetlands may be impacted. These agencies also may work out a shared lead under a Memorandum of Understanding, if there are significant issues best led by both agencies for a given project.

6.1.1 NEPA for Major Reservoir Storage Projects

The following discussion characterizes the typical actions of the NEPA process applicable to a reservoir storage project. A separate discussion in Section 6.1.2 addresses other potential watershed rehabilitation or improvement projects.

Prepare a Purpose and Need Statement for the Project. Establishing a well-conceived statement of the Purpose and Need is one of the first steps in the NEPA process. The purpose and need for a project provides the basis for developing reasonable alternatives, establishes project objectives, and helps to define criteria for the alternative screening process, including the option of not doing the project at all (i.e., no action alternative). The Purpose and Need statement provides an overall or basic purpose for the potential action, which must be supported by some quantitative means. As project planning unfolds, additional needs may be revealed through stakeholder input, project constraints, or other factors.

Should the USACE be identified as the lead agency, the Purpose and Need must include a reference to finding the “least damaging practicable alternative.” This reference relates to the CWA Section 404 requirements that are under the jurisdiction of the USACE and is an important part of the NEPA process for a reservoir storage project. Additional details are provided in Section 6.2. The project sponsor, TBGA, other project participants, and the public all should be part of defining the Purpose and Need statement.

Develop Project Alternatives and NEPA Documentation Determination. The NEPA process requires analysis of both build and no-build (no action) alternatives that fully address the project’s purpose and need. The reasonable range of alternatives may include multiple “build” alternatives, including multiple locations, depending on the nature and extent of potential project impacts and level of NEPA documentation required.

For new reservoir storage projects, key issues associated with alternative development will or may include:

- Potential loss of wetland and riparian habitat from direct inundation by a new reservoir
- Potential impacts on threatened and endangered species;
- Potential impacts on fish and other aquatic species
- Potential impacts on other wildlife (e.g., sage grouse; big game)

Based on these issues, and the fact that some of the potential projects are as simple as wells (which should require no NEPA involvement on private lands) the potential projects will be Categorical Exclusions (CE) or Environmental Assessments (EA). An EA may or may not involve analysis of more than one build alternative and typically can be completed in less than 18 months. The outcome of an EA is either a Finding of No Significant Impact (FONSI) or a recommendation to prepare an EIS. If an EA is prepared, a possible outcome is a requirement for an EIS. This could occur as a result of “significant impact findings” or as a result of substantial public controversy over the project’s effects. Significant impacts should be identified early on in the EA effort, thus allowing the owner to move the project to a “least damaging alternative” location and avoid the potential for having an EA result in a requirement for an EIS. This decision should be reviewed during a Level II study to identify locations that would be best to avoid, from an environmental risk perspective.

Conduct a Proactive Public Involvement Program. The NEPA process begins with public and agency outreach, and provides the public the opportunity to comment on the proposed project’s impacts, potential mitigation measures, and the potential alternatives to be analyzed during the development of the required NEPA document. The public must be informed of the potential benefits and potential adverse impacts of the proposed project and alternatives. A pro-active public involvement program focuses on achieving public awareness and community interaction throughout the entire project development process. The public involvement process can influence alternative development, mitigation measures, the level of NEPA documentation to be prepared (EA or EIS), and the selection of the preferred alternative.

Collect and Analyze Environmental Baseline Data. It is important to carefully identify environmental constraints and considerations early and incorporate them into alternative development efforts as a means of avoiding and minimizing potential impacts. Early field investigations and agency consultation and coordination efforts help to focus this effort and streamline subsequent analysis methods, schedule needs, and budget requirements. Creating "self-mitigating" alternatives is highly advantageous and fully consistent with the intent of NEPA.

NEPA is an "umbrella" law that requires compliance with other federal, state, and local laws and regulations. Integrating the National Historic Preservation Act, Endangered Species Act, CWA and other compliance processes will reduce overall permitting time frames and costs, and streamline agency decision-making. These issues are discussed in Section 6.2.

Prepare the Draft and Final Environmental Impact Statement. The draft EIS would be prepared in two versions. A preliminary draft EIS would be prepared for internal review. The draft EIS would respond to comments on the preliminary draft EIS. The draft EIS would be circulated for public review and would be the subject of a public hearing. The final EIS would also be prepared in two versions. A preliminary final EIS would be prepared for internal review. The final EIS would respond to comments on the preliminary final EIS. The final EIS would be circulated for public review and would be the subject a public hearing. A Record of Decision (ROD) would be prepared to complete the NEPA process.

6.1.2 NEPA for Other Project Types

The level of NEPA documentation needed for projects other than major (non-stock pond) reservoir storage must be determined on a project-specific basis. For example, proposed new wildlife/livestock watering developments, including tank/pipeline systems that cross and/or serve federal or state rangeland will require that an appropriate NEPA process be followed. In this case, and for many of the lesser potential impact projects (e.g., a well, stock/wildlife pond, guzzler, etc.), it is related to the discussion in Section 6.1 above.

BLM. Under current practice, NEPA evaluations and processes for both reservoir storage projects and other types of projects that may be proposed where BLM is the lead federal agency will be performed by BLM staff or qualified, independent third-party experts responsible to BLM. These experts may include specialists from other federal and/or state agencies working under Memorandum of Understanding , or other appropriate arrangements. Compliance with NEPA will be guided in large part by the Medicine Bow National Forest Revised Land and Resource Management Plan and ROD (USFS, 2003), and the Thunder Basin National Grassland Revised Land and Resource Management Plan and ROD (USFS, 2002), and any subsequent new or additional guidance and/or updates. All BLM-led. NEPA-related processes and studies are administered by the lead BLM district staff (Newcastle, Buffalo, or Casper staff), with assistance, as necessary and appropriate, from BLM state office staff. NEPA-related processes and studies are administered by the USFS Rocky Mountain Region for projects located on Medicine Bow-Routt National Forest-Thunder Basin Grasslands.

Other State/Federal Agencies. Depending on the specific circumstances of a particular project, it is possible that another state or federal agency may lead the NEPA process. All of the relevant state and federal land management agencies have management plans developed from NEPA-compliant processes where appropriate. As discussed above for BLM and USFS, these plans will guide these agencies' NEPA process for any applicable proposed projects or improvements.

Watershed-Wide Environmental Analysis. Given the large number of planned and potential wildlife/livestock water development projects and the opportunity for larger-scale projects, it is recommended that serious consideration be given to the potential benefits of conducting a comprehensive "watershed-wide" environmental analysis for these and other potential water-resources related improvement projects. A key benefit of this approach would be to develop a single baseline characterization and impacts assessment of the relevant environmental issues associated with these types of projects. That approach is preferable to repeating the same assessments for many similar individual projects. A watershed-wide environmental analysis should substantially reduce the overall resources and time necessary to conduct the required environmental permitting (especially NEPA compliance) for individual projects. If necessary, the overall environmental analysis could be supplemented on a case-by-case basis for specific projects with particular issues.

6.2 Permitting/Clearances/Approvals

6.2.1 Dam and Reservoir Construction

Environmental resources are protected by a variety of state and federal regulations such as the CWA and the Endangered Species Act (ESA). Coordination with multiple agencies will be necessary to move forward with the dam and reservoir construction. Potential permits and/or agency contacts are explained in more detail below.

USACE Section 404 Permit. The USACE, through requirements contained in Section 404 of the CWA, regulates activities involving the discharge of dredged or fill material into waters of the United States. As such, any dam and reservoir storage project in the Thunder Basin watershed will need to address Section 404 permitting issues. Among other things, the proposed project must demonstrate that the least environmentally damaging practicable alternative (LEDPA) was selected to achieve the project's purpose. This is the alternative most likely to receive a permit.

Endangered Species Act (Section 7 Consultation). The lead agency would prepare a biological assessment to determine project effects on threatened and endangered plant and animal species listed or proposed for listing (candidate species) under the ESA (16 U.S.C. § 1531 et seq.). The USFWS would then issue an opinion on whether federal actions are likely to jeopardize the continued existence of a threatened or endangered species, or destroy or adversely modify critical habitat. USFWS must approve the preparation of a biological assessment to comply with the ESA in order to render its decision. If USFWS determines that the preferred alternative would jeopardize the continued existence of a species, it may offer a reasonable and prudent alternative that would preclude jeopardy.

Fish and Wildlife Coordination Act. The Fish and Wildlife Coordination Act requires federal agencies involved in actions that will result in the control or structural modification of any natural stream or body of water for any purpose to take action to protect the fish and wildlife resources which may be affected by the action. It requires federal agencies or applicants to first consult with state and federal wildlife agencies to prevent, mitigate and compensate for project-caused losses of wildlife resources, as well as to enhance those resources.

Migratory Bird Treaty Act. The Migratory Bird Treaty Act (MBTA) recommends avoiding construction activities in grassland, wetland, stream, and woodland habitats and bridges that may result in the taking of migratory birds, eggs, young, and/or active nests. In Wyoming, most migratory bird activity occurs during the period of April 1 to July 15.

The USFWS has indicated that if the proposed construction period is planned to occur during the primary nesting season, or at any other time that may result taking the nests of migratory birds, a survey should be performed. The USFWS recommends that a qualified biologist conduct a field survey of the affected habitats and structures to evaluate the presence of nesting migratory birds during nesting season. The survey results of the survey should be maintained with the project files and made available to USFWS personnel upon request. The USFWS should be contacted immediately if active nests are identified within the construction area that cannot be avoided.

If construction of the roadway falls within the primary nesting season, a survey of nesting birds will be conducted. As requested by the USFWS, a biologist will perform a field survey before construction activities to inspect the project construction corridor for nesting birds. The USFWS will be contacted if active nests are identified within the construction area and within a half-mile line of sight east and west from the construction area, that cannot be avoided. The results of the field survey for nesting birds, along with the information regarding the qualifications of person or persons performing the survey, will be documented and maintained on file for potential review.

Should active nests be observed that cannot be avoided until after the birds have fledged (left the nest), and if no practicable or reasonable avoidance alternatives are identified, then the contractor will complete a Federal Fish and Wildlife License/Permit Application Form 37 and submit it to the USFWS's Migratory Bird Program Office in Denver, Colorado. The contractor may proceed with work on the affected project activities following receipt of the approved permit from the USFWS.

Laws Addressing Cultural Resources. Because federal approvals may be involved with the potential projects, a consideration of the impact on cultural resources must be undertaken (Section 106 consultation), as required under the National Historic Preservation Act (NHPA) of 1966. Federal agencies will request a determination from the State of Wyoming Historic Preservation Office regarding the significance of cultural resources potentially affected by ground-disturbing activities.

In addition, consultation with relevant Native American groups concerning traditional cultural properties is required. Guidelines for evaluation of traditional cultural properties are contained in Bulletin 38 issued by the National Park Service.

Wyoming Board of Land Commissioners. The Wyoming Board of Land Commissioners, consisting of the five statewide elected officials, is responsible for regulating all activities on state lands, including granting of rights-of-way. This is accomplished through the Office of State Lands and Investments. Any project to be constructed on state or school lands must have a right-of-way, as required in the “Rules and Regulations Governing the Issuance of Rights Of Way” (W.S. 36-20 and W.S. 36-202).

Wyoming State Engineer's Office Surface Water Storage Permit. The state engineer's office administers the water rights system of appropriation within the state. The applicant must obtain the necessary water rights permits from the State of Wyoming for the diversion and storage of the state's surface water.

Wyoming State Engineer's Office Permit to Construct/Dam Safety Review. The Wyoming Dam Safety Law (W.S. 41-3) requires that any persons, public company, government entity or private company who proposes to construct a dam which is greater than 20 feet high or which will impound more than 50 acre-feet of water, or a diversion system which will carry more than 50 cubic feet of water per second (cfs), must obtain approval for construction of the dam or ditch from the state engineer's office. The approval by the state engineer's office of a dam's construction is contingent upon the office's review and approval of all dam plans and specifications, which must be prepared by a registered professional engineer licensed in Wyoming. Design, construction, and operation of jurisdictional dams must also comply with dam safety regulations promulgated pursuant to the Dam Safety Act. At present, these regulations are in final draft form and formal issuance is anticipated soon.

Wyoming State Engineer's Office Ditch Enlargement Permit. In addition to the permits and clearances that will be required for reservoir construction, if an enlargement to an existing ditch or storage facilities is needed, an enlargement filing with the state engineers office is required. Even if physical enlargement of an existing ditch was found not be to required, the enlargement filing would be required as a legal formality of a water right requirement.

Wyoming Department of Environmental Quality – National Pollution Discharge Elimination System (NPDES) permit and Section 401 Certification. The federal CWA is administered in Wyoming by the WDEQ, Water Quality Division (WQD) and is consistent with the Wyoming Environmental Quality Act. The Section 401 Certification is the state's approval to ensure that the activities authorized under Section 404 meet state water quality standards and do not degrade water quality. Any discharge of pollutants into the broadly defined "waters of the state" requires application to and permit issuance by WQD in accord with WQD's Rules and Regulations. This body of regulations sets forth classification of surface and groundwater uses and establishes water quality standards (Wyoming Water Quality Standards). The WQD administers the NPDES permit system including stormwater permits and construction-related, short-term discharge permits.

Implementation of any of the action alternatives would require application for and compliance with the provisions of the statewide general NPDES Construction Storm Water Discharge Permit (WYR10-000). Construction activities associated with dam construction or enlargement often result in the requirement to temporarily discharge pumped water. These discharges are provided for in a general permit. Upon acceptance of the application by DEQ, the temporary discharge must comply with the terms of the general permit and any stipulations applied as a result of the application's review.

EPA has oversight responsibility for federal CWA delegated to and administered by the State WQD. EPA also may intervene to resolve interstate disputes where discharges of pollutants in an upstream state may affect water quality in a downstream state.

Mining Permit. A Wyoming mining permit is not required for development of an aggregate and/or borrow material source solely for use in construction of one of the various reservoir alternatives, and whose product is not for commercial sale. US Army Corps of Engineers USACE – 404 Permitting. Any activities involving placement of fill or dredging of materials from jurisdictional waters of the United States requires permitting with the USACOE.

Special Use Permits/Rights-of-Way/Easements. Special use permits, rights-of-way (ROW) or easements will be required wherever access across the lands of others (private, state or federal) is needed for construction and/or operation of the project facilities. These may be temporary (e.g., access to a temporary borrow area or quarry site to be closed and reclaimed; construction of a new haul road; etc.) or permanent (e.g., construction of a wildlife/livestock pipeline alignment). Usually privately owned lands that will be rendered permanently unavailable (such as the dam and reservoir footprint of a storage project) would be purchased unless the owner desires, and the sponsoring entity concurs, a permanent easement instead. Permanent use of BLM lands likely would be administered under a grant with an appropriate term issued under their ROW process; the USFS would use their equivalent special use process. An easement or ROW from the Wyoming Department of Transportation (WyDOT), and/or from Weston, Campbell, Converse, Niobrara, and/or Natrona counties also may be required. The specific requirements for ROW, special use permits and easements vary widely and should be determined as part of the early stages of planning for a specific proposed project. This will help to avoid the potential for project delay, higher costs, or required changes in location/alignment or design during project development and implementation

Other. In addition to the above, there may be other permits and clearances required for a given dam and reservoir project. These might include permits typically required to be provided by the construction contractor (e.g., air quality permit; trash/slash burning permit; etc.).

6.2.2 Other Project Types

Permits, clearances and approvals for projects other than major dams and storage reservoirs will depend on the specific nature and location of the project. Various permits and clearances discussed above in Section 6.2.1 may also apply to other types of projects. The specific permits and clearances necessary for a particular project should be determined early in the planning stages of the project to ensure compliance with applicable laws and regulations, and to avoid possible delays, increased costs and possibly redesign later during project implementation.

6.3 Environmental Considerations

6.3.1 General Habitat Description

The study area consists of a variety of habitats including mixed–grass prairie, ponderosa pine, sage brush, cactus, riparian habitats, open water, and local oil and gas operations. The animal and plant resources with an emphasis on those that are proposed, threatened or endangered species are described in the following section. The ranges of three important game species (antelope, mule and whitetail deer) are illustrated on Maps 39-41. Although the species are not endangered, protection of their habitat is important to the hunters and wildlife enthusiasts of Thunder Basin.

6.3.2 Animal and Plant Resources

Proposed, Threatened and Endangered Species. The following federally-listed species are identified as occurring within the counties of the study area: black-footed ferret (*Mustela nigripes*), blowout penstemon (*Penstemon haydenii*), and Ute ladies' tresses orchid (*Spiranthes diluvialis*) (U.S. Fish and Wildlife Service: Mountain-Prairie Region Individual County information, 2008).

Other Animal Species of Concern. The Wyoming Natural Diversity Database (WYNDD) (2007) identifies 101 species of concern within the four counties. The species are as follows:

Birds - Common loon *(Gavia immer),* Clark's grebe *(Aechmophorus clarkia [Achemophorus occidentalis]),* American white pelican *(Breeding colonies) (Pelecanus erythrorhynchos),* trumpeter swan *(Cygnus buccinators), b*ald eagle *(Haliaeetus leucocephalus),* northern goshawk *(Accipiter gentilis),* ferruginous hawk *(Buteo regalis)*, greater sage grouse *(Centrocercus urophasianus),* snowy plover *(Charadrius alexandrinus),* mountain plover *(Charadrius montanus),* long-billed curlew *(Numenius americanus),* black-billed cuckoo *(Coccyzus erythropthalmus), y*ellow-billed cuckoo *(Coccyzus americanus),* burrowing owl *(Athene cunicularia),* short-eared owl *(Asio flammeus),* Boreal owl *(Aegolius funereus),* Lewis' woodpecker *(Melanerpes lewis),* Williamson's sapsucker *(Sphyrapicus thyroideus),* three-toed woodpecker *(Picoides tridactylus),* glack-backed woodpecker *(Picoides arcticus),* loggerhead shrike *(Lanius ludovicianus),* Western scrub-jay *(Aphelocoma californica [Aphelocoma coerulescens]),* bushtit *(Psaltriparus minimus),* Pygmy nuthatch *(Sitta pygmaea),* Virginia's warbler *(Vermivora virginiae),* black-throated gray warbler *(Dendroica nigrescens),* sage sparrow *(Amphispiza belli),* Baird's sparrow *(Ammodramus bairdii),* McCown's longspur *(Calcarius mccownii),* chestnut-collared longspur *(Calcarius ornatus),* bobolink *(Dolichonyx oryzivorus),* black-rosy finch [Rosy finch] *(Leucosticte atrata [Leucosticte artcoa])*

Mammals - Hayden's shrew *(Sorex haydeni),* fringed myotis (statewide) *(Myotis thysanodes),* Black Hills fringed myotis *(Myotis thysanodes pahasapensis),* Yuma myotis *(Myotis yumanensis),* Townsend's big-eared bat *(Corynorhinus townsendii [Plecotus townsendii]),* Black Hills yellow-bellied marmot *(Marmota flaviventris dacota),* black-tailed, prairie dog (Large towns) *(Cynomys ludovicianus),* white-tailed prairie dog (Large towns) *(Cynomys leucurus),* Black Hills red squirrel *(Tamiasciurus hudsonicus dakotensis),* Black Hills southern red-backed vole *(Clethrionomys gapperi brevicaudus),* Bear Lodge meadow jumping mouse *(Zapus hudsonius campestris),* Preble's meadow jumping mouse *(Zapus hudsonius preblei),* swift fox *(Vulpes velox),* river otter *(Lontra canadensis [Lutra Canadensis])*

Fish - Shovelnose sturgeon *(Scaphirhynchus platorynchus),* Western silvery minnow *(Hybognathus argyritis [Hybognathus nuchalis]),* sturgeon chub *(Macrhybopsis gelida [Hybopsis gelida]),* Pearl dace [Northern dace] *(Margariscus margarita [Semotilus margarita]),* hornyhead chub *(Nocomis biguttatus),* finescale dace *(Phoxinus neogaeus)*

Amphibians – Boreal western toad (Southern Rocky Mountain population) *(Bufo boreas boreas (undescribed taxon)),* Great Basin spadefoot toad *(Spea intermontana [Scaphiopus intermontanus]),* Northern leopard frog *(Rana pipiens)*

Reptiles - Northern many-lined skink *(Eumeces multivirgatus multivirgatus),* red-lipped prairie lizard [Orange-lipped plateau lizard] *(Sceloporus undulatus erythrocheilus),* Northern prairie lizard *(Sceloporus undulatus garmani),* smooth green snake (eastern and western) *(Liochlorophis vernalis [Lv. Vernalis, L.v. blanchardi; Opheodrys v. vernalis, O.v. blanchardi]),* Black Hills redbelly snake *(Storeria occipitomaculata pahasapae)*

Other Animal Species of Concern. The WYNDD (2007) identifies 49 species of potential concern. These species are as follows:

Birds - Snowy egret *(Egretta thula),* black-crowned night-heron *(Nycticorax nycticorax),* ring-necked duck *(Aythya collaris),* bufflehead *(Bucephala albeola),* Tundra swan *(Cygnus columbianus),* common goldeneye *(Bucephala clangula),* golden eagle *(Aquila chrysaetos),* osprey *(Pandion haliaetus),* Merlin *(Falco columbarius),* Arctic peregrine falcon *(Falco peregrinus tundrius),* Virginia rail *(Rallus limicola),* Sandhill crane *(Grus Canadensis),* piping plover *(Charadrius melodus),* black-necked stilt *(Himantopus mexicanus),* American avocet *(Recurvirostra americana),* red-necked phalarope *(Phalaropus lobatus),* winter wren *(Troglodytes troglodytes),* golden-crowned kinglet *(Regulus satrapa),* Eastern bluebird *(Sialia sialis),* Dickcissel *(Spiza americana),* grasshopper sparrow *(Ammodramus savannarum),* Brewer's sparros *(Spizella breweri),* white-winged junco *(Junco hyemalis aikeni),* Northern bobwhite (Native populations) *(Colinus virginianus),* California gull (Breeding colonies) *(Larus californicus),* barn owl *(Tyto alba),* Eastern screech-owl *(Otus asio),* flammulated owl *(Otus flammeolus)*, chimney swift *(Chaetura pelagica)*, ash-throated flycatcher *(Myiarchus cinerascens),* canyon wren *(Catherpes mexicanus)*, sage thrasher *(Oreoscoptes montanus),* red-eyed vireo *(Vireo olivaceous),* blue grosbeak *(Guiraca caerulea),* white-winged crossbill *(Loxia leucoptera)*, clay-colored sparrow *(Spizella pallida),* indigo bunting *(Passerina cyanea)*

Fish - Common shiner *(Luxilus cornutus),* Iowa darter *(Etheostoma exile),* sauger *(Stizostedion canadense)*

Amphibians – Tiger salamander *(Ambystoma tigrinum),* Great Plains toad *(Bufo cognatus)*

Reptiles - Western plains garter snake *(Thamnophis radix haydenii),* Eastern yellowbelly racer *(Coluber constrictor flaviventris)*, spiny softshell turtle *(Apalone spinfera [Trionyx spiniferus])*

Mammals - Dwarf shrew *(Sorex nanus),* hoary bat *(Lasiurus cinereus),* silver-haired bat *(Lasionycteris noctivagans),* Western small-footed myotis *(Myotis ciliolabrum [Myotis leibii]),* long-legged myotis *(Myotis volans),* long-eared myotis *(Myotis evotis),* Wyoming ground squirrel *(Spermophilus elegans),* Northern flying squirrel (Black Hills population) *(Glaucomys sabrinus (undescribed taxon)),* olive-backed pocket mouse *(Perognathus fasciatus),* white-footed mouse *(Peromyscus leucopus),* common gray fox *(Urocyon cinereoargenteus),* American marten [Pine marten] (Bighorn Mountain population) *(Martes americana (undescribed taxon)),* least weasel *(Mustela nivalis [Mustela rixosa]),* plains (eastern) spotted skunk *(Spilogale putorius interruptua),* Bighorn sheep *(Ovis canadensis)*

Some of these species may occur in appropriate habitats within the study area. For example, some known raptor nesting areas are shown on Map 42 – Raptor Nesting Areas and sage grouse leks are shown on Map 43 – Sage Grouse Leks. Sage grouse are identified as a sensitive species/species of concern and merit special attention as discussed in some detail in the following paragraphs.

The greater sage grouse (*Centrocercus urophasianus*) is a species native to the area and is almost entirely dependent on open sagebrush plain. They are considered omnivores, eating insects, sagebrush and seeds; but are most reliant upon sagebrush for both cover from predators and for food. The greater sage grouse is listed as a sensitive species by the BLM, and a species of concern by WGFD. The BLM defines a sensitive species as a species that easily could become endangered or extinct in the state, including: (a) species under status review by the USFWS/National Marine and Fisheries Service; (b) species whose numbers are declining so rapidly that federal listing may become necessary; (c) species with typically small or fragmented populations; and, (d) species inhabiting specialized refugia or other unique habitats. WGFD lists the greater sage grouse as a species that is widely distributed, with population status or trends unknown but suspected to be stable; habitat restricted or vulnerable but no recent or on-going significant loss; species likely sensitive to human disturbance. The sage grouse is not listed as a threatened or endangered species and does not receive any protections from the Endangered Species Act; however, BLM and WGFD have developed restrictions/recommendations to help protect the sage grouse.

It is recommended that coordination with BLM and WGFD occur regarding any proposed or alternative project that has the potential to affect sage grouse habitat. Note that providing water to areas where water is limited may create a beneficial impact for sage grouse and should be considered when evaluating the net potential impacts to this species.

Rare Plant Species of Concern. The WYNDD has 48 known sensitive plant species of concern located in the study area: Slender false-foxglove (*Agalinis tenuifolia var. parviflora),* robust toothcup (*Ammannia robusta),* small-flower columbine *(Aquilegia brevistyla),* Laramie columbine *(Aquilegia laramiensis),* Curtis' three-awn *(Artistida curtissii),* prairie three-awn *(Artistida oligantha),* Porter's sagebrush *(Artemisia porteri),* maidenhair spleenwort *(Asplenium trichomanes),* long-stalked racemose milkvetch *(Astragalus racemosus var. longisetus),* racemose milkvetch *(Astragalus racemosus var. racemosus),* dissected bahia *(Bahia dissecta),* little-leaved brickell-bush *(Brickellia microphylla var. scabra),* hairy wood brome *(Bromus pubescens),* Sartwell's sedge *(Carex sartwellii var. sartwellii),* Watson goosefoot *(Chenopodium watsonii),* many-stemmed spider-flower *(Cleome multicaulis),* Wyoming dodder *(Cuscuta plattensis),* Williams' waferparsnip *(Cymopterus williamsii),* short-point flatsedge *(Cyperus acuminatus),* nine-anther prairie-clover *(Dalea enneandra),* slim-leaf witchgrass *(Dichanthelium linearifolium),* showy prairie-gentian *(Eustoma grandiflorum),* bighead pygmycudweed *(Filago prolifera), h*airy fimbry *(Fimbristylis puberula var. interior), s*lender cottonweed *(Froelichia gracilis),* sidesaddle bladderpod *(Lesquerella arenosa var. argillosa)*, broad-leaved twayblade *(Listera convallarioides),* great blue lobelia *(Lobelia siphilitica),* Texas spreading loeflingia *(Loeflingia squarrosa var. texana), w*inged loosestrife *(Lythrum alatum var. alatum),* few-seed stickleaf *(Mentzelia oligosperma),* Ciliolate-toothed monkeyflower *(Mimulus rubellus),* Maybell locoweed *(Oxytropis bessyi var. obnapiformis),* rosy palafoxia *(Palafoxia rosea var. macrolepis),* crown-seed fetid-marigold *(Pectis angustifolia var. angustifolia),* small-flowered fame-flower *(Phemeranthus parviflorus), w*oolly twinpod *(Physaria lanata),* Rocky Mountain polypody *(Polypodium saximontanum),* dwarf woolly-heads *(Psilocarphus brevissimus),* Cusick's alkali-grass *(Puccinellia cusickii),* viscid tansy-aster *(Rayjacksonia annua),* wild yellowcress *(Rorippa truncata),* nodding leafy bulrush *(Scirpus pendulus),* large bur-reed *(Sparganium eurycarpum),* Laramie false sagebrush *(Sphaeromeria simplex),* longleaf dropseed *(Sporobolus compositus),* Northern dropseed *(Sporobolus heterolepis),* slim-pod Venus' looking-glass *(Triodanis leptocarpa)*. The potential exists for some of these species to occur within appropriate habitats within the project area. However, none of these species receive federal or state protection.

Big Game. The Thunder Basin watershed contains portions of crucial big game habitat for elk and pronghorn (see Map 44 – Crucial Big Game Habitats) managed by the WGFD. The WGFD maps the seasonal ranges of the big game species and makes note of areas listed as crucial habitat.

Creating a dam/reservoir near critical habitat may have a positive effect on the area by providing additional water sources to the various wildlife species near the sites. Coordination with WGFD will need to occur to fully assess and evaluate potential impacts and mitigation measures for crucial big game habitat/parturition.

Fisheries. Map 31 (WDEQ Stream Classifications) shows the different rivers and their associated tributaries within Thunder Basin. The map identifies the name of the rivers and tributaries within Thunder Basin, and these waterways are further classified by their respective stream classification. Two different classifications exist within the Thunder Basin study area (as described in Section 3.4.1.

Impacts to the various streams and associated fishery resources may occur with any of the potential dam and reservoir storage projects and should be considered during further environmental evaluation of these sites as discussed further below under mitigation in Section 6.5.

Wetland Resources. A formal wetland delineation in accordance with the USACE' guidelines has not been conducted across Thunder Basin. GIS digital mapping from the National Wetland Inventory (NWI) does exist and was acquired to preliminarily identify wetland habitats in the study area. The wetland habitats inferred to be present within the study area based on NWI mapping are shown on Map 12 – National Wetland Inventory Map. The entire basin is not available digitally, however, hard copies of the areas without digital coverage can be purchased, as necessary.

Some areas identified as wetlands may in fact not qualify as jurisdictional wetlands upon field investigation. This is due to limitations in the methodology used to prepare the NWI maps and the nature of wetlands to change over time based on natural events. As discussed previously, a formal delineation should be conducted once potential sites are selected to determine the level of impacts to wetlands located in the future project area.

6.4 Cultural Resources

Cultural resources encompass archaeological, traditional, and built environment resources, including, but, not necessarily limited to, buildings, structures, objects, districts, and sites. Cultural resources in this context include prehistoric and historic cultural resources, paleontological resources, and natural history resources. Known cultural resources within the Thunder Basin watershed include Stinking Water Gulch, Holdup Hollow, Nine Mile, and other segments of the Bozeman Trail. These trail segments are listed on the National Register of Historic Places and thereby protected from any future disturbance. Although a Class I cultural resources survey was not included in the scope of this Level I study, it is very likely that other cultural resources will be found in the watershed, possibly at potential project sites or along potential project alignments.

6.5 Mitigation

Mitigation may be required for impacts to resources, including wetland and riparian vegetation, stream channel habitat, cultural resources, fish and game resources, and possibly threatened or endangered species. A variety of mitigation measures are presented in Appendix 3 – Wyoming BLM Guidelines for Surface-Disturbing and Disruptive Activities (BLM, 1998). As noted previously, it is preferred to avoid the need for mitigation of a potentially significant impact by relocation and/or "self-mitigating" design if technically and economically feasible.

If mitigation is required for wetland impacts, a detailed mitigation plan would need to be prepared and approved by USACE prior to construction of a dam. Wetland mitigation most likely be suggested near the reservoir, as hydrophytic communities will develop along the reservoir created by the dams.

Mitigation of potential raptor and big game impacts would generally involve control of certain construction activities during sensitive time periods, and avoidance of direct disturbance of the subject species. If any threatened and endangered species have the potential to occur at a given site, special studies would be required to determine if appropriate mitigation could be implemented. In general, any such impacts should be avoided to the greatest extent possible.

Additional cultural resource fieldwork would need to be completed to identify and document any such resources that would be inundated or otherwise affected as a result of constructing any dams and reservoirs. This would include, in turn, a Class I (literature search) survey, a Class II (reconnaissance inventory) survey, and if needed, a Class III (intensive inventory) survey. Ultimately, a mitigation plan for cultural resources would be developed which would culminate in a MOA between the Wyoming State Historic Preservation Office and the lead federal agency, with concurrence by the project sponsor(s), and possibly affected Native American tribes.

7.0 Economic Analysis and Project Financing

This section presents the potential funding sources and funding scenarios for the improvement projects identified in Section 4 of this report. The WWDC has requested that there be a semblance of consistency between the different watershed studies. This section, therefore, will be structured similar to the report prepared by Short Elliott Hendrickson Inc., 2007 (SEH 2007) and will address the following elements:

- Benefits associated with the alternative projects;
- The ability-to-pay of local irrigators;
- The minimum cost of water to irrigators under current WWDC guidelines; and
- The sponsor's ability-to-pay under different grant/loan scenarios.

The benefit to the grazing association participants from the majority of the proposed improvements are difficult to quantify because these benefits, primarily calf weight gain, are also greatly influenced by other factors, most notably weather. It is, therefore, difficult to perform a true economic analysis on the proposed modifications. The benefit analysis presented here is based on some general gross assumptions.

Potential funding sources are identified in Section 7.4. This is a general listing of funding sources identified and they may not all be applicable to the improvement projects identified. These funding sources may be applicable for future projects, yet to be identified, and are therefore provided here as a resource tool.

7.1 Direct Benefits Analysis

Most of the projects identified in Section 4 target improvements to livestock grazing practices and as such it is difficult to quantify the immediate direct benefits due to the other factors that affect livestock production, most important of which is weather. The benefits of these improvements are discussed later in section 7.1.2 "Livestock Watering Improvements". The following discussion will pertain to the proposed irrigation system improvements.

7.1.1 Irrigation System Improvements

The proposed improvements to the existing irrigation system target improving the delivery efficiency and minimizing the operational and maintenance expenses. Historically Wyoming meadows produce on average 1.2 tons of native hay per acre (Jacobs, et.al., 2006). In the Northeast Wyoming River Basin Plan prepared for the WWDC (HKM, 2002), the average volume of surface water depleted (consumed) by crops in the drainages in the project area is approximately 1.1 ac-ft per irrigated acre. The predominant crop that is irrigated in the project drainages is native grass hay. Due to the lack of diversion volume records in the area, the efficiency of the delivery system is uncertain. Using an efficiency estimate of 40% (Short Elliott Hendrickson Inc., 2007), the volume of irrigation water that is diverted to meet this depletion requirement is 2.75 ac-feet per acre. Therefore, in the study area it is assumed that approximately 0.4 tons of native hay is produced per acre-foot of irrigation water diverted (1.2 tons/acre divided by 2.75 ac-ft/acre). By implementing the proposed modifications to the delivery systems and improving the efficiency of the irrigated water delivery system, theoretically, the production from the irrigated meadows could be increased by approximately 0.004 tons for each percentage point of efficiency increase. This linear correlation of acre-feet of water to tonnage production is probably only applicable for a very small percentage increase, i.e. less than 10%.

The market value for this increased yield due to a more efficient delivery system will depend upon the current crop prices. The average cost of for native hay for the last 5 years[1] was $97.80 per ton with a high of $121/ton and a low of $74.60/ton. At these prices, the increased benefit realized from the proposed irrigation improvements would range from approximately $0.30 to $0.48 per acre per each percent of increased efficiency.

Because there would be no increase to the amount of irrigated acres due to these improvements, there would be only a marginal increase in the production cost. This cost would be associated with the increase in the loading and stacking activities since the area actually being baled would not be increasing, therefore, the increased cost for baling per acre would be negligible.

The proposed construction of the storage reservoirs could potentially result in an increase in the irrigated acreage in the study area. Previous reports for the WWDC (Short Elliott Hendrickson Inc., 2007) have addressed the cost benefits of providing additional hay production resulting from additional storage water. Applying the assumed production of 1.1 tons of hay per acre-foot of consumptively used irrigation water with a 40 percent delivery efficiency, every acre-feet of additional irrigation storage diverted will result in an increase in hay production of 0.44 tons (0.4 x 1.1 tons/acre-ft).

Using the reported cost for production (1995 dollars) of $26.12 per ton (Short Elliott Hendrickson Inc., 2007) and adjusting it to today's adjusted cost value results in a production cost of $41.11 per ton. Based on these numbers, the economic benefit from developing additional irrigation water supply from the storage facilities can be estimated. The value from the increased production, using the average cost of native hay over the last 5 years ($97.80), is $43.03 (0.44 tons x $97.80/ton) for the increased production. The net benefit after subtracting the production costs of $18.09 ($41.11/ton x 0.44 tons) results in a net benefit estimate of $24.94 for each available acre-foot of supplemental irrigation water stored in the proposed storage reservoirs.

7.1.2 Livestock Watering Improvements

The following discussion on the benefits from providing additional pasture water sources and more specifically, tank water sources was borrowed from reports prepared by the Alberta Agriculture, Food and Rural Development entitled "Pasture Water Systems for Livestock" and from a report prepared for the Montana State Extension Service entitled "Dryland Pastures in Montana and Wyoming, Species and Cultivars, Seeding Techniques and Grazing Management by Larry Holzworth, Jeff Mosley, Dennis Cash, David Koch and Kelly Crane. Most ranchers want to maximize the return of their livestock enterprise while sustaining the resources used. Maximizing returns while ignoring the sustainability of the resources will result in eventual economic and environmental disaster. Ranchers who have been economically sustainable over generations must have learned how to work within environmental constraints. Water distribution is critical for improving livestock production while sustaining or improving the grazing conditions. Ranchers continue to improve the distribution of water by providing additional water sources where it has not been available before. This has allowed ranchers to utilize forage resources that were unused or had limited use in the past because of their distance from water.

Recently, there has been much more emphasis placed on developing rotational grazing systems that will benefit the pasture land, riparian areas and the livestock. Poor access to water and poor water quality can affect livestock behavior and production on pasture. The benefits to developing a pasture watering system include:

- water source protection, thus longer water source life
- improved herd health
- increased livestock production, in some situations
- better pasture utilization
- riparian protection and, thus, a more environmentally friendly livestock industry

7.2 Indirect Benefits Analysis

Indirect benefits stem from the increase in income from one sector of business in a region upon other business sectors. An example of this would be the anticipated additional income from the additional weight gain in the cattle from the proposed Thunder Basin improvements being spent locally which increases the income in other business sectors in the area. The Bureau of Economic Analysis of the U.S. Department of Commerce (USDOC) produces periodic estimates of indirect income multipliers for Wyoming's agricultural sector. Their latest published estimate of this multiplier is 3.36 (USDOC, 1992); meaning that for each dollar of additional farm/ranch income, total income in Wyoming increases by $3.36. The $3.36 is comprised of $1.00 of farm/ranch income and $2.36 of indirect income, which can be an indirect benefit of new irrigation and/or grazing improvement projects.

7.3 Ability to Pay Analysis

The ability of the grazing association member's ability to pay for the proposed improvements will be predicated by the benefits realized and the generated income from the increased benefits (tonnage of hay and/or livestock weight gain) will be dependent upon the current market values for the respective crop. Data Summary 7.3-1 (in Appendix A) – Summary of Maximum Potential

Benefits of Project Alternatives presents the maximum potential benefits of the proposed project improvements. The reservoir benefits assume that 50% of the reservoir storage will be available for supplemental or additional irrigation supply. As described earlier in section 7.1.1, the estimated direct benefit from the additional storage volume is assumed to be $24.94 for each additional acre foot of storage. The benefits from the irrigation system improvements were based on an assumed 10% increase in consumptive irrigation volumes. As described in section 7.1.1, it was assumed that the production would increase by 0.004 tons per acre per percentage point increase in efficiency. Finally, the benefit from the pasture improvements was based on an assumed increase of 5% weight gain applied to a calf weighing an average of 600 pounds. Data Summary 7.3-1 (in Appendix A) shows the benefits of this weight gain when applied to 100 head of cattle.

The column entitled "Maximum Potential Present Value of All Direct Benefits" is the "Present Value" of the projects based on an interest rate of 4% over a 50-year loan period. This interest rate and loan period were chosen to remain consistent with earlier basin study data. This "Present Value" reflects the break even project cost if no grant money is used and only a loan at a 4% interest rate over a 50-year period is used to finance the project. The final column represents the total benefit of the project (direct and indirect) to the economy in the region. This column reflects the "Present Value" multiplied by the 3.36 economy based ratio of total benefit to direct farm/ranch benefit increase.

Earlier reports (Short Elliott Hendrickson Inc., 2007) effectively addressed the lack of incentive to make system improvements if 100% of the additional income is required to retire the debt incurred in making the improvements. Therefore, for this ability to pay study, it is assumed that the ability to pay will be 50% of the additional income that could be generated from the proposed system improvements.

7.4 WWDC Financing Guidelines

The WWDC typically offers a 67% grant, 33% loan split for eligible projects. This can be increased to as much as a 75% grant, 25% loan for sponsors that can demonstrate severe financial hardship. The current and minimum interest rate is 4% for program loans. The loan period shall not exceed the greater of 50 years or the economic life of the project. Additionally, the sponsor's method of loan repayment shall be considered in establishing the term of the loan. See Section 7.4 for additional information regarding the WWDC's available project options. Additional information regarding the terms and conditions of WWDC financing may be found in the Operating Criteria of the Wyoming Water Development Program contained in the following online document: http://wwdc.state.wy.us/opcrit/final_opcrit.pdf

Table 7.4-1 is a summary of the project sponsor's ability to pay for the recommended reservoir system improvements utilizing the WWDC project financing format with a 67% Grant and 33% Loan combination. The loan was assumed to be financed by the State Loan Board at a rate of 4% annually for a 50 year period. The Level III project costs do not include future operation and maintenance costs, which were estimated to be 0.75% of the construction cost per year, based on NRCS recommendations.

Table 7.4-1 Summary of Ability to Pay for Storage Project Alternatives - 67% Grant

Alternative	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Antelope Creek Storage Reservoir	$9,300,000	$3,069,000	$143,015	$21,800	15.2%
Black Thunder Creek Storage Reservoir	$11,000,000	$3,630,000	$169,158	$17,950	10.6%
Cheyenne River 1 Storage Reservoir	$19,500,000	$6,435,000	$299,871	$36,400	12.1%
Cheyenne River 2 Storage Reservoir	$15,000,000	$4,950,000	$230,670	$53,500	23.2%

As shown in Table 7.4-1, even with a 67% Grant, the project sponsor is only capable of paying approximately 11 to 23 percent of the anticipated annual loan payments for the proposed reservoirs. For comparison sakes, two additional grant/loan scenarios were reviewed – 75% and 90% Grant monies. These are shown in Tables 7.4-2 and 7.4-3, respectively.

Table 7.4-2 Summary of Ability to Pay for Storage Project Alternatives - 75% Grant

Alternative	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Antelope Creek Storage Reservoir	$9,300,000	$2,325,000	$108,345	$21,800	20.1%
Black Thunder Creek Storage Reservoir	$11,000,000	$2,750,000	$128,150	$17,950	14.0%
Cheyenne River 1 Storage Reservoir	$19,500,000	$4,875,000	$227,175	$36,400	16.0%
Cheyenne River 2 Storage Reservoir	$15,000,000	$3,750,000	$174,750	$53,500	30.6%

Table 7.4-3 Summary of Ability to Pay for Storage Project Alternatives - 90% Grant

Alternative	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Antelope Creek Storage Reservoir	$9,300,000	$930,000	$43,338	$21,800	50.3%
Black Thunder Creek Storage Reservoir	$11,000,000	$1,100,000	$51,260	$17,950	35.0%
Cheyenne River 1 Storage Reservoir	$19,500,000	$1,950,000	$90,870	$36,400	40.1%
Cheyenne River 2 Storage Reservoir	$15,000,000	$1,500,000	$69,900	$53,500	76.5%

Even at the increased grant rate of 90%, the project sponsor would still need to seek additional funding sources.

The ability of the project sponsor to pay for improvements to the present irrigation system was based on funding through the WWDC Small Water Project Program (SWPP). For consistency within the report, it was assumed that the loan rate would be 4% over a 50-year period when calculating the “Sponsor’s Annual Payment”. As shown in Table 7.4-4 if the only benefit from these improvements is to increase slightly the production from the existing fields, the incentive to perform this work will be marginal. However, if additional acreage or additional benefits, other than a slight increase in the tonnage per acre can be realized these projects become more economically enticing.

Table 7.4-4 Summary of Ability to Pay for Irrigation Improvement Project Alternatives - 50% Grant

Alternative	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Cheyenne Watershed (Black Thunder Creek) Improvements					
Stroh Ranch - Replace headgate, diversion, and regrade ditches	$53,275	$26,638	$1,241	$131	10.6%
Stroh Ranch - Re-grade ditch 3	$6,315	$3,158	$147	$127	86.4%
Cheyenne Watershed (Cheyenne River) Improvements					
Harshbarger Ranch - Replace Head gate and re-grade ditches	$38,825	$19,413	$905	$170	18.8%
Antelope Creek Watershed Improvements					
Turner Ranch - Construct Spreader dikes	$14,700	$7,350	$343	$37	10.8%
Dry Fork Cheyenne Watershed Improvements					
Pellatz Ranch - Install headgate and regrade ditch	$53,000	$25,000	$1,165	$137	11.8%
Pellatz Ranch - Build dike and regrade ditch	$55,285	$27,643	$1,288	$92	7.1%

Table 7.4-5 Summary of Ability to Pay for Irrigation Improvement Project Alternatives - 75% Grant

Alternative	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Cheyenne Watershed (Black Thunder Creek) Improvements					
Stroh Ranch - Replace Head gate, diversion, and re-grade ditches	$53,275	$13,319	$621	$131	21.1%
Stroh Ranch - Re-grade ditch 3	$6,315	$1,579	$74	$127	172.8%
Cheyenne Watershed (Cheyenne River) Improvements					
Harschbarger Ranch - Replace Head gate and re-grade ditches	$38,825	$9,706	$452	$170	37.6%
Antelope Creek Watershed Improvements					
Turner Ranch - Construct Spreader dikes	$14,700	$3,675	$171	$37	21.7%
Dry Fork Cheyenne Watershed Improvements					
Pellatz Ranch - Install headgate and regrade ditch	$53,000	$13,250	$617	$137	22.2%
Pellatz Ranch - Build dike and regrade ditch	$55,285	$13,821	$644	$92	14.3%

A similar funding scenario is presented for the proposed upland water/pasture improvement projects. The ability to pay summary for these projects is shown in Table 7.4-5. This analysis was based upon an assumed average cost for a upland water/pasture improvement project and it was assumed that this pasture would benefit 100 head of cattle.

Table 7.4-6 Summary of Ability to Pay for Upland Water/Pasture Improvement Project Alternatives - 50% Grant

Project	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Antelope Creek Watershed Improvements					
Bell Ranch	$37,200	$18,600	$867	$1,500	173.1%
Haefele Ranch	$33,940	$16,970	$791	$1,500	189.7%
Moore Ranch	$89,800	$44,900	$2,092	$1,500	71.7%
Upper Cheyenne Watershed Improvements					
Lynch Ranch	$15,600	$7,800	$363	$1,500	412.7%
Stroh Ranch	$57,900	$28,950	$1,349	$1,500	111.2%

Table 7.4-7 Summary of Ability to Pay for Upland Water/Pasture Improvement Project Alternatives - 75% Grant

Project	Level III Project Costs	Sponsor's Share of Project Costs	Sponsor's Annual Payment	Sponsor's Maximum Ability to Pay	Sponsor's Percentage Ability to Pay
Antelope Creek Watershed Improvements					
Bell Ranch	$37,200	$9,300	$433	$1,500	346.1%
Haefele Ranch	$33,940	$8,485	$395	$1,500	379.4%
Moore Ranch	$89,800	$22,450	$1,046	$1,500	143.4%
Upper Cheyenne Watershed Improvements					
Lynch Ranch	$15,600	$3,900	$182	$1,500	825.4%
Stroh Ranch	$57,900	$14,475	$675	$1,500	222.4%

As indicated in Tables 7.4-4 through 7.4-7, if a 5% livestock weight gain could be realized by improving the water source or grazing conditions, these improvement projects appear to be the most economically beneficial to the association based purely upon a rate of return on their investment dollar.

7.5 Project Funding Sources

There are a variety of funding sources that may be able to offer funding for various portions of the project. The general criteria and applicability of each of the funding sources are discussed in this section and categorized by project type. A summary of the funding sources can be found in Data Summary 7.5-1 (in Appendix A).

Funding sources presented here are not necessarily inclusive of all funding options available. Information presented here is also subject to change as funding sources may change their terms and criteria. The contacts listed for the various funding sources are also considered volatile and may change in time.

The primary local resources for the project are the local conservation districts, the NRCS, the BLM, and USFS. These entities offer local expertise relative to the area as well as intimate knowledge of potential funding programs that may apply to the projects outlined in this report. These key local resources include, but are not limited to:

- Weston County Natural Resource District (307-746-3264)
- Campbell County Conservation District (307-682-1824)
- Niobrara Conservation District (307-334-2953)
- Converse County Conservation District (307-358-5719)
- US Forest Service US Forest Service – Douglas, WY (307-358-4690)
- Bureau of Land Management
  - Buffalo Field Office - Buffalo, WY (307-684-1100)
  - Newcastle Field Office – Newcastle, WY (307-746-6600)
- Natural Resource Conversation Service Offices:
  - Weston County - Newcastle, WY (307-746-3264)
  - Campbell County - Gillette, WY (307-682-8843)
  - Niobrara County - Lusk, WY (307-334-2953)
  - Converse County – Douglas, WY (307-358-3050)

Additionally, there are two online resources that that outline a variety of funding sources for grant, loan, and in-kind support for watershed related projects. These two resources were used extensively for researching available funding sources for this project. The first is the Water Management & Conservation Assistance Programs Directory available from the WWDC which was last updated in May, 2009. The directory is available online:
http://wwdc.state.wy.us/wconsprog/consdir/ConservationDirectoryFinal.pdf

The second site is an online Catalog of Federal Funding Sources for Watershed Protection developed and maintained by the Environmental Protection Agency. The catalog can be accessed online: http://cfpub.epa.gov/fedfund/

The WGFD has published "Habitat Extension Bulletin No. 50 – Fisheries and Wildlife Habitat Cost-Share Programs and Grants." The Bulletin provides a listing of potential funding sources for fisheries and wildlife habitat projects and may be viewed online:
http://gf.state.wy.us/habitat/ExtBulletinsCont/index.asp

7.5.1 Local Agencies

7.5.1.1 Weston County Natural Resource District

The Weston County Natural Resource District (WCNRD) operates in conjunction with the programs offered by NRCS. The District does not reserve any funds for rangeland improvements. They also have experience in attaining funds from the WWDC for projects.

7.5.1.2 Campbell County Conservation District

The Campbell County Conservation District's (CaCCD) mission is to "*provide leadership for the conservation of Wyoming's soil and water, protect the agriculture resource base, promote the control of soil erosion, promote and protect the quality and quantity of Wyoming's water, provide assistance to reduce the siltation of stream channels and reservoirs, promote wise use of Wyoming's water and all other natural resources, preserve and enhance wildlife habitat, protect the tax base and promote the health, safety and general welfare of the citizens of this state through a responsible conservation ethic.*" The CCCD is funded through optional 1% sales tax imposed in Campbell County. The budget received by the District is determined by the county commissioners and is typically about $270,000 annually. They typically fund educational based projects, but might consider contributing to a specific project cost if it is deemed to be beneficial to county residents. For consideration, a proposal should be made outlining the improvements and should discuss why those improvements will benefit the mission of the CaCCD.

7.5.1.3 Niobrara Conservation District

The Niobrara County Conservation District (NCCD) operates in conjunction with the programs offered by NRCS. The District does not reserve any funds for rangeland improvements. They also have experience in attaining funds from the WWDC for projects.

7.5.1.4 Converse County Conservation District

The Converse County Conservation District (CoCCD) is funded primarily though a local mill levy tax and grant funds. Additional funding is acquired by the district's equipment rental and seedling tree program. The CoCCD typically aids and administers funding from outside sources such as the NRCS, but expressed the possibility of funding projects that prove beneficial to the District's mission for up to $10,000 tentatively.

7.5.2 State Agencies

7.5.2.1 Wyoming Department of Environmental Quality

The WDEQ provides financial assistance for best management practices to address non-point sources of pollution under Section 319 of the CWA. Grant funding requires a 40% match from the applicant. The match may come from the local landowner, a conservation or irrigation district, or a non-profit organization. Applications are typically due in late summer of each year.

7.5.2.2 Wyoming Game and Fish Department

The WGFD offers a variety of funding options and is best summarized from the Water Management & Conservation Assistance Program Directory (see previous link):

The Wyoming Game and Fish Department offers a funding program to help landowners, conservation groups, institutions, land managers, government agencies, industry and non-profit organizations develop and/or maintain water sources for fish and wildlife. This program also provides funding for the improvement and/or protection of riparian/wetland areas for fish and wildlife resources in Wyoming. Applications for projects are accepted any time with approval on January 1 and August 1 of each year.

Riparian Habitat Improvement Grant. The purpose of this program is to improve or maintain riparian and wetland resources. Fencing, herding, stock water development, stream bank stabilization, small damming projects and beaver transplanting are a few examples of efforts that qualify under this program. Permits, NEPA compliance, construction, maintenance, access and management planning are all grantee responsibilities. There is $10,000/project maximum available with 50% cash or in-kind required from grantee.

Water Development/Maintenance Habitat Project Grant. The purpose of this program is to develop or maintain water for fish and wildlife. Spring development, windmills, guzzlers, water protection and pumping payments are examples of the extent of this program. Permits, NEPA compliance, maintenance, access and water righting are responsibilities of the grantee. There is a maximum of $7,500/project and 50% cash or in-kind contribution required from the grantee.

Industrial Water Habitat Project Fund. The purpose of this program is to develop water sources beneficial to fish and wildlife that are located by industrial drilling, mining or excavation operations. Examples of projects are tapped artesian wells, springs or groundwater that could be used for wildlife watering or creation of wetlands or ponds. Industry must meet set criteria, obtain permitting and access, clean-up and restore the site and provide NEPA compliance. There is neither a funding limit nor matching contribution needed for these projects.

Upland Development Grant. The purpose of this program is to develop upland wildlife habitat. Examples of projects in this program are shrub management, grazing systems, prescribed burning, wildlife food plots such as oat, millet or corn plantings, range pitting and range seeding. Permits, NEPA compliance, maintenance, access and management planning are responsibilities of the grantee. There is a maximum of $10,000/project and 50% cash or in-kind contribution required from the grantee.

Fish Wyoming. The purpose of this program is to develop public fishing opportunities. Examples of projects within this effort are boat ramps and fishing access. This program provides a 50% match of funding which is channeled through a private organization or municipality.

7.5.2.3 Wyoming Office of State Lands and Investments

The Wyoming Office of State Lands and Investments offers a variety of funding options and is best summarized from the Water Management & Conservation Assistance Program Directory (see previous link):

The Office of State Lands & Investments is the administrative arm of the 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 five divisions: Financial Programs and Management Services, Real Estate Management and Farm Loans, Mineral Leasing and Royalty Compliance, Wyoming State Forestry and Information Technology. Collectively these divisions serve the trust beneficiaries - 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.

Farm Loan Program established in 1921, provides long term real estate loans to Wyoming’s agricultural operators. The use of this program has been expanded over the years to also include loans for the purchase of livestock and to assist beginning agricultural producers.

The Irrigation Loans Program established in 1955, is designed to support small and large agricultural water development projects. The Legislature has allocated a total of $275 million for loans under the Farm Loan Program and $20 million for the Irrigation Loan Program. Both programs are funded from the Wyoming Permanent Mineral Trust Fund.

Joint Powers Act Loan Program was established in 1974 by the Legislature authorized the Joint Powers Act Loan Program to benefit local communities for infrastructure needs. These loans are approved from funds within the State’s Permanent Mineral Trust Fund. These programs are an aid to cities, counties and special districts in providing needed government services and public facilities. For the period January 1, 2009 through December 31, 2009, the interest rate is 5.06% for Joint Powers Act Loans. In January 2010, the State Treasurer will calculate a new interest rate for calendar year 2010.

7.5.2.4 Wyoming Water Development Commission

The WWDC offers a variety of funding options for reconnaissance and feasibility studies as well as construction projects. Reconnaissance and feasibility studies are typically 100% grant funded. Eligible construction projects are typically funded on a 67% grant, 33% loan split. Projects typically funded include, but are not limited to agriculture, environmental, erosion control, new storage (dams and reservoirs), new water supply sources, watershed improvements, and recreation.

New Development Program. The New Development Program provides an opportunity for sponsors to develop water supplies for anticipated future needs to insure that lack of water supply will not inhibit economic growth. The program encourages water development through state/local partnerships. The sponsor can complete a water supply project with state funding assistance.

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 (15) years. Rehabilitation projects are typically 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 insure dam safety, decrease operation, maintenance, and replacement costs and/or provide a more efficient means of using existing water supplies.

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 shall be emphasized in the development of reservoir operating plans, recreation, environmental enhancement, flood control, erosion control, and hydropower uses should be explored as secondary purposes.

Small Water Project Program. The Small Water Project Program (SWPP) is intended to be compatible with the WWDC conventional program and criteria and to parallel and partner with other local, state and federal programs that perform water resource planning and water development in Wyoming. Small water projects are defined as those projects that provide multiple benefits and where estimated construction costs, permit procurement, construction engineering and project land procurement are one hundred thousand dollars ($100,000) or less, or where the maximum financial contribution from the commission is fifty percent (50%) of project costs or twenty-five thousand dollars ($25,000), whichever is less.

Projects eligible for SWPP grant funding assistance include the construction or rehabilitation of small reservoirs, wells, pipelines and conveyance facilities, springs, solar platforms, irrigation works, windmills and wetland developments. Planning for small water projects will be generated by a WWDC watershed study or equivalent as determined by the WWDO. A watershed study will incorporate, at a minimum, available technical information describing conditions and assessments of the watershed including hydrology, geology, geomorphology, geography, soils, vegetation, water conveyance infrastructure, and stream system data. A plan outlining the site specific activities that may remediate existing impairments or address opportunities beneficial to the watershed shall also be included.

It is the intention of WWDC to work closely with the land management agencies and the sponsoring entities in the administration of this program. This additional source of grant funding will help develop a partnership where local, state, and Federal agencies can work together for the benefit of the people of Wyoming.

More Information. The options are best summarized from the Water Management & Conservation Assistance Program Directory (see previous link) and the Operating Criteria of the Wyoming Water Development Program (see previous link).

7.5.2.5 Wyoming Wildlife and Natural Resource Trust

The wildlife and Natural Resource Trust was created in 2005 and is funded by interest earned on a permanent account, donations, and legislative appropriations. The purpose of the program is to enhance and conserve wildlife habitat and natural resource values throughout the state. Any project designed to improve wildlife habitat or natural resource values is eligible for funding.

Wildlife and Natural Resource Trust funding is available for a wide variety of projects throughout the state, including natural resource programs of other agencies. Examples of projects eligible for funding include, but are not limited to:

- Projects that improve or maintain existing terrestrial habitat necessary to maintain optimum wildlife populations may include grassland restoration, changes in management, prescribed fire, or treatment of invasive plants.
- Improvements and maintenance of aquatic habitats, including wetland creation or enhancement, stream restoration, water management or other methods.
- Mitigation of impacts detrimental to wildlife habitat, the environmental and the multiple use of renewable natural resources, or mitigation of conflicts and reduction of potential disease transmission between domestic wildlife and domestic livestock.

7.5.3 Federal Agencies

7.5.3.1 Bureau of Land Management

The BLM offers three distinct programs for funding which are best summarized in the Water Management & Conservation Assistance Programs Directory (see previous link):

- **Riparian Habitat Management Program.** The program offers the opportunity to coordinate with outside interests in 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. 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.

- **Range Improvement Planning and Development.** The program is a cooperative effort not only with the livestock operator but also with other outside interests including the various environmental/conservation groups. Water development whether it be for better livestock distribution or improved wetland habitats for wildlife, is key to healthy rangelands and biodiversity. Before actual range improvement development occurs, an approved management plan must be in place. All rangeland improvement projects on lands administered by the BLM require the execution of a Permit. Although there are a couple of methods for authorizing range improvements on public lands, Cooperative Agreement for Range Improvements form 4120-6 is the method most commonly used. This applies equally to range improvement projects involving water such as reservoirs, pits, springs, and wells including any associated pipelines for distribution. The major funding source for the BLM's share comes from the range improvement fund which is generated from grazing fees collected. There is also a limited amount of funding from general rangeland management appropriations. Contributions come either in the form of labor or may provide some material costs as well and is typically in the form of a grant.
- **Watershed and Water Quality Improvement.** Efforts are undertaken in a cooperative approach with the State of Wyoming, Conservation Districts, livestock operators, and various conservation groups. Wyoming's BLM is partnering in the implementation of several Section 319 watershed plans state-wide. This program is a cooperative effort between the BLM and the WDEQ. Goals of the program for watershed projects will typically be the restoration and maintenance of healthy watershed function and are typically accomplished through best management practices, prescribed burns, vegetation treatment, in-stream structures, to enhance vegetation cover, control accelerated soil erosion, increase water infiltration, and enhance stream flows and water quality.

7.5.3.2 Bureau of Reclamation

The Bureau of Reclamation's mission emphasizes water conservation, recycling, reuse, development of partnerships with customers, states and tribes, bringing competing interests together to address needs, transferring title and operation of some facilities to local beneficiaries to enhance efficiency and achieving a higher level of fiscal responsibility to the tax payer.

- **Challenge Grant Program.** Through Water for America, Bureau of Reclamation administers the Challenge Grant Program, which generally provides up to $300,000 in Federal funding per project, for projects that will improve water efficiency, demonstrate advanced water treatment technologies, and help to avoid the decline of candidate species. Challenge Grant Funding is allocated through a west-wide competitive process that prioritizes projects that will address the most critical issues from a west-wide perspective.
- **Water Conservation Field Services Program.** Provides smaller amounts of funding up to $100,000 per project through local competitions within the region or area. The projects funded are generally smaller in scope than the Challenge Grant Projects, and are focused on fundamental conservation improvements as identified in water conservation plans developed by water users. Financial assistance provided through the Challenge Grant Program and the WCFSP must be cost shared on at least a 50-50% split between the recipient and Bureau of Reclamation. More information can be found online: www.grants.gov

7.5.3.3 Environmental Protection Agency

The EPA administers The Targeted Watershed Grants Program. The grant program is summarized as:

> *Established in 2003, the Targeted Watersheds Grant Program is designed to encourage successful community-based approaches and management techniques to protect and restore the nation's watersheds. The Targeted Watersheds Grant program is a competitive grant program based on the fundamental principles of environmental improvement: collaboration, new technologies, market incentives, and results-oriented strategies. The Targeted Watersheds Grant Program focuses on multi-faceted plans for protecting and restoring water resources that are developed using partnership efforts of diverse stakeholders. Targeted Watersheds Implementation Grants are focused on individual watershed organizations. Successful watershed organizations are chosen because they best demonstrated the ability to achieve on-the-ground, measurable environmental results relatively quickly, having already completed the necessary watershed assessments and developed a technically sound watershed plan. Each of the watershed organizations exhibits strong partnerships with a wide variety of support; creative, socio-economic approaches to water restoration and protection; and explicit monitoring and environmentally-based performance measures. Proposals must be nominated by either a Governor or a Tribal Leader from the state in which the project resides. More information can be found at: http://www.epa.gov/watershed/initiative/*

7.5.3.4 Farm Service Agency

The Farm Service agency (FSA) is a member agency of the United States Department of Agriculture. Programs administered through the FSA are offered through local county committees. Technical assistance needed for implementation of FSA programs is provided through the NRCS. The FSA programs available are:

- **Conservation Resource Program.** This program offers agricultural producers annual rental payments to remove highly erodible cropland from production. Farmers and ranchers establish long-term conservation practices on erodible and environmentally sensitive land. In exchange, they receive 10-15 years of annual rental payments and cost share assistance. This is a voluntary program specifically for highly erodible lands currently in active production planted 2 of the 5 most recent crop years. Land offered for the program is ranked according to environmental benefit for wildlife habitat, erosion control, water quality, and air quality.
- **Continuous Sign-Up for High Priority Conservation Practices.** Continuous sign-up provides management flexibility to farmers and ranchers to implement certain high-priority conservation practices on eligible land. Land must meet the requirements of the Conservation Reserve Program and be determined by NRCS to eligible and suitable for riparian buffers, filter strips, grass waterways, shelter belts, field windbreaks, living snow fences, contour grass strips, salt tolerant vegetation, and shallow water areas for wildlife. This is a cost share program that offers rental rates based on the average value of Dryland cash rent with an additional financial incentive of up to 20% of the soil rental rate for field windbreaks, grass waterways, filter-strips, and riparian buffers. An additional 10% may be added if the land is located in an EPA-designated wellhead protection area. There is also a provision for cost share of up to 50% of the cost of establishing permanent cover.

- **Emergency Conservation Program.** The program provides emergency funding and technical assistance for farmers and ranchers to rehabilitate farmland damaged by natural disasters and for carrying out emergency water conservation measures for livestock during periods of severe drought. Participants receive cost-share assistance of up to 75% of the cost to implement approved emergency conservation practices as determined by county FSA committees. Some conservation practices are removing debris, restoring fences and conservation structures, and providing water for livestock in drought situations.

More information for each of the programs can be found at:
http://www.fsa.usda.gov/FSA/webapp?area=home&subject=landing&topic=landing

7.5.3.5 Fish and Wildlife Service

The USFWS offers technical and financial assistance to a variety of entities. They offer four programs addressing the management, conservation, restoration, or enhancement of wildlife and aquatic habitat.

- **Partners for Wildlife Habitat Restoration.** This program provides technical and financial assistance directly to private landowners through voluntary cooperative agreements called Wildlife Extension Agreements (WEA). The program targets habitats that are in need of management, restoration or enhancement such as riparian areas, streams, wetlands, and grasslands. Under these WEA's, private landowners agree to maintain the restoration projects as specified in the agreement, but otherwise retain full control of the land. Depending on the number of partners, the cost share may vary somewhat, but is typically 75% partners and 25% landowner.
- **Wildlife Conservation and Appreciation Program.** This program provides grants to state fish and wildlife agencies to fund projects that bring together USFWS, state agencies, private organizations, and individuals. Projects include identification of significant problems that can adversely affect fish and wildlife and their habitats, actions to conserve species and their habitats, actions that will provide opportunities for the public to use and enjoy fish and wildlife through non-consumptive activities, monitoring of species, and identification of significant habitats.
- **Cooperative Endangered Species Conservation Fund.** This program is available to states that have a cooperative agreement with the Secretary of Interior. The intent is to provide Federal assistance to any state to assist in the development of programs for the conservation of endangered and threatened species. Potential programs include animal, plant, and habitat surveys, research, planning, management, land acquisition, protection and public education. Single states may receive up to 75% of program costs.
- **North American Wetlands Conservation Act 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 non-profit entities or individuals establishing public-private sector partnerships are eligible. Cost-share partners must at least match grant funds with non-federal monies.

7.5.3.6 Natural Resource Conservation Service

The NRCS provides leadership in a partnership effort to help people voluntarily conserve, improve, and sustain natural resources on private lands. The purpose and mission of the agency is to help landowners treat every acre of their private property according to its needs and within its capability. The treatment includes a balance between the land use for economic return and protecting its ability to be productive from generation to generation. Technical and cost share assistance is available through NRCS. The NRCS administers the following 2009 Farm Bill programs:

- **Environmental Quality Incentives Program (EQIP).** Through EQIP, technical assistance, cost share and inventive payments are available to agricultural producers to implement conservation practices that improve water quality, enhance grazing lands, and/or increase water conservation.
- **Conservation Security Program (CSP).** The CSP is available in selected watersheds across the nation. The program is designed to reward farmers and ranchers who are implementing conservation on working lands and encourage them to do more.
- **Wildlife Habitat Incentives Program (WHIP).** Through WHIP, technical and financial assistance is provided to landowners and others to develop and improve wildlife habitat on private lands.
- **Wetlands Reserve Program (WRP).** Eligible landowners may receive technical and financial assistance through the WRP to address wetland, wildlife habitat, soil, water and related natural resource concerns on private lands.
- **Grassland Reserve Program (GRP).** This program emphasizes support for grazing operations, plant and animal biodiversity, and grassland and land containing shrubs and forbs under the greatest threat of conservation.
- **Farm and Ranch Lands Protection Program (FRPP).** The program is designed to help farmers and ranchers keep their land in agriculture. It provides matching funds to State, Tribal or local governments and non-governmental organizations with existing farm and ranch land protection programs to purchase conservation easements.
- **Resource Conservation and Development (RC&D).** Wyoming's five RC&D areas assist communities by promoting conservation, development, and use of natural resources; improving the general level of economic activity; and enhancing the environmental standard of living for residents of those communities.

7.5.4 Non-Profit and Other Organizations

7.5.4.1 Ducks Unlimited

Ducks Unlimited, Inc. is a funding source for wetlands and waterfowl restoration. Ducks Unlimited (DU) conducts program development through a “Partner” agency in providing short term project funding assistance. Money availability is limited to what is within the organizational system. Generally there is $20,000 to $30,000 available annually statewide with additional funding support from project specific donations.

Ducks Unlimited offers a waterfowl habitat development and protection program called MARSH which stands for Matching Aid to Restore States Habitat. This is a reimbursement program that provides matching funds for restoration, protection or enhancement of wetlands. The financial extent of this program is dependent on DU's income within the state. Projects receiving funding support must demonstrate at least 30 years of beneficial life at a minimum.

7.5.4.2 National Fish and Wildlife Foundation

The National Fish and Wildlife Foundation provides a number of charter grant programs for regions across the nation. The most applicable programs for this project are:

- **Five-Star Restoration Matching Grants Program.** Provides modest financial assistance on a competitive basis to support community-based wetland, riparian, and coastal habitat restoration projects that build diverse partnerships and foster local natural resource stewardship through education, outreach and training activities.
- **Bring Back the Natives.** The National Fish and Wildlife Foundation (NFWF), in cooperation with the USFWS, BLM, U.S.D.A. Forest Service (FS), and Trout Unlimited (TU), is pleased to request pre-proposals from nonprofit organizations, universities, Native American tribes, and local, state, and federal agencies interested in restoring, protecting, and enhancing native populations of sensitive or listed aquatic species, especially on lands on or adjacent to federal agency lands. Funding for the BBN program is administered through NFWF from federal agencies cooperating to support this program. This funding requires a $2 non-federal match for each federal dollar requested by applicants. Since 1991, BBN has supported 279 projects and benefited over 120 species, 29 of which are federally listed as threatened or endangered.
- **Native Plant Conservation Initiative.** The National Fish and Wildlife Foundation (NFWF) is soliciting proposals for the 2009 Native Plant Conservation Initiative (NPCI) grants cycle. The NPCI grant program is conducted in cooperation with the Plant Conservation Alliance (PCA), a partnership between the Foundation, ten federal agencies, and more than 270 non-governmental organizations. PCA provides a framework and strategy for linking resources and expertise in developing a coordinated national approach to the conservation of native plants. Since 1995, the NPCI grant program has funded multi-stakeholder projects that focus on the conservation of native plants and pollinators under any of the following 6 focal areas: conservation, education, restoration, research, sustainability, and data linkages.
- **Pulling Together Initiative.** The Pulling Together Initiative seeks proposals that will help control invasive plant species, mostly through the work of public/private partnerships such as Cooperative Weed Management Areas. PTI applications are accepted from private non-profit (501)(c) organizations, federally recognized Tribal governments, local, county, and state government agencies, and from field staff of federal government agencies. Individuals and for-profit businesses are not eligible to receive PTI grants, but are encouraged to work with eligible applicants to develop and submit applications to PTI. PTI applications must provide a 1:1 non-federal match for their grant request.

More information for each of these funding options and others can be found at NFWF's website: http://www.nfwf.org

7.5.4.3 Trout Unlimited

The mission of the Wyoming Council of Trout Unlimited is to conserve, protect, and restore Wyoming's coldwater (trout) fisheries and their watersheds. Trout Unlimited provides funding and volunteer labor for a variety of stream and watershed projects such as erosion control and fish habitat structures, willow and other riparian plantings, and stream protection fencing. Embrace-A-Stream grants are available for up to $10,000 per project. Partnerships are encouraged and can include local conservation districts and state and federal agencies.

7.5.5 Funding for Sage Grouse Conservation Efforts

Sage Grouse conservation in the Thunder Basin area will provide a number of benefits as well as pitfalls relative to the construction and funding of projects proposed. There are a great number of funding sources whose mission is to benefit the habitat and success of the sage grouse. There are also a number of organizations who will have special requirements for any construction or modification to the local habitat. The Wyoming Game and Fish Department has compiled a list of funding opportunities for Wyoming Sage Grouse Conservation Efforts. More information may be found at the Wyoming Game and Fish Department's web site:
http://gf.state.wy.us/wildlife/wildlife_management/sagegrouse/index.asp

7.5.5.1 State of Wyoming Sources

- **Wyoming Wildlife and Natural Resource Trust Account.** Created by legislative action in 2005 for the purposes of preserving and enhancing Wyoming's wildlife and natural resources. Income from the trust account is used to fund a wide variety of conservation programs. http://wwnrt.state.wy.us/
- **Wyoming Game and Fish Department (WGFD) Trust Fund.** Matching grants program for riparian or upland habitat improvement, water development, and industrial water projects.
- http://gf.state.wy.us
- **WGFD/U.S. Fish & Wildlife Service. Landowner Incentive Program (LIP) -** Provides Federal funds to enhance habitats for sensitive fish and wildlife species on private lands. Priorities in Wyoming are grassland, sagebrush and prairie watersheds. Matching funds, goods or services are required. http://gf.state.wy.us
- **WGFD/Wyoming State General Fund. Wyoming Sage-Grouse Conservation Fund -** Funding approved by the legislature via the Governor's budget request designed to implement projects identified in local Sage-Grouse Conservation Plans. http://gf.state.wy.us
- **Wyoming Animal Damage Management Board (ADMB).** Provides funding for the purposes of mitigating damage caused to livestock, wildlife and crops by predatory animals, predacious birds and depredating animals or for the protection of human health and safety. http://www.wyadmb.com

7.5.5.2 Federal Sources

U.S. Dept. of Interior, Fish and Wildlife Service http://www.fws.gov

- **Partners for Fish and Wildlife Program**. Provides assistance to private landowners who want to restore or improve habitat on their property. The landowner is reimbursed based on the cost sharing formula in the agreement, after project completion.
- **Private Stewardship Program**. Provides grants or other assistance to individuals and groups engaged in private conservation efforts that benefits species listed or proposed as endangered or threatened under the Endangered Species Act, candidate species, or other at-risk species on private lands. Maximum Federal share is 90%.

- **Cooperative Conservation Initiative**. Supports efforts to restore natural resources and establish or expand wildlife habitat. Maximum Federal share is 50%.
- **Multistate Conservation Grant Program**. Supports sport fish and wildlife restoration projects identified by the International Association of Fish and Wildlife Agencies. Maximum Federal share is 100%.
- **Tribal Landowner Incentive Program**. For actions and activities that protect and restore habitats that benefit Federally listed, proposed, or candidate species, or other at-risk species on tribal lands. Maximum Federal share is 75%.
- **Tribal Wildlife Grants**. Provides for development and implementation of programs for the benefit of tribal wildlife and their habitat. Maximum Federal share is 100%.
- **Conservation Grants**. Provides financial assistance to States to implement wildlife conservation projects such as habitat restoration, species status surveys, public education and outreach, captive propagation and reintroduction, nesting surveys, genetic studies and development of management plans. Maximum Federal share is 75 % for a single state or 90% for two or more states implementing a joint project.

U.S.D.A. Farm Service Agency (FSA) http://www.fsa.usda.gov/pas/

- **Conservation Reserve Program (CRP).** A voluntary program for agricultural landowners. Through CRP, you can receive annual rental payments and cost-share assistance to establish long-term, resource conserving covers and enhance wildlife habitat on eligible agricultural land.

U.S.D.A. Natural Resource Conservation Service (NRCS) http://www.wy.nrcs.usda.gov

- **Conservation Innovation Grants (CIG).** CIG is a voluntary program that enables the NRCS to work with public and private entities to accelerate the development and adoption of innovative conservation approaches and technologies in conjunction with agricultural production.
- **Conservation Technical Assistance (CTA)**. Provides voluntary conservation technical assistance to land-users, communities, units of state and local government, and other Federal agencies in planning and implementing conservation systems. This assistance is for planning and implementing conservation practices that address natural resource issues.
- **Environmental Quality Incentives Program (EQIP)**. Provides a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible goals. EQIP offers financial and technical help to assist eligible participants install or implement structural and management practices on eligible agricultural land.
- **Wildlife Habitat Incentives Program (WHIP).** Provides a voluntary program to develop and improve wildlife habitat primarily on private land by providing both technical assistance and up to 75% cost-share assistance to establish and/or improve fish and wildlife habitat.
- **Sage-Grouse Restoration Project (SGRP).** Cooperative effort involving private landowners, agencies, organizations and universities in a process to evaluate and document, through research and demonstration areas, the effects of NRCS conservation practices in restoring sage-grouse habitat and populations.

- **Grazing Land Conservation Initiative (GLCI) Grants**. A nationwide collaborative process of individuals and organizations working to maintain and improve the management, productivity, and health of the Nation's privately owned grazing land. This process has formed coalitions that actively seek sources to increase technical assistance and public awareness activities that maintain or enhance grazing land resources.
- **Cooperative Conservation Partnership Initiative (CCPI).** A voluntary program established to foster conservation partnerships that focus technical and financial resources on conservation priorities in watersheds and airsheds of special significance. Under CCPI, funds are awarded to State and local governments and agencies; Indian tribes; and non-governmental organizations that have a history of working with agricultural producers.
- **Conservation Security Program (CSP).** A unique program that goes beyond the past approach of installing conservation practices. Instead, CSP offers rewards to those who have been good stewards of the soil and water resources on their working agricultural land. It also offers incentives for those who wish to exceed the minimum levels of resource protection and enhance the natural resources on the land they manage. The program is available in designated watersheds.

U.S. Dept. of Interior, Bureau of Land Management http://www.blm.gov

- **Challenge Cost Share**. This program is designed to leverage funds with partners to monitor and inventory resources; implement habitat improvement projects; develop recovery plans; protect or document cultural resources; provide enhanced recreational experiences; and to better manage wild horse and burro populations. Matching funds, goods or services are required.
- **Cooperative Conservation Initiative (CCI)**. CCI was designed to remove barriers to citizen participation in the stewardship of our natural resources and to help people take conservation into their own hands by undertaking projects at the local level. Projects must seek to achieve the actual restoration of natural resources and/or the establishment or expansion of habitat for wildlife. Matching funds, goods or services are required.

U.S.D.A. Forest Service http://www.fs.fed.us

- **Cooperative project funding.** Contact local U.S. Forest Service staff for information about opportunities to develop partnerships in projects involving National Forests or National Grasslands.
- **Partnership Resource Center**. The Partnership Resource Center of the National Forest Foundation (NFF) and the USDA - Forest Service (FS) provides partnering organizations and FS staff with the information to enhance working relationships. Partnerships expand opportunities for obtaining grants. Many funding sources prefer or require them because projects involving partnerships have an increased potential for success.
  http://www.partnershipresourcecenter.org

7.5.5.3 Other Potential Sources

- **Wildlife Heritage Foundation of Wyoming.** The Wyoming Wildlife Heritage Foundation is an independent, charitable organization whose purpose is to provide financial support, through philanthropy, to critical wildlife conservation efforts in Wyoming. http://whfw.org
- **Wyoming Governor's Big Game License Coalition.** Funding generated from the sale of Governor's licenses placed in five accounts: bighorn sheep, moose, elk, mule deer and general wildlife. Funds administered by the Wildlife Heritage Foundation of Wyoming. http://whfw.org
- **National Fish and Wildlife Foundation (NFWF). General Matching Grant Program -** Provides matching grants to priority projects that address fish and wildlife conservation and the habitats on which they depend, work proactively to involve other conservation and community interests, leverage NFWF funding, and evaluate project outcomes. Government agencies, educational institutions, and nonprofit organizations may apply. Grants typically range from $10,000-$150,000. http://www.nfwf.org
- **National Fish and Wildlife Foundation. Native Plant Conservation Initiative (NPCI) -** NPCI grants of federal dollars are provided to non-profit organizations and agencies for conservation of native plants. NPCI grants range from $5,000 to $40,000, averaging $15,000. Non-Federal matching funds, goods or services are required. There is a strong preference for "on-the-ground" projects that involve local communities and citizen volunteers in the restoration of native plant communities. http://www.nfwf.org/programs/npci.cfm
- **National Fish and Wildlife Foundation. Pulling Together Initiative (PTI) -** Provides support for the formation of local Weed Management Area (WMA) partnerships. These partnerships engage federal resource agencies, state and local governments, private landowners, and others in developing weed management projects within an integrated pest management strategy. Non-Federal matching funds, goods or services are required. http://www.nfwf.org/programs/pti.cfm
- **Intermountain West Joint Venture (IWJV). Joint Venture Cost-Share -** Habitats within the IWJV area support nearly 100% of the range of all high priority sagebrush steppe land bird species, such as: Sage Sparrow, Sage Thrasher, Sage-Grouse and Brewer's Sparrow. The purpose of Cost-Share is long-term conservation of bird habitat through partnerships. http://iwjv.org/costshare.htm
- **The Nature Conservancy (TNC).** TNC works with conservation supporters and partner organizations to create funding for conservation worldwide using a variety of creative methods. http://nature.org
- **Tom Thorne Sage-Grouse Conservation Fund.** Provides grants for the conservation of sage-grouse in the Upper Green River Basin. The fund was created by Shell Exploration & Production Co. and managed by a board overseen by the Wyoming Community Foundation. www.wycf.com
- **Rocky Mountain Elk Foundation (RMEF).** RMEF is a wildlife conservation organization with an emphasis on elk. It advocates sustainable, ethical use of resources and seeks common ground among stakeholders. RMEF funds habitat restoration and improvement projects, acquires land or conservation easements. http://www.rmef.org

- **Mule Deer Foundation (MDF).** MDF's goals center on restoring, improving and protecting mule deer habitat. MDF achieves its goals through partnering with state and federal wildlife agencies, conservation groups, businesses and individuals to fund and implement habitat enhancement projects on both public and private lands. http://www.muledeer.org
- **One Shot Antelope Foundation -Water for Wildlife.** Water for Wildlife is a conservation program designed to benefit wildlife and the environment in arid regions of the West. Emphasis focuses on the development of supplemental water resources in areas where both the habitat and wildlife are being impaired by lack of this vital resource. http://www.waterforwildlife.com
- **North American Grouse Partnership (NAGP).** Promotes the conservation of prairie grouse and the habitats necessary for their survival and reproduction. http://www.grousepartners.org
- **Pheasants Forever (PF)**. Some sage-grouse populations in Wyoming occur within areas that have a local PF chapter. Local chapters determine how their funds are spent. Game birds other than pheasants may be eligible for funding. http://www.pheasantsforever.org/chapters/

8.0 Conclusions and Recommendations

This section provides a summary of the conclusions and recommendations presented throughout this report. The conclusions pertain to the watershed inventory and current conditions of the watershed. The recommendations include the proposed watershed improvements projects, environmental permitting and financing.

8.1 Conclusions

Natural Environment

Thunder Basin watershed lies within the geologic structural basin called the Powder River Basin, which is part of the Missouri Plateau of the Great Plains. Thunder Basin watershed consists of a dissected, rolling upland plain with low to moderate relief, broken by buttes, mesas, hills, and ridges. The present-day landforms of the semiarid region have been shaped mostly by the action of water, even though precipitation is low and evaporation greatly exceeds precipitation. Erosion-resistant clinker, produced by the natural burning of coal beds, caps many hills and ridges within Thunder Basin with a characteristic broken, red brick colored rock. The drainages dissecting Thunder Basin are incised, typically are ephemeral or intermittent, and do not naturally provide permanent or year-round sources of water along the entirety of their reaches. Augmenting surface precipitation runoff are springs and seeps that are fed by groundwater from shallow aquifers.

Climate - The climate of the Thunder Basin watershed can be classified as semiarid with average annual rainfall of 14 inches. Since 2000, the watershed has experienced drought conditions as exemplified by the 2008 U.S Drought Monitor map that identified the southern portion of the watershed as affected by drought conditions. Of the10 weather stations that used to monitor the Thunder Basin Watershed, only one in Dull Center is still operational. At Dull Center, the average annual precipitation is 12.8 inches per year.

Vegetation and Land Cover - The bulk of upland vegetation in Thunder Basin is comprised of plant communities in which grasses are predominant, biologically, and visually. In addition, especially in the uplands of the north-central, south central and far west portions the grass component is joined by a substantial presence of big sagebrush. Vegetational components that have particular importance with respect to the water resources and watershed function of Thunder Basin include the Russian olive, salt cedar, and noxious weeds such as Canada thistle.

- Salt cedar is capable of establishing, far from known occurrences, in areas with only the slightest moisture accumulation. Salt cedar is established in the Cow Creek and Red Hills areas and has recently begun to appear on Antelope Creek and the Cheyenne River, as well as certain tributaries.
- Establishment of young Russian olive on Antelope Creek and the Cheyenne River has been particularly heavy. If allowed to proceed, new establishment of stands of Russian olive and salt cedar can produce dense thickets. This will, in turn, increase depletion of massive amounts of shallow groundwater (with direct connection to surface water). Besides the loss of water, the dense thickets can be expected to shade out and out-compete previously existing riparian species, including the native cottonwoods and willows.
- Other noxious weeds are present in the study area and the most abundant is Canada thistle. To the extent that any of these noxious weeds displace diverse native plant communities to form extensive monocultures, they may not only diminish livestock and wildlife forage values, but they may negatively influence watershed function.

Soils - A comprehensive soil survey was completed by the NRCS across the entire Thunder Basin. Soils within the Thunder Basin watershed have developed in residual material and alluvium in a climatic regime characterized by cold winters, warm summers, and low-to-moderate precipitation. Soils in the Thunder Basin watershed are generally low in organic matter and are alkaline. Textures range from clay loams to sandy loams with varying amounts of gravel or coarser materials. Slopes range from nearly level to very steep with deeper soils found in the less steeply sloping areas. These soils support little crop agriculture except in irrigated valleys of perennial streams. Across Thunder Basin the predominant land use is rangeland. Vegetation developed on the soils is predominantly grass-shrub, used for grazing and wildlife habitat.

Geology - Surficial and bedrock deposits across the watershed are divided into three distinct types: 1) Bedrock, residuum and mined areas; 2) River Valley Deposits; and, 3) Upland Deposits. The four shallow bedrock units that directly underlie the surficial deposits, or are exposed in isolated outcrops and along ridges/slopes of Thunder Basin have played an important role in soil formation and other geomorphologic processes. The four shallow bedrock units from youngest to oldest include:

- Tertiary Wasatch Formation
- Tertiary Fort Union Formation; Lebo member
- Tertiary Fort Union Formation; Tullock member
- Cretaceous Lance Formation

Most of the surficial geologic material across Thunder Basin watershed is described as residuum with eolian and alluvium. The residuum deposits are composed of fine clay, silt, and sand ranging up to coarse sands and gravels. The river valley deposits are significant to the watershed study because they represent a significant source of surface and groundwater. The upland deposits include eolian deposits with scattered alluvium. Slopewash with colluvium is mapped along the steeper slopes in the western portion of the watershed.

Landslides - Small, localized, slope failures can occur along the banks of active channels. Slope instability increases during times of material saturation accompanying storm events when undercutting of stream banks is most intense. For this reason, watershed improvement projects should include site-specific geologic hazard analyses, including an evaluation of the site's susceptibility to landslides.

Groundwater - Groundwater in Thunder Basin occurs in both alluvial (shallow) and bedrock (deeper) aquifers. Alluvial aquifers occur in the stream-valley alluvium located along rivers and major drainages. The alluvial aquifers are generally less than 50 feet in thickness but can be as thick as 100 feet in some valleys west of Thunder Basin. The alluvial aquifers yield 5-10 gpm on average with some isolated occurrences of higher production. The bedrock aquifers are part of the Northern Great Plains aquifer system and in Thunder Basin, the aquifer system includes the Tertiary aquifers exposed at the surface, as well as the deeper regional aquifers within older sedimentary rocks deposited during the Upper and Lower Cretaceous and Paleozoic. Bedrock wells can produce up to 500 gpm. Springs occur where the groundwater table intersects the ground surface. Springs occur across Thunder Basin but are abundant along exposures of clinker deposits.

Surface Water Hydrology - Within the Thunder Basin Watershed, there is only one active (and six historic) USGS streamflow gaging stations. Most of the gages show the majority of flow occurring between March and August with peaks generally occurring in May and March. With this sparse dataset and information developed for the Northeast Wyoming River Basins Plan Final Report, water availability and shortages as related to proposed water storage projects in the Thunder Basin study area were evaluated. The following reaches within Thunder Basin were identified to have the following annual available flow during an average year (in acre feet): Antelope Creek (2,837), Cheyenne River above Gage 06365900 (3,696), Cheyenne above Sheep Creek (6,341), Cheyenne River above Black Thunder Creek (7,074), Black Thunder Creek (5,120), Cheyenne River above Lodgepole Creek (12,193), and Cheyenne River above Snyder Creek (12,674).

Stream Geomorphology - A Rosgen Level I classification was completed across the main tributaries of Thunder Basin. The results are summarized as follows: The majority of the stream channels are classified as B (moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools, very stable plan and profile with stable banks) and C channels (low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains). The Type G channels, or gullies, are typical in the upper reaches where the slope breaks and the head cut features formed along the slopes. Channel reaches of the Cheyenne River and tributaries are still adjusting their dimensions but are moving toward a more stable form.

Land Uses and Management Activities

Land Ownership - The majority of land in Thunder Basin is privately owned with the second largest landowner being the Federal Government. Land ownership will play an important role in project implementation in that permitting and financing options depends heavily on land ownership and intended beneficial use.

Range Conditions – Shrub abundance varies response to both substrates and range condition. Stress in the form of drought, or long-lasting grazing, can encourage the establishment of shrubs, as grass competition is lessened. Based on state and transition model information present in the NRCS Ecological Site Descriptions, most ecological sites of the Thunder Basin area can be expected to come to experience greater shrub cover as the effects of stress compound. It is important to note that grazing effects are likely not responsible for the presence of sagebrush in all cases. Extended drought is also an effective stressor. Some evidence also supports the view that sagebrush (and even abundant sagebrush) is a natural plant community component and not a vestige of stress, with abundance proportional to precipitation and snow cover (WGFD 2009).

Oil and Gas Production – The petroleum industry has been exploring and producing oil and gas in Wyoming for over 124 years and since that time, oil and gas production has become an important economic commodity in Thunder Basin. In the last 10 years there has been a decrease in the number of new oil wells and a substantial increase in the number of CBM wells, especially in southeastern Campbell County. This trend is expected to continue into the foreseeable future with increased demands on domestic sources of oil and gas.

Mining and Mineral Resources – Thunder Basin is the single largest source of coal mined in the United States and contains one of the largest deposits of coal in the world. The mines in Thunder Basin produce low-sulphur, sub-bituminous coal suitable for power station fuel without any preparation except crushing. Coal production is expected to continue into the foreseeable future with the potential for expansion as the energy demands increase across the nation. Other mineral deposits within Thunder Basin include uranium, which has a similar outlook for production in response to energy demand.

Watershed Inventory

Irrigation Inventory – Irrigation systems to irrigate grass/hay fields are documented on less than 1 percent of Thunder Basin. The systems are privately owned small spreader dike systems that irrigate areas ranging in size from less than 20 acres to several hundred acres. Most of the systems visited were not functional due to drought conditions and/or are in need of repair. Significant improvement in the systems could be achieved through sediment removal and/or replacement or repair of diversion structures.

Groundwater – Groundwater is used for livestock/wildlife watering but not for irrigation purposes. The reason for this has to do with the depth and yield of the aquifers in Thunder Basin. Groundwater is a viable resource for livestock/wildlife watering and should be expanded in areas where watering opportunities are scarce.

Water Storage Inventory – There are no natural lakes of significant size in the Thunder Basin watershed, however, there are 67 dams within the Thunder Basin study area. The combined storage behind the identified dams is 19,741 acre-feet. Available water for water storage projects was described above. Based on available stream gage and modeling information, during years of average precipitation, there is adequate available water for storage opportunities. The study area contains approximately 194 small impoundments and stock watering ponds. There are 119 breached dam locations with a median pond size of 0.3 acres and a median estimated volume of 1.5 acre-feet. The total estimated volume that could be achieved by rehabilitation of the dams was 1,096 acre-feet. Rehabilitation of the breached dams within Thunder Basin could provide viable livestock/wildlife watering opportunities.

Water Quality **–** Based on a recent study of surface water quality, total dissolved iron levels were high and sometimes exceeded WDEQ criteria levels in the streams. The water quality criteria most often exceeded in samples collected throughout Thunder Basin were sulfate, specific conductance, and manganese. Exceeding the criteria does not necessarily indicate that water is unsuitable for livestock watering or agriculture. It does suggest that livestock and less tolerant plants might not be as productive as they would be with lower levels of the constituent.

Economic Analysis and Project Financing

- An economic analysis on the watershed rehabilitation plans proposed in this report was completed that included an indirect benefits analysis, ability to pay analysis and an evaluation of WWDC financing guidelines. Based on this analysis the livestock watering (upland well development) improvement projects appear to be the most economically beneficial to the association based purely upon a rate of return on their investment dollar.
- Project financing sources include federal, state, local and non-profit agencies. The primary sources of funding for the improvements presented in this report include the WWDC, NRCS and BLM. Numerous other opportunities are presented and should be pursued should the projects move to the next phase of implementation.

8.2 Recommendations

Irrigation Systems

- Rehabilitation plans are proposed for each of the ditches inventoried as requested by ranchers/landowners in Thunder Basin. The rehabilitation plans focus on rehabilitation/replacement of existing structures, enhanced delivery of water, reduction in annual operation and maintenance costs, improvement in ditch management and efficiency, and economic practicality and physical feasibility. Additional improvements could be made across Thunder Basin using the plans and cost estimates provided in this report as a guide for conceptual design, cost, and financing opportunities.
- The recommendations include regrading ditches, head gate replacements, and construction of spreader dikes. The cost estimates for the projects range from $14,700 to construct spreader dikes to $55,285 to build a 1,000 foot dike and regrade nearly one mile of ditch.
- The recommended improvements include thirteen different projects at four ranches. The individual projects can be implemented individually or as a complete package based on the preferences and financial ability of the owner. The most likely sources of funding for these projects is the WWDC Small Water Project Program and programs through the NRCS.

Surface Water Storage

- An evaluation of water available for storage projects was completed based on the existing datasets accessible for such an analysis. It is recommended that if any of the proposed Account III storage projects is undertaken that StateMod or similar model be developed so that water rights can be appropriately exercised and potential water availability can be more accurately estimated.

- Due to the lack of streamflow and watershed yield data, temporary stream gages should be installed at sites for which storage projects are desired.
- Four WWDC Account III multipurpose storage sites were identified in Thunder Basin. Based on the financial evaluations and local landowner input, it is unlikely that any requests for Level II studies of these sites will move forward. They remain, however, sites that could be further evaluated in the future.
- Property owner storage evaluation requests were completed and four projects are recommended for further study and/or implementation. The projects include a storage reservoir on Sand Creek near the Haefele Ranch, construction of a dam on the Cheyenne River downstream of an existing run-of-the river dam that diverts water to the Harshbarger property, rehabilitation of Sherwin Dam, also on the Harshbarger property, and construction of a dam on Red Rock Draw near the Moore property.
- Livestock/wildlife watering opportunities were evaluated based on the assumption that cattle will graze up to a mile from a water source. Using this criterion, an analysis of the watershed was conducted to identify locations where additional water storage for livestock watering could be beneficial.
- Supplemental storage at existing breached dam locations is a viable option to address the areas underserved with the existing network of stock wells and functional stock ponds. Six breached dams were identified outside of the cattle grazing ranges around existing water sources. The cost associated with rehabilitation of the breached dams ranged in cost from $20,000 to $44,000. The most likely source of funding for breached dam rehabilitation is the WWDC Small Water Project Program, the Wyoming Wildlife and Natural Resource Trust, or the Bureau of Land Management Range Improvement Planning and Development Program.
- For expansion of existing reservoirs, each of the 67 dams identified in the NID was evaluated to determine whether each dam has enough watershed area to yield a minimum of 1,000 acre-feet of available water based on the averages described in the preceding paragraph. Of the 67 dams, only one dam emerged as a potential site, “Peterson No. 1” located on Black Thunder Creek downstream of Dull Center Road and upstream of the confluence with the Cheyenne River. It is estimated that the cost to expand the dam to capture and store a minimum of 1,000 acre-feet would be approximately $6 to $7 million based on the average cost per acre-foot of stored water developed for new dams presented in this report.

Groundwater Development

- One of the best options to enhance rangeland and riparian habitat is to ensure that there are adequate watering opportunities in the upland areas of the watershed. Currently drainage ways are often the location of the water that is available and therefore livestock pressure in these portions of the landscape is disproportionately great. With dispersal of livestock watering sources to uplands, not only are riparian areas relieved of grazing and trampling pressure, but little used forage on remote uplands may be accessed by foraging animals. For these reasons upland water development projects in underserved areas are recommended. All five upland water development projects are recommended for funding through the WWDC Small Water Project Program. These projects include the combinations of the following elements: installation of shallow to moderately deep groundwater wells, solar powered pumps, stock tanks, piping and fencing to maximize water distribution for livestock and wildlife. The projects range in cost from $15,900 to $89,800.

- Additional upland water development improvements could be made across Thunder Basin using the plans and cost estimates provided in this report as a guide for conceptual design, cost, and financing opportunities.
- Development of deep aquifer irrigation wells is not deemed feasible for this area unless significant advances in technology for installation and long-term pumping are realized.

Other Management Practices

- Control of noxious weeds including Russian olive, salt cedar and Canada thistle, to name a few, should continue to be implemented to promote overall health of the rangeland. Efforts should be concentrated in areas of large infestations in both rangeland and riparian areas.
- Continued implementation of the grazing management plans developed for the Thunder Basin is recommended. These plans provide methods for pasture rotation and riparian habitat protection that will continue to add to the value and health of the watershed.
- Based on the geomorphologic evaluation completed across Thunder Basin, it is recommended that channel restoration and stabilization efforts should be coordinated as the proposed projects are implemented. For example, at the Harshbargers' ranch a series of cross vane type structures could be constructed to provide an increase in head elevation for the diversion point and at the Stroh ranch, as part of the headgate repair/replacement an in-channel diversion structure will be needed. Additionally, the large storage structures will require additional evaluations to ensure stream stability after project implementation. These more detailed geomorphologic evaluations (i.e., Level II Rosgen Classifications) can be implemented as part of the Level II feasibility studies that will be completed during the next phase of project implementation.

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10.0 Acronyms

AMPs	Allotment Management Plan
BLM	U.S .Bureau of Land Management
CaCCD	Campbell County Conservation District
CBM	Coal Bed Methane
CFS	Cubic feet per second
CoCCD	Converse County Conservation District
CWA	Clean Water Act
EA	Environmental Assessments
EPA	U.S. Environmental Protection Agency
ESD	Ecological Site Description
EIS	Environmental Impact Statement
GIS	Geographic Information System
gpm	Gallons per minute
IDF	Inflow Design Flood
NDC	No Defined Channel
NEPA	National Environmental Policy Act
NIDS	National Inventory of Dams
NRCS	Natural Resources Conservation Services
PMF	Probable Maximum Flood
PRB	Powder River Basin
ROW	Rights-of-way
TBGA	Thunder Basin Grazing Association
TDS	Total Dissolved Solids
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDEQ	Wyoming Department of Environmental Quality
WGFD	Wyoming Game and Fish Department
WSGS	Wyoming State Geologic Survey
WSEO	Wyoming State Engineer's Office
WWDC	Wyoming Water Development Commission
WYNDD	Wyoming Natural Diversity Database
WYPDES	Wyoming Pollutant Discharge Elimination System

Appendix A

Data Summaries

Data Summary 1.2-1 GIS Layer Information		
Data Name in Map	**Directory in Geodatabase**	**Filename in Geodatabase**
Bureau of Land Management (BLM)		
Grazing Allotment - BLM	Administrative	Allotments_BLM
Land Ownership	Administrative	Landown24k
Sage Grouse Habitat	Animals	Sage_Grouse_Habitat
Sage Grouse Leks - BLM	Animals	SageGrouseLeks2007
Wildfires	Environment	wywildfires01to08
ESRI		
Generalized Lakes	Hydrology	HydroPoly_ESRI
Generalized Streams	Hydrology	HydroLine_ESRI
National Agriculture Imagery Program (NAIP)		
2006 NAIP Aerials		
Natural Resources Conservation Service (NRCS)		
Watershed Boundary	Hydrology	HUC12
Thunder Basin Grazing Association (TBGA)		
Sage Grouse Leks - TBGA	Animals	TBGA_SageGrouseLeks
Grazing Allotment - TBGA	Administrative	Allotments_TBGA
U.S. Army Corps of Engineers (USACE)		
National Inventory of Dams	Hydrology	Dams
U.S. Bureau of Mines (USBM)		
Oil Field	Geology	Oil_Fields
U.S. Census Bureau (USCB)		
Cities	Administrative	Cities
Major Roads	Infrastructure	major_roads_1
City	Statewide	City
Major Roads	Statewide	major_roads
U.S. Department of Agriculture (USDA)		
STATSGO Soils	Geology	STATSGOSoils
	Geology	SSURGOsoils
U.S. Fish & Wildlife Service (USFWS)		
NWI Arcs	Hydrology	NWI_Arcs
NWI Polygons	Hydrology	NWI_Polygons
Raptor Nesting Areas	Animals	RaptorNestingAreas
U.S. Geological Survey (USGS)		
Electrical Power Service	Administrative	Utilities
Springs/Seeps	Hydrology	NHD_Point
Regions for Peak-Flow Characteristics	Hydrology	PeakFlowRegions
Gauging Station	Hydrology	USGS_SiteInformation
1:250,000 Topographic Maps	Not applicable	Not applicable
University of Wyoming (UWYO)		
Counties	Administrative	State_Counties
Horizontal Acceleration	Geology	horiz_accel
County	Statewide	county
Wyoming Department of Environmental Quality (WDEQ)		
WYPDES Permitted Discharge	Environment	NPDESOutfalls
WDEQ Stream Classification	Hydrology	WDEQClassification
Wyoming Game and Fish Department (WGFD)		
Antelope Range	Animals	Antelope_Range
Big Game Crucial Ranges	Animals	BigGameCrucialRanges
Mule Deer Range	Animals	Mule_Deer_Range
White-Tailed Deer Range	Animals	WhiteTailed_Deer_Range
Wyoming Geographic Information Science Center (WyGISC)		
Sections	Administrative	PLSS
Townships	Administrative	Townships
Land Cover	Environment	LandCover
Landslides	Geology	Landslides
Watersheds	Hydrology	Watersheds
Coal Mines	Minerals	coal_mine_locations

Coal Potential	Minerals	coal
Mineral Potential	Minerals	uranium_clip
Uranium Mines	Minerals	uranium_mine
Watersheds	Statewide	Watershed_topo
Wyoming Natural Diversity Database (WYNDD)		
Prebles	Predictive Species	Prebles
Ute Ladies Tresses	Predictive Species	UteLadiesTresses
Wyoming State Engineers Office (WSEO)		
SEO Wells	Hydrology	SEO_Wells
Stock Pond	Hydrology	Surface_Water
Wyoming State Geological Survey (WSGS)		
Major Pipeline	Infrastructure	Pipelines
Railroads	Infrastructure	Railroads
Wyoming Water Development Commission (WWDC)		
Bedrock Geology	Geology	BedrockGeology
Surficial Geology	Geology	SurfaceGeology
Irrigated Lands	Northeast Wyoming Water Plan Data	IrrigatedLands
Irrigation Points of Diversion	Northeast Wyoming Water Plan Data	Points of Diversion
Developed for Project		
Property Boundary	Administrative	RanchPropertyBoundary
StudyAreaExtents	Administrative	StudyAreaExtent
Potential Additional Watering Opportunities	Animals	PotentialWateringOpportunities
Watering Opportunities	Animals	WateringOpportunities
Ground Elevation Contours	Contours	Contours_10FT_fromDEM
Annual Flow	Dam Information	annual_flow
Breached Dam	Dam Information	BreachedDams
Breached Dam Outline	Dam Information	Breached_Dam_Lines
Dam Centerline	Dam Information	DamCenterline
Dam Pools	Dam Information	DamPools
Point of Interest	Dam Information	PointofInterest
Potential Dam Site	Dam Information	PotentialDamSite
Canal Headgate/Siphon	Irrigation	Headgate_Siphon
Ditch/Dam/Terrace	Irrigation	Dam_Ditch
Field/Storage	Irrigation	Fields_Storage
Hillshade	Not applicable	Not applicable
RanchPageLayouts		RanchPageLayouts.shp
Western Regional Climate Center (WRCC)		
Weather Station	Weather	PrecipitationStations
Thunder Basin Grazing Association (TBGA) and Weston & Converse County Conservation Districts		
Small Water Project Wells	Hydrology	SmWtrPrj
ESCO		
Ecological Sites Legend	ESCO	ECOCLASSES
Weston Ecological Site	ESCO	WESTON_EcoSite_SDV
Niobrara Ecological Site	ESCO	NIOBRARA_EcoSite_SDV
Natrona Ecological Site	ESCO	NATRONA_EcoSite_SDV
Converse Ecological Site	ESCO	CONVERSE_EcoSite_SDV
Campbell Ecological Site	ESCO	CAMPBELL_EcoSite_SDV
Weston Irrigation Capability	ESCO	WESTON_IrrCap_SDV
Niobrara Irrigation Capability	ESCO	NIOBRARA_IrrCap_SDV
Natrona Irrigation Capability	ESCO	NATRONA_IrrCap_SDV
Converse Irrigation Capability	ESCO	CONVERSE_IrrCap_SDV
Campbell Irrigation Capability	ESCO	CAMPBELL_IrrCap_SDV
STREAM STEADY		
Rosgen Classification	StreamSteady	RosgenClassification

Data Summary 2.1.4-1 List of Soil Property Data Available and Report Name

Soil Property	Report Name
Map unit acres	Acreage and Proportionate Extent
Map unit name	Acreage and Proportionate Extent
Map unit percent	Acreage and Proportionate Extent
Calcium carbonate content Chemical Soil Properties	Chemical Soil Properties
Cation exchange capacity (CEC) Chemical Soil Properties	Chemical Soil Properties
Effective cation exchange capacity (ECEC) Chemical Soil Properties	Chemical Soil Properties
Gypsum content Chemical Soil Properties	Chemical Soil Properties
Horizon depths	Chemical Soil Properties
Salinity (EC)	Chemical Soil Properties
Sodium absorption ration (SAR)	Chemical Soil Properties
Soil reaction (pH)	Chemical Soil Properties
Component composition by map unit	Component Legend
Component kind	Component Legend
Component name by map unit	Component Legend
Slope range by component	Component Legend
AASHTO classification	Engineering Properties
Fragment content, by weight	Engineering Properties
Horizon depths	Engineering Properties
Liquid Limit	Engineering Properties
Percent passing sieves	Engineering Properties
Plasticity Index	Engineering Properties
Texture by horizon	Engineering Properties
Unified soil classification	Engineering Properties
Available Water Capacity	Physical Soil Properties
Clay content	Physical Soil Properties
Horizon depths	Physical Soil Properties
Kf erosion factor	Physical Soil Properties
Kw erosion factor	Physical Soil Properties
Linear Extensibility (shrink-swell)	Physical Soil Properties
Organic Matter content	Physical Soil Properties
Sand content	Physical Soil Properties
Sand content RUSLE2	Physical Soil Properties
Saturated Hydraulic Conductivity (Ksat)	Physical Soil Properties
Silt content	Physical Soil Properties
T factor	Physical Soil Properties
Wind erodibility group (WEG)	Physical Soil Properties
Wind erodibility index (WEI)	Physical Soil Properties
Clay content RUSLE2	Related Attributes
Hydrologic Soil Group RUSLE2	Related Attributes
Kf erosion factor RUSLE2	Related Attributes
Silt content RUSLE2	Related Attributes
T factor RUSLE2	Related Attributes
Potential frost action	Soil Features
Restrictive Layer depth	Soil Features
Restrictive Layer hardness	Soil Features

Soil Property	Report Name
Restrictive Layer kind	Soil Features
Restrictive Layer thickness	Soil Features
Risk of corrosion - concrete	Soil Features
Risk of corrosion - steel	Soil Features
Subsidence	Soil Features
Flooding duration, frequency Water Features	Water Features
Hydrologic Soil Group	Water Features
Ponding depth, duration, frequency	Water Features
Runoff	Water Features
Water table depth	Water Features

Note: Data available from NRCS Soil Data Mart - http://SoilDataMart.nrcs.usda.gov/

Data Summary 2.1.6-1 of Ground Availability/Development Potential of Major Aquifer Systems, Central and Eastern Flanks of the Powder River Structural Basin, Northeast River Basin Plan Area, Wyoming (Feathers, Libra, Stephenson and Eisen, 1981)

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability/Development Potential [C]	Remarks
Quaternary Alluvial Aquifer System	Alluvium and Terrace Deposits	0-100+	Clay rich sandy silt, silt, sand and gravel; unconsolidated and interbedded; present along most streams. Thickness generally less than 50 feet but may be thicker. Coarser deposits in valleys of the Belle Fourche and the Cheyenne Rivers. Alluvium overlying formations of Tertiary age is generally fine to medium grained in central part of basin. (Hodson, Pearl and Druse, 1971)	Yield of 1000 gpm possible, often through induced recharge. Terraces topographically high and often drained. Specific capacity, 0.3-18 gpm/ft; porosity, 28-45%; permeability, 0.1-1100 gpd/ft^2; transmissivity, 15-64000 gpd/ft; specific yield, 2-39%. Coarser deposits have better aquifer properties.	TDS content generally range from about 100 to >4000 mg/l, and chemical characteristics of water differ geographically. Chemical type and mineralization of the water can be expected to vary depending on underlying rock types and the nature and degree of interconnection with underlying bedrock aquifers as well as surface water. Moderate to high mineralization tolerable for stock and domestic use. Suitability for irrigation generally limited to salt tolerant crops. Water in the alluvium in Black Hills generally is better quality than central part of basin (Hodson, Pearl and Druse, 1971).	Historical source for domestic and stock use. Production has ranged from 1 to 900 gpm. Ground water development potential generally better in coarse-grained deposits and poorer in fine-grained materials. Yields in the high end of the above range might be possible to optimally located and properly designed wells if induced infiltration from surface water can be tolerated (Belle Fourche, Cheyenne and Niobrara River Basins). Potential source for irrigation, municipal / public and industrial sources where more than 40 feet of saturated well sorted sand and gravel are present.	Quaternary alluvial aquifers generally in hydraulic connection with all bedrock aquifers in outcrop areas and also with surface waters. Alluvial aquifers in larger valleys provide hydraulic interconnection between otherwise hydraulically isolated bedrock aquifers (Whitcomb, 1965). Alluvial aquifers also serve as interchange point and storage for ground water in the hydrologic cycle (Davis and Rechard, 1977), (Davis, 1976). Induced recharge from surface waters is probable in areas of extensive development.
Middle Tertiary Aquifer	Arikaree Formation	0-500 (southeast only)	Tuffaceous sandstone, fine-grained with silty zones, coarse sand lenses and concretionary zones.	Yields up to 1000 gpm; specific capacity up to 232 gpm/ft; porosity, 5-24%; permeability <1-300 gpd/ft^2; transmissivity up to 77,000 gpd/ft.	TDS content of water ranges from 261 to 535 mg/l. Composition mainly Calcium Bicarbonate (Whitcomb, 1965). Median TDS content in samples from 12 wells in Niobrara County 321 mg/l (Larson, 1984).	Historical source for municipal / public, industrial, domestic, stock and irrigation supply with tested production ranging as high as 195 to 730 gpm (Whitcomb, 1965). Yields of 1000 gpm might be possible to optimally located and properly designed wells.	Water level data available from two observation wells located east and south east of Lusk in Niobrara County (32-62-05-baa01), (32-62-32-bbb01). Water levels have shown approximately 6 to 13 feet decline in water levels in the aquifer since the 1970s with possibly some stabilization and slight recovery since early to mid 1990s (USGS, 2001).
Fort Union / Wasatch Aquifer System	Wasatch Formation	up to 1600	Fine- to coarse-grained lenticular sandstones interbedded with shale and coal, coarser in south.	Yields generally <15 gpm, locally flowing wells exist. Yields historically could be expected to range from 10 to 50 gpm in the north part of the basin with the possibility of higher yields up to 500 gpm in the south part of the basin (Hodson, Pearl and Druse, 1973). Specific capacity, 0.10-14 gpm/ft (Hodson, Pearl and Druse, 1973); porosity, 28-30%; permeability, 0.01-65 gpd/ft^2; transmissivity, average 500 gpd/ft range 1-4000 gpd/ft.	TDS content of waters is variable and ranges from <200 to > 8000 mg/l (Hodson, Pearl and Druse, 1973). Sodium Sulfate and Sodium Bicarbonate are general dominate water types. Major ion composition varies with depth and shows more Sodium and Bicarbonate content with depth. Radium 226 + 228 may be of concern near uranium deposits.	Historical source for municipal / public, domestic and stock supply. Yields ranging from 10 to 50 gpm in the north part of the basin can be expected with the possibility of higher yields up to 500 gpm in the south part of the basin (Hodson, Pearl and Druse, 1973).	Water level data available from two observation wells located in Campbell County (50-72-21-aba01), (42-71-35-aaa01) and one observation well in Converse County (37-70-10-cbb01). Water levels in the aquifer have shown about a 40 feet rise between 1983 and 2000 in Gillette and about a 40 to 50 feet decline south east of Wright in Campbell County. Water levels in the aquifer in northwest Converse County have shown a rise of about 7 feet between 1988 and 1999 after a decline of about 6 feet between 1986 and 1988. (USGS, 2001)

Data Summary 2.1.6-1 of Ground Availability/Development Potential of Major Aquifer Systems, Central and Eastern Flanks of the Powder River Structural Basin, Northeast River Basin Plan Area, Wyoming (Feathers, Libra, Stephenson and Eisen, 1981)

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability/Development Potential [C]	Remarks
Fort Union / Wasatch Aquifer System (continued)	Fort Union Formation	1100-2270	Sandstone, fine- to medium-grained, lenticular, interbedded with siltstone, coal and shale. Middle part may be shalier in north, upper part siltier in south. "Clinker" associated with coal outcrops.	Flowing yields of 1-60 gpm where confined. Pumped yields up to 250 gpm with several hundred feet of drawdown. Specific capacity, 0.1-2 gpm/ft; permeability, 0.01-100 gpd/ft^2; transmissivity, 1-5000 gpd/ft. Coal and clinker generally have better aquifer properties than sandstones. Locally clinker transmissivity up to 3,000,000 gpd/ft; Anisotropy and leaky confining layers are common.	TDS content and major ion composition of Fort Union Formation Waters as above. Water co-produced with coal bed methane is predominantly Sodium Bicarbonate type with TDS content and SAR (32 samples), 270 - 1170 mg/l (mean of 653 mg/l) and 5.7 - 12 (mean of 7.85) respectively (Rice, Ellis & Bullock, 2000). BLM Wyodak EIS assumed average TDS concentration of 764 mg/l (USDI,BLM, 1999). High radionuclide content of concern in areas near uranium ore zones.	Historical source for municipal / public, domestic and stock supply. Maximum expected yields of about 130 to 150 gpm (Hodson, Pearl and Druse, 1973), (Wester - Wetstein and Associates, Inc., 1994). Exploration and development of new Fort Union well field including conjunctive use / recharge of Coal Bed Methane production water under consideration for the City of Gillette.	Source for approximately 14 municipal and public water supply systems including the City of Gillette and adjacent Districts, Joint Powers Boards and Privately Owned Water Systems and Water Users Associations in Campbell County. City of Gillette mixes Fort Union Formation water with that from the Madison and Fox Hills/Lance system for municipal / public water supply. Total of 5285 Coal Bed Methane wells permitted with WSEO in planning area as of 12/31/00. Maximum, minimum and mean depths and range of actual yields listed on permits were 138 -5507 (mean 772) feet below ground surface (bgs), and 1 - 120 (mean 27) gpm respectively. Range of depths to main water bearing zone listed on WSEO Permits were 124 - 1558 (mean 124) feet bgs. BLM Wyodak EIS assumed average expected water production to be 12 gpm over the estimated 12 year life of each CBM well (USDI,BLM, 1999). BLM Wyodak Drainage EA assumed average water production for each CBM well to be 11.1 gpm (USDI,BLM, 2000).
Fox Hills/Lance Aquifer System	Lance Formation	500-1000 (North) 1600-3000 (South)	Sandstone, fine- to medium-grained, lenticular, interbedded with sandy siltstone and claystone.	Yields up to 350 gpm but with large drawdowns and long well completion intervals. Locally flowing wells exist. Specific capacity, 0.05-2 gpm/ft; permeability, 6-35 gpd/ft^2; transmissivity, 170-2100 gpd/ft	TDS content in waters at Foxhills/Lance System outcrops north of Niobrara County range from 600 - 1,500 mg/l, and in Niobrara County range from 1,000 - 3,300 mg/l. Composition mainly Sodium - Bicarbonate - Sulfate. Fluoride enrichment is characteristic of Fox Hills/Lance Formation waters. Possible high Sodium, and radionuclide content could be of concern in some areas.	Lance Formation historical source for municipal / public, domestic and stock supply. Generally yields less than 20 gpm, but yields of several hundred gallons per minute may be possible from complete section of the formation. (Hodson, Pearl and Druse, 1973)	High Fluoride content is of concern for development as source for municipal / public water systems.
	Fox Hills Sandstone	150-200 (North) 400-700 (South)	Sandstone, fine-to medium-grained, interbedded with shale and siltstone.	Yields up to 705 gpm but with large drawdowns and long well completion intervals. Locally flowing wells exist. Specific capacity, 0.05-2 gpm/ft; permeability, 34 gpd/ft^2; transmissivity, 76-1600 gpd/ft for wells also completed in Lance.	Similar to Lance Formation	Historical source for municipal / public, industrial, domestic and stock supply. Tested yields of Gillette municipal / public supply wells have ranged from 85 to 705 gpm (Wester-Wetstein and Associates, Inc., 1994).	High Fluoride content is of concern for development as source for municipal / public water systems. Has been used for oil well water flooding operations. Water level data available from one observation well completed in the aquifer south east of Gillette in Campbell County (49-70-31bbb01) has shown approximately 50 feet decline since 1983 (USGS, 2001).

Data Summary 2.1.6-1 of Ground Availability/Development Potential of Major Aquifer Systems, Central and Eastern Flanks of the Powder River Structural Basin, Northeast River Basin Plan Area, Wyoming (Feathers, Libra, Stephenson and Eisen, 1981)

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability/Development Potential [C]	Remarks
Dakota Aquifer System	Newcastle Sandstone	0-60 (Northeastern Basin) 0-100 (Southeastern Basin)	Sandstone, fine-to medium-grained, locally conglomeratic, lenticular, with interbedded siltstone, shale and claystone.	Minor unit of Dakota Aquifer System exploited near outcrop only; often excessive pumping lift. Oil field data: porosity, 5-27%; permeability, <11 gpd/ft^2; transmissivity, 0-140 gpd/ft.	Waters at Dakota System outcrop generally contain over 1,000 mg/l TDS. TDS content 180 - 3200 mg/l in 17 samples in Weston County (Larson, 1984). Composition changes basinward from Calcium - Magnesium - Sulfate at outcrop to Sodium - Sulfate, to Sodium - Bicarbonate. Deep Basin waters > 10,00 mg/l TDS & are enriched to Sodium - Chloride. Possible high Fluoride, Selenium and radionuclide content could be of concern in some areas.	Dakota Aquifer System historical source for domestic and stock use.	Few reported wells in northern Black Hills (1958) due to excessive drilling depths except in outcrop areas. Yields typically adequate for stock and domestic purposes. Historically, wells typically have been completed in both the Lakota and Fall River Formations to obtain maximum production. (Whitcomb, Morris, Gordon & Robinove, 1958) Water level data available from one observation well completed in the aquifer (Lakota Formation) northeast of Lusk in Niobrara County (36-62-28ab02) has shown approximately 23 feet decline between 1974 and 2000 (USGS, 2001).
	Fall River Formation	95-150 (Northeastern Basin) 35-85 (Southeastern Basin)	Sandstone, fine-to coarse-grained with interbedded shale and siltstone.	Flowing yield 1-10 gpm; wells often also completed in Lakota Formation. Specific capacity, <0.5 gpm/ft. Oil field data: porosity, 11-23%; permeability, 0-36 gpd/ft^2 ; transmissivity, 1-900 gpd/ft.			
	Lakota Formation	45-300 (Northeastern Basin) 115-200 (Southeastern Basin)	Sandstone, fine-to coarse-grained, in places conglomeratic, very lenticular, irregularly interbedded with shale which becomes dominant at top (Fuson Shale).	Flowing yield 1-10 gpm, up to 150 gpm. Water well data: specific capacity, 0.01-1.4 gpm/ft; permeability, 2-14 gpd/ft^2 transmissivity, 220-810 gpd/ft for 2 wells also in Fall River.			
Madison Aquifer System	Minnelusa Formation (Hartville Formation)[D]	600-800 (Northeastern Basin) 1000± (Southeastern Basin)	Sandstone, fine-to coarse-grained, interbedded with limestone, dolomite, and shale, locally gypsiferous, especially at top.	Upper part has historically been considered part of Madison Aquifer System, middle is aquitard, lower is minor aquifer in hydraulic connection with Madison. Flowing yields of over 200 gpm possible; specific capacity, 1-5 gpm/ft. Oil field data: porosity, 6-25%; permeability, <0.1-18 gpd/ft^2; transmissivity, 2-900 gpd/ft.	Similar to Madison Formation Waters at Outcrop (TDS < 600mg/l, predominantly Calcium - Magnesium - Bicarbonate type water). TDS content 230 - 2450 mg/l from 26 samples in Crook County with median and mean of 520 and 773 mg/l respectively (Larson, 1984). Some east basin waters near outcrops show TDS up to 3,000 mg/l (Calcium & Sulfate enrichment). Deep basin waters TDS > 10,000 mg/l (mainly Sodium - Chloride type water). Fluoride enrichment characteristic of Madison System waters throughout the basin. Concentrations of radionuclides could be of concern in some areas.	Historical source for municipal / public water supply, domestic and stock use.	Large quantities of water produced from flowing wells at Huelett (1958). Generally deeply buried (> 600 - 700 feet minimum) in area (northern Black Hills - 1958), (Whitcomb, Morris, Gordon & Robinove, 1958). Subject of USGS investigation with Pahasapa / Madison Limestone (Ogle, 2001). Water level data available from one observation well located in Crook (44-62-36-cbb02) and one in Niobrara (36-62-28-bbd01) Counties. Water levels have risen about 2 feet (since 1998) and 15 feet (since 1995) respectively in the two observation wells (USGS, 2001).

Data Summary 2.1.6-1 of Ground Availability/Development Potential of Major Aquifer Systems, Central and Eastern Flanks of the Powder River Structural Basin, Northeast River Basin Plan Area, Wyoming (Feathers, Libra, Stephenson and Eisen, 1981)

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability/Development Potential [C]	Remarks
Madison Aquifer System (Continued)	Pahasapa Limestone (Madison Limestone)[D]	550-990 (Northeastern Basin) 250± (Southeastern Basin)	Massive fine-grained limestone and dolomitic limestone, locally cherty or cavernous.	Principal unit of Madison Aquifer System. Flowing or pumped yields up to 1000 gpm; specific capacity, 0.5-50+ gpm/ft, flow-dependent; transmissivity, 1000-60,000 gpd/ft locally to 300,000 gpd/ft+.	Waters at Outcrop (TDS < 600mg/l, predominantly Calcium - Magnesium - Bicarbonate type water). TDS increase basinward to > 3,000 mg/l, Sodium - Sulfate - Chloride predominating. Fluoride enrichment characteristic of Madison System waters throughout the basin. Concentrations of radionuclides could be of concern in some areas.	Probably most important high yield aquifer in Wyoming. Historical source for municipal / public water supply, industrial, irrigation and stock use. Several fish hatcheries use Pahasapa / Madison aquifer as water source. Base flow and spring discharge from the Pahasapa / Madison aquifer form part of the surface run-off in the Black Hills area. (Ogle, 2001) Tested pumping rate of seven City of Gillette Pahasapa / Madison aquifer wells ranged from 535 to 900 gpm (Wester-Wetstein and Associates, Inc., 1994).	Subject of USGS investigation with the Minnelusa Formation (Ogle, 2001). Water level data available from nine observation wells located in Crook (56-67-28-aab01), (56-67-28-aab02), (53-65-18bbd02), (52-63-25-dcd01), (49-62-36-cbb01), Weston (48-65-35ccb01), (46-66-25dbb01), (44-63-26cac01), and Niobrara (36-62-28-ab01) Counties. Water levels have generally risen from 13 to 40 feet in some of the observation wells since 1995 (USGS, 2001). Total estimated recharge to the Madison Limestone in the Powder River Basin in 1973 was about 75,000 acre feet/year (WSEO, 1976).
	Englewood Limestone (Gurnsey Formation, part)[D]	30-60 (Northeastern Basin) 0-50± (Southeastern Basin)	Thin-bedded limestone, locally shaley.	Minor unit of Madison Aquifer System; USGS test: porosity, 15-18%; permeability, <0.1 gpd/ft^2.			Generally no ground water development in area (Northern Black Hills - 1958). Formations may contain some water in permeable zones, but are generally considered to be too deeply bured to be considered important aquifers. (Whitcomb, Morris, Gordon & Robinove, 1958)
	Whitewood Dolomite	50-60 (Northeastern Basin) absent (Southeastern Basin)	Massive bedded dolomite, locally cherty.	Minor unit of Madison Aquifer System; the few existing wells also produce from the Madison aquifer. USGS test: porosity, 10-25%; specific capacity, 15 gpm/ft; permeability, <0.1-11 gpd/ft^2; transmissivity, 6400 gpd/ft.			

[A]Reported yields may reflect development needs rather than aquifer capability; higher yields can sometimes be expected, with corresponding drawdown increases. Reported water well transmissivities or permeabilities may be for wells completed in two aquifers or screened in only part of a single aquifer. Reported ranges include varying amounts of data. (Feathers, Libra, Stephenson and Eisen, 1981)

[B]Oilfield (and USGS test) data are variously derived resulting in internal inconsistencies in this compilation. Permeabilities are measured on cores or derived from other data and transmissivities are from drill stem tests or calculated from permeability. Test data are usually for limited horizons of high anticipated yields and are not therefore representative of the formation as a whole. (Feathers, Libra, Stephenson and Eisen, 1981)

[C]Actual development potential will require site specific office and field investigations to define aquifer capability and constraints unique to each project and site.

[D]Nomenclature for equivalent strata exposed in the Hartville uplift on the southeastern basin flank (Feathers, Libra, Stephenson and Eisen, 1981).

Data Summary 2.1.7-1 Watershed Hydrologic Features Index	
HUC 12 ID Number	Watershed Name
101201010101	Upper Sand Creek-Antelope Creek
101201010102	Middle Sand Creek
101201010103	Stinking Water Creek
101201010104	Lower Sand Creek-
101201010105	Upper Bear Creek-Antelope Creek
101201010106	Lower Bear Creek-Antelope Creek
101201010201	Antelope Creek-Bull Gulch
101201010202	Upper Wind Creek
101201010203	Lower Wind Creek
101201010204	Antelope Creek-Sandy Draw
101201010205	Ninemile Creek
101201010206	Upper Bates Creek
101201010207	Lower Bates Creek
101201010208	Little Bates Creek
101201010301	Antelope Creek-Horse Creek
101201010302	Spring Creek-Antelope Creek
101201010303	Upper Porcupine Creek-Antelope Creek
101201010304	Lower Porcupine Creek-Antelope Creek
101201010305	Antelope Creek-Beckwith Creek
101201020101	Dry Fork Cheyenne River-South Fork Dry Fork Cheyenne River
101201020102	North Fork Dry Fork Cheyenne River
101201020103	Dry Fork Cheyenne River-Brown Springs Creek
101201020104	Dry Fork Cheyenne River-Ray Draw
101201020105	Willow Creek-Dry Fork Cheyenne River
101201020106	Duck Creek-Dry Fork Cheyenne
101201020201	Dry Fork Cheyenne River-Cottonwood Draw
101201020202	Dry Fork Cheyenne River-Dugout Creek
101201020203	Dry Fork Cheyenne River-Woody Creek
101201020204	Barker Draw
101201020205	Lake Creek
101201030101	Cheyenne River-Meadow Creek
101201030102	Cheyenne River-Keyton Creek
101201030103	Frog Creek
101201030104	Cheyenne River-Owl Creek
101201030105	Cheyenne River-Barrel Draw
101201030201	Black Thunder Creek-Cottonwood Creek
101201030202	Black Thunder Creek-H A Creek
101201030203	Bacon Creek-Black Thunder Creek
101201030204	Buck Creek
101201030205	Black Thunder Creek-Praire Creek
101201030206	Black Thunder Creek-Lion Creek
101201030207	Black Thuncer Creek-Poddy Creek
101201030301	Upper Little Thunder Creek
101201030302	North Prong Little Thunder Creek
101201030303	Middle Little Thunder Creek
101201030304	Lower Little Thunder Creek
101201030401	Cheyenne River-Count Creek
101201030402	Upper Snyder Creek
101201030403	Lower Snyder Creek
101201030404	Cheyenne River-Sevenmile Creek
101201030405	Boggy Creek
101201030501	Sage Creek-Lodgepole Creek
101201030502	Lodge Creek-Rough Draw
101201030503	Lodgepole Creek-Field Draw
101201030504	West Fork Hay Creek
101201030505	Hay Creek-Lodgepole Creek
101201030506	Deep Creek-Lodgepole Creek
101201030507	Lodgepole Draw-Newton Draw
101201030508	Lodgepole Creek-Dupont Creek
101201030509	Wildcat Creek

F:\Projects\008-1217\Documents\Reports\Surface water report docs\HUC12IDs.xlsx

Data Summary 2.1.8-1	Reach ID's

Reach ID	Watershed	Reach Name	Sub-Branch	Reach Number
A-Ant-1-B	Antelope	Antelope Creek		1
A-Ant-2-B	Antelope	Antelope Creek		2
A-Ant-3-C	Antelope	Antelope Creek		3
A-Ant-4-B	Antelope	Antelope Creek		4
A-Ant-5-C	Antelope	Antelope Creek		5
A-Ant-6-C	Antelope	Antelope Creek		6
A-Ant-7-C	Antelope	Antelope Creek		7
A-Ant-8-C	Antelope	Antelope Creek		8
A-Ant-9-C	Antelope	Antelope Creek		9
A-Ant-10-C	Antelope	Antelope Creek		10
A-Ant-11-C	Antelope	Antelope Creek		11
A-Ant-12-B	Antelope	Antelope Creek		12
A-Ant-13-C	Antelope	Antelope Creek		13
A-Bat-1-B	Antelope	Bates Creek		1
A-Bea-N1-B	Antelope	Bear Creek	North	1
A-Bea-N2-B	Antelope	Bear Creek	North	2
A-Bea-S1-B	Antelope	Bear Creek	South	1
A-Bea-S2-B	Antelope	Bear Creek	South	2
A-Bea-S3-D	Antelope	Bear Creek	South	3
A-Bea-1-G	Antelope	Bear Creek		1
A-Bea-2-F	Antelope	Bear Creek		2
A-Bea-3-B	Antelope	Bear Creek		3
A-Bec-1-C	Antelope	Beckwith Creek		1
A-Bec-2-	Antelope	Beckwith Creek		2
A-Bec-3-C	Antelope	Beckwith Creek		3
A-Bet-1-F	Antelope	Betty Supply Ditch		1
A-Bet-2-F	Antelope	Betty Supply Ditch		2
A-Lon-1-B	Antelope	Lonetree Creek		1
A-MCr-1-C	Antelope	MCreek		1
A-Nin-1-C	Antelope	Ninemile Creek		1
A-Por-1-C	Antelope	Porcupine Creek		1
A-Por-2-C	Antelope	Porcupine Creek		2
A-Por-3-C	Antelope	Porcupine Creek		3
A-Por-4-	Antelope	Porcupine Creek		4
A-Por-5-C	Antelope	Porcupine Creek		5
A-Por-6-C	Antelope	Porcupine Creek		6
A-San-N1-E	Antelope	Sand Creek	North	1
A-San-1-B	Antelope	Sand Creek		1
A-San-2-C	Antelope	Sand Creek		2
A-San-3-C	Antelope	Sand Creek		3
A-San-4-C	Antelope	Sand Creek		4
A-San-5-C	Antelope	Sand Creek		5
A-San-6-C	Antelope	Sand Creek		6
A-San-7-C	Antelope	Sand Creek		7
A-San-8-C	Antelope	Sand Creek		8
A-Spr-1-B	Antelope	Spring Creek		1
A-Spr-2-D	Antelope	Spring Creek		2
A-Spr-3-B	Antelope	Spring Creek		3

Reach ID	Watershed	Reach Name	Sub-Branch	Reach Number
A-Sti-N1-E	Antelope	Stinking Water Creek	North	1
A-Sti-N2-C	Antelope	Stinking Water Creek	North	2
A-Sti-1-E	Antelope	Stinking Water Creek		1
A-Sti-2-C	Antelope	Stinking Water Creek		2
A-Sti-3-C	Antelope	Stinking Water Creek		3
A-Sti-4-C	Antelope	Stinking Water Creek		4
A-Sti-5-E	Antelope	Stinking Water Creek		5
A-Wil-1-C	Antelope	Wildcat Creek		1
A-Wil-2-B	Antelope	Wildcat Creek		2
A-Win-1-C	Antelope	Wind Creek		1
A-Win-2-D	Antelope	Wind Creek		2
A-Win-3-C	Antelope	Wind Creek		3
D-Alt-1-C	Dry Fork Cheyenne	Alta Creek		1
D-Bad-1-G	Dry Fork Cheyenne	Bad Creek		1
D-Bad-2-E	Dry Fork Cheyenne	Bad Creek		2
D-Bro-1-B	Dry Fork Cheyenne	Brown Springs Creek		1
D-Bro-2-D	Dry Fork Cheyenne	Brown Springs Creek		2
D-Bro-3-C	Dry Fork Cheyenne	Brown Springs Creek		3
D-Bro-4-D	Dry Fork Cheyenne	Brown Springs Creek		4
D-Bro-5-C	Dry Fork Cheyenne	Brown Springs Creek		5
D-Bro-6-E	Dry Fork Cheyenne	Brown Springs Creek		6
D-Bro-7-F	Dry Fork Cheyenne	Brown Springs Creek		7
D-Bru-1-C	Dry Fork Cheyenne	Brush Creek		1
D-Bru-2-C	Dry Fork Cheyenne	Brush Creek		2
D-Bru-3-C	Dry Fork Cheyenne	Brush Creek		3
D-Dry-M1-A	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	1
D-Dry-M2-A	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	2
D-Dry-M3-D	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	3
D-Dry-M4-G	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	4
D-Dry-M5-B	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	5
D-Dry-M6-C	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	6
D-Dry-M7-A	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	7
D-Dry-M8-C	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	8
D-Dry-M9-B	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	9
D-Dry-M10-B	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	10
D-Dry-M11-C	Dry Fork Cheyenne	Dry Fork Cheyenne	Middle	11
D-Dry-N1-A	Dry Fork Cheyenne	Dry Fork Cheyenne	North	1
D-Dry-N2-A	Dry Fork Cheyenne	Dry Fork Cheyenne	North	2
D-Dry-N3-B	Dry Fork Cheyenne	Dry Fork Cheyenne	North	3
D-Dry-N4-B	Dry Fork Cheyenne	Dry Fork Cheyenne	North	4
D-Dry-N5-B	Dry Fork Cheyenne	Dry Fork Cheyenne	North	5
D-Dry-N6-B	Dry Fork Cheyenne	Dry Fork Cheyenne	North	6
D-Dry-N7-B	Dry Fork Cheyenne	Dry Fork Cheyenne	North	7
D-Dry-N8-D	Dry Fork Cheyenne	Dry Fork Cheyenne	North	8
D-Dry-N9-B	Dry Fork Cheyenne	Dry Fork Cheyenne	North	9
D-Dry-S1-A	Dry Fork Cheyenne	Dry Fork Cheyenne	South	1
D-Dry-S2-G	Dry Fork Cheyenne	Dry Fork Cheyenne	South	2
D-Dry-S3-G	Dry Fork Cheyenne	Dry Fork Cheyenne	South	3
D-Dry-S4-B	Dry Fork Cheyenne	Dry Fork Cheyenne	South	4
D-Dry-S5-G	Dry Fork Cheyenne	Dry Fork Cheyenne	South	5
D-Dry-S6-C	Dry Fork Cheyenne	Dry Fork Cheyenne	South	6

Reach ID	Watershed	Reach Name	Sub-Branch	Reach Number
D-Dry-S7-C	Dry Fork Cheyenne	Dry Fork Cheyenne	South	7
D-Dry-S8-B	Dry Fork Cheyenne	Dry Fork Cheyenne	South	8
D-Dry-S9-	Dry Fork Cheyenne	Dry Fork Cheyenne	South	9
D-Dry-S10-	Dry Fork Cheyenne	Dry Fork Cheyenne	South	10
D-Dry-S11-	Dry Fork Cheyenne	Dry Fork Cheyenne	South	11
D-Dry-S12-B	Dry Fork Cheyenne	Dry Fork Cheyenne	South	12
D-Dry-S13-B	Dry Fork Cheyenne	Dry Fork Cheyenne	South	13
D-Dry-1-C	Dry Fork Cheyenne	Dry Fork Cheyenne		1
D-Dry-2-B	Dry Fork Cheyenne	Dry Fork Cheyenne		2
D-Dry-3-D	Dry Fork Cheyenne	Dry Fork Cheyenne		3
D-Dry-3a-D	Dry Fork Cheyenne	Dry Fork Cheyenne		3a
D-Dry-4-B	Dry Fork Cheyenne	Dry Fork Cheyenne		4
D-Dry-5-B	Dry Fork Cheyenne	Dry Fork Cheyenne		5
D-Dry-5a-B	Dry Fork Cheyenne	Dry Fork Cheyenne		5a
D-Dry-6-A	Dry Fork Cheyenne	Dry Fork Cheyenne		6
D-Dry-7-E	Dry Fork Cheyenne	Dry Fork Cheyenne		7
D-Dry-8-B	Dry Fork Cheyenne	Dry Fork Cheyenne		8
D-Dry-9-C	Dry Fork Cheyenne	Dry Fork Cheyenne		9
D-Dry-10-C	Dry Fork Cheyenne	Dry Fork Cheyenne		10
D-Dry-11-C	Dry Fork Cheyenne	Dry Fork Cheyenne		11
D-Dry-12-E	Dry Fork Cheyenne	Dry Fork Cheyenne		12
D-Dry-13-C	Dry Fork Cheyenne	Dry Fork Cheyenne		13
D-Dry-14-C	Dry Fork Cheyenne	Dry Fork Cheyenne		14
D-Dry-15-C	Dry Fork Cheyenne	Dry Fork Cheyenne		15
D-Dry-16-C	Dry Fork Cheyenne	Dry Fork Cheyenne		16
D-Dry-17-B	Dry Fork Cheyenne	Dry Fork Cheyenne		17
D-Dry-18-B	Dry Fork Cheyenne	Dry Fork Cheyenne		18
D-Dry-19-B	Dry Fork Cheyenne	Dry Fork Cheyenne		19
D-Dry-20-D	Dry Fork Cheyenne	Dry Fork Cheyenne		20
D-Dry-21-B	Dry Fork Cheyenne	Dry Fork Cheyenne		21
D-Dry-22-F	Dry Fork Cheyenne	Dry Fork Cheyenne		22
D-Dry-23-F	Dry Fork Cheyenne	Dry Fork Cheyenne		23
D-Dry-24-B	Dry Fork Cheyenne	Dry Fork Cheyenne		24
D-Dry-25-F	Dry Fork Cheyenne	Dry Fork Cheyenne		25
D-Dry-26-B	Dry Fork Cheyenne	Dry Fork Cheyenne		26
D-Dry-27-B	Dry Fork Cheyenne	Dry Fork Cheyenne		27
D-Dry-28-B	Dry Fork Cheyenne	Dry Fork Cheyenne		28
D-Dry-29-C	Dry Fork Cheyenne	Dry Fork Cheyenne		29
D-Dry-30-D	Dry Fork Cheyenne	Dry Fork Cheyenne		30
D-Dry-31-B	Dry Fork Cheyenne	Dry Fork Cheyenne		31
D-Duc-1-B	Dry Fork Cheyenne	Duck Creek		1
D-Duc-2-C	Dry Fork Cheyenne	Duck Creek		2
D-Duc-3-C	Dry Fork Cheyenne	Duck Creek		3
D-Duc-4-C	Dry Fork Cheyenne	Duck Creek		4
D-Dug-1-B	Dry Fork Cheyenne	Dugout Creek		1
D-Dug-2-C	Dry Fork Cheyenne	Dugout Creek		2
D-Dug-3-B	Dry Fork Cheyenne	Dugout Creek		3
D-Lak-1-E	Dry Fork Cheyenne	Lake Creek		1
D-Lak-2-C	Dry Fork Cheyenne	Lake Creek		2
D-Lak-3-E	Dry Fork Cheyenne	Lake Creek		3
D-Phi-1-B	Dry Fork Cheyenne	Phillips Creek		1

Reach ID	Watershed	Reach Name	Sub-Branch	Reach Number
D-Phi-2-C	Dry Fork Cheyenne	Phillips Creek		2
D-Sku-1-E	Dry Fork Cheyenne	Skunk Creek		1
D-Sku-2-C	Dry Fork Cheyenne	Skunk Creek		2
D-Sku-3-B	Dry Fork Cheyenne	Skunk Creek		3
D-Sku-4-C	Dry Fork Cheyenne	Skunk Creek		4
D-Sku-4a-C	Dry Fork Cheyenne	Skunk Creek		4a
D-Sku-4b-C	Dry Fork Cheyenne	Skunk Creek		4b
D-Sku-4c-C	Dry Fork Cheyenne	Skunk Creek		4c
D-Spr-1-C	Dry Fork Cheyenne	Spring Creek		1
D-Wil-N1-C	Dry Fork Cheyenne	Willow Creek	North	1
D-Wil-S1-C	Dry Fork Cheyenne	Willow Creek	South	1
D-Wil-1-C	Dry Fork Cheyenne	Willow Creek		1
D-Wil-2-B	Dry Fork Cheyenne	Willow Creek		2
D-Woo-1-C	Dry Fork Cheyenne	Woody Creek		1
D-Woo-2-G	Dry Fork Cheyenne	Woody Creek		2
D-Woo-3-F	Dry Fork Cheyenne	Woody Creek		3
D-Woo-4-B	Dry Fork Cheyenne	Woody Creek		4
U-Bla-1-C	Upper Cheyenne	Black Thunder Creek		1
U-Bla-2-C	Upper Cheyenne	Black Thunder Creek		2
U-Bla-3-B	Upper Cheyenne	Black Thunder Creek		3
U-Bla-4-C	Upper Cheyenne	Black Thunder Creek		4
U-Bla-5-C	Upper Cheyenne	Black Thunder Creek		5
U-Bla-6-B	Upper Cheyenne	Black Thunder Creek		6
U-Bla-7-B	Upper Cheyenne	Black Thunder Creek		7
U-Bla-8-B	Upper Cheyenne	Black Thunder Creek		8
U-Bog-1-B	Upper Cheyenne	Boggy Creek		1
U-Che-1-C	Upper Cheyenne	Cheyenne River		1
U-Che-1a-C	Upper Cheyenne	Cheyenne River		1a
U-Che-1b-C	Upper Cheyenne	Cheyenne River		1b
U-Che-2-C	Upper Cheyenne	Cheyenne River		2
U-Che-2a-C	Upper Cheyenne	Cheyenne River		2a
U-Che-3-C	Upper Cheyenne	Cheyenne River		3
U-Che-4-C	Upper Cheyenne	Cheyenne River		4
U-Che-4a-C	Upper Cheyenne	Cheyenne River		4a
U-Che-4b-C	Upper Cheyenne	Cheyenne River		4b
U-Che-5-B	Upper Cheyenne	Cheyenne River		5
U-Che-6-B	Upper Cheyenne	Cheyenne River		6
U-Che-6a-B	Upper Cheyenne	Cheyenne River		6a
U-Che-6b-B	Upper Cheyenne	Cheyenne River		6b
U-Che-7-B	Upper Cheyenne	Cheyenne River		7
U-Che-8-B	Upper Cheyenne	Cheyenne River		8
U-Che-8a-B	Upper Cheyenne	Cheyenne River		8a
U-Che-8b-B	Upper Cheyenne	Cheyenne River		8b
U-Che-8c-B	Upper Cheyenne	Cheyenne River		8c
U-Che-9-C	Upper Cheyenne	Cheyenne River		9
U-Che-10-C	Upper Cheyenne	Cheyenne River		10
U-Che-11-	Upper Cheyenne	Cheyenne River		11
U-Coy-1-B	Upper Cheyenne	Coyote Creek		1
U-Coy-2-B	Upper Cheyenne	Coyote Creek		2
U-Cro-1-B	Upper Cheyenne	Crooked Creek		1
U-Fro-1-B	Upper Cheyenne	Frog Creek		1

Reach ID	Watershed	Reach Name	Sub-Branch	Reach Number
U-Fro-1a-B	Upper Cheyenne	Frog Creek		1a
U-Fro-1b-B	Upper Cheyenne	Frog Creek		1b
U-Hay-1-B	Upper Cheyenne	Hay Creek		1
U-Hay-2-B	Upper Cheyenne	Hay Creek		2
U-Hor-1-B	Upper Cheyenne	Horse Creek		1
U-Key-1-C	Upper Cheyenne	Keyton Creek		1
U-Key-2-C	Upper Cheyenne	Keyton Creek		2
U-Lit-1-B	Upper Cheyenne	Little Thunder Creek		1
U-Lit-2-C	Upper Cheyenne	Little Thunder Creek		2
U-Lit-3-B	Upper Cheyenne	Little Thunder Creek		3
U-Lod-1-C	Upper Cheyenne	Lodgepole Creek		1
U-Lod-2-B	Upper Cheyenne	Lodgepole Creek		2
U-Lod-3-D	Upper Cheyenne	Lodgepole Creek		3
U-Lod-4-B	Upper Cheyenne	Lodgepole Creek		4
U-Lod-5-C	Upper Cheyenne	Lodgepole Creek		5
U-Lod-6-C	Upper Cheyenne	Lodgepole Creek		6
U-Lod-7-B	Upper Cheyenne	Lodgepole Creek		7
U-Lod-8-B	Upper Cheyenne	Lodgepole Creek		8
U-Lod-9-B	Upper Cheyenne	Lodgepole Creek		9
U-Sev-1-B	Upper Cheyenne	Sevenmile Creek		1
U-Sev-2-C	Upper Cheyenne	Sevenmile Creek		2
U-She-1-C	Upper Cheyenne	Sheep Creek		1
U-Sny-1-E	Upper Cheyenne	Snyder Creek		1
U-Sny-2-B	Upper Cheyenne	Snyder Creek		2
U-Sny-3-C	Upper Cheyenne	Snyder Creek		3
U-Sny-4-B	Upper Cheyenne	Snyder Creek		4
U-Sny-5-B	Upper Cheyenne	Snyder Creek		5
U-Sny-6-C	Upper Cheyenne	Snyder Creek		6
U-Sny-7-B	Upper Cheyenne	Snyder Creek		7
U-Sny-8-C	Upper Cheyenne	Snyder Creek		8
U-Sny-9-B	Upper Cheyenne	Snyder Creek		9
U-Wag-1-C	Upper Cheyenne	Wagonhound Creek		1
U-Wag-2-B	Upper Cheyenne	Wagonhound Creek		2

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
A-Ant-1-B	alluvial fan	II	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	no	B	
A-Ant-2-B	alluvial fan	II	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	no	B	
A-Ant-3-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Ant-4-B	alluvial fan	II	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	yes	B	
A-Ant-5-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Ant-6-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Ant-7-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Ant-8-C	alluvial fan	II	none	flat	riffle/pool	>40 w:d	active apparer	single	slight	no	C	
A-Ant-9-C	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-Ant-10-C	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Ant-11-C	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Ant-12-B	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
A-Ant-13-C	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Bat-1-B	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
A-Bea-N1-B	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
A-Bea-N2-B	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
A-Bea-S1-B	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	none apparent	single	moderate	yes	B	
A-Bea-S2-B	alluvial fan	III	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
A-Bea-S3-D	floodplain	IX	multiple	flat	riffle/pool	>40 w:d	active apparer	multiple	slight	no	D	
A-Bea-1-G	alluvial fan	III	none	flat	riffle/pool	<12 w:d	active apparer	single	entrenched	yes	G	
A-Bea-2-F	alluvial fan	III	none	flat	riffle/pool	12-40 w:d	active apparer	single	entrenched	yes	F	
A-Bea-3-B	alluvial fan	III	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
A-Bec-1-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-Bec-2-	alluvial fan	VIII	none	flat	riffle/pool	>40 w:d	active apparent					Beckwith Reservoir
A-Bec-3-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-Bet-1-F	floodplain	III	none	flat	step/pool	12-40 w:d	none apparent	single	entrenched	yes	F	
A-Bet-2-F	floodplain	III	none	flat	step/pool	12-40 w:d	none apparent	single	entrenched	yes	F	Break in flow of the ditch @ intersection with stream @ A-Bet-2-F
A-Lon-1-B	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	none apparent	single	moderate	yes	B	
A-MCr-1-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-Nin-1-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-Por-1-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Por-2-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Por-3-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Por-4-	alluvial fan											Creek breaks @ coal mine
A-Por-5-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Creek resumes
A-Por-6-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Porcupine Reservoir
A-San-N1-E	alluvial fan	II	none	flat	riffle/pool	<12 w:d	active apparer	single	slight	yes	E	
A-San-1-B	glacial/fluvial terrac	II	none	steep	riffle/pool	<12 w:d	none apparent	single	moderate	yes	B	
A-San-2-C	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-San-3-C	alluvial fan	III	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
A-San-4-C	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-San-5-C	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-San-6-C	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-San-7-C	alluvial fan	III	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-San-8-C	alluvial fan	III	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Spr-1-B	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
A-Spr-2-D	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	multiple	slight	no	D	
A-Spr-3-B	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
A-Sti-N1-E	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	E	
A-Sti-N2-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-Sti-1-E	alluvial fan	II	none	flat	riffle/pool	<12 w:d	active apparer	single	slight	no	E	
A-Sti-2-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Sti-3-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
A-Sti-4-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	This reach appears disturbed adjacent to Hardy Ranch (correct ranch?)
A-Sti-5-E	alluvial fan	II	none	flat	riffle/pool	<12 w:d	active apparer	single	slight	no	E	
A-Wil-1-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-Wil-2-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
A-Win-1-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
A-Win-2-D	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	multiple	slight	yes	D	
A-Win-3-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
D-Alt-1-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Bad-1-G	alluvial fan	VII	none	steep	riffle/pool	<12 w:d	none apparent	single	moderate	yes	G	
D-Bad-2-E	alluvial fan	VII	none	steep	riffle/pool	<12 w:d	active apparer	single	slight	no	E	
D-Bro-1-B	glacial/fluvial terrac	II	none	steep	riffle/pool	<12 w:d	none apparent	single	moderate	yes	B	
D-Bro-2-D	glacial/fluvial terrac	II	none	flat	riffle/pool	>40 w:d	active apparer	multiple	slight	no	D	
D-Bro-3-C	glacial/fluvial terrac	II	none	steep	riffle/pool	<12 w:d	active apparer	single	slight	no	C	
D-Bro-4-D	glacial/fluvial terrac	II	none	flat	riffle/pool	<12 w:d	active apparer	multiple	slight	no	D	
D-Bro-5-C	glacial/fluvial terrac	II	none	flat	riffle/pool	<12 w:d	active apparer	single	slight	no	C	
D-Bro-6-E	glacial/fluvial terrac	II	none	steep	riffle/pool	<12 w:d	none apparent	single	slight	yes	E	
D-Bro-7-F	glacial/fluvial terrac	I	none	steep	riffle/pool	<12 w:d	none apparent	single	moderate	yes	F	
D-Bru-1-C	glacial/fluvial terrac	II	none	steep	riffle/pool	>40 w:d	active apparer	single	slight	no	C	
D-Bru-2-C	glacial/fluvial terrac	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Bru-3-C	glacial/fluvial terrac	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Dry-M1-A	glacial/fluvial terrac	II	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	Beginning Dry-M
D-Dry-M2-A	glacial/fluvial terrac	II	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	
D-Dry-M3-D	glacial/fluvial terrac	II	none	steep	step/pool	<12 w:d	none apparent	multiple	entrenched	yes	D	
D-Dry-M4-G	glacial/fluvial terrac	II	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	G	Some alluvial features apparent in valley type, but not dominant
D-Dry-M5-B	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	none apparent	single	moderate	yes	B	Terrace features more defined but still not dominant
D-Dry-M6-C	glacial/fluvial terrac	II	multiple	steep	riffle/pool	12-40 w:d	none apparent	single	slight	yes	C	Floodplain developing but not dominant
D-Dry-M7-A	glacial/fluvial terrac	II	none	steep	step/pool	<12 w:d	none apparent	single	moderate	yes	A	
D-Dry-M8-C	glacial/fluvial terrac	III	multiple	steep	riffle/pool	12-40 w:d	none apparent	single	slight	no	C	

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
D-Dry-M9-B	glacial/fluvial terrac	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	
D-Dry-M10-B	alluvial fan	II	multiple	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Dry-M11-C	alluvial fan	VII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Dry-N1-A	glacial/fluvial terrac	II	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	Beginning -Dry-N
D-Dry-N2-A	glacial/fluvial terrac	I	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	Valley slightly narrower
D-Dry-N3-B	glacial/fluvial terrac	II	none	steep	step/pool	12-40 w:d	none apparent	single	moderate	yes	B	Few terrace features forming
D-Dry-N4-B	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Few terrace features forming
D-Dry-N5-B	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Terrace features more defined but still not dominant
D-Dry-N6-B	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Dry-N7-B	glacial/fluvial terrac	II	multiple	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Dry-N8-D	glacial/fluvial terrac	II	multiple	steep	riffle/pool	12-40 w:d	active apparer	multiple	slight	no	D	
D-Dry-N9-B	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Dry-S1-A	glacial/fluvial terrac	I	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	A	
D-Dry-S2-G	glacial/fluvial terrac	II	none	steep	step/pool	<12 w:d	none apparent	single	entrenched	yes	G	
D-Dry-S3-G	glacial/fluvial terrac	II	none	steep	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	G	
D-Dry-S4-B	glacial/fluvial terrac	II	none	steep	riffle/pool	<12 w:d	none apparent	single	moderate	no	B	
D-Dry-S5-G	glacial/fluvial terrac	II	none	steep	riffle/pool	<12 w:d	none apparent	single	entrenched	yes	G	
D-Dry-S6-C	glacial/fluvial terrac	II	multiple	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Dry-S7-C	glacial/fluvial terrac	VII	multiple	steep	riffle/pool	>40 w:d	active apparer	single	slight	no	C	
D-Dry-S8-B	glacial/fluvial terrac	VII	multiple	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Dry-S9-	glacial/fluvial terrac	VII										
D-Dry-S10-												
D-Dry-S11-												
D-Dry-S12-B	glacial/fluvial terrac	II	multiple	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence N & S forks
D-Dry-S13-B	glacial/fluvial terrac	II	multiple	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Dry-1-C	glacial/fluvial terrac	VII	multiple	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Dry-2-B	glacial/fluvial terrac	VII	multiple	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Dry-3-D	glacial/fluvial terrac	VII	multiple	steep	riffle/pool	>40 w:d	active apparer	multiple	slight	no	D	
D-Dry-3a-D	glacial/fluvial terrac	VII	multiple	steep	riffle/pool	>40 w:d	active apparer	multiple	slight	no	D	Confluence Phillips Creek & DFC
D-Dry-4-B	glacial/fluvial terrac	VII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Dry-5-B	glacial/fluvial terrac	VII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
D-Dry-5a-B	glacial/fluvial terrac	VII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	Confluence Brown Springs Creek & DFC
D-Dry-6-A	alluvial fan	VIII	multiple	flat	riffle/pool	<12 w:d	active apparer	single	moderate	yes	A	
D-Dry-7-E	alluvial fan	VIII	multiple	flat	riffle/pool	<12 w:d	active apparer	single	slight	no	E	
D-Dry-8-B	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence of Skunk Creek & DFC
D-Dry-9-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Dry-10-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Dry-11-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence of Alta Creek & DFC
D-Dry-12-E	floodplain	VIII	multiple	flat	riffle/pool	<12 w:d	active apparer	single	slight	no	E	
D-Dry-13-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Dry-14-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Ox-bow @ beginning of reach

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
D-Dry-15-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Dry-16-C	floodplain	VIII	multiple	flat	riffle/pool	>40 w:d	active apparer	single	slight	no	C	
D-Dry-17-B	floodplain	VIII	multiple	flat	riffle/pool	>40 w:d	active apparer	single	moderate	no	B	
D-Dry-18-B	floodplain	VIII	multiple	flat	riffle/pool	>40 w:d	active apparer	single	moderate	no	B	Confluence of Dugout Creek & River
D-Dry-19-B	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Dry-20-D	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	multiple	moderate	no	D	
D-Dry-21-B	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
D-Dry-22-F	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	entrenched	yes	F	
D-Dry-23-F	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	entrenched	yes	F	Confluence of Bad Creek & DFC
D-Dry-24-B	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
D-Dry-25-F	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	entrenched	yes	F	Confluence of Woody Creek & DFC
D-Dry-26-B	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
D-Dry-27-B	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
D-Dry-28-B	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	Confluence of Lake Creek & DFC
D-Dry-29-C	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Earth Dam and retaining pond @ start of reach
D-Dry-30-D	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	multiple	moderate	no	D	Group of old & semi-active ox-bows
D-Dry-31-B	floodplain	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Ends @ confluence of DFC & Antelope Creek
D-Duc-1-B	glacial/fluvial terrac	I	none	steep	riffle/pool	12-40 w:d	none apparent	single	moderate	yes	B	
D-Duc-2-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Duc-3-C	glacial/fluvial terrac	II	none	steep	riffle/pool	>40 w:d	active apparer	single	slight	no	C	
D-Duc-4-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Dug-1-B	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
D-Dug-2-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Series of earthen retaining dams breaks creek into multiple independent channels
D-Dug-3-B	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Lak-1-E	alluvial fan	II	none	flat	riffle/pool	<12 w:d	active apparer	single	slight	yes	E	
D-Lak-2-C	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Lak-3-E	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	E	
D-Phi-1-B	glacial/fluvial terrac	II	none	steep	riffle/pool	<12 w:d	active apparer	single	moderate	yes	B	
D-Phi-2-C	glacial/fluvial terrac	II	none	flat	riffle/pool	<12 w:d	active apparer	single	slight	no	C	
D-Sku-1-E	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	E	
D-Sku-2-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Sku-3-B	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
D-Sku-4-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Sku-4a-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Willow & Skunk Creek
D-Sku-4b-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Duck & Skunk Creek
D-Sku-4c-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Brush & Skunk Creek
D-Spr-1-C	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Wil-N1-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Wil-S1-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Wil-1-C	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Wil-2-B	glacial/fluvial terrac	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	

Data Summary 2.1.8-2 Reach Information

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
D-Woo-1-C	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
D-Woo-2-G	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	none apparen	single	moderate	yes	G	
D-Woo-3-F	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	entrenched	yes	F	
D-Woo-4-B	alluvial fan	II	none	steep	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Bla-1-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
U-Bla-2-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Bla-3-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
U-Bla-4-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Black Thunder Creek & Bacon Creek
U-Bla-5-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Black Thunder Creek & Huck Creek
U-Bla-6-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Black Thunder Creek & Prarie Creek
U-Bla-7-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Black Thunder Creek & Little Thunder Creek
U-Bla-8-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Bog-1-B	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Che-1-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Che-1a-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Cheyenne River & Sheep Creek
U-Che-1b-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Cheyenne River & Wagonhound Creek
U-Che-2-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Cheyenne River & Horse Creek
U-Che-2a-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Cheyenne River & Keyton Creek
U-Che-3-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Cheyenne River & Frog Creek
U-Che-4-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Che-4a-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Che-4b-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Cheyenne River & Black Thunder Creek
U-Che-5-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
U-Che-6-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Cheyenne River & Lodgepole Creek
U-Che-6a-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Cheyenne River & Coyote Creek
U-Che-6b-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Cheyenne River & Count Creek
U-Che-7-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Cheyenne River & Snyder Creek
U-Che-8-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
U-Che-8a-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Cheyenne River & Crooked Creek
U-Che-8b-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Cheyenne River & Boggy Creek
U-Che-8c-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Cheyenne River & Sevenmile Creek
U-Che-9-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Che-10-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Che-11-	alluvial fan	VIII										End of reach in Upper Cheyenne Watershed
U-Coy-1-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Coy-2-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Cro-1-B	alluvial fan	II	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	yes	B	
U-Fro-1-B	alluvial fan	VIII	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	yes	B	
U-Fro-1a-B	alluvial fan	VIII	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	yes	B	Earthen dam/reservoir 1
U-Fro-1b-B	alluvial fan	VIII	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	yes	B	Earthen dam/reservoir 2
U-Hay-1-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence East & West forks of Hay Creek

Data Summary 2.1.8-2 Reach Information

Reach ID	Landform	Valley Type	Terrace Features	Channel Slope	Bed Features	Channel Shape	Floodplain	Pattern	Confinement	Lateral Containment	Channel Type	Notes
U-Hay-2-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
U-Hor-1-B	alluvial fan	VIII	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	yes	B	
U-Key-1-C	alluvial fan	VIII	multiple	flat	riffle/pool	<12 w:d	active apparer	single	slight	yes	C	
U-Key-2-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
U-Lit-1-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
U-Lit-2-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Little Thunder Creek & School Creek
U-Lit-3-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Little Thunder Creek & Piney Creek
U-Lod-1-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Lod-2-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	Confluence Lodgepole Creek & Lone Tree Creek
U-Lod-3-D	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	multiple	slight	no	D	
U-Lod-4-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
U-Lod-5-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	Confluence Lodgepole Creek & Hay Creek
U-Lod-6-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Lod-7-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	Confluence Lodgepole Creek & Wildcat Creek
U-Lod-8-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
U-Lod-9-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Sev-1-B	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Sev-2-C	alluvial fan	II	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-She-1-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Sny-1-E	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	E	
U-Sny-2-B	alluvial fan	VIII	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	no	B	
U-Sny-3-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Sny-4-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Sny-5-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Sny-6-C	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	slight	yes	C	
U-Sny-7-B	alluvial fan	VIII	multiple	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	yes	B	
U-Sny-8-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Sny-9-B	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	moderate	no	B	
U-Wag-1-C	alluvial fan	VIII	none	flat	riffle/pool	12-40 w:d	active apparer	single	slight	no	C	
U-Wag-2-B	alluvial fan	VIII	none	flat	riffle/pool	<12 w:d	active apparer	single	moderate	yes	B	

Data Summary 2.1.8-3 Channel Type Statistics by Watershed

Watershed	Antelope	
Channel Type	Data	Total
A	Sum of Percents	0.0%
	Sum of Count	0
B	Sum of Percents	25.0%
	Sum of Count	15
C	Sum of Percents	53.3%
	Sum of Count	32
D	Sum of Percents	5.0%
	Sum of Count	3
E	Sum of Percents	6.7%
	Sum of Count	4
F	Sum of Percents	5.0%
	Sum of Count	3
G	Sum of Percents	1.7%
	Sum of Count	1
Blank	Sum of Percents	3.3%
	Sum of Count	2
Total Sum of Percents		100.0%
Total Sum of Count		60

Watershed	Dry Fork Cheyenne	
Channel Type	Data	Total
A	Sum of Percents	6.5%
	Sum of Count	7
B	Sum of Percents	32.7%
	Sum of Count	35
C	Sum of Percents	33.6%
	Sum of Count	36
D	Sum of Percents	7.5%
	Sum of Count	8
E	Sum of Percents	6.5%
	Sum of Count	7
F	Sum of Percents	4.7%
	Sum of Count	5
G	Sum of Percents	5.6%
	Sum of Count	6
Blank	Sum of Percents	2.8%
	Sum of Count	3
Total Sum of Percents		100.0%
Total Sum of Count		107

Watershed	Upper Cheyenne	
Channel Type	Data	Total
A	Sum of Percents	0.0%
	Sum of Count	0
B	Sum of Percents	55.2%
	Sum of Count	37
C	Sum of Percents	40.3%
	Sum of Count	27
D	Sum of Percents	1.5%
	Sum of Count	1
E	Sum of Percents	1.5%
	Sum of Count	1
F	Sum of Percents	0.0%
	Sum of Count	0
G	Sum of Percents	0.0%
	Sum of Count	0
Blank	Sum of Percents	1.5%
	Sum of Count	1
Total Sum of Percents		100.0%
Total Sum of Count		67

Data Summary 2.2.3-1
Oil and Gas Fields

ID Number	Name
1	FIDDLER CREEK, FIDDLER CREEK EAST
2	HILIGHT,ROCKY HILL
3	QUEST
4	HAY CREEK
5	LONETREE CREEK
6	GEORGE RANCH
7	LONETREE CREEK
8	LONETREE CREEK
9	TODD
10	LODGEPOLE CREEK
11	LODGEPOLE CREEK
12	LODGEPOLE CREEK
13	HOUSE CREEK
14	MUSH CREEK WEST
15	CLARETON,CHEYENNE RIV.,HAMPSHIRE,BL. THU
16	HA CREEK
17	RW CREEK
18	RW CREEK
19	ROCKY HILL
20	THUNDER CREEK
21	UNNAMED
22	PORCUPINE
23	UNNAMED
24	LITTLE THUNDER
25	K-BAR
26	PAYNE
27	TUIT DRAW
28	PAYNE
29	PAYNE
30	TUIT DRAW
31	PORCUPINE
32	THUNDER CREEK
33	ROCHELLE
34	TUIT DRAW
35	PINE TREE
36	ARCHIBALD
37	WILDCAT CREEK
38	ARCHIBALD
39	TURNERCREST
40	TURNERCREST
41	SCHOOL CREEK
42	BUCK DRAW NORTH
43	KEYTON ROAD
44	TURNERCREST
45	SHERWIN, FROG CREEK
46	PORCUPINE
47	TURNERCREST
48	MONGOOSE
49	JIGGS THOMPSON
50	UNNAMED
51	JIGGS THOMPSON
52	BUCK DRAW
53	JIGGS THOMPSON
54	FENTON
55	POWELL
56	NINEMILE
57	FROG CREEK
58	SCHOOL CREEK
59	UNNAMED
60	GLASSER DRAW
61	FROG CREEK
62	PINE TREE
63	LOGAN DRAW
64	TAYLOR
65	CLARETON
66	MARY DRAW
67	GLASSER DRAW
68	CLARETON
69	DENNEL DRAW
70	BUCK DRAW
71	POWELL
72	PINE TREE
73	MARY DRAW
74	BUCK DRAW
75	JIGGS THOMPSON
76	SEEDY DRAW
77	GIBSON DRAW
78	MOORE
79	UNNAMED
80	UNNAMED
81	BOGGY CREEK
82	SNYDER CREEK
83	FINLEY DRAW
84	SHERWOOD
85	GIBSON DRAW
86	ROSS
87	MOORE
88	POISON DRAW
89	BOGGY CREEK
90	SUPPLY CREEK
91	SUPPLY CREEK
92	RAWLES
93	SPEARHEAD RANCH
94	SUPPLY CREEK
95	FINLEY DRAW
96	SPEARHEAD RANCH
97	SPEARHEAD RANCH
98	AVERY DRAW
99	MANNING
100	UNNAMED
101	OGALALLA HILLS
102	UNNAMED
103	SPEARHEAD RANCH
104	STEINLE RANCH
105	SPEARHEAD RANCH
106	UNNAMED
107	DILTS
108	SAND CREEK NORTH
109	DRY FORK
110	NUTCRACKER
111	POWELL
112	POWELL
113	POWELL
114	SNAKE CHARMER DRAW
115	BRUSH CREEK
116	ALLEMAND
117	BRUSH CREEK
118	HORNBUCKLE
119	POWELL
120	BEAR CREEK
121	HORNBUCKLE
122	PHILLIPS CREEK
123	SPEARHEAD RANCH
124	SPEARHEAD RANCH
125	ORMSBY ROAD
126	PHILLIPS CREEK
127	SPEARHEAD RANCH
128	COLE NORTHEAST
129	HORNBUCKLE
130	HARVEY DRAW, SCOTT DRAW, SCOTT
131	SAND DUNES
132	COLE NORTHEAST
133	MARTIN SPRING
134	BLUE HILL
135	BLUE HILL
136	BLIZZARD
137	DERRICK DRAW

Data Summary 3.3.2-1. Dams within the Thunder Basin Watershed Included in the National Inventory of Dams

NID ID	Dam Name	River	Height (ft) (feet)	Storage (acre-ft)	Year Completed	Owner	Longitude	Latitude	County
WY00949	SATELLITE NO. 2 PURGE STORAGE	BOB DRAW AND VARIOUS WELLS	23	549	1979	POWER RESOURCES, INC	-105.5736	43.1031	CONVERSE
WY00533	HORNBUCKLE NO. 1	DRY FORK	23	302	1970	HORNBUCKLE RANCH (DICK HORNBUCKLE)	-105.6445	43.2211	CONVERSE
WY02114	CATFISH RESERVOIR	FLY DRAW	30	80	1977	JOE PATTERSON	-105.9492	43.2256	CONVERSE
WY01869	GENE NO. 2 STOCK	HITTNER DRAW	25	18	1984	HARDY ENTERPRISES C/O EUGENE HARDY	-105.5794	43.2595	CONVERSE
WY02024	HARDY-BEAR CREEK NO. 3	ALBERT DRAW	25	142	1980	HARDY ENTERPRISES C/O EUGENE HARDY	-105.6178	43.2792	CONVERSE
WY00768	REED	REED DRAW	15	276	1953	EARL REED	-105.1900	43.3000	CONVERSE
WY01960	WHEATON NO. 1	WHEATON DRAW	26	67	1969	HARDY ENTERPRISES, INC.	-105.6775	43.3161	CONVERSE
WY00797	HARDY NO. 1	STINKING WATER CREEK	16	124	1949	HARDY RANCH COMPANY	-105.6842	43.3303	CONVERSE
WY01721	JOY NO. 1	STINKING WATER CR TRIB SAND CK	25	103	1984	HARDY ENTERPRISES C/O EUGENE HARDY	-105.6886	43.3306	CONVERSE
WY83458	B. K. Draw Dam Embankment	---	0	0	0	Thunder Basin Coal Company	-105.3333	43.3333	CAMPBELL
WY83459	Little Thunder Creek Dam Embankment	---	0	0	0	Thunder Basin Coal Company	-105.3333	43.3333	CAMPBELL
WY83460	Reservoir 26-SR-1	---	0	0	0	Thunder Basin Coal Company	-105.3333	43.3333	CAMPBELL
WY00433	BEAR CREEK NO. 1	BEAR CREEK	19	150	1972	JERRY J. DILTS TRUST	-105.5583	43.3347	CONVERSE
WY01306	BRENNER	BRENNER DRAW TR S FK CHEY RIV	27	84	1975	WILLIAM TUMBLIN & WYO BOARD LAND COMM.	-104.5483	43.3553	NIOBRARA
WY00582	BOGGY	BOGGY CREEK	32	577	1951	WILLIAM TUMBLIN	-104.5364	43.3675	NIOBRARA
WY00431	NEW DEAL NO. 1	BOGGY CREEK	46	1499	1972	JACK MARCHANT	-104.4539	43.3872	NIOBRARA
WY00613	BETTY NO. 1	BEAR CREEK	33	2029	1956	RANCH CO. (STEVE DILTS)	-105.4661	43.3944	CONVERSE
WY00580	BOB DIXON NO. 1	S SNYDER CREEK	42	989	1959	USDI BLM	-104.6003	43.4072	NIOBRARA
WY00757	DULL	SHEEP CREEK	29	376	1937	NACHTMAN LAND & LIVESTOCK, INC.	-104.9458	43.4133	CONVERSE
WY00759	BALLARD NO. 4	SNYDER CREEK	30	127	1941	USDI BLM	-104.7350	43.4181	NIOBRARA
WY82401	MORTON NO F S 9-231-38	RUSSELL DRAW	26	19	1971	---	-105.2450	43.4200	CONVERSE
WY00604	LAZY Y NO. 1	LAZY Y DRAW	45	1251	1957	POWDER RIVER CAOL COMPANY	-105.3483	43.4294	CONVERSE
WY00579	HELEN DIXON NO. 2	GARLAND DRAW	27	136	1952	HELEN DIXON	-104.6417	43.4300	NIOBRARA
WY00725	ZERBST	SNYDER CREEK	20	182	1947	C. R. ZERBST	-104.5467	43.4300	NIOBRARA
WY00591	JENSON NO. 1	JENSON DRAW	30	124	1955	RICHARD JANSSEN, ETAL	-105.6483	43.4381	CONVERSE
WY00799	GAFFORD	S FORK WIND CREEK	35	80	1951	FRANK SHEPPERSON	-106.0533	43.4358	CONVERSE
WY00803	DIXON	DIXON DRAW	25	55	1949	CLAYTON R. DIXON, ETAL	-104.6356	43.4417	NIOBRARA
WY00440	WINDMILL NO. 1	SOUTH FORK WINDMILL DRAW	50	649	1956	D & W LIVESTOCK COMPANY, INC.	-104.7511	43.4483	NIOBRARA
WY00723	WAGON HOUND	WAGON HOUND CREEK	30	331	1946	IRENE S PADLOCK RANCH (NEIL IRENE)	-104.9172	43.4542	CONVERSE
WY00801	HANSON NO. 2	HANSON DRAW	30	79	1950	GLEN HANSON	-104.4767	43.4683	NIOBRARA
WY00769	FRED NO. 1	FRED DRAW	31	284	1957	D & W LIVESTOCK COMPANY, INC.	-104.7706	43.4861	NIOBRARA
WY00734	BECKWITH	BECKWITH DRAW	25	196	1951	IRWIN LIVESTOCK	-105.1383	43.4867	CONVERSE
WY00771	SHERWIN	PINEY CREEK	28	843	1952	USDI BLM	-104.8831	43.4939	NIOBRARA
WY00733	PORCUPINE	ANTELOPE CREEK	35	865	1979	POWDER RIVER COAL CO.	-105.2450	43.4950	CONVERSE
WY01279	KEATON FS 9-249-13	KEATON CREEK	26	73	1960	USDA FOREST SERVICE	-104.9500	43.5000	WESTON
WY00749	GASKILL	COYOTE CREEK	25	470	1941	ROBERT L. STODDARD	-104.5206	43.4994	NIOBRARA
WY00714	SPRING DRAW	SPRING DRAW	25	78	1959	LATAL FISHER	-104.6672	43.5011	WESTON
WY82410	#9-249-12 FROG CREEK	FROG CREEK	39	295	1954	---	-104.9181	43.5017	WESTON
WY01782	NORTH ANTELOPE SHOP	PORCUPINE CREEK	29	18	1983	POWDER RIVER COAL CO. (PHILIP MURPHEE)	-105.2725	43.5189	CAMPBELL
WY01289	BARREL FLOODWATER DETENTION	BARREL DRAW	36	694	1973	BOB GASKILL	-104.7344	43.5228	WESTON
WY02085	ROUGH DRAW	ROUGH DRAW	26	57	1972	USDA FOREST SERVICE	-105.0425	43.5356	WESTON
WY01780	NORTH ANTELOPE 2A	CINDY S DRAW TR. PORCUPINE CRK	28	19	1985	NORTH ANTELOPE COAL COMPANY	-105.2775	43.5370	CAMPBELL

Data Summary 3.3.2-1. Dams within the Thunder Basin Watershed Included in the National Inventory of Dams

NID ID	Dam Name	River	Height (ft) (feet)	Storage (acre-ft)	Year Completed	Owner	Longitude	Latitude	County
WY00436	TECKLA NO. 1	SPRING CREEK	18	330	1969	FLOYD RENO JR.	-105.4992	43.5425	CAMPBELL
WY82407	SHERWIN 9-249-6	CHEYENNE RIVER	31	97	1954	---	-104.8750	43.5500	WESTON
WY00590	FROG CREEK #1	FROG CREEK	16	130	1955	SHERWIN BROTHERS	-104.9742	43.5519	WESTON
WY02091	ARTESIAN LOWER	ARTESIAN CREEK	30	507	1951	MARK IBERLIN	-105.5167	43.5517	CAMPBELL
WY01649	FIVEMILE NO.1	FIVE MILE CREEK	23	81	1954	FRANK G. THOMPSON	-104.5097	43.5550	WESTON
WY01330	PETERSON NO. 1	BLACK THUNDER CREEK	20	246	1976	ALLEN SLAGLE	-104.6950	43.5683	WESTON
WY00739	F.C.R. DETENTION	W FORK SPRING CREEK	20	120	1968	FLOYD RENO JR.	-105.5275	43.5761	CAMPBELL
WY01923	THUNDER BASIN NO. 9	LITTLE FROG CREEK	25	53	1939	USDA FOREST SERVICE	-105.0095	43.5800	WESTON
WY00820	BUTTE	SPRING CREEK	28	49	1963	FRANK THOMPSON ESTATE	-104.5297	43.5833	WESTON
WY01317	TECKLA NO. F.S. 9-298-4	SCHOOL CREEK	18	60	1974	USDA FOREST SERVICE	-105.1711	43.5861	CAMPBELL
WY01848	SEDGWICK 9-394-1	WILDCAT CREEK	26	42	1940	USDA FOREST SERVICE	-104.7500	43.6500	WESTON
WY00866	RENO	PORCUPINE CREEK	9	166	1910	ELMER RENO	-105.5683	43.6633	CAMPBELL
WY01531	26-SR-1	LITTLE THUNDER CREEK	33	241	1986	THUNDER BASIN COAL CO. (ERIC SANDBERG)	-105.2347	43.6745	CAMPBELL
WY01356	FIELD	FIELD DRAW	20	61	1957	USDA FS	-104.8400	43.6750	WESTON
WY82414	THUNDER BASIN NO 10	LITTLE THUNDER CREEK	23	197	1938	---	-105.3750	43.6833	CAMPBELL
WY01522	THUNDER BASIN NO. 10	LITTLE THUNDER CREEK	27	197	1938	USDA FOREST SERVICE	-105.3767	43.6911	CAMPBELL
WY01846	BARNDS STOCK	BURNING COAL BANK DRAW	23	76	1980	JACOBS RANCH COAL CO. (DARYL MAUNDER)	-105.2297	43.6994	CAMPBELL
WY01326	FIELD 9-207-5	SOUTH FIELD DRAW	36	72	1965	USDA FS	-104.8000	43.7000	WESTON
WY01742	LITTLE THUNDER CREEK	N. PRONG OF LITTLE THUNDER CR.	40	1492	1987	THUNDER BASIN COAL CO. (ERIC SANDBERG)	-105.3000	43.7000	CAMPBELL
WY00719	STUART	DRY FORK LITTLE THUNDER CR	19	333	1946	JAMES & IRENE STUART	-105.3728	43.7314	CAMPBELL
WY01320	CELLERS NO. F.S. 9-499-4	OKEEFE DRAW	23	56	1969	USDA FOREST SERVICE	-104.8675	43.7844	WESTON
WY01325	CELLERS WILDLIFE	WILDLIFE DRAW	23	69	1963	USDA FOREST SERVICE	-104.8789	43.7872	WESTON
WY00618	RODA BAUGH	RODABAUGH DRAW	25	95	1940	J. A. RODABAUGH	-104.9031	43.7925	WESTON
WY00532	SOUTH LODGEPOLE NO. 1	WELL DRAW, TRIB LODGE POLE CRK	18	197	1969	ERNEST S. TODD	-104.9058	43.8158	WESTON
WY01337	TODD DETENTION DAM	LODGEPOLE CREEK	22	214	1977	ERNEST TODD & WYO BOARD OF LAND COMM.	-104.9339	43.8483	WESTON

Data Summary 3.4.3-1. Water Quality Standards for Irrigation and Animal Watering

Constituent	Units	Agriculture			Livesock and Wildlife Watering		
		WDEQ (2007)	Ayres and Westcot (1994)	Bauder, et al. (2006)	WDEQ (2007)	Ayres and Westcot (1994)	Raisbeck, et al. (2007)
Aluminum	µg/L	5000	5000	--	5000	5000	--
Arsenic	µg/L	100	100	--	200	200	1000
Beryllium	µg/L	100	100	--	--	100	--
Boron	µg/L	750	--	4100-6000[2]	5000	5000	--
Cadmium	µg/L	10	10	--	50	50	--
Chloride	mg/L	100	--	141-350[3]	2000	--	--
Chromium	µg/L	100	100	--	50	1000	--
Cobalt	µg/L	50	50	--	--	1000	--
Copper	µg/L	200	200	--	500	500	--
Flouride	µg/L	--	1000	--	--	2000	2000
Iron	µg/L	5000	5000	--	--	--	--
Lead	µg/L	5000	5000	--	100	100	--
Lithium	µg/L	2500	2500	--	--	--	--
Magnesium	mg/L	--	--	--	--	250-500	--
Manganese	µg/L	200	200	--	--	50	--
Mercury	µg/L	--	--	--	0.05	10	--
Molybdenum	µg/L	--	10	--	--	10	300
Nickel	µg/L	200	200	--	--	200	--
Nitrate (NO3-N)	mg/L	--	--	--	10	--	500
Nitrite (NO2-N)	mg/L	--	--	--	100	--	100
(NO3+NO2)-N	mg/L	--	5-30[1]	--	10	100	--
Selenium	µg/L	20	20	--	50	50	100
Sulfate	mg/L	200	--	--	3000	--	1800 - acute 1000 - chronic
Vanadium	µg/L	100	100	--	100	100	--
Zinc	µg/L	2000	2000	--	25000	24000	--
Oil and Grease	mg/L	10	--	--	10	--	--
Radium 226 and 228	pCi/L	5	--		5	--	
Total Strontium 90	pCi/L	8	--	--	8	--	--
Gross alpha particle radioactivity (including Radium 226 but excluding Radon and Uranium)	pCi/L	15	--	--	15	--	--
TDS	mg/L	2000	450-2000[1]	--	5000	--	--
pH	Standard units	4.5-9.0	--	--	6.5-8.5	--	--
Residual Sodium Carbonate (RSC)	meq/L	1.25	--	--	--	--	--
SAR	n/a	8	--	9	--	--	--
Specific Conductance	µS/cm	--	2000	760-2000[4]	--	5000-8000	--

[1] Range of slight to moderate use restriction; i.e., no use restrictions on lower values, severe use restrictions higher values

[2] Alfalfa tolerance range

[3] Range that causes injury for moderately tolerant plants; concentrations in the range of 351-700 mg/L causes foliar damage to alfalfa

[4] Leaching is required to mitigate potential accumulation in soil

Data Summary 3.4.3-2 Surface Water Suitability for Irrigation and Animal Watering Based on Comparison of USGS Water Quality Samples to Standards

Constituent	USGS Code[1]	Units	USGS Gage Identification																				
			6364300	6364700	6365300	6365900	6375600	6378300	4305521-05343401	4306521-05442001	4306521-05442001	4306521-05442001	4318401-05352201	4319461-05340401	4321401-04195501	4325261-04293501	4330221-04522001	4332401-04431001	4334121-05270301	4341191-05224201	4344331-05193601
Aluminum	1106	µg/L		10-<100	40-<100	10-20	<10-230	210	40-230											20	
Aluminum	1105 UF	µg/L	55-773	11-528	<100-4800	4-16100		117-25800													
Arsenic	1000	µg/L	0.9-4.8	0.3-1.1	1-2	0.4-2	1-2	0.49-2	1-10											8	
Arsenic	1002 UF	µg/L	2.1-3.2	0.6-1.3	1-2	0.4-3.9	1-4	0.93-10	2-12												
Beryllium	1010	µg/L		<10	<10	<10	<10	<3	<1-10												
Beryllium	1012 UF	µg/L	0.03-0.12	<0.12	<10	<10	<10	<0.04-2.79	<10-10												
Boron	1020	µg/L		50-540	90-300	50-270	50-302	60-320	50-290							100, 140	100, 120	110, 120			
Cadmium	1025	µg/L		<1	<1	<2	<1-2	<3	<3-10											<1	
Cadmium	1027 UF	µg/L			<20	<20			<20												
Chloride	940	mg/L	9.6-26.4	3.7-31	5.3-73	3.3-42	2-290	0.84-60.9	3.6-33	6.8	13	24	23	23	35	23, 35	22, 24	25, 39			
Chromium	1030	µg/L		<20	<20	10-20	<1-20	20	10											<1	
Chromium	1034 UF	µg/L		4-10	10-20	10-30	10-30	30	10-30												
Cobalt	1035	µg/L		<3		<3	<9	<8	<8												
Cobalt	1037 UF	µg/L							<2												
Copper	1040	µg/L		<2-40	20	<2-40	<1-30	<20	20-70											2.4	
Copper	1042 UF	µg/L		10-<20	10-20	10-30	<20-20	10-20	10-<20												
Flouride	950	µg/L	0.9-1.86	0.2-1.1	0.1-1.5	0.18-0.86	0.1-0.9	0.2-1.64	0.2-1.3	0.2	0.5	0.3	0.1	0.1	0.7	0.6, 1.0	0.5, 0.6	0.4, 0.5			
Iron	1046	µg/L	8-117	8-1700	20-1200	10-3080	6-350	5-130	20-500	<10	60	10	20	20	50	20, 60	20, 40				
Iron	1045 UF	µg/L		110-530	110-3300	70-12000	310-5900	760-4100	1000-4400												
Lead	1049	µg/L		<2			<30	<25												<1	
Lead	1051 UF	µg/L		<200	<200	<200			<2-100												
Lithium	1130	µg/L		20-60	20-50	20-60	7-48	10-20	<10-20												
Lithium	1132 UF	µg/L		30-50	20-60	20-60	<10-30	20	<10-30												
Magnesium	925	mg/L	30.9-115	13-154	20-190	6.0-226	6.5-140	4.2-162	5.1-41	16	48	31	56	59	64	57, 65	83, 85	92, 120			
Manganese	1056	µg/L	10.6-515	<10-4850	1-<10	20-2350	<10-260	1.1-136	<10-140		400	10	40	150							
Manganese	1055 UF	µg/L		30-780	20-4500	60-1100	80-280	50-200	50-240												
Mercury	71890	µg/L		<0.1-0.4	<0.1-0.5	<0.1-1.5	<0.1-3	0.3	<0.1-0.5											<0.1	
Mercury	71900 UF	µg/L			<0.1-1.3	<0.5	<0.1-0.5	0.1-0.3	<0.1-0.5												
Molybdenum	1060	µg/L		<10	1-<10	1-10	<10-40	<25	<25												
Molybdenum	1062 UF	µg/L		<1-3		<1-16	1-3	1	<1-9												
Nickel	1065	µg/L		<2		<2	2-<30		<2											1.1	
Nickel	1067 UF	µg/L		<2-<50	<2-<50	<200															
Nitrate (NO3-N)	618	mg/L		0.03			0.03-0.35														
Nitrate (NO3-N)	71851	mg/L		0.004-0.005			0.14-1.54														
Nitrite (NO2-N)	613	mg/L		0.001-0.008			0.001-0.019														
Nitrite (NO2-N)	71856	mg/L		<0.1-0.4			0.004-0.061														
(NO3+NO2)-N	602	mg/L		0.5-1.1		0.38-0.78	0.6-0.9	1.5	0.24-1.5												
(NO3+NO2)-N	600 UF	mg/L		0.2-1.8	0.5-2.2	0.07-2.4	0.5-4.1	1.9-2.4	0.93-4						0.52	0.44, 0.86	0.39, 0.37	0.43, 0.58			
Selenium	1145	µg/L		<1	<1-2	<1	<1-2	1-3	<1	73	1	71	22	18				<1		<1	10
Selenium	1147 UF	µg/L	0.1-1.8	0.07-2.4	<1-2	<1-2.4	<1-1	0.57-3	<1-4												
Sulfate	945	mg/L	291-1820	150-1570	110-7500	64-3100	82-2200	42.2-2350	140-1600	200	160	250	910	920	1400	1000, 1400	1100	1200, 1500			
Vanadium	1085	µg/L		<6		0.4-<6	1-<18	<8	0.3-<8												
Zinc	1090	µg/L		3-30	<20-60	<3-30	3-52	3-10	10-70											<20	
Zinc	1092 UF	µg/L			10-110	10-200	10-80	70-140	20-40												
Oil and Grease		mg/L																			
Radium 226 and 228	9511	pCi/L		0.127	0.13-0.31					2.5	0.28	0.55	0.3	0.24							
Total Strontium 90		pCi/L																			
Gross alpha particle radioactivity (including Radium 226 but excluding Radon and Uranium)		pCi/L																			
TDS		mg/L																			
pH	400	Standard units	7.8-9.8	7.0-8.4	6.8-8.2	7.1-8.7	7.4-8.9	7.5-8.6	8.0-9.1	8.2	8.9		8.2	8.2	7.7	7.8, 8.3	7.1	8, 8.1	8.7	8.4	9.3
Residual Sodium Carbonate (RSC)		meq/L																			
SAR		n/a[2]																			
Specific Conductance	95	µS/cm	1330-5080	435-2300	630-2600	263-6560	232-7500	197-4640	695-5000	670	870	940	1750	1800	2550	2300, 3300	2300, 2700	2500, 3200	788	761	14500

Notes:

[1]UF = unfiltered sample

[2]n/a = not available

Blank cells indicate no results were available

Values in red indicate exceedance of one or more criteria in Table 3.4.3-1

Values in blue indicate potential exceedance of one or more criteria in Table 3.4.3-1

Data Summary 4.2.2-1. Normal Year Hydrologic Conditions Available Flow for Potential Account III Dams

NE WY River Basins Model Reach	Reach or Potential Dam Site	Drainage Area, mi²	Available Flow, Normal Year Hydrologic Conditions in acre-feet (AF)													
			Annual	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Sum of Monthly Flows
Reach 7	Antelope Creek, AF	1,040	2,837	18	83	72	530	573	1,032	355	69	45	50	13	16	2,856
Reach 7	Antelope Creek, AF/mi²	1,040	2.73	0.02	0.08	0.07	0.51	0.55	0.99	0.34	0.07	0.04	0.05	0.01	0.02	2.75
	Antelope Creek potential dam, AF	777	2,120	13	62	54	396	428	771	265	52	34	37	10	12	2,134
Reach 13	Cheyenne River above Black Thunder Creek, AF	1,762	7,074	113	493	345	573	2,821	1,922	405	90	128	91	95	26	7,102
Reach 13	Cheyenne above BT Creek, AF/mi²	1,762	4.01	0.06	0.28	0.20	0.33	1.60	1.09	0.23	0.05	0.07	0.05	0.05	0.01	4.03
	Cheyenne 1 potential dam, AF	1,713	6,877	110	479	335	557	2,743	1,869	394	87	124	88	92	25	6,904
Reach 14	Black Thunder Creek, AF	561	5,120	44	97	126	196	2,696	903	53	16	834	69	12	0	5,046
Reach 14	Black Thunder Creek, AF/mi²	561	9.13	0.08	0.17	0.22	0.35	4.81	1.61	0.09	0.03	1.49	0.12	0.02	0.00	8.99
	Black Thunder Creek potential dam, AF	506	4,618	40	87	114	177	2,432	814	48	14	752	62	11	0	4,551
Reach 15	Cheyenne River above Lodgepole Cr, AF	2,362	12,193	169	590	471	769	5,568	2,825	458	106	962	160	107	26	12,211
Reach 15	Cheyenne River above Lodgepole Cr, AF/mi²	2,362	5.16	0.07	0.25	0.20	0.33	2.36	1.20	0.19	0.04	0.41	0.07	0.05	0.01	5.17
	Cheyenne 2 potential dam, AF	2,335	12,054	167	583	466	760	5,504	2,793	453	105	951	158	106	26	12,071

Data Summary 4.2.2-2. Alternative Surface Water Storage Sites

Potential Dam Sites	Antelope Creek	Cheyenne River 1	Cheyenne River 2	Black Thunder Creek
Local Information				
USGS 7.5-minute Topographic Quadrangle	Betty Reservoir	Poddy Creek	The Nose West and East	Darlington Draw East
County	Converse	Weston	Weston	Weston
Onstream / Offstream	Onstream	Onstream	Onstream	Onstream
Basin Characteristics and Hydrology				
Drainage Area (mi^2)	777	1,713	2,335	506
Estimated PMF Flood Characteristics				
Estimated Peak Discharge (cfs)	158,605	244,399	301,417	133,753
Estimated Runoff Volume (ac-ft)	394,373	924,815	1,277,344	240,715
Annual Peak Flow Characteristics				
Region	Eastern Basins/Plains	Eastern Basins/Plains	Eastern Basins/Plains	Central Basins/Northern Plains
Average Annual Precipitation (in)	14.0	14.0	14.0	14.0
Average Annual Available Water (ac-ft)	2,134	6,904	12,071	4,551
Reservoir Characteristics and Operation				
Normal High Water				
Capacity (ac-ft)	3,509	5,840	8,575	2,879
Surface Area (ac)	311	527	764	320
Water Surface Elevation	4615.40	4142.00	3999.50	4191.20
Average Water Depth (ft)	11	11	11	9
Site Geology				
Geology				
Karst				
Klinker				
Seepage				
Structure				
Liquefaction Potential				
Disperse/Soluble Soils				
Foundation Strength				
Reservoir Rim Conditions				
Landslide Deposits				
Bedrock Geology Units	Tfl	Qa, Tft	Kl, Qa	Tft
Surficial Geology Units	ai, ri	ai, ti, tdi	ai, sci, ti, ri	ai
Borrow				
Relative apparent availability				
Relative apparent quality				
Site Environmental Conditions				
Environmental Issues				
NWI Wetlands (ac)	0.0	19.5	13.0	1.9
Stream Classification (Rosgen)				
WYDEQ Stream Classification	3B	2ABWW	2ABWW	3B
Sage Grouse Leks				
Big Game Habitat - Crucial				
Big Game Parturition (Birthing Areas)				
Raptor Nesting Area				
Mineral Resources				
Coal Potential				
Uranium				
Sulfur				
Bentonite				
Other Metals				
Infrastructure and Ownership				
Infrastructure/Utilities Conflicts				
Residences/Facilities	2	0	0	4
Highways (mi)	0.1	0	0	0
Railroads (mi)	0	0	0	0
Pipelines (mi)	0	0	0	0
Transmission Lines1 (mi)				
Transmission Lines2 (mi)				
Distribution Lines1 (mi)				
Irrigated Lands (ac)	0	0	0	
Energy Resources				
Oil Field		X	X	
Gas Field				
Land Ownership				
Private	X	X	X	X
State		X		
Federal				
Dam Characteristics and Hydraulic Structures				
Dam				
Freeboard/Head Spillway (ft)	12.34	13.76	13.83	12.93
Crest Elevation (ft)	4627.74	4155.76	4013.33	4204.13
Total Crest Length (ft)	1,300	3,600	3,270	2,320
Crest Width (ft)	14	14	14	14
Maximum Dam Height (ft)	43	39	46	40
Foundation Excavation Volume (1000 cy)	96	219	153	132
Total Earthwork Fill Volume (1000 cy)	482	1,094	766	662
Storage Efficiency (ac-ft/1000 cy)	7.3	5.3	11.2	4.3
Height Efficiency (ft/1000 ac-ft)	12.1	6.8	5.4	13.9
Outlet Works				
Proposed Type	Conduit	Conduit	Conduit	Conduit
Outlet Elevation	4585.23	4116.32	3967.29	4164.16
Principle Spillway				
Proposed Type	Concrete Chute	Concrete Chute	Concrete Chute	Concrete Chute
Crest Elevation (ft)	4615.40	4142.00	3999.50	4191.20
Design Capacity (cfs)	51,750	85,745	98,885	15,710
Approximate Width (ft)	385	542	620	109
Approximate Length (ft)	95	81	102	86
Emergency Spillway				
Crest Elevation (ft)	4622	4149	4006.5	4197.25
Design Capacity (cfs)	27,553	36,454	51,823	51,166
Approximate Width (ft)	700	800	1,200	1,200
Approximate Length (ft)	1,226	1,089	1,307	1,103
Cut Volume (1000 cy)	91	109	198	169
Supply and Delivery Facilities				
Supply Diversions				
Length (mi)				
Terrain				
Delivery Canals				
Length (mi)				
Terrain				
Other				
Access				
Cultural Resources				
Costing				
Total Project Cost	$1,367,000	$737,000	$12,915,000	$60,000
Total Project Cost per cy of Fill	$2.83	$0.67	$16.87	$0.09
Total Project Cost per ac-ft of Storage	$390	$126	$1,506	$21

Excellent or more than adequate
Favorable or adequate
Marginal or unfavorable value
Probable fatal flaw or very unfavorable value

Data Summary 4.2.2-3. Breached Dam Locations and Estimated Sizes

Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)
36	73	15	17410	0.40	5	87050	2.0
36	74	4	12475	0.29	5	62375	1.4
36	74	12	3444	0.08	5	17220	0.4
36	75	11	25206	0.58	5	126030	2.9
36	76	23	22678	0.52	5	113390	2.6
37	73	7	23322	0.54	5	116610	2.7
37	74	3	44991	1.03	5	224955	5.2
37	75	2	132801	3.05	5	664005	15.2
37	75	10	153123	3.52	5	765615	17.6
37	76	9	7674	0.18	5	38370	0.9
37	76	15	23783	0.55	5	118915	2.7
37	76	21	6224	0.14	5	31120	0.7
37	76	27	21622	0.50	5	108110	2.5
38	69	6	18735	0.43	5	93675	2.2
38	70	11	7916	0.18	5	39580	0.9
38	74	34	7024	0.16	5	35120	0.8
38	74	35	3622	0.08	5	18110	0.4
39	62	8	4662	0.11	5	23310	0.5
39	63	4	13259	0.30	5	66295	1.5
39	63	7	8391	0.19	5	41955	1.0
39	63	17	27673	0.64	5	138365	3.2
39	63	19	7757	0.18	5	38785	0.9
39	63	19	20132	0.46	5	100660	2.3
39	63	21	5193	0.12	5	25965	0.6
39	63	22	14443	0.33	5	72215	1.7
39	64	3	10843	0.25	5	54215	1.2
39	64	4	4089	0.09	5	20445	0.5
39	64	24	7948	0.18	5	39740	0.9
39	64	24	5355	0.12	5	26775	0.6
39	64	28	6625	0.15	5	33125	0.8
39	68	3	54184	1.24	5	270920	6.2
39	69	30	7885	0.18	5	39425	0.9
39	70	11	3657	0.08	5	18285	0.4
39	71	21	8671	0.20	5	43355	1.0
39	72	34	3522	0.08	5	17610	0.4
39	76	27	382846	8.79	5	1914230	43.9
39	76	35	9994	0.23	5	49970	1.1
40	64	13	60363	1.39	5	301815	6.9
40	64	15	113161	2.60	5	565805	13.0
40	66	11	5005	0.11	5	25025	0.6
40	66	30	9000	0.21	5	45000	1.0
40	71	18	24593	0.56	5	122965	2.8
40	71	30	9703	0.22	5	48515	1.1
40	71	31	38081	0.87	5	190405	4.4
40	72	4	6693	0.15	5	33465	0.8
40	72	25	12592	0.29	5	62960	1.4
40	73	3	9122	0.21	5	45610	1.0
40	73	8	7193	0.17	5	35965	0.8
40	76	27	8680	0.20	5	43400	1.0
41	64	1	182806	4.20	5	914030	21.0
41	64	22	16846	0.39	5	84230	1.9
41	64	27	9519	0.22	5	47595	1.1
41	66	8	15978	0.37	5	79890	1.8
41	66	29	164841	3.78	5	824205	18.9
41	67	15	13605	0.31	5	68025	1.6
41	67	16	426333	9.79	5	2131665	48.9
41	67	27	1426918	32.76	20.3	28923840	664.0
41	71	13	6736	0.15	5	33680	0.8
41	71	13	6736	0.15	5	33680	0.8
41	73	28	42518	0.98	5	212590	4.9
41	74	1	22469	0.52	5	112345	2.6

Data Summary 4.2.2-3. Breached Dam Locations and Estimated Sizes

Township (N)	Range (W)	Section	Area (ft^2)	Area (acre)	Assumed Depth (ft)	Volume (ft^3)	Volume (acre-ft)
41	74	23	3271	0.08	5	16355	0.4
41	74	25	7199	0.17	5	35995	0.8
41	74	35	34696	0.80	5	173480	4.0
41	75	1	23994	0.55	5	119970	2.8
41	75	4	13949	0.32	5	69745	1.6
42	64	9	7604	0.17	5	38020	0.9
42	64	8	8534	0.20	5	42670	1.0
42	64	6	25259	0.58	5	126295	2.9
42	67	15	4562	0.10	5	22810	0.5
42	67	16	6273	0.14	5	31365	0.7
42	67	29	30946	0.71	5	154730	3.6
42	68	15	124065	2.85	5	620325	14.2
42	68	8	3046	0.07	5	15230	0.3
42	71	3	82640	1.90	5	413200	9.5
42	71	28	7110	0.16	5	35550	0.8
42	71	29	6250	0.14	5	31250	0.7
42	71	30	18915	0.43	5	94575	2.2
42	73	31	9796	0.22	5	48980	1.1
43	64	33	10800	0.25	5	54000	1.2
43	65	12	17628	0.40	5	88140	2.0
43	65	8	26220	0.60	5	131100	3.0
43	66	4	9361	0.21	5	46805	1.1
43	67	12	15586	0.36	5	77930	1.8
43	67	13	6247	0.14	5	31235	0.7
43	67	16	8220	0.19	5	41100	0.9
43	67	21	17471	0.40	5	87355	2.0
43	71	19	85495	1.96	5	427475	9.8
43	73	22	7372	0.17	5	36860	0.8
44	65	22	18554	0.43	5	92770	2.1
44	65	29	16293	0.37	5	81465	1.9
44	65	34	14585	0.33	5	72925	1.7
44	66	12	14836	0.34	5	74180	1.7
44	66	19	30165	0.69	5	150825	3.5
44	68	10	3217	0.07	5	16085	0.4
44	68	14	5317	0.12	5	26585	0.6
44	68	14	7784	0.18	5	38920	0.9
44	68	25	77897	1.79	5	389485	8.9
44	70	30	19745	0.45	5	98725	2.3
44	70	30	9608	0.22	5	48040	1.1
45	65	18	57537	1.32	5	287685	6.6
45	66	1	8087	0.19	5	40435	0.9
45	66	24	15838	0.36	5	79190	1.8
45	67	10	9056	0.21	5	45280	1.0
45	67	17	12253	0.28	5	61265	1.4
45	67	17	36158	0.83	5	180790	4.2
45	67	19	13572	0.31	5	67860	1.6
45	67	22	34325	0.79	5	171625	3.9
45	67	22	12920	0.30	5	64600	1.5
45	67	28	128844	2.96	5	644220	14.8
45	67	28	5805	0.13	5	29025	0.7
45	68	1	7244	0.17	5	36220	0.8
45	68	26	98827	2.27	5	494135	11.3
45	68	26	65409	1.50	5	327045	7.5
45	69	23	19030	0.44	5	95150	2.2
45	70	33	15115	0.35	5	75575	1.7
46	66	20	11719	0.27	5	58595	1.3
46	66	33	12846	0.29	5	64230	1.5
46	67	25	8505	0.20	5	42525	1.0

Location outside of cattle range

Data Summary 7.3-1
Summary of Maximum Potential Benefits of Project Alternatives

Alternative	Reservoir Capacity (acre-feet)	Assumed Annual Reservoir Yield (acre-feet)	Acres Serviced	Benefit Per Acre Based upon a 10% Increase in Water Delivery Efficiency with an Average Cost of $97.80/Ton	Head of Cattle	Average Weight of Market Calves (lbs)	Benefit Per Single Animal Based upon a 5% Increase in Weight Gain at Market Price of $100/cwt	Maximum Potential Annual Benefits From Improvement Projects ($ per year)	Maximum Potential Present Value of All Direct Benefits ($)	Maximum Potential Present Value of All Direct and Indirect Benefits ($)
Storage Projects										
Antelope Creek Storage Reservoir	3509	1750						$43,600	$936,600	$3,147,000
Black Thunder Creek Storage	2879	1440						$35,900	$771,200	$2,591,200
Cheyenne River 1 Storage Reservoir	5840	2920						$72,800	$1,563,900	$5,254,700
Cheyenne River 2 Storage Reservoir	8575	4290						$107,000	$2,298,600	$7,723,300
Irrigation Projects										
Stroh Ranch - Replace Head gate, diversion, and re-grade ditches			67	$ 3.91				$262	$5,600	$18,800
Stroh Ranch - Re-grade ditch 3			65	$ 3.91				$254	$5,500	$18,500
Harschbarger Ranch - Replace Head gate and re-grade ditches			87	$ 3.91				$340	$7,300	$24,500
Turner Ranch - Construct Spreader dikes			19	$ 3.91				$74	$1,600	$5,400
Pellatz Ranch - Install headgate and regrade ditch			70	$ 3.91				$274	$5,900	$19,800
Pellatz Ranch - Build dike and regrade ditch			47	$ 3.91				$184	$4,000	$13,400
Livestock Watering Projects										
Livestock Watering - Pasture Rotation Improvement					100	600	$30	$3,000	$64,400	$216,400

Data Summary 7.5-1

Primary Potential Funding Sources

Agency/Entity	Program Name	Project Type(s)	Internet URL	Telephone	Email
Local					
Weston County Natural Resource District	N/A	Liaison, In-Kind administrative and technical assistance, program coordination/partnering	N/A	307-746-3264	christina.schmidt@wy.nacdnet.net
Campbell County Conservation District	N/A	Liaison, In-Kind administrative and technical assistance, program coordination/partnering	www.cccdwy.net	307-682-1824	icd@vcn.com
Niobrara County Conservation District	N/A	Liaison, In-Kind administrative and technical assistance, program coordination/partnering	N/A	307-334-2953	lshaw@wyoming.com
Converse County Conservation District	N/A	Liaison, In-Kind administrative and technical assistance, program coordination/partnering	www.conserveconverse.com	307-358-3050	michelle.huntington@wy.nacdnet.net
State					
Wyoming Department of Environmental Quality	Nonpoint Source Implementation Grants (Section 319 Program)	Water Quality Best Management Practices	http://deq.state.wy.us/wqd/watershed/	307-777-6709	dwater@wyo.gov
Wyoming Game and Fish Department	Riparian Habitat Improvement Grant	Fencing, Herding, Stockwater Development, stream bank stabilization, small dams, etc.	http://gf.state.wy.us/habitat/StrategicPlan/index.asp	307-777-4565	gbutle@state.wy.us
	Water Development/Maintenance Habitat Project Grant	Spring Development, Windmills, Guzzlers, Water Protection, and Pumping Payments, etc.			
	Industrial Water Habitat Project Fund	Tapped Artesial Wells, Springs or Groundwater for Wildlife, Creation of Wetlands/ponds, etc.			
	Upland Development Program	Shrub Management, Grazing Systems, Prescribed Burning, Wildlife Food Plots, Range Seeding, etc.			
	Fish Wyoming	Boat Ramps, Fishing Acces, etc.			
Wyoming Office of State Lands and Investments	Farm Loan Program	Agricultural and Livestock Assistance	http://slf-web.state.wy.us/	307-777-7331	lboomg@state.wy.us
	The Irrigation Loans Program	Small and large Agricultural Water Development Projects			
	Joint Powers Act Loan Program	Government Services and Public Facilities			
Wyoming Water Development Commission	New Development Program	Water Supply Development	http://wwdc.state.wy.us/	307-777-7626	jwade@state.wy.us
	Rehabiliation Program	Improvements of Existing Water Projects			
	Dam and Reservoir Program	New Dams and Dam expansion			
	Small Water Projects Program	Construction/Rehabilitation of Small Reservoirs, Wells, Pipelines, Springs, Solar Platforms, Irrigation Works, Windmills, and Wetland Development			
Wyoming Wildlife and Natural Resource Trust	N/A	Wildlife Habitat Improvements and Natural Resource Improvements/Preservation	http://wwnrt.state.wy.us/	307-856-4665	bbudd@state.wy.us
Federal					
Bureau of Land Management	RiparianHabitat Management Program	Improve/Restore/Protect Riparian Areas	http://www.blm.gov/wy/st/en.html	307-775-6092	rick_schulder@blm.gov
	Range Improvement Planning and Development	Water Development for Livestock, Livestock BMP,			
	Watershed and Water Quality Improvement	Restoration and Maintenance of Watershed Function			
Bureau of Reclamation	Challenge Grant Program	Improve Water Efficiency, Water Treatment, Habitat Preservation	http://www.usbr.gov/gp/wyao/	307-261-5671	jlawson@gp.usbr.gov
	Water Conservation Field Services Program	Conservation Improvements			
Environmental Protection Agency	Targed Watersheds Grants Program	Riparian, Wetland, Aquatic and Upland Habit Protection and Improvement	http://www.epa.gov/watershed/initiative/	303-312-6692	eriksen.stacey@epa.gov
Farm Service Agency	Conservation Resource Program	Removal of Highly Erodible Cropland from Production	www.fsa.usda.gov/wy/	307-261-5081	cindy.hottel@wy.usda.gov
	Continuous Sign-Up for High Priority Conservation Practices	Riparian Buffers, Filter Strips, Grass Waterways, Shelter Belts, Field Windbreak, Living Snow Fences, Contour Grass Strips, Salt Tolerant Vegetation, and Shallow Water Areas			
	Emergency Conservation Program	Farmland Rehabilitation Damaged by Natural Disasters or Emergency Water Conservation for Livestock			
Fish and Wildlife Service	Partners for Wildlife Habitat Restoration	Habitat Restoration and Improvements	http://www.fws.gov/	307-332-8719	mark_j_hogan@fws.gov
	Wildlife Conservation and Appreciation Program	Identification and Preservation of Fish and Widlife and Their Habitats			
	Cooperative Endangered Species Conservation Fund	Conservation of Threatened and Endangered Species			
	North American Wetlands Conservation Act Grant Program	Conservation of Wetland Ecosystems, Waterfowl, Fish, and Wildlife			
Natural Resource Conservation Service	Environmental Quality Incentives Program	Improve Water Quality, Enhance Grazing Lands, and Increase Water Conservation	http://www.wy.nrcs.usda.gov/	307-233-6750	cherie.schoonover@wy.usda.gov
	Conservation Security Program	Promotes BMP and Conservation			
	Wildlife Habitat Incentives Program	Improve Wildlife Habitats on Private Lands			
	Wetlands Reserve Program	Wetland, Wildlife Habitat, Soil, Water, and Related Natural Resource Concerns on Private Lands			
	Grassland Reserve Program	Grazing Operations, Pland and Animal Biodiversity, and Foliage			
	Farm and Ranch Lands Protection Program	Farm and Ranch Land Preservation			
	Resource Conservation and Development	Promote Conservation, Development, and use of Natural Resources			
Non-Profit and Other Organizations					
Ducks Unlimited	Matching Aid to Restore States Habitat	Wetlands and Waterfowl Restoration	http://www.ducks.org/	307-472-6980	carol.m.perry@wellsfargo.com
National Fish and Wildlife Foundation	Five-Star Restoration Matching Grants Program	Wetland, Riparian, and Coastal Habitat Restoration	http://www.nfwf.org/	202-857-0166	lacy.alison@nfwf.org
	Bring Back the Natives	Preserve/Enhance Native Aquatic Species			barrett.Bohnengel@nfwf.org
	Native Plant Conservation Initiative	Conservation of Native Plantlife			ellen.gabel@nfwf.org
	Pulling Together Initiative	Invasive Plant Species Control			ellen.gabel@nfwf.org
Trout Unlimited	Watershed Restoration	Protect and Restore Coldwater Fisheries and their Watersheds	http://www.tu.org	307-733-6991	syates@tu.org
Sage Grouse Initiatives (multiple)	Multiple	Habitat Improvements to Benefit Sage Grouse	Varies, See Section 7.4.5		

Appendix B

Precipitation Data

NEWCASTLE 14 W, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(486662) NEWCASTLE 14 W														
From Year=1948 To Year=1958														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.65	3.15	1949	0.00	1952	2.25	06/1949	2	1	1	0	5.7	14.0	1953
February	0.30	0.86	1953	0.00	1950	0.50	23/1949	2	1	0	0	5.3	25.0	1955
March	0.56	1.13	1950	0.00	1949	0.95	01/1953	3	1	0	0	8.5	17.0	1958
April	0.97	2.05	1958	0.00	1952	0.70	10/1950	5	4	1	0	2.5	13.0	1957
May	2.43	4.76	1949	0.25	1958	2.20	22/1952	7	5	1	0	0.1	1.0	1953
June	2.11	3.91	1957	0.73	1952	1.18	04/1957	6	5	1	0	0.0	0.0	1949
July	1.11	2.69	1957	0.17	1955	1.08	13/1952	4	3	1	0	0.0	0.0	1949
August	1.39	2.30	1955	0.82	1950	1.10	11/1956	5	4	1	0	0.0	0.0	1949
September	0.70	1.81	1955	0.00	1954	0.53	07/1951	3	3	0	0	0.3	2.5	1955
October	0.44	1.23	1949	0.00	1951	0.65	08/1949	2	2	0	0	1.8	6.0	1954
November	0.36	1.25	1955	0.00	1949	0.70	12/1955	2	1	0	0	7.1	26.5	1956
December	0.27	0.90	1948	0.00	1950	0.60	24/1948	1	1	0	0	3.6	8.5	1948
Annual	11.29	15.80	1957	5.46	1954	2.25	19490106	42	30	7	1	34.9	61.5	1955
Winter	1.22	4.76	1949	0.09	1954	2.25	19490106	5	3	1	0	14.6	31.0	1955
Spring	3.97	6.16	1949	1.81	1954	2.20	19520522	15	10	2	0	11.2	20.0	1958
Summer	4.60	7.84	1957	3.09	1954	1.18	19570604	16	12	3	0	0.0	0.0	1949
Fall	1.49	3.18	1955	0.51	1954	0.70	19551112	7	5	1	0	9.1	28.0	1956

Table updated on Jul 16, 2008
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons
Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

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HAMPSHIRE 3 SW, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(484225) HAMPSHIRE 3 SW														
From Year=1921 To Year=1955														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.39	2.86	1925	0.00	1942	2.50	27/1925	2	1	0	0	4.0	15.0	1949
February	0.28	2.30	1953	0.00	1941	0.80	09/1953	2	1	0	0	3.2	21.0	1953
March	0.51	1.48	1954	0.02	1921	1.04	16/1945	4	2	0	0	6.0	15.0	1943
April	1.31	3.92	1941	0.11	1952	2.27	16/1940	5	3	1	0	3.9	11.5	1933
May	2.03	4.58	1935	0.04	1936	4.66	31/1927	8	5	1	0	1.7	17.5	1942
June	2.21	5.06	1946	0.44	1933	3.04	18/1946	8	5	2	0	0.0	0.0	1934
July	1.48	3.52	1937	0.13	1940	1.45	21/1927	6	4	1	0	0.0	0.0	1932
August	1.38	3.27	1930	0.00	1940	2.48	28/1933	5	3	1	0	0.0	0.0	1932
September	0.80	2.62	1923	0.00	1924	2.46	28/1923	4	2	0	0	0.2	2.0	1945
October	0.77	2.10	1931	0.00	1952	2.10	08/1924	3	2	1	0	1.5	7.0	1950
November	0.25	0.97	1947	0.00	1935	1.10	04/1922	2	1	0	0	2.9	15.5	1947
December	0.18	0.48	1946	0.00	1947	1.03	07/1924	2	1	0	0	2.5	7.5	1940
Annual	11.61	15.70	1941	7.82	1933	4.66	19270531	53	29	6	2	25.9	35.4	1942
Winter	0.86	3.55	1953	0.11	1943	2.50	19250127	7	3	0	0	9.7	31.0	1953
Spring	3.85	6.98	1942	1.17	1936	4.66	19270531	17	10	2	1	11.6	29.4	1942
Summer	5.08	7.16	1945	0.85	1940	3.04	19460618	19	12	3	1	0.0	0.0	1934
Fall	1.83	3.62	1946	0.22	1953	2.46	19230928	9	5	1	0	4.5	16.5	1947

Table updated on Jul 16, 2008
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons
Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

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CLARETON 16 SW, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(481752) CLARETON 16 SW														
From Year=1948 To Year=1957														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.31	1.17	1949	0.00	1952	0.80	04/1949	2	1	0	0	4.4	15.4	1949
February	0.21	0.70	1957	0.00	1950	0.41	27/1954	2	1	0	0	3.0	14.0	1953
March	0.40	1.08	1950	0.00	1957	0.28	23/1950	4	2	0	0	4.9	12.0	1954
April	0.98	1.77	1957	0.12	1952	1.10	30/1949	5	3	0	0	1.2	4.0	1950
May	1.96	3.55	1952	0.71	1954	2.35	22/1952	8	5	1	0	1.1	8.0	1950
June	1.81	3.16	1955	0.43	1954	1.40	13/1955	6	4	1	0	0.1	0.5	1951
July	1.13	2.57	1957	0.31	1954	0.93	18/1957	4	3	1	0	0.0	0.0	1950
August	0.99	1.65	1954	0.00	1957	1.12	11/1951	3	2	1	0	0.0	0.0	1950
September	0.52	1.06	1950	0.00	1952	0.67	21/1950	2	2	0	0	0.0	0.0	1950
October	0.46	1.06	1954	0.00	1951	0.86	13/1954	2	1	0	0	1.1	5.0	1950
November	0.28	1.09	1955	0.00	1951	0.68	11/1955	2	1	0	0	1.6	3.5	1948
December	0.34	1.66	1955	0.00	1953	0.60	28/1955	2	1	0	0	2.0	4.0	1951
Annual	9.40	8.95	1951	6.73	1953	2.35	19520522	39	26	5	1	19.5	32.1	1953
Winter	0.86	1.72	1956	0.26	1951	0.80	19490104	6	3	0	0	9.4	27.8	1953
Spring	3.33	5.01	1949	1.85	1951	2.35	19520522	16	10	1	0	7.3	22.0	1950
Summer	3.94	5.59	1951	2.39	1954	1.40	19550613	12	9	3	0	0.1	0.5	1951
Fall	1.27	2.04	1955	0.63	1952	0.86	19541013	6	4	1	0	2.7	7.0	1950

Table updated on Jul 16, 2008
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons
Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, mailto:wrcc@dri.edu

ROCHELLE 3 E, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(487810) ROCHELLE 3 E														
From Year=1927 To Year=2002														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.26	1.11	1932	0.00	1989	0.44	04/1928	4	1	0	0	4.5	17.0	1932
February	0.37	1.08	1987	0.00	1940	0.55	17/1991	4	2	0	0	5.5	17.0	1987
March	0.72	2.01	1958	0.02	1974	1.24	06/1990	5	3	0	0	7.0	22.0	1958
April	1.56	5.62	1940	0.03	1928	3.20	14/1927	7	4	1	0	5.7	20.0	1963
May	2.40	6.30	1962	0.20	2001	2.06	29/1976	9	6	2	0	0.9	9.0	1965
June	2.08	5.77	1999	0.20	1988	2.25	10/1999	8	5	1	0	0.2	7.0	1951
July	1.66	7.17	1958	0.00	1964	2.30	27/1997	6	4	1	0	0.0	0.0	1927
August	1.16	3.83	1968	0.00	1940	2.50	27/1933	5	3	1	0	0.0	0.0	1927
September	0.96	4.21	1973	0.00	1954	1.55	01/1963	4	3	1	0	0.5	9.0	1965
October	0.84	4.59	1998	0.00	1933	1.50	17/1998	4	2	1	0	2.1	16.0	1995
November	0.47	1.46	2000	0.00	1939	1.02	01/2000	4	2	0	0	5.1	18.0	1985
December	0.35	1.18	1955	0.00	1930	0.51	24/1955	4	1	0	0	5.5	16.0	1982
Annual	12.84	21.89	1998	5.95	1988	3.20	19270414	65	36	7	1	37.1	64.0	1975
Winter	0.98	1.97	1932	0.17	1931	0.55	19910217	12	4	0	0	15.5	29.2	1932
Spring	4.68	10.11	1971	1.48	1974	3.20	19270414	22	13	3	1	13.6	32.0	1970
Summer	4.91	10.70	1958	1.27	1940	2.50	19330827	19	12	3	1	0.2	7.0	1951
Fall	2.26	7.34	1998	0.35	1958	1.55	19630901	12	7	1	0	7.7	22.0	1985

Table updated on Jul 16, 2008
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
Years with 1 or more missing months are not considered
Seasons are climatological not calendar seasons
Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, mailto:wrcc@dri.edu

DULL CENTER 1 SE, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(482725) DULL CENTER 1 SE														
From Year=1926 To Year=2008														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.23	0.87	1944	0.00	1933	0.75	15/1953	3	1	0	0	4.7	18.0	1972
February	0.36	1.65	1953	0.00	1941	1.25	09/1953	3	1	0	0	5.3	16.0	1976
March	0.64	2.18	2003	0.00	1974	1.58	06/1990	5	2	0	0	8.6	26.8	1998
April	1.45	4.83	1941	0.13	1952	2.40	20/1933	6	4	1	0	7.1	31.0	1984
May	2.29	6.93	1978	0.07	2001	3.20	22/1952	8	5	1	0	1.2	12.0	1978
June	2.25	7.92	1999	0.02	1961	3.24	10/1999	8	5	1	0	0.1	6.0	1969
July	1.69	5.95	1926	0.00	1949	2.22	28/1997	6	4	1	0	0.0	0.0	1932
August	1.32	4.37	1933	0.00	1969	3.15	10/1926	4	3	1	0	0.0	0.0	1932
September	1.06	3.59	1973	0.00	1958	2.00	29/1929	5	3	1	0	0.6	13.0	1965
October	0.86	4.38	1998	0.00	1933	1.73	08/1993	4	2	0	0	2.5	15.4	1993
November	0.44	2.00	1983	0.00	1939	1.05	21/1937	3	1	0	0	5.4	29.5	1983
December	0.30	1.55	1992	0.00	1947	0.58	12/1992	3	1	0	0	5.8	29.5	1978
Annual	12.89	19.52	1998	5.64	1988	3.24	19990610	58	32	7	2	41.3	75.0	1983
Winter	0.89	2.87	1993	0.28	1951	1.25	19530209	9	3	0	0	15.8	41.0	1979
Spring	4.37	9.86	1971	1.12	1960	3.20	19520522	19	11	2	1	16.9	39.0	1970
Summer	5.26	15.11	1926	1.64	1996	3.24	19990610	18	12	3	1	0.1	6.0	1969
Fall	2.37	5.95	1998	0.12	1958	2.00	19290929	12	6	1	0	8.5	29.5	1983

Table updated on Jul 16, 2008
For monthly and annual means, thresholds, and sums:
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Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, mailto:wrcc@dri.edu

BILL 10 NE, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(480727) BILL 10 NE														
From Year=1948 To Year=1958														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.18	0.99	1953	0.00	1950	0.70	14/1953	2	0	0	0	4.6	13.0	1953
February	0.28	0.85	1955	0.00	1949	0.40	09/1955	2	1	0	0	4.8	15.8	1953
March	0.57	1.61	1958	0.00	1949	0.82	26/1958	4	2	0	0	7.5	16.5	1958
April	1.11	2.31	1950	0.18	1952	1.00	09/1950	6	3	1	0	6.9	21.0	1956
May	2.04	4.32	1957	0.68	1953	2.04	22/1952	8	5	1	0	1.3	11.0	1950
June	1.54	3.13	1955	0.71	1953	1.18	26/1952	6	4	1	0	0.1	0.5	1951
July	1.48	3.72	1951	0.48	1955	1.25	30/1951	6	3	1	0	0.0	0.0	1949
August	1.01	2.27	1955	0.43	1956	0.79	07/1955	4	3	1	0	0.0	0.0	1949
September	0.87	1.95	1951	0.19	1956	1.00	20/1950	4	2	1	0	0.0	0.0	1948
October	0.53	1.27	1954	0.11	1955	0.80	13/1954	3	1	0	0	1.4	4.5	1954
November	0.44	1.35	1953	0.00	1951	0.81	11/1955	2	1	0	0	4.1	9.0	1953
December	0.35	1.15	1955	0.00	1948	0.40	25/1951	3	1	0	0	5.0	16.8	1955
Annual	10.40	14.92	1955	6.74	1956	2.04	19520522	49	27	7	1	35.7	67.5	1955
Winter	0.81	1.83	1953	0.00	1950	0.70	19530114	7	3	0	0	14.4	32.2	1953
Spring	3.72	6.16	1957	1.55	1951	2.04	19520522	18	11	2	0	15.7	35.0	1950
Summer	4.03	6.10	1951	1.90	1956	1.25	19510730	16	10	3	0	0.1	0.5	1951
Fall	1.83	2.67	1957	0.64	1952	1.00	19500920	8	4	2	0	5.5	9.0	1953

Table updated on Jul 16, 2008
For monthly and annual means, thresholds, and sums:
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Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, mailto:wrcc@dri.edu

BILL, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(480725) BILL															
From Year=1948 To Year=1978															
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.38	2.03	1949	0.00	1958	1.60	05/1949	3	1	0	0	3.8	15.0	1953
February	0.33	1.75	1953	0.00	1974	0.40	13/1952	3	1	0	0	3.6	21.0	1953
March	0.59	1.84	1950	0.00	1949	1.44	22/1950	4	2	0	0	6.6	20.0	1958
April	1.41	3.48	1971	0.19	1961	1.33	18/1971	6	4	1	0	4.6	13.0	1968
May	2.66	7.72	1978	0.14	1966	2.92	17/1978	7	6	2	1	0.6	10.0	1965
June	1.83	4.11	1967	0.00	1973	2.00	29/1959	6	4	1	0	0.1	3.0	1969
July	1.57	5.31	1951	0.00	1959	2.50	27/1951	4	3	1	0	0.0	0.0	1949
August	0.86	3.52	1972	0.00	1973	1.54	18/1972	3	2	0	0	0.0	0.0	1949
September	0.88	2.81	1961	0.00	1958	1.40	02/1973	3	2	1	0	0.5	14.0	1965
October	0.67	2.08	1961	0.00	1960	1.54	06/1962	3	2	0	0	1.6	10.0	1971
November	0.43	1.75	1953	0.00	1949	0.82	01/1973	2	1	0	0	2.4	9.0	1953
December	0.53	3.16	1949	0.00	1959	1.50	20/1949	3	2	0	0	4.2	11.0	1970
Annual	12.14	16.41	1971	5.16	1960	2.92	19780517	48	31	7	2	28.0	63.5	1953
Winter	1.24	3.83	1950	0.09	1977	1.60	19490105	9	4	0	0	11.7	38.0	1953
Spring	4.67	11.62	1971	1.31	1960	2.92	19780517	17	11	3	1	11.7	30.0	1968
Summer	4.25	7.94	1951	1.19	1971	2.50	19510727	14	10	3	1	0.1	3.0	1969
Fall	1.98	4.89	1961	0.35	1958	1.54	19621006	9	5	1	0	4.5	15.0	1966

Table updated on Jul 16, 2008
For monthly and annual means, thresholds, and sums:
Months with 5 or more missing days are not considered
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Seasons are climatological not calendar seasons

Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, mailto:wrcc@dri.edu

BILL 12 W, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(480729) BILL 12 W															
From Year=1948 To Year=1957															
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.28	0.61	1953	0.00	1952	0.33	15/1953	2	1	0	0	5.6	20.2	1949
February	0.33	1.87	1953	0.00	1949	0.93	10/1953	2	1	0	0	5.2	25.0	1953
March	0.43	1.00	1950	0.00	1953	0.52	26/1950	2	2	0	0	5.7	12.0	1952
April	1.11	2.21	1957	0.05	1952	0.59	04/1955	5	4	1	0	7.1	25.0	1956
May	2.46	4.10	1957	0.92	1955	1.82	22/1952	8	6	2	0	0.0	0.0	1949
June	1.48	2.61	1955	0.42	1950	1.27	26/1952	5	4	1	0	0.0	0.0	1949
July	0.72	2.24	1951	0.00	1953	1.31	28/1951	3	2	0	0	0.0	0.0	1949
August	0.84	3.44	1952	0.00	1951	1.42	04/1952	1	1	1	0	0.0	0.0	1949
September	0.79	1.53	1950	0.06	1952	1.20	20/1955	3	2	1	0	0.0	0.0	1948
October	0.71	1.62	1954	0.14	1952	0.94	07/1949	3	2	1	0	2.2	10.0	1950
November	0.36	1.19	1953	0.00	1949	0.95	06/1953	2	1	0	0	3.8	11.0	1956
December	0.27	0.81	1955	0.10	1950	0.36	28/1955	2	1	0	0	3.1	11.0	1955
Annual	9.78	9.96	1952	7.17	1954	1.82	19520522	36	26	6	1	32.6	70.5	1955
Winter	0.88	2.60	1953	0.19	1954	0.93	19530210	6	3	0	0	13.8	36.0	1953
Spring	4.00	6.85	1957	2.33	1955	1.82	19520522	15	11	3	0	12.8	32.0	1956
Summer	3.03	5.33	1952	1.36	1950	1.42	19520804	9	7	2	1	0.0	0.0	1949
Fall	1.86	2.63	1948	0.48	1952	1.20	19550920	7	5	1	0	6.0	12.0	1950

Table updated on Jul 16, 2008
For monthly and annual means, thresholds, and sums:
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Western Regional Climate Center, mailto:wrcc@dri.edu

VERSE 8 NW, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(489305) VERSE 8 NW															
From Year=1940 To Year=1959															
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.38	1.21	1949	0.00	1958	0.64	14/1953	4	1	0	0	5.0	15.0	1949
February	0.38	1.56	1953	0.04	1941	0.58	09/1953	3	1	0	0	4.8	19.8	1953
March	0.79	1.59	1958	0.22	1953	0.74	16/1945	5	3	0	0	8.6	14.5	1950
April	1.93	7.01	1941	0.45	1954	2.04	06/1941	7	4	1	0	6.1	17.5	1956
May	2.25	5.20	1957	0.90	1954	2.19	22/1952	9	6	1	0	2.2	15.8	1950
June	1.86	3.46	1947	0.72	1954	1.24	26/1952	8	4	1	0	0.0	0.0	1941
July	1.32	4.81	1958	0.06	1959	1.70	10/1944	6	3	1	0	0.0	0.0	1940
August	0.96	2.79	1941	0.12	1944	1.97	01/1953	4	2	1	0	0.0	0.0	1940
September	0.86	2.18	1950	0.00	1953	1.38	03/1943	4	3	1	0	0.2	3.0	1944
October	0.82	3.04	1942	0.19	1953	1.06	13/1942	4	2	0	0	1.7	9.4	1949
November	0.49	1.50	1953	0.00	1951	0.51	06/1953	3	2	0	0	4.5	12.5	1947
December	0.48	1.42	1955	0.00	1947	0.50	29/1945	3	2	0	0	5.3	17.0	1955
Annual	12.52	17.30	1957	7.95	1954	2.19	19520522	60	34	6	1	38.4	64.5	1955
Winter	1.24	2.71	1953	0.77	1958	0.64	19530114	10	4	0	0	15.1	33.4	1953
Spring	4.98	8.66	1957	2.15	1954	2.19	19520522	22	13	3	1	16.9	36.3	1950
Summer	4.13	7.19	1941	2.20	1943	1.97	19530801	18	10	2	1	0.0	0.0	1941
Fall	2.17	5.05	1942	0.70	1958	1.38	19430903	11	7	1	0	6.4	16.5	1947

Table updated on Jul 16, 2008
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Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

Western Regional Climate Center, mailto:wrcc@dri.edu

ROSS, WYOMING

Period of Record General Climate Summary - Precipitation

Station:(487895) ROSS														
From Year=1938 To Year=1961														
	Precipitation											Total Snowfall		
	Mean	High	Year	Low	Year	1 Day Max.		>= 0.01 in.	>= 0.10 in.	>= 0.50 in.	>= 1.00 in.	Mean	High	Year
	in.	in.	-	in.	-	in.	dd/yyyy or yyyymmdd	# Days	# Days	# Days	# Days	in.	in.	-
January	0.52	1.60	1949	0.00	1961	0.85	05/1949	6	2	0	0	9.9	40.0	1949
February	0.51	1.16	1947	0.00	1941	0.60	09/1953	5	2	0	0	7.5	17.0	1940
March	0.79	1.42	1950	0.29	1953	0.72	18/1954	7	3	0	0	10.8	25.0	1950
April	1.43	2.65	1940	0.32	1952	1.38	13/1941	9	4	1	0	9.7	26.5	1945
May	2.18	5.54	1952	0.22	1940	2.96	22/1952	10	5	1	0	2.9	16.0	1950
June	1.76	4.26	1947	0.32	1961	1.36	18/1946	9	4	1	0	0.0	0.0	1939
July	1.31	5.65	1958	0.21	1955	1.70	11/1956	7	3	1	0	0.0	0.0	1939
August	0.73	2.45	1941	0.01	1944	1.42	11/1941	5	2	0	0	0.0	0.0	1939
September	0.91	2.12	1945	0.07	1956	0.88	03/1943	6	3	0	0	0.5	6.0	1945
October	0.83	2.74	1942	0.11	1952	1.06	13/1942	6	3	0	0	3.2	10.2	1946
November	0.64	1.46	1942	0.00	1939	0.64	11/1955	6	2	0	0	8.9	20.6	1948
December	0.50	1.36	1955	0.03	1959	0.65	22/1941	5	2	0	0	7.7	23.0	1955
Annual	12.10	15.73	1946	10.09	1950	2.96	19520522	79	35	6	1	61.2	96.9	1945
Winter	1.52	3.23	1946	0.47	1951	0.85	19490105	16	5	0	0	25.1	59.5	1949
Spring	4.39	8.27	1957	2.69	1939	2.96	19520522	26	12	2	0	23.4	56.5	1950
Summer	3.80	8.35	1958	1.59	1942	1.70	19560711	21	9	2	1	0.0	0.0	1939
Fall	2.38	5.43	1942	1.11	1958	1.06	19421013	17	8	1	0	12.6	26.8	1942

Table updated on Jul 16, 2008
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Winter = Dec., Jan., and Feb. Spring = Mar., Apr., and May
Summer = Jun., Jul., and Aug. Fall = Sep., Oct., and Nov.

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Appendix C

Ecological Site Description

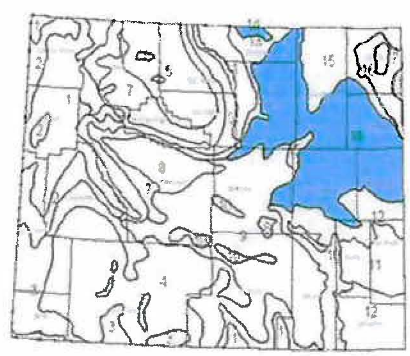
UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

ECOLOGICAL SITE DESCRIPTION

ECOLOGICAL SITE CHARACTERISTICS

Site Type: Rangeland

Precipitation Zones for Rangeland Ecological Site Descriptions



Site Name: Loamy (Ly) 10-14" Northern Plains Precipitation Zone

Site ID: R058BY122WY

Major Land Resource Area: 058B - Northern Rolling High Plains, Southern Part

Physiographic Features

This site occurs on gently undulating rolling land.

Land Form: (1) Hill
(2) Alluvial fan
(3) Ridge

	Minimum	Maximum
Elevation (feet):	3800	5100
Slope (percent):	0	30
Water Table Depth (inches):		
Flooding:		
Frequency:	None	None
Duration:	None	None
Ponding:		
Depth (inches):	0	0
Frequency:	None	None
Duration:	None	None
Runoff Class:	Negligible	High

Aspect: No Influence on this site

Climatic Features

Annual precipitation ranges from 10-14 inches per year. Wide fluctuations may occur in yearly precipitation and result in more drought years than those with more than normal precipitation. Temperatures show a wide range between summer and winter and between daily maximums and minimums. This is predominantly due to the high elevation and dry air, which permits rapid incoming and outgoing radiation. Cold air outbreaks from Canada in winter move rapidly from northwest to southeast and account for extreme minimum temperatures. Chinook winds may occur in winter and bring rapid rises in temperature. Extreme storms may occur during the winter, but most severely affect ranch operations during late winter and spring.

Wind speed averages about 8 mph, ranging from 10 mph during the spring to 7 mph during late summer. Daytime winds are generally stronger than nighttime and occasional strong storms may bring brief periods of high winds with gusts to more than 75 mph.

Growth of native cool season plants begins about April 1 and continues to about July 1. Native warm season plants begin growth about May 15 and continue to about August 15. Green up of cool season plants may occur in September and October of most years.

The following information is from the "Clearmont 5 SW" climate station:
Frost-free period (32 F): 76 - 132 days; (5 yrs. out of 10, these days will occur between May 30 – September 11)
Freeze-free period 28 F): 110 - 145 days; (5 yrs. out of 10, these days will occur between May 16 – September 21)
Mean annual precipitation: 12.4 inches
Mean annual air temperature: 43.2 F (28.4 F Avg. Min. – 57.9 F Avg. Max.)
For detailed information visit the Natural Resources Conservation Service National Water and Climate Center at http://www.wcc.nrcs.usda.gov/ website. Other climate station(s) representative of this precipitation zone include: "Dull Center"

	Minimum	Maximum
Frost-free period (days):	76	132
Freeze-free period (days):	110	145
Mean annual precipitation (inches):	10.0	14.0

Monthly precipitation (inches) and temperature (°F):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precip. Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Precip. Max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temp. Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Temp. Max.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Climate Stations:

Influencing Water Features

Stream Type: None

Wetland Description:	System	Subsystem	Class

Representative Soil Features

The soils of this site are deep to moderately deep (greater than 20" to bedrock), well drained & moderately permeable. Layers of the soil most influential to the plant community varies from 3 to 6 inches thick. These layers consist of the A horizon with very fine sandy loam, loam, or silt loam texture and may also include the upper few inches of the B horizon with sandy clay loam, silty clay loam or clay loam texture.
Major Soil Series correlated to this site includes: Bidman, Cambria, Cushman, Forkwood, Kishona, Parmleed, Theedle and Zigweid.

Other Soil Series correlated to this site in MLRA 58B include: Absted, Arvada, Ascalon, Big Horn, Bowbac, Briggsdale, Cambria Variant, Cedak Dry, Clarkelen, Connerton, Docpar, El Rancho, Emigha, Emigrant, Forkwood Variant, Fort Collins, Garrett, Glendo, Harlan, Harlan Dry, Haverdad, Hiland, Jonpol, Kadoka, Keota, Keyner, Kim, Kirtley, Larim, Larimer, Lawver, Lohsman, Maysdorf, Neville, Noden, Nuncho, Platmak, Platmak Dry, Pugsley, Recluse, Recluse Dry, Redbow, Reddale, Renohill, Roughlock, Senlar, Spearman, Stoneham, Teckla, Thirtynine, Ulm, Ulm Dry, Wages, Wolf, Wolf Variant, Wolf Dry, and Wyotite.

Predominant Parent Materials:
Kind: Alluvium
Origin: Sandstone and shale

Surface Texture: (1) Loam
(2) Gravelly Sandy loam
(3) Cobbly Very fine sandy loam

Subsurface Texture Group: Loamy

	Minimum	Maximum
Surface Fragments <=3" (% Cover):	0	0
Surface Fragments > 3" (% Cover):	0	10
Subsurface Fragments <=3" (% Volume):	0	15
Subsurface Fragments > 3" (% Volume):	0	10

Drainage Class: Moderately well drained To Well drained
Permeability Class: Moderately slow To Moderate

	Minimum	Maximum
Depth (inches):	20	60
Electrical Conductivity (mmhos/cm):	0	4
Sodium Absorption Ratio:	0	5
Calcium Carbonate Equivalent (percent):	0	10

Soil Reaction (1:1 Water):	6.6	8.4
Soil Reaction (0.01M CaCl2):		
Available Water Capacity (inches):	3.0	6.3

Plant Communities

Ecological Dynamics of the Site

As this site deteriorates because of a combination of frequent and severe grazing, species such as blue grama and big sagebrush will increase. Cool-season grasses such as green needlegrass, needleandthread, and rhizomatous wheatgrasses will decrease in frequency and production.

Big sagebrush may become dominant on some areas with an absence of fire. Wildfires are actively controlled in recent times so chemical control using herbicides has replaced the historic role of fire on this site. Recently, prescribed burning has regained some popularity.

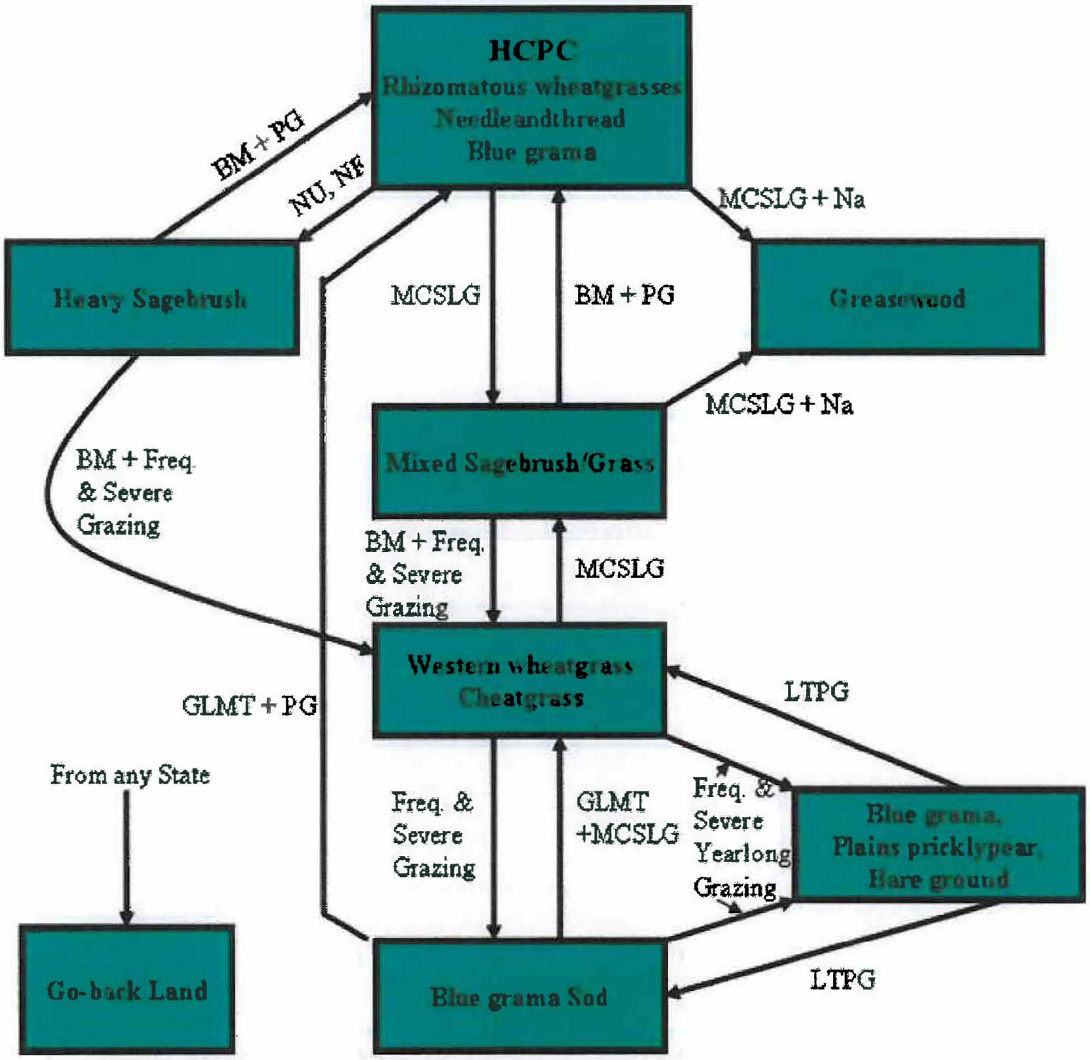
Due to the amount and pattern of the precipitation, the big sagebrush component typically is not resilient once it has been removed if a healthy and vigorous stand of grass exists and is maintained. The exception to this is where the herbaceous component is severely degraded at the time of treatment, growing conditions are unfavorable after treatment, and/or recovery periods are inadequate.

The Historic Climax Plant Community (description follows the plant community diagram) has been determined by study of rangeland relic areas, or areas protected from excessive disturbance. Trends in plant communities going from heavily grazed areas to lightly grazed areas, seasonal use pastures, and historical accounts have also been used.

The following is a State and Transition Model Diagram that illustrates the common plant communities (states) that can occur on the site and the transitions between these communities. The ecological processes will be discussed in more detail in the plant community narratives following the diagram.

Site Type: Rangeland
MLRA: 58B – Northern Rolling High Plains

Loamy 10-14" P.Z.
R058BY122WY



BM - Brush Management (fire, chemical, mechanical)
Freq. & Severe Grazing - Frequent and Severe Utilization of the Cool-season Mid-grasses during the Growing Season
GLMT - Grazing Land Mechanical Treatment
LTPG - Long-tem Prescribed Grazing
MCSLG - Moderate, Continuous Season-long Grazing
NU, NF - No Use and No Fire
PG - Prescribed Grazing (proper stocking rates with adequate recovery periods during the growing season)
VLTPG - Very Long-term Prescribed Grazing (could possibly take generations)
Na - found adjacent to a saline site

This plant community is the interpretive plant community for this site and is considered to be the Historic Climax Plant Community (HCPC). This plant community evolved with grazing by large herbivores and is well suited for grazing by domestic livestock. This plant community can be found on areas that are properly managed with grazing and/or prescribed burning, and sometimes on areas receiving occasional short periods of rest. The potential vegetation is about 75% grasses or grass-like plants, 15% forbs, and 10% woody plants. This state is dominated by cool season mid-grasses.

The major grasses include western wheatgrass, needleandthread, and green needlegrass. Other grasses occurring in this state include Cusick's and Sandberg's bluegrass, bluebunch wheatgrass, and blue grama. A variety of forbs and half-shrubs also occur, as shown in the preceding table. Big sagebrush is a conspicuous element of this state, occurs in a mosaic pattern, and makes up 5 to 10% of the annual production. Plant diversity is high.

The total annual production (air-dry weight) of this state is about 1,200 lbs./acre, but it can range from about 700 lbs./acre in unfavorable years to about 1,500 lbs./acre in above average years.

This plant community is extremely stable and well adapted to the Northern Great Plains climatic conditions. The diversity in plant species allows for high drought tolerance. This is a sustainable plant community (site/soil stability, watershed function, and biologic integrity).

Transitions or pathways leading to other plant communities are as follows:

• No use and no fire for 20 years or more will convert this plant community to the Heavy Sagebrush Plant Community.

• Moderate, continuous season-long grazing will convert the plant community to the Mixed Sagebrush/Grass Plant Community.

• Moderate continuous season-long grazing, where greasewood occurs adjacent to the site, will convert the plant community to the Greasewood Plant Community.

• When cropped annually and then abandoned without reseeding, the site is converted to the Go-back Land Plant Community.

Rhizomatous wheatgrasses/Needleandthread/Blue Grama Plant Community Plant Species Composition:

Grass/Grasslike

Group	Group Name	Common Name	Scientific Name	Annual Production in Pounds Per Acre Low	High
1				175	375
		thickspike wheatgrass	*Elymus lanceolatus ssp. lanceolatus*	175	375
		western wheatgrass	*Pascopyrum smithii*	175	375
2				105	225
		green needlegrass	*Nassella viridula*	105	225
3				175	375
		needle and thread	*Hesperostipa comata*	175	375

4				70	150
		Cusick's bluegrass	Poa cusickii	70	150
5				105	225
		blue grama	Bouteloua gracilis	105	225
6				175	375
		Indian ricegrass	Achnatherum hymenoides	35	75
		hairy grama	Bouteloua hirsuta	35	75
		needleleaf sedge	Carex duriuscula	35	75
		threadleaf sedge	Carex filifolia	35	75
		plains reedgrass	Calamagrostis montanensis	35	75
		prairie Junegrass	Koeleria macrantha	35	75
		Sandberg bluegrass	Poa secunda	35	75
		bluebunch wheatgrass	Pseudoroegneria spicata	35	75

Forb

Group	Group Name	Common Name	Scientific Name	Annual Production in Pounds Per Acre Low	High
7				105	225
		yarrow	Achillea	35	75
		textile onion	Allium textile	35	75
		rosy pussytoes	Antennaria rosea	35	75
		aster	Aster	35	75
		milkvetch	Astragalus	35	75
		tapertip hawksbeard	Crepis acuminata	35	75
		white prairie clover	Dalea candida	35	75
		purple prairie clover	Dalea purpurea	35	75
		sulphur-flower buckwheat	Eriogonum umbellatum	35	75
		scarlet beeblossom	Gaura coccinea	35	75
			Haplopappus acaulis (Syn)	35	75
		desertparsley	Lomatium	35	75
		bluebells	Mertensia	35	75
		large Indian breadroot	Pediomelum esculentum	35	75
		upright prairie coneflower	Ratibida columnifera	35	75
		American vetch	Vicia americana	35	75

Shrub/Vine

Group	Group Name	Common Name	Scientific Name	Annual Production in Pounds Per Acre Low	High
8				70	150
		big sagebrush	Artemisia tridentata	70	150
9				35	75
		winterfat	Krascheninnikovia lanata	35	75

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0

Mixed Sagebrush/Grass Plant Community

Historically, this plant community evolved under grazing by bison and a low fire frequency. Currently, it is found under moderate, season-long grazing by livestock in the absence of fire or brush management. Wyoming big sagebrush is a significant component of this plant community. Cool-season grasses make up the majority of the understory with the balance made up of short warm-season grasses, annual cool-season grasses, and miscellaneous forbs.

Dominant grasses include needleandthread, western wheatgrass, and green needlegrass. Grasses of secondary importance include blue grama, prairie junegrass, and Sandberg bluegrass. Forbs commonly found in this plant community include plains wallflower, hairy goldaster, slimflower scurfpea, and scarlet globemallow. Sagebrush canopy ranges from 20% to 30%. Fringed sagewort is commonly found. Plains pricklypear can also occur.

When compared to the Historic Climax Plant Community, sagebrush and blue grama have increased. Production of cool-season grasses, particularly green needlegrass, has been reduced. The sagebrush canopy protects the cool-season mid-grasses, but this protection makes them unavailable for grazing. Cheatgrass (downy brome) has invaded the site. The overstory of sagebrush and understory of grass and forbs provide a diverse plant community that will support domestic livestock and wildlife such as mule deer and antelope.

The total annual production (air-dry weight) of this state is about 900 pounds per acre, but it can range from about 700 lbs./acre in unfavorable years to about 1,200 lbs./acre in above average years.

This plant community is resistant to change. A significant reduction of big sagebrush can only be accomplished through fire or brush management. The herbaceous species present are well adapted to grazing; however, species composition can be altered through long-term overgrazing. If the herbaceous component is intact, it tends to be resilient if the disturbance is not long-term.

Transitions or pathways leading to other plant communities are as follows:

• Brush management (chemical, fire, or mechanical), followed by prescribed grazing, will convert this plant community to the Rhizomatous wheatgrasses, Needleandthread, Blue grama Plant Community. The probability of this occurring is high. When prescribed fire is used, sufficient fine fuels will need to be present. This may require deferment from grazing prior to treatment. Post management is critical to ensure success. This can range from two or more years of rest to partial growing season deferment, depending on the condition of the understory at the time of treatment and the growing conditions following treatment. In the case of an intense wildfire that occurs when desirable plants are not completely dormant, the length of time required to reach the Rhizomatous wheatgrasses, Needleandthread, Blue grama Plant Community may be increased.

• Brush management, followed by frequent and severe grazing, will convert the plant community to the Western Wheatgrass/Cheatgrass Plant Community. The probability of this occurring is high. If bare areas exist after treatment, along with no recovery periods from grazing, cheatgrass will invade and plants not as resistant to grazing as western wheatgrass will be reduced.

• Moderate continuous season-long grazing, where greasewood occurs adjacent to this state, will convert the plant community to the Greasewood Plant Community.

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0

Heavy Sagebrush Plant Community

This plant community is the result of long-term protection from grazing and fire. Sagebrush eventually dominates this plant community with canopy cover often exceeding 60%. At first, excessive litter builds up, shading out some of the grasses and forbs. Other plants become decadent with low vigor. Bunch grasses often develop dead centers. Eventually, the interspaces between plants increase in size leaving more soil surface exposed. Organic matter oxidizes in the air rather than being incorporated into the soil.

The dominant plants tend to be somewhat similar to those found in the Historic Climax Plant Community. Weedy species, cool-season grasses, and sedges have increased. Blue grama has decreased. Rodent activity has resulted in an increase in soil disturbance. Cactus and sageworts often increase. Noxious weeds such as Dalmatian toadflax, leafy spurge, or Canada thistle may invade the site if a seed source is present. Plant diversity is moderate to high.

The total annual production (air-dry weight) of this state is about 800 pounds per acre, but it can range from about 600 lbs./acre in unfavorable years to about 1,000 lbs./acre in above average years.

This plant community is not resistant to change and is more vulnerable to severe disturbance than the HCPC. The introduction of grazing or fire quickly changes the plant community.

Soil erosion is accelerated because of increased bare ground. Water flow patterns and pedestaling are obvious. Infiltration is reduced and runoff is increased.

Transitions or pathways leading to other plant communities are as follows:

• Brush management, followed by prescribed grazing, will return this plant community to at or near the Rhizomatous Wheatgrasses, Needleandthread, Blue Grama Plant Community.

• Brush management, followed by frequent and severe grazing, will convert the plant community to the Western Wheatgrass/Cheatgrass Plant Community. The probability of this occurring is high because of the amount of bare ground exposed to cheatgrass invasion.

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0

Western Wheatgrass/Cheatgrass Plant Community

This plant community is created when the Mixed Sagebrush/Grass Plant Community or the Heavy Sagebrush Plant Community is subjected to fire or brush management not followed by prescribed grazing. Rhizomatous wheatgrasses and annuals will eventually dominate the site.

Compared to the HCPC, cheatgrass has invaded with western wheatgrass and thickspike wheatgrass maintaining at a similar or slightly higher level. Virtually all other cool-season mid-grasses are severely decreased. Blue grama is the same or slightly less than found in the HCPC. Plant diversity is low.

The total annual production (air-dry weight) of this state is about 600 pounds per acre, but it can range from about 450 lbs./acre in unfavorable years to about 750 lbs./acre in above average years.

This plant community is relatively stable with the rhizomatous wheatgrasses being somewhat resistant to overgrazing and the cheatgrass effectively competing against the establishment of perennial cool-season grasses.

An increase in bare ground reduces water infiltration and increases soil erosion. The watershed is usually functioning. The biotic integrity is reduced by the lack of diversity in the plant community.

Transitions or pathways leading to other plant communities are as follows:

• Moderate continuous season-long grazing will eventually return this plant community to the Mixed Sagebrush/Grass Plant Community.

• Frequent and severe grazing will convert this plant community to Blue Grama Sod Plant Community.

• Frequent and severe yearlong grazing will convert this plant community to Blue grama, Plains Pricklypear, Bare Ground Plant Community.

• Long-term, prescribed grazing will eventually return this plant community to at or near the Rhizomatous Wheatgrasses, Needleandthread, Blue Grama Plant Community.

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0

Blue Grama Sod Plant Community

This plant community is the result of frequent and severe grazing during the growing season of the cool-season mid-grasses. A dense sod of blue grama dominates it. Pricklypear cactus can become dense enough so that livestock cannot graze forage growing within the cactus clumps.

When compared to the Historic Climax Plant Community, blue grama and threadleaf sedge have increased. All cool-season mid-grasses and forbs have been greatly reduced. Plant diversity is extremely low.

The total annual production (air-dry weight) of this state is about 600 pounds per acre, but it can range from about 450 lbs./acre in unfavorable years to about 750 lbs./acre in above average years.

This sod bound plant community is very resistant to water infiltration. While this sod protects the site itself, off-site areas are affected by excessive runoff that can cause gully erosion. This sod is very resistant to change and may require a grazing land mechanical treatment, such as chiseling, to return the cool-season grass component.

Transitions or pathways leading to other plant communities are as follows:

• Grazing land mechanical treatment (chiseling, etc.) and pricklypear cactus control (if needed), followed by prescribed grazing, will return this plant community to near Historic Climax Plant Community condition.

• Grazing land mechanical treatment, followed by moderate continuous season-long grazing, will convert this plant community to the Western Wheatgrass/Cheatgrass Plant Community.

• Frequent and severe yearlong grazing will eventually convert this state to the Blue Grama, Plains Pricklypear, Bare Ground Plant Community.

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0

Greasewood Plant Community

This plant community can occur where states are subjected to continuous season-long grazing at moderate stocking rates and where greasewood occurs adjacent to the site. It is dominated by an overstory of greasewood and possibly big sagebrush. Rhizomatous wheatgrasses, cheatgrass, and inland saltgrass make up the understory. Salts in the surface will increase due to the shedding of the salt-filled leaves of the greasewood. Plant diversity is high.

The total annual production (air-dry weight) of this state is about 700 pounds per acre, but it can range from about 525 lbs./acre in unfavorable years to about 875 lbs./acre in above average years.

This plant community is resistant to change. A significant reduction of greasewood can only be accomplished through repeated brush control treatments. The herbaceous species present are well adapted to grazing; however, species composition can be altered through long-term overgrazing. If the herbaceous component is intact, it tends to be resilient if the disturbance is not long-term.

The site is protected from erosion as long as ground cover is maintained. The biotic integrity of this state is somewhat intact because of the woody overstory and perennial grass understory. The watershed is functioning as long as a grass cover is maintained.

• Recovery to near Historic Climax Plant Community condition is difficult due to the resistance of greasewood to herbicides and accumulated effects of salts on the soil.

Plant Growth Curve:
Growth Curve Number: WY1401
Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0

Blue Grama Sod/Plains Pricklypear/Bare Ground Plant Community

This plant community is the result of frequent and severe yearlong grazing over the long-term. Perennial plants are decreased. Cheatgrass, annual weeds, and bare ground are increased. Plains pricklypear may have increased, rendering much of the forage unusable by livestock.

This plant community is highly variable depending on the severity, frequency, and duration of the grazing and also the condition of the plant community when this level of grazing began. Virtually all plants not resistant to overgrazing may have been eliminated. Dominant plants may include blue grama, threeawns, annuals, and, to a lesser degree, rhizomatous wheatgrasses. Perennial plant diversity is low.

The total annual production (air-dry weight) of this state is about 500 pounds per acre, but it can range from about 375 lbs./acre in unfavorable years to about 625 lbs./acre in above average years.

This state is unhealthy and subject to increased erosion. Runoff is high on this state due to the sod nature of blue grama and bare ground.

Transitions or pathways leading to other plant communities are as follows:

• Long-term prescribed grazing will convert this plant community initially to the Blue Grama Sod Plant Community, when this state is dominated by blue grama sod at the time of treatment.

• Long-term prescribed grazing will convert this plant community to the Western Wheatgrass /Cheatgrass Plant Community, when this state has large amounts of cheatgrass, annual weeds, and bare ground at the time of treatment. Control of plains pricklypear cactus may be necessary.

Reseeding areas with native plant species and proper grazing management may be necessary to accelerate recovery where few desirable plants remain.

Plant Growth Curve:
Growth Curve Number: WY1401

Growth Curve Name: 10-14NP upland sites
Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0

Go-back Land

This plant community occurs on land that has been cropped annually in the past and then abandoned without reseeding. Natural succession has resulted in a plant community dominated by varying combinations of red threeawn, cheatgrass, blue grama, Sandberg bluegrass, and some rhizomatous wheatgrasses. Forage production is low and grasses such as red threeawn and cheatgrass are not used efficiently by livestock.

The total annual production (air-dry weight) of this state is about 600 pounds per acre, but it can range from about 500 lbs./acre in unfavorable years to about 900 lbs./acre in above average years.

The potential for accelerated erosion can be highly variable depending on amount of bare ground present. Biological diversity is low.

Transitions or pathways leading to other plant communities are as follows:

• Prescribed grazing may be used to increase desirable native cool-season grass production. It is usually difficult to return to near Historic Climax Plant Community condition in a timely manner because of past soil loss.

• Grazing land mechanical treatment (i.e., chiseling) may improve forage production where significant rhizomatous wheatgrass is present to respond.

Where there is a lack of perennial grasses, reseeding to tame or native species may be necessary to return these lands to production in the form of pastureland. These pastures are normally seeded to crested wheatgrass, pubescent wheatgrass, or Russian wildrye. They require considerable investment to establish and have a variable life expectancy. They do produce up to 50% more than native range, but their value as forage is somewhat limited due to the single species usually seeded. In some cases, the single species or certain groups of species (e.g., wheatgrasses) may be more vulnerable to infestation by associated insects and/or diseases (e.g., black grass bugs).

Plant Growth Curve:
Growth Curve Number: WY1401
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Growth Curve Description:

Percent Production by Month

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	10	30	35	10	5	5	5	0	0

Ecological Site Interpretations

Animal Community:

Animal Community – Wildlife Interpretations

Rhizomatous Wheatgrasses, Needleandthread, Blue Grama Plant Community (HCPC): The predominance of grasses in this plant community favors grazers and mixed-feeders, such as bison, elk, and antelope. Suitable thermal and escape cover for deer may be limited due to the low quantities of woody plants. However, topographical variations could provide some escape cover. When found adjacent to sagebrush dominated states, this plant community may provide brood rearing/foraging areas for sage grouse, as well as lek sites. Other birds that would frequent this plant community include western meadowlarks, horned larks, and golden eagles. Many grassland obligate small mammals would occur here.

Mixed Sagebrush/Grass Plant Community: The combination of an overstory of sagebrush and an understory of grasses and forbs provide a very diverse plant community for wildlife. The crowns of sagebrush tend to break up hard crusted snow on winter ranges, so mule deer and antelope may use this state for foraging and cover year-round, as would cottontail and jack rabbits. It provides important winter, nesting, brood-rearing, and foraging habitat for sage grouse. Brewer's sparrows' nest in big sagebrush plants, and hosts of other nesting birds utilize stands in the 20-30% cover range.

Heavy Sagebrush Plant Community: This plant community can provide important winter foraging for elk, mule deer and antelope, as sagebrush can approach 15% protein and 40-60% digestibility during that time. This community provides excellent escape and thermal cover for large ungulates, as well as nesting and brood rearing habitat for sage grouse.

Western Wheatgrass/Cheatgrass Plant Community: This plant community may be useful for the same large grazers that would use the Historic Climax Plant Community. However, the plant community composition is less diverse, and thus, less apt to meet the seasonal needs of these animals. It may provide some foraging opportunities for sage grouse when it occurs proximal to woody cover. Good grasshopper habitat equals good foraging for birds.

Blue Grama Sod and Go-back Land Plant Communities: These communities provide limited foraging for antelope and other grazers. They may be used as a foraging site by sage grouse if proximal to woody cover and if the Historic Climax Plant Community or the Western Wheatgrass/Cheatgrass Plant Community is limiting. Generally, these are not target plant communities for wildlife habitat management.

Greasewood Plant Community: This plant community exhibits a low level of plant species diversity due to the accumulation of salts in the soil. It may provide some thermal and escape cover for deer and antelope if no other woody community is nearby, but in most cases it is not a desirable plant community to select as a wildlife habitat management objective.

Blue Grama, Plains Pricklypear, Bare Ground Plant Community: Benefits to other wildlife are largely due to the subterranean structure created by the prairie dogs, not the sparse vegetation found on this plant community.

Introduced Pasture: These communities are highly variable depending on the species planted. Refer to Forage Suitability Groups for more information.

Animal Community – Grazing Interpretations

The following table lists suggested stocking rates for cattle under continuous season-long grazing under normal growing conditions. These are conservative estimates that should be used only as guidelines in the initial stages of the conservation planning process. Often, the current plant composition does not entirely match any particular plant community (as described in this ecological site description). Because of this, a field visit is recommended, in all cases, to document plant composition and production. More precise carrying capacity estimates should eventually be calculated using this information along with animal preference data, particularly when grazers other than cattle are involved. Under more intensive grazing management, improved harvest efficiencies can result in an increased carrying capacity. If distribution problems occur, stocking rates must be reduced to maintain plant health and vigor.

Plant Community Production Carrying Capacity*
(lb./ac) (AUM/ac)
Rhizomatous WG, Needleandthread, Blue Grama 700-1500 .4
Heavy Sagebrush 800-1400 .3
Blue Grama Sod 400-1000 .2
Mixed Sagebrush/Grass 700-1200 .33
Western Wheatgrass/Cheatgrass 600-1200 .2
Blue grama, Plains Pricklypear, Bare ground 300-800 .1
Greasewood 525-875 .3
Go-back Land 500-900 .2

* - Continuous, season-long grazing by cattle under average growing conditions.

Grazing by domestic livestock is one of the major income-producing industries in the area. Rangeland in this area may provide yearlong forage for cattle, sheep, or horses. During the dormant period, the forage for livestock use needs to be supplemented with protein because the quality does not meet minimum livestock requirements.

Plant Preference by Animal Kind:

Animal Kind: All Antelope

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
yarrow	*Achillea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Indian ricegrass	*Achnatherum hymenoides*	Leaves	N	N	N	P	P	P	N	N	N	D	D	D
textile onion	*Allium textile*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	*Andropogon gerardii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sand bluestem	*Andropogon hallii*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rosy pussytoes	*Antennaria rosea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
silver sagebrush	*Artemisia cana*	Leaves	P	P	P	P	P	P	P	P	P	P	P	P
tarragon	*Artemisia dracunculus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort	*Artemisia frigida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	*Artemisia pedatifida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn	*Aristida purpurea var. longiseta*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	*Artemisia tridentata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
twogrooved milkvetch	*Astragalus bisulcatus*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
aster	*Aster*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	*Astragalus*	Entire plant	D	D	D	P	P	P	P	P	P	D	D	D
fourwing saltbush	*Atriplex canescens*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P

Gardner's saltbush	*Atriplex gardneri*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sideoats grama	*Bouteloua curtipendula*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
blue grama	*Bouteloua gracilis*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	*Bouteloua hirsuta*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
	Buchloe dactyloides (Syn)	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint	*Calamagrostis canadensis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needleleaf sedge	*Carex duriuscula*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
threadleaf sedge	*Carex filifolia*	Leaves	P	P	P	P	P	P	P	P	P	P	P	P
inland sedge	*Carex interior*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sandreed	*Calamovilfa longifolia*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
plains reedgrass	*Calamagrostis montanensis*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	*Carex nardina*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Nebraska sedge	*Carex nebrascensis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
yellow rabbitbrush	*Chrysothamnus viscidiflorus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
water hemlock	*Cicuta*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	*Conium maculatum*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	*Crepis acuminata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
white prairie clover	*Dalea candida*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
purple prairie clover	*Dalea purpurea*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
	Deschampsia caespitosa (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
saltgrass	*Distichlis spicata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	*Elymus caninus*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
Canada wildrye	*Elymus canadensis*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D
silverberry	*Elaeagnus commutata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
squirreltail	*Elymus elymoides ssp. elymoides*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
thickspike wheatgrass	*Elymus lanceolatus ssp. lanceolatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
slender wheatgrass	*Elymus trachycaulus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
horsetail	*Equisetum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	*Ericameria nauseosa*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sulphur-flower buckwheat	*Eriogonum umbellatum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom	*Gaura coccinea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	*Glycyrrhiza lepidota*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Haplopappus acaulis (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread	*Hesperostipa comata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	*Iris*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Juncus balticus (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Rocky Mountain juniper	*Juniperus scopulorum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie Junegrass	*Koeleria macrantha*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	*Krascheninnikovia lanata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
basin wildrye	*Leymus cinereus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
desertparsley	*Lomatium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluebells	*Mertensia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains muhly	*Muhlenbergia cuspidata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
mat muhly	*Muhlenbergia richardsonis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	*Nassella viridula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	*Pascopyrum smithii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot	*Pediomelum esculentum*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	*Pinus ponderosa*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Poa canbyi (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass	*Poa cusickii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P

plains cottonwood	*Populus deltoides ssp. monilifera*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass	*Poa secunda*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
	Poa secunda ssp. juncifolia (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
bluebunch wheatgrass	*Pseudoroegneria spicata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nuttall's alkaligrass	*Puccinellia nuttalliana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie coneflower	*Ratibida columnifera*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
skunkbush sumac	*Rhus trilobata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	*Rosa woodsii var. woodsii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
willow	*Salix*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
greasewood	*Sarcobatus vermiculatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
little bluestem	*Schizachyrium scoparium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
blue-eyed grass	*Sisyrinchium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
alkali sacaton	*Sporobolus airoides*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sand dropseed	*Sporobolus cryptandrus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
alkali cordgrass	*Spartina gracilis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Pursh seepweed	*Suaeda calceoliformis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	*Symphoricarpos occidentalis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Thermopsis rhombifolia var. annulocarpa (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	*Triglochin*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	*Typha angustifolia*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
broadleaf cattail	*Typha latifolia*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American vetch	*Vicia americana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca	*Yucca glauca*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: All Cattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
yarrow	*Achillea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U

Animal Kind: all Cattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Indian ricegrass	*Achnatherum hymenoides*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P

Animal Kind: All Cattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
textile onion	*Allium textile*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	*Andropogon gerardii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand bluestem	*Andropogon hallii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
rosy pussytoes	*Antennaria rosea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
tarragon	*Artemisia dracunculus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort	*Artemisia frigida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	*Artemisia pedatifida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn	*Aristida purpurea var. longiseta*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	*Artemisia tridentata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
aster	*Aster*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	*Astragalus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
fourwing saltbush	*Atriplex canescens*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Gardner's saltbush	*Atriplex gardneri*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sideoats grama	*Bouteloua curtipendula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue grama	*Bouteloua gracilis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	*Bouteloua hirsuta*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
	Buchloe dactyloides (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint	*Calamagrostis canadensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P

needleleaf sedge	*Carex duriuscula*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
threadleaf sedge	*Carex filifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland sedge	*Carex interior*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
prairie sandreed	*Calamovilfa longifolia*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains reedgrass	*Calamagrostis montanensis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	*Carex nardina*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nebraska sedge	*Carex nebrascensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
yellow rabbitbrush	*Chrysothamnus viscidiflorus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
water hemlock	*Cicuta*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	*Conium maculatum*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	*Crepis acuminata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
white prairie clover	*Dalea candida*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
purple prairie clover	*Dalea purpurea*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
	Deschampsia caespitosa (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
saltgrass	*Distichlis spicata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	*Elymus caninus*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Canada wildrye	*Elymus canadensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
silverberry	*Elaeagnus commutata*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
squirreltail	*Elymus elymoides ssp. elymoides*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
thickspike wheatgrass	*Elymus lanceolatus ssp. lanceolatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
slender wheatgrass	*Elymus trachycaulus*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
horsetail	*Equisetum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	*Ericameria nauseosa*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
sulphur-flower buckwheat	*Eriogonum umbellatum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom	*Gaura coccinea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	*Glycyrrhiza lepidota*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Haplopappus acaulis (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread	*Hesperostipa comata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	*Iris*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Juncus balticus (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Rocky Mountain juniper	*Juniperus scopulorum*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie Junegrass	*Koeleria macrantha*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	*Krascheninnikovia lanata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
basin wildrye	*Leymus cinereus*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
desertparsley	*Lomatium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluebells	*Mertensia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains muhly	*Muhlenbergia cuspidata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
mat muhly	*Muhlenbergia richardsonis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	*Nassella viridula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	*Pascopyrum smithii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot	*Pediomelum esculentum*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	*Pinus ponderosa*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Poa canbyi (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass	*Poa cusickii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains cottonwood	*Populus deltoides ssp. monilifera*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass	*Poa secunda*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: all Cattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
	Poa secunda ssp. juncifolia (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: All Cattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
bluebunch wheatgrass	*Pseudoroegneria spicata*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Nuttall's alkaligrass	*Puccinellia nuttalliana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie coneflower	*Ratibida columnifera*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
skunkbush sumac	*Rhus trilobata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	*Rosa woodsii var. woodsii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
willow	*Salix*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
greasewood	*Sarcobatus vermiculatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
little bluestem	*Schizachyrium scoparium*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
alkali sacaton	*Sporobolus airoides*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand dropseed	*Sporobolus cryptandrus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: all Cattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
alkali cordgrass	*Spartina gracilis*	Leaves	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: All Cattle

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Pursh seepweed	*Suaeda calceoliformis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	*Symphoricarpos occidentalis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Thermopsis rhombifolia var. annulocarpa (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	*Triglochin*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	*Typha angustifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
broadleaf cattail	*Typha latifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
American vetch	*Vicia americana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca	*Yucca glauca*	Fruits/Seeds	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: All Deer

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
yarrow	*Achillea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
textile onion	*Allium textile*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	*Andropogon gerardii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sand bluestem	*Andropogon hallii*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rosy pussytocs	*Antennaria rosea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
tarragon	*Artemisia dracunculus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort	*Artemisia frigida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	*Artemisia pedatifida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn	*Aristida purpurea var. longiseta*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	*Artemisia tridentata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Wyoming big sagebrush	*Artemisia tridentata ssp. wyomingensis*	Entire plant	P	P	P	P	P	P	D	D	D	D	D	D
twogrooved milkvetch	*Astragalus bisulcatus*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
aster	*Aster*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	*Astragalus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
fourwing saltbush	*Atriplex canescens*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Gardner's saltbush	*Atriplex gardneri*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sideoats grama	*Bouteloua curtipendula*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
blue grama	*Bouteloua gracilis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	*Bouteloua hirsuta*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
	Buchloe dactyloides (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint	*Calamagrostis canadensis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U

needleleaf sedge	Carex duriuscula	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
threadleaf sedge	Carex filifolia	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland sedge	Carex interior	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sandreed	Calamovilfa longifolia	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
plains reedgrass	Calamagrostis montanensis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	Carex nardina	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Nebraska sedge	Carex nebrascensis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
yellow rabbitbrush	Chrysothamnus viscidiflorus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
water hemlock	Cicuta	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	Conium maculatum	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	Crepis acuminata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
white prairie clover	Dalea candida	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
purple prairie clover	Dalea purpurea	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
	Deschampsia caespitosa (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
saltgrass	Distichlis spicata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	Elymus caninus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Canada wildrye	Elymus canadensis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
silverberry	Elaeagnus commutata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
squirreltail	Elymus elymoides ssp. elymoides	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
thickspike wheatgrass	Elymus lanceolatus ssp. lanceolatus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
slender wheatgrass	Elymus trachycaulus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
horsetail	Equisetum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	Ericameria nauseosa	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sulphur-flower buckwheat	Eriogonum umbellatum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom	Gaura coccinea	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	Glycyrrhiza lepidota	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Haplopappus acaulis (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread	Hesperostipa comata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	Iris	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Juncus balticus (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Rocky Mountain juniper	Juniperus scopulorum	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
prairie Junegrass	Koeleria macrantha	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	Krascheninnikovia lanata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
basin wildrye	Leymus cinereus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
desertparsley	Lomatium	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluebells	Mertensia	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains muhly	Muhlenbergia cuspidata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
mat muhly	Muhlenbergia richardsonis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	Nassella viridula	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	Pascopyrum smithii	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot	Pediomelum esculentum	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	Pinus ponderosa	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Poa canbyi (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass	Poa cusickii	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains cottonwood	Populus deltoides ssp. monilifera	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass	Poa secunda	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
	Poa secunda ssp. juncifolia (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
bluebunch wheatgrass	Pseudoroegneria spicata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nuttall's alkaligrass	Puccinellia nuttalliana	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie														

coneflower	*Ratibida columnifera*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
prairie coneflower	*Ratibida*	Entire plant	D	D	D	P	P	P	D	D	D	D	D	D
skunkbush sumac	*Rhus trilobata*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	*Rosa woodsii var. woodsii*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
willow	*Salix*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
greasewood	*Sarcobatus vermiculatus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
little bluestem	*Schizachyrium scoparium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
blue-eyed grass	*Sisyrinchium*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
alkali sacaton	*Sporobolus airoides*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
sand dropseed	*Sporobolus cryptandrus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
alkali cordgrass	*Spartina gracilis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Pursh seepweed	*Suaeda calceoliformis*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	*Symphoricarpos occidentalis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
	Thermopsis rhombifolia var. annulocarpa (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	*Triglochin*	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	*Typha angustifolia*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
broadleaf cattail	*Typha latifolia*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American vetch	*Vicia americana*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca	*Yucca glauca*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: All Horses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
yarrow	*Achillea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Indian ricegrass	*Achnatherum hymenoides*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
textile onion	*Allium textile*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	*Andropogon gerardii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand bluestem	*Andropogon hallii*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
rosy pussytoes	*Antennaria rosea*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
silver sagebrush	*Artemisia cana ssp. cana*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
tarragon	*Artemisia dracunculus*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort	*Artemisia frigida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	*Artemisia pedatifida*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn	*Aristida purpurea var. longiseta*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	*Artemisia tridentata*	Entire plant	U	U	U	N	N	N	N	N	N	U	U	U
aster	*Aster*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	*Astragalus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
fourwing saltbush	*Atriplex canescens*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Gardner's saltbush	*Atriplex gardneri*	Entire plant	D	D	D	U	U	U	U	U	U	D	D	D
sideoats grama	*Bouteloua curtipendula*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue grama	*Bouteloua gracilis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	*Bouteloua hirsuta*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
	Buchloe dactyloides (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint	*Calamagrostis canadensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
needleleaf sedge	*Carex duriuscula*	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
threadleaf sedge	*Carex filifolia*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland sedge	*Carex interior*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
prairie sandreed	*Calamovilfa longifolia*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains reedgrass	*Calamagrostis montanensis*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	*Carex nardina*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nebraska sedge	*Carex nebrascensis*	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
yellow rabbitbrush	*Chrysothamnus viscidiflorus*	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

water hemlock	Cicuta	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	Conium maculatum	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	Crepis acuminata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
white prairie clover	Dalea candida	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
purple prairie clover	Dalea purpurea	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
	Deschampsia caespitosa (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
saltgrass	Distichlis spicata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	Elymus caninus	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Canada wildrye	Elymus canadensis	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
silverberry	Elaeagnus commutata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
squirreltail	Elymus elymoides ssp. elymoides	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
thickspike wheatgrass	Elymus lanceolatus ssp. lanceolatus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
slender wheatgrass	Elymus trachycaulus	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
horsetail	Equisetum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	Ericameria nauseosa	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
sulphur-flower buckwheat	Eriogonum umbellatum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom	Gaura coccinea	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	Glycyrrhiza lepidota	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Haplopappus acaulis (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread	Hesperostipa comata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	Iris	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Juncus balticus (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Rocky Mountain juniper	Juniperus scopulorum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie Junegrass	Koeleria macrantha	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	Kraschenninnikovia lanata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
basin wildrye	Leymus cinereus	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
desertparsley	Lomatium	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bluebells	Mertensia	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains muhly	Muhlenbergia cuspidata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
mat muhly	Muhlenbergia richardsonis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	Nassella viridula	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	Pascopyrum smithii	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot	Pediomelum esculentum	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	Pinus ponderosa	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Poa canbyi (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass	Poa cusickii	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains cottonwood	Populus deltoides ssp. monilifera	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass	Poa secunda	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: all Horses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
	Poa secunda ssp. juncifolia (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: All Horses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
bluebunch wheatgrass	Pseudoroegneria spicata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Nuttall's alkaligrass	Puccinellia nuttalliana	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie coneflower	Ratibida columnifera	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
skunkbush sumac	Rhus trilobata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	Rosa woodsii var. woodsii	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U

willow	Salix	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: all Horses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
greasewood	Sarcobatus vermiculatus	Leaves	U	U	U	U	U	U	U	U	U	U	U	U

Animal Kind: All Horses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
little bluestem	Schizachyrium scoparium	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue-eyed grass	Sisyrinchium	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
alkali sacaton	Sporobolus airoides	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand dropseed	Sporobolus cryptandrus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: all Horses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
alkali cordgrass	Spartina gracilis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: All Horses

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
Pursh seepweed	Suaeda calceoliformis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	Symphoricarpos occidentalis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Thermopsis rhombifolia var. annulocarpa (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	Triglochin	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	Typha angustifolia	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
broadleaf cattail	Typha latifolia	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
American vetch	Vicia americana	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca	Yucca glauca	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Animal Kind: All Sheep

Common Name	Scientific Name	Plant Part	J	F	M	A	M	J	J	A	S	O	N	D
yarrow	Achillea	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Indian ricegrass	Achnatherum hymenoides	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
textile onion	Allium textile	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
big bluestem	Andropogon gerardii	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand bluestem	Andropogon hallii	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
rosy pussytoes	Antennaria rosea	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
silver sagebrush	Artemisia cana	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
tarragon	Artemisia dracunculus	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie sagewort	Artemisia frigida	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
birdfoot sagebrush	Artemisia pedatifida	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Fendler threeawn	Aristida purpurea var. longiseta	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
big sagebrush	Artemisia tridentata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Wyoming big sagebrush	Artemisia tridentata ssp. wyomingensis	Entire plant	P	P	P	D	D	D	D	D	D	P	P	P
twogrooved milkvetch	Astragalus bisulcatus	Entire plant	N	N	N	T	T	T	T	T	T	T	T	T
aster	Aster	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
milkvetch	Astragalus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
fourwing saltbush	Atriplex canescens	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Gardner's saltbush	Atriplex gardneri	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue grama	Bouteloua gracilis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
hairy grama	Bouteloua hirsuta	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
	Buchloe dactyloides (Syn)	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluejoint	Calamagrostis canadensis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
needleleaf sedge	Carex duriuscula	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U

threadleaf sedge	Carex filifolia	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
inland sedge	Carex interior	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
prairie sandreed	Calamovilfa longifolia	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
plains reedgrass	Calamagrostis montanensis	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
spike sedge	Carex nardina	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Nebraska sedge	Carex nebrascensis	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
yellow rabbitbrush	Chrysothamnus viscidiflorus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
water hemlock	Cicuta	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
poison hemlock	Conium maculatum	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
tapertip hawksbeard	Crepis acuminata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
white prairie clover	Dalea candida	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
purple prairie clover	Dalea purpurea	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
	Deschampsia caespitosa (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
saltgrass	Distichlis spicata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
bearded wheatgrass	Elymus caninus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Canada wildrye	Elymus canadensis	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
silverberry	Elaeagnus commutata	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
squirreltail	Elymus elymoides ssp. elymoides	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
thickspike wheatgrass	Elymus lanceolatus ssp. lanceolatus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
slender wheatgrass	Elymus trachycaulus	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
horsetail	Equisetum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
rubber rabbitbrush	Ericameria nauseosa	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
sulphur-flower buckwheat	Eriogonum umbellatum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
scarlet beeblossom	Gaura coccinea	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American licorice	Glycyrrhiza lepidota	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
broom snakeweed	Gutierrezia sarothrae	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Haplopappus acaulis (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
needle and thread	Hesperostipa comata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
iris	Iris	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Juncus balticus (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
Rocky Mountain juniper	Juniperus scopulorum	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
prairie Junegrass	Koeleria macrantha	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
winterfat	Krascheninnikovia lanata	Entire plant	P	P	P	D	D	D	D	D	D	P	P	P
basin wildrye	Leymus cinereus	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
desertparsley	Lomatium	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
bluebells	Mertensia	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains muhly	Muhlenbergia cuspidata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
mat muhly	Muhlenbergia richardsonis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
green needlegrass	Nassella viridula	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
western wheatgrass	Pascopyrum smithii	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
large Indian breadroot	Pediomelum esculentum	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
ponderosa pine	Pinus ponderosa	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Poa canbyi (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Cusick's bluegrass	Poa cusickii	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
plains cottonwood	Populus deltoides ssp. monilifera	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Sandberg bluegrass	Poa secunda	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
	Poa secunda ssp. juncifolia (Syn)	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
bluebunch wheatgrass	Pseudoroegneria spicata	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
Nuttall's alkaligrass	Puccinellia nuttalliana	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
upright prairie														

coneflower	Ratibida columnifera	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
skunkbush sumac	Rhus trilobata	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Woods' rose	Rosa woodsii var. woodsii	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
willow	Salix	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
greasewood	Sarcobatus vermiculatus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
little bluestem	Schizachyrium scoparium	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
blue-eyed grass	Sisyrinchium	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
sand dropseed	Sporobolus cryptandrus	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D
Pursh seepweed	Suaeda calceoliformis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
western snowberry	Symphoricarpos occidentalis	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
	Thermopsis rhombifolia var. annulocarpa (Syn)	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
arrowgrass	Triglochin	Entire plant	T	T	T	T	T	T	T	T	T	T	T	T
narrowleaf cattail	Typha angustifolia	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
broadleaf cattail	Typha latifolia	Entire plant	U	U	U	U	U	U	U	U	U	U	U	U
American vetch	Vicia americana	Entire plant	P	P	P	P	P	P	P	P	P	P	P	P
soapweed yucca	Yucca glauca	Entire plant	D	D	D	D	D	D	D	D	D	D	D	D

Legend: P = Preferred D = Desirable U = Undesirable N = Not consumed E = Emergency T = Toxic X = Used, but degree of utilization unknown

Hydrology Functions:
Water is the principal factor limiting forage production on this site. This site is dominated by soils in hydrologic group B and C, with localized areas in hydrologic group D. Infiltration ranges from moderately slow to moderate. Runoff potential for this site varies from low to moderate depending on soil hydrologic group and ground cover. In many cases, areas with greater than 75% ground cover have the greatest potential for high infiltration and lower runoff. An example of an exception would be where short-grasses form a strong sod and dominate the site. Areas where ground cover is less than 50% have the greatest potential to have reduced infiltration and higher runoff (refer to Part 630, NRCS National Engineering Handbook for detailed hydrology information).

Rills and gullies should not typically be present. Water flow patterns should be barely distinguishable if at all present. Pedestals are only slightly present in association with bunchgrasses. Litter typically falls in place, and signs of movement are not common. Chemical and physical crusts are rare to non-existent. Cryptogamic crusts are present, but only cover 1-2% of the soil surface.

Recreational Uses:
This site provides hunting opportunities for upland game species. The wide variety of plants which bloom from spring until fall have an esthetic value that appeals to visitors.

Wood Products:
No appreciable wood products are present on the site.

Other Products:
None noted.

Other Information:

Supporting Information

Associated Sites:

Site Name	Site ID	Site Narrative
Clayey (Cy) 10-14" Northern Plains Precipitation Zone	R058BY104WY	Clayey
Lowland (LL) 10-14" Northern Plains Precipitation Zone	R058BY128WY	Lowland
Overflow (Ov) 10-14" Northern Plains Precipitation Zone	R058BY130WY	Overflow
Sandy (Sy) 10-14" Northern Plains Precipitation Zone	R058BY150WY	Sandy
Shallow Loamy (SwLy) 10-14" Northern Plains Precipitation Zone	R058BY162WY	Shallow Loamy

Similar Sites:

Site Name	Site ID	Site Narrative
Loamy (Ly) 15-17" Northern Plains Precipitation Zone	R058BY222WY	Loamy 15-17" Northern Plains P.Z. has higher production.

State Correlation:
This site has been correlated with the following states:
MT

Inventory Data References:
Information presented here has been derived from NRCS clipping data and other inventory data. Field observations from range trained personnel was also used. Those involved in developing this site include: Glen Mitchell, Range Management Specialist, NRCS; Chuck Ring, Range Management Specialist, NRCS; and Everet Bainter, Range Management Specialist. Other sources used as references include USDA NRCS Water and Climate Center, USDA NRCS National Range and Pasture Handbook, and USDA NRCS Soil Surveys from various counties.

Inventory Data References
Data Source Number of Records Sample Period State County
SCS-RANGE-417 12 1971-1994 WY Campbell & others
Ocular estimates 5 1990-1999 WY Campbell & others

Type Locality:

Relationship to Other Established Classifications:

Other References:
Field Offices
Buffalo, Douglas, Gillette, Lusk, Newcastle, Sheridan

Site Description Approval:

Author	Date	Approval	Date
G. Mitchell	4/25/2000	E. Bainter	3/7/2008

Reference Sheet

Author(s)/participant(s):

Contact for lead author:

Date: 4/1/2005 **MLRA:** 058B **Ecological Site:** Loamy (Ly) 10-14" Northern Plains Precipitation Zone R058BY122WY This *must* be verified based on soils and climate (see Ecological Site Description). Current plant community cannot be used to identify the ecological site.

Composition (indicators 10 and 12) based on: X Annual Production, Foliar Cover, Biomass

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Indicators. For each indicator, describe the potential for the site. Where possible, (1) use numbers, (2) include expected range of values for above- and below-average years for **each** community and natural disturbance regimes within the reference state, when appropriate and (3) cite data. Continue descriptions on separate sheet.

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1. **Number and extent of rills:** Rills should not be present.

2. **Presence of water flow patterns:** Barely observable.

3. **Number and height of erosional pedestals or terracettes:** Essentially non-existent.

4. **Bare ground from Ecological Site Description or other studies (rock, litter, standing dead, lichen, moss, plant canopy are not bare ground):** Bare ground is 20-30% occurring in small areas throughout site.

5. **Number of gullies and erosion associated with gullies:** Active gullies should not be present.

6. **Extent of wind scoured, blowouts and/or depositional areas:** None

7. **Amount of litter movement (describe size and distance expected to travel):** Little to no plant litter movement. Plant litter remains in place and is not moved by erosional forces.

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):** Plant cover and litter is at 70% or greater of soil surface and maintains soil surface integrity. Soil Stability class is anticipated to be 5 or greater.

9. **Soil surface structure and SOM content (include type and strength of structure, and A-horizon color and thickness):** Use Soil Series description for depth and color of A-horizon.

10. **Effect on plant community composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:** Grass canopy and basal cover should reduce raindrop impact and slow overland flow providing increased time for infiltration to occur. Healthy deep rooted native grasses enhance infiltration and reduce runoff. Infiltration is Moderate.

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11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):** No compaction layer or soil surface crusting should be present.

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12. **Functional/Structural Groups (list in order of descending dominance by above-ground weight using symbols: >>, >, = to indicate much greater than, greater than, and equal to) with dominants and sub-dominants and "others" on separate lines:**
    Dominant: Cool Season Bunch grasses > Cool Season Rhizomatous grasses > Short stature grasses/grasslikes > Forbs = Shrubs
    Sub-dominant:
    Other:
    Additional:

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13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):** Very Low.

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14. **Average percent litter cover (%) and depth (inches):** Average litter cover is 25-35% with depths of 0.25 to 1.0 inches.

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15. **Expected annual production (this is TOTAL above-ground production, not just forage production:** 1200 lbs/ac

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16. **Potential invasive (including noxious) species (native and non-native). List Species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicator, we are describing what in NOT expected in the reference state for the ecological site:** Blue grama, Threadleaf sedge, Fringed sagewort, Prickly Pear, Big sagebrush, Broom Snakeweed, and Species found on Noxious Weed List

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17. **Perennial plant reproductive capability:** All species are capable of reproducing.

Reference Sheet Approval:

Approval	Date
E. Bainter	3/7/2008