Mailing Address:
Water Resources Data System
University of Wyoming, Dept 3943
1000 E University Avenue
Laramie, WY 82071

Physical Address:
Wyoming Hall, Room 249
University of Wyoming
Laramie, WY 82071

Phone: (307) 766-6651
Fax: (307) 766-3785

Funding for WRDS and the creation of this electronic document was provided by the Wyoming Water Development Commission (http://wwdc.state.wy.us)

UPPER GREEN WATERSHED STUDY
LEVEL I

For

Wyoming Water Development Commission

Sublette County Conservation District

Prepared by:

King Mapping Technologies

Parsons Water

SUNRISE ENGINEERING

47 E. 4th Avenue
Afton, WY 83110
Tel: (307) 885-8500
Fax: (307) 885-8501

Biota research & consulting inc.

140 East Broadway, Suite 23
Jackson, WY 83002
Tel: (307) 733-4216
Fax: (307) 733-1245

UPPER GREEN WATERSHED STUDY
LEVEL I

For

Wyoming Water Development Commission

Sublette County Conservation District

Professional Engineer (Civil)
F. DAVID KENNINGTON
9565
Date 12-23-14
WYOMING

Prepared by:

King Mapping Technologies

Parsons Water

SUNRISE ENGINEERING
47 E. 4th Avenue
Afton, WY 83110
Tel: (307) 885-8500
Fax: (307) 885-8501

Biota
140 East Broadway, Suite 23
Jackson, WY 83002
Tel: (307) 733-4216
Fax: (307) 733-1245

UPPER GREEN PROPOSED TABLE OF CONTENTS/REPORT FORMAT

Appendices contained in separate volume. Table of Contents for reference only. Our Upper Green tables and exhibits may differ.

FIGURES, EXHIBITS, TABLES AND CHARTS

I. INTRODUCTION

In June 2012 Sunrise Engineering was contracted by the Wyoming Water Development Commission (WWDC) to provide professional services for the preparation of the Upper Green River Watershed – Level I Study. The purpose of the contract was to provide professional and technical services necessary to 1) assess, describe, and inventory the watershed and 2) develop management and rehabilitation plans for the watershed. The watershed study provides both practical and economical recommendations that, if implemented, will help solve issues and realize opportunities identified during the inventory and assessment of the Upper Green River Watershed. Additionally, the study analyzes the potential for developing surface water within the Upper Green River watershed with particular emphasis on small upland water projects. These small upland projects include both public and private lands and are intended to advance grazing management through public-private partnerships that develop small and under-utilized water resources. Larger scale water storage was evaluated in light of the many studies already completed while relying on the detailed analysis and concepts of earlier studies. To date, at least sixty-seven State or Federal studies related to basin water resources have been completed. Twenty-two of these studies have a significant focus on reservoirs.

The study was conducted in association with Biota Research and Consulting, Inc. (Biota), Parsons Water Consulting (Parsons), King Mapping Technologies (King), Nelson Engineering (NE), and Surveyor Scherbel, LTD. (SS). Figure 1.1 Location Map; outlines the location and extent of the Upper Green watershed. The New Fork River Drainage, despite being part of the Upper Green River Watershed, was excluded due to its size and the potential for it to be a stand-alone watershed study in the future.

1.1 PROJECT OVERVIEW

The State of Wyoming has recognized the benefits of basin planning efforts within watersheds that frequently do not fit within political boundaries (e.g. cities, counties, or states). The WWDC describes the watershed planning process as follows:

> *"Today, conservation by watershed is an old concept with new horizons. Watersheds have long been recognized in the western United States for their significant natural resources and the interrelationships found contained in land areas connected by stream systems. These relationships were recognized by John Wesley Powell from his early expeditions of the west and resulted in proposed conservation, low density open grazing, irrigation systems and state boundaries based on watershed areas.*
>
> *The conservation concept developed over time to coalesce in the early 1930's with the formation of special districts whose boundaries were often based on watersheds. At that time the relationship between stream systems and landscape function was recognized. This relationship was broadened to embrace watershed condition and quality and its response to human influences. This further provided some understanding of the historic land use effect*

on watershed condition and how management and restoration needs to be based on local landscape characteristics.

Today, these relationships are embraced by the Wyoming Water Development Commission and Office through a watershed study program. On behalf of a local community sponsor, a watershed study can provide a comprehensive evaluation, analysis and description of the resources associated with a watershed and the watershed's water development opportunities. It is best stated that information related to the physical sciences is incorporated into a biological system.

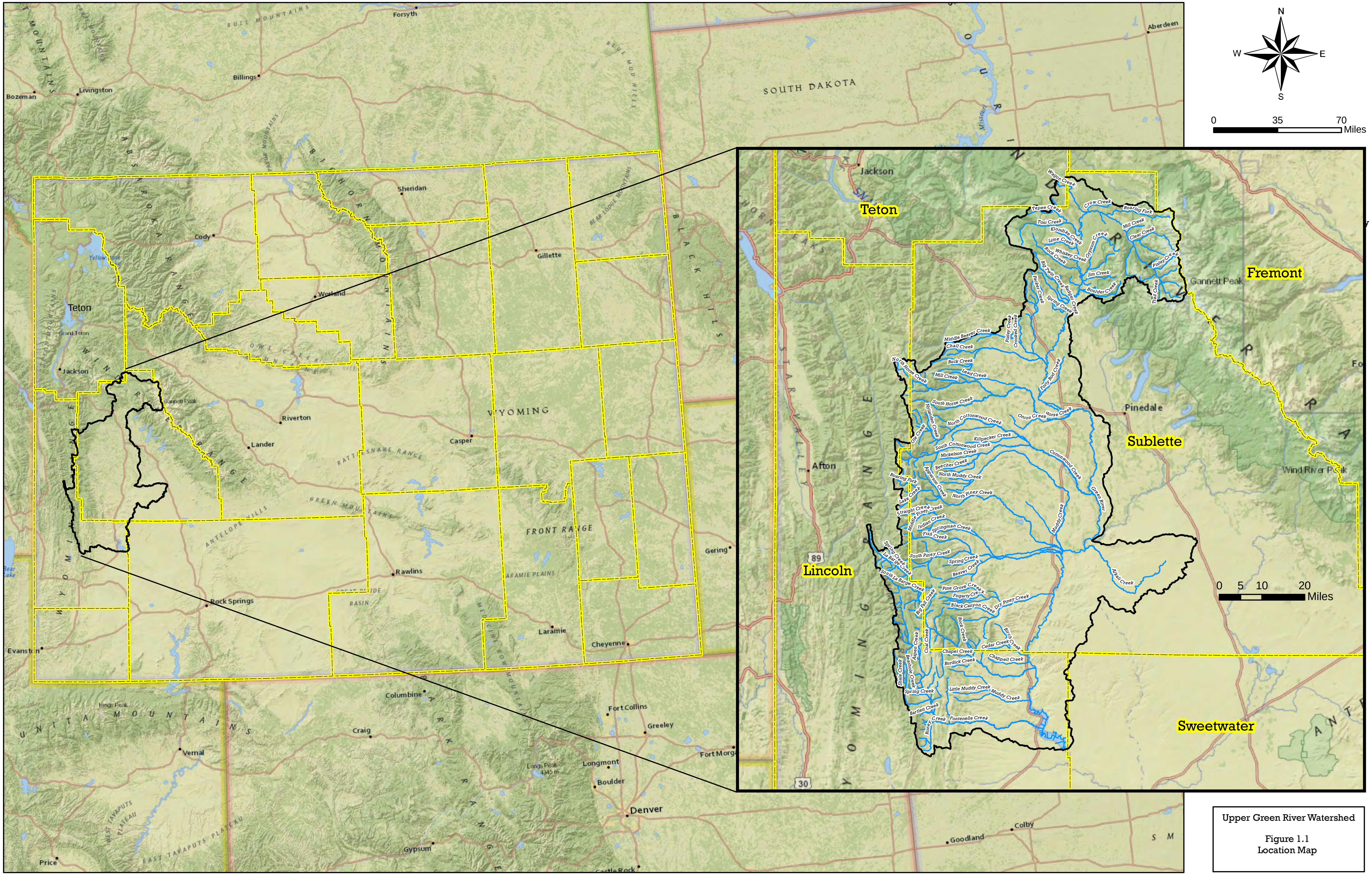
There are three prominent issues that are important considerations in a watershed information review and study. The first is surface water storage. Surface water storage is often of significant interest to a watershed community in order to address seasonal and/or annual shortages of water supply, augment late season stream flow to benefit riparian habitat, fisheries and wildlife, address flood impacts, enhance recreation opportunities, improve water quality and stream channel stability.

Second is the evaluation of irrigation infrastructure and development of information necessary to guide its rehabilitation and conservation. Of interest to local water users are ways to improve water delivery and on-farm irrigation efficiencies often timed to address annual or seasonal shortages of water supply or irrigation water delivery issues. Third is the enhancement of upland water resources and distribution for livestock and wildlife that allows grazing management adjustments for range resource improvement. Benefits to the watershed, through plant community invigoration, reduction of erosion and stream channel stabilization, can be achieved from water development projects being strategically implemented over the watershed. Other issues and opportunities such as making beneficial use of produced water and removal of high water demand invasive species can also be important.

A watershed study, providing management and rehabilitation plans for water storage, irrigation systems and upland water development, can help empower a community to proactively enhance their watershed. Conservation by watershed can be an effective holistic approach to embracing the natural resource challenges and opportunities facing a community. A watershed study can provide the information to meet those challenges."

The Upper Green River Watershed Study is one of several watershed planning studies that have been completed or are ongoing including:

Shell Valley Watershed Study
Prairie Dog Creek Watershed Study
Popo Agie River Watershed Study
Middle Platte Watershed Study
Little Snake River Watershed Study
Thunder Basin Watershed Study
Kirby Creek Watershed Study
Badwater-Poison Creek Watershed Study
Nowood Watershed Study
Clear Creek Watershed Study
Buffalo Creek Watershed Study
Sweetwater River Watershed Study
Cottonwood Creek/Grass Creek Watershed Study



Upper Green River Watershed

Figure 1.1
Location Map

Projection: NAD 83 - UTM Zone 12

1.2 BACKGROUND

Sublette County Conservation District; the project sponsor; requested the WWDC contract a study within the Upper Green River watershed in order to evaluate watershed function and to work with landowners to identify irrigation and upland livestock/wildlife water management and rehabilitation opportunities. Wetlands and riparian areas, development of a geomorphic classification for the watershed and a synopsis of past surface water storage efforts were of secondary interest to the District. The intent of the information generated from the watershed study is to provide baseline information from which the District can pursue implementation of management practices that address natural resource issues and capitalize on opportunities within the drainage.

The Upper Green River watershed is approximately 1.9 million acres in size and is located primarily within Sublette County (79%), to a lesser degree in eastern Lincoln County (20%), and a combined 1% in southeastern Teton County and northwestern Sweetwater County. The watershed includes the main stem of the Green River, the primary river system; a variety of larger tributaries including Tosi Creek, Klondike Creek, Rock Creek, Gypsum Creek, Beaver Creeks, Horse Creek, Cottonwood Creek, Piney Creeks, LaBarge Creek and Fontenelle Creek; and numerous smaller tributaries. Elevations range from the 13,804’ Gannett Peak down to the top of the Fontenelle Reservoir conservation pool at 6,506’.

Land ownership in the Upper Green drainage is a mixture of public (federal and state) and private land. The ownership breakdown is as follows: BLM (42%); Forest Service (30%); private land (23%); State of Wyoming (3%); The Nature Conservancy (.1%); and unknown (>1%). There are three incorporated municipalities within the project area; Big Piney and Marbleton in Sublette County, and La Barge in Lincoln County. In addition, there are 7 unincorporated towns within the project area; Daniel, Daniel Junction, Halfway, Merna, and Bronx in Sublette County, and Calpet and Viola in Lincoln County.

Administratively the study areas falls within Division IV of the State Engineers agency divisions and includes Districts 5, 10, and 11.

During preparation of this study it became apparent that the watershed faces the following general challenges with regard to its land and water resources:

- Distribution of water resources
- Energy development pressures on land and water resources
- Water quality
- Infrastructure maintenance
- Wildlife habitat preservation
- Rangeland health
- Maintenance of riparian habitat

1.3 PURPOSE AND SCOPE

The primary purpose of this Level I Study was to gather relevant existing information and combine that information with data generated by this study to form a comprehensive Watershed Management and Rehabilitation Plan. Specific objectives of the project include the following:

1. Conduct an evaluation and description of the watershed, including quantity and quality of surface water resources, and riparian/upland conditions.
2. Conduct an evaluation of water storage needs and opportunities to augment upland water available for livestock and wildlife.
3. Conduct an irrigation system inventory and develop a rehabilitation plan for those ditches expressing an interest to participate.
4. Promote public participation in the study.
5. Facilitate participation and consensus building with the landowners and the public at large, the Conservation District, and the Wyoming Water Development Commission.
6. Identify natural resource issues within the watershed and propose practical economic solutions.
7. Identify permits, easements, and clearances necessary for plan implementation.
8. Develop a watershed management and rehabilitation plan describing and prioritizing potential alternative projects and management strategies to address water resource related issues and potential water development opportunities identified in the watershed inventory.
9. Develop conceptual-level estimates of the costs of the potential projects identified in the watershed management and rehabilitation plan.
10. Compile and collate all spatial data, relevant published and unpublished reports, and collected information into a comprehensive digital library to facilitate the completion of this project and also to be available as a resource for the District and future studies.
11. Conduct a geomorphic investigation of primary tributary channels within the watershed and identify potential mitigation measures to improve impaired channel reaches.

1.4 POTENTIAL EFFECTS AND BENEFITS IDENTIFIED THROUGH A WATERSHED STUDY

The Wyoming Water Development Commission's (WWDC) Level I Watershed Study is a fundamental landscape analysis confined to a hydrologically connected drainage area or watershed and is focused on two primary components. The first is an identification of the physical attributes of that analysis area. This is accomplished by conducting a comprehensive inventory of the natural resources and subsequently using that inventory to articulate a description of the current natural resource conditions. The second is a long range plan outlining management and/or rehabilitation opportunities and activities that address ecological enhancement and watershed function.

Such activities, in the conservation community, are commonly referred to as best management practices (BMPs) or conservation practices. These BMPs and conservation practices are eligible for grant funding assistance through the WWDC's Small Water Project Program (SWPP). The WWDC's SWPP funds are mainly used for installing BMPs and conservation practices such as stock ponds, water wells, buried water delivery pipelines, stock tanks, spring developments, solar platforms and pumps, wetland enhancement and restoration, windmills, and irrigation diversion and conveyance improvements.

There can be one or more benefits resulting from the implementation of BMPs and conservation practices. Such benefits can be either quantitative, qualitative, or both. Benefits can be local or global, specific or surrogate, depending on multiple factors unique and specific to the BMP or conservation practice, ecological site, watershed, or major land resource area. BMPs and conservation practices also provide opportunities to relieve grazing pressure on riparian areas and create the potential to induce improvements to soil health, plant community diversity, and improved forage production. They allow for grazing deferment in the event that rest is required due to invasive species control efforts, which can also stimulate water release.

Benefits to ecosystem functionality and landscape health can be and is a response to soil health, water infiltration/percolation and a functioning water cycle. Expected project benefits can be related to watershed function including collection and storage of water along with ecological enhancements such as plant and animal habitat and stream corridor or riverine stability as well as societal values including economic stability and open space maintenance. Multiple benefits can result from improvement opportunities for water resources, which are critical to meet the daily water demands of the resident population of man and beast, develop, increase or extend irrigation water availability, and improve fishery habitat and potential recreational benefits.

1.4.1 NRCS CONSERVATION EFFECTS ASSESSMENT PROJECT

In 2003, in the interest of government accountability, Congress and the Office of Management and Budget requested information from the U.S. Department of Agriculture (USDA) about the effectiveness of its conservation programs. In response, the Conservation Effects Assessment Project (CEAP) was initiated by NRCS to provide quantitative information about the environmental impacts of its conservation practices on agricultural lands within the contiguous 48 United States. The CEAP is a joint effort of the NRCS, Agricultural Research Service (ARS), National Institute for Food and Agriculture, other federal agencies, and university scientists to quantify the environmental effects of conservation practices and develop the science base for managing the agricultural landscape for environmental quality. Initially focused on croplands, the CEAP effort was expanded to include wildlife, wetlands, pastures, and rangelands.

Project findings have been used to guide USDA conservation policy and program development that will assist conservationists, farmers, and ranchers with informed conservation decisions" [Spaeth et al., 2013]. The end product of the CEAP is a literature review and concise collation of information from hundreds of published scientific papers, journals, and additional references. Consequently, the CEAP documents provide a valuable source of information pertaining to BMPs incorporated in a watershed management plan and is referenced throughout the remainder of this document.

1.4.1.1 WATERSHED FUNCTION

Identifying improvement opportunities for hydrologic and watershed function, including water quantity, yield and use, is an essential element of the Level I Watershed Study. Hydrologically, there are three fundamental watershed functions: (1) collection of the water from rainfall, snowmelt, and storage that becomes runoff, (2) storage of various amounts and durations, and (3) discharge of water as runoff [Black, 1997]. Watershed characteristics such as geologic structure, soils, landform, topography, vegetation, and climate influence the capture or collection of precipitation, infiltration and storage of surface and ground water, and the runoff or discharge of water.

1.4.1.2 WATER QUANTITY

Implementation of BMPs and conservation practices can affect water resource quantity through improvement of plant communities, vegetative diversity, and ecological site health achieved from water development and the creation of reliable water sources in areas devoid of such allows for the establishment of grazing systems and changes in grazing distribution.

Hydrological responses to grazing are strongly contingent on the vegetative community composition, with communities that provide greater cover and obstruction to overland flow, such as midgrass-dominated communities having greater hydrological function, including infiltration rate, than shortgrass-dominated communities [Wood and Blackburn 1981b; Thurow 1991; Natural Resources Conservation Service, 2011]. Poor water distribution has been the primary cause of poor livestock distribution [Holecheck, 1997]. Livestock distribution and grazing behavior can be modified by adjusting the location of supplemental feed and water, implementation of patch burns, and herding in addition to the traditional practice of fencing [Williams 1954; Ganskopp 2001; Fuhlendorf and Engle 2004; Bailey 2005]. Natural Resources Conservation Service [2011] reviewed many studies and found that water distribution, steep slopes, and high elevations unequivocally influenced livestock distribution. Also sufficient evidence existed to recommend that NRCS increase the role of herding and supplement placement along with water development and fences for managing livestock distribution [Natural Resources Conservation Service, 2011]. Section 4.2 will more particularly describe the livestock water sources in the Upper Green River watershed study area.

Soil vegetative cover is widely recognized as a critical factor in maintaining soil surface hydrologic condition and reducing soil erosion [Gifford, 1985; Natural Resources Conservation Service, 2011]. Stocking rates, regardless of grazing system, that reduce soil surface vegetative cover below a site-specific threshold increases detachment and mobilization of soil particles due to raindrop impact, decreases soil organic matter and soil aggregate stability, increases soil surface crusting and reduces soil surface porosity, and thus decreasing infiltration and increasing soil erosion and sediment transport [Blackburn, 1984]. Sufficient vegetative cover, critical soil cover, or residual biomass must remain during and following grazing to protect soil surface condition (e.g., porosity, aggregate stability, and organic matter) and hydrologic properties (e.g., infiltration), however, these site-specific vegetation cover requirements vary depending on cover type (e.g., vegetation, litter, or rock), soil type, rainfall intensities, and water quality goals [Gifford 1985]. The erosive energy of water and the long-term reduction of organic matter additions to soil detrimentally affect numerous soil properties, including the increase of bulk density, disruption of biotic crusts, reduced aggregate stability, and organic matter content, which collectively reduce infiltration rate and increase sediment yield and runoff [Natural Resources Conservation Service, 2011].

These efforts can increase water infiltration/percolation, stimulate spring flows and increase flow volume and duration. An example of restoring watershed function and water quantity was in a 74,000 acre watershed in West Texas near San Angelo where West Rocky Creek, a dry, intermittent stream for decades, started flowing again [Moseley, 1983; Wiedenfeld, 1986]. In the early part of the 20th century, West Rocky Creek was a yearlong flowing stream until the late 1910s, when it became an intermittent stream and by 1935, the springs feeding the creek had been dried up by mesquite and other invading woody plants [Moseley, 1983; Wiedenfeld, 1986].

During the 1950s and 1960s, ranchers and landowners on five ranches, covering about half the watershed, began conservation work including root-plowing, reseeding, tree-dozing, aerial spraying, and chaining of mainly mesquite and juniper brush, which limited water availability for native grasses such as sideoats grama, buffalograss, curly mesquite, and tobosa [Moseley, 1983]. About 30,000 acres or 70 percent of the mesquite was removed from the watershed, and the original prairie was restored [Moseley, 1983; Wiedenfeld, 1986]. In the mid to late 1960s, one of the 5 ranchers noticed that a spring, which was dry since 1935, had started flowing again and by replacing the water-hungry brush with a good grass cover, more rainfall soaked into the aquifer, recharging the dormant springs which began flowing on all 5 ranches by 1970 [Moseley, 1983]. Ongoing grazing management on each ranch enhanced the cover of grasses in the watershed with soils producing an estimated 2,000 to 2,500 pounds of forage per acre which helps retard brush succession; the ranchers periodically must do maintenance brush control to keep the desired vegetation balance [Moseley, 1983].

In southeast Arizona, long-term data on soils, vegetation, hydrology, and climate have been collected for over five decades on the Walnut Gulch Experimental Watershed, which is operated by the USDA’s Agricultural Research Service (ARS). The Walnut Gulch Experimental Watershed is one of the most intensively instrumented semiarid experimental watersheds in the world, with a 10 to 100-year record of abiotic and biotic measurements and photographs [Moran et al, 2008]. Researchers studied the interaction between rainfall intensity and soils and vegetation by comparing the frequency of runoff producing summer events between a shrub-dominated watershed and a grass-dominated watershed and found that it takes higher rainfall intensities to produce runoff on the grassed watershed [USDA Agricultural Research Service, 2013]. Results also indicate that the grassland plant community is producing more plant material than the shrubland, with close to the same amount of precipitation input, making the grassland ecosystem more water use efficient [USDA Agricultural Research Service, 2013]. The researchers found that runoff quantities at the watershed scale are controlled more by infiltration of water into alluvial channels and spatial distribution of thunderstorm rainfall [USDA Agricultural Research Service, 2013].

1.4.1.3 ECOLOGICAL ENHANCEMENT

An ecological enhancement is any activity that improves an ecosystem such as stabilizing erosive soils, increasing soil quality, planting or maintaining native grasses, shrubs, or trees, removing and controlling invasive species, and improving or maintaining riparian/wetland areas. Ecological sites are complex and varied within a watershed study area. And so are the potential benefits achieved from project activities and implementations that influence the condition of those ecological sites and characteristics. Section 4 discusses several potential management and rehabilitation strategies.

Conjunctive to soil function is plant community diversity, health and productivity and subsequent forage diversity, production and wildlife habitat. Benefits accrued to water quality are significant as improvements to the chemical, physical, and biological constituents of a water body produce both local site enhancements and those transferred downstream. Wetland enhancement and restoration provides benefits to ecological stabilization as well as contributions to water quality and quantity. Ecologically, watersheds function by providing diverse sites and pathways along which vital chemical reactions occur and furnishing habitat for the flora and fauna that constitute the biological elements of ecosystems [Black, 1997].

1.4.1.4 PLANT AND ANIMAL HABITAT

Locations of conservation practices and rangeland infrastructure can have a large, indirect impact on overall vegetation change with the spatial design of infrastructure including the locations of fences, watering points, and feeders that are used to modify patterns of animal movement and forage utilization, taking into account livestock behavior and the template of topography and plant communities to which livestock respond [Laca, 2009; Natural Resources Conservation Service, 2011]. The use of rangelands for sustainable livestock production has the potential to ensure the maintenance of wildlife habitat which will ensure that wildlife habitat will persist into the future [Natural Resources Conservation Service, 2011]. Livestock grazing can have negative or positive impacts on game bird habitat, depending on timing and intensity of grazing and the habitat being influenced [Beck and Mitchell, 2000]. Wildlife responses to conservation practices are usually species and even species-habitat specific, meaning not only that each species may respond differently to any specific practice but also that a single species may respond differently to the same practice in different vegetation associations or conditions [Natural Resources Conservation Service, 2011].

Free-stranding water has been considered to be a resource that limits distribution and abundance of many species of wildlife in arid regions of the United States, and water developments have been used since the 1940s to improve wildlife habitat [Simpson et al, 2011]. Simpson et al [2011] compiled and evaluated available literature for evidence of effects of water sources on wildlife populations. Positive effects of water developments on wildlife have been documented, and species thought previously not to use free-standing water developments do so when it is available [Simpson et al, 2011]. Additionally, researchers studied effects of wildlife water developments in southwestern Arizona and found that water developments were used by a diverse array of wildlife, including mule deer, game birds, a number of nongame species [Rosenstock et al, 2004].

1.4.1.5 STREAM CORRIDORS AND RIPARIAN/WETLAND AREAS

Reducing impact to riparian plant communities through the development of upland water resources can result in stream corridor benefits. Riparian plant community diversity and regeneration of desirable important woody species can help restore local water tables, trap sediments, increase wildlife habitat and migration corridors, and stabilize stream banks which can affect localized land loss. In addition, aquatic population benefits can accrue and recreation potential can be realized.

Livestock distribution practices such as water developments, supplement placement, and herding are effective means of managing the intensity and season of livestock grazing in riparian areas [Natural Resources Conservation Service, 2011]. Season of grazing also determines livestock grazing effects on riparian plant communities, particularly woody plants, and can be managed to conserve riparian habitats and their associated services [Natural Resources Conservation Service, 2011]. Sufficient evidence in peer-reviewed studies existed that Natural Resources Conservation Service [2011] suggested riparian grazing management that maintains or enhances key riparian vegetation attributes (i.e., species composition, root mass and root density, cover, and biomass) will enhance stream channel and riparian soil stability, which will in turn support ecosystem services, such as flood and pollutant attenuation and high-quality riparian habitat. Peer-reviewed literature generally supports the effectiveness of water developments, supplement placement and herding for reducing riparian vegetation utilization, or time spent in riparian areas [Natural Resources Conservation Service, 2011].

1.4.1.6 SOCIETAL VALUE

Natural resource stewardship not only has economic value in terms of forage, livestock, and wildlife production relationships, but also can have non-economic value placed on those conservation practices by society. Those values can even influence the perception of those implementing conservation practices and can be as much an influence in the decision process to implement conservation as is an economic value. Additionally, it is possible for a BMP or conservation practice that provides an ecological service to accrue more value to society in general than to a local landowner. Ecosystem services are defined as those things or experiences produced by natural systems on which humans place value [Natural Resources Conservation Service, 2011]. Ecosystem services benefit society in numerous and diverse ways while each of the conservation practices can potentially produce different kinds, qualities, and amounts of these goods and services, depending on location, natural potentials, current states, and other factors.

Non-economic values can and should be considered in determining watershed enhancement programs, particularly when considering public investment in conservation. The Natural Resources Conservation Service [2011] found little to no research exists showing the direct noneconomic effects of BMPs and conservation practices on individuals, households, or social systems but acknowledged it was likely that producers do realize psychological benefits from conservation because stewardship typically ranks high among the management goals of livestock producers [Huntsinger and Fortmann, 1990; Sayre, 2004]. Moreover, livestock producers who believe strongly in a responsibility to society are more likely to engage in environmentally desirable management practices, such as invasive weed control and riparian protection [Kreuter et al, 2006].

In 2012, in cooperation with the Wyoming Stock Growers Association (WGSA), University of Wyoming, and University of California-Davis, research scientists with the USDA's ARS Rangeland Resources Research Unit in Cheyenne, Wyoming investigating effects of rangeland management decision-making asked WGSA producer members about their goals, ranching operations, and management practices via a mail survey and received a total of 307 rancher responses to the survey [Kacheris et al, 2013; Wyoming Livestock Roundup, 2013]. Livestock production and forage production were the top management goals, with ecosystem characteristics that support these goals (e.g., soil health, water quality) tied for second [Kacheris et al, 2013; Wyoming Livestock Roundup, 2013].

In addition to other social values and ecological enhancements, open spaces have long been held with high value to Wyoming and other western region states. From a ranching industry perspective, tourism interest, outdoor recreationist activity, or a real estate value, open space is significant. Preservation of our custom and culture has been and continues to be a focal point of consideration. Open spaces are critical for upland/riparian conductivity, wildlife migrations and habitat, and recreational opportunity. Open space is valued for preservation of cultural resources and for the reduction or prevention of land conversion to a condition that can be stewarded to an improved ecological condition.

1.4.2 EXAMPLES OF EFFECTS AND BENEFITS OF WATERSHED MANAGEMENT PLAN COMPONENTS

The watershed management and rehabilitation plan and components presented in the final report of a watershed study provides recommendations for improvements for the following:

- Irrigation system rehabilitation components
- Livestock/wildlife upland watering opportunities
- Grazing management opportunities
- Storage opportunities
- Stream channel condition and stability
- Wetland enhancement opportunities
- Other watershed management opportunities.

An itemized priority list of components and associated conceptual cost estimates are typically tabulated in the watershed management plan along with specific recommendations for addressing water issues in the watershed. In the following sections, the potential effects and benefits associated with key BMPs and conservation practices are discussed in relation to the various plan components: Livestock/wildlife water supply, irrigation system rehabilitation, and stream channel. The intent of this discussion is to provide the decision makers with the background necessary to make informed decisions regarding future planning efforts.

The NRCS prepares Networks Effects Diagrams (NEDs) of conservation practices or BMPs which act together to achieve desired purposes. The NEDs "are flow charts of direct, indirect and cumulative effects resulting from installation of the practices. Completed network diagrams are an overview of expert consensus on the direct, indirect and cumulative effects of installing proposed practice installation. They show the potential positive and negative outcomes of practice installation, and are useful as a reference point for next steps, and as a communication tool with partners and the public" [Natural Resources Conservation Service, 2014].

Benefits associated with a particular conservation practice or BMP can be classified as direct, indirect or cumulative. Direct and indirect benefits would be considered measureable or tangible benefits. For example, construction of a reservoir designed to augment late season irrigation water supplies provides the direct or measurable benefit, of providing a supply of water commensurate with its storage capacity. An indirect benefit could be the habitat provided to wildlife. Likewise, the same reservoir could provide the cumulative benefit of increased income to producers and improved health of the local economy.

As previously discussed, such benefits can be quantitative, qualitative, or both. Benefits can be local or global and specific or surrogate, depending on multiple factors unique and specific to the BMP, ecological site, watershed, or major land resource area. Project benefits can be related to ecological enhancement, water quantity, economic stability, stream corridor or riverine stability, or maintenance of open spaces. Examples of the NRCS NED for common conservation practices and/or BMPs from a typical watershed management plan are presented in the following section of this document.

A broader supplemental Network Effects Diagrams (NEDs) spreadsheet is contained in Appendix K. With links to resource documents for over 160 conservation practices.

1.4.2.1 IRRIGATION WATER CONVEYANCE—PIPELINE

The rehabilitation and replacement of existing irrigation system delivery conveyance structures help to efficiently deliver or convey water from a source of supply or diversion structures to areas of application or storage to facilitate management of irrigation water. The practice reduces erosion, conserves water, and protects water quality. Underground pipelines serve as an integral part of the irrigation water distribution system and significantly improve the overall efficiency of the system. Several irrigation projects were identified during completion of this study and are outlined in Section 5.4.

Strategies defining placement of irrigation water conveyance pipelines typically involve:

- Rehabilitation/replacement of existing structures
- Mitigation of seepage losses
- Enhanced delivery of irrigation water
- Reduction in annual operation and maintenance costs
- Improvement in ditch management and efficiency through water management

- Facilitation of irrigation water management plans
- Economic practicality
- Physical feasibility.

Effects and benefits of rehabilitating and improving water conveyance for irrigation systems are numerous and are displayed in the NRCS's NED in Figure 1.4.2.1 As shown in this figure, direct and indirect benefits associated with this BMP include:

- Water availability for irrigation
    - Plant growth and productivity
- Infiltration and evaporation losses
    - Increased plant growth and productivity
    - Decreased leaching of nutrients
- Erosion associated with practice
    - Decreased sediment delivery to surface waters

Cumulative effects/benefits of provision of reliable water supplies are described as:

- Positive impacts to income and stability of individual producers and the community
- Improved aquatic health of humans, domestic animals and wildlife
- Improved stream fauna and environmental quality.

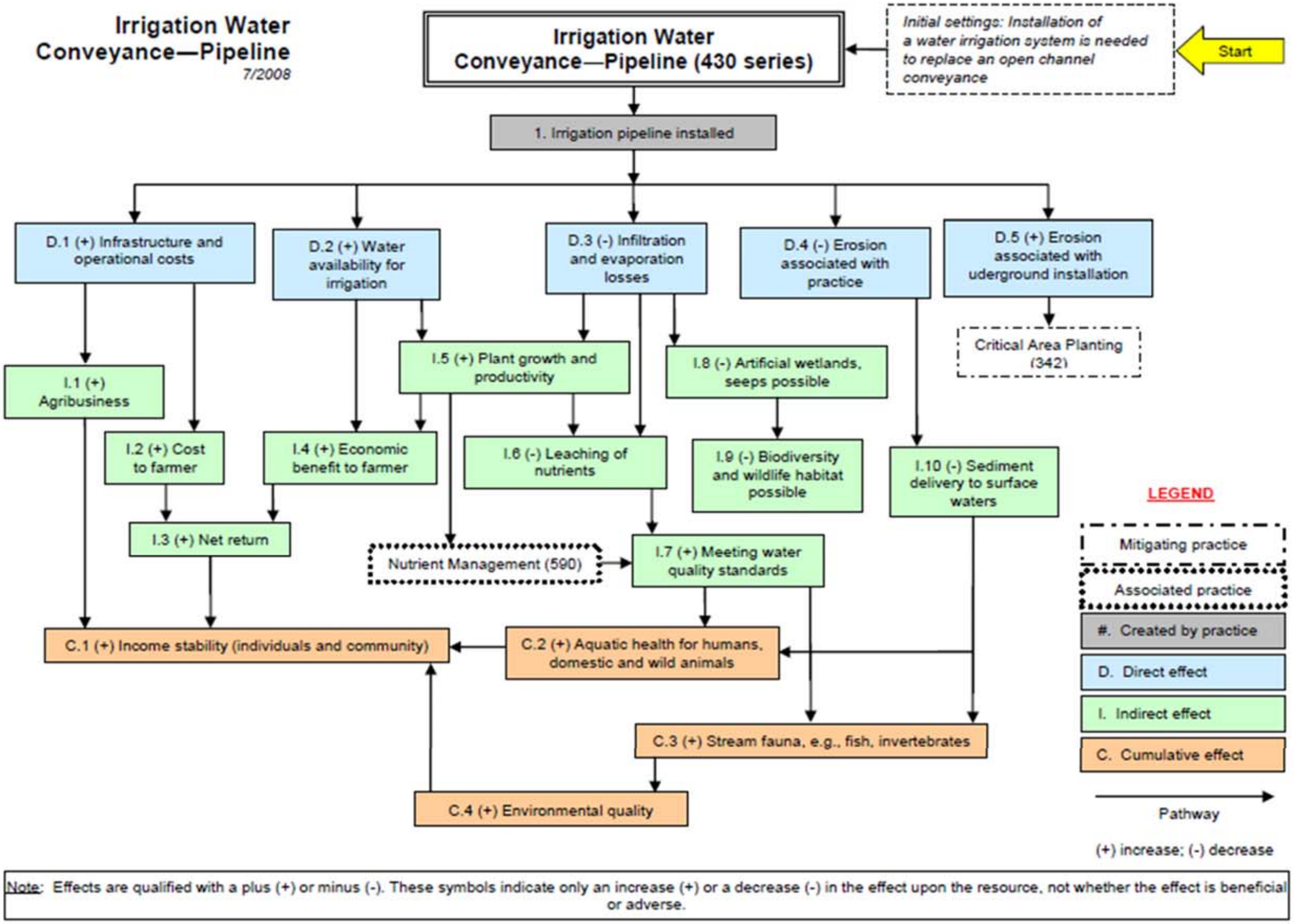


Figure 1.4.2.1 Network Effects Diagram for Irrigation Conveyance—Pipeline.

1.4.2.2 LIVESTOCK/WILDLIFE WATER SUPPLY FACILITIES

The development of reliable watering facilities in areas otherwise lacking reliable sources of water for livestock and wildlife, help to promote improved rangeland conditions in several ways. Watering facilities may be associated with wells, springs, streams, ponds or hauled water. Reliable water sources are integral aspects of a range management plan involving distribution of livestock. Section 4 contains basin specific upland water projects identified during completion of this study.

Strategies defining placement of water facilities typically involve:

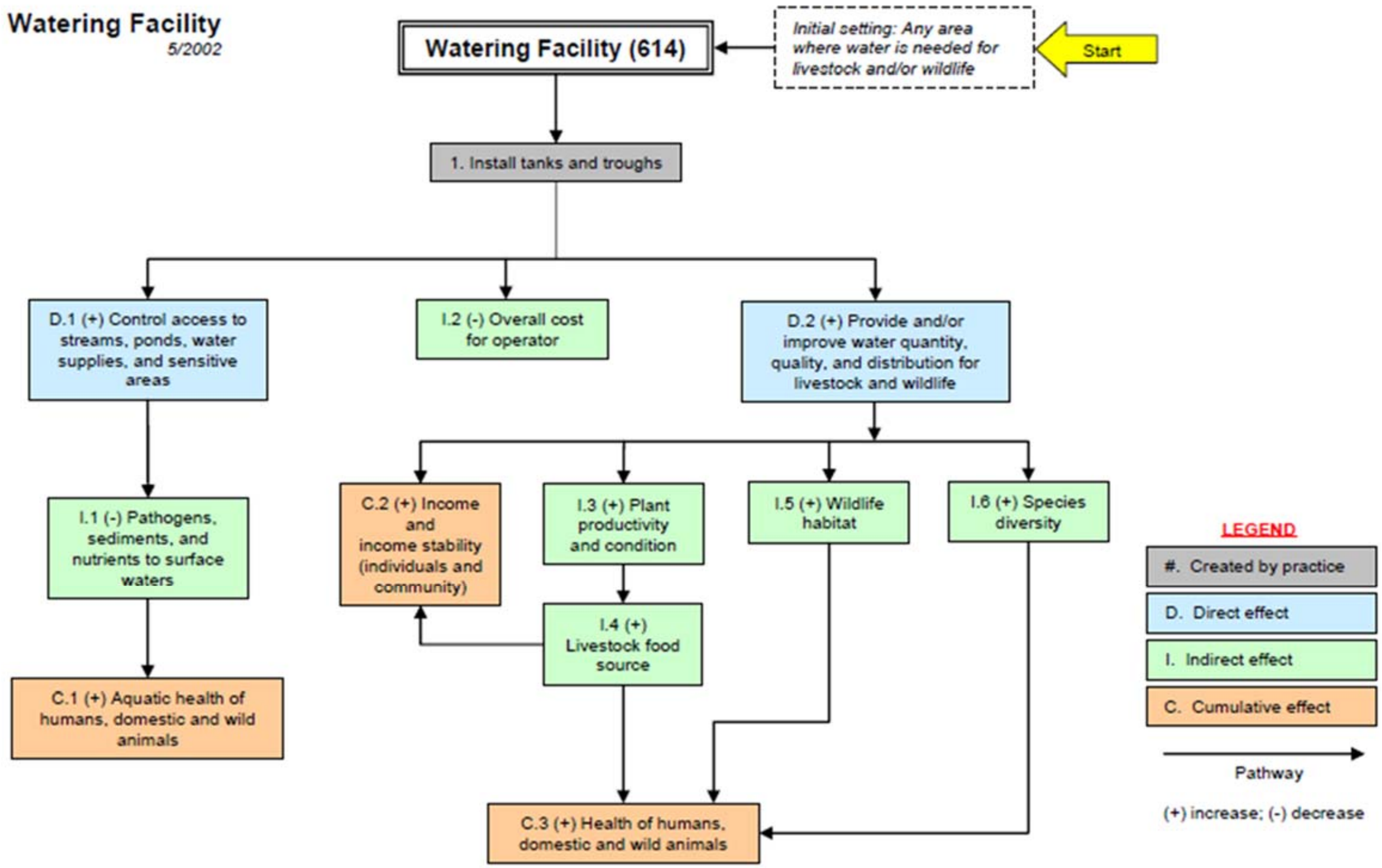
- Facilitation of prescribed grazing management plans
- Alternative water supplies to riparian sources
- Provision of a reliable source where no other sources may exist
- Optimization of upland range resources.

Benefits of providing reliable water facilities for livestock and wildlife are numerous and are displayed in the NRCS's NED in Figure 1.4.2.2. As shown in this figure, direct and indirect benefits associated with this BMP include:

- Controlled access to streams, ponds, water supplies, and sensitive areas (when combined with proper fencing),
    - Decreased loading of pathogens, sediments, and nutrients to existing surface waters,
- Improved water quality, quantity and distribution of livestock and wildlife
    - Increased plant productivity
    - Improved wildlife habitat
    - Increased species diversity
    - Increased livestock food sources

Cumulative benefits of provision of reliable water supplies are described as:

- Positive impacts to income and stability of individual producers and the community,
- Improved aquatic health of humans, domestic animals and wildlife, and
- Improved health of humans, domestic animals and wildlife.



Note: Effects are qualified with a plus (+) or minus (-). These symbols indicate only an increase (+) or a decrease (-) in the effect upon the resource, not whether the effect is beneficial or adverse.

Figure 1.4.2.2 Network Effects Diagram for Livestock/Wildlife Watering Facility

1.4.2.3 GRAZING MANAGEMENT AND PRESCRIBED GRAZING

The watershed study and management plan includes conservation practices and BMPs such as water developments, fencing, salting and herding, ecological sites and state and transition models, prescribed fire, and application of chemicals and other tools that can be used to facilitate and enhance grazing distribution and optimize range conditions through prescribed grazing. Prescribed grazing is the controlled harvest of vegetation with grazing animals managed with the intent to achieve a specific objective. Prescribed grazing may be applied on lands where grazing and/or browsing animals are managed. A grazing schedule is prepared for allotments, pastures to be grazed. Removal of vegetation by the grazing animals is in conformity with realistic yield goals, plant growth needs, and management goals. Duration and intensity of grazing is based on desired plant health and productivity of the forage species to meet management objectives.

Strategies for applying prescribed grazing involve managing the intensity, frequency, duration, distribution, and season of grazing by:

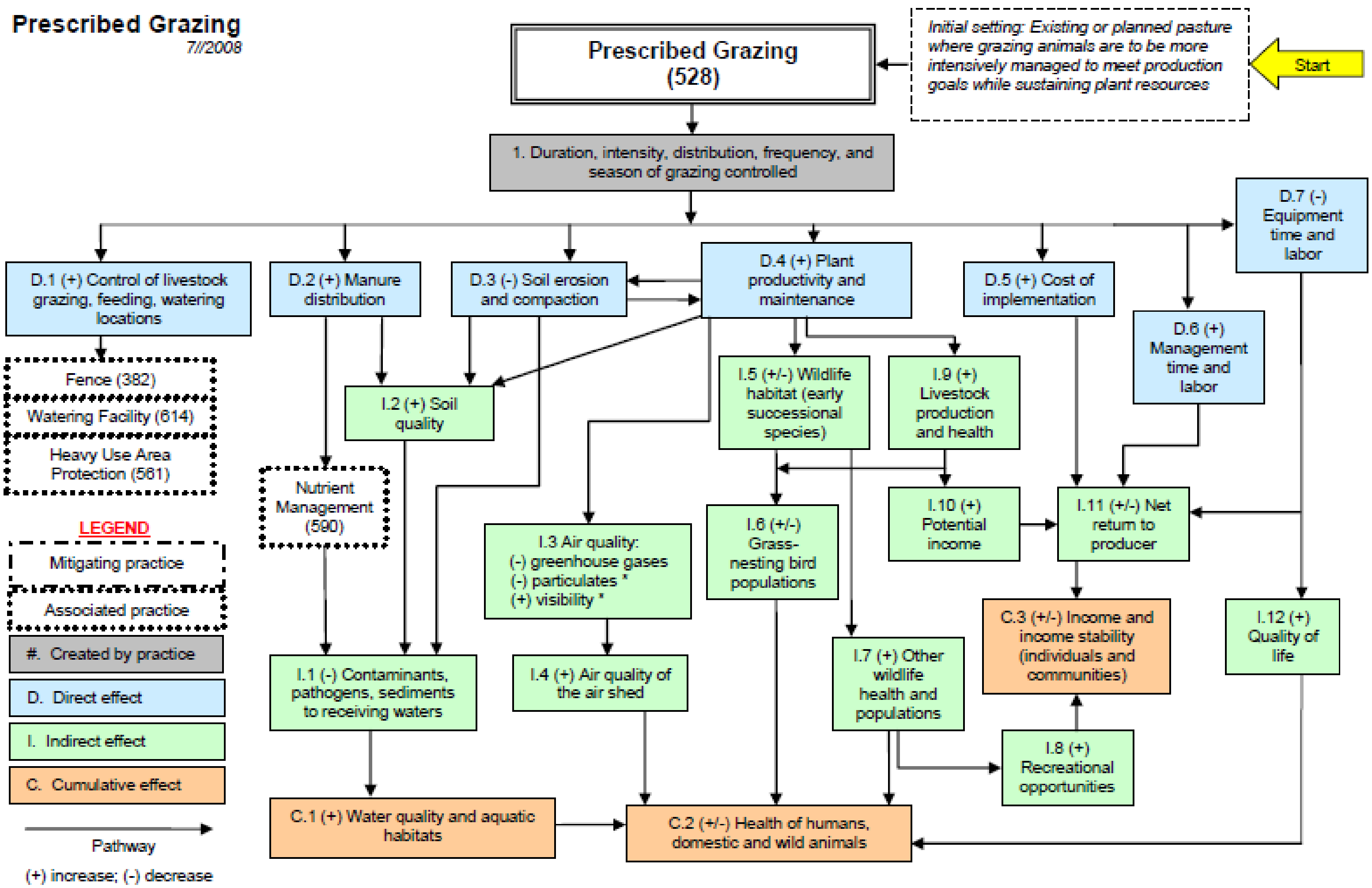
- Defining landowner and/or manager goals and objectives
- Identifying needs for reliable water sources and supplies
- Feed and forage inventories and analyses
- Range condition and health evaluations and assessments
- Managing desirable and undesirable plant communities to meet grazing objectives

Benefits of implementing prescribed grazing and associated BMPs and conservation practices are numerous and are displayed in the NRCS's NED in Figure 1.4.2.3. As shown in this figure, direct and indirect benefits associated with this BMP include:

- Increased control of livestock grazing, feeding, watering locations
  - Decreased loading of pathogens, sediments, and nutrients to surface waters,
- Increased manure distribution
  - Increased soil quality
  - Reduced contaminants, pathogens, sediments to receiving waters
- Soil erosion and compaction
- Increased plant productivity and maintenance
  - Increased livestock production and health
  - Increased wildlife health and populations

Cumulative benefits of implementing prescribing grazing could include:

- Positive impacts to income and stability of individual producers and the community
- Improved water quality and aquatic habitat
- Improved health of humans, domestic animals and wildlife.



Note: Effects are qualified with a plus (+) or minus (-). These symbols indicate only an increase (+) or a decrease (-) in the effect upon the resource, not whether the effect is beneficial or adverse.

Figure 1.4.2.3 Network Effects Diagram for Prescribed Grazing.

1.4.2.4 STREAM CHANNEL RESTORATION PROJECTS

The watershed study and management plan includes conservation practices and BMPs such as installation of stream channel degradation/incision and streambank erosion mitigation measures based upon site-specific evaluation of conditions along with routine monitoring of completed stream projects to identify necessary maintenance repairs and determine their effectiveness. Appropriate measures could be 'hard' engineering, 'soft' approaches, or combinations of both. Streambank and shoreline protection is the stabilization and protection of streambanks, constructed channels, and shorelines of lakes and reservoirs. Strategies for applying streambank and shoreline protection involve:

- Streambanks of natural or constructed channels and shorelines of lakes and reservoirs where they are susceptible to erosion.
- Various materials may be used for protection of streambanks and shorelines,
- A site-specific assessment should be conducted to determine if the causes are local or systemic and used to select appropriate treatment to achieve the desired objective,
- Functional and stable treatments for design flows and sustainable for higher flows.
- Preventing the loss of adjacent land or damage to land uses or other facilities
- Protecting historical, archeological, and traditional cultural properties
- Reducing the offsite or downstream effects of sediment resulting from bank erosion
- Improving the stream corridor for fish and wildlife habitat, aesthetics, and recreation

Benefits of implementing streambank and shoreline protection and associated BMPs and conservation practices are numerous and are displayed in the NRCS's NED in Figure 1.4.2.4. As shown in this figure, direct and indirect benefits associated with this BMP include:

- Decreased streambank and/or shoreline erosion
    - Increased soil quality
    - Decreased sedimentation
- Increased flow capacity of streams and channels
- Increased streambank vegetation and root matrices
    - Increased soil quality
    - Increased native plant recruitment
    - Decreased invasive/noxious species

Cumulative benefits of implementing streambank and shoreline protection could include:

- Positive impacts to income and stability of individual producers and the community,
- Improved water quality and aquatic and/or terrestrial habitat,

Improved recreational opportunities.

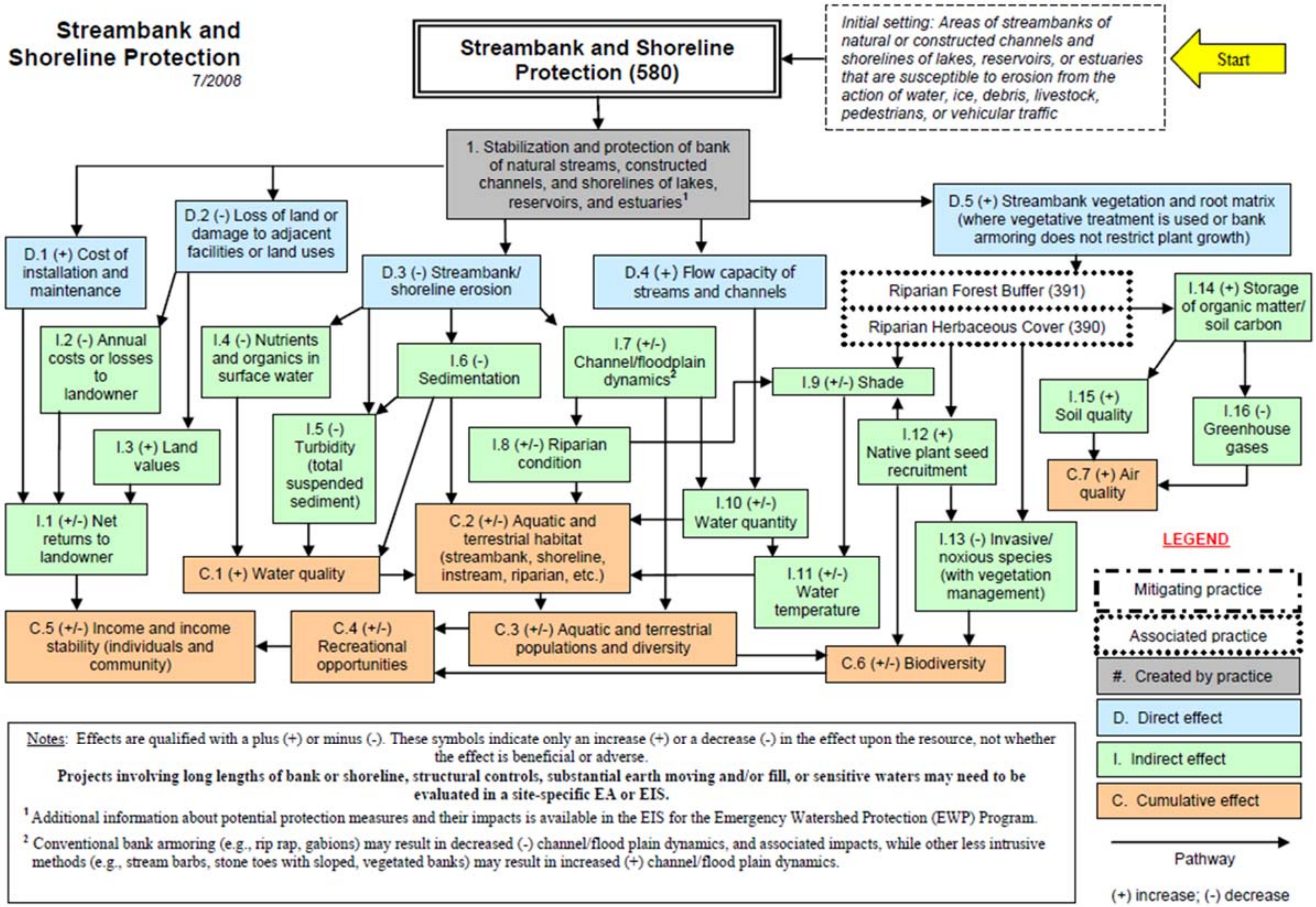


Figure 1.4.2.4 Network Effects Diagram for Streambank and Shoreline Protection.

REFERENCES

Bailey, D. W., 2005. “Identification and Creation of Optimum Habitat Conditions for Livestock,” *Rangeland Ecology and Management*, Vol. 58, pp. 109–118.

Black, P. E., 1997. “Watershed Functions,” *Journal of the American Water Resources Association*, Vol. 33, No. 1, pp. 1–11.

Blackburn, W. H., 1984. “Impacts of Grazing Intensity and Specialized Grazing Systems on Watershed Characteristics and Responses,” *Developing Strategies for Rangeland Management*, B. D. Gardner and J. H. Brothov (eds.), Westview Press, Boulder, CO, pp. 927–983.

Fuhlendorf, S. D. and D. M. Engle. 2004. Application of the Fire-Grazing Interaction to Restore a Shifting Mosaic on Tallgrass Prairie,” *Journal of Applied Ecology*, Vol. 41, pp. 604–614.

Ganskopp, D., 2001. “Manipulating Cattle Distribution With Salt and Water in Large Arid-Land Pastures: A GPS/GIS Assessment,” *Applied Animal Behavior Science*, Vol. 73, pp. 251–262.

Gifford, G. F., 1985. “Cover Allocation in Rangeland Watershed Management (A Review),” *Watershed Management in the Eighties*, E. B. Jones and T. J. Ward (eds.), American Society of Civil Engineers, New York, NY, pp. 23–31.

Holecheck, J. L., 1997. “The Effects of Rangeland Water Developments on Livestock Production and Distribution for “Symposium on,” *Symposium on Environmental, Economic, and Legal Issues Related to Rangeland Water Development*, ASU College of Law, Tempe, AZ, November 13–15.

Huntsinger, L. and L. P. Fortmann, 1990. “California’s Privately Owned Oak Woodlands: Owners, Use, and Management,” *Journal of Range Management*, Vol. 43, pp. 147–152.

Kachergis E., J. Derner, L. Roche, K. Tate, M. Lubell, R. Mealor, J. Magagna, 2013. “Characterizing Wyoming Ranching Operations: Natural Resource Goals, Management Practices and Information Sources,” *Natural Resources*, Vol. 4, pp. 45–54.

Kreuter, U. P., H. E. Amestoy, M. M. Kothmann, D. N. Ueckert, W. A. McGinty, and S. R. Cummings, 2005. “The Use of Brush Management Methods: a Texas Landowner Survey,” *Rangeland Ecology and Management*, Vol. 58, pp. 284–291.

Laca, E. A., 2009. “New Approaches and Tools for Grazing Management,” *Rangeland Ecology and Management*, Vol. 62, pp. 407–417.

Mealor, R., 2013. “Rangeland Decision-Making” *Wyoming Livestock Roundup*, Vol. 24, No. 36, p. 8.

Moran, S. M., W. E. Emmerich, D. C. Goodrich, P. Heilman, C. D. Holifield Collins, T. O. Keefer, M. A. Nearing, M. H. Nichols, K. G. Renard, R. L. Scott, J. R. Smith, J. J. Stone, C. L. Unkrich, and J. Wong, 2008. “Preface to Special Section on Fifty Years of Research and

Data Collection: U.S. Department of Agriculture Walnut Gulch Experimental Watershed," *Water Resources Research*, Vol. 44.

Moseley, M. E., 1983. "Conservation Helps a Dry Creek Flow Again," *Rangelands*, Vol. 5, No. 6, pp. 257–258.

Natural Resources Conservation Service, 2011. *Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps*, D. D. Briske (ed.), Allen Press, Inc., Lawrence, KS.

Rosenstock, S. S., C. S. O'Brien, R. B. Waddell, and M. J. Rabe. 2004. *Studies of Wildlife Water Developments in Southwestern Arizona: Wildlife Use, Water Quality, Wildlife Disease, Wildlife Mortalities and Influences on Native Pollinators*, Technical Guidance Bulletin No. 8. Arizona Game and Fish Department, Phoenix, AZ.

Simpson, N. O., K. M. Stewart, and V. C. Bleich, 2011. "What Have We Learned About Water Developments for Wildlife? Not enough!" *California Fish and Game*, Vol. 97. No. 4, pp. 190–209.

Spaeth, K., M. Weltz, D. D. Briske, L. W. Jolley, L. J. Metz, and C. Rossi, 2013. "Rangeland CEAP," *Rangelands*, Vol. 35, No. 1, pp. 2–10.

Sayre, N. F., 2004. "Viewpoint: The Need for Qualitative Research to Understand Ranch Management," *Journal of Range Management*, Vol. 57, pp. 668–674.

Thurow, T., 1991. "Hydrology and Erosion," *Grazing Management: An Ecological Perspective*, R. K. Heitschmidt and J. W. Stuth (eds.), Timber Press, Portland, OR, pp. 141–159.

U.S. Department of Agriculture, 2013. *Walnut Gulch Experimental Watershed, Tombstone, Arizona*, prepared by the U.S. Department of Agriculture, Southwest Watershed Research Center, Tucson, AZ, and Agriculture Research Service, Albany, NY.

Wiedenfeld, C. C., 1986. *Soil Survey of Irion County, Texas*, prepared for the Natural Resources Conservation Service, Washington, DC.

Williams, R. E., 1954. "Modern Methods of Getting Uniform Use of Ranges," *Journal of Range Management*, Vol. 7, pp. 77–81.

Wood, M. K., and W. H. Blackburn. 1981b. "Sediment Production as Influenced by Livestock Grazing in the Texas Rolling Plains," *Journal of Range Management*, Vol. 34, pp. 228–231.

II. PROJECT MEETINGS

2.1 INTRODUCTION

Various meetings were held by the Wyoming Water Development Office (WWDO) staff to inform the Sublette County Conservation District and the community of the WWDC's watershed study process. The meetings held were as follows:

- July 12, 2011 - SCCD Board Meeting
- October 11, 2011 - SCCD Board Meeting
- February 13, 2012 - Big Piney Landowner Meeting
- February 13, 2012 - Pinedale Landowner Meeting
- March 20, 2012 - Pre-Proposal Meeting
- May 10, 2012 - Consultant Interviews/Selection w/ Sponsor

During the course of the study, meetings were conducted on two different levels. The first level of meetings were the publicly advertised and attended meetings held at the Marbleton Town Hall, the Sublette County Library, or at the Offices of the Sublette County Conservation District. These meetings were general project meetings discussing approach and project findings. The attendanace at the meetings was between eight and twenty individuals with roughly half being land owners at the public meetings. The remaining attendees were from State and Federal agencies. The Conservation District provided an initial contact list for the first meeting. Invitations to the meetings were by postcard, email, or telephone as contact information dictated. The meetings held were as follows:

- July 17, 2012 - Project Kickoff Meeting, Marbleton
- July 17, 2012 - Project Kickoff Meeting, Pinedale
- December 5, 2012 - SCCD Board Meeting
- April 23, 2013 - Open House/Workshop, Marbleton
- July 1, 2013 - DRAFT Report Presentation, Marbleton

The second level of meetings were arranged with individual property owners to review their proposed upland water projects and irrigation improvement projects. These contacts were initially made at the public meeting, or by referrals from the Conservation District, or by word of mouth.

2.2 FIELD VISITS

2.2.1 UPLAND WATER VISITS

The meetings with individual property owners were held in the field and where practical, (favorable weather and access conditions) included a site visit. In some cases the review was made using aerial photography. During the meeting, the landowner or allotment lesee described the purpose and location of the proposed improvement. In instances of existing failed infrastructure, the landowner provided information as to the probable cause of failure and ideas on what might be changed to rectify the problem. Using this data, proposed development concepts were discussed with the landowner. The engineer subsequently prepared a sketch and estimate of cost for the proposed project.

A second follow-up meeting with individual landowners was accomplished via an open-house held at the Marbleton Town Hall. At the meeting, maps and project descriptions based on the initial consultation were reviewed for accuracy by the landowner. After the landowner review, sketches and estimates were finalized according to the review comments. Section IV of this study contains additional detail and description of the results of these efforts.

2.2.2 TEMPORARY STREAM GAUGING VISITS

Field visits were also made to locate, install and retrieve data from several temporary stream gauges installed as part of the project. Field observations of stream conditions, riparian conditions and upland range conditions were also conducted as part of the study.

The Green River and Cottonwood Creek gauge stations were established on November 20, 2012 when permanent benchmarks were set, water stage recorded, and discharge measured. Due to the presence of anchor and shore ice at that time, these gauges were not operational until the spring of 2013.

Landowner permission to access the Beaver Creek and Horse Creek gauge sites was obtained by the SCCD during the winter of 2012, by which time anchor and shelf ice abundance precluded correlation of stage to discharge or activation of those gauging stations. All 4 temporary gauge stations were activated as soon as environmental conditions enabled in the spring of 2013 (on April 23, 2013). Sites were visited every 6 to 8 weeks after initial activation for the purpose of downloading data and conducting field measurements of discharge and stage to maintain accurate rating correlations. Data loggers were pulled from all gauging stations near the end of the study period on August 8, 2013.

Field measurements of stage and discharge, developed rating correlations, channel survey data, and hydraulic model information are presented in Appendix C. Field measurements and channel survey products are pertinent to hydrologic investigations, morphologic classification, and assessment of fluvial and riparian conditions. Data were therefore collected from various sites within the watershed during numerous multi-disciplinary site investigations during the study period. Hydraulic and morphologic data collected at each gauging station can be used to continue operation of stream gauges, to estimate local discharge based upon stage readings, or to monitor changes in channel form or aquatic habitat conditions through time.

2.3 AGENCY/LANDOWNER COORDINATION

Landowner coordination was direct with the Sublette County Conservation District. The District assisted with landowner access for the stream gauges and was also a point of contact for landowners with upland water projects. The District provided helpful insight and assisted with questions from both landowners and the consultants working on the study. Landowner names were forwarded from the District to the project engineer along with contact information and a brief description of the landowner initiated project.

The GIS data sets were coordinated with the State GIS clearinghouse as well as several agencies such as the USFS, BLM, Oil and Gas Commission, the Wyoming Natural Diversity Database, Sublette County, and Lincoln County.

III. WATERSHED DESCRIPTION AND INVENTORY

3.1 INTRODUCTION

A considerable amount of information pertaining to the Upper Green River watershed already exists. These data span a wide variety of disciplines, including basin hydrology, water quality, wetlands, wildlife, land use and ownership, climate, geology, soils, agricultural practices and others. The data comes from Federal, State, local, corporate, and private interests and spans the previous century. Interest in the above topics began with early settlement in the basin and has since grown to the point of massive amounts of data being available to the general public at present through the use of computers and public data sets.

A primary goal of watershed planning studies conducted on behalf of the Wyoming Water Development Commission (WWDC) is to:

1. Collect, review, and compile pertinent information regarding the project area;
2. Collate the data in a single dataset; and
3. Use this information to characterize the watershed and facilitate current and future planning, permitting, and improvement efforts within the watershed.

3.2 DATA COLLECTION AND MANAGEMENT

3.2.1 COLLECTION OF EXISTING INFORMATION

The information collected during the course of this study primarily came from existing data sets already in existence. Many Federal, State and local governmental agencies have successfully cataloged and scanned historic paper documents into electronic data bases and have made these documents available. In addition, on-going research and more recent studies completed in electronic format are available from various contacts including the following:

U.S. Geological Survey (USGS)

U.S. Forest Service (USFS)

U.S. Department of Agriculture (USDA)

U.S. Fish and Wildlife Service (FWS)

U.S. Environmental Protection Agency (EPA)

U.S. Bureau of Land Management (BLM)

U.S. Department of the Interior Bureau of Reclamation (BOR)

USDA Natural Resources Conservation Service (NRCS)

Wyoming Water Development Office (WWDO)

Wyoming Department of Environmental Quality (WDEQ)

Wyoming State Engineers Office (SEO)

Wyoming Game and Fish Department (WGFD)

Wyoming State Geological Survey (WSGS)

Wyoming Geographic Information Science Center (WyGISC)

Wyoming State Geological Survey (WSGS)

Wyoming Oil and Gas Conservation Commission (WOGCC)

Wyoming Secretary of State's Office

Sublette County

Sublette County Conservation District

Sublette County Weed and Pest

3.2.2 GEOGRAPHIC INFORMATION SYSTEM

Much of the collected data and some data generated during the preparation of the study are in GIS format. GIS is a powerful mapping tool that allows the map creator to collect and display graphical information in a variety of combinations and formats. The map becomes a window into larger data sets of attributes (tables of facts, descriptions, and numbers) associated with the graphically displayed map data. The non GIS user can access the data sets through the user interface and the "geo-pdf" figures of the study. In this way, a simple exhibit depicting various basin features can contain vast amounts of tabular data. For instance, a map of soil types can access portals to tabular data such as soil abbreviations, soil types, soil characteristics, acreage by type, etc. The interface is based on Adobe Reader or Adobe Acrobat with "TerraGo" (a free program) added. The user can interrogate the geo-pdf and also add data to the geo-pdf. The user can also manipulate the layers that are shown on the pdf.

The following Table 3.2.2 outlines in general terms the available information.

Table 3.2.2. List of GIS Data Coverage

Project Study Area	Fish and Wildlife
Upper Green Watershed Boundary	Pronghorn Antelope Ranges
Political	Mule Deer Ranges
Towns Lincoln County	Moose Ranges
Towns Sublette County	Elk Ranges
Towns Sweetwater County	Big Horn Sheep Ranges
Towns Teton County	Sensitive Plant Species
County Boundaries	Greater Sage Grouse
UTM Zones	Trout Stream Classifications
Land Management	Geology, Soils, ESD, Geomophology
Land Ownership Sublette County Parcel Data	Ecological Sites
Land Ownership Lincoln County Parcel Data	Mining and Mineral Resources
Land Ownership Sweetwater County Parcel Data	Surficial Geology
Land Ownership Private	Bedrock Geology
Land Ownership State	Geologic Hazards
Land Ownership Nature Conservancy	Earthquakes
BLM Allotments Data and Boundaries	Faults
USFS Allotments and Boundries	Dikes
BLM Boundaries	Soils Data
USFS Boundaries	
BLM Recreation/Special Management Areas	Cultural Sites
USDA Bridger Wilderness Boundaries	Sites Eligible for Inclusion on the National Register of
USDA Gros Ventre Wilderness Boundaries	Historic Places
Land Cover/Land Use	Climate
NWGAP Land Cover	Weather Stations
Weed Points	Average Annaul Precipitation 1981-2010
Infrastructure	
Oil and Gas Wells	Irrigation
Permanently Abandoned Wells	Irrigated Acres
Pipelines	Points of Diversion
County Roads - Lincoln, Sublette and Sweetwater	
Communications Towers	Hydrology
Electric Transmission Corridors	Study Identified Existing Water Features
State of Wyoming Roads	Beaver Ponds
WPDES Permitted Discharges	Lakes
Upland Water	Ponds
Existing SEO Permitted Wells	Springs
SEO Permitted Stock Reservoirs	Potholes
Existing Wells and Springs Permitted for Stock Watering	USGS Mapped Springs
Developed Water Features	HUC 12 Boundaries
Pipeline	Rivers and Streams Hydrography
Wells	Geomorphological Classification
Stock Pond/Reservoirs	Streamflow Gauging Stations
Proposed Upland Water Projects	SEO Gauging Stations
Reservoirs	USGS Gauging Stations Active
Stock Ponds	USGS Gauging Stations Historical
Pipeline	Wetland and Deep Water Habitat
Wells	Disequilibrium Channel Reaches

3.2.3 DIGITAL LIBRARY

As part of compiling the information for this study, a digital library was created. The digital library is a collection of documents pertaining to this project. Some of the documents were originally bound paper, but have now been scanned electronically. Other documents were generated in electronic format at the outset. All public documents provided to the study or located during the study have been included when possible. The collection of documents in the digital library improves access to the information so it can be used in current and future planning, permitting and improvement efforts in the watershed. There are some data sets of a sensitive nature and not all data was provided or the data was provided in a general sense. An example of this type of sensitive data would be cultural resources, where a general presence is noted on the map; however specifics regarding the location and particular nature of the site have been withheld.

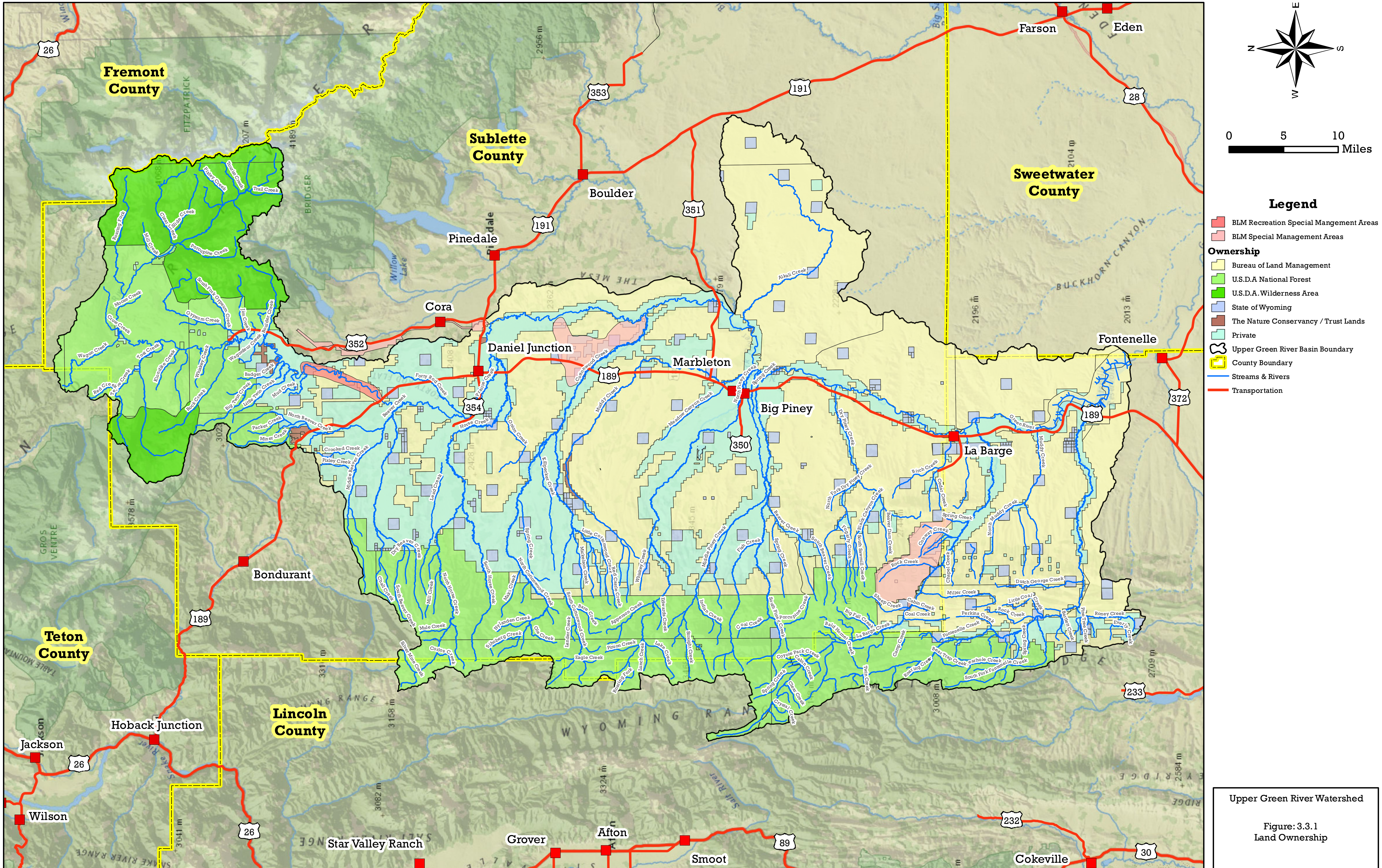
3.3 LAND USES AND ACTIVITIES

3.3.1 LAND OWNERSHIP

The Upper Green River watershed totals 1,882,254 acres in size and is located primarily within Sublette County (1,494,696 acres, Figure 3.3.1). In addition, 375,949 acres of land is located in eastern Lincoln County, 6,566 acres in southeastern Teton County, 4,568 acres northwestern Sweetwater County, and 475 acres are unknown. Because Wyoming Conservation Districts are primarily linked to counties, the watershed falls within the jurisdiction of 4 different conservation districts; however, the project is sponsored by the Sublette Conservation District in whose jurisdiction most of the watershed occurs.

Figure 3.3.1. Upper Green River Watershed Land Ownership shows ownership in watershed, with county boundaries depicted.

The majority of land within the watershed (1,371,208 acres, 72%) is administered by Federal agencies with the Bureau of Land Management (BLM) administering 793,245 acres (42%) and the USDA Forest Service (USFS) administering 577,963 acres (30%) (Chart 3.3.2). Private lands constitute 441,325 acres (23%) and State of Wyoming constitutes 65,550 acres (3%); the remaining land is owned by The Nature Conservancy (3,724 acres) or is unknown (475 acres). Ownership within the watershed, displayed on a per county basis, is depicted in Chart 3.3.3 for Sublette County and Chart 3.3.4 for Lincoln County. Ownership within Teton County is entirely USFS and within Sweetwater County is entirely BLM; therefore, no ownership figures are provided.



Upper Green River Watershed

Figure: 3.3.1
Land Ownership

Projection: NAD 83 - UTM Zone 12

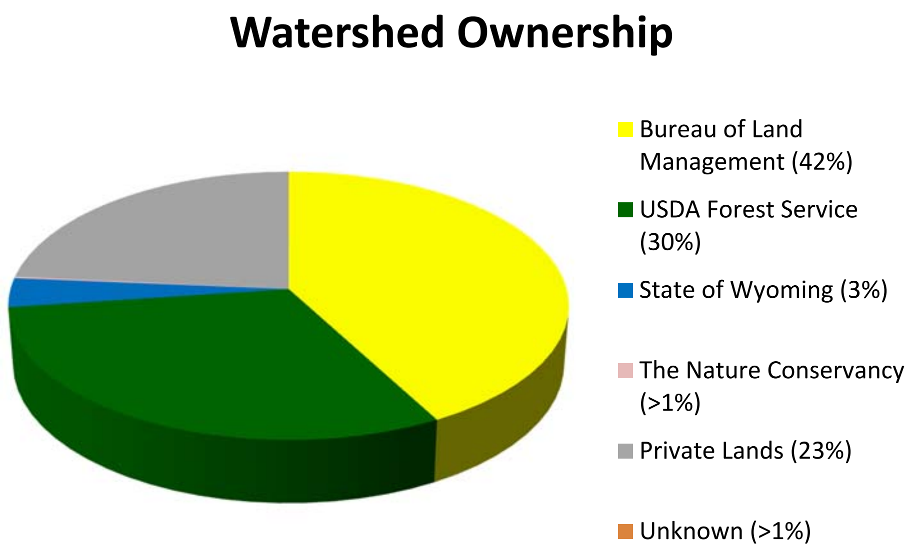


Chart 3.3.2 Proportion of land ownership within the Upper Green River Watershed.

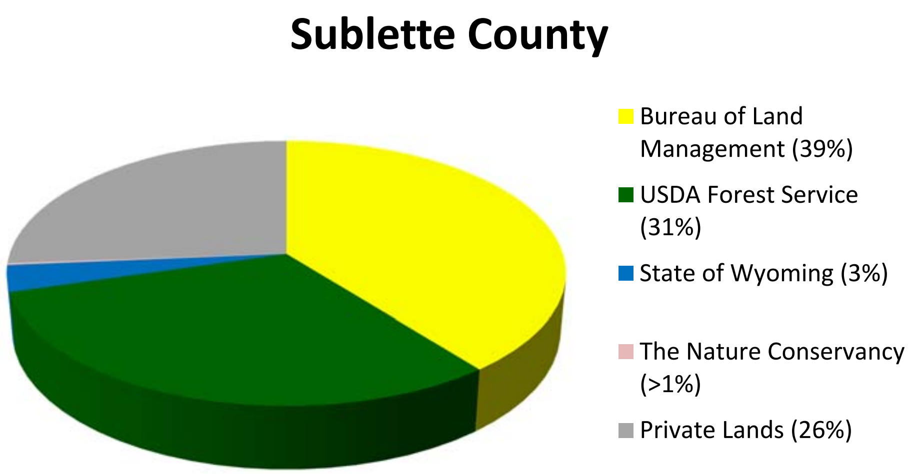


Chart 3.3.3 Proportion of land ownership in Sublette County within the Upper Green River Watershed.

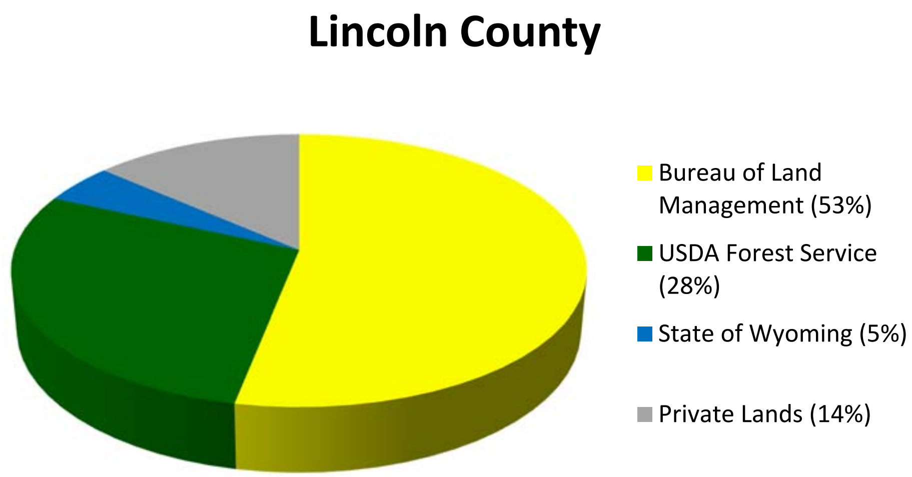


Chart 3.3.4 Proportion of land ownership in Lincoln County within the Upper Green River Watershed.

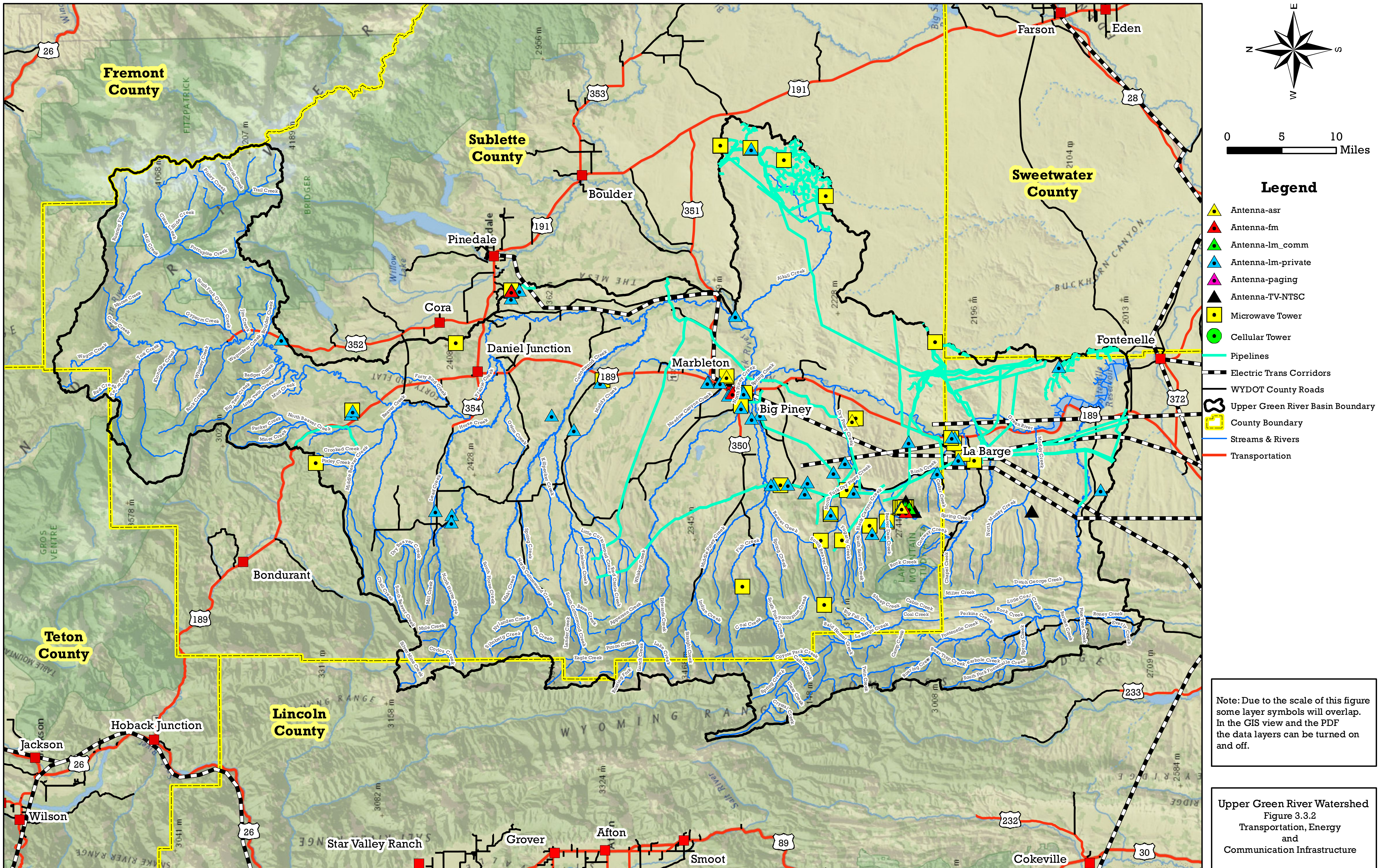
3.3.2 TRANSPORTATION, ENERGY & COMMUNICATION INFRASTRUCTURE

The Upper Green River watershed area is not directly served by any Interstate Highways or rail lines. The principal two-lane highways within the watershed are U.S. Highways 189 and 191 (Figure 3.3.2). Highway 189/191 enters the northern portion of the watershed from Bondurant to Daniel Junction where the two highways split. At this junction, Highway 189 goes south toward Daniel, Marbleton, Big Piney, and on to La Barge outside of the watershed, while Highway 191 goes southeasterly to Pinedale, Boulder, and on to Farson and Eden outside of the watershed. State Highway 351 (Big Piney Cutoff) connect Highways 189 and 191. State Highway 352 services Cora from Highway 191 between Daniel Junction and Pinedale.

Several County Roads are also present within the watershed (Figure 3.3.2). CR350 going west from Highway 189 at Big Piney, CR 235 which loops from Highway 189 south of Big Piney to Calpet and then back to Highway 189 at LaBarge. CR 354 departs Highway 189/191 at Daniel Junction and goes west to Merna. An extension of State Highway 351 crosses US Highway 189 and goes west towards Middle and North Piney Creeks.

Electric power service within the watershed is primarily provided by Rocky Mountain Power and, to a lesser degree by PacificCorp Company. Figure 3.3.2 depicts mapping of electrical transmission lines/corridors within the watershed.

Nearly 2,500 pipelines are present within the watershed (Figure 3.3.2). Four companies own the majority of these pipelines: Colorado Interstate Gas, Pinedale Natural Gas, Williams Field Services, and Questar Pipeline Co. Additionally, six companies own multiple pipelines; Rockies Express Pipeline, DCP Midstream, Northwest Pipeline Corporation, Phillips 66 Pipeline, Southern



Note: Due to the scale of this figure some layer symbols will overlap. In the GIS view and the PDF the data layers can be turned on and off.

Upper Green River Watershed
Figure 3.3.2
Transportation, Energy and Communication Infrastructure

Projection: NAD 83 - UTM Zone 12

Star Central Gas Pipeline, and Enterprise Products. The remainders of the pipelines are owned by ten other companies.

Numerous antennae are scattered throughout the watershed (Figure 3.3.2) including cellular (N=3) and antenna structure registration (N=6); microwave (N=127); paging (N=2); FM radio (N=3); television (N=6); and liquid metal-commercial (N=6) and private (N=107).

3.3.3 IRRIGATION

Agricultural Water use in the Upper Green River Basin consists primarily of irrigation and to a lesser degree stock watering. The predominant source of irrigation supply is surface water with 25 main-stem diversions and 262 tributary diversions. A network of canals and ditches were constructed by producers to convey water from the natural tributaries and main stream Green River to the meadows and cultivated lands. Flood irrigation remains the principal method of applying water to the fields. Center pivots and pressurized irrigation are finding increased application within the basin thanks to NRCS assistance. At present between 130,000 to 140,000 acres are under irrigation depending on water availability. Consumptive use ranges between 130,000 acre-feet in dry years to 150,000 acre-feet in a wet year. Section V of this plan contains detailed irrigation information.

3.3.4 RANGE CONDITIONS/GRAZING PRACTICES

3.3.4.1 GRAZING ALLOTMENT ADMINISTRATION

Background and History. Since the late 1800s, cattlemen have been wintering livestock in the protected valleys of the Upper Green River basin. Homesteaders began ranching and farming along the major streams and rivers around 1900 (BLM 2010). The rangeland surrounding the private homesteads remained part of the public domain and was used for pasturing livestock (primarily sheep and cattle) throughout the warmer months of the year. Livestock were driven back to private property to overwinter. After lambing and calving in the spring, livestock would be returned back to public rangeland. This pattern of seasonal livestock grazing on public lands remains much the same today as it was at the beginning of the 20th Century.

The Federal Government passed the Taylor Grazing Act in 1934, which regulated the use of public lands for grazing and limited use to a specific geographic area or grazing allotment. Ranchers were allowed a specific number of livestock for a specific season of use. During the 1930s and 1940s, the Federal Government began to perform surveys to determine the amount of forage available on each allotment. The results of these surveys led to an eventual reduction in grazing permits, the construction of allotment boundary fences, and the development of numerous off-site water projects to improve livestock distribution.

Federal Grazing Allotments. Today, grazing allotments on federal lands within the watershed are administered by the BLM and the USFS. The USFS allotments are located in the mountains in the northern and western portions of the study area, while BLM allotments are primarily located in the basin and foothills. Several BLM allotments in the southern portion of the study area are located within the Rock Springs and Kemmerer BLM planning areas, but the majority of BLM allotments within the watershed occur in the Pinedale planning area. According to geospatial data provided by the BLM, there are 154 individual allotments on BLM lands within the watershed (Figure 3.3.4). Allotment boundaries are typically not coincident with watershed boundaries; therefore some of these allotments are not located entirely within the Upper Green River watershed. The average size of BLM allotment in the watershed is 3,400 acres, with an average stocking rate of 765 animal unit months (AUMs). Appendix D contains additional allotment information.

Since the passage of the Federal Land Policy and Management Act (FLPMA) in 1976, numerous laws, regulations, and policies have directed the BLM to manage its riparian and wetland areas "for the benefit of the nation and its economy". "According to the Department of the Interior's final rule on grazing administration, effective August 21, 1995, the Wyoming BLM State Director is responsible for the development of standards for healthy rangelands and guidelines for livestock grazing management on 18 million acres of Wyoming's public rangelands." (BLM 1997). The purpose of these standards and guidelines are to achieve the four fundamentals of rangeland health outlined in the grazing regulations. These are: 1) watersheds are functioning properly; 2) water, nutrients, and energy are cycling properly; 3) water quality meets State standards; and 4) habitat for special status species is protected.

In response to the Department of the Interior's final rule and to address the health, productivity and sustainability of BLM-administered lands in Wyoming, the BLM established 6 Standards for Healthy Rangelands. The standards are outlined below.

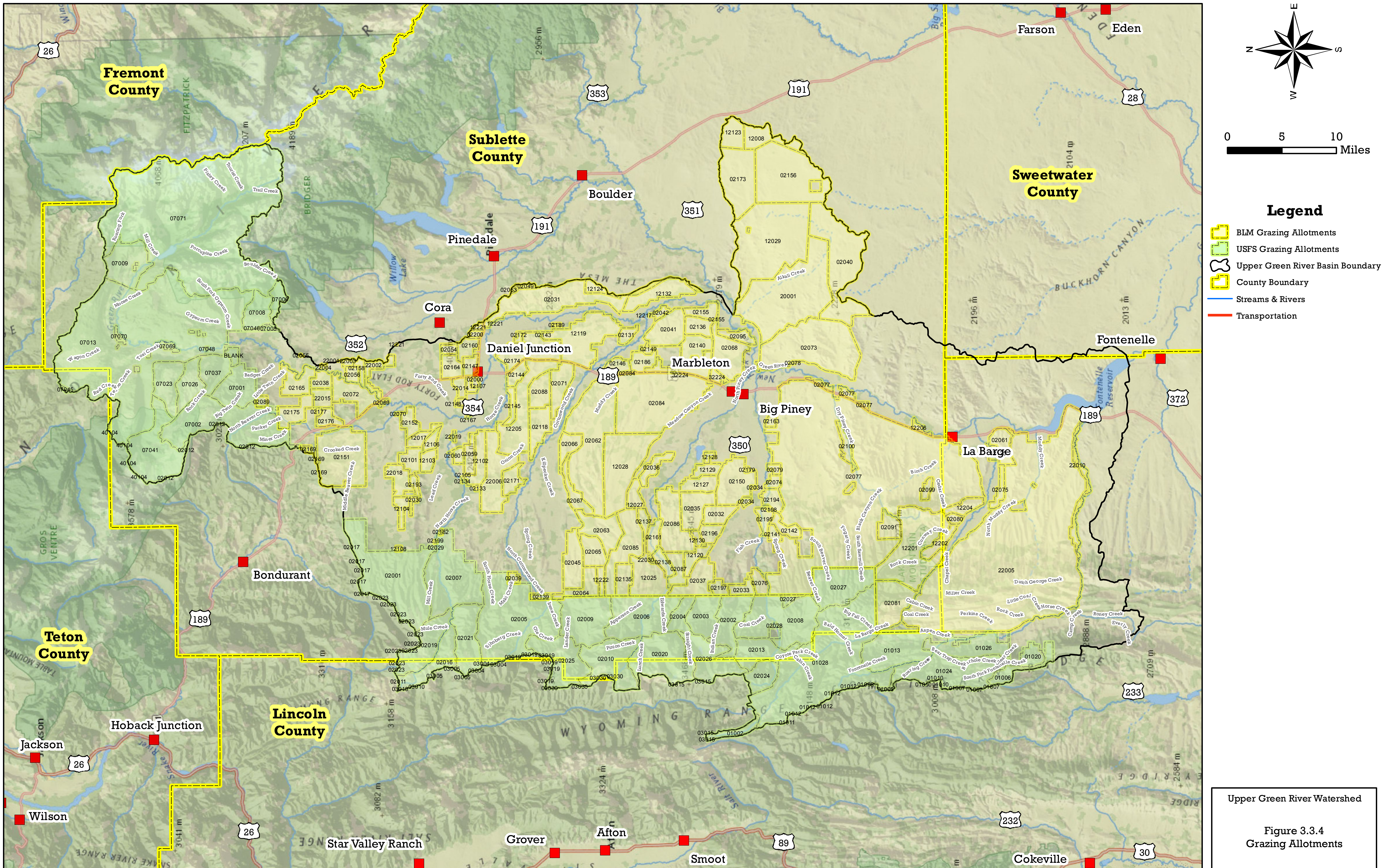
Additional information on the standards can be found in the BLM Standards for Healthy Rangelands and Guidelines for Livestock Grazing Management document (http://www.blm.gov/pgdata/etc/medialib/blm/wy/wildlife/baldeagle.Par.18820.File.dat/be-appb.pdf).

Standard #1 – Within the potential ecological site (soil type, landform, climate, and geology), soils are stable and allow for water infiltration to provide for optimal plant growth and minimal surface runoff.

Standard #2 – Riparian and wetland vegetation has structural, age, and species diversity characteristic of the stage of channel succession and is resilient and capable of recovering from natural and human disturbance in order to provide forage and cover, capture sediment, dissipate energy, and provide for groundwater recharge.

Standard #3 – Upland vegetation on each ecological site consists of plant communities appropriate to the site which are resilient, diverse, and able to recover from natural and human disturbance.

Standard #4 – Rangelands are capable of sustaining viable populations and a diversity of native plant and animal species appropriate to the habitat. Habitats that support or could support



Upper Green River Watershed

Figure 3.3.4
Grazing Allotments

Projection: NAD 83 - UTM Zone 12

threatened species, endangered species, species of special concern, or sensitive species will be maintained or enhanced.

Standard #5 – Water quality meets State standards

Standard #6 – Air quality meets State standards

In addition to these standards, the BLM has developed guidelines for livestock grazing management on BLM-administered lands in the state. Implementation of the standards and guidelines is to be accomplished by reviewing individual allotments based on the BLM's current allotment categorization and prioritization process. The review first determines if an alloment meets each of the six standards. If it does, no further action is necessary. If any of the standards are not met, then a rationale explaining the contributing factors is prepared. If livestock grazing practices are found to be among the contributing factors to not meeting a standard, then corrective actions consistent with the livestock management guidelines are developed and implemented.

The BLM utilizes a selective management policy to administer grazing leases. The policy requires that the agency prioritize and direct resources to lands providing the greatest potential for improvement and publc benefit. As such, grazing leases are separated into 3 management categories: maintain, improve, and custodial. The "improve" category leases typically include large blocks of public land where resources that are far below the desired condition. Current management is typically not sufficient to meet or maintain resource objectives. These larger blocks of public land offer the best opportunity for the BLM to take actions or authorize uses to meet various resource objectives. The "maintain" lands are similar in regards to the amount of public land included in the lease, but these lands are typically near or at the desired condition. The "custodial" category typically includes small, isolated tracts of public land. Resource conditions on "custodial" lands are typically near desired condition, and management actions are comprised of administrative actions such as lease renewals, billings, and transfers.

In the early 1990s, the BLM began using Proper Functioning Condition (PFC) assessments to qualitatively assess the physical function of riparian areas within allotments and to determine if these areas are properly functioning under their current management regime. Using this approach, riparian areas are assigned one of 4 functional ratings. These include: proper functioning condition; functioning – at risk; non-functional; or unknown. A comprehensive PFC survey was completed on all stream reaches on allotments within the Pinedale planning area from 1994-2001.

In recent years, the agency has moved towards a more quantitative approach utilizing the Multiple Indicator Monitoring (MIM) protocol (http://www.blm.gov/nstc/library/pdf/MIM.pdf). The MIM protocol is designed to be an objective, efficient, and effective methodology for monitoring streambanks, stream channels, and streamside riparian vegetation. It improves upon previous monitoring approaches by assessing multiple indicators in each monitoring reach. Rather than focusing on one or 2 indicators, the MIM protocol combines observations of up to 10 indicators along the same stream reach into one protocol, using mostly simple adaptations of existing procedures. The 10 indicators include:

1. Stubble height
2. Streambank alteration
3. Woody species use

4. Greenline composition
5. Woody species height class
6. Streambank stability and cover
7. Woody species age class
8. Greenline-to-greenline width
9. Substrate
10. Residual pool depth and pool frequency

To date, the Pinedale field office has collected MIM data on 3 allotments and is working towards the eventual implementation of MIM on all allotments.

The most comprehensive information on range conditions in the Pinedale planning area is presented in the Resource Management Plan (RMP) and Environmental Impact Statement (EIS) for the Pinedale Field Office. The purpose of this RMP is to provide a comprehensive framework for managing the BLM-administered public lands and resources within the Pinedale planning area.

In 2005, the EIS and RMP for the Pinedale planning area, as well as 15 other RMPs and associated EISs were challenged in court. The plaintiffs alleged that each of these RMPs, and their associated EISs, failed to adequately consider the environmental impacts of grazing and energy development on sage grouse. The Court found that the Pinedale EIS failed to (1) identify how or where energy and grazing impacts to sage-grouse would occur; (2) map sage-grouse winter use areas; (3) adequately discuss the failure of one third of allotment acres to meet rangeland health standards due to grazing; (4) adequately address the cumulative impacts to sage-grouse ; (5) analyze the cumulative impacts due to energy development, including energy development in adjoining field offices such as the Kemmerer Field Office; and (6) address the Wyoming Basin Eco-Regional Assessment and the WAFWA Conservation Assessment. In November 2012, the latest version of the Pinedale RMP was remanded back to BLM for additional work.

The latest data from the USFS indicate that there are currently 61 allotments on lands administered by the USFS in the watershed (Figure 3.3.4.1), all of which are within the Bridger-Teton National Forest. Appendix D contains additional allotment information.

Three Ranger Districts (Pinedale, Big Piney, and Kemmerer) are responsible for administering leases on these allotments, and several allotments include portions of the surrounding watersheds. The Bridger-Teton National Forest 1990 Forest Plan states that "Stocking rates across the Bridger-Teton National Forest are approximately in line with range capacity; however, some allotments may have to be adjusted downward due to poor range conditions, particularly in riparian areas. Ranchers are working with the Forest Service to improve conditions on these allotments." The Federal Land Policy and Management Act of 1976 requires that all USFS allotments are managed under the direction of allotment management plans (AMPs) that determine range capacity, season of use, range condition and trend, grazing systems, and range improvement priorities. These plans are tailored to specific range conditions in each allotment and are designed to meet the needs of the resource, the livestock, the lessee(s), and the government.

The following excerpt is taken from the 2010 Draft Supplemental Environmental Impact Statement for the Upper Green grazing allotment complex, which is the largest allotment in the National Forest system:

"*The Forest Service proposes to authorize continued grazing under a specific management regime designed to sustain ecological conditions where they are meeting desired condition and improve the ecological conditions where they do not meet desired conditions. The Pinedale Ranger District is proposing to authorize domestic livestock grazing use under updated grazing management direction, in order to move existing rangeland resource conditions toward the desired condition via prescriptions developed to achieve compliance with Forest Plan direction. That direction includes standards, guidelines, goals, objectives and desired future conditions. The updated direction would be incorporated in respective Allotment Management Plans (AMPs) to guide grazing management within the project area.*

State Lands. All of the state-owned parcels in the watershed are leased to private ranching operations (Michael Henn, Wyoming Department of State Lands and Investments, personal communication, March 8, 2013). These parcels are often grazed in concert with adjacent private and/or federal lands. Leases are administered by the Wyoming Office of State Lands and Investments, but all maintenance, range improvements, and/or monitoring is the responsibility of the lessee. No range monitoring on the Upper Green River tracts has been performed by the state. Therefore, little is known about the overall range conditions on these tracts.

The state has a policy for range management improvements and associated expenditures. The policy reads that should a lessee lose a lease on a particular tract (due to being outbid), he/she will get reimbursed for any improvement expenditures over $2,000 by the new lessee.

Private Lands. Grazing on private lands within the watershed is conducted by private landowners or lessees. Technical and/or financial assistance for planning, management, and range improvements is often provided by the NRCS and local conservation districts. Although no information regarding resource condition on private lands was obtained for this report, circumstantial evidence suggests that range conditions vary and depend on the particular property and the associated land management.

REFERENCES

U.S. Department of the Interior. Bureau of Land Management. 2010. Proposed resource management plan and final environmental impact statement for the Pinedale Field Office. Pinedale, Wyoming.

U.S. Department of the Interior. Bureau of Land Management. 1997. Standards for healthy rangelands and guidelines for livestock grazing managementfor public lands administered by the BLM in the State of Wyoming. 21pp.

3.3.4.2 EXISTING WATER SUPPLY

Numerous water sources are present within the watershed, and these sources include both naturally occurring and man-made features:

Natural	Water Development
Rivers	Reservoirs
Streams	Stock Reservoirs
Springs	Stock Wells
Ponds	Pits
Potholes	Guzzlers/Raintraps/Water Tanks
Lakes	Water Spreaders

The Green River, and perennial, seasonal, and intermittent tributary streams are well distributed within the Green River Watershed, with the exception of the east-central and southeastern portions. Many of the perennial streams and creeks have resident beavers that have built and maintain one or more ponds on these watercourses. Springs are abundant, especially at mid-elevations of the Wyoming Range in the western portion, and most of the springs are expected to flow year-round. A number of high elevations lakes and numerous ponds at mid- to high elevations are scattered throughout the western and northern portions. Potholes are abundant in the upper Green River drainage as a result of ancient glacier scouring. In combination, these natural water features provide reliable water sources to both livestock and wildlife.

In contrast, the lower-elevation, drier region located in the east-central and south-eastern portions of the watershed are dominated by intermittent and ephemeral streams, and these surface water sources do not provide reliable water sources. In these areas in particular and elsewhere within the watershed in localized areas, water development features have been constructed in an effort to augment natural water sources. Stock reservoirs, and to a lesser degree water spreaders and guzzlers/raintraps/water tanks have been constructed within these intermittent and ephemeral drainages in order to capture and store spring snowmelt and runoff during precipitation events. Stock wells have also been constructed and some springs have been developed to capture and store water in tanks and pits.

Fontenelle Reservoir is the largest water development project within the watershed. Fontenelle Reservoir currently functions as a storage reservoir as part of the U.S. Bureau of Reclamation's Colorado River Storage Project. This reservoir asserts Wyoming's water rights, while also providing for power generation and water for local industries. Although originally designed to also provide water for agriculture, efficient irrigation delivery and uses have proved problematic.

Through 1962 and 1974 contracts with the United States, the State of Wyoming has the right to perpetually market 120,000 acre-feet of the original active capacity of 190,250 acre-feet. The State of Wyoming presently has four active contracts for Fontenelle storage water: PacifiCorp has contracted for up to 35,000 acre-feet to be used as cooling water at their Jim Bridger Power Plant;

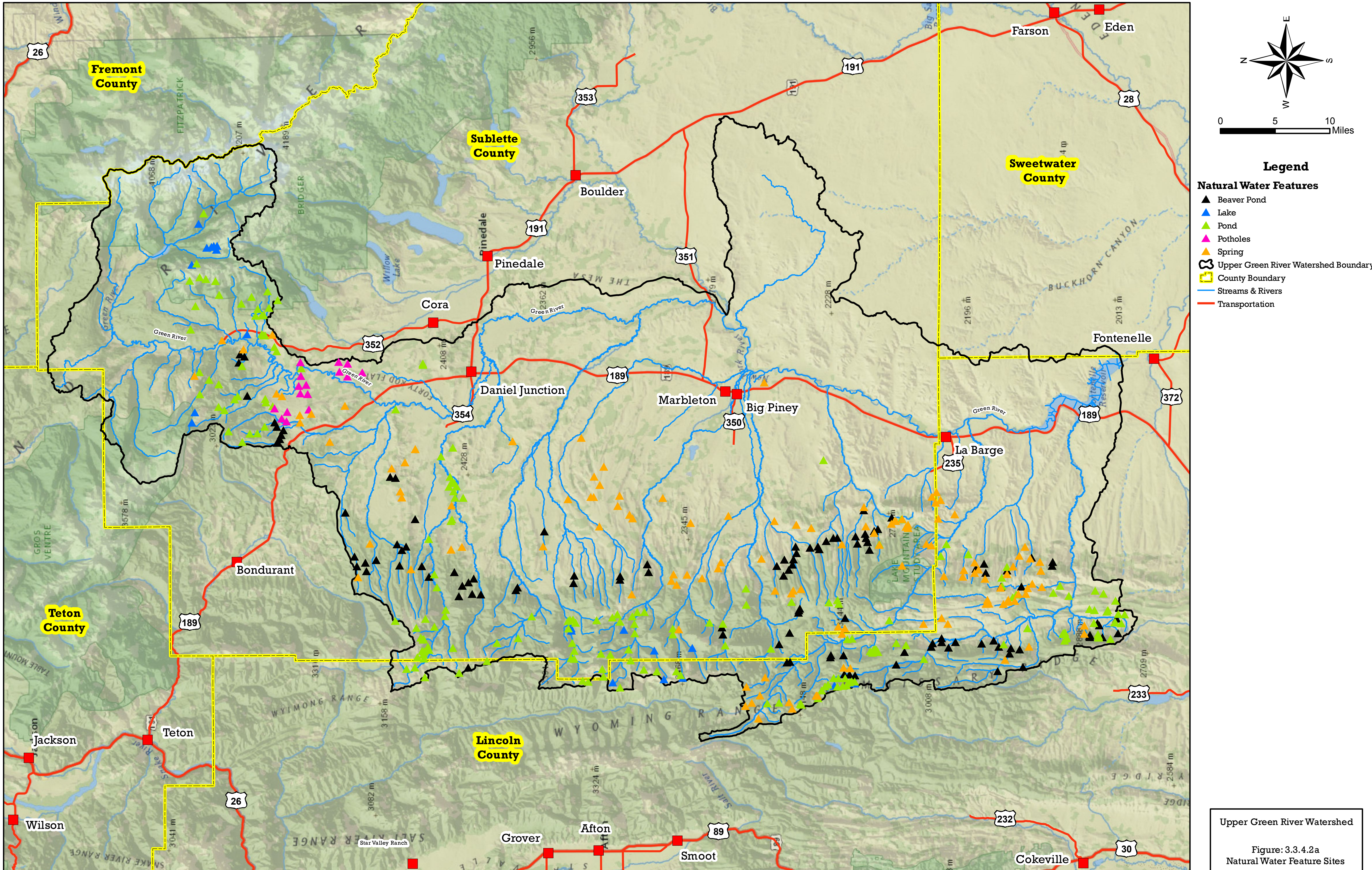
FS Industries, has contracted for up to 10,000 acre-feet of water for producing chemical fertilizer at their Rock Springs facilities; Church and Dwight has contracted for up to 1,250 acre-feet of water for their “Arm and Hammer Baking Soda” production facility near Green River; and Exxon has contracted for up to 300 acre-feet for domestic purposes and for use in the production of natural gas at their Shute Creek Plant. These contracts could result in the ultimate use of 46,550 acre-feet per year of Fontenelle storage water. While these contractors are annually making “readiness-to-serve” payments, there has never been a request for water delivery for use. [Use of Wyoming's Contract Storage Water In Fontenelle Reservoir Technical Memorandum. Wyoming Water Development Office. February 2011.]

Numerous upland livestock/wildlife water development projects have been completed within the watershed in coordination and/or cooperation with the BLM, USFS, NRCS, and private landowners. Along with the natural water sources, these features needed to be documented to the greatest extent possible. Efforts to evaluate the general availability of upland water sources began with data requests to the BLM, the USFS, and the Wyoming State Engineers Office (WSEO) for the locations of water development projects. In reviewing the results of these queries, it became clear that a number of water projects have been constructed on private and federal lands that do not show up in datasets provided by these agencies. Efforts were then undertaken to locate additional water features by visually reviewing USGS Quadrangles, and true color (NAIP 2009) and color infrared (2001) aerial photography. This qualitative assessment of natural and water development features yielded a minimum of 617 natural and 975 water development water sources.

Figure 3.3.4.2a depicts the results of this analysis for natural water features and Figure 3.3.4.2b for water development features. Figures 3.4.4.2c and 3.3.4.2d depict permitted wells and USGS mapped springs.

It is assumed that most of the natural water features remain reliable water sources seasonally or year-round. However, it is expected that an unknown number of the water development projects within the watershed have either failed or have filled with sediment and are no longer viable sources of livestock and wildlife water. It was impossible to parse out non-viable water features from the functional water development projects with 100% surety for several reasons. Aerial photography that was used, in part, to locate these features is both dated and of relatively poor quality. Some stock reservoirs may not have shown evidence of water presence due to breaching of the impoundment structure or other form of leakage; being filled within sediment and having no capacity; were not filled because of the time of year the photograph was taken; or other factors.

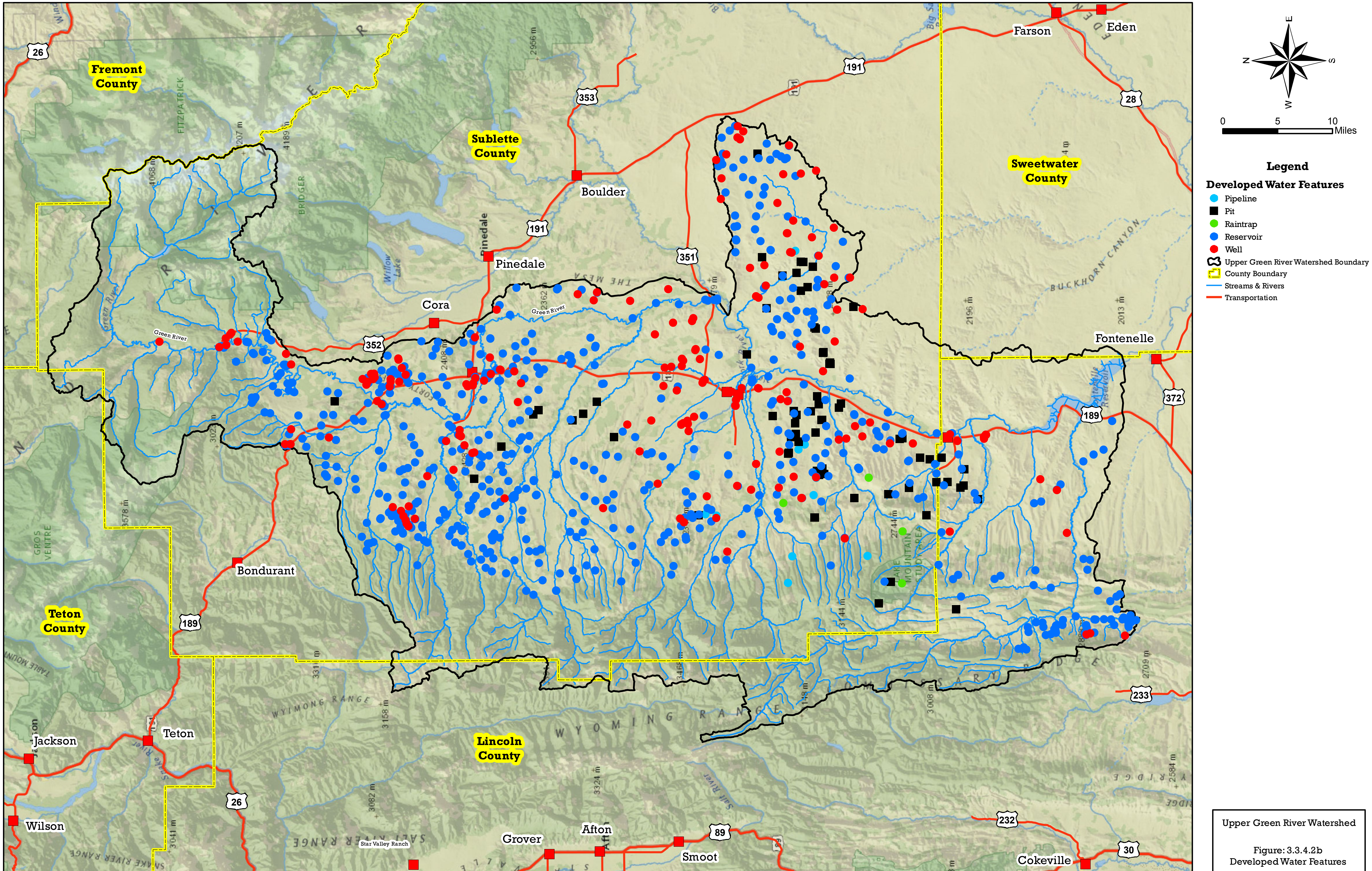
Acknowledging that an assessment of water development project viability may be flawed for the above reasons and possibly others, a qualitative assessment was performed in order to get an estimation of efficacy of existing water development projects within the watershed. A total of 646 water features were identified as being some form of constructed reservoir and were visually examined using aerial photography, including 2001 color infrared, 2006 NAIP, 2009 NAIP, and 2012 NAIP. Each reservoir that was visually examined was classified as “viable”, “non-viable”, or “unknown” based on evidence provided by one or more aerial photography sets, beginning with the most recent. The results of this efforts showed that 550 reservoirs were classified as “viable”, 68 reservoirs were classified as “non-viable”, and 28 reservoirs were classified as “unknown”. Figure 3.3.4.2e illustrates the location of these reservoirs.



Upper Green River Watershed

Figure: 3.3.4.2a
Natural Water Feature Sites

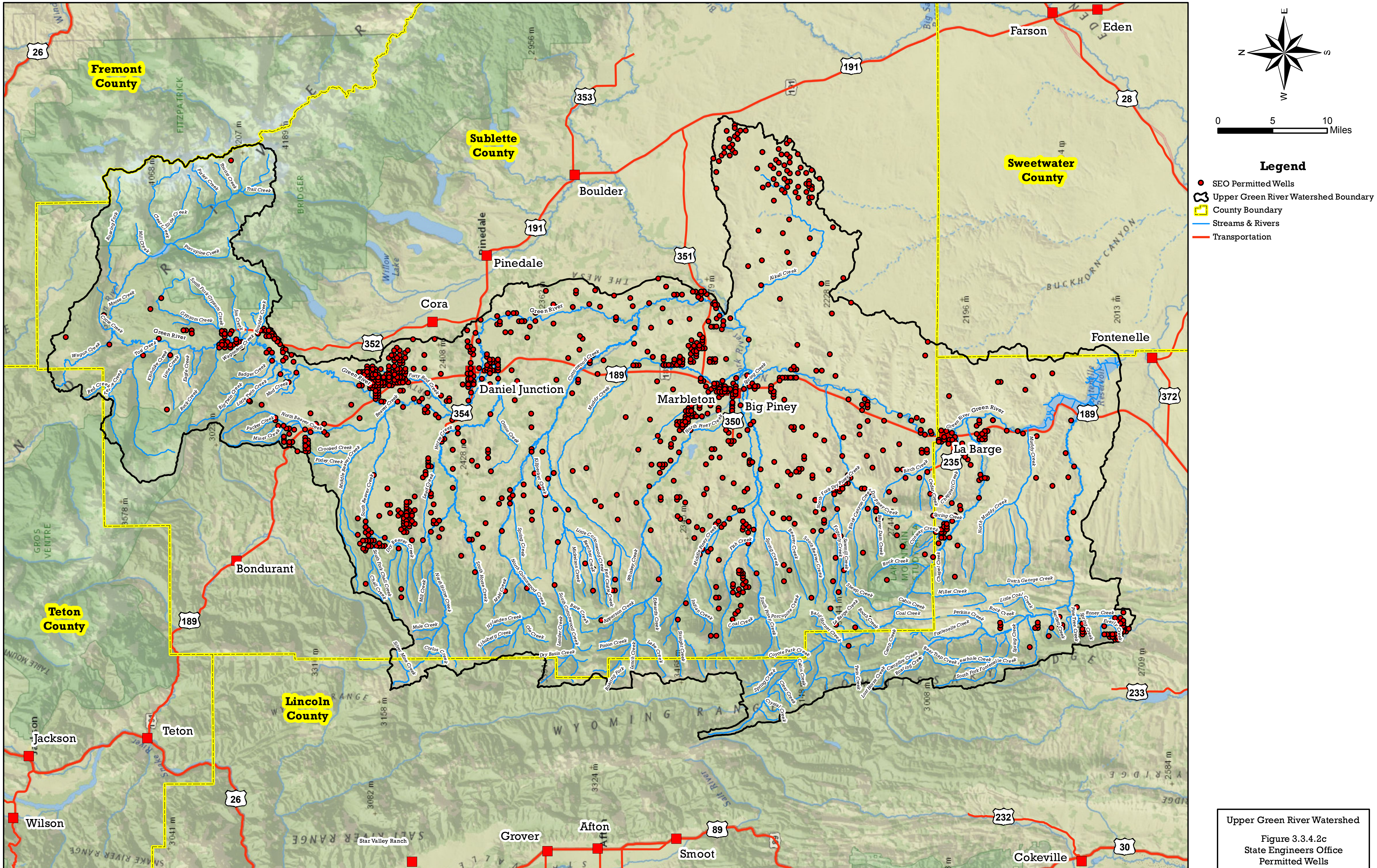
Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

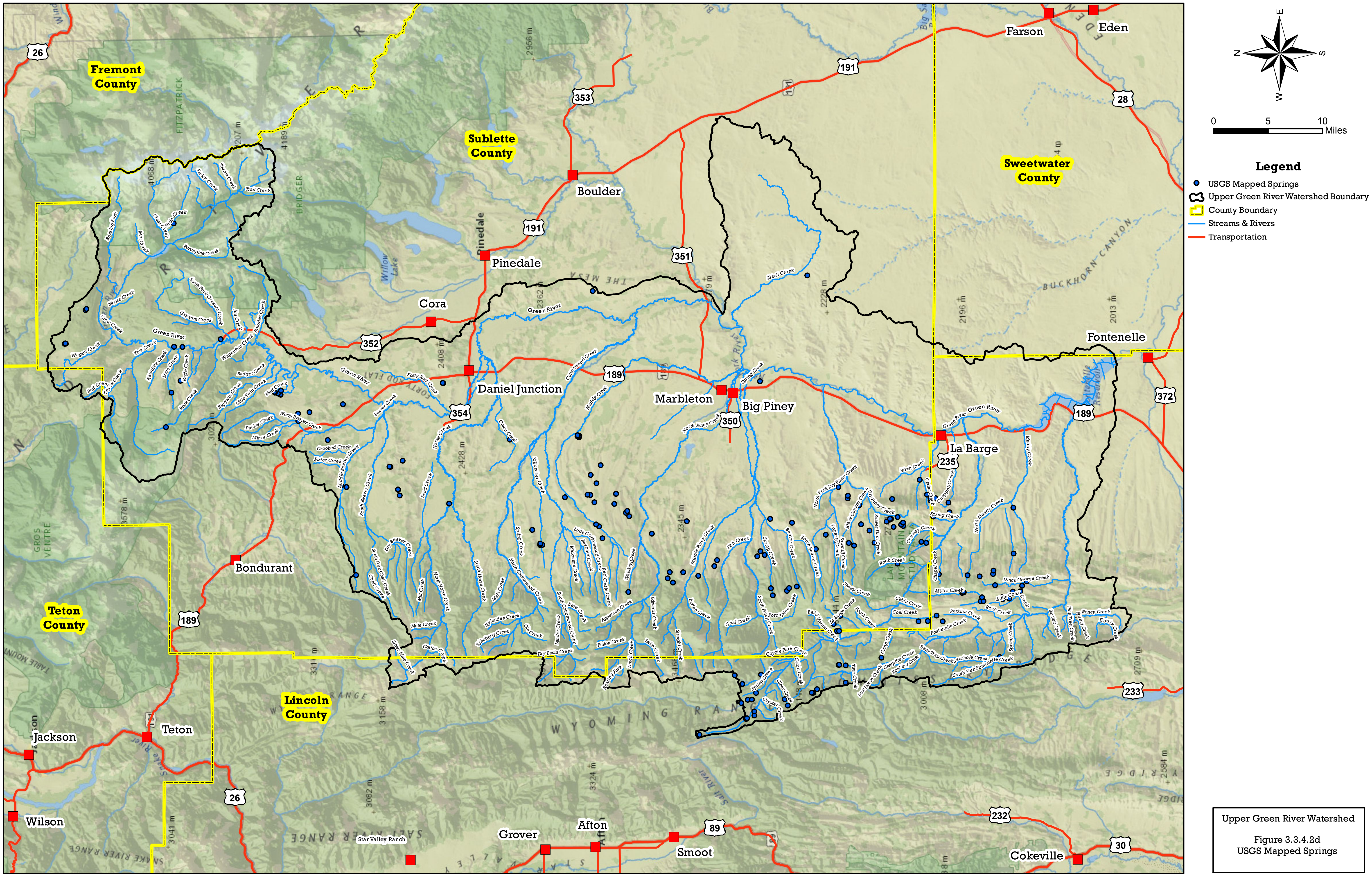
Figure: 3.3.4.2b
Developed Water Features

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

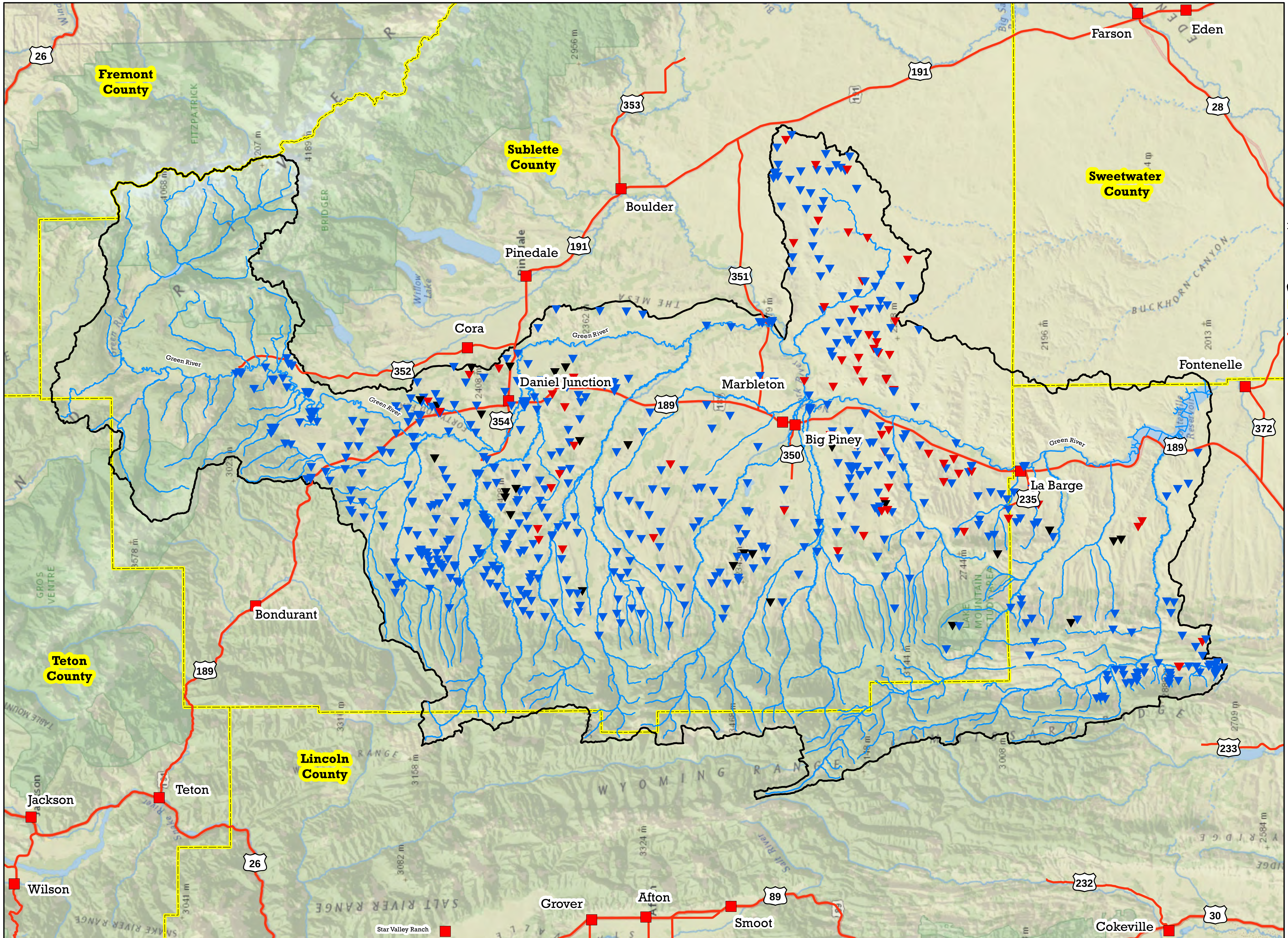
Figure 3.3.4.2c
State Engineers Office
Permitted Wells



Upper Green River Watershed

Figure 3.3.4.2d
USGS Mapped Springs

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

Figure 3.3.4.2e
Reservoir Viability

Projection: NAD 83 - UTM Zone 12

3.3.4.3 ECOLOGICAL SITE DESCRIPTIONS

The NRCS defines ecological sites as "*A distinctive kind of land with specific soil and physical characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation, and in its ability to respond similarly to management actions and natural disturbances.*" Information about individual ecological sites is compiled into an ecological site description (ESD) report, which is used to classify a landscape based on the interaction between soils, vegetation, and land management. Information included in each ESD is categorized into the following sections:

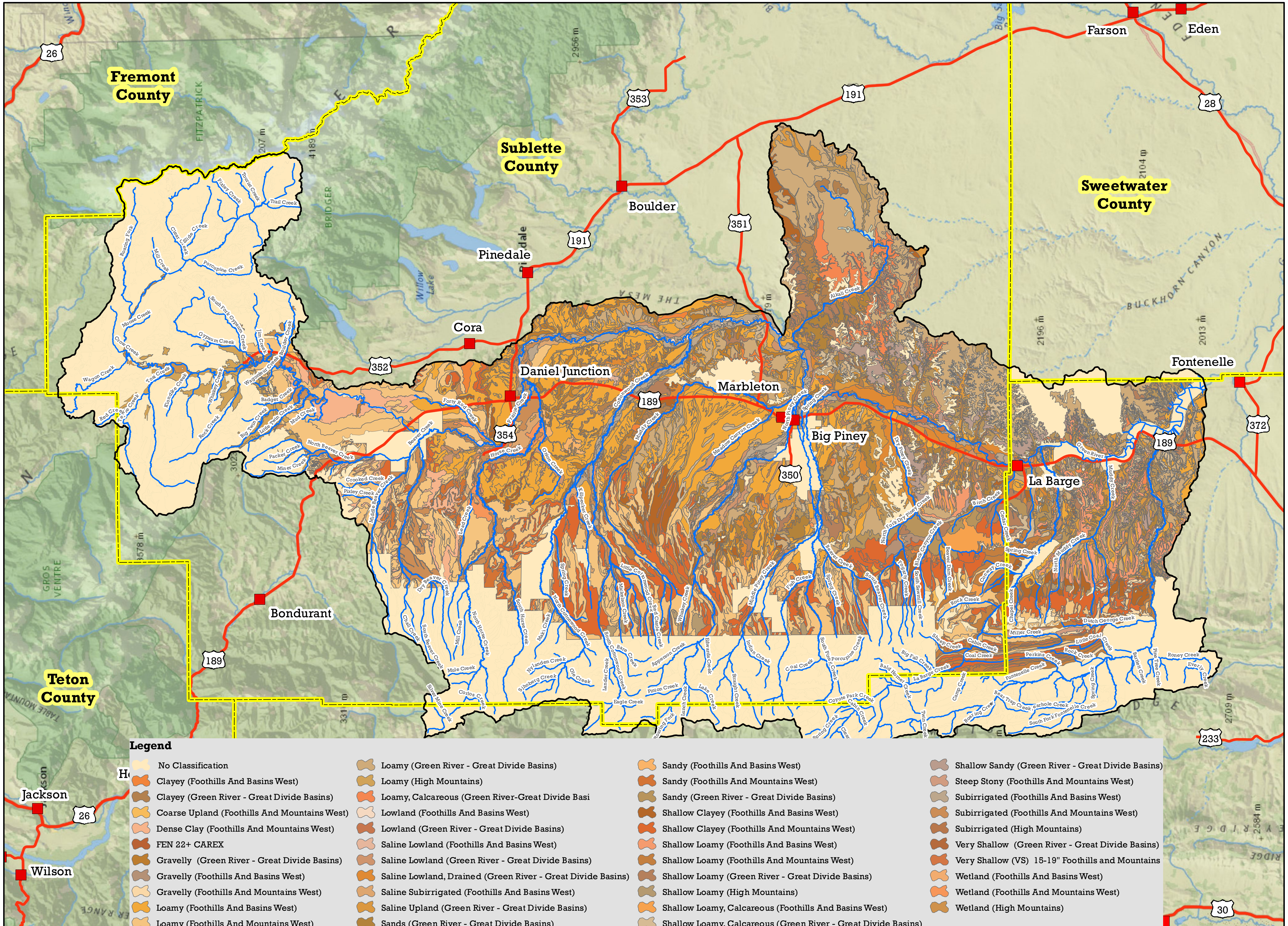
- **Site Characteristics** - Identifies the site and describes the physiographic, climate, soil, and water features associated with the site.
- **Plant Communities** - Describes the ecological dynamics and the common plant communities comprising the various vegetation states of the site. The disturbances that cause a shift from one state to another are also described.
- **Site Interpretations** - Interpretive information pertinent to the use and management of the site and its related resources.
- **Supporting Information** - Provides information on sources of information and data utilized in developing the site description and the relationship of the site to other ecological sites.

The reports provide a wealth of site-specific ecological information and can be used to predict plant community composition and guide management decisions. ESD reports can be obtained through the following website (https://esis.sc.egov.usda.gov/Welcome/pgESDWelcome.aspx).

Ecosite information is typically included with soil mapping data; however, soil mapping in certain areas has not been updated and is not yet associated with ecosite data. The portion of the Upper Green River watershed that is managed by the USDA Forest Service (31.3% of the watershed) has not been assigned ecosite data, and 11.6% of the watershed is classified as "Dominant Ecosite Undetermined". Ecosite data is available for the remainder (57%) of the watershed. The three most prominent ecosites in this portion of the watershed are: Loamy 10–14" (Foothills and Basin West), Loamy 15-19" (Foothills and Mountain West), and Loamy 7-9" (Green River – Great Divide Basins). A brief description of these ESDs as provided by NRCS is presented below. All available ecosite data for the watershed is summarized in Table 3.3.4.3 and presented graphically in Figure 3.3.4.3a Ecological Sites.

Table 3.3.4.3. A tabulation of ecological sites in the Upper Green River watershed.

	Area	
Ecological Site Description	**Acres**	**Percent of Watershed**
USFS Surveys - No Ecosite Data	587,551	31.3%
Dominant Ecosite Undetermined	217,981	11.6%
Loamy (Foothills And Basins West)	171,139	9.1%



0 5 10 Miles

Legend

- Upper Green River Basin Boundary
- County Boundary
- Streams & Rivers
- Transportation

Upper Green River Watershed

Figure 3.3.4.3a
Ecological Sites

Projection: NAD 83 - UTM Zone 12

Loamy (Foothills And Mountains West)	141,704	7.5%
Loamy (Green River - Great Divide Basins)	128,422	6.8%
Shallow Clayey (Foothills And Mountains West)	84,131	4.5%
Subirrigated (Foothills And Mountains West)	58,004	3.1%
Saline Upland (Green River - Great Divide Basins)	47,636	2.5%
Sandy (Green River - Great Divide Basins)	42,534	2.3%
Subirrigated (Foothills And Basins West)	32,121	1.7%
Saline Lowland, Drained (Green River - Great Divide Basins)	29,465	1.6%
Shallow Loamy (Foothills And Mountains West)	28,515	1.5%
Shallow Loamy (Green River - Great Divide Basins)	27,439	1.5%
Shallow Clayey (Foothills And Basins West)	26,585	1.4%
Gravelly (Green River - Great Divide Basins)	25,824	1.4%
Shallow Loamy, Calcareous (Green River - Great Divide Basins)	24,533	1.3%
Shallow Loamy (Foothills And Basins West)	24,293	1.3%
Sands (Green River - Great Divide Basins)	21,597	1.1%
Dense Clay (Foothills And Mountains West)	21,205	1.1%
Clayey (Green River - Great Divide Basins)	19,064	1.0%
Loamy, Calcareous (Green River-Great Divide Basins)	16,821	0.9%
Shallow Sandy (Green River - Great Divide Basins)	14,846	0.8%
Saline Lowland (Green River - Great Divide Basins)	14,361	0.8%
Water	11,529	0.6%
Clayey (Foothills And Basins West)	11,425	0.6%
Saline Subirrigated (Foothills And Basins West)	8,505	0.5%
Shallow Loamy, Calcareous (Foothills And Basins West)	6,508	0.3%
Wetland (Foothills And Mountains West)	6,278	0.3%
Sandy (Foothills And Mountains West)	5,848	0.3%
Gravelly (Foothills And Mountains West)	5,142	0.3%
Shallow Loamy (High Mountains)	3,476	0.2%
Lowland (Green River - Great Divide Basins)	2,681	0.1%
Lowland (Foothills And Basins West)	2,511	0.1%
Gravelly (Foothills And Basins West)	2,472	0.1%
Sandy (Foothills And Basins West)	1,728	0.1%
Very Shallow (VS) 15-19" Foothills and Mountains	1,604	0.1%
Limy Cold Desert	1,217	0.1%
Wetland (Foothills And Basins West)	1,048	0.1%
Coarse Upland (Foothills And Mountains West)	961	0.1%
Saline Lowland (Foothills And Basins West)	315	<0.1%
Very Shallow (Green River - Great Divide Basins)	164	<0.1%
FEN 22+ CAREX	128	<0.1%

Loamy, 10 to 14-inch Precipitation Zone, Foothills and Basins West

Site Characteristics

These sites usually occur in upland positions on relatively flat to moderately sloping land on all exposures, at elevations between 6,500 and 7,000 feet. Associated land features typically include: alluvial fans, ridges, and stream terraces. The soils of these sites are deep to moderately deep (greater than 20" to bedrock) and well-drained. Textures range from loamy to very fine sandy loam, and parent material is alluvium and residuum from sedimentary rock.

Annual precipitation ranges from 10 to 14 inches per year. Wide inter-annual precipitation fluctuations are not uncommon, and they typically result in dryer than average years. 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. Growth of native cool season plants begins about April 15 and continues to about August 15. Some green-up of cool season plants usually occurs in September depending upon fall moisture occurrences.

Plant Communities

These plant community narratives may not represent every possibility, but they probably are the most prevalent and repeatable plant communities. The Historic Climax Plant Community (HCPC) has been determined by study of rangeland relic areas, or areas protected from excessive disturbance. The HCPC for this site is a mixed grass/mountain big sage plant community. This community evolved with grazing by large herbivores and is well suited for grazing by domestic livestock. Potential vegetation is estimated at 75% grasses or grass-like plants, 10% forbs, and 15% woody plants. The major grasses include rhizomatous wheatgrass, bluebunch wheatgrass, Letterman needlegrass, Canby bluegrass, and needle-and-thread. Other grasses may include Indian ricegrass, prairie junegrass, and bottlebrush squirreltail, Sandberg and mutton bluegrass, thread-leaf and needle-leaf sedge, and plains reedgrass. Wyoming big sagebrush is the dominant woody plant. Other woody species may include green rabbitbrush and winterfat.

A typical plant composition for the HCPC consists of rhizomatous wheatgrass 10-30%, bluebunch wheatgrass 5-15%, Letterman needlegrass 5-15%, needleandthread 5-10%, Canby bluegrass 5-10%, other grasses and grass-like plants 10-20%, perennial forbs 5-15%, Wyoming big sagebrush 10-20%, and 5-10% other woody species. 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. Ground cover, by ocular estimate, varies from 40-50%.

As this site deteriorates from of a combination of frequent and severe grazing, species such as big sagebrush, rabbitbrush, phlox, and yarrow will increase, while cool-season bunchgrasses such as bluebunch wheatgrass, Indian ricegrass, and needle-and-thread will decrease in frequency and production. Big sagebrush will become dominant on some areas with an absence of fire. Wildfires are often actively controlled, so chemical control using herbicides has replaced the historic role of fire on this site. Prescribed burning has regained some popularity recently.

Site Interpretations

Mixed Grass/Big Sagebrush Plant Community (HCPC): This plant community provides suitable thermal and escape cover for mule deer, elk, and antelope. Sagebrush, which can approach 15% protein and 40-60% digestibility, provides important winter forage for mule deer and antelope. Year-round habitat is provided for sage grouse and many other sagebrush obligate species such as the sage sparrow, Brewer's sparrow, sage thrasher, pygmy rabbit, sagebrush vole, horned lizard, and pronghorn antelope. Other birds that would frequent this plant community include horned larks and golden eagles.

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.

Loamy, 15 to 19-inch Precipitation Zone, Foothills and Mountains West

Site Characteristics

This site occurs on gentle to steep mountain slopes, valley bottoms, and steep glacial moraines. It is found on all exposures at high elevations, but primarily on north and east slopes at lower elevations.

Dominant landforms include hills, ridges, and alluvial fans, and typical elevations are between 5,600 and 8,300 feet. Annual precipitation ranges from 15 to 19 inches, and wide inter-annual precipitation fluctuations are not uncommon. 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 in winter move rapidly from northwest to southeast and account for extreme low temperatures. Extreme storms may occur during the winter, but most severely affect ranch operations during spring. Prevailing winds are from the southwest, and strong winds are less frequent than over other areas of Wyoming. Occasional storms, however, can bring brief periods of high winds with gusts exceeding 50 mph.

Growth of native cool season plants begins about May 15 and continues to about August 15. The soils of this site are moderately deep (greater than 20" to bedrock) to very deep and well-drained with textures ranging from very fine sandy loams through clay loams. Some soils have a lime horizon below 3 feet. The overlying soil is usually noncalcareous.

Plant Communities

The HCPC for this site is a mixed grass/mountain big sage plant community. This community evolved with grazing by large herbivores and is well suited for grazing by domestic livestock. Potential vegetation is estimated at 75% grasses or grass-like plants, 15% forbs, and 10% woody plants. The major grasses include bluebunch wheatgrass, Idaho fescue, blue wildrye, mountain brome, Canby bluegrass, and spike fescue. Other grasses and grass-likes may include big, mutton, and Sandberg bluegrass, basin wildrye, prairie junegrass, bottlebrush squirreltail, Letterman, western, and Columbia needlegrass, sun sedge, California and timber oatgrass, slender and thickspike wheatgrass, and nodding brome. Mountain big sagebrush is the dominant woody plant. Other woody species may include bitterbrush, snowberry, serviceberry, silver sagebrush, and green rabbitbrush.

A typical plant composition for this state consists of bluebunch wheatgrass 10-25%, Idaho fescue 10-25%, blue wildrye 5-10%, mountain brome 5-10%, spike fescue 5-10%, Canby bluegrass 5-10%, other grasses and grass-like plants 10-25%, perennial forbs 10-20%, mountain big sagebrush 1-10%, and up to 5% other woody species. Ground cover, by ocular estimate, varies from 55-60%.

As this site deteriorates because of a combination of frequent and severe grazing, species such as mountain big sagebrush, buckwheat, and yarrow will increase. Less palatable grasses such as Letterman needlegrass, Idaho fescue, rhizomatous wheatgrass, and Sandberg bluegrass also increase. Kentucky bluegrass often invades. Cool-season grasses such as bluebunch wheatgrass, blue wildrye, mountain brome, Columbia needlegrass, and spike fescue will decrease in frequency and production. Mountain big sagebrush will become dominant with the absence of fire. Wildfires are often actively controlled so chemical control using herbicides has replaced the historic role of fire on this site. Recently, prescribed burning has regained some popularity.

<u>Site Interpretations</u>

Mixed Grass/Mountain Big Sage Plant Community (HCPC): This plant community provides suitable thermal and escape cover for mule deer, elk, and antelope. Sagebrush, which can approach 15% protein and 40-60% digestibility, provides important winter forage for mule deer and elk. Year-round habitat is provided for many sagebrush obligate species such as the sage grouse, sage sparrow, Brewer’s sparrow, sage thrasher, pygmy rabbit, sagebrush vole, horned lizard, and pronghorn antelope. Other birds that would frequent this plant community include horned larks and golden eagles.

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.

Loamy, 7 to 9-inch Precipitation Zone, Green River and Great Divide Basins

<u>Site Characteristics</u>

These sites typically occur in an upland position on relatively flat to moderately sloping land on all exposures at elevations between 6,000 to 7,200 feet. Associated land features typically include: alluvial fans, ridges, and stream terraces. Annual precipitation ranges from 7 to 9 inches per year. Wide inter-annual precipitation fluctuations are not uncommon, and they typically result in dryer than average years.

Temperatures vary widely 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 in winter move rapidly from northwest to southeast and account for extreme minimum temperatures. Growth of native cool season plants begins about April 15 and continues to about July 15. Some green up of cool season plants may occur in September if moisture is available.

The soils of these sites are moderately deep to very deep (greater than 15" to bedrock), well drained and moderately permeable. Thin coarse-loamy surface layers are common. Layers of the soil most influential to the plant community varies from 3 to 6 inches thick. Textures range from loam to very fine sandy loam.

Plant Communities

The HCPC for these sites is a mixed grass/big sagebrush community, which evolved with grazing by large herbivores and is well suited for grazing by domestic livestock. Potential vegetation is estimated at 75% grasses or grass-like plants, 10% forbs, and 15% woody plants. The major grasses include: thickspike wheatgrass, needle-and-thread, Indian ricegrass, bluebunch wheatgrass, prairie junegrass, and bottlebrush squirreltail. Other grasses occurring in this climax community may include Sandberg and Canby bluegrass, thread-leaf and needle-leaf sedge, and plains reedgrass. Wyoming big sagebrush is the dominant woody plant, and other woody species may include green rabbitbrush, bud sagebrush, shadscale, spiny hopsage, and winterfat.

A typical plant composition for this community consists of thickspike wheatgrass 10-30%, needle-and-thread 10-20%, Indian ricegrass 10-20%, up to 10% prairie junegrass, up to 10% bottlebrush squirreltail, up to 10% bluebunch wheatgrass, other grasses and grass-like plants 5-15%, perennial forbs 5-15%, Wyoming big sagebrush 5-15%, and 5-15% other woody species. 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. Ground cover, by ocular estimate, varies from 20-35%. This plant community is extremely stable and well adapted to the Cool Central Desertic Basins and Plateaus climatic conditions. The diversity in plant species allows for high drought tolerance.

As these ecosites deteriorate because of frequent and severe grazing, species such as big sagebrush, rabbitbrush, phlox, and yarrow will increase, while cool-season bunchgrasses such as bluebunch wheatgrass, Indian ricegrass, and needleandthread will decrease in frequency and production. These plant community narratives may not represent every possibility, but they are likely the most prevalent and repeatable plant communities.

Site Interpretations

Mixed Grass/Big Sagebrush Plant Community (HCPC): Suitable thermal and escape cover for mule deer may be limited due to the low height of woody plants. However, sagebrush, which can approach 15% protein and 40-60% digestibility, provides important winter forage for mule deer and antelope. Year-round habitat is provided for sage grouse and many other sagebrush obligate species such as the sage sparrow, Brewer’s sparrow, sage thrasher, pygmy rabbit, sagebrush vole, horned lizard, and pronghorn antelope. Other birds that would frequent this plant community include horned larks and golden eagles.

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.

3.3.4.4 RANGE CONDITION AND NEEDS

Livestock grazing occurs on federal, state, and private land within the study area, and associated land and livestock management practices vary widely. Detailed, site-specific information regarding range condition is outside the scope of this project, and no field investigations were conducted to specifically assess range condition. Data collected on several federal allotments within the study area were acquired, but it is not possible to draw conclusions about overall range condition within the watershed from such a small dataset.

As is typical in sagebrush grasslands of the arid west, livestock and wildlife use is generally concentrated around waterways and riparian areas. Unless measures are taken to disperse livestock and wildlife from riparian areas, range health in these areas often suffers. Riparian vegetation is often overgrazed and/or grazed late in the season when perennial plants need to store and transfer carbohydrate reserves to root systems to prepare for the dormant season. Overgrazing often results in reduced productivity and poor health within these plant communities. Animal concentration in these areas can contribute to soil compaction, which further inhibits plant productivity. Additionally, many upland areas are underutilized due to their relative isolation from watering sites.

A number of management techniques can be used to disperse livestock from riparian zones and encourage grazing in underutilized areas (e.g., fencing, herding, strategic salting), but most are only effective if implemented along with the development of upland watering sites. As such, the development of upland wildlife/livestock watering projects is a key focus of this study.

Fencing is a versatile management tool that can be utilized to protect riparian areas and other sensitive environmental sites from trampling, soil compaction, overgrazing, and other impacts caused by concentrated livestock use. To accomplish this, fence can be constructed in a manner that excludes livestock from these sensitive areas, and off-site watering systems can be developed to provide drinking water for the excluded livestock. The exclusion of livestock from these areas has numerous benefits at a local scale, as well as improving overall watershed function. Once livestock pressure on the riparian plant community within the exclosure fence is eliminated and it is allowed time to recover, the restored plant community will provide a number of benefits including: streambank stabilization, increased water infiltration rates, wildlife cover and forage, woody debris and instream cover for fish, and improved water quality.Although not applicable in some situations, fences can also be used to divide pastures and facilitate rotational grazing systems. If given a choice, cattle will eat the highest quality, most palatable plants in a pasture first, and this can result in inefficient, uneven use of the pasture and increase undesirable weedy species. More efficient livestock use of the available forage can be encouraged through the implementation of a managed rotational grazing system, involving high density stocking for short time periods in smaller pastures.

Rotational grazing systems have been successfully implemented throughout the world, and have also been successfully used to enhance wildlife habitat and rehabilitate desirable vegetation. The basic elements of a rotational grazing system are:

- Proper timing of grazing corresponding to plant physiological stage;
- Proper intensity of grazing and duration in each pasture;
- Substantial residue or plant height remaining after grazing;
- Proper duration of rest to facilitate regrowth.

Rotational grazing involves periodical movement of livestock between smaller pastures, with specific attention paid to pasture health and stubble height. It is necessary to retain adequate leaf area after grazing for subsequent regrowth. Each pasture typically needs 14 to 45 days of rest (depending on plant community and moisture levels) to allow for adequate regrowth.

Active herding and salting can be useful tools to assist with preventing livestock from concentrating in riparian areas and encouraging grazing in underutilized areas. These practices are more practical in large pastures, where fence construction and maintenance is cost prohibitive. Strategic salting involves the placement of salt blocks in underutilized areas and away from riparian areas, with the goal of luring livestock out of the riparian areas. Salting areas should be rotated during the grazing season and from year to year. See Section 4.4.2 of this report for further information on livestock management.

3.3.5 OIL AND GAS RESOURCES

Oil and natural gas have been produced in Wyoming since the mid-1800s. However increased demand coupled with recent improvements in resource detection and extraction technologies have driven a substantial increase in the volume of production over the last 15 years, primarily due to the growth in the natural gas industry. The Upper Green River basin is within the largest contiguous concentration area of onshore oil and gas reserves in the lower 48 states, and the Greater Green River Basin, located primarily in southwestern Wyoming and Northwestern Colorado leads recently inventoried geologic basins in volume of oil and natural gas reserves. There are over 70 named fields of producing oil and gas wells within the project study area, including all or portions of intensely developed fields such as the Jonah Field, Big Piney-LaBarge, and a small portion of the Pinedale Anticline Field. These fields overlay federal, state, and private lands. The Jonah Field and Pinedale Anticline combined constitute the 2nd largest producing gas field by volume in the United States (BLM 2012).

Table 3.3.5. Tabulation of 2012 Oil, Gas, and Water Production from the Upper Green River Watershed.

Wells	Oil	Gas	Water
	(Bbls)	(Mcf)	(Bbls)
3,353	2,146,559	466,755,394	9,332,148

Oil and gas development within the study area is concentrated south of Pinedale and in the Big Piney-LaBarge area, in association with oil and gas bearing geologic formations. The BLM administers development of the federal subsurface mineral estate, and to a much lesser degree Wyoming Land Quality Division administers development of State Trust mineral revenue. There is very little on-going oil and gas activity on National Forest within the watershed study area; however, supplemental analysis of the SEIS and ROD denying Federal leasing of over 44,000 acres of potential oil and natural gas development in the Wyoming Range – Big Piney Ranger District is on-going, and the proposed expansion area occurs entirely within the Upper Green River basin study area. Figure 3.3.5 Oil and Gas Resources illustrates the well distribution across the basin. The locations of all active and permanently abandoned oil and gas wells were obtained from the Wyoming Oil and Gas Conservation Commission (WOGCC) website: http://wogccms.state.wy.us/.

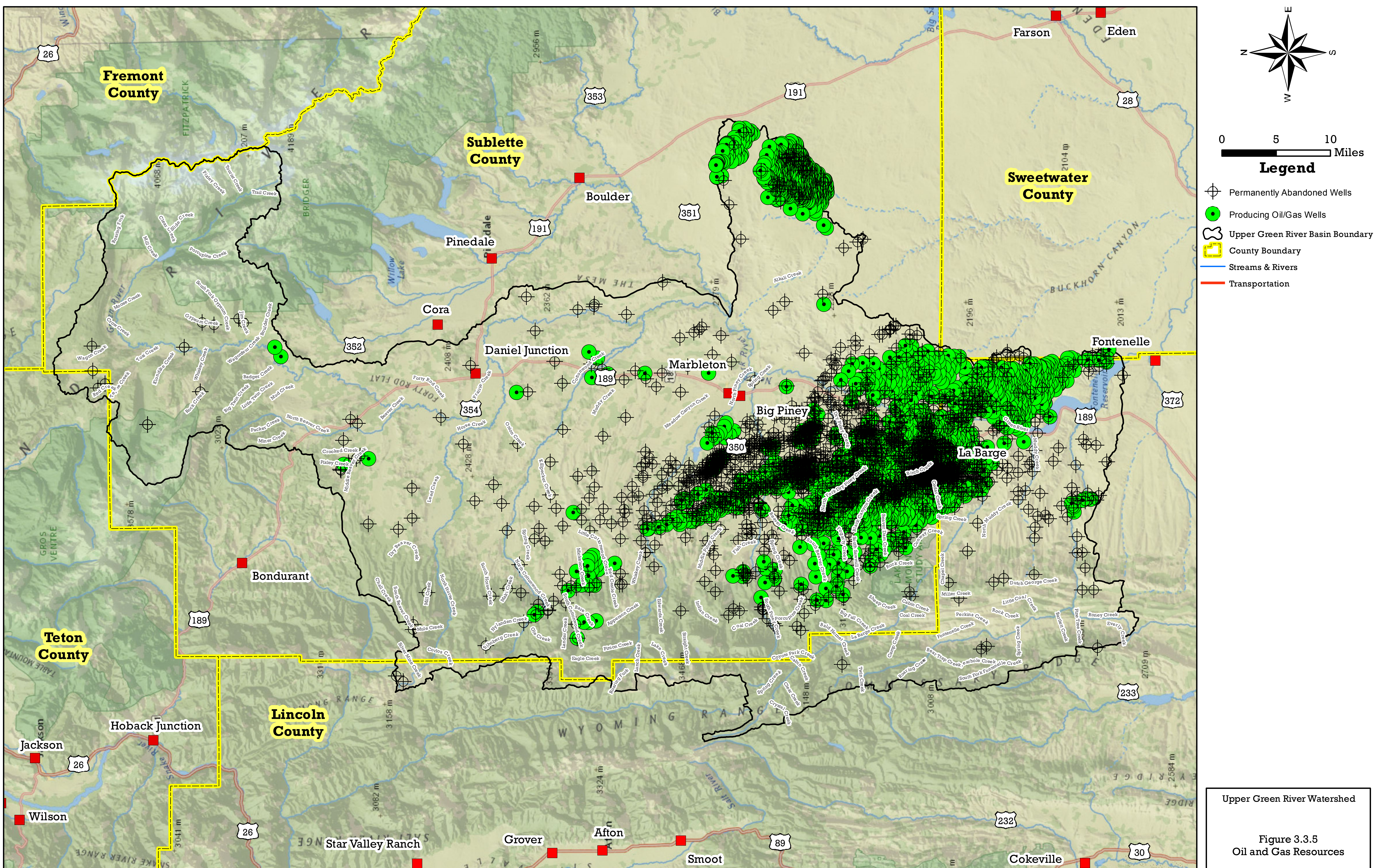
In association with natural gas production helium as a byproduct is commercially produced at the Riley Ridge Facility west of Big Piney. The facility processes natural gas from the Riley Ridge Field, one of the largest helium-rich natural gas fields in the United States. The Riley Ridge field is believed to contain sufficient helium reserves to support production for decades. The plant has a reported capacity of 5.7 million cubic meters per year.

3.3.6 MINING & MINERAL RESOURCES

Coal, uranium, trona, bentonite, rare earth elements and metallic minerals such as gold and copper are important mineral resources in the state of Wyoming. However, there is limited current or historic mining and mineral extraction described from the Upper Green River watershed study area. Though no longer active, small-scale underground coal mining within the La Barge coal field was the most notable mining of this nature pursued at any time within the watershed. The most significant saleable mineral currently found and actively mined within the watershed is aggregates, or sand and gravel. In general, extensive deposits of commercial grade sand and gravel can be found in both terrace and alluvial deposits along the Green River and its major tributaries (Figure 3.3.6). Wyoming DEQ also reports several active graphite mines in the south central portion of the watershed, primarily along the Green River south of Big Piney. Generally, significant occurrences of mineralized zones are limited within the watershed. There is very little future development potential for these resources within the watershed based on low in-place tonnage and low grades of existing mineral deposits. Commercial extraction of non-fluid minerals such as coal, oil shale, phosphate and sodium are not projected to be economically easible to any large degree in the foreseeable future. Figure 3.3.6 mining and mineral resources outlines developed sites within the basin.

3.3.7 CULTURAL RESOURCES

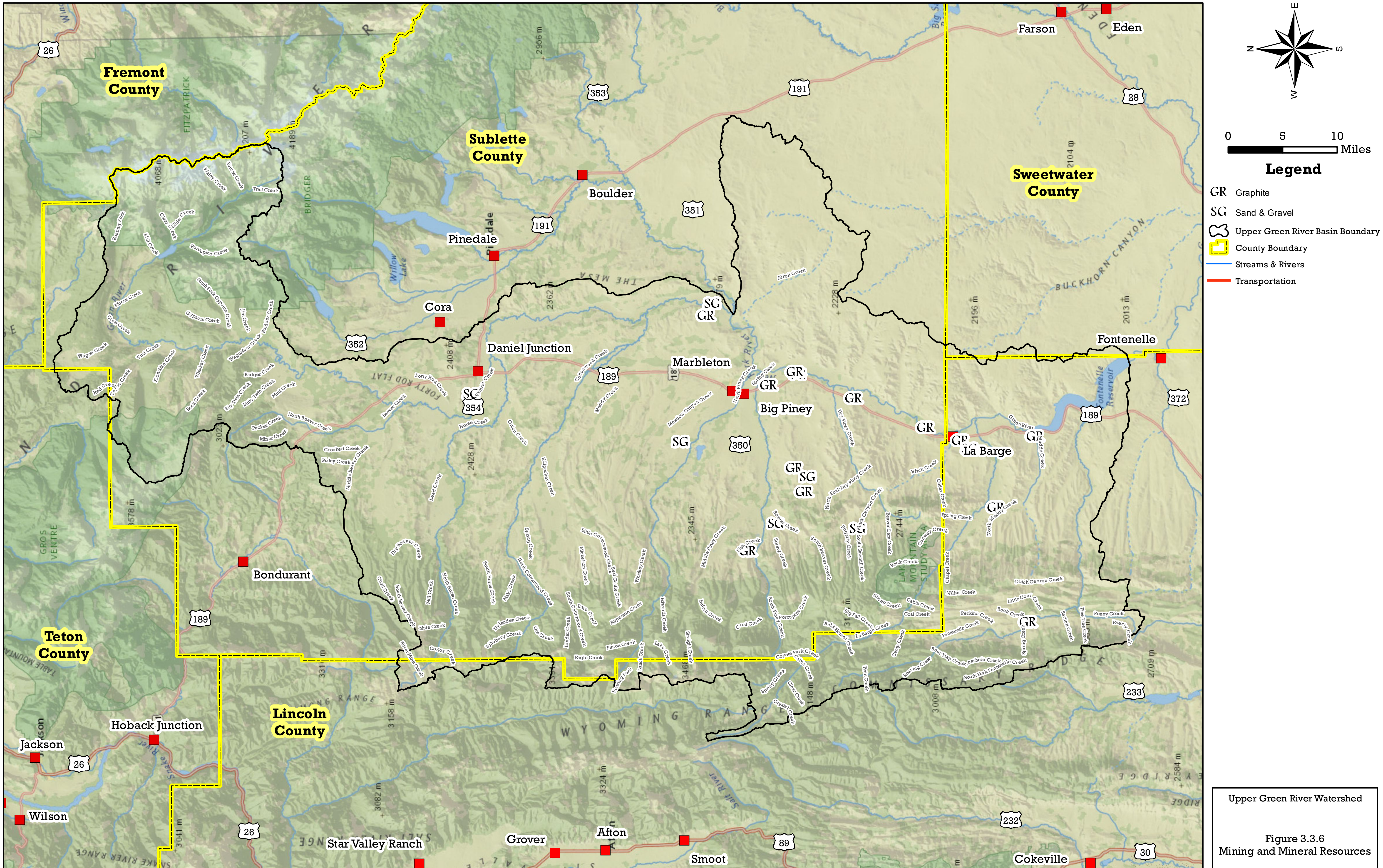
The watershed contains a diverse range of cultural resources, as described in detail in the Proposed Resource Management Plan and Final Environmental Impact Statement for the Pinedale Field Office (USDI-BLM 2008). The primary types of cultural resources are prehistoric, historic, and Native American.



Upper Green River Watershed

Figure 3.3.5
Oil and Gas Resources

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

Figure 3.3.6
Mining and Mineral Resources

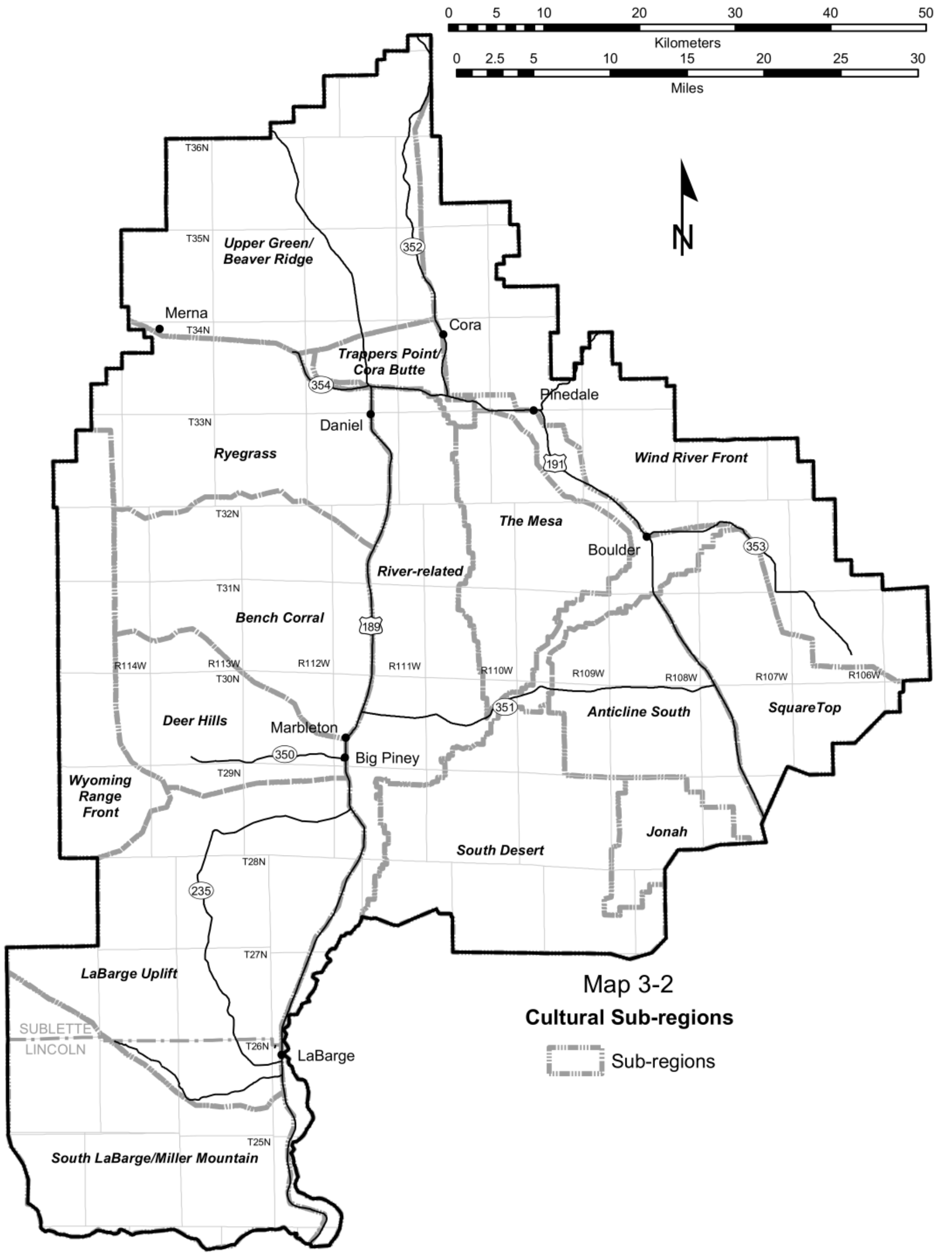
Projection: NAD 83 - UTM Zone 12

Prehistoric Cultural Resources – A variety of classes of prehistoric archeological remains are present within the watershed. The most prevalent archeological remains include fire and baking pits; discarded cooking rock; flaked stone tools and waste flakes; and animal bone fragments. When two or more of these classes are co-located it is typically classified as a campsite. Open campsites and lithic scatters comprise the majority of prehistoric archeological sites. Stone circle sites are also relatively common in some parts, a characteristic that distinguishes the watershed from the rest of the Green River Basin. Other site types correspond to more specialized activity, such as animal kill and butchering sites, plant processing locales, and tool stone source areas. Two particularly prominent animal-kill and processing sites, the Wardell site (a bison trapping site) and the Trappers Point site (a pronghorn antelope procurement and processing site), have been excavated. A few other important and particularly sensitive classes of prehistoric sites are also present, including rock art sites and human interments.

Historic Cultural Resources – A majority of the total recorded cultural sites within the watershed are historic archeological sites, ranging from prominent resources such as the Lander Cutoff of the Emigrant Trail or historic ranches, to trash scatters. The origin of these historic archeological sites range from the early fur-trapping industry to the recent oil and gas development. The most common historic archeological site types are those associated with ranching activities, frequently occuring on private land and dating from the 1880s to 1920s. However, a number of ancillary site types are common on federal lands. The more prominent of such sites include line camps, corrals, windmills, irrigation ditches, fence lines, sheepherder monuments and rock cairns, stock driveways (including the Green River Drift), and numerous trash scatters that were associated with stock herding camps. Sites associated with historic oil and coal mining, particularly in the LaBarge area, include historic oil field camps and associated ancillary facilities; historic coal mine complexes, including associated residential structures; historic oil well locations and oil field equipment; roads; and a variety of features produced as a result of construction or maintenance of wells. Other prominent historic site types in the planning area include fur trade and rendezvous-related sites along the Green River; early camp and town site locations; tie hacks and logging remains such as flumes; and Civilian Conservation Corps camp remains.

Native American Cultural Resources – Cultural resources sensitive and potentially sacred to modern Native American tribes within the watershed include burials; rock art; rock features and alignments (such as stone circles, cairns, and medicine wheels); trails, and certain religiously significant natural landscapes and features. Some or all of these resources may be formally designated as “Traditional Cultural Properties” and thereby meet the criteria for National Register of Historic Places eligibility.

Cultural Resource Subregions – Cultural resources are not distributed evenly within the watershed. TRC Mariah Associates (2006) defined 15 cultural resource subregions within the Green River Basin to better characterize the nature and sensitivity of the resource base. The following Map 3-2 illustrates the subregions from the BLM.



NO WARRANTY IS MADE BY THE BLM FOR USE OF THE DATA FOR PURPOSES NOT INTENDED BY BLM.

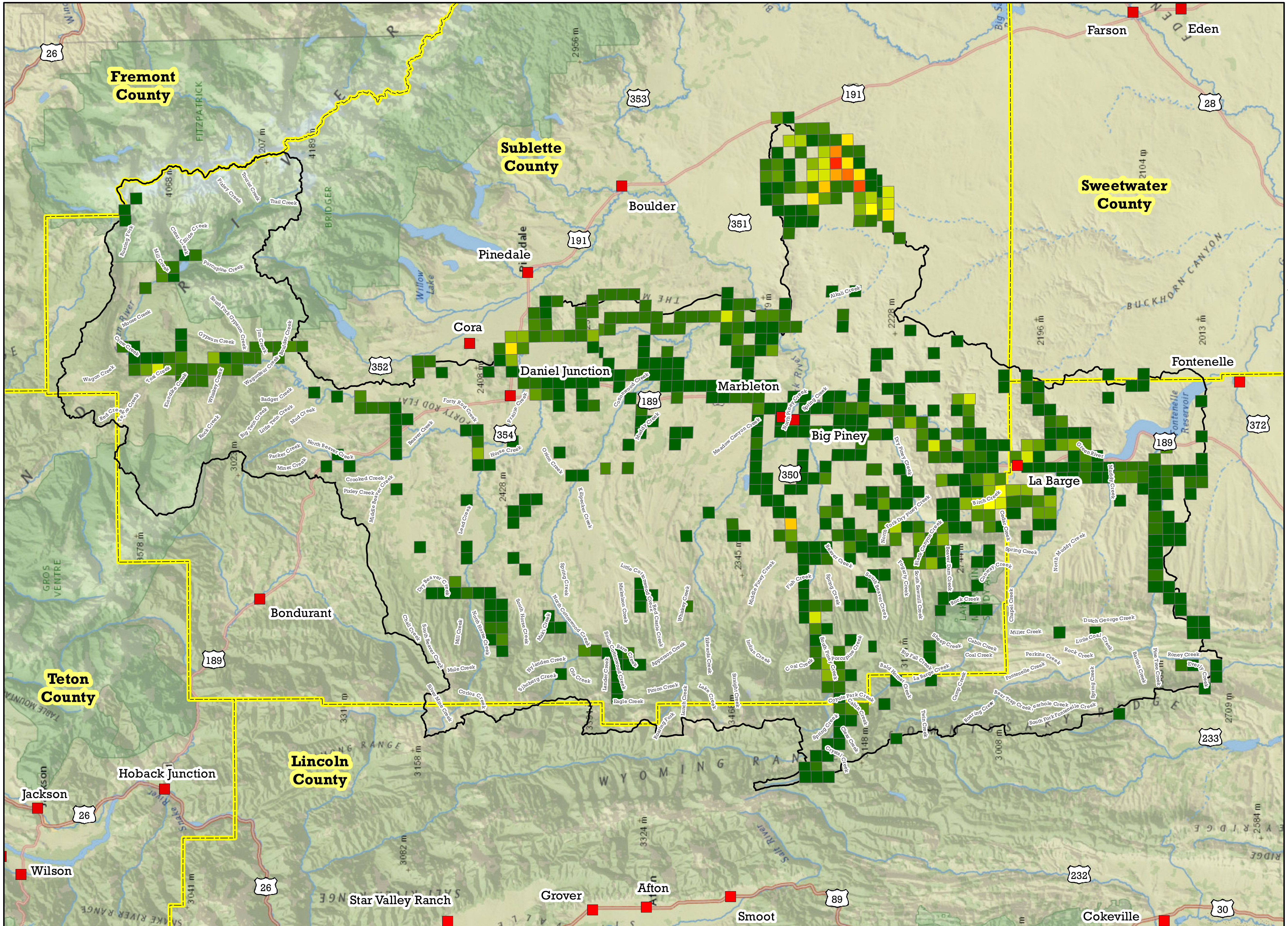
Subregions relevant to the watershed include Bench Corral, Deer Hills, LaBarge Uplift, River-related, Ryegrass, South Desert, South LaBarge/Miller Mountain, The Mesa, Trappers Point/Cora Butte, Upper Green/Beaver Ridge, Anticline South, Jonah, and Wyoming Range Front. Subregions that contain relatively high densities of significant prehistoric cultural resources include the LaBarge Uplift, Deer Hills, Anticline South, Jonah, and Upper Green River/Beaver Ridge subregions. Subregions that may contain low densities of significant prehistoric sites include Bench Corral, Ryegrass, and South Desert.

Inventories – A variety of cultural resource inventories have been performed in the watershed in the past 20+ years, generally in response to proposed undertakings on federal lands (e.g., energy exploration and development, highway construction, and power distribution). Nearly 171,000 acres have been inventoried for cultural resources, yielding the location of about 6,300 cultural sites (State Historic Preservation Office CRISP database). Before the mid-1990s, the vast majority of inventories were conducted in the LaBarge Uplift subregion. Since the mid- 1990s, however, the Jonah subregion has become the focus of the greatest amount of work, and the Deer Hills, Anticline South, Square Top, and Mesa subregions have received greatly increased examination. Other subregions such as the Ryegrass, South LaBarge, and River-related remain minimally studied and poorly documented.

Actions on federal land that will potentially result in ground disturbance are required to comply with Section 106 of the National Historic Preservation Act. As part of Section 106 compliance, the Wyoming State Historic Preservation Office (SHPO) maintains a database of inventoried cultural and historic sites within the state, and a determination of each site's eligibility for inclusion in the National Register of Historic Places. The Wyoming Geographic Information Science Center (WYGISC) website provides spatial coverage from SHPO that generally locates (on a per Section basis) cultural and historic sites; attributes recorded for each section include: # of sites; acres inventoried; report numbers; and eligible site number. Figure 3.3.7 Cultural Sites, presents the results of the cultural and historic sites database query. Each section within the study area has been color-coded based upon the number of sites within it determined to be eligible for inclusion on the Register.

The National Register of Historic Places is the nation's official list of cultural/historic resources determined to be worthy of preservation. Administered on a federal level by the National Park Service and managed locally by the SHPO, the National Register is part of a program to coordinate and support both public and private efforts to identify, evaluate, and protect historic and archeological resources. The National Register recognizes the accomplishments of those who have contributed to the history and heritage of the United States, the state, and local communities.

Listing a property on the National Register of Historic Places is a form of acknowledgment and prestige, which places no restraints on the property. The National Register does not restrict the rights of property owners to use, develop, or sell the property. Although placing a property on the National Register neither stops alterations to a building nor requires owners to provide the public access to the property, it can provide the owner with eligibility for certain financial incentives (NPS, 2009 at http://www.nps.gov/history/nr/).



Legend
- Upper Green River Basin Boundary
- County Boundary
- Streams & Rivers
- Transportation

0 5 10 Miles

Number of Cultural Sites Eligible for Inclusion on the National Register of Historic Places (Per PLSS Section)

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 15, 19, 22, 24

Upper Green River Watershed

Figure 3.3.7
Cultural Sites

Projection: NAD 83 - UTM Zone 12

To date, twelve sites within the study area have been included in the Register and are presented below.

Table 3.3.7 Sites Listed on the National Register of Historic Places

Site	County	Year	Smithsonian #
Bridge over Green River	Sublette County	1985	48SU978
Calpet Rockshelter	Sublette County	1994	48SU354
Circle Ranch	Sublette County	1987	48SU537
Daniel School	Sublette County	1990	48SU949
Father DeSmet's "Prairie Mass"	Sublette County	1970	48SU28
Fort Bonneville	Sublette County	1970	48SU29
Sommers Ranch Headquarters Historic District	Sublette County	2009	48SU450
Trappers Point	Sublette County	2007	48SU1006
Upper Green River Rendezvous Site National Historic Landmark	Sublette County	1963	48SU52
Wardell Buffalo Trap	Sublette County	1971	48SU301
Emigrant Springs	Lincoln County	1976	48LN40
Names Hill	Lincoln County	1969	48LN39

The following are brief profiles and photos related to the above listed sites.

Bridge Over The Green River, Sublette County, Wyoming

Date Added to Register: 1985

Smithsonian Number: 48SU978

The ETD Bridge over Green River is a Pratt through truss bridge located near Fontenelle, Wyoming, which carries Sweetwater County Road CN4-8SS (Fontenelle Townsite Road) over the Green River. The bridge was built in 1913 by the Colorado Bridge and Construction Company. The 150-foot (46 m) long bridge is one of the longest Pratt through truss bridges built in the early stages of Wyoming bridge construction. The bridge was added to the National Register of Historic Places on February 22, 1985. It was one of several bridges added to the NRHP for their role in the history of Wyoming bridge construction.

Calpet Rockshelter, Sublette County, Wyoming

Date Added to Register: 1994

Smithsonian Number: 48SU354

The Calpet Rockshelter/Petroglyphs encompasses a sandstone outcrop at the base of a butte in Sublette County, Wyoming. It includes a rockshelter with two stratified cultural levels, scattered fire-cracked rock and a few surface artifacts with at least two buried components on the colluvial slope below the shelter, and nine petroglyph panels distributed throughout the site area. Radiocarbon dating shows that the site dates to the Late Prehistoric Period. Cultural affiliation of at least the lower cultural level in the shelter can be ascribed to the Fremont. The petroglyph panels reflect utilization of the site area by the Fremont and Prehistoric/Protohistoric or Historic Period Shoshoni, as well as visitation of the site by Euro-Americans.

Circle Ranch, Big Piney, Wyoming

Date Added to Register: 1987

Smithsonian Number: 48SU537

The historic Circle Ranch, also known as the R.L. Miller Ranch, is located about four miles southwest of Big Piney, Wyoming. The Circle Ranch complex consists of fourteen buildings, including a large wood frame ranch house built in 1905, garage, pumphouse, storage house, ice house, two bunkhouses, chicken coop, pig sty, and barn. The key buildings in the complex are two original log structures. The first is a homestead cabin built by early pioneer Nicolas Swan between 1878 and 1880, and the second is the homestead cabin of Otto Leifer also built between 1878 and 1880. The Circle Ranch has been continuously occupied as a working cattle ranch for over 100 years. It became one of the most economically successful and enduring cattle operations in Wyoming and provided an important economic base for the town of Big Piney and the surrounding ranching community. Furthermore, its owners served the community and state in political and business leadership roles. It was established by Otto Leifer in 1878 in an unsettled region nearly 100 miles from the nearest railhead. In 1895 he sold his ranch and livestock to a pioneer LaBarge rancher, James Mickelson. In a short period of time, Mickelson developed the Circle Ranch into the largest ranch in the region and it has remained in the Mickelson family since.

Daniel School, Sublette County, Wyoming

Date Added to Register: 1990

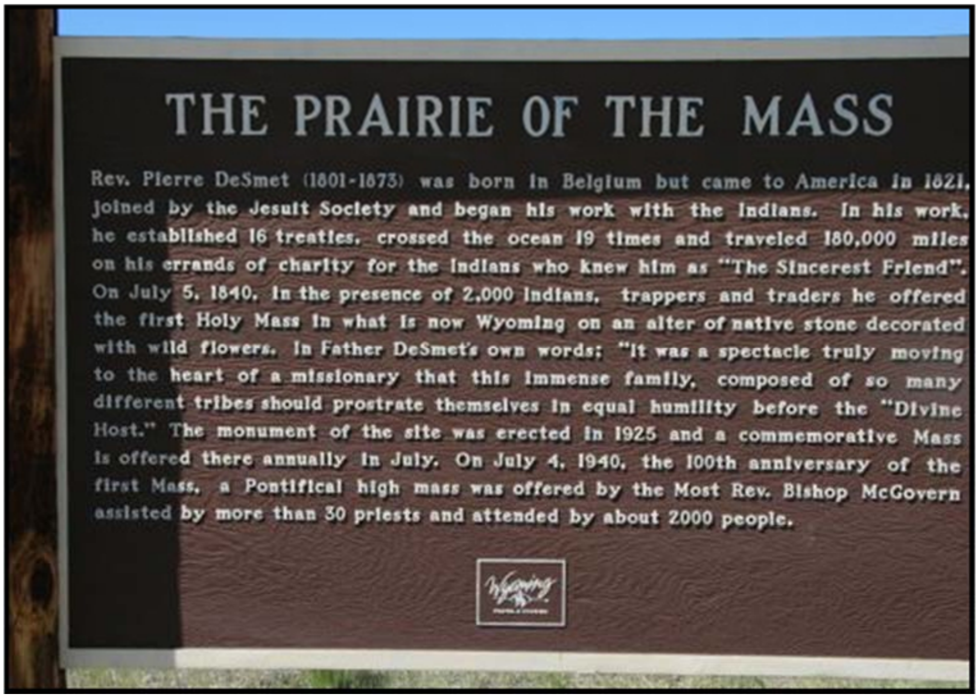
Smithsonian Number: 48SU949

The Daniel School was built in 1920 and was used until 1939 when School District No. 8 was combined with Pinedale School District No. 1, and students were then transported to Pinedale for classes. In 1936 it had twenty pupils' desks, two teachers' desks, blackboards, a library, a coal stove for heat, individual drinking cups for water, artificial lights, and swings and seesaws in a fenced playground.

Father DeSmet’s “Prairie Mass”, Sublette County, Wyoming

Date Added to Register: 1970

Smithsonian Number: 48SU28



Rev. Pierre DeSmet (1801-1973) was born in Belgium but came to America in 1821, joined by the Jesuit Society and began his work with the Indians. In his work, he established 16 treaties, crossed the ocean 19 times and traveled 180,000 miles on his errands of charity for the Indians who knew him as “The Sincerest Friend”. On July 5, 1840, in the presence of 2,000 Indians, trappers and traders he offered the first Holy Mass in what is now Wyoming on an alter of native stone decorated with wild flowers. In Father DeSmet’s own words; “It was a spectacle truly moving to the heart of a missionary that this immense family, composed of so many different tribes should prostrate themselves in equal humility before the “Divine Host.” The monument of the site was erected in 1925 and a commemorative Mass is offered there annually in July. On July 4, 1940, the 100th anniversary of the first Mass, a Pontifical high mass was offered by the Most Rev. Bishop McGovern assisted by more than 30 priests and attended by about 2000 people.

Fort Bonneville, Sublette County, Wyoming

Date Added to Register: 1970

Smithsonian Number: 48SU29

Following in the tracks of the fur traders Captain Benjamin Bonneville, 7th U.S. Infantry, headed West with an expedition in May of 1832. Taking an extended leave of absence from the Army, Bonneville was interested in establishing new enterprises in the fur business. An additional and unofficial purpose of his expedition was to explore the region of the Rocky Mountains and report to the government about the natural features of the region as well as the conditions of the fur trade and the character and customs of the native Indian tribes. Backing for the venture was obtained through eastern financiers.

Leaving form Fort Osage on the Missouri, the party consisted of 110 men, about 20 wagons and an assortment of mules, horses and cattle. By August of 1832 Captain Bonneville's band had reached the Green River, or "Sisk ke dee" as it was then called by the trappers. In arriving at the Green River the Bonneville party had traversed South Pass and had achieved the distinction of being the first to take wheeled vehicles across the continental divide of the Rocky Mountains. Bonneville became apprehensive about the presence of hostile Blackfeet Indians in the vicinity and directed his men to construct a fortified winter camp on the right bank of the Green River. Designed primarily for protection the stockaded structure was completed August 9, 1832. In all probability Bonneville intended to also operate this "fort" as a fur trading center in the heart of the mountain trapping grounds. Nature intervened when the early and heavy fall snows caused Bonneville to change his mind and abandon the site, apparently believing the location to be a poor one. The Bonneville party moved south and west from the Green River during the remainder of 1832 exploring many areas of what is now Wyoming.

The considerable amount of labor expended in constructing Fort Bonneville, followed by its almost immediate abandonment, led many to refer to it as "Fort Nonsense" or "Bonneville's

Folly." Though Bonneville's post was of little lasting significance it was the first of its kind in the region and heralded the coming of the fixed trading post concept in the fur trade.

Sommers Ranch Headquarters Historic District, Sublette County, Wyoming

Date Added to Register: 2009

Smithsonian Number: 48SU450

The Sommers Ranch Headquarters Historic District is eligible for listing in the National Register of Historic Places under Criterion A as a representative example of the numerous modest ranches of the upper Green River Valley basin. The majority of these ranches are small cattle operations that began as homesteads. The period of significance begins in 1908 when the Sommers established the ranch headquarters with the corrals, bunkhouse, chicken house, and ditch continuing through to 1957 with the completion of the "new" house. The buildings, a mix of log, frame, and modern metal sheds, are typical of other ranches in the valley. Most successful ranches in the valley contain this mixture of historic buildings as well as modern metal structures and trailers

The Sommers Ranch is situated on the east side of the Green River between the confluence of Horse Creek and Cottonwood Creek in the midst of the sagebrush-covered hills of Sublette County. Surrounding land is used for the production of hay as well as grazing. Irrigation canals fed by the Green River and originally built with teams and fresnos, provide water for raising hay on the meadowlands. Multiple springs on the west side of the Green River provide water for cattle during the winter.

The Ranch Headquarters is an interesting mixture of hand crafted vernacular buildings along with modern buildings that help maintain the economic viability of this ranching operation, and is typical of how ranches in the Green River Valley grew from the turn of the century. Working ranch buildings, regardless of age and material, are part of the evolution of ranching in the Green River Valley. The property retains a high degree of integrity of location, setting, feeling, and association. The modern intrusions do not detract from the historic ranch but merely reflect a pattern typical of ranching in the region, involving moving and re-using buildings as well as construction of new ones as needed.

The Trappers Point Site, Sublette County, Wyoming

Date Added to Register: 2007

Smithsonian Number: 48SU1006

Between 1990 and 1992, the Office of the Wyoming State Archaeologist undertook testing and data recovery on behalf of the Wyoming Department of Transportation at the Trappers Point site (48SU1006) in the upper Green River Basin, Wyoming. The project was under the auspices of the Bureau of Land Management, Pinedale Resource Area.

Trappers Point is a stratified, multi-component, Early Archaic site located near Pinedale in Sublette County. It contains three intact cultural components ranging in age from 7880-4690 radiocarbon years ago, along with ephemeral evidence for later occupations. Analyses of the chipped stone, fauna, geology, botanical remains, and features collectively provide one of the most comprehensive records of Early Archaic occupation in the region to date. Well preserved pronghorn remains indicate a spring season of use for the middle of the three occupations, based on fetal skeletal development and postnatal tooth eruption and wear.

Comparisons of pronghorn skeletal morphology and behavior between prehistoric and modern populations has generated provocative observations about the antiquity of migration patterns, and prompted more critical comparisons with paleoenvironmental evidence. The database also suggests the possibility of a Mountain Complex whose adaptive characteristics may be more or less independent from either the Great Plains or Great Basin.

Upper Green River Rendezvous Site National Historic Landmark, Sublette County, Wyoming

Date Added to Register: Thursday, November 07, 1963

Smithsonian Number: 48SU52

The Upper Green River Rendezvous were held in various places near Daniel, Wyoming from 1825 to 1840. The Rendezvous was a colorful trading fair at which trappers, traders, and Indians gathered. It was instituted during the early Rocky Mountain fur trade by General William Ashley, and it effectively revolutionized the trade. Instead of a system of fixed posts to which Indians and trappers came, the rendezvous was a previously established meeting place to which the great supply caravans from St. Louis brought trade goods which were exchanged for the furs. The rendezvous lasted for a few days or at most a few weeks. Grazing and hunting requirements forced the wide dispersal of trappers and traders during the annual get-togethers. The area they encompassed was river grassland from 15 to 20 miles long and from one to five miles wide. Of the 15 annual meetings held, eight of the Rendezvous took place at a Green River site and five convened near the junction of Horse Creek and the Green River. Each year in July a reenactment of the Rendezvous is held in nearby Pinedale.

Wardell Buffalo Trap Near Big Piney, Wyoming

Date Added to Register: Thursday, August 12, 1971

Smithsonian Number: 48SU301

The Wardell Buffalo Trap is the site of the earliest known communal bison kill involving the use of the bow and arrow on the Northwestern Plains. A bison corral located near the Green River was used by hunters to intercept bison herds moving from grazing lands to the water. Nearly five feet of stratified bison bone levels with radiocarbon dates spanning 500 years of the Late Prehistoric Period have been identified at the site. A large butchering and processing area and campsite are located nearby. Archaeological excavations at the site the early 1970s uncovered outlines of an ancient fence located near the end of a box-canyon into which animals were driven.

Emigrant Springs, Lincoln County, Wyoming

Date Added to Register: 1976

Smithsonian Number: 48LN40

A main branch of the Sublette Cutoff crossed Willow Creek and then headed directly for Emigrant Spring where the Slate Creek Cutoff rejoined the Sublette. The spring issued from the base of a cliff near the head of Emigrant Creek, a headwater of Slate Creek, and is located in a hollow. The descent to it is steep and eroded. During the emigration era, this site was sometimes known as Indian Springs.

At least two other springs may have been nearby during the emigrant period. On the cliffs surrounding the spring, many names and dates can be found. Unfortunately, they are seriously degraded. At least two unmarked graves can be found in the high sage nearby. During the 1920s and 1930s, a slate slab engraved "Oregon Trail, 1843-1915" existed in this area. It can no longer be found.

Names Hill, Lincoln County, Wyoming

Date Added to Register: 1969

Smithsonian Number: 48LN39

This sandstone cliff, located on the west side of the Green River, was a popular place for the emigrants to leave their signatures, indicating their successful negotiation of the Green. Today, Names Hill is noted most often for the inscription of "James Bridger, Trapper, 1844." Since Bridger is known to have been illiterate, the "signature" lends itself to controversy. Some contend that Bridger may have known enough to write his own name. Others believe that he had a traveling companion inscribe it for him. Still others suspect it was inscribed much later by someone who knew that the old trapper would have often made this trek. In any case, it is a fitting reminder of this seasoned mountain man, guide, and explorer whose name has been well-engraved in the annals of history.

Indian petroglyphs are also found on Names Hill. J. Goldsborough Bruff, who sketched this formation, described them this way: "…vertical cliffs of a mouse-colored sandstone, on the face of which was engraved with a fine-pointed instrument, an Indian diagram, representing 43 rifles, nearly vertical, and a chief and horse, apparently separated from 4 other Indians and a horse laying down, by a streak with a small fork to it…." Bruff also noted the nearby grave of "Mary, Consort of J. M. Fulkerson, Died July 14, 1847." This is the mother of Frederick Fulkerson whose grave is located near Devil's Gate . Unfortunately, Mary Fulkerson's grave is no longer to be found.

REFERENCES

TRC Mariah Associates, Inc. 2006. Cultural Resources Overview of the Pinedale Field Office, Bureau of Land Management, Wyoming. In three volumes, prepared by TRC Mariah Associates, Laramie, Wyoming. Report on file, BLM Pinedale Field Office, Pinedale, Wyoming.

USDI-BLM. 2008. Proposed Resource Management Plan and FINAL Environmental Impact Statement for Public Lands Administered by the Bureau of Land Management Pinedale Field Office Pinedale, Wyoming. August 2008.

3.4 NATURAL ENVIRONMENT

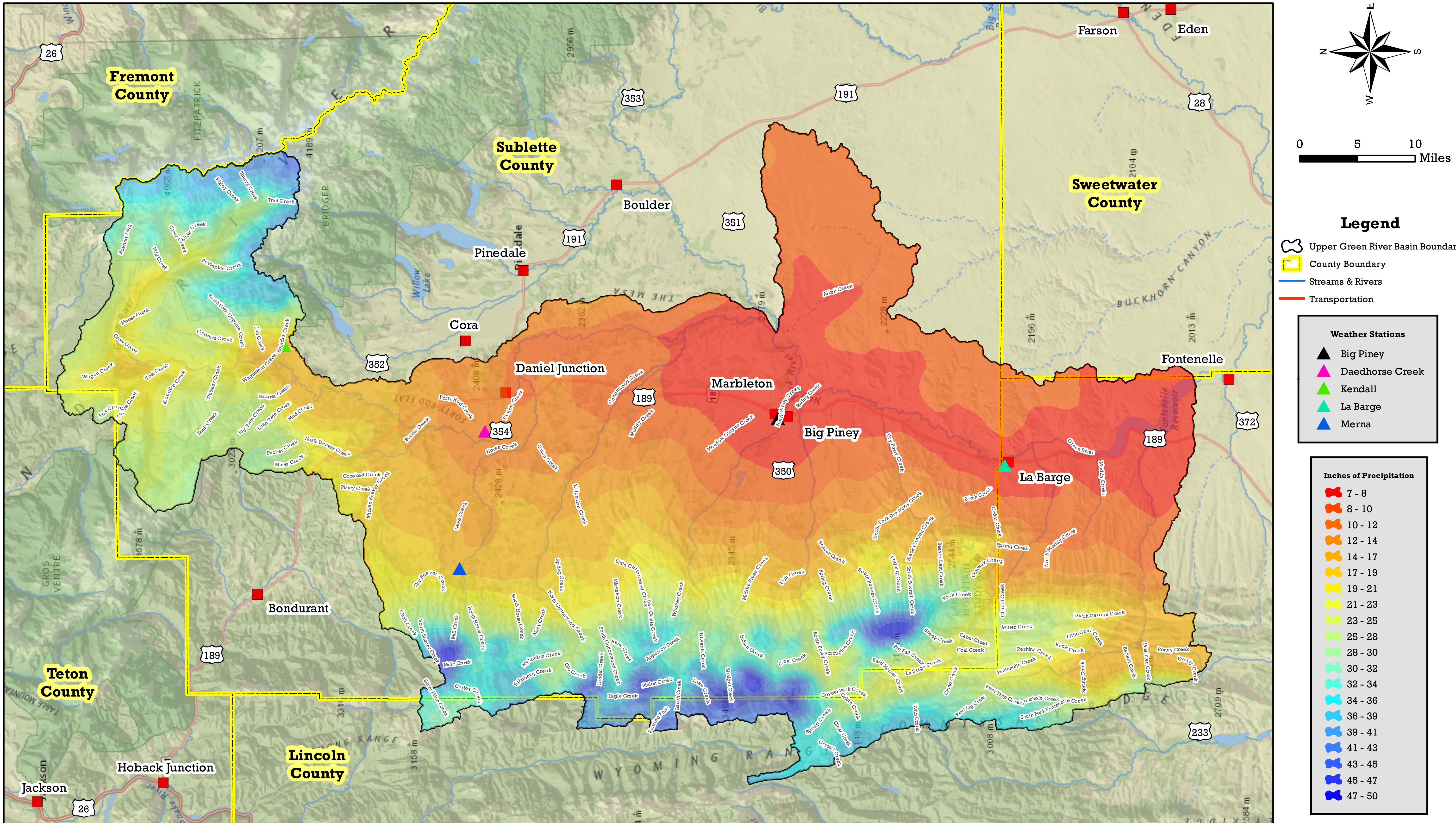
3.4.1 CLIMATE

The climate in the Upper Green River watershed is variable based on the diverse topography and elevation within the project area. Elevations range from 6,370 feet below Fontenelle Dam to 13,804 feet on Gannett Peak (the highest elevation in Wyoming). The climate classification ranges from alpine to semiarid. Four weather stations are maintained in the watershed through cooperative agreements with the National Weather Service (NWS) and seven SNOTEL sites are maintained in the watershed by the Natural Resources Conservation Service (NRCS).

National Weather Stations	SNOTEL Sites
Cora	Gunsight Pass
Daniel Fish Hatchery	Kendall R.S.
Big Piney-Marbleton	Loomis Park
La Barge	East Rim Divide
	Blind Bull Sum
	Triple Peak
	Snider Basin

The location of the four NWS weather stations along with average annual precipitation data between 1981 and 2010 are depicted on Figure 3.4.1. Data used to generate this figure was obtained from the PRISM Climate Group at Oregon State University using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) climate mapping system. Lower elevations in the south-central and southeastern portions of the watershed receive between 8 and 10 inches of precipitation per year. Annual precipitation increases with elevation in the northern and western portions of the watershed where 50 inches accumulate per year.

Data recorded at NWS stations were obtained from the Western Regional Climate Center and the NRCS. Table 3.4.1.1 provides a summary of temperature and precipitation data collected at the four NWS weather stations. Table 3.4.1.2 provides a summary of precipitation data collected at the seven SNOTEL stations.



Upper Green River Watershed

Figure 3.4.1
Average Annual Precipitation
1981 - 2010
NWS Weather Stations

Projection: NAD 83 - UTM Zone 12

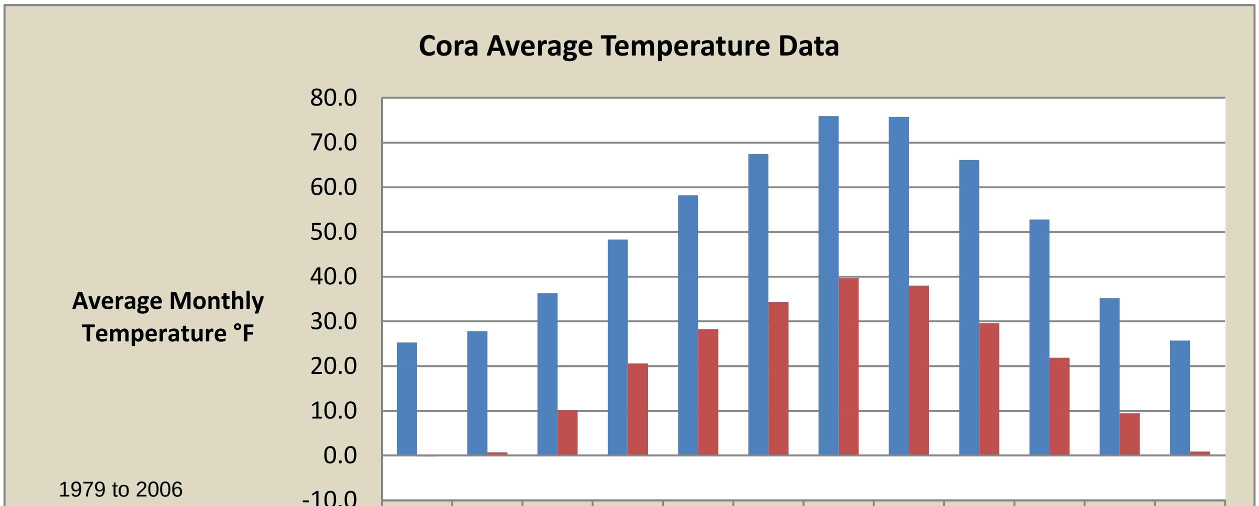
Table 3.4.1.1 Summary of Temperature and Precipitation Climate Data

Weather Station	**(482054) CORA**												
Period of Record	From Year 1979 To Year 2006												
Monthly Averages	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Average High Temperature °F	25.3	27.8	36.3	48.3	58.2	67.4	75.9	75.7	66.1	52.8	35.2	25.7	49.6
Average Low Temperature °F	-0.2	0.7	10.2	20.6	28.3	34.4	39.7	38.0	29.6	21.9	9.5	0.9	19.5
Mean Temperature °F	12.5	14.3	23.2	34.4	43.2	50.8	57.5	56.8	47.6	37.4	22.3	13.3	34.4
Mean Precipitation inches	0.86	0.66	0.64	0.73	1.78	1.25	1.17	1.09	1.3	0.94	0.73	0.72	11.87
Weather Station	**(482242) DANIEL FISH HATCHERY**												
Period of Record	From Year 1989 To Year 2006												
Monthly Averages	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Average High Temperature °F	26.2	28.8	37.4	48.9	59.3	68.2	77.1	76.0	66.6	54.4	37.8	27.2	50.7
Average Low Temperature °F	-3.6	-4.1	7.1	19.9	28.2	34.6	38.6	36.2	28.6	18.9	8.9	-2.0	17.6
Mean Temperature °F	11.3	12.3	22.3	34.4	43.7	51.4	57.9	56.1	47.6	36.6	23.4	12.6	34.1
Mean Precipitation inches	0.78	0.69	0.75	0.83	1.68	1.18	0.91	1.18	1.27	0.75	0.65	0.79	11.46
Weather Station	**(480695) BIG PINEY**												
Period of Record	From Year 1948 To Year 2012												
Monthly Averages	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Average High Temperature °F	26.0	30.3	39.0	51.1	62.0	71.1	80.1	78.6	69.6	57.6	39.6	28.3	52.8
Average Low Temperature °F	-5.0	-1.6	8.6	19.6	29.0	36.3	40.0	36.5	27.5	18.0	7.1	-3.0	17.8
Mean Temperature °F	10.5	14.4	23.7	35.3	45.6	53.7	60.1	57.5	48.5	37.7	23.3	12.6	35.2
Mean Precipitation inches	0.38	0.31	0.43	0.64	1.03	0.89	0.74	0.78	0.81	0.54	0.38	0.39	7.32
Weather Station	**(485252) LA BARGE**												
Period of Record	From Year 1958 To Year 2012												
Monthly Averages	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Average High Temperature °F	30.1	33.8	43.2	53.9	64.3	73.4	83.6	81.5	71.0	59.0	41.5	30.8	55.5
Average Low Temperature °F	-2.4	0.2	13.8	23.5	31.9	39.1	44.4	42.5	33.1	22.8	10.5	-0.9	21.5
Mean Temperature °F	13.8	17.0	28.5	38.6	31.9	56.2	64.1	62.1	52.0	40.9	26.0	14.9	37.2
Mean Precipitation inches	0.31	0.36	0.4	0.78	1.28	1.03	0.62	0.89	0.75	0.63	0.42	0.47	7.94

Table 3.4.1.2 Precipitation Data Collected at Upper Green Watershed SNOTEL Sites

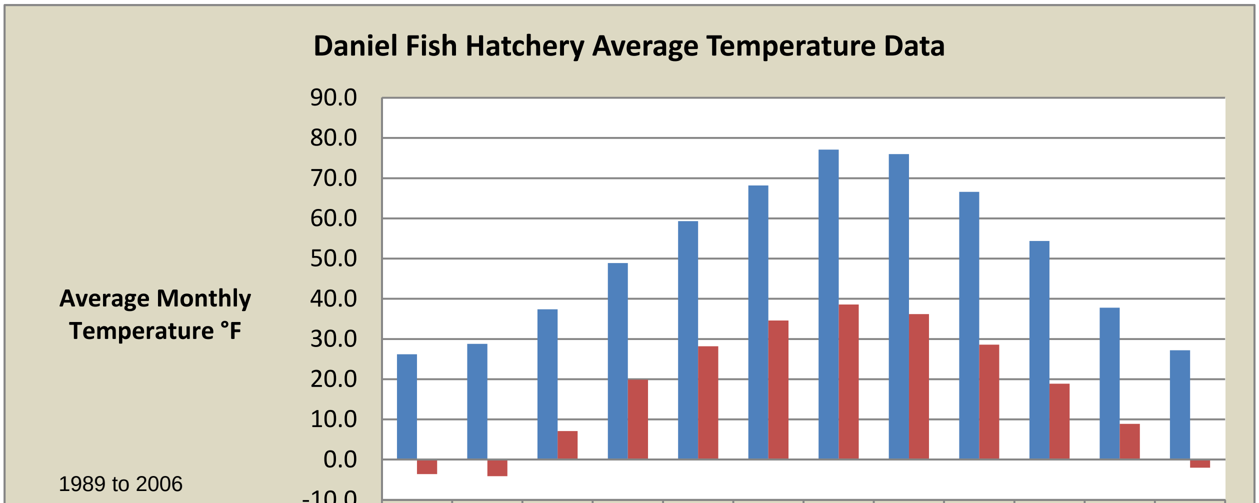
Median Snow Water Equivalent (1981-2010)													
Snider Basin (765)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Totals
Average End of Month Snow Water Equivalent(in)	0.2	2.8	5.1	7.4	9.5	12.1	9.5	0.0	0.0	0.0	0.0	0.0	
Average Cumulative Precipitation(in)	1.4	3.8	6.5	9.2	11.5	13.6	15.5	17.5	18.8	19.8	20.6	21.9	
Average Total Monthly Precipitation(in)	1.4	2.4	2.7	2.7	2.3	2.1	1.9	2.0	1.3	1.0	0.8	1.3	21.9
Triple Peak (831)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Totals
Average End of Month Snow Water Equivalent(in)	1.1	5.0	8.2	13.1	16.7	21.5	17.9	0.0	0.0	0.0	0.0	0.0	
Average Cumulative Precipitation(in)	2.2	6.7	10.9	15.9	20.2	24.3	27.8	31.4	33.7	35.0	36.5	38.0	
Average Total Monthly Precipitation(in)	2.2	4.5	4.2	5.0	4.3	4.1	3.5	3.6	2.3	1.3	1.5	1.5	38.0
Blind Bull Sum (353)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Totals
Average End of Month Snow Water Equivalent(in)	1.3	4.9	9.0	13.7	17.7	22.2	23.4	12.3	0.0	0.0	0.0	0.0	
Average Cumulative Precipitation(in)	2.0	5.5	9.2	12.8	15.9	18.7	21.2	24.3	26.3	27.7	29.0	30.7	
Average Total Monthly Precipitation(in)	2.0	3.5	3.7	3.6	3.1	2.8	2.5	3.1	2.0	1.4	1.3	1.7	30.7
East Rim Divide (460)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Totals
Average End of Month Snow Water Equivalent(in)	0.2	1.9	4.3	6.8	8.0	9.9	8.3	0.0	0.0	0.0	0.0	0.0	
Average Cumulative Precipitation(in)	1.3	3.4	5.4	7.7	9.6	11.3	12.8	15.0	16.6	17.4	18.6	19.8	
Average Total Monthly Precipitation(in)	1.3	2.1	2.0	2.3	1.9	1.7	1.5	2.2	1.6	0.8	1.2	1.2	19.8
Loomis Park (597)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Totals
Average End of Month Snow Water Equivalent(in)	0.5	3.1	6.5	9.4	11.7	14.4	11.2	0.0	0.0	0.0	0.0	0.0	
Average Cumulative Precipitation(in)	1.8	4.7	8.0	11.2	14.0	16.6	18.8	21.4	23.2	24.5	25.9	27.7	
Average Total Monthly Precipitation(in)	1.8	2.9	3.3	3.2	2.8	2.6	2.2	2.6	1.8	1.3	1.4	1.8	27.7
Kendall R.S. (555)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Totals
Average End of Month Snow Water Equivalent(in)	0.3	2.5	4.8	7.8	9.7	11.4	4.8	0.0	0.0	0.0	0.0	0.0	
Average Cumulative Precipitation(in)	1.6	3.9	6.5	9.2	11.6	13.7	15.4	17.6	19.2	20.2	21.4	22.8	
Average Total Monthly Precipitation(in)	1.6	2.3	2.6	2.7	2.4	2.1	1.7	2.2	1.6	1.0	1.2	1.4	22.8
Gunsight Pass (944)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Totals
Average End of Month Snow Water Equivalent(in)	0.9	3.2	6.0	8.2	10.5	13.3	12.8	3.4	0.0	0.0	0.0	0.0	
Average Cumulative Precipitation(in)	2.2	4.0	6.4	8.8	10.8	13.1	16.0	18.6	20.8	22.1	23.6	25.6	
Average Total Monthly Precipitation(in)	2.2	1.8	2.4	2.4	2.0	2.3	2.9	2.6	2.2	1.3	1.5	2.0	25.6

Average high and low temperatures for each of the four NWS station's period of record are depicted in Figures 3.4.2 through 3.4.5. Figure 3.4.6 shows the average monthly precipitation and Figure 3.4.7 depicts the total annual precipitation for each weather station for their entire respective period of record.



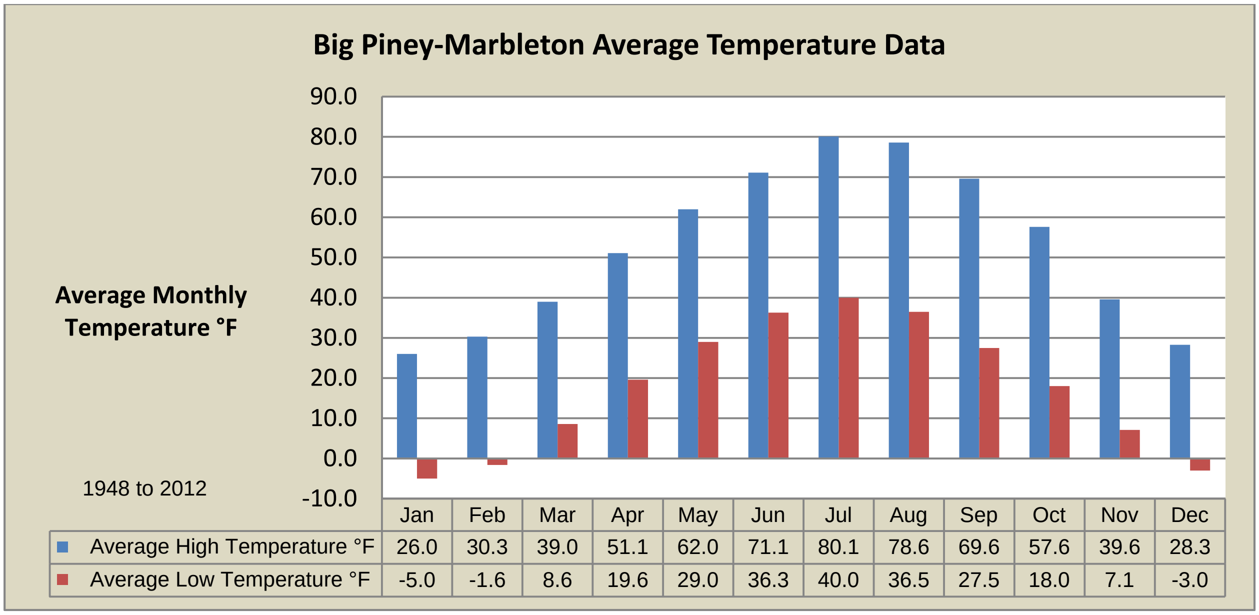
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average High Temperature °F	25.3	27.8	36.3	48.3	58.2	67.4	75.9	75.7	66.1	52.8	35.2	25.7
Average Low Temperature °F	-0.2	0.7	10.2	20.6	28.3	34.4	39.7	38.0	29.6	21.9	9.5	0.9

Figure 3.4.2 Average high and low temperatures for the Cora weather station, Upper Green River Watershed.



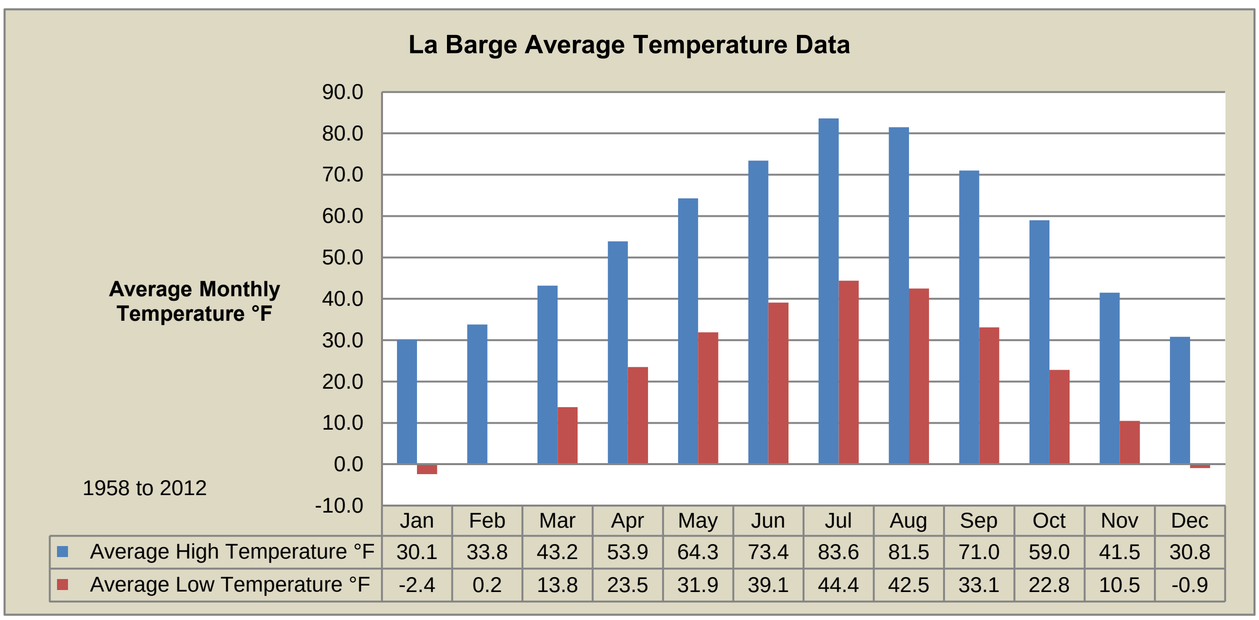
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average High Temperature °F	26.2	28.8	37.4	48.9	59.3	68.2	77.1	76.0	66.6	54.4	37.8	27.2
Average Low Temperature °F	-3.6	-4.1	7.1	19.9	28.2	34.6	38.6	36.2	28.6	18.9	8.9	-2.0

Figure 3.4.3 Average high and low temperatures for the Daniel Fish Hatchery weather station, Upper Green River Watershed.



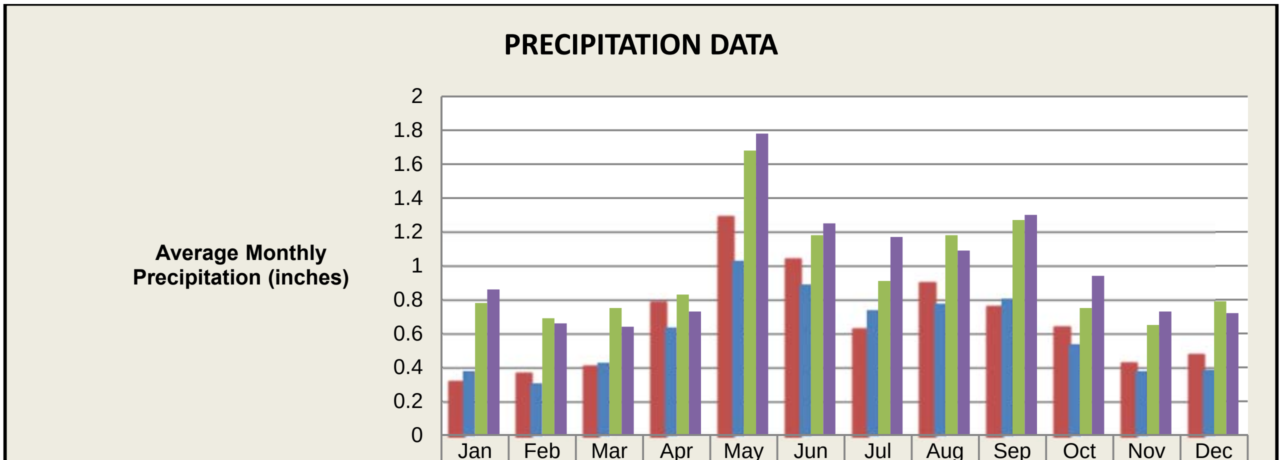
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average High Temperature °F	26.0	30.3	39.0	51.1	62.0	71.1	80.1	78.6	69.6	57.6	39.6	28.3
Average Low Temperature °F	-5.0	-1.6	8.6	19.6	29.0	36.3	40.0	36.5	27.5	18.0	7.1	-3.0

Figure 3.4.4. Average high and low temperatures for the Big Piney-Marbleton weather station, Upper Green River Watershed.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average High Temperature °F	30.1	33.8	43.2	53.9	64.3	73.4	83.6	81.5	71.0	59.0	41.5	30.8
Average Low Temperature °F	-2.4	0.2	13.8	23.5	31.9	39.1	44.4	42.5	33.1	22.8	10.5	-0.9

Figure 3.4.5. Average high and low temperatures for the La Barge weather station, Upper Green River Watershed.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Station:(485252) La Barge	0.31	0.36	0.4	0.78	1.28	1.03	0.62	0.89	0.75	0.63	0.42	0.47
Station:(480695) Big Piney	0.38	0.31	0.43	0.64	1.03	0.89	0.74	0.78	0.81	0.54	0.38	0.39
Station:(482242) Daniel Fish Hatchery	0.78	0.69	0.75	0.83	1.68	1.18	0.91	1.18	1.27	0.75	0.65	0.79
Station:(482054) Cora	0.86	0.66	0.64	0.73	1.78	1.25	1.17	1.09	1.3	0.94	0.73	0.72

Figure 3.4.6. Average monthly precipitation for NWS weather stations within the Upper Green River Watershed.

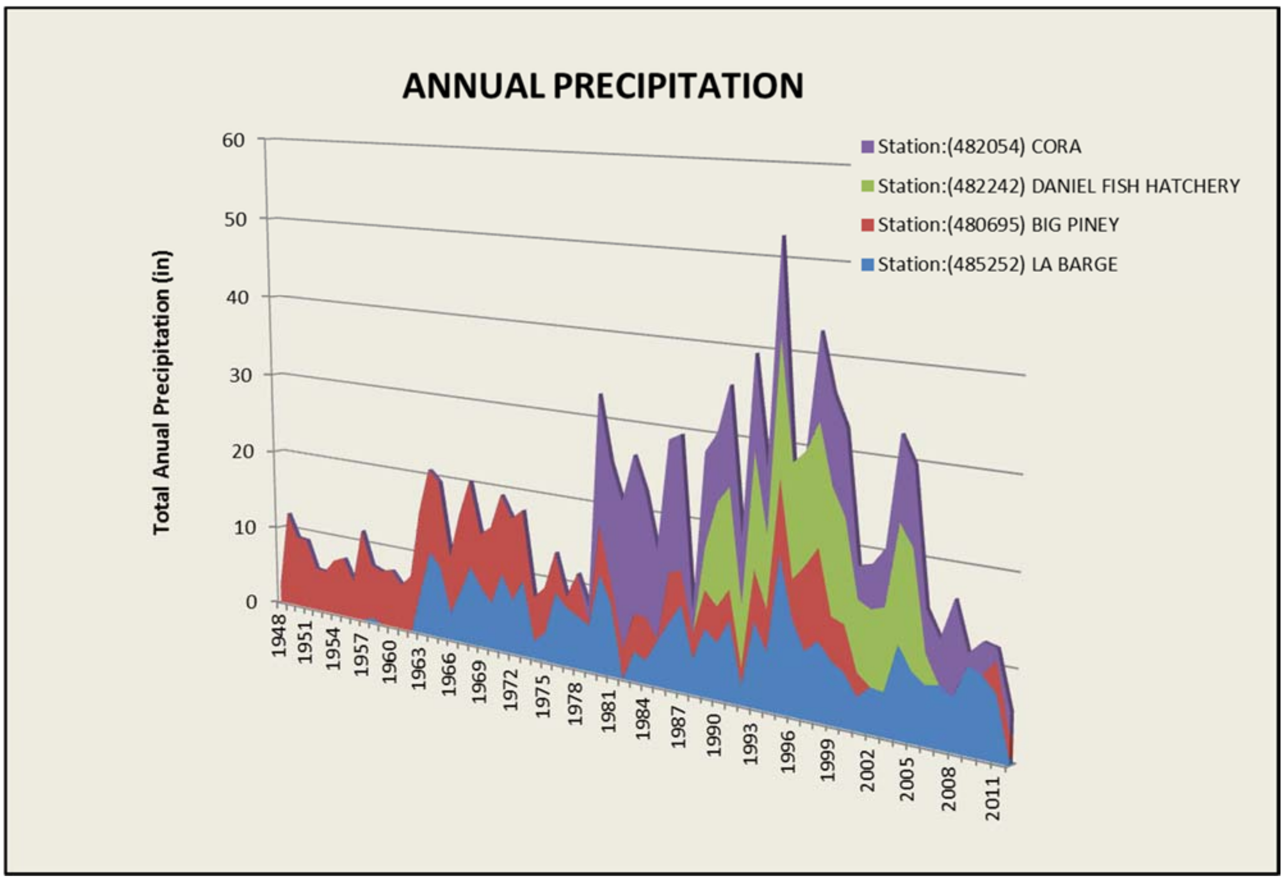


Figure 3.4.7. Yearly total annual precipitation for NWS weather stations within the Upper Green River Watershed.

Freezes in mid spring and mid fall are common throughout the watershed. The average last occurrence of 32 degrees and 28 degrees in the spring and the average first occurrence of 32 degrees and 28 degrees in the fall along with the average length of the 32 degrees and 28 degrees growing season at each weather station is shown in Table 3.4.1.3.

Table 3.4.1.3. Comparison of early and late freezes and general growing season derived from NWS Weather Stations within the Upper Green River Watershed.

Weather Station	**Average Last Spring Occurrence of 32.5° F**	**Average 1st Fall Occurrence of 32.5° F**	**Average # Days > 32.5° F**	**Average Last Spring Occurrence of 28.5° F**	**Average Last Fall Occurrence of 28.5° F**	**Average # Days > 28.5° F**
La Barge	22-Jun	31-Aug	70	1-Jun	10-Sep	101
Big Piney-Marbleton	14-Jul	9-Aug	26	21-Jun	25-Aug	65
Daniel Fish Hatchery	14-Jul	11-Aug	28	17-Jun	25-Aug	69
Cora	12-Jul	22-Aug	41	25-Jun	1-Sep	68

Data Provided By the Western Regional Climate Center

3.4.2 REGIONAL GEOLOGY

The geologic descriptions that follow have been adapted from Clarey et al. (2004), McNab and Avers (1994), and West (1969). The Green River basin lies entirely within the Middle Rocky Mountain Physiographic Province, which consists primarily of mountainous terrain and alluvial basins.

3.4.2.1 STRUCTURAL GEOLOGY

The core of the Green River basin and surrounding mountain ranges is comprised of Precambrian igneous and metamorphic rock. Thick layers of sedimentary rock, primarily of lacustrine origin, have been deposited on top of this Precambrian basement over time. These sedimentary layers consist of Paleozoic, Mesozoic, and Cenozoic formations. The Paleozoic formations have an average combined thickness of about 5,000 feet. The Mesozoic formations have an average combined thickness of about 12,000 feet, and the Cenozoic formations in the basin have an average combined thickness of between 5,000 and 8,000 feet. A graphical representation of the geologic time scale is is presented for reference in Table 3.4.2.1 on the following page.

Table 3.4.2.1 Geologic time scale. (* Data from USGS 2001; MYA = Million Years Ago)

Eon		Era	Period	Epoch	Informal subdivisions	MYA	MYA
Phanerozoic		Cenozoic	Quaternary	Holocene		0	0.008
				Pleistocene	late	0.008	
					early		1.8
			Tertiary	Pliocene	late	1.8	
					early		5.3
				Miocene	late	5.3	
					middle		23.8
					early	23.8	
				Oligocene	late		
					early		33.7
				Eocene	late	33.7	
					middle		
					early		55.5
				Paleocene	late	55.5	
					early		65
		Mesozoic	Cretaceous	Late		65	
				Early			145
			Jurassic	Late		145	
				Middle			
				Early			213
			Triassic	Late		213	
				Middle			
				Early			248
		Paleozoic	Permian	Late		248	
				Early			286
			Pennsylvanian	Late		286	
				Middle			
				Early			325
			Mississippian	Late		325	
				Early			360
			Devonian	Late		360	
				Middle			
				Early			410
			Silurian	Late		410	
				Middle			
				Early			440
			Ordovician	Late		440	
				Middle			
				Early			505
			Cambrian	Late		505	
				Middle			
				Early			544
Precambrian	Proterozoic	Neoproterozoic, Late (Z)				544	
		Mesoproterozoic, Middle (Y)					
		Paleoproterozoic, Early (X)					
	Archean	Neoarchean, Late (W)					
		Mesoarchean, Middle (V)					
		Paleoarchean, Early (U)					
		Eoarchean, earliest					
		preArchean		(Hadean or Priscoan)			4500

The general topography of the basin reflects the undulations of the Precambrian basement surface, which formed by the faulting and folding of Earth's crust under compressional stress in the Sevier and Laramide orogenies. Portions of the Precambrian basement subsided and formed the structural basin, while other areas were faulted and thrust upward to form ridges, uplifts, and mountains. This fold-thrust faulting resulted in a structural offset of up to 44,000 feet between Precambrian basement rocks. The best example of this "unconformity" is near Pinedale, where Precambrian rocks were uplifted to almost 14,000 feet in the Wind River Range, and the Precambrian surface in the deepest part of the basin is more than 30,000 feet below sea level.

The Upper Green River Basin is bounded on the west by the Overthrust Belt, to the northwest by the Hoback Rim and Gros Ventre range, the Wind River Range to the northeast, and the Rock Springs uplift on the east (Figure 3.4.2.1). These ranges vary in lithic composition, and a brief description of each is provided below.

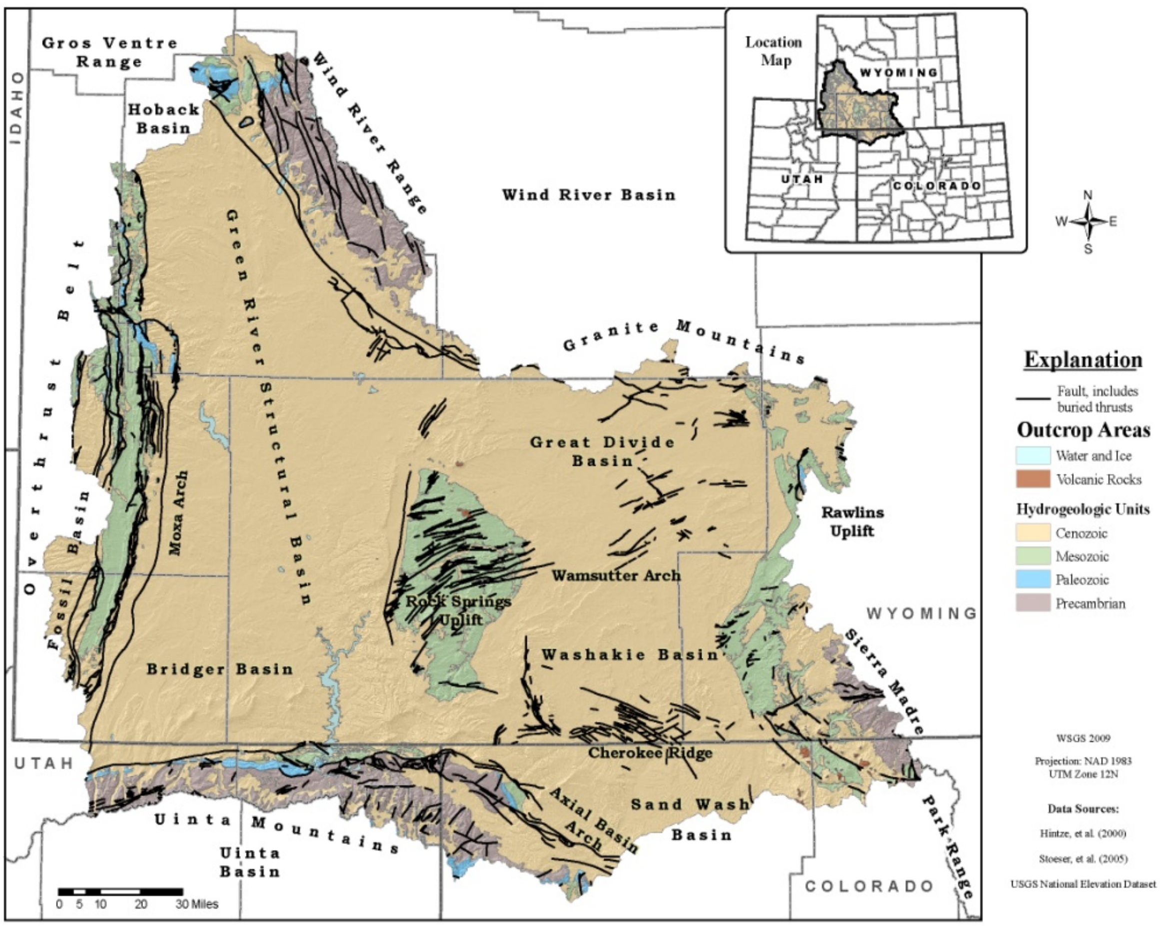


Figure 3.4.2.1. Geologic features of the greater Green River Basin.

Overthrust Belt

The Overthrust Belt is located in western Wyoming and adjacent areas of Idaho and Utah. The associated mountain ranges include the Teton, Wyoming, and Salt River Ranges in Wyoming; Snake River, Caribou, Portneuf, Webster, Aspen, Bannock, and Bear River Ranges in Idaho; and the Wasatch Range in Utah (McNab and Avers 1994). The Overthrust Belt is primarily comprised of Paleozoic and Mesozoic marine sedimentary rocks (West 1969). A combination of folding, thrust faulting, reverse faulting, and overthrust faulting in the late Jurassic through the early Eocene has resulted in the north-south trending linear valleys and ridges that define these mountain ranges. The Teton Range is the highest in this complex, and these along with other high elevation areas within the Overthrust Belt have been exposed to several glacial advances. Mass movements are common and helped form the Wyoming Range. Some Precambrian rock is exposed near Pocatello, Idaho, but Paleozoic and Mesozoic sedimentary rocks such as limestones, siltstone, cherts, sandstones, and shales dominate the Overthrust Belt.

Wind River Mountains

These high alpine mountains comprised of Precambrian igneous and metamorphic rock have experienced several periods of glaciation, and some small valley glaciers still exist among the highest peaks in the range. Resulting glacial landscape features such as troughs, cirque headwalls, and floors are common. Areas of orthogneiss and paragneiss with Precambrian granites are common. Precambrian metasedimentary rocks also occur, with Quaternary deposits on the west side of the range. Elevation ranges from 6,000 feet to 13,000 feet.

Gros Ventre Range

This range has approximately the same orientation as the Wind River Range but is much smaller in terms of elevation and surface area. The southern part of the Gros Ventre range abuts the northern part of the Overthrust Belt. The rugged peaks have largely been carved from layered sedimentary rocks of Paleozoic and Mesozoic age (WSGS 2013). The Cache Creek thrust fault is a major crustal fracture that exists under the southern portion of the range. This fault inclines northward and extends southeast from near Jackson along Cache Creek valley to the Green River, where it merges with the Wind River thrust fault system. The southwest flank of the Gros Ventre Range has been thrust southward over the Mesozoic and Tertiary rocks of the Hoback Basin.

Rock Springs Uplift

The Rock Springs Uplift has an area of approximately 1,750 square miles, and elevations range from 6,200 feet to 8,680 feet on the southern half of the uplift and to more than 7,500 feet in the Leucite Hills. The Precambrian basement lies about 8,000 feet below the current land surface in the central Baxter Basin area of the Rock Springs Uplift. The Rock Springs Uplift is a doubly-plunging, asymmetric anticlinal fold, with its western flank steeper than its eastern flank. The axis of the anticline plunges on both the north and south ends of the uplift. This uplift is similar to many of the surrounding mountain ranges, except that when it formed during the Late Cretaceous and early Tertiary, it was not uplifted enough to expose the Precambrian basement rock as in the larger mountain ranges (WSGS 2013).

3.4.2.2 SURFICIAL MATERIALS

The majority of surficial geologic material in the study area is comprised of alluvium, colluvium, residuum, landslide, glacial, and slopewash deposits. In general terms, this material is rock detritus deposited by running water and/or glacial activity. These rocks are primarily Tertiary and Quaternary deposits. Mapping of surficial materials by the Wyoming State Geological Survey (WSGS) is depicted in Figure 3.4.2.2 Surficial Geology, and presented in a tabular form in Table 3.4.2.2.

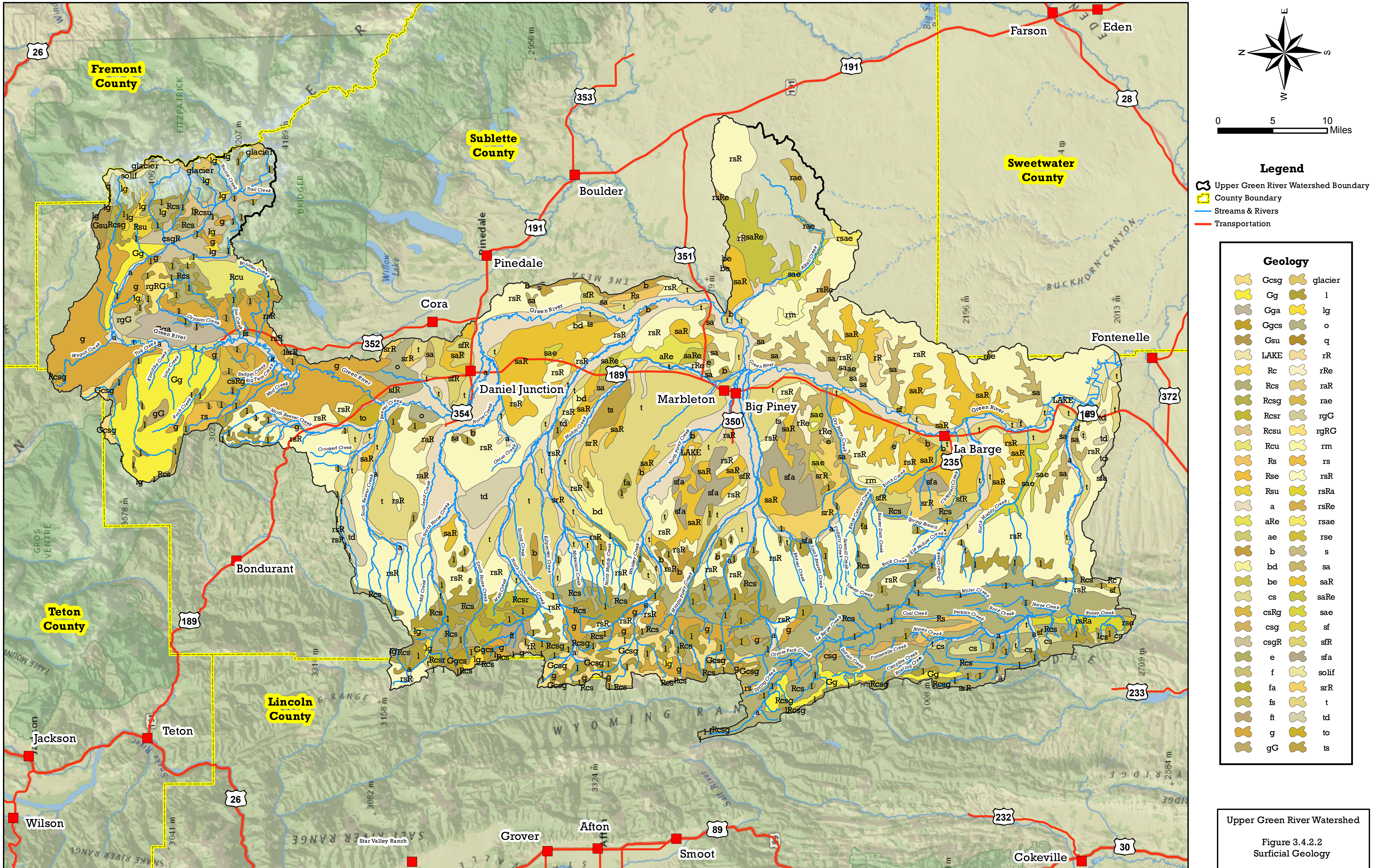
Table 3.4.2.2. A tabulation of mapped surficial geologic units in the upper Green River watershed.

Map Symbol	Description	Area	
		Acres	Percent of Watershed
rsR	Residuum and slopewash deposits with scattered bedrock outcrops	440,974	24.4%
a	Alluvium deposits	186,676	10.3%
Rcs	Bedrock with a mantle of colluvium and slopewash	181,200	10.0%
t	Terrace deposits	176,810	9.8%
saR	Slopewash and alluvium deposits with scattered bedrock outcrops	130,485	7.2%
l	Landslide deposit	123,351	6.8%
g	Glacial deposits	111,244	6.1%
Gg	Glaciated bedrock with a mantle of glacial deposits	58,206	3.2%
sa	Slopewash and alluvium deposits	43,493	2.4%
srR	Slopewash and residuum deposits with scattered bedrock outcrops	27,422	1.5%
Gcsg	Glaciated bedrock with a mantle of colluvium, slopewash and glacial deposits	25,432	1.4%
sfa	Slopewash, alluvial fan, and alluvium deposits	24,709	1.4%
saRe	Slopewash and alluvium with scattered bedrock outcrops and eolian deposits	19,274	1.1%
csgR	Colluvium,slopewash and glacial deposits with scattered bedrock outcrops	17,593	1.0%
td	Terrace and dissected eolian deposits	17,042	0.9%
sfR	Slopewash and alluvial fan deposits with scattered bedrock outcrops	14,864	0.8%
sae	Slopewash, alluvium and eolian deposits	13,295	0.7%
bd	Bench and dissected eolian deposits	13,003	0.7%
Rs	Glaciated bedrock with a mantle of slopewash	12,600	0.7%
Gga	Glaciated bedrock with a mantle of glacial deposits and alluvium	12,141	0.7%
Rcu	Bedrock with a mantle of colluvium and grus deposits	11,911	0.7%
o	Glacial outwash deposits	10,083	0.6%
b	Bench deposits	9,465	0.5%
Rcsr	Bedrock with a mantle of colluvium, slopewash, and residuum	9,232	0.5%
LAKE	Lake	8,859	0.5%
csRg	Colluvium,slopewash and scattered bedrock outcrops with glacial deposits	8,552	0.5%
lg	Landslide and glacial deposits	7,446	0.4%
ts	Terrace and slopewash deposits	7,207	0.4%
aRe	Alluvium and eolian deposits with scattered bedrock outcrops	6,581	0.4%
Rcsg	Bedrock with a mantle of colluvium, slopewash and glacial deposits	6,490	0.4%
cs	Colluvium and slopewash deposits	6,217	0.3%

rsRa	Residuum and slopewash deposits with scattered bedrock outcrops and alluvium	5,241	0.3%
csg	Colluvium,slopewash and glacial deposits	4,961	0.3%
rgRG	Residuum and glacial deposits with scattered bedrock and glaciated bedrock outcrops	4,631	0.3%
to	Terrace and glacial outwash deposits	4,231	0.2%
rR	Residuum with scattered glaciated bedrock outcrops	3,724	0.2%
rRe	Residuum with scattered glaciated bedrock outcrops and eolian deposits	3,577	0.2%
ft	Alluvial fan deposits mixed with terrace deposits	3,531	0.2%
rgG	Residuum and glacial deposits with scattered glaciated bedrock outcrops	3,279	0.2%
glacier	Glacier	2,889	0.2%
Rsu	Bedrock with a mantle of slopewash and grus deposits	2,861	0.2%
rae	Residuum, alluvium, and eolian deposits	2,770	0.2%
Ggcs	Glaciated bedrock with a mantle of glacial deposits, colluvium and slopewash	2,760	0.2%
rm	Residuum and mesa deposits	2,687	0.1%
Gsu	Glaciated bedrock with a mantle of slopewash and grus deposits	2,429	0.1%
Rcsu	Bedrock with a mantle of colluvium, slopewash and grus deposits	2,348	0.1%
raR	Residuum and alluvium deposits with scattered bedrock outcrops	2,129	0.1%
solif	Slopewash, glacial outwash, landslide, other surficial, and alluvial fan deposits	2,051	0.1%
sf	Slopewash and alluvial fan deposits	2,023	0.1%
rsRe	Residuum and slopewash deposits with scattered bedrock outcrops and eolian deposits	1,979	0.1%
rsae	Residuum, slopewash, alluvium and eolian deposits	1,935	0.1%
ae	Alluvium and eolian deposits	1,867	0.1%
Rse	Bedrock with a mantle of slopewash and eolian deposits	1,332	0.1%
fa	Alluvial fan deposits mixed with alluvium	930	0.1%
e	Eolian deposits	868	<.01%
fs	Alluvial fan deposits mixed with slopewash	529	<.01%
f	Alluvial fan deposits	272	<.01%
Rc	Bedrock with a mantle of colluvium	231	<.01%
q	Periglacial deposits	128	<.01%
s	Slopewash deposits	116	<.01%
be	Bench and eolian deposits	69	<.01%

3.4.2.3 BEDROCK

The primary mapped bedrock types in the study area include: alluvium and colluviums; gravel pediment, and fan deposits; Wasatch formation; Green River formation; and glacial deposits. Several episodes of glaciation occurred in the Quaternary period. Mapping of bedrock materials by the WSGS is depicted in Figure 3.4.2.3 Bedrock Geology and presented in a tabular form in Table 3.4.2.3. A geologic cross section of the greater Green River Basin is depicted in Figure 3.4.2.3a.



Upper Green River Watershed

Figure 3.4.2.2
Surficial Geology

Projection: NAD 83 - UTM Zone 12

Table 3.4.2.3. A tabulation of mapped bedrock types in the Upper Green River watershed.

Map Symbol	Description	Area	
		Acres	Percent of Watershed
Qa	Alluvium and colluvium	314,038	16.8%
Qt	Gravel, pediment, and fan deposits	281,188	15.1%
Twlc	Wasatch formation: La Barge and Chappo members	183,169	9.8%
Twg	Wasatch and Green River formations: New Fork tongue of Wastach and Fontenelle tongue or member of Green River	177,745	9.5%
Qg	Glacial deposits	118,959	6.4%
Twd	Wasatch formation, diamictite and sandstone	107,100	5.7%
Tgl	Green River formation: Laney member	88,710	4.8%
@ad	Ankareh formation, Thaynes limestone, Woodside shale, and Dinwoody formation	54,249	2.9%
Ugn	Oldest Gneiss Complex	54,194	2.9%
Tgw	Green River formation: Wilkins Peak member	47,137	2.5%
Tp	Bass Peak formation and equivalents	45,620	2.4%
Jst	Stump formation, Preuss sandstone or redbeds, and Twin Creek limestone	40,519	2.2%
Kbb	Blind Bull formation	33,788	1.8%
J@n	Nugget sandstone	31,631	1.7%
Pp	Phosphoria formation and related rocks	30,339	1.6%
Ka	Aspen shale	27,919	1.5%
MD	Madison limestone and Darby formation	23,422	1.3%
P&M	Wells and Amsden formations	21,960	1.2%
Kbr	Bear River formation	20,287	1.1%
PM	TenSleep sandstone and Amsden formation	15,500	0.8%
Tw	Wasatch formation, main body	15,483	0.8%
Kg	Gannett group	15,029	0.8%
Wg	Granitic Rocks of 2,600Ma Age Group	14,201	0.8%
J@nd	Nuggest sandstone and Chugwater and Dinwoody Formations	13,203	0.7%
@cd	Chugwater and Dinwoody formations	12,725	0.7%
H2O	Water	12,177	0.7%
O_	Bighorn dolomite, Gallatin limestone, GrosVentre formation, and Flathead sandstone	10,630	0.6%
Kh	Hilliard shale	9,752	0.5%
Jsg	Sundance and Gypsum Spring formations	8,086	0.4%
WVg	Plutonic Rocks	5,289	0.3%
Kft	Frontier formation and Mowry and Thermopolis shales	4,406	0.2%
KJ	Cloverly and Morrison formations	4,112	0.2%
Qls	Landslide deposits	4,018	0.2%
KJg	Cloverly, Morrison, Sundance and Gypsum Spring formations	3,179	0.2%
Tgrw	Green River and Wasatch formations	2,879	0.2%
ICE	Ice	2,144	0.1%
Kf	Frontier formation	1,939	0.1%
Kc	Cody shale	1,656	0.1%
Kav	Adaville formation	1,490	0.1%
Twc	Wastach Formation: Cathedral Bluffs tongue	1,284	0.1%
Kmt	Mowry and Thermoplis shales	960	0.1%
Tep	Conglomerate of Roaring Creek (Eocene or Paleocene)	878	<0.1%

shear	Shear	715	<0.1%
Tb	Bridger formation	637	<0.1%
Th	Hoback formation	560	<0.1%
Mm	Madison limestone or group	324	<0.1%
TKp	Pinyon conglomerate	122	<0.1%
Tdb	Devils Basin formation	95	<0.1%
Kss	Sage Junction, Quely, Cokeville, Thomas Fork, and Smiths formations	21	<0.1%
QTg	Terrace gravel (Pleistocene and/or Pliocene)	16	<0.1%

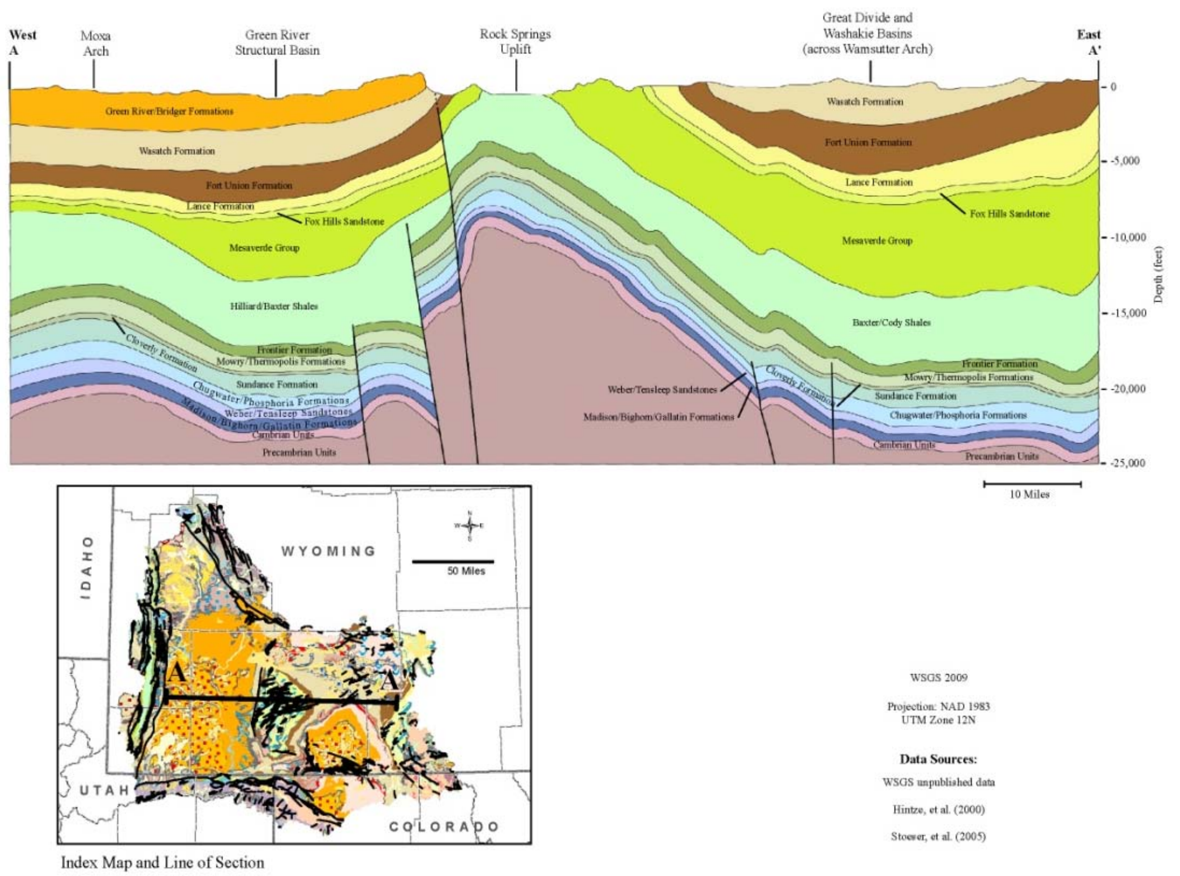
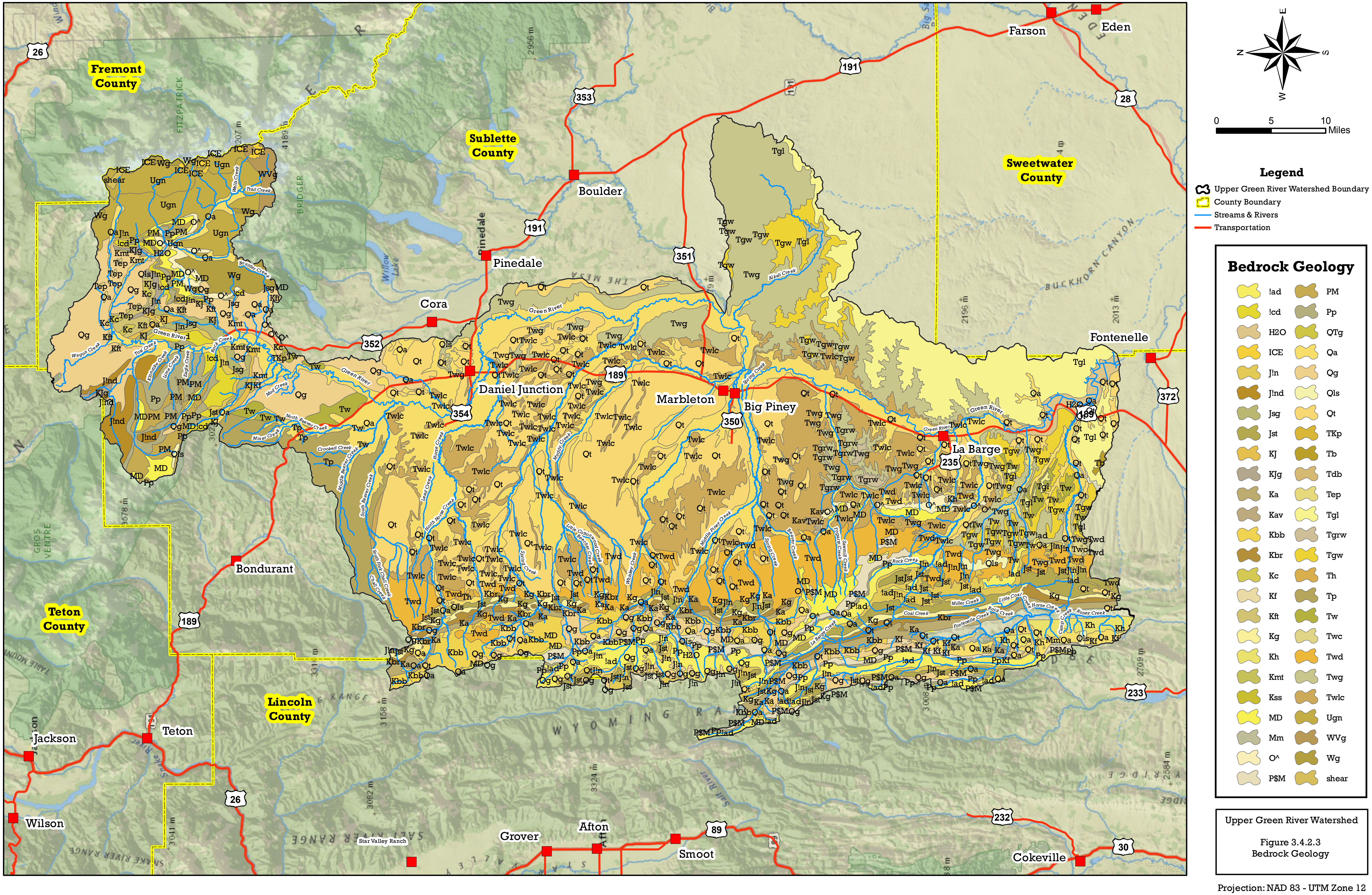


Figure 3.4.2.3a Geologic cross section of the greater Green River Basin in southwestern Wyoming.

3.4.2.4 GEOLOGIC IMPACTS TO WATERSHED HYDROLOGY

Geology influences the hydrology of all watersheds. It affects the quantity, quality, and location of groundwater reservoirs; the timing and direction of surface and groundwater flow; and the rates of erosion and sedimentation.



Fremont County
Sublette County
Sweetwater County
Teton County
Lincoln County
Farson
Eden
Boulder
Pinedale
Cora
Daniel Junction
Marbleton
Big Piney
La Barge
Fontenelle
Bondurant
Jackson
Teton
Wilson
Grover
Afton
Smoot
Cokeville
Star Valley Ranch
Green River
WYOMING RANGE
BUCKHORN CANYON
26
191
353
351
352
354
189
350
235
28
372
233
232
30
89
0 5 10 Miles
Legend
Upper Green River Watershed Boundary
County Boundary
Streams & Rivers
Transportation
Bedrock Geology
!ad
!cd
H2O
ICE
J!n
J!nd
Jsg
Jst
KJ
KJg
Ka
Kav
Kbb
Kbr
Kc
Kf
Kft
Kg
Kh
Kmt
Kss
MD
Mm
O^
P$M
PM
Pp
QTg
Qa
Qg
Qls
Qt
TKp
Tb
Tdb
Tep
Tgl
Tgrw
Tgw
Th
Tp
Tw
Twc
Twd
Twg
Twlc
Ugn
WVg
Wg
shear
Upper Green River Watershed
Figure 3.4.2.3
Bedrock Geology
Projection: NAD 83 - UTM Zone 12

Groundwater occurs in the interstitial space between grains of certain rocks and in fractures and dissolution openings. Porosity, the measure of void space within a rock, and permeability, the rate a liquid flows through a porous material, are important physical properties that control the ability of a geologic unit to both store water and yield water to wells or springs (Eddy-Miller et al., 1996). The quantity and quality of groundwater stored within the various geologic units in the study area is dictated by the lithologic, chemical and structural composition of the rocks. Although lithologic and water-yielding characteristics are not available for all geologic units in the study area, Table 3.4.2.4 depicts these characteristics for geologic units in Lincoln County, Wyoming.

Table 3.4.2.4 Lithologic and water-yielding characteristics of geologic units in Lincoln County, Wyoming (from Eddy-Miller et al., 1996).

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Paleozoic	Permian		[7]Phosphoria Formation and related rocks	[1]200-400 [5]230-360	"Upper part is dark- to light-gray chert and shale with black shale and phosphorite at top; lower part is black shale, phosphorite, and cherty dolomite."[6] "Mainly phosphatic, carbonaceous, and cherty shale and sandstone."[3]	Rocks in the Phosphoria Formation are mostly impermeable and in most areas are probably capable of only yielding small quantities of water. Where extensively fractured, the Phosphoria is capable of yielding moderate quantities of water.[3] "Unit is minor aquifer, locally confining."[1]	--
Paleozoic	Permian and Pennsylvanian	Permian, Upper and Middle Pennsylvanian	Tensleep Sandstone	[1]450-1,000	White, grey, and pink well-sorted fine-grained sandstone and quartzite, and thin layers of white siliceous, dolomitic limestone.[3]	"Sandstone aquifer in the Wells Formation and Tensleep Sandstone are capable of yielding moderate to large quantities of water. Availability is dependent upon local conditions of recharge, continuity of beds and development of permeability. These sandstones on topographic highs may be drained, especially if underlying limestones have extensive solution development."[3] "Major aquifer of Paleozoic System."[1]	[1]210-700
Paleozoic	Permian and Pennsylvanian	Permian, Upper and Middle Pennsylvanian	Wells Formation	[3]450-1,000	"Gray thick-bedded quartzite, calcareous sandstone, and limestone mainly in the upper part."[3]	"Sandstone aquifer in the Wells Formation and Tensleep Sandstone are capable of yielding moderate to large quantities of water. Availability is dependent upon local conditions of recharge, continuity of beds and development of permeability. These sandstones on topographic highs may be drained, especially if underlying limestones have extensive solution development."[3]	--
Paleozoic	Pennsylvanian/ Mississippian	Middle and Lower Pennsylvanian and Upper Mississippian	Amsden Formation	[1]400-700 [4]150-390	"Varicolored mudstone, siltstone, and sandstone, and gray cherty limestone".[3]	Few hydrogeologic data are available for the Amsden Formation. Small quantities of water may be available from the cherty limestone in the Amsden Formation, but, on topographic highs, the Amsden is probably well drained, especially if underlying limestones have extensive solution development.[3] "Minor aquifer in Green River Basin, but locally confining in Overthrust Belt..."[1]	--

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Cenozoic	Quaternary	Sequence in table does not indicate age relative to other Quaternary entries	Alluvium and colluvium	[1]<100 in the Green River Basin [1]up to 410 in the Overthrust Belt	"Clay, silt, sand, and gravel; includes some slopewash material. Coarser alluvial deposits are in Green River valley north of Green River and along streams in and near highlands..."[2] "Unconsolidated sand and gravel interbedded with silt and clay. The maximum thickness of alluvium in the Bear (and) Salt... River valleys is unknown; however, wells that are 200 ft deep have not penetrated the full thickness in these areas."[3]	Ground-water possibilities good in coarser deposits, but poor where silt and clay predominate. Clean sand and gravel near perennial streams would probably have yields of 500 ± gal/min.[2] "Sand and gravel in alluvium is the most utilized aquifer in the thrust belt. Irrigation and municipal wells in the Bear (and) Salt...River valleys yield 1,000 to 2,000 gal/min. Yields of wells that tap alluvium are dependent on the thickness, the sorting of the saturated sand and gravel, and the well construction."[3]	[1]50-500
Cenozoic	Quaternary	Sequence in table does not indicate age relative to other Quaternary entries	Gravel, pediment, and fan deposits	[4]15-30	"Gravel, pebble to boulder size, sand, and silt. Located at several terrace levels above the streams and in scattered patches along highlands; includes some glacial outwash material."[2]	"Known well yields are less than 20 gal/min."[2]	[2]<20
Cenozoic	Quaternary	Sequence in table does not indicate age relative to other Quaternary entries	Glacial deposits	[5]<100	"Till and outwash of sand, gravel, and boulders."[6] "Poorly sorted silt, sand, gravel, and boulders as much as 40 feet in diameter."[3]	Glacial deposits may yield small quantities of water to wells. Water yield is limited due to poorly sorted material and small saturated thickness. [3]	[2]<20
Cenozoic	Quaternary	Sequence in table does not indicate age relative to other Quaternary entries	Landslide deposits	[4]<30	"Locally includes intermixed landslide and glacial deposits, talus, and rock-glacier deposits."[6]	"Rock debris is not a potential source of water because of its poorly sorted material and small saturated thickness."[3]	--
Cenozoic	Quaternary	Sequence in table does not indicate age relative to other Quaternary entries	Dune sand and loess	[4]<10	Unconsolidated sand and silt.[2] "Includes active and dormant dunes."[6]	"Generally too thin to hold much water, but aids recharge to underlying formations."[2]	--

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Cenozoic	Tertiary	Pliocene and Miocene	Intrusive and extrusive igneous rocks	--	"Composition ranges from hornblende monzonite to basalt."[6] Exposure is confined to small outcrops in the northern part of Lincoln County.	"No ground water possibilities."[2] Igneous rocks generally have little primary permeability, but fractures may contain water.	--
Cenozoic	Tertiary	Pliocene and Miocene	Salt Lake Formation	[3]<1000	"White, gray, and green limy tuff, siltstone, sandstone, and conglomerate."[6] "Pale-reddish gray conglomerate, grit, sandstone, siltstone, clay, and white volcanic ash. The formation is most extensive in the Star Valley, where it has a maximum thickness of about 1,000 ft."[3]	The availability of water from this type of aquifer is limited because the conglomerates are usually well indurated, poorly sorted, and have little primary permeability. Springs issue from the conglomerates on side hills, but their flows rarely exceed 20 gal/min.[3]	[3]<20
Cenozoic	Tertiary	Miocene	Teewinot Formation	--	"White lacustrine clay, tuff and limestone. In thrust belt includes conglomerate."[6]	"Poorly consolidated conglomerates are well drained. Yields generally range from 10 to 120 gal/min."[1]	[1]10-120
Cenozoic	Tertiary	Eocene	Bridger Formation	[1]0-2,300	"Mudstone, sandy, tuffaceous, gray to green, locally banded with pink; medium grained, tuffaceous, muddy, brownish-gray sandstone; and thin bedded limestone and marlstone...Contains fewer red beds and much more volcanic ash than Wasatch Formation; base interfingers with Laney Member and generally is poorly defined. Present in much of southern half of (Green River) basin."[2]	"A major aquifer in the southern Green River Basin-Overthrust area. Yields from springs commonly range from 2 to 100 gal/min."[1] Generally, ground-water possibilities from the Bridger Formation are limited in the Green River Basin. Sandstones locally might contain good water where overlain by alluvial or gravel deposits.[2]	[1]2-100
Cenozoic	Tertiary	Pliocene (?) and Eocene	Fowkes Formation	[1]0-2,600	"Light-colored tuffaceous sandstone and siltstone, locally conglomeratic. Locally designated by some as Norwood Tuff."[6] The Fowkes Formation is subdivided into the following units, in ascending order: The Sillem Member (100 to 400 ft thick); the Bulldog Hollow Member (200 to 2,000 ft thick); and the Gooseberry Member (more than 200 ft thick).[3]	"Locally yields water to wells and springs in Overthrust Belt."[1] "Tuffaceous sandstone in the Fowkes is probably capable of yielding small quantities of water to wells."[3]	--

Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
[2]100-1,000 [4]<250 [2]20-265	"Marlstone, oil shale, tuff, siltstone, fine- to medium- grained sandstone; characteristically brown and buff colored."[2]	"Sandstone lenses in Laney Shale generally yield 3 to 100 gal/min to springs and wells."[1] Ground-water possibilities are fair. Sandstone is a significant constituent and yields of about 300 gal/min can probably be obtained locally, but water may contain high dissolved solids.[2]	[1]1-75
[2]0-1,400 [4]<250	"Marlstone, claystone, oil shale, siltstone, tuff, fine-grained sandstone, limestone; contains saline minerals of trona, shortite, halite, etc..."[2]	"Ground-water possibilities poor. Might yield less than 30 gal/min of brine locally..."[2]	[2]<30
[4]<200	"Light-gray to buff, mainly white-weathering siliceous limestone, calcareous shale, and siltstone."[4]	One spring inventoried had a discharge of 1 gal/min.	--
[4]260-330	"Includes light-gray, tan, and buff limestone, calcareous siltstone, marlstone, and shale, and brown laminated carbonaceous shale and very thinly laminated ("papery") oil shale; tuffaceous interbeds common."[4]	Springs issuing from the Fossil Butte Member had discharges ranging from 1 to 200 gal/min.	--
[1]2,500-5,250 Vasatch ormation) [1]100-2,800 reen River ormation)	"Wasatch: Thrust Belt-variegated mudstone and sandstone; southwest-drab to variegated claystone and siltstone, carbonaceous shale and coal, buff sandstone, arkose and conglomerate. Green River: Thrust Belt-buff laminated marlstone and limestone, brown oil shale, and siltstone; Southwest-oil shale, light-colored tuffaceous marlstone and sandstone."[6]	"Conglomeratic sandstones and conglomerates in the Wasatch are capable of yielding large quantities of water to wells... Small to moderate quantities of water are available from finer grained sandstones in the Wasatch and Green River Formations, but well yields are greatly dependent on the thickness of saturated sandstone that is tapped."[3] Major aquifer of the Green River Basin. [1]	[1]<50 (Wasatch Formation)
[2]0-3,500	"Claystone, silty to sandy, generally variegated red, orange, purple, brown, green, or gray; lenticular beds of fine- to medium-grained sandstone becoming conglomeratic locally at basin periphery."[2]	"A good source of water...Contains more than one aquifer; wells tapping deeper sandstones flow in some areas...Yields of wells range from 1 to 688 gal/min."[2]	--

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Cenozoic	Tertiary	Eocene	Wasatch Formation-diamictite and sandstone	[5]<1,000	"Diamictite grades laterally into members of the formation."[6] "Unsorted boulders and blocks in mudstone matrix."[5]	Unknown	--
Cenozoic	Tertiary	Eocene and Paleocene	Wasatch Formation-La Barge and Chappo Members	[5]<1,700	La Barge Member consists of red and brown mudstone and conglomerate, yellow sandstone and pisolitic limestone.[5] Chappo Member consists of red to gray conglomerate and sandstone.[5]	Unknown	--
Cenozoic	Tertiary	Eocene and Paleocene	Conglomerate of Sublette Range	[5]<600	"Boulder- to pebble-sized gravel, sand, and silt, crudely stratified."[5]	Unknown	--
Cenozoic and Mesozoic	Tertiary and Cretaceous	Paleocene and Upper Cretaceous	Evanston Formation	[1]1,350-2,900 [5]<800	"Lower member of mudstone, siltstone, claystone, and carbonaceous sandstone; middle member of conglomerate in a matrix of coarse sand; upper member consists of carbonaceous sandy to clayey siltstone interbedded with sandstone and conglomerate."[1]	"The Evanston Formation includes 1,300 to 2,900 feet of well-sorted conglomerates and conglomeratic sandstones that are capable of moderate to large well yields."[1]	--
Mesozoic	Cretaceous	Upper Cretaceous	Adaville Formation	[1]1,400-5,000 [5]<2,100	"Brown and buff fine- to medium-grained calcareous sandstone, gray carbonaceous mudstone, and numerous coal beds. The proportions of sandstone to mudstone are about equal. Thickness varies because of the irregularity of the unconformity that separates the Adaville and overlying Cretaceous rocks."[3]	"Generally considered a minor aquifer of the Overthrust Belt area..."[1] "Small quantities of water are available from sandstone in the base of the Adaville Formation."[3]	--
Mesozoic	Cretaceous	Upper Cretaceous	Blind Bull Formation	[5]<9,200	"Fine-grained to conglomeratic sandstone, siltstone, and shale with some beds of bentonite and coal."[3]	Small quantities of water are available from sandstone layers in the Blind Bull Formation.[3]	--
Mesozoic	Cretaceous	Upper Cretaceous	Hilliard Shale	[1]3,000-6,800? [5]<5,600	"Dark-gray to tan claystone, siltstone, and sandy shale."[6]	"Major regional confining unit of Green River Basin and Overthrust Belt. Locally yields small quantities to wells from sand lenses."[1]	--

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Mesozoic	Cretaceous	Upper Cretaceous	Frontier Formation	[1]1,100-3,000? [5]<2,600	"Gray, fine- to medium-grained sandstone, and gray mudstone, claystone, and siltstone with some beds of coal. The Oyster Ridge Sandstone Member is near the top of the formation and it contains numerous oyster shells."[3]	"Sandstone aquifers in the Frontier Formation are capable of yielding moderate quantities of water...."[3]	[1]5-50
Mesozoic	Cretaceous	Lower Cretaceous	Sage Junction Formation	[5]<3,300	"Gray and tan sandy siltstone and shale, tan sandstone and quartzite, porcelanite, fossiliferous limestone, and a few coal beds in lower part."[3]	Few hydrologic data are available for the Sage Junction Formation. Based on lithologies, small quantities of water are probably available from sandstone layers in this formation.[3]	--
Mesozoic	Cretaceous	Lower Cretaceous	Aspen Shale	[1]400-2,200 [5]1,100-2,000	"Light- to dark-gray siliceous tuffaceous shale and siltstone, thin bentonite beds, and quartzitic sandstone."[6] "Light gray to black shale, gray fine-grained sandstone, and white to gray porcelanite."[3]	"Locally utilized aquifer, maximum spring and well yields 25 to 30 gal/min. Water yields are mainly from stray sands and fracture zones."[1]	[1]25-30
Mesozoic	Cretaceous	Lower Cretaceous	Quealy Formation	[5]500-1,100	"Red and variegated pastel-tinted mudstone and tan sandstone."[5]	Few hydrologic data are available for the Quealy Formation. Based on lithologies, water is probably not available from this formation.[3]	--
Mesozoic	Cretaceous	Lower Cretaceous	Wayan Formation	[5]<3,900	"Variegated mudstone, siltstone, and sandstone."[6]	Unknown	--
Mesozoic	Cretaceous	Lower Cretaceous	Cokeville Formation	[4]<2,500 [5]850-3,000	"Gray and tan sandstone, siltstone, gray shale, highly fossiliferous limestone, porcelanite, bentonite, and a few coal beds in upper part. About 1,600 ft thick near Cokeville and as much as 2,500 ft thick near Sage Junction."[3]	Few hydrologic data are available for the Cokeville Formation. Based on lithologies, small quantities of water are probably available from sandstone layers in this formation.[3]	--
Mesozoic	Cretaceous	Lower Cretaceous	Bear River Formation	[1,3]800-1,500	"Black shale, fine-grained brown sandstone, thin limestone, and bentonite beds."[6] "Mainly gray to black fissile shale with interbeds of gray sandstone. Thickness generally ranges from 800 to 1,500 ft."[3]	"Minor aquifer with spring yields generally 4 to 15 gal/min and similar well yields."[1] "Small quantities of water are available from sandstone in the Bear River Formation."[3]	[1]4-15
Mesozoic	Cretaceous	Lower Cretaceous	Thomas Fork Formation	[4]300-1,300 [5]400-1,700	"Red and variegated mudstone and sandstone with calcareous nodules."[3]	Few hydrologic data are available for the Thomas Fork Formation. Based on lithologies, small quantities of water are probably available from sandstone layers in this formation.[3]	--
Mesozoic	Cretaceous	Lower Cretaceous	Smiths Formation	[4]110-390 [5]300-850	"Interbedded tan quartzitic and black ferruginous shale. About 755 ft thick along Smiths Fork but thins southward."[3]	Few hydrologic data are available for the Smiths Formation. Based on lithologies, small quantities of water are probably available from sandstone layers in this formation.[3]	--
Mesozoic	Cretaceous	Lower Cretaceous	Gannett Group includes: Smoot Formation, Draney Limestone, Bechler Conglomerate, Peterson Limestone, Ephraim Conglomerate	[1,3]800-5,000 [5]790-3,000	Lithologies of the Gannett Group include: brick-red and maroon siltstone and clay-stone, red to brown calcareous to quartzitic sandstone, red to brown conglomerate, and gray to tan nodular limestone (Ephraim Conglomerate); finely crystalline limestone (Peterson Limestone); red sandstone and conglomerate, and purplish- to reddish-gray siltstone and mudstone with thin limestone interbeds (Bechler Conglomerate); gray finely crystalline limestone and gray calcareous siltstone (Draney Limestone); and red siltstone and mudstone (Smoot Formation).[3]	"Water-bearing units restricted to sandstones and conglomerate in lower part."[1] Rocks in the Gannett Group are mostly impermeable and in most areas they are only capable of yielding small quantities of water. Where the conglomerates are fractured, moderate quantities are available.[3]	[1]5-75
Mesozoic	Jurassic	Upper and Middle Jurassic	Stump Formation	[3]90-120 [5]160-330	"Green to greenish-gray glauconitic sandstone, siltstone and limestone."[3]	The sandstone of the Stump Formation is relatively impermeable and in most areas is capable of yielding only small quantities of water.[3] "Unit is considered a poor aquifer."[1]	--
Mesozoic	Jurassic	Upper and Middle Jurassic	Preuss Sandstone or Preuss Redbeds	[5]360-1,600	Red, maroon, brown, and orange calcareous siltstone, mudstone, and sandstone, and some beds of rock salt in the Overthrust Belt.[3]	The Preuss Sandstone or Preuss Redbeds is relatively impermeable and in most areas is capable of yielding only small quantities of water.[3]	--
Mesozoic	Jurassic	Middle Jurassic	Twin Creek Limestone	[1]800-3,800 [5]980-3,300	"Light-gray to black limestone and shale in the upper part, and red, brown, and orange claystone and gray mainly brecciated but partly honeycombed limestone in the lower part...3,800 ft thick in the southern part of Lincoln County."[3]	Upper part of the Twin Creek Limestone is relatively impermeable and in most areas is capable of yielding only small quantities of water.[3] "Minor aquifer in Overthrust Belt."[1]	[1]20-300

Erathem	System	Series	Geologic unit	Range of thickness (ft)	Lithology	Water-yielding characteristics	Range of most common water yields (gal/min)
Mesozoic	Jurassic(?) Triassic(?)		Nugget Sandstone	[1,3]750-1,300 [5]590-1,000	"Varicolored (generally pink to salmon) crossbedded fine- to medium-grained well-sorted quartzitic sandstone, and a few beds of maroon, red, and brown mudstone in the lower part. About 1,300 ft thick in southern part of Lincoln County."[3]	The Nugget Sandstone is capable of yielding moderate to large quantities of water where outcrop or recharge areas are large; bedding is continuous and not offset by faults, and in topographic lows where large thicknesses occur. Many springs issue from the Nugget and flows greater than 1,000 gal/min are common.[3]	[1]3-300
Mesozoic	Triassic	Upper and Lower Triassic	Ankareh Formation	[1]200-800 [3]200-600	"Red to brown shale, siltstone, and fine-grained sandstone, and, locally, greenish-gray limestone in about the middle part. About 200 ft thick in the northern part of Lincoln County and about 600 ft thick in the southern part."[3]	Rocks in the Ankareh Formation are relatively impermeable and in most areas are probably capable of only yielding small quantities of water.[3] "Minor regional aquifer, locally confining." [1]	--
Mesozoic	Triassic	Lower Triassic	Thaynes Limestone	[1,3]1,100-2,600 [4]700-1,300 [5]980-1,600	"Mainly buff to dark-gray silty limestone, and red to tan siltstone and shale predominately in the upper part. About 1,100 ft thick in the northern part of Lincoln County and 2,400 to 2,600 ft thick in the southern part."[3]	"Where the Thaynes has secondary permeability in the form of fractures and (or) solution openings, the limestone will yield moderate quantities of water to wells."[3] "Generally considered a regional aquifer with spring flows of 5 to 1,800 gal/min..."[1]	[1]5-1,800
Mesozoic	Triassic	Lower Triassic	Woodside Shale	[1]350-600 [3]350-500	"Mainly red and orange partly anhydritic siltstone and mudstone, and some orange fine-grained sandstone."[3]	Rocks in the Woodside Shale are mostly impermeable and in most areas they are probably capable of only yielding small quantities of water.[3]	--
Mesozoic	Triassic	Lower Triassic	Dinwoody Formation	[1]250-700 [5]250-1,600	"Gray to olive-drab dolomitic siltstone."[6]	Rocks in the Dinwoody Formation are mostly impermeable and in most areas are probably capable of only yielding small quantities of water.[3]	--
Mesozoic	Triassic	Upper and Lower Triassic	Chugwater Formation	--	"Chugwater-red siltstone and shale."[6]	Unknown	--

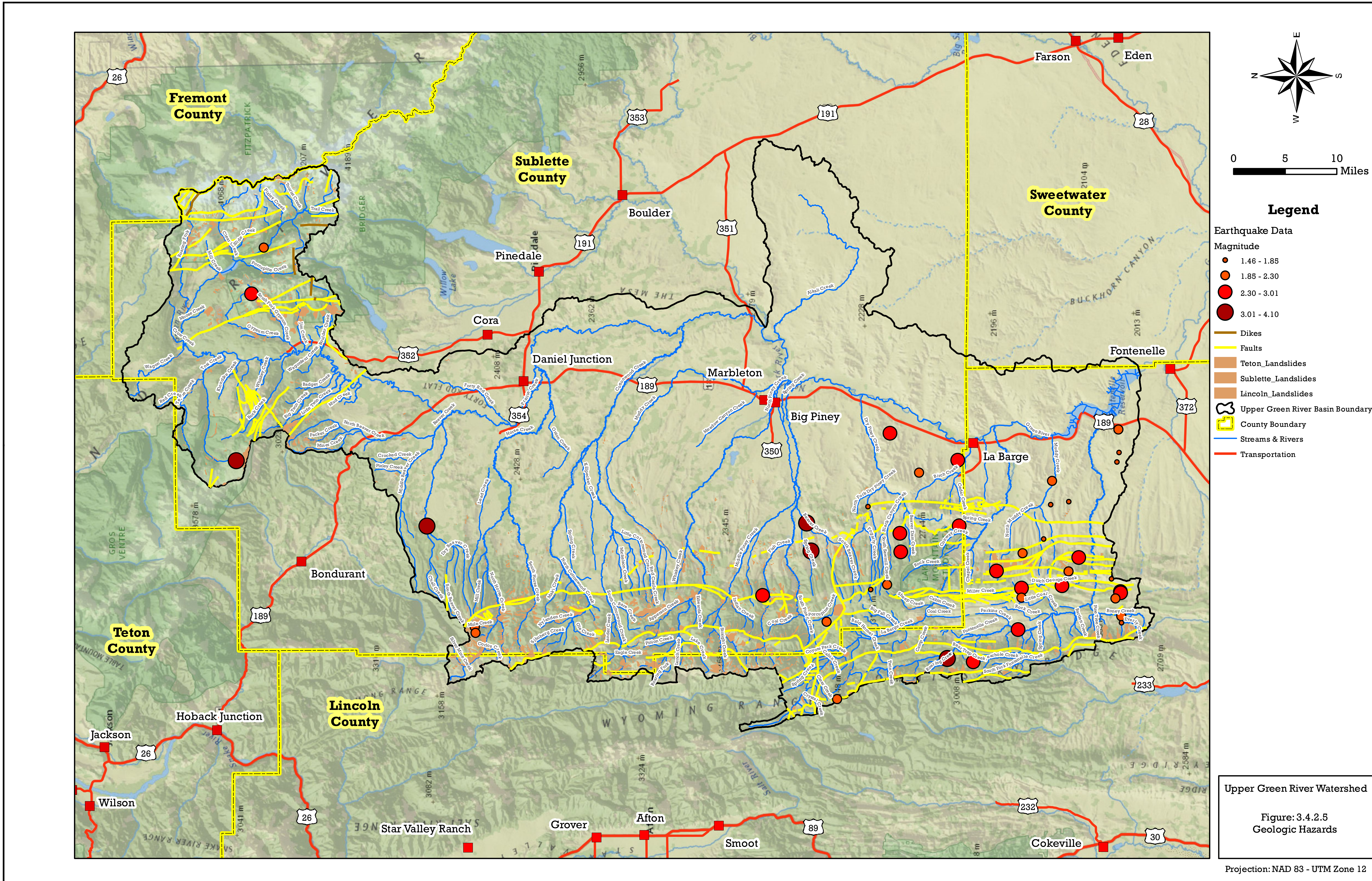
3.4.2.5 GEOLOGIC HAZARDS

The primary geologic hazards within the study area are earthquakes, landslides, shrinking/swelling soils, and subsidence.

<u>Earthquakes</u>

The most significant seismic activity in the region occurs in western Wyoming, and the largest historical earthquakes have occurred in the Yellowstone area. The Wyoming Earthquake Database produced by the WSGS has a record of only 3 earthquakes with epicenters within the watershed, the strongest of which was a 3.2 magnitude quake in the southern portion of the study area in 2000. Although there are a number of major faults in the western portion of the study area, very few are active. According to WSGS, "faults in Wyoming are considered active if they have shown displacement or seismic activity during the Holocene Epoch (the last 12,000 years). The Teton Fault, located in Jackson Hole, is the most famous of the active faults, though there are numerous other active faults around the state." Figure 3.4.2.5-Geologic Hazards depicts the faults found in the basin. Note that most are found in the eastern 1/3 of the basin along eastern slopes of the Wyoming Range.

The USGS has developed a web application that provides seismic design criteria for any location within the U.S. (http://geohazards.usgs.gov/designmaps/us/application.php). The application can generate maximum horizontal response data (S_s and S_1) based on Lat/Long coordinates and has a searchable map feature. The data provided by this tool can be used to assess peak horizontal ground acceleration.



Upper Green River Watershed

Figure: 3.4.2.5
Geologic Hazards

Landslides

Landslides include rock slides, debris flows, mudflows, slumps, and creep. Landslides can cause considerable damage to or loss of property. The WSGS has mapped more than 30,000 landslides in Wyoming, and maintains a database of these locations. Mapped landslides within the study area are depicted in Figure 3.4.2.5-Geologic Hazards. According to WSGS mapping of surficial materials, landslide deposits comprise approximately 7% of the watershed. These deposits are concentrated in the northern and western mountainous portions of the watershed. Landslides are often triggered by earthquakes or other natural events, such as precipitation sufficient to initiate earth movements. Certain geologic formations such as the Green River Formation are more susceptible to landslides than others.

Shrinking/Swelling Soils

Bentonite is a swelling clay formed from weathered prehistoric volcanic ashfalls. According to WSGS mapping, this type of clay is found in several soils that occur in the western and northern portions of the study area. Changes in soil moisture cause bentonite to expand or contract, which can result in large volumetric changes in the soil. If development occurs on these soils without proper mitigation procedures, the expansion or contraction of the soil can cause cracking, movement, or even failure of a structure.

Subsidence

Subsidence is the vertical sinking of earth due to a natural or man-made void in underlying rock formations. Areas with potential for natural subsidence typically include those with karst topography and caves. Karst is formed in areas of limestone, gypsum, or dolomite. A few areas with limestone bedrock exist within the study area; however, man-made underground mines likely pose the biggest risk for subsidence. Anthropogenic subsidence can occur in areas overlying extensive underground mine workings or in areas of aquifer drawdown or removal of other fluids, such as natural gas or oil. Underground coal and trona mines are particularly susceptible to subsidence because of their large extent. Underground mining within the watershed is limited to a few small-scale, inactive coal mines near La Barge, but these areas do pose a risk for subsidence (see section 3.3.6. of this report for further information on mining and mineral resources in the watershed).

REFERENCES

Case, J.C., Arneson, C.S., and Hallberg, L.L. 1998. Preliminary 1:500,000-scale digital surficial geology map of Wyoming: Wyoming State Geological Survey, Geologic Hazards Section Digital Map 98-1 (HDSM 98-1), scale 1:500,000.

Clarey, K.E., T. Bartos, D. Copeland, L. L. Hallberg, M. L. Clark, and M. L. Thompson. 2010. WWDC Green River Basin Water Plan II – Groundwater study Level I (2007–2009). Available groundwater determination. *Technical Memorandum.*

Eddy-Miller, C.A., M. Plafcan, and M. Clark 1996. Water Resources of Lincoln County, Wyoming. U.S. Geological Survey Water-Resources Investigations Report 96-4246.

McNab, W.H. and P.E. Avers. 1994. Ecological Subregions of the United States. Prepared in cooperation with Regional Compilers and the ECOMAP Team of the Forest Service. WO-WSA-5. http://www.fs.fed.us/land/pubs/ecoregions/

Lyn Topinka, 2001. The Geologic Time Scale: U.S. Geological Survey, http://vulcan.wr.usgs.gov/Glossary/geo_time_scale.html.

West, R.M. 1969. Geology and vertebrate paleontology of the northwestern Green River Basin, Wyoming. 21st Annual Field Conference. Wyoming Geological Association Guidebook. Pp. 77-92.

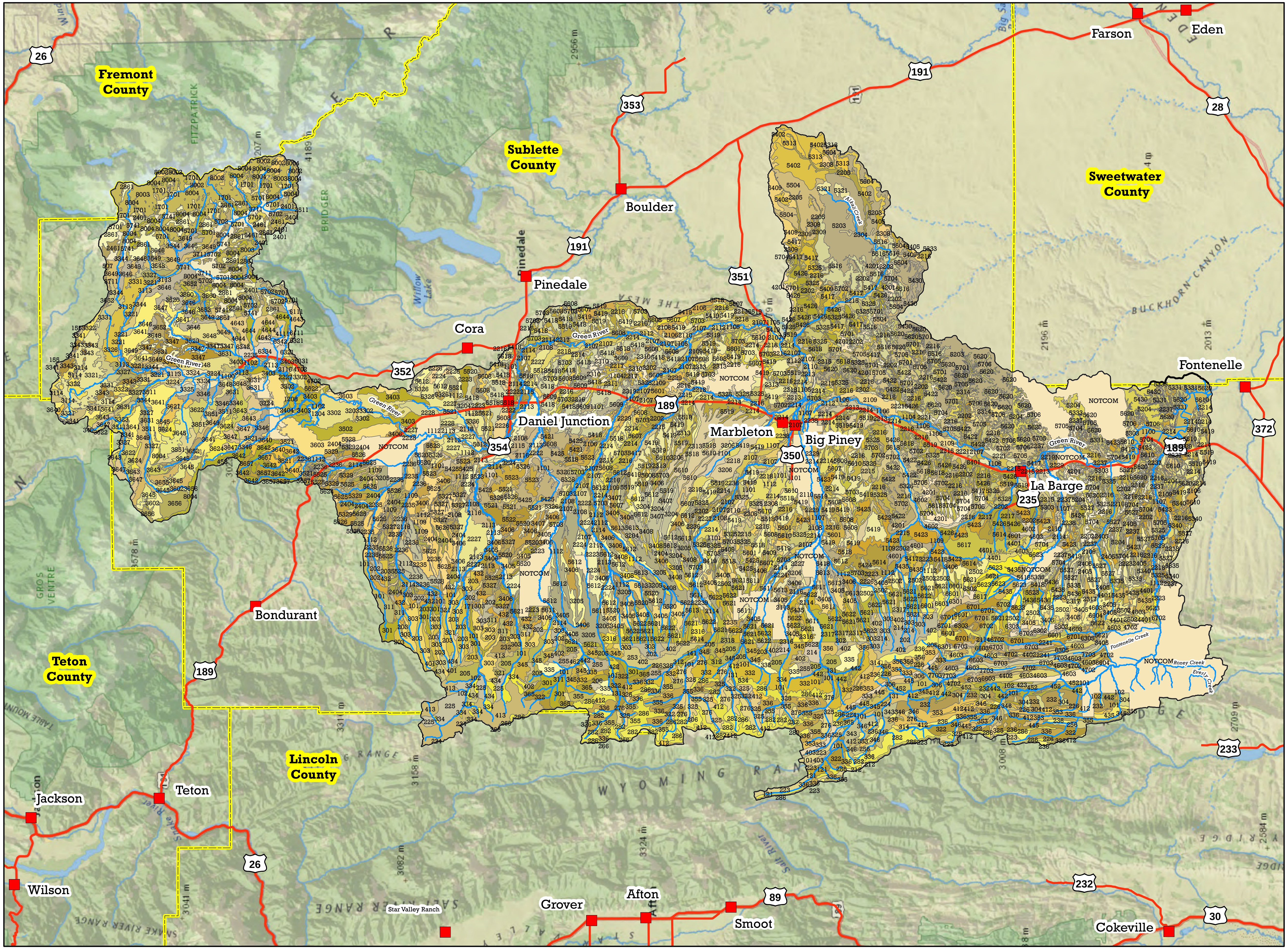
Wyoming State Geological Survey, 2013. Rock Spring Uplift overview. http://www.wsgs.uwyo.edu/research/stratigraphy/RockSpringsUplift/Default.

3.4.3 SOILS

The USFS and NRCS have mapped soils throughout the Upper Green River watershed. Soils data for all but 7% of the watershed have been digitized and are included in the project GIS (Figure 3.4.3.1 Soils Data; http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). The Upper Green River watershed contains more than 290 distinct soil mapping units, and the three most prominent mapping units are:

- Sandbranch-Scooby complex, 1 to 8 percent slopes;
- Jonah-Luhon-Burmaloaf complex, 1 to 6 percent slopes; and
- Fonce-Taffom-Twocabin complex, 2 to 15 percent slopes

A tabulation of soil mapping units within the watershed is presented in Table 3.4.3 found in Appendix E.



0 5 10 Miles

Legend

- Upper Green River Watershed Boundary
- County Boundary
- Streams & Rivers
- Transportation

Upper Green River Watershed

Figure 3.4.3.1
Soils Data

Projection: NAD 83 - UTM Zone 12

3.4.4 WATERSHED HYDROLOGY

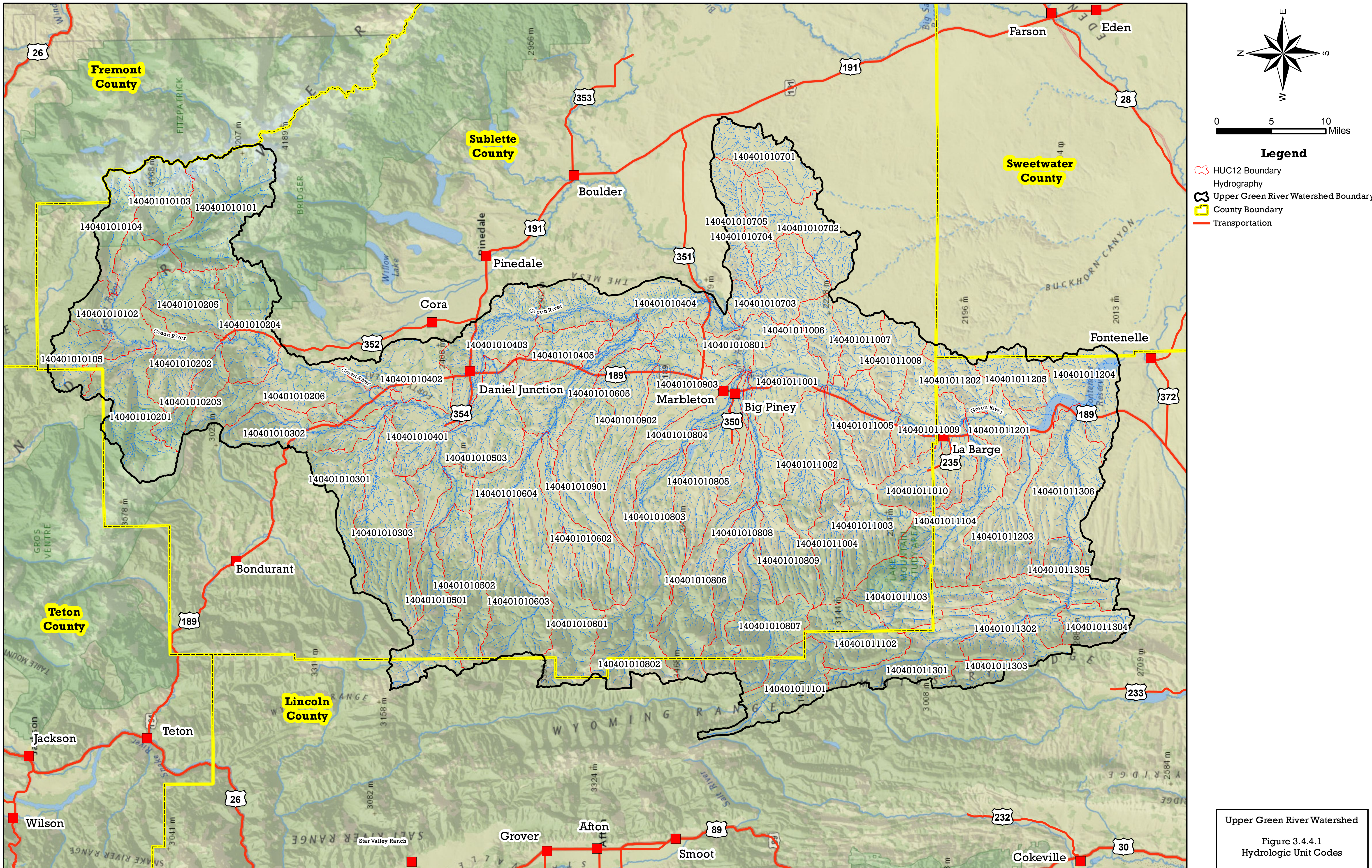
3.4.4.1 SURFACE WATER

The Green River watershed is a sub-basin of the Colorado River drainage. The catchment is bounded by the Salt River and Wyoming Mountain Ranges to the west, the Gros Ventre Range to the northwest, the Wind River Range to the north, and the Great Divide Basin to the east. The Upper Green River watershed study area does not include the New Fork River sub-basin; the area and physical attributes of the New Fork River catchment are omitted from the textual discussion of study area hydrology, but the New Fork River catchment was incorporated into the study area as necessary during quantitative hydrologic analyses in order to accurately reflect the physical attributes of the total catchment. The Upper Green River watershed study catchment is approximately 2,936 square miles (4,188 square miles including the New Fork River sub-basin), has a peak elevation of approximately 13,533 feet, a minimum elevation of approximately 6,520 ft, total relief of approximately 7,013 ft, and a mean basin elevation of 8,077 feet.
The study area includes approximately 208 miles of the mainstem Green River, and major tributaries including Rock Creek, Piney Creek, LaBarge Creek, Klondike Creek, Horse Creek, Gypsum Creek, Fontenelle Creek, Cottonwood Creek, Beaver Creek, and Tosi Creek. The dominant basin hydrologic regime is perennial because watercourses convey surface water discharge year-round during most years. Peak flows correspond to spring snow-melt runoff, and the hydrograph in most sub-basins demonstrates a decline through the summer and fall, and base flows occur in the winter season.

Multiple analyses were performed to quantitatively investigate the hydrologic regime within the project area including acquisition of historic stream flow gauge station data, installation and maintenance of temporary stream flow gauges, and application of multiple regional regression equations that quantify hydrologic discharge parameters based upon catchment attributes.

The Watershed Boundary Dataset developed jointly by the USGS and the NRCS was obtained from the NRCS Geospatial Data Gateway. Hydrologic Units (HU) are delineated and presented in the dataset at various scales. Each HU is identified by a unique numerical identifier, or a 2-digit code referred to as a Hydrologic Unit Code. The largest scale of delineated watersheds is identified by 2-digit codes referred to as HUC12s. Additional 2-digit codes are added to the numerical identifier to describe nested sub-watersheds. The smallest nationwide dataset of delineated HUs are identified by 6 two-digit codes, and are referred to as 12-digit Hydrologic Unit Codes (or HUC12s).

All HUC12s contained within the Upper Green River watershed are imported into the project GIS, and are depicted in Figure 3.4.4.1 with National Hydrography Dataset (water lines) derived at the 1:24,000 scale. HUC12s are classified as ‘complete’ if the subject HUC12 catchment does not receive natural surface water inputs from adjacent HUC12s, or as ‘composite’ if the subject HUC12 receives natural surface water input from an adjacent HUC12. The sub-basins associated with each composite HUC12 were delineated by merging all HUC12 that comprise the subject catchment. The New Fork River basin was incorporated as needed to delineate the complete sub-basin of composite HUC12s located in the southern portion of the Upper Green River watershed study area. These analyses enabled quantification of various attributes (drainage area, maximum



Upper Green River Watershed

Figure 3.4.4.1
Hydrologic Unit Codes

Projection: NAD 83 - UTM Zone 12

and mean elevation, aspect, slope) of sub-basins corresponding to the downstream extent of each HUC12.

The methodologies presented in Water-Resources Investigations Report 03-4107 (Miller 2003) were used to develop quantitative estimates of hydrologic regime in each HUC12. The approach utilizes unique regional regression equations for various defined hydrologic regions, and the Upper Green River watershed study area spans 3 of those regions including the Rocky Mountain, High Desert, and Overthrust Belt. Hydrologic regions were input into the project GIS enabling geographic analyses of sub-basins within the study area for the purpose of applying regionally appropriate regression equations. Regression equations for catchments in the Rocky Mountain region incorporate basin attributes of area, mean elevation, and longitude; High Desert region equations are based upon area and latitude; Overthrust Belt region equations are based upon area and mean January precipitation. Sub-basins that span more than 1 hydrologic region are addressed in accordance with the procedure outlined in the report (Miller 2003). Results of the hydrologic analyses (Table 3.4.4.1.1) include peak flow rates (in cubic feet per second) at the downstream boundary of each HUC12 associated with various recurrence intervals (1.5 years to 500 years). Analysis results are presented in the project GIS, in which a user can access all recurrence interval peak flow rates at the downstream end of any HUC12 with a single click.

Table 3.4.4.1.1. Multiple recurrence interval peak flow rates in HUC12 sub-basins within the Upper Green River Watershed.

HUC12	HUC12_Name	Area_acres	1.5-yr RI (cfs)	2-yr RI (cfs)	2.33-yr RI (cfs)	5-yr RI (cfs)	10-yr RI (cfs)	25-yr RI (cfs)	50-yr RI (cfs)	100-yr RI (cfs)	200-yr RI (cfs)	500-yr RI (cfs)
140401010101	Porcupine Creek-Green River	45,099	1,024	1,250	1,208	1,476	1,649	1,857	1,960	2,073	2,199	2,335
140401010102	Mill Creek-Green River	133,922	2,153	2,680	2,533	3,088	3,447	3,879	4,090	4,325	4,579	4,862
140401010103	Clear Creek	22,173	624	751	737	902	1,008	1,136	1,200	1,269	1,348	1,432
140401010104	Roaring Fork	15,721	385	471	469	594	680	785	843	905	975	1,053
140401010105	Wagon Creek	14,745	317	393	394	510	591	693	752	814	884	965
140401010201	Tosi Creek	35,896	525	668	661	867	1,017	1,205	1,317	1,436	1,567	1,724
140401010202	Lime Creek-Green River	192,480	2,682	3,373	3,168	3,877	4,340	4,899	5,176	5,484	5,814	6,186
140401010203	Rock Creek	12,480	192	245	251	343	413	503	561	623	691	776
140401010204	Boulder Creek-Green River	259,914	3,295	4,166	3,889	4,756	5,324	6,007	6,346	6,723	7,125	7,579
140401010205	Gypsum Creek	24,509	389	493	492	649	764	909	996	1,089	1,191	1,314
140401010206	Big Twin Creek-Green River	300,286	3,459	4,403	4,105	5,052	5,679	6,437	6,822	7,248	7,699	8,217
140401010301	North Beaver Creek-Beaver Creek	94,874	459	584	642	897	1,107	1,364	1,539	1,719	1,895	2,111
140401010302	Miner Creek-North Beaver Creek	24,057	192	235	254	336	402	480	533	586	639	703
140401010303	South Beaver Creek	41,571	174	229	255	375	477	607	699	794	889	1,009
140401010401	Web Draw-Green River	439,888	3,814	4,884	4,203	5,765	6,567	7,536	8,065	8,638	9,229	9,916
140401010402	Forty Rod Creek	26,509	173	238	245	366	467	606	705	813	933	1,094
140401010403	Tyler Draw-Green River	586,024	4,117	5,265	4,361	6,322	7,250	8,372	9,007	9,691	10,387	11,200
140401010404	Mesa Spring-Green River	1,601,601	7,594	9,779	8,785	10,543	11,696	13,100	13,794	14,588	15,416	16,382
140401010405	Soap Hole Basin	19,748	34	52	63	121	187	290	383	489	611	790

140401010501	Upper Horse Creek	63,972	441	539	583	772	922	1,100	1,219	1,339	1,455	1,596
140401010502	South Horse Creek	27,546	182	228	248	339	413	503	565	627	689	765
140401010503	Lower Horse Creek	111,430	515	650	638	990	1,218	1,501	1,696	1,897	2,098	2,346
140401010601	Upper South Cottonwood Creek	30,535	334	389	414	514	590	678	735	792	846	912
140401010602	Lower South Cottonwood Creek	53,017	443	529	568	730	856	1,003	1,099	1,196	1,290	1,402
140401010603	Upper North Cottonwood Creek	36,611	283	344	372	490	583	694	768	843	916	1,005
140401010604	Lower North Cottonwood Creek	72,450	376	476	523	727	894	1,098	1,238	1,381	1,521	1,692
140401010605	Ball Island-Cottonwood Creek	153,105	748	926	854	1,365	1,656	2,012	2,256	2,508	2,759	3,069
140401010701	Sand Draw Reservoir Number 4	22,906	41	64	78	151	232	361	476	608	757	978
140401010702	Upper Alkali Creek	49,675	68	104	125	236	357	545	710	896	1,105	1,409
140401010703	Lower Alkali Creek	103,874	103	155	185	340	505	757	974	1,214	1,483	1,867
140401010704	Granite Reservoir	12,199	27	43	52	102	159	252	335	432	542	708
140401010705	North Alkali Draw	15,894	32	50	61	119	184	289	383	491	615	799
140401010801	Ferry Island-Green River	1,980,750	7,474	9,636	8,630	10,344	11,478	12,870	13,572	14,374	15,212	16,196
140401010802	Upper North Piney Creek	37,762	441	508	537	655	744	844	909	973	1,035	1,108
140401010803	Middle North Piney Creek	61,933	512	611	655	840	983	1,150	1,259	1,369	1,475	1,601
140401010804	Lower North Piney Creek	118,364	586	728	660	1,081	1,319	1,613	1,819	2,032	2,246	2,516
140401010805	Deer Hill Draw	25,545	70	99	90	186	255	353	431	516	607	733
140401010806	Middle Piney Creek	41,674	333	401	412	562	665	788	872	957	1,040	1,144
140401010807	Upper South Piney Creek	33,489	258	315	341	450	536	639	709	779	847	930
140401010808	Middle South Piney Creek	91,383	513	638	672	945	1,147	1,391	1,556	1,726	1,892	2,095
140401010809	Lower South Piney Creek	22,025	132	168	185	259	320	395	447	501	554	620
140401010901	Upper Muddy Creek	35,598	140	183	150	304	393	515	608	708	814	958
140401010902	Middle Muddy Creek	65,625	182	243	177	421	558	748	897	1,058	1,231	1,467
140401010903	Lower Muddy Creek	99,836	206	281	196	507	686	941	1,146	1,368	1,609	1,940
140401011001	Spring Creek-Green River	2,132,070	7,431	9,585	8,576	10,275	11,405	12,795	13,500	14,306	15,148	16,141
140401011002	Dry Basin Draw	29,859	66	96	88	190	269	381	473	573	682	833
140401011003	Dry Piney Creek	52,257	272	346	366	533	659	816	926	1,039	1,151	1,291
140401011004	North Fork Dry Piney Creek	16,799	115	144	158	217	265	325	366	408	450	502
140401011005	Bird Draw-Green River	2,252,758	7,414	9,567	8,559	10,265	11,407	12,819	13,546	14,373	15,240	16,265
140401011006	Reardon Draw	12,351	29	45	55	109	170	268	357	460	578	755
140401011007	Chapel Canyon	14,343	32	50	61	119	186	293	389	501	628	818
140401011008	Figure Four Canyon	15,808	35	55	66	131	203	320	425	545	683	889
140401011009	Chappell Creek-Green River	2,305,232	7,415	9,573	8,568	10,289	11,449	12,886	13,636	14,486	15,378	16,438
140401011010	Birch Creek	16,506	39	56	65	109	150	207	251	298	346	411
140401011101	Headwaters La Barge Creek	25,960	290	338	359	446	513	589	639	689	737	795
140401011102	Upper La Barge Creek	51,801	454	540	578	736	859	1,001	1,094	1,188	1,278	1,386
140401011103	Middle La Barge Creek	83,635	651	779	836	1,075	1,260	1,475	1,615	1,757	1,893	2,054
140401011104	Lower La Barge Creek	119,708	715	874	872	1,259	1,509	1,811	2,015	2,224	2,431	2,684
140401011201	Delaney Canyon-Green River	2,452,986	7,385	9,538	8,532	10,247	11,409	12,854	13,614	14,474	15,377	16,452
140401011202	Steed Canyon	14,038	35	55	66	132	206	326	434	559	701	915
140401011203	Muddy Creek	30,824	95	132	116	244	335	463	566	679	800	969

140401011204	Fontenelle Reservoir-Green River	2,680,396	7,360	9,516	8,512	10,244	11,432	12,919	13,719	14,618	15,565	16,699
140401011205	Anderson Canyon	15,871	39	61	75	148	232	366	487	626	785	1,022
140401011301	Headwaters Fontenelle Creek	28,359	260	311	334	429	503	590	648	706	762	830
140401011302	Upper Fontenelle Creek	67,266	460	563	609	807	963	1,149	1,272	1,397	1,518	1,665
140401011303	South Fork Fontenelle Creek	13,793	131	158	170	221	262	310	343	376	408	448
140401011304	Roney Creek	13,104	58	77	86	130	168	217	252	289	327	375
140401011305	Middle Fontenelle Creek	103,628	554	694	758	1,039	1,265	1,539	1,723	1,911	2,095	2,317
140401011306	Lower Fontenelle Creek	146,267	584	745	664	1,166	1,459	1,833	2,103	2,384	2,671	3,039

The Miller 2003 report presents regional regression equations for recurrence interval discharge that revise those previously presented in Lowham 1988. However the USGS Water Resources Publications Bibliography (http://wy.water.usgs.gov/publications/statebiblio/flood2.htm) includes the following statement indicating that the regional regression equations from Lowham associated with mean annual discharge remain valid:

The regression equations using physical and climatic basin characteristics have been superseded by those in WRIR 03-4107 (Miller, 2003). WRIR 88-4045 also includes procedures and equations for estimating peak discharge using the channel width, mean annual discharge using basin characteristics or channel width, and mean monthly discharge. Those procedures and equations have not been revised or superseded.

The Lowham report identifies 2 hydrologic regions that overlap the study area. In the Mountainous Region, which overlaps the north and western portion of the study area, hydrologic attributes are correlated to either (1) basin area and mean elevation or (2) basin area and mean annual precipitation. In the High Desert region, which includes the southern and eastern portions of the study area, hydrologic attributes are correlated to basin area and mean annual precipitation. Sub-basins that span both regions were address using procedure presented in the report (Lowham 1988). Regression equation for mean annual discharge (the average daily discharge rate experienced during the year) were applied to the sub-basins associated with the downstream boundary of each HUC12s within the study area. Results were used to calculate total annual yield based upon a 1-year duration of mean annual discharge (Table 3.4.4.1.2). Analysis results are presented in the project GIS, in which a user can access the mean annual discharge and total annual yield at the downstream end of any HUC12 with a single click.

Table 3.4.4.1.2. Mean annual discharge and total annual yield in HUC12 sub-basins within the Upper Green River Watershed.

HUC12	HUC12_Name	Mean Annual Discharge (elevation method, cfs)	Total Annual Yield (elevation method, ac-ft)	Mean Annual Discharge (precipitation method, cfs)	Total Annual Yield (precipitation method, ac-ft)
140401010101	Porcupine Creek-Green River	96.7	70,034	109.0	78,926
140401010102	Mill Creek-Green River	243.7	176,439	239.0	173,062
140401010103	Clear Creek	52.6	38,059	53.9	39,033
140401010104	Roaring Fork	32.1	23,275	34.3	24,825
140401010105	Wagon Creek	27.0	19,583	21.5	15,591
140401010201	Tosi Creek	53.3	38,583	53.1	38,444
140401010202	Lime Creek-Green River	324.9	235,231	308.1	223,049
140401010203	Rock Creek	17.4	12,567	22.0	15,942
140401010204	Boulder Creek-Green River	420.1	304,142	395.5	286,339
140401010205	Gypsum Creek	37.3	27,001	43.6	31,565
140401010206	Big Twin Creek-Green River	438.6	317,528	409.9	296,778
140401010301	North Beaver Creek-Beaver Creek	69.9	50,640	77.6	56,187
140401010302	Miner Creek-North Beaver Creek	23.0	16,649	29.9	21,617
140401010303	South Beaver Creek	25.8	18,646	31.7	22,929
140401010401	Web Draw-Green River	476.8	345,221	431.5	312,419
140401010402	Forty Rod Creek	n.a	n.a	1.1	828
140401010403	Tyler Draw-Green River	516.8	374,121	461.3	333,975
140401010404	Mesa Spring-Green River	1,105.7	800,478	859.1	621,998
140401010405	Soap Hole Basin	n.a	n.a	0.6	465
140401010501	Upper Horse Creek	60.1	43,547	88.3	63,944
140401010502	South Horse Creek	25.4	18,381	38.6	27,962
140401010503	Lower Horse Creek	60.8	43,985	69.8	50,520
140401010601	Upper South Cottonwood Creek	34.5	24,970	61.2	44,281
140401010602	Lower South Cottonwood Creek	39.5	28,615	59.6	43,122
140401010603	Upper North Cottonwood Creek	34.9	25,295	54.9	39,729
140401010604	Lower North Cottonwood Creek	37.2	26,924	45.0	32,553
140401010605	Ball Island-Cottonwood Creek	73.2	52,968	83.5	60,446
140401010701	Sand Draw Reservoir Number 4	n.a	n.a	0.7	524
140401010702	Upper Alkali Creek	n.a	n.a	1.4	995
140401010703	Lower Alkali Creek	n.a	n.a	2.5	1,837
140401010704	Granite Reservoir	n.a	n.a	0.4	273
140401010705	North Alkali Draw	n.a	n.a	0.5	362
140401010801	Ferry Island-Green River	1,146.1	829,768	862.5	624,404

140401010802	Upper North Piney Creek	51.1	37,010	93.0	67,329
140401010803	Middle North Piney Creek	49.4	35,775	71.9	52,040
140401010804	Lower North Piney Creek	44.3	32,054	47.0	34,051
140401010805	Deer Hill Draw	1.4	1,026	1.3	928
140401010806	Middle Piney Creek	35.2	25,490	52.9	38,279
140401010807	Upper South Piney Creek	41.9	30,351	68.9	49,855
140401010808	Middle South Piney Creek	79.0	57,169	105.5	76,379
140401010809	Lower South Piney Creek	17.9	12,994	25.8	18,684
140401010901	Upper Muddy Creek	6.2	4,512	6.3	4,590
140401010902	Middle Muddy Creek	6.9	5,001	6.2	4,465
140401010903	Lower Muddy Creek	7.3	5,261	6.0	4,338
140401011001	Spring Creek-Green River	1,214.8	879,465	916.9	663,828
140401011002	Dry Basin Draw	n.a	n.a	1.2	860
140401011003	Dry Piney Creek	24.4	17,670	28.7	20,763
140401011004	North Fork Dry Piney Creek	10.5	7,568	15.6	11,271
140401011005	Bird Draw-Green River	1,226.6	888,042	916.4	663,477
140401011006	Reardon Draw	n.a	n.a	0.4	262
140401011007	Chapel Canyon	n.a	n.a	0.4	305
140401011008	Figure Four Canyon	n.a	n.a	0.5	349
140401011009	Chappell Creek-Green River	1,217.5	881,446	902.1	653,087
140401011010	Birch Creek	n.a	n.a	0.7	495
140401011101	Headwaters La Barge Creek	33.8	24,449	60.3	43,657
140401011102	Upper La Barge Creek	64.7	46,822	102.7	74,336
140401011103	Middle La Barge Creek	101.1	73,170	148.2	107,320
140401011104	Lower La Barge Creek	105.9	76,697	133.6	96,712
140401011201	Delaney Canyon-Green River	1,319.7	955,468	985.0	713,132
140401011202	Steed Canyon	n.a	n.a	0.4	313
140401011203	Muddy Creek	9.5	6,854	8.0	5,793
140401011204	Fontenelle Reservoir-Green River	1,416.9	1,025,775	1,045.8	757,170
140401011205	Anderson Canyon	n.a	n.a	0.4	316
140401011301	Headwaters Fontenelle Creek	33.5	24,246	54.4	39,353
140401011302	Upper Fontenelle Creek	72.7	52,622	99.4	71,944
140401011303	South Fork Fontenelle Creek	16.0	11,570	26.0	18,839
140401011304	Roney Creek	11.5	8,290	13.2	9,575
140401011305	Middle Fontenelle Creek	100.6	72,838	120.4	87,142
140401011306	Lower Fontenelle Creek	93.9	67,967	94.7	68,575

3.4.4.2 STREAM GAUGING STATIONS

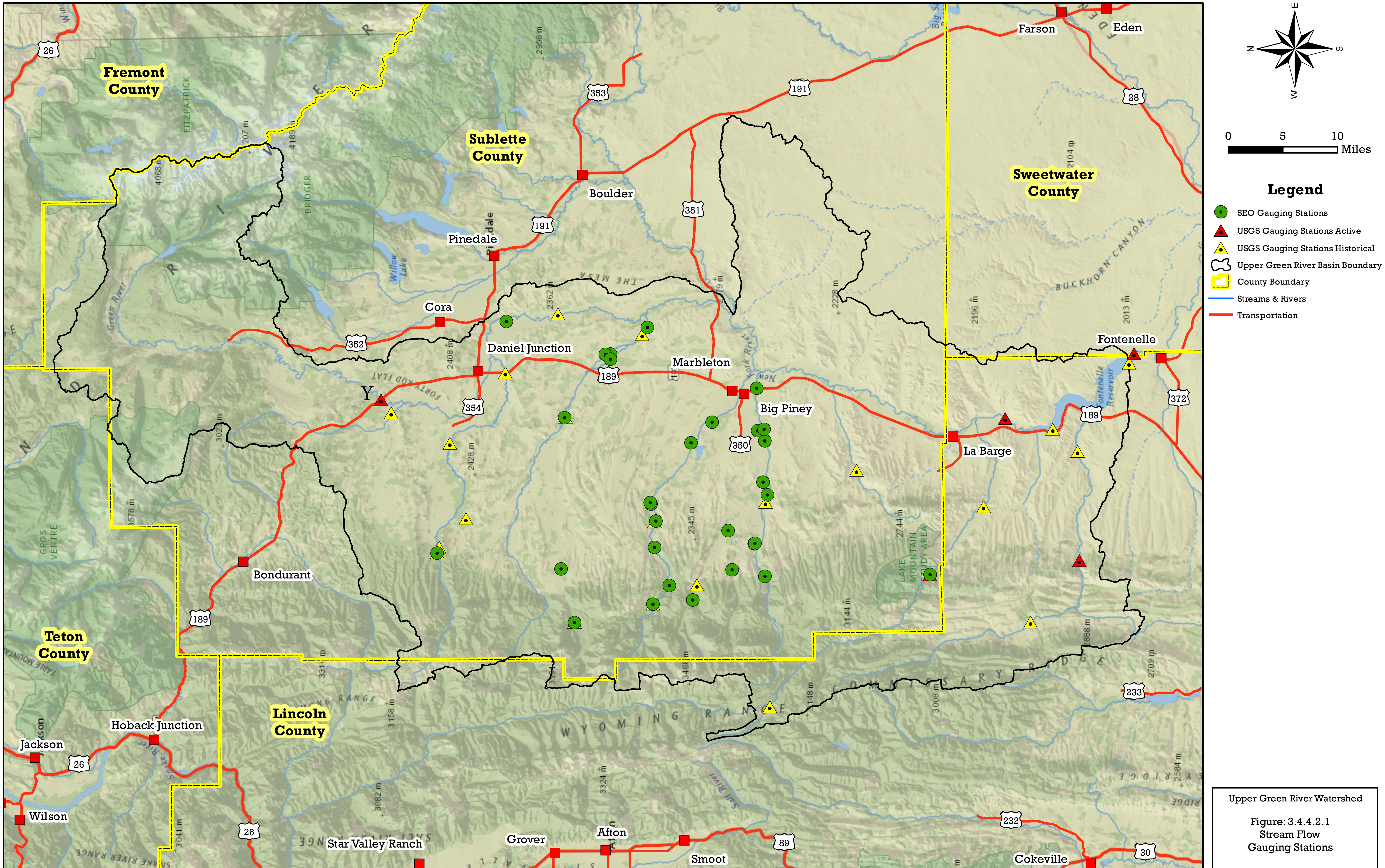
Historic and currently active stream gauging stations operated in the study area by the USGS or WYSEO are presented in Figure 3.4.4.2.1 with numerical identifier, and gauge station details are presented in Table 3.4.4.2.1. The USGS currently maintains 5 stream flow gauge stations in the Upper Green River watershed study area, and there are an additional 21 historic USGS gauges in the basin. The WYSEO currently maintains 32 stream flow gauge stations in watercourses, ditches, and delivery systems in the basin. The following links connect to the realtime State and the USGS stream gauge data; http://seoflow.wyo.gov/WDPortal http://waterwatch.usgs.gov/?m=real&r=wy

Table 3.4.4.2.1. Stream flow gauging stations located within the Upper Green River Watershed.

ID	Agency	Site ID	Site Name	Drainage Area (sqmi)	Operation Begin	Operation End	Period of Record yrs	Gauge Elevation ft
A	USGS	9211150	Fontenelle Reservoir Fontenelle, WY (Field/Lab-Water Quality Samples)	4280	7/9/1975	7/9/1975	0	6506
B	USGS	9210500	Fontenelle Creek nr Herschler Ranch, nr Fontenelle	152	10/1/1951	present	61	6950
C	USGS	9211000	Fontenelle Creek nr Fontenelle	224	10/1/1915	9/30/1953	26	6580
D	USGS	9209500	Green River nr Fontenelle	3970	10/1/1946	3/31/1965	18	6490
E	USGS	9210000	Fontenelle Creek at Upper Station nr Fontenelle	58	5/1/1941	10/31/1942	1	--
F	USGS	9209400	Green River nr La Barge	3910	10/1/1963	present	66	6520
G	USGS	9208500	La Barge Creek nr Viola	172	10/1/1940	9/30/1949	13	6890
H	USGS	9208400	La Barge Creek above Viola	122	10/1/1982	9/30/2012	9	7270
I	USGS	9207700	Dry Piney Creek nr Big Piney	67	4/1/1965	9/30/1973	8	7150
J	USGS	9208000	La Barge Creek nr La Barge Meadows Ranger Station	6.3	10/1/1950	10/9/1981	33	8450
K	USGS	9207500	South Piney Creek nr Big Piney	117	10/1/1938	11/30/1942	4	--
L	USGS	9206000	Middle Piney Creek bel South Fork, nr Big Piney	34.3	8/1/1939	9/30/1954	15	7980
M	USGS	9205500	North Piney Creek nr mason	58	10/1/1915	9/30/1972	43	7510
N	USGS	9205490	North piney Creek ab Apperson Creek, nr Mason	29.6	10/1/1982	9/30/1984	2	8090
O	USGS	9192500	Cottonwood Creek nr mouth nr Big Piney	238	10/1/1938	9/30/1954	2	--
P	USGS	9191300	South Cottonwood Creek nr Big Piney	21.4	10/1/1982	9/30/1984	2	8260
Q	USGS	9191500	Cottonwood Creek nr Daniel	202	10/1/1938	9/30/1954	16	7205
R	USGS	9191000	Green River nr Daniel	932	10/1/1912	11/30/1932	20	7040
S	USGS	9190500	Horse Creek at Daniel	173	5/1/1913	11/30/1918	6	7185
T	USGS	9189550	South Horse Creek nr Merna	33.3	10/1/1982	9/30/1985	2	7575
U	USGS	9190000	Horse Crek nr Daniel	106	10/1/1931	9/30/1985	26	7350
V	USGS	9189500	Horse Creek at Sherman Ranger Station	43	10/1/1954	10/2/1974	20	7770
W	USGS	9189495	North Horse Creek ab Sherman Ranger Station	42.8	10/1/1982	9/30/1984	2	7805
X	USGS	9189000	Beaver Creek nr Daniel	141	10/1/1938	9/30/1954	16	7440

Y	USGS	9188500	Green River at Warren Bridge, nr Daniel	468	10/1/1931	present	80	7468
Z	USGS	9211200	Green River below Fontenelle Reservoir	4280	12/1/1963	present	49	6378
AA	SEO	0411NH01	North Horse Creek nr Sherman RS					
AB	SEO	0411BC05	Ballow-Plank	n/a	n/a	n/a	n/a	n/a
AC	SEO	0410CC05	Alpha	n/a	n/a	n/a	n/a	n/a
AD	SEO	0410SP45	Aurora	n/a	n/a	n/a	n/a	n/a
AE	SEO	0410MP31	Beaver					
AF	SEO	0410NP40	Dewey	n/a	n/a	n/a	n/a	n/a
AG	SEO	0410SP40	Empire No 2	n/a	n/a	n/a	n/a	n/a
AH	SEO	0410CC16	Essex	n/a	n/a	n/a	n/a	n/a
AI	SEO	0410MP41	Finnegan	n/a	n/a	n/a	n/a	n/a
AJ	SEO	0410SP39	Fish Creek Ditch	n/a	n/a	n/a	n/a	n/a
AK	SEO	0410GR36	Green River Supply	n/a	n/a	n/a	n/a	n/a
AL	SEO	0410GR99	Green River Supply Canal - Cottonwood Crk					
AM	SEO	0410NP28	H. McKay	n/a	n/a	n/a	n/a	n/a
AN	SEO	0410MP45	Homestake (Middle Piney)	n/a	n/a	n/a	n/a	n/a
AO	SEO	0410SP09	Homestake (South Piney)	n/a	n/a	n/a	n/a	n/a
AP	SEO	IVMP01	Middle Piney Creek ab Forest Boundary					
AQ	SEO	0410SP01	Midmerrmac	n/a	n/a	n/a	n/a	n/a
AR	SEO	0410NP44	Muir No. 2	n/a	n/a	n/a	n/a	n/a
AS	SEO	0410CC42	Munn	n/a	n/a	n/a	n/a	n/a
AT	SEO	0410NP41	North Piney Canal	n/a	n/a	n/a	n/a	n/a
AU	SEO	0410CC13	Ranchero	n/a	n/a	n/a	n/a	n/a
AV	SEO	0410SP06	Reardon	n/a	n/a	n/a	n/a	n/a
AW	SEO	0410NP39	Red Bluff	n/a	n/a	n/a	n/a	n/a
AX	SEO	0410NP23	S McKay No. 2	n/a	n/a	n/a	n/a	n/a
AY	SEO	0410SP20	South Piney Canal	n/a	n/a	n/a	n/a	n/a
AZ	SEO	0410MP18	South Piney Canal (Middle Piney)	n/a	n/a	n/a	n/a	n/a
BA	SEO	IVSP10	South Piney Creek blw Snider Basin					
BB	SEO	0410CC02	Spencer	n/a	n/a	n/a	n/a	n/a
BC	SEO	0410NP46	Vermillion	n/a	n/a	n/a	n/a	n/a

Mean daily discharge data were obtained from three long established USGS stream gauging stations in the basin including the Green River near La Barge (USGS site 9209400) with a 41 year period of record, the Green River at Warren Bridge (USGS site 9188500) with a 72 year period of record, and Fontenelle Creek near Herschler Ranch (USGS site 9210500) with a 53 year period of record. Figure 3.4.4.2.2 depicts mean daily discharge data with 80% and 20% values recorded at these locations. The hydrographs depict the typical timing and magnitude of flows within the upper and lower mainstem Green River and the tributary system. Elevated flows typically occur for about a three month period spanning from May to July during spring snowmelt, declining flows are typical of the late summer, and base flows occur for about a 4-5 month period during the winter months.



Upper Green River Watershed

Figure: 3.4.4.2.1
Stream Flow
Gauging Stations

Projection: NAD 83 - UTM Zone 12

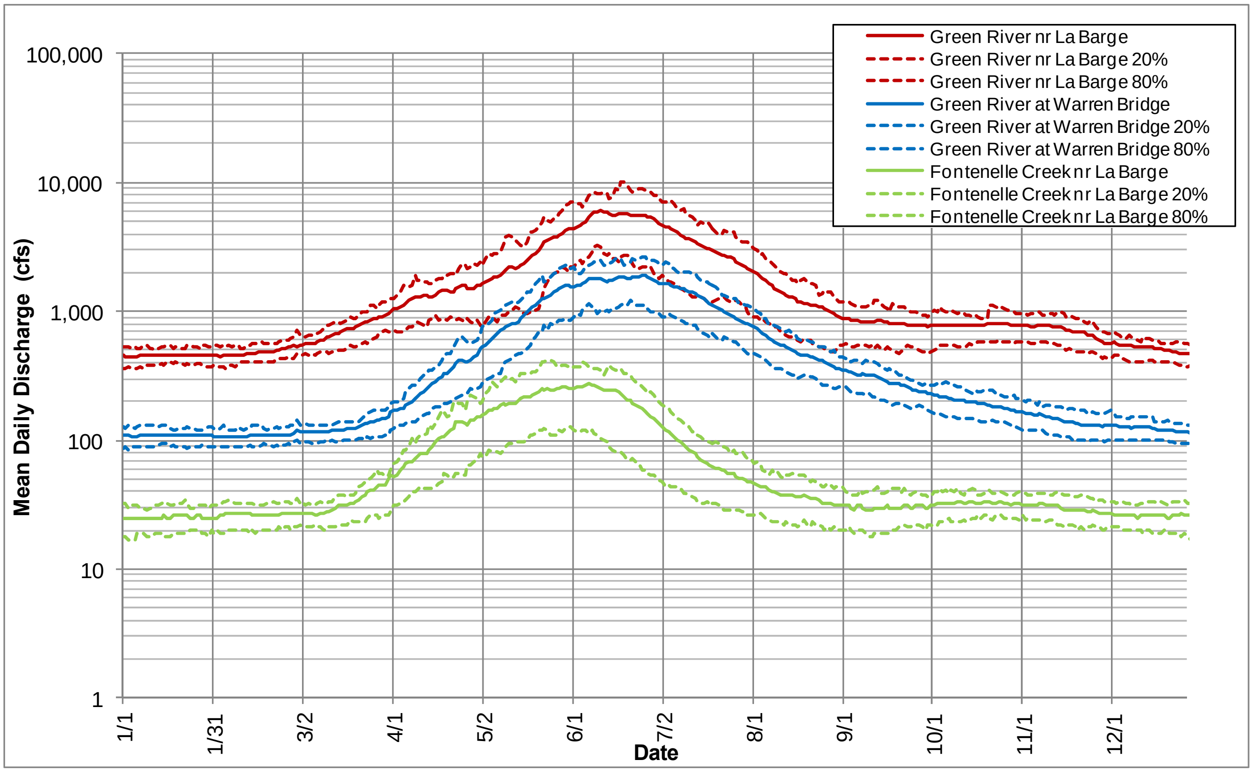


Figure 3.4.4.2.2. Mean daily discharge values with 80% and 20% values from 3 USGS gauging stations with long period of record in the Upper Green River Watershed.

Figure 3.4.4.2.3 depicts mean daily discharge flow duration curves developed from recorded flow data at the three gauging station locations. Flow duration curves from the upper and lower mainstem Green River and the tributary basin have similar slopes, reflective of the flashy snow-melt driven hydrologic regime in the basin. At all three locations, the 50 percent exceedance discharge is about 4% of the recorded peak mean daily discharge, and the 100% exceedance discharge is less than 1% of the recorded peak.

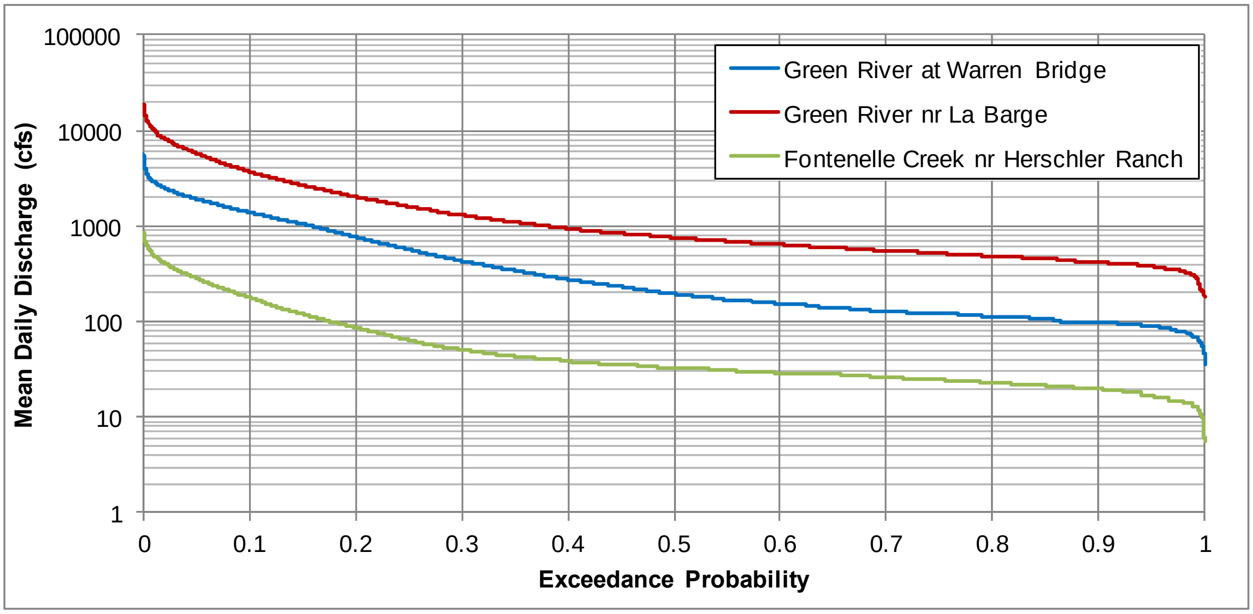


Figure 3.4.4.2.3. Mean daily discharge flow duration curves developed from USGS flow data recorded at three gauging stations with long period of record in the Upper Green River Watershed.

3.4.4.3 TEMPORARY STREAM GAUGING STATIONS

Temporary stream flow gauging stations were established to investigate the movement of surface water resources through the watershed study area and to investigate previously utilized correlations between ungauged and gauged stream reaches in which gauges have subsequently been deactivated. A new gauge site was established in the mainstem of the Green River upstream of the New Fork confluence. Temporary gauges were also established at locations approximating historic USGS gauge locations in Beaver Creek, Cottonwood Creek, and Horse Creek.

Temporary stream flow gauging stations were equipped with permanent elevation benchmarks located on the floodplain, a staff plate, and a pressure transducer data logger (manufactured by Schlumberger) set to record stage at 15-minute intervals throughout the deployment period. Gauge sites were placed in single thread channel reaches with stable channel morphology appropriate to maintain a relationship between stage and discharge at all anticipated discharge rates.

The Green River mainstem and Cottonwood Creek gauges were established in November of 2012 as soon as landowner permissions could be obtained. The Beaver Creek and Horse Creek gauges were established in April of 2013, after the project sponsor was successful in reaching landowners and securing authorization for site access.

Discharge measurements were performed at all gauging stations using a Marsh-McBirney digital conductance flow meter and a top-set wading rod in accordance with established protocols (i.e., USGS Techniques of Water-Resources Investigations Book 3 Applications of Hydraulics; USGS Water Supply Paper 2175 by Rantz, 1982). Multiple discharge measurements were performed at each gauging station location across the range of flow rates experienced during the study period. Site-specific stage-discharge correlations were developed from measured discharge and stage data. In addition, channel surveys were conducted at all gauging station locations in order to quantify local channel slope, sinuosity, staff plate elevation, local floodplain elevation, and the geometry of the controlling channel section. Survey data were subsequently used in conjunction with measured channel roughness (Manning's n-value) and open channel flow equations to calculate discharge at moderate to high stages. Calculated hydraulic conditions were utilized to further assess stage-discharge correlations, and to bolster the middle and upper portions of the stage-discharge rating curves. Figure 3.4.4.3 shows the relative location of the temporary gauge locaitons.

Figure 3.4.4.3 General Temporary Gauge Locations

Green River Mainstem

A gauging station was established in the Green River mainstem upstream of the confluence with the New Fork River (42.56855960 N, 109.9513970 W). The staff plate and local elevation benchmarks were established in November of 2012 and an instantaneous discharge of 180.6 cfs was measured. However, the gauging station was not activated at that time due to freezing conditions that could damage computerized hardware and because prevalent shore and anchor ice were altering local hydraulic conditions (i.e. the relationship between stage and discharge). The site was equipped with pressure transducer and data logger on April 23, 2013 and was operated until August 8, 2013. Figure 3.4.4.3.1 depicts the instantaneous discharge (15-minute interval), the mean daily discharge, and the cumulative conveyance based upon 2013 data recorded at the site. The instantaneous peak discharge is 1,173 cfs and the peak mean daily discharge is 1,156 cfs. During the 2013 study period from April 23 to August 8, the location conveyed approximately 105,397 ac-ft of water.

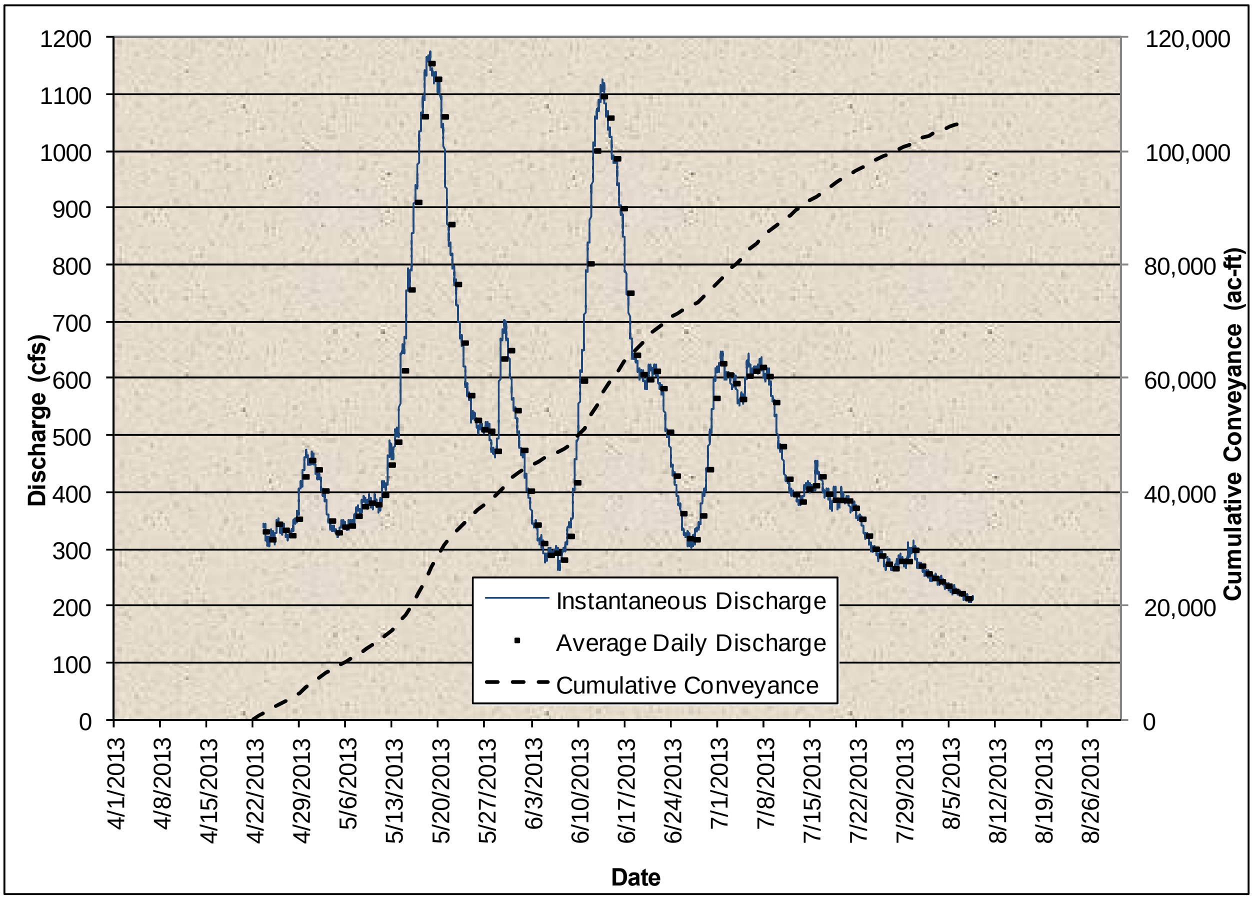


Figure 3.4.4.3.1. Instantaneous discharge, mean daily discharge, and cumulative conveyance at Green River mainstem gauging station, Sublette County, Wyoming.

Beaver Creek

A gauging station was established in Beaver Creek downstream of the confluence of the South and North forks (43.00257123 N, 110.1388433 W), at the approximate location of a historical USGS gauging station. Hardware or benchmarks from the historical gauging station operations could not be located in the field, so the temporary gauging station was established in a single channel reach with stable morphology. The gauging station was established and activated on April 26, 2013 and was operated continuously until August 8, 2013. Figure 3.4.4.3.2 depicts the instantaneous discharge (15-minute interval), the mean daily discharge, and the cumulative conveyance based upon 2013 data recorded at the site. The instantaneous peak discharge is 175 cfs and the peak mean daily discharge is 138 cfs. During the 2013 study period from April 26 to August 8, the location conveyed approximately 3,135 ac-ft of water.

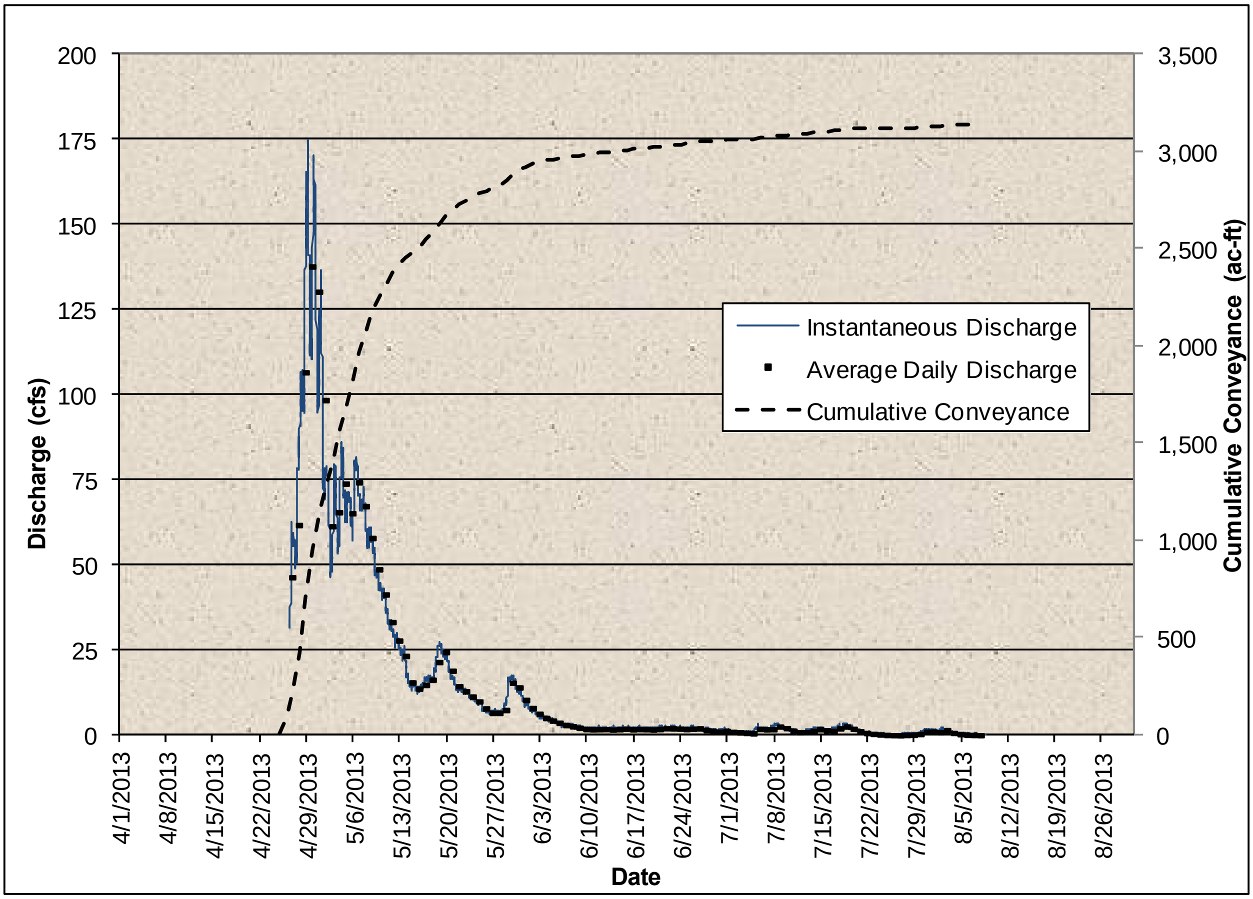


Figure 3.4.4.3.2. Instantaneous discharge, mean daily discharge, and cumulative conveyance at the Beaver Creek gauging station, Sublette County, Wyoming.

Horse Creek

A gauging station was established in Horse Creek downstream of the confluence of North and South Horse Creeks (42.9246888 N, 110.1858028 W), about 0.5 miles downstream of the location of a historical USGS gauging station. The historical gauging station hardware had been removed and private land access could not be obtained for the historical site, so the temporary gauging station was established as a new site in a single channel reach with stable morphology. The gauging station was established and activated on April 26, 2013 and was operated continuously until August 8, 2013. Figure 3.4.4.3.3 depicts the instantaneous discharge (15-minute interval), the mean daily discharge, and the cumulative conveyance based upon 2013 data recorded at the site. The instantaneous peak discharge is 455 cfs and the peak mean daily discharge is 400 cfs. During the 2013 study period from April 26 to August 8, the location conveyed approximately 15,342 ac-ft of water.

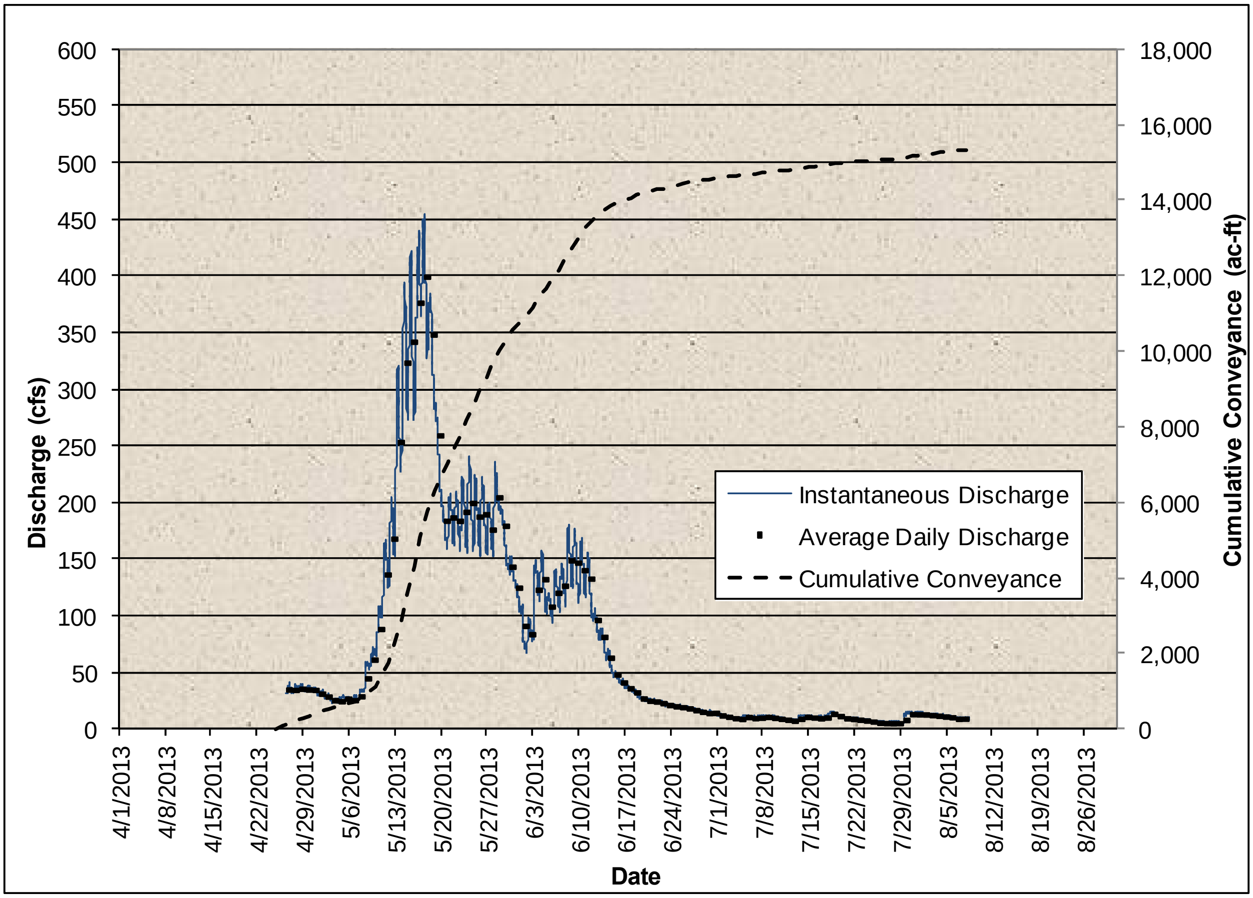


Figure 3.4.4.3.3. Instantaneous discharge, mean daily discharge, and cumulative conveyance at the Horse Creek gauging station, Sublette County, Wyoming.

Cottonwood Creek

A gauging station was established in Cottonwood Creek downstream of the confluence of North and South Cottonwood Creeks (42.77652402 N, 110.1578983 W), at the approximate location of a historical USGS gauging station. Hardware or benchmarks from the historical gauging station operations could not be located in the field, so the temporary gauging station was established in a single channel reach with stable morphology. The staff plate and local elevation benchmarks were established in November of 2012 and an instantaneous discharge of 22.2 cfs was measured. However, the gauging station was not activated at that time due to freezing conditions that could damage computerized hardware and because prevalent shore and anchor ice were altering local hydraulic conditions (i.e. the relationship between stage and discharge). The site was equipped with pressure transducer and data logger on April 23, 2013 and was operated until August 8, 2013. Figure 3.4.4.3-4 depicts the instantaneous discharge (15-minute interval), the mean daily discharge, and the cumulative conveyance based upon 2013 data recorded at the site. The instantaneous peak discharge is 124 cfs and the peak mean daily discharge is 105 cfs. During the 2013 study period from April 23 to August 8, the location conveyed approximately 6,933 ac-ft of water.

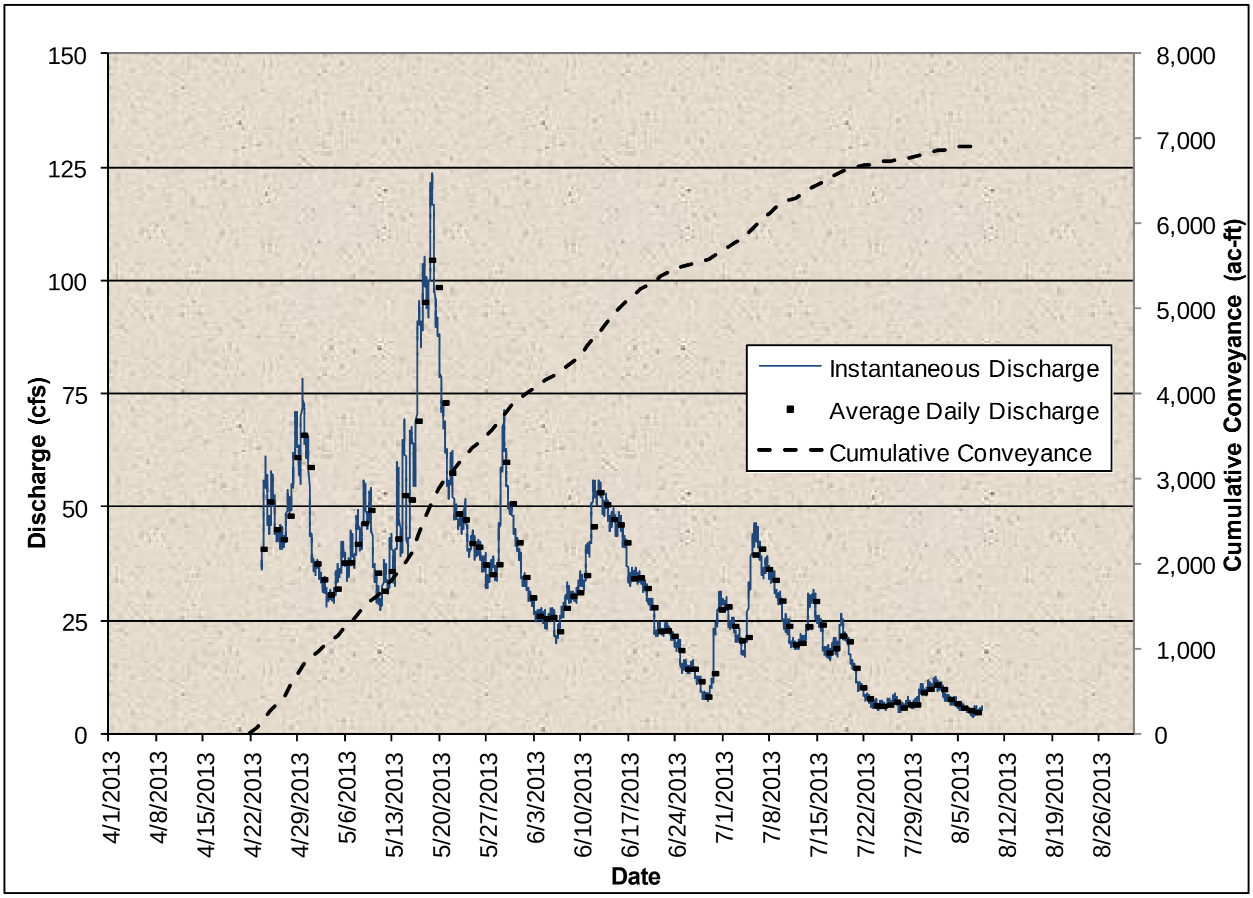


Figure 3.4.4.3.4. Instantaneous discharge, mean daily discharge, and cumulative conveyance at the Cottonwood Creek gauging station, Sublette County, Wyoming.

Conclusion

Analysis of recorded flow data from the US Geological Survey Green River stream gauging station near La Barge (#9209400) indicates that 2013 was a relatively dry year. Mean daily discharge data from the entire period of record (1964-present) were obtained from the site. Data were used to rank water years by percentile based upon the mean daily discharge for the study period (April 26 to August 8). The median year from the period of record has a mean daily discharge of 3,191 cfs. The mean daily discharge during the 2013 study period is 1,383 cfs, which corresponds to approximately the 10th percentile year from the period of record. Figure 3.4.4.3.5 depicts the cumulative conveyance at the USGS Green River near La Barge gauging station during 1996 which represents a wet year (D80), during 2000 which represents a dry year (D20), during 1968 which represents the median year (D50), and during the 2013 study period. The cumulative water conveyance in 2013 is 287,423 ac-ft, which is approximately 43% of that conveyed during the median water year. Analysis indicates that mean daily discharge and cumulative water conveyance recorded at the temporary stream gauging locations during the 2013 study period reflect conditions during a dry year (10th percentile), and likely represent approximately 43% of a normal, or median, water year.

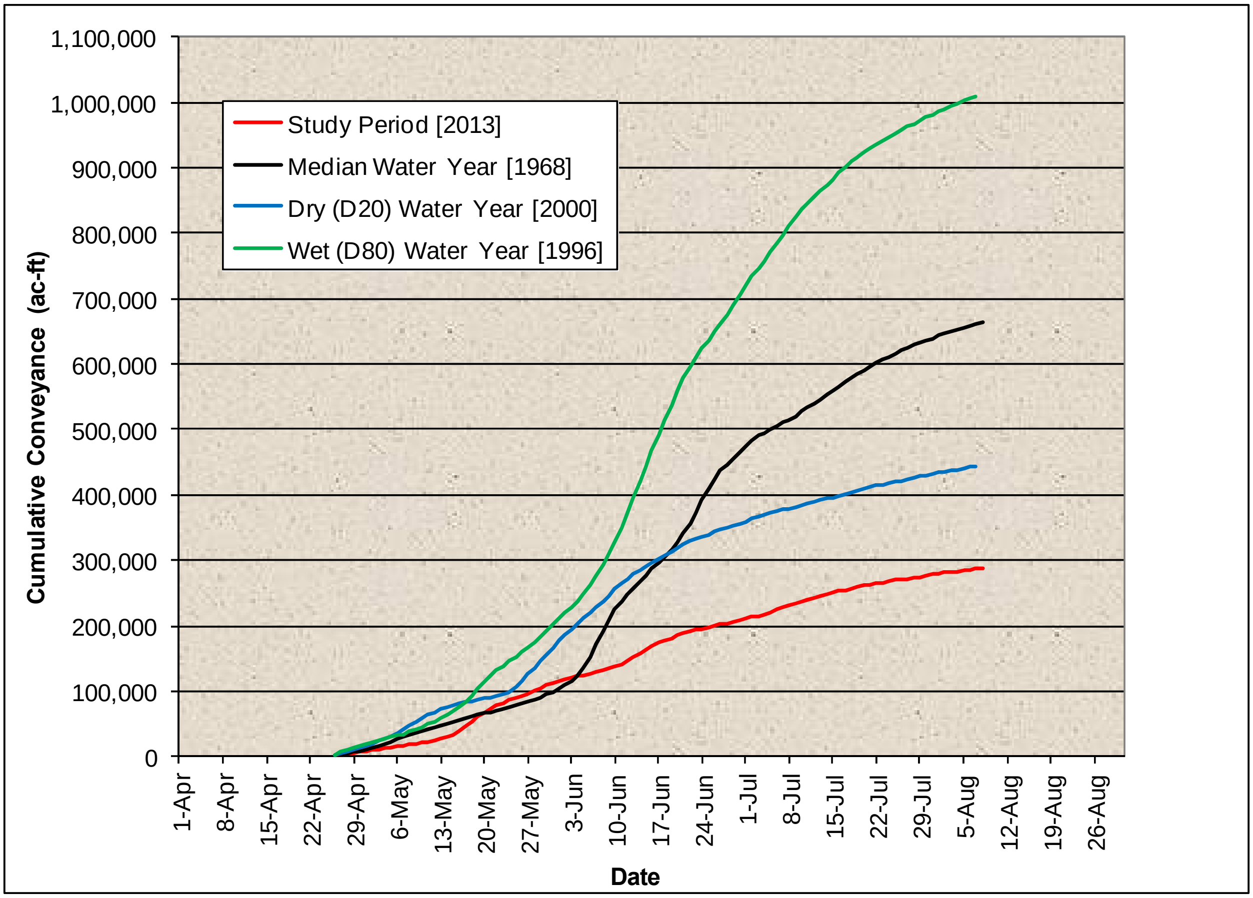


Figure 3.4.4.3.5. Cumulative conveyance at the USGS Green River near La Barge gauging station (9209400), Upper Green River Basin, Wyoming.

3.4.4.4 STATE MOD MODELING

A number of hydrological models have been developed for the Upper Green River basin. A Basin Plan spreadsheet model for the entire Green River basin within Wyoming was developed in 2001. The Basin Plan spreadsheet model was updated in 2010. The spreadsheet models have been used to estimate available flow over one year, on a monthly time step. Three spreadsheet models have been developed – one each for a representative wet, dry, and average hydrologic year.

A StateMod format model was originally developed for the Green River Basin above Fontenelle Reservoir to support the Upper Green River Level II Storage Study Model (Kleinfelder, 2005). Representation of the Piney Creek tributary basin was refined to support the Upper Green River Level II Westside Storage Study Model (Short Elliott Hendrickson, 2007). The geographic extent of the Upper Green StateMod model was extended down to the Town of Green River to support the 2009 planning effort by WWC Engineering and AECOM. The 2007 and 2009 models both represented a 1971 through 2006 study period.

A StateMod format model of the Upper Green River Basin was enhanced for the Watershed Study. An historical data set was developed over the 1971 through 2011 using a monthly time step. Natural flows were developed based on historical streamflows, diversions and reservoir contents over the 41-year study period. Unlike the spreadsheet models, the StateMod model distributes water to meet demands per Wyoming Water Law, based on the natural flows and user input water rights. The hydrologic model is described in detail in Appendix F.

Although the geographic focus of the Watershed Study is the Upper Green River basin (excluding the New Fork River), the 2007 StateMod model and 2009 StateMod model were combined to develop one complete StateMod format model for use in the Watershed Study. Figure 3.4.4.4.1 Green River Model Network Diagram shows the network diagram for the Green River Model. It includes 126 nodes that represent the study area, including stream gages, diversion nodes, reservoir nodes and instream flow nodes.

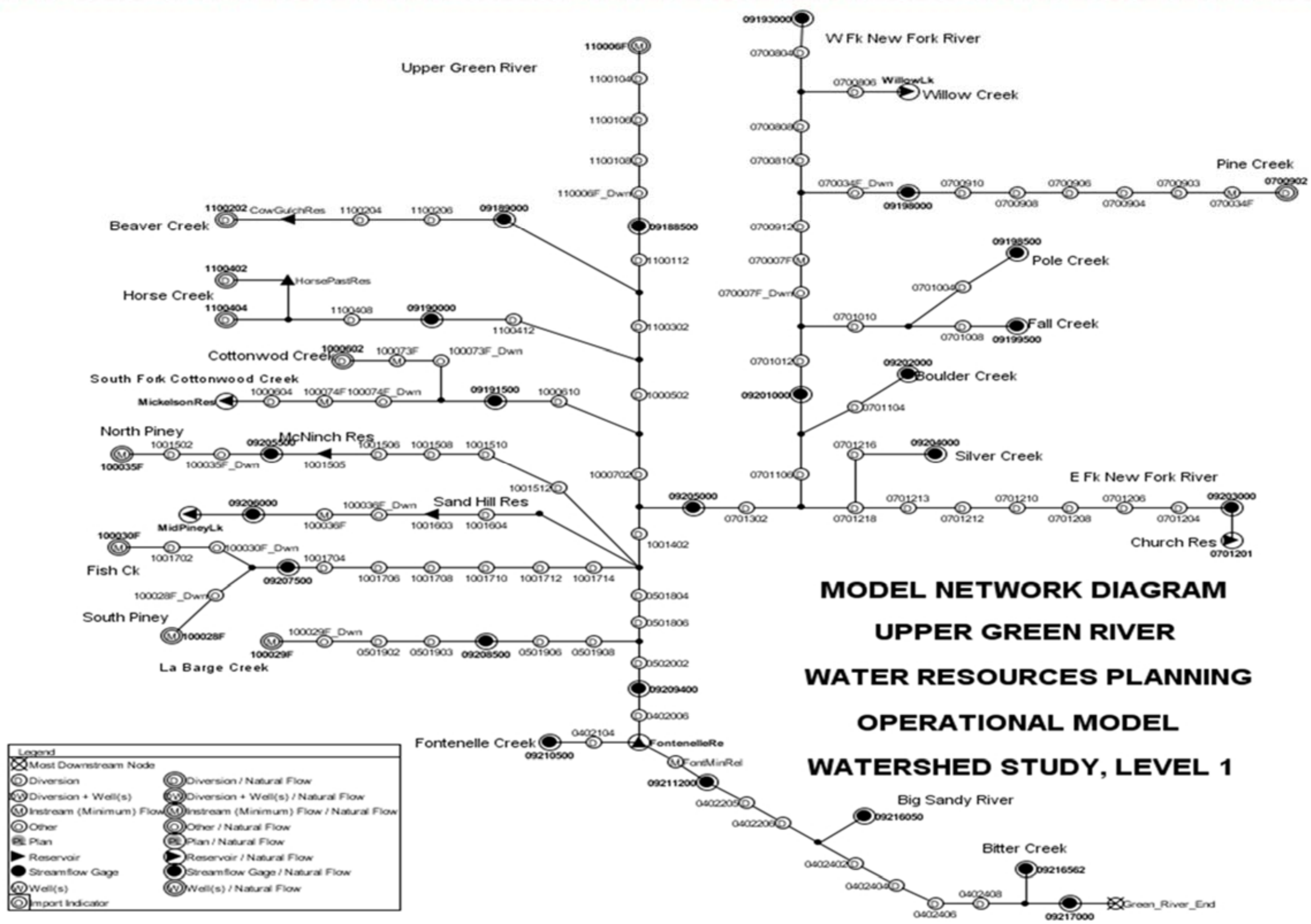


Figure 3.4.4.4.1 Green River Model Network Diagram

A Baseline data set was prepared that simulates existing water resources systems online and operational for 1971 through present. The Baseline data set simulation results represent the Baseline shortages to current irrigation demands and the availability of water for junior water rights.

Table 3.4.4.4 summarizes the average annual shortage for water years 1971 through 2011, by Water District over the entire model network, including municipal and industrial structures.

Table 3.4.4.4 Average Annual Demands and Simulated Diversions by Water District (1971 – 2011) Baseline Run (ac-ft/yr)

Water District	Demand	Simulated Diversion	Shortage (Demand – Diversion)	
			Volume	Percent
WD 4 – Below Fontenelle Reservoir	71,056	69,337	1,720	2%
WD 5 – Below Piney Creek to Fontenelle	44,311	42,238	2,072	5%
WD 7 – New Fork River	229,739	196,994	32,745	14%
WD 10 – Cottonwood Creek to below	298,090	219,606	78,485	26%
WD 11 – Above Cottonwood Creek	179,636	159,564	20,072	11%
Basin Total	822,831	687,739	135,093	16%

The monthly shortages within sections of the Green River main stem and the various tributaries over the study period are illustrated in Figures 3.4.4.4.2 through 3.4.4.4.9. Also represented in the figures is the amount of Available Flow – the portion of the physical flow that is available for diversion after all other rights in the model are simulated. The figures provide some insight into the frequency and magnitude of shortages and available flows in different areas within the basin over wet, dry and average hydrologic years. The following link connects the user with the WWDC 2010 Green River Basin Spreadsheet models:
http://waterplan.state.wy.us/plan/green/2010/models/models.html

Refer to Section VI. Water Supply and Storage Opportunities for more information regarding water supply and storage.

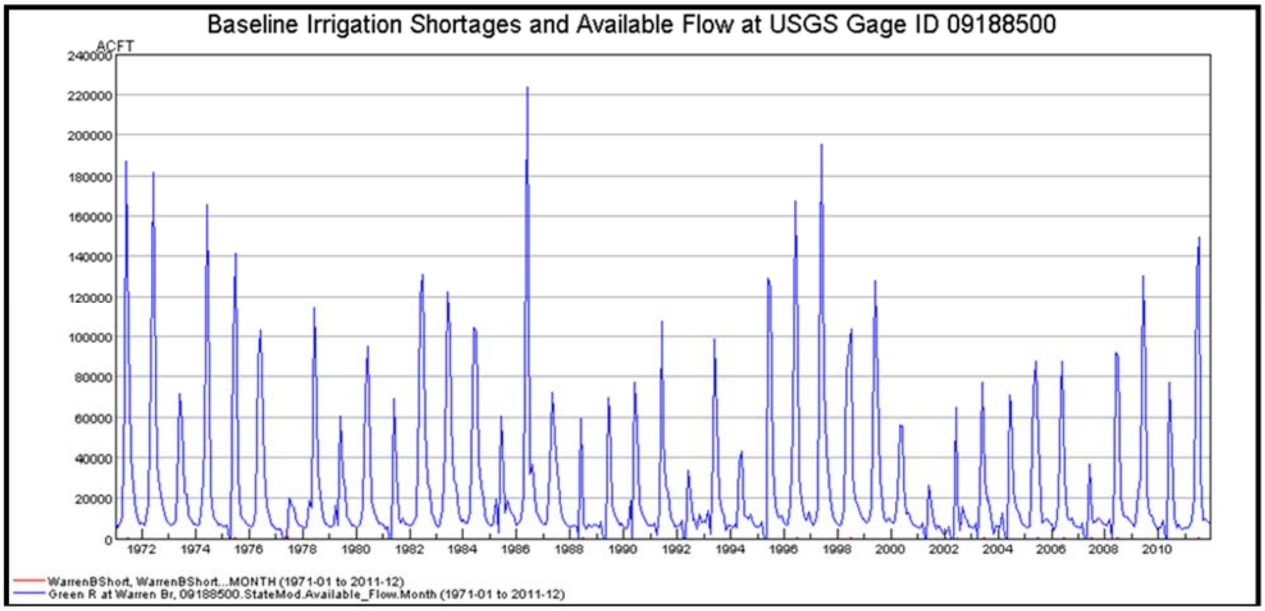


Figure 3.4.4.4.2 Baseline and Available Flow – Green River at Warren Bridge

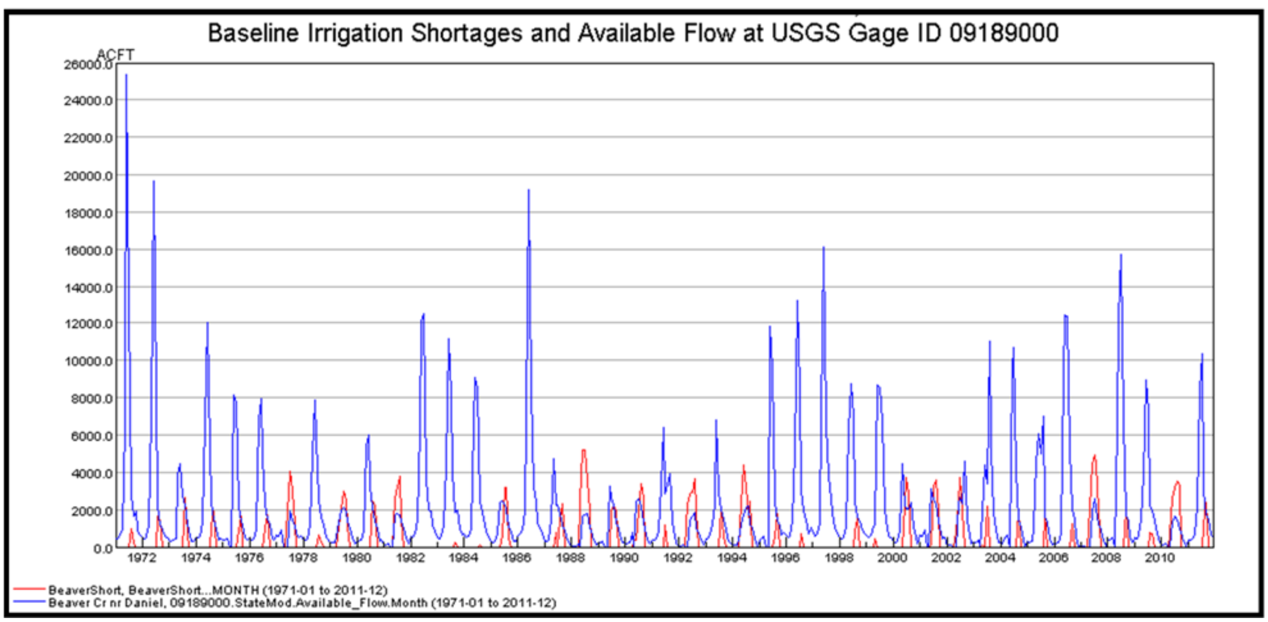


Figure 3.4.4.4.3 Baseline and Available Flow – Beaver Creek near Daniel

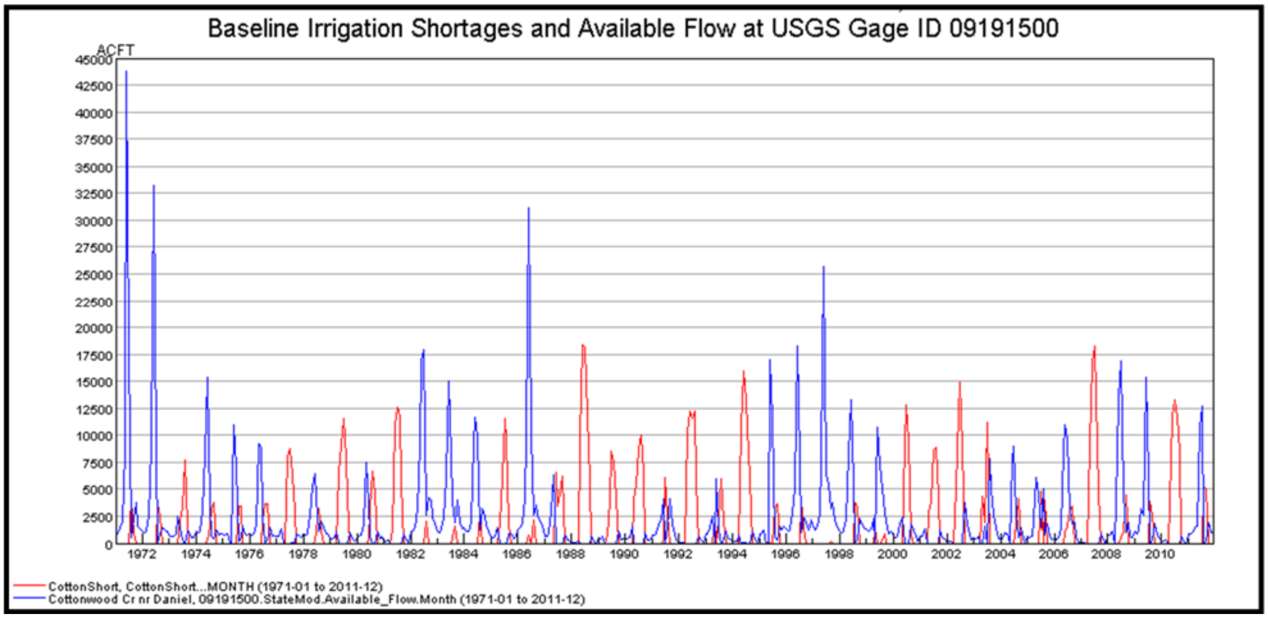


Figure 3.4.4.4.4 Baseline and Available Flow – Cottonwood Creek near Daniel

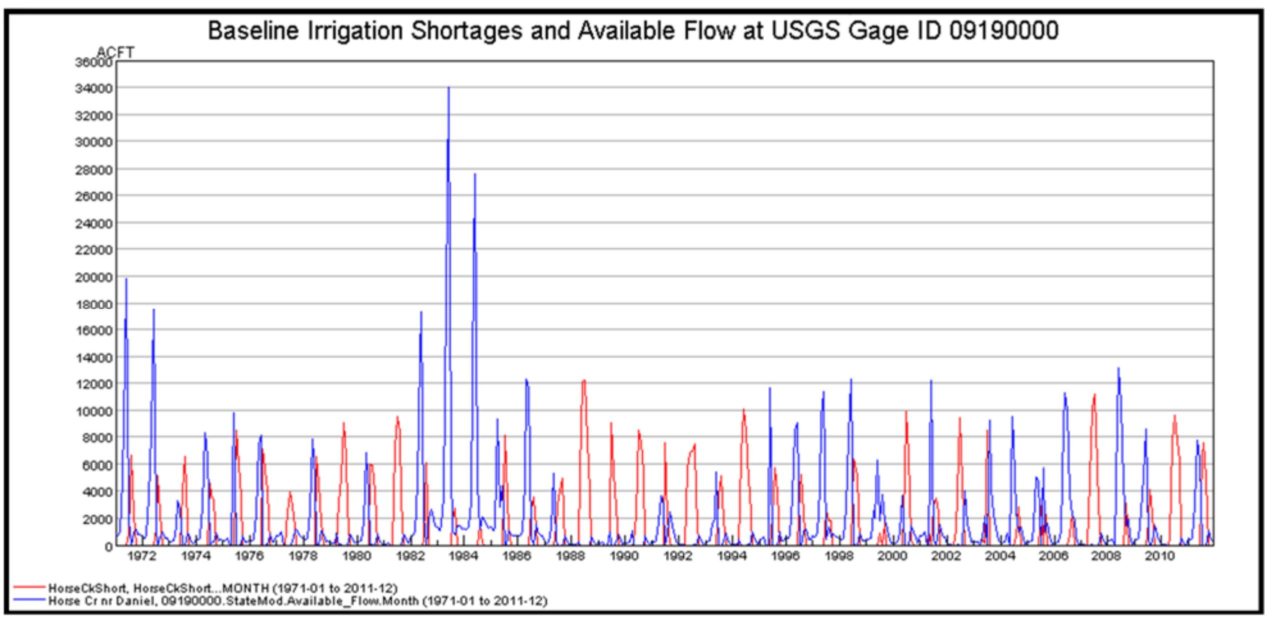


Figure 3.4.4.4.5 Baseline and Available Flow – Horse Creek near Daniel

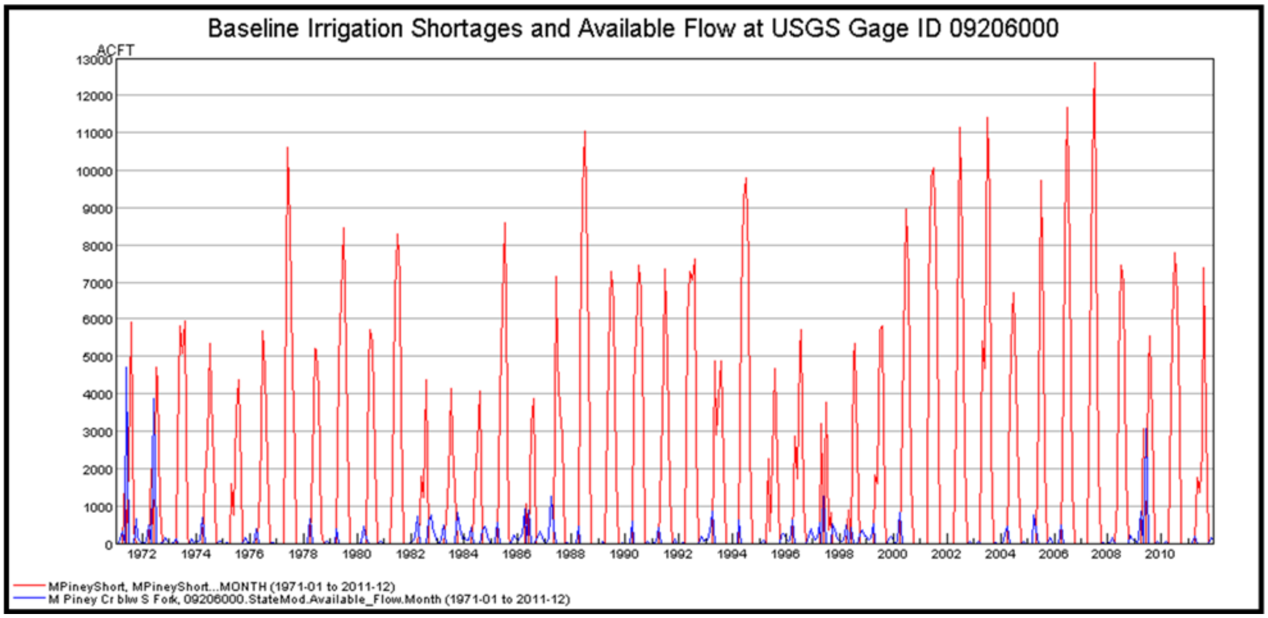


Figure 3.4.4.4.6 Baseline and Available Flow – Middle Piney Creek below South Fork

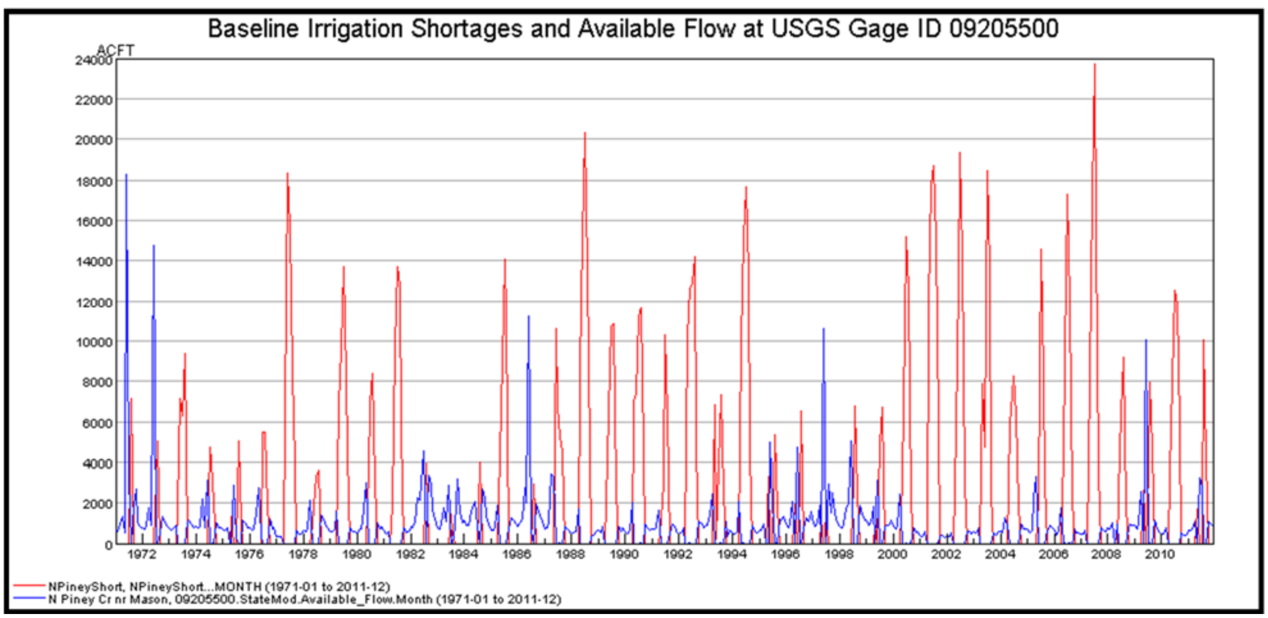


Figure 3.4.4.4.7 Baseline and Available Flow – North Piney Creek near Mason

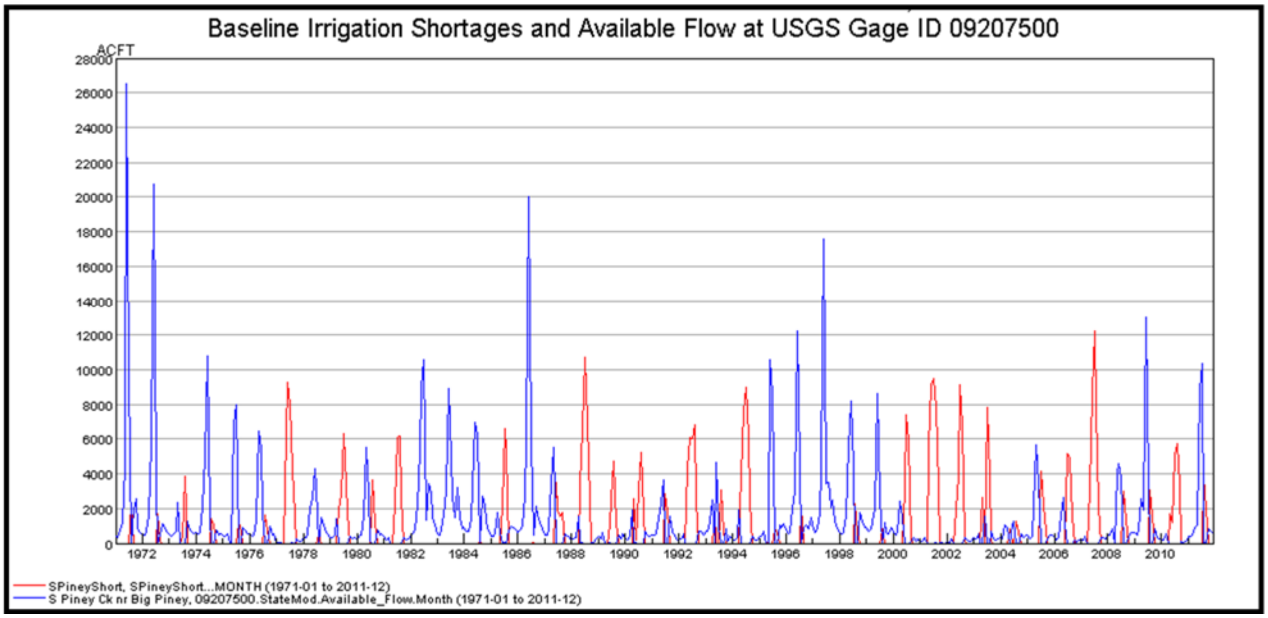


Figure 3.4.4.4.8 Baseline and Available Flow – South Piney Creek near Big Piney

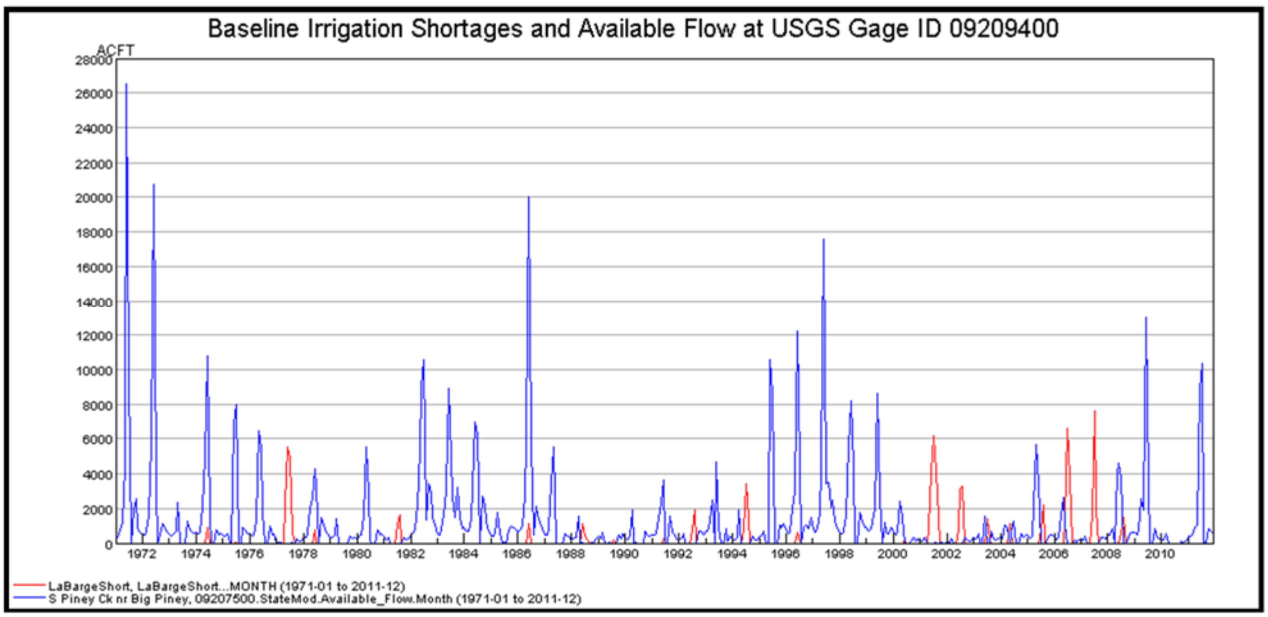


Figure 3.4.4.4.9 Baseline and Available Flow – Green River near LaBarge

3.4.4.5 EXISTING STORAGE FACILITIES

Within the Upper Green River watershed study area the benefits of storage have long been recognized. The benefits of storage take on national significance as in the case of Fontenelle

Reservoir. Several smaller storage facilities exist in the basin having local significance and benefit. Existing storage sites within the Upper Green River watershed study area are listed in Table 3.4.4.5.

Table 3.4.4.5 Existing Reservoirs in Upper Green Watershed

Reservoir Site Name	Water Course	County	Sec.	Twn.	Rng.	Pemit No.	Priority Date	Permitted Uses	HWL Area (Ac)	HWL Capacity (AF)	Reservoir Owner/Manager	Year of Cert. of Construction	Notes
Middle Piney	Middle Piney Creek	Sublette	8	30	115	3578R	7/4/1919	I, S, D	164.56	4,201	USDA Forest Service	1944	
McNinch No. 1	Spring Creek	Sublette	11	30	113	5413R	3/5/1941	I, S, D	108.2	873	E.W. McNinch and Louis C. McNinch	1956	Total Cap = 1086.35 AF.
						5801R	7/17/1947	I, S, D	107.04	213.35		1956	
McNinch No. 2	McNinch Draw	Sublette	11	30	113	5412R	3/5/1941	I, S, D	26.4	198	E.W. McNinch and Louis C. McNinch	1957	
Sixty Seven	North Piney Creek	Sublette	17	30	112	535R	7/8/1904	S, D	293.568	3,373.73	Mr. Jay Downes	1935	Total Cap = 4329 AF.
						2778R	7/12/1915	S, D	333	953.268		1935	
Fontenelle Reservoir	Green River	Lincoln	25	24	112	6629R	1/22/1962	I, D, Ind, M, S, H, Fl, R	8,058	345,397	USBR	1992	Enlargement activated previously inactive cap.
						9502R	12/7/1973	I, D, Ind, M, S, H, Fl, R	No Change	No Change			

From the 2010 Green River Basin Plan II, a Technical Memorandum "Major Reservoir Information" describes the existing sites as follows:

Middle Piney: *"Middle Piney Lake is located on the headwaters of Middle Piney Creek in the Bridger National Forest. It is situated about 15 miles due west of the McNinch reservoirs. The reservoir contains 4,201 AF of storage permitted for irritation, stock and domestic uses. In 1997, the interest in the reservoir was assigned to the USDA Forest Service. Currently the reservoir is operated with outlet gates fully open, essentially passing water through the reservoir."* The State of Wyoming, WWDC is currently working with USFS to rehabilitate the Middle Piney dam and provide utility to irrigators on Middle Piney Creek.

McNinch No. 1 & McNinch No. 2: *"The McNinch reservoirs are private impoundments located on McNinch Wash, tributary to North Piney Creek. They are situated about one mile west of Sixty Seven Reservoir. McNinch No. 1 is fed by Beaver Creek and Spring Creek, both tributary to North Piney Creek. McNinch No. 2 is fed by McNinch Wash (McNinch Draw). Capacities are 1,086 AF for No. 1 and 198 for No. 2. Both reservoirs are permitted for irrigation, stock and domestic uses."*

Sixty Seven: *"This reservoir is an off-channel structure fed by the Hughes Ditch from North Piney Creek and from Spring Creek, a tributary of North Piney Creek. As enlarged, the reservoir stores 4,329 AF for irrigation, stock and domestic purposes. The reservoir is located about 6 miles northwest of the Town of Big Piney."*

Fontenelle Reservoir: *"Another Bureau of Reclamation project, Fontenelle Reservoir is an earthen dam on the main stem of the Green River, located just downstream of the Town of LaBarge. With a storage capacity of 345,397 AF, Fontenelle is a multi-purpose project with permitted uses that include irrigation, domestic, industrial, municipal, stock, fisheries, recreation and hydropower."* Additional information is available from the USBR at www.usbr.gov.,http://www.usbr.gov/projects/Project.jsp?proj_Name=Seedskadee%20Project, & http://waterplan.state.wy.us/plan/green/2010/finalrept/fontenelle.html. The memorandum at this State site additionally mentions the four contracts the State of Wyoming presently has with regard to Fontenelle Reservoir: Pacificorp – 35,000 acre-feet for cooling water at Jim Bridger, FS Industries – 10,000 acre-feet for fertilizer production at Rock Springs, Arm and Hammer Baking Soda – 1,250 acre-feet for production near Green River and Exxon for domestic and production purposes at their Shute Creek Plant.

The full storage memorandum from the 2010 Green River Basin Plan II can be found in Appendix G. This memorandum contains additional detail for each site such as area/capacity tables, evaporation, and operating notes.

3.4.4.6 GROUNDWATER

The Upper Green River Watershed study area is an arid region and groundwater conditions are highly variable due to variable geologic and hydrogeologic conditions. However, groundwater is generally either the primary or secondary source for sustaining human activity in the basin. Groundwater conditions reflect geologic setting within the basin. The basin topography follows undulations on the Precambrian basement surface formed by shifts and adjustments of the earth's crust. There is a structural depression proximate to Pinedale where the Precambrian basement is deeper than 35,000 feet below land surface. The trend along the deepest part of the Green River Basin is northwest-to-southeast, approximately parallel to the Wind River Range.

Alluvial aquifers, generally considered unconfined aquifers, are typically close to the land surface and include continuous layers of permeable material. Proximate to the land surface, alluvial aquifers are relatively vulnerable to anthropogenic influence and impacts. These aquifers consist primarily of river, floodplain, and terrace deposits that border major river systems, and these aquifers are composed primarily of sand, silt, and gravel on top of a bedrock foundation. Alluvial aquifers range in thickness from 10 to 100 feet or more, and water in the valley-fill sediments of alluvial aquifers is typically suitable for most purposes.

Structural basin aquifers are typically surrounded by mountain ranges with steep sediment outcrops on their slopes. In these conditions, hydrologic units often function as regional aquifers. Permeable sandstone, limestone, siltstone, or fractured formations are the geologic formations that comprise structural basin aquifers. Structural basin aquifers are typically less vulnerable to human influence because they are protected by a less permeable layer. Groundwater in these basins can be confined or unconfined, and confined aquifers can discharge water through springs. Section 3.4.2.4 contains additional data and water-yeilding characteristics of the aquifers.

The 2010 Green River Basin Plan Groundwater Report contains additional detailed information. This report can be found at: http://waterplan.state.wy.us/plan/green/2010/finalrept/ gw_toc.html.

A digital dataset generated by the WSGS containing digitized USGS spring location data within the Green River Basin was obtained. The dataset depicts 181 mapped springs within the Upper Green River watershed study area (Figure 3.3.4.2d).

The WYSEO database of permitted wells within the Upper Green River Watershed Study Area was obtained. The database includes well parameters of permit number, priority date, facility name, applicant name, permitted uses, location, appropriation, total depth, static water level, and depth of pump. Most wells in the basin are constructed into the Cenozoic hydrogeologic units (lower Tertiary, upper Tertiary, and Quaternary hydrogeologic units). Some springs with small yields are included in the groundwater-permit database for the basin. The WYSEO identifies a permitted use for each well location. Major categories of permitted uses include coalbed methane, commercial, domestic, industrial, irrigation, municipal, miscellaneous, monitoring/test, and stock water. A total of 1,995 wells are permitted within the Upper Green River basin (Figure 3.3.4.2c), and the primary (first listed) permitted uses are broken down by category in Table 3.4.4.6.1 and Figure 3.4.4.6.1. A total of 65% of all permitted wells in the basin are classified as domestic use, and the second most abundant classification (at 15%) is for stock water.

Table 3.4.4.6.1. Well types within the Upper Green River Watershed Study Area.

Well Type	Quantity
Coalbed Methane (CBM)	10
Commercial (COM)	2
Domestic (DOM)	1,289
Industrial (IND)	40
Irrigation (IRR)	8
Municipal (MUN)	18
Miscellaneous (MIS)	204
Monitor/Observation/Test (MON/TES)	125
Stock (STO)	299

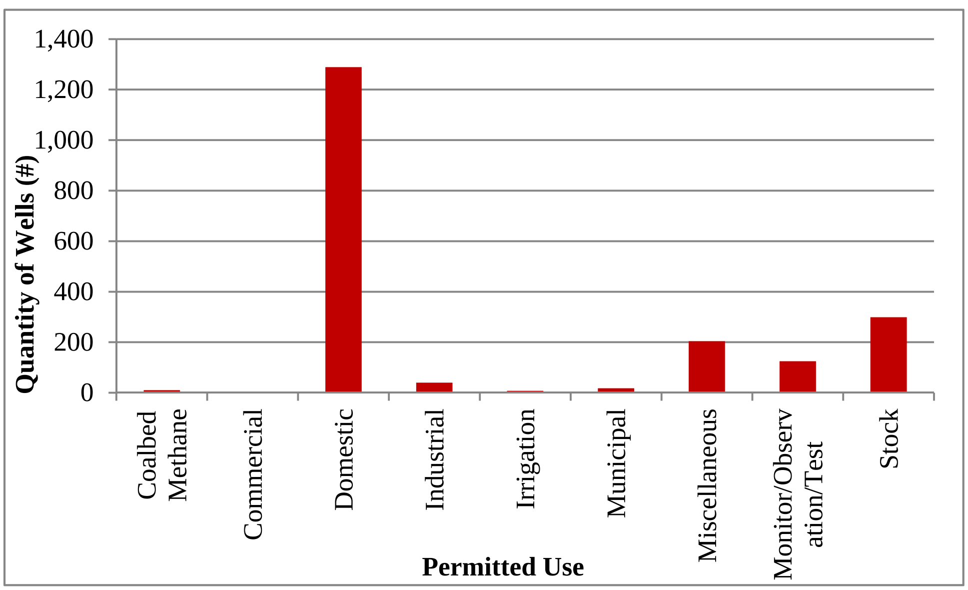


Figure 3.4.4.6.1. Histogram of well types within the Upper Green River Watershed Study Area.

The depths of permitted wells in the Upper Green River Basin are presented in Table 3.4.4.6.2 and Figure 3.4.4.6.2. The majority of wells in the basin (27%) are between 100 and 200 feet deep, and the deepest wells in the basin are more than 4,000 ft deep.

Table 3.4.4.6.2. Well depths within the Upper Green River Watershed Study Area.

Well Depth (ft)	Quantity
0 to 50	298
51 to 100	339
101 to 200	543
201 to 400	229
401 to 600	46
601 to 800	39
801 to 1000	19
1001 to 2000	11
2001 to 3000	4
3001 to 4000	5
>4000	2
No data	460

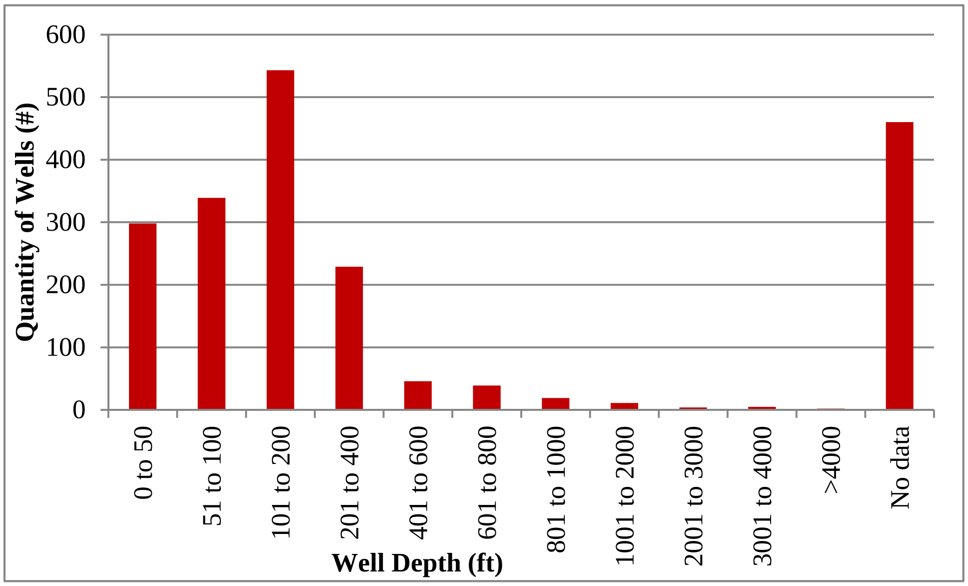


Figure 3.4.4.6.2. Histogram of well depths within the Upper Green River Watershed Study Area.

The static water levels of permitted wells in the Upper Green River Basin are presented in Table 3.4.4.6.3 and Figure 3.4.4.6.3. The majority of wells in the basin (48%) have static water level between 0 and 50 feet deep, and the deepest static water levels are from 1,001 to 2,000 ft deep.

Table 3.4.4.6.3. Static water level depth in permitted wells within the Upper Green River Watershed Study Area.

Static Water Level (ft)	Quantity
0 to 50	961
51 to 100	254
101 to 200	95
201 to 400	46
401 to 600	6
601 to 800	5
801 to 1000	1
1001 to 2000	3
-1 to -10	218
No data	406

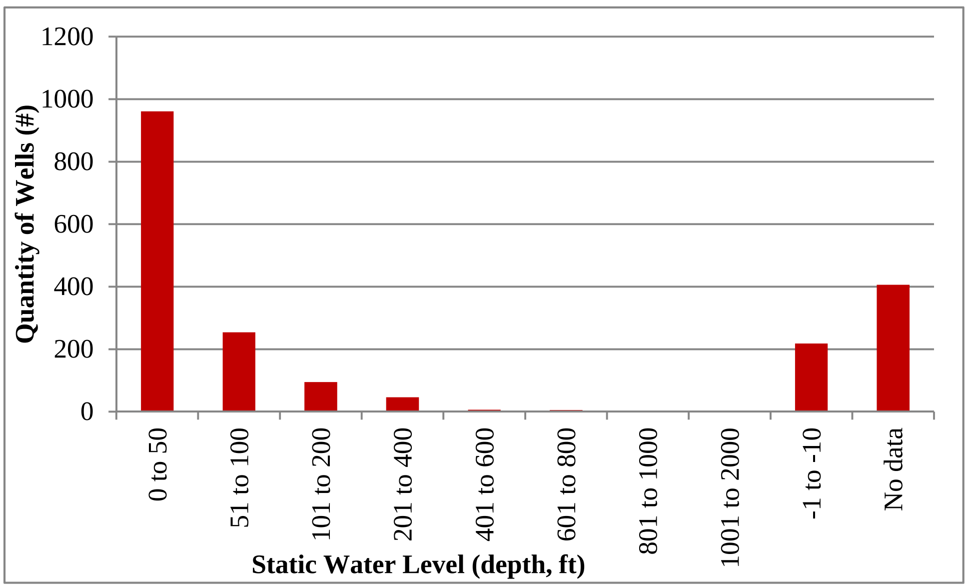


Figure 3.4.4.6.3. Histogram of static water level depths within the Upper Green River Watershed Study Area.

The reported yield of permitted wells in the Upper Green River Basin is presented in Table 3.4.4.6.4 and Figure 3.4.4.6.4. The majority of wells in the basin (46%) have reported yield of less than 5 gpm, but there are 7 high capacity wells that produce more than 200 gpm.

Table 3.4.4.6.4. Reported yield of wells within the Upper Green River Watershed Study Area.

Well Yield (gpm)	Quantity
0 to 5	924
6 to 10	294
11 to 25	660
26 to 50	42
51 to 100	48
101 to 200	20
201 to 500	6
501 to 1000	1

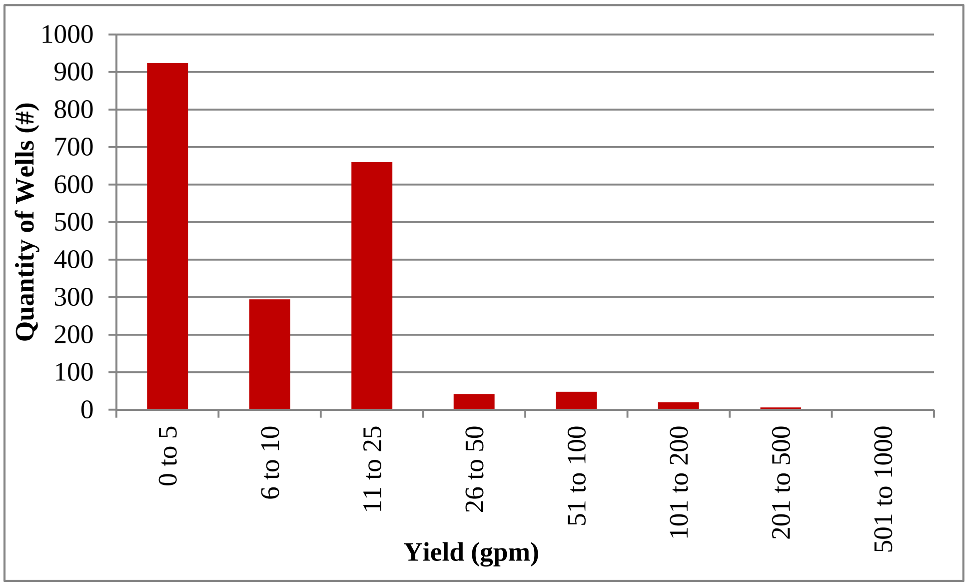


Figure 3.4.4.6.4. Histogram of reported yield of wells within the Upper Green River Watershed Study Area.

3.4.5 FLUVIAL GEOMORPHOLOGY

Fluvial geomorphology is the study of the processes and physical form of riverine systems. Dependent variables such as channel dimension, pattern, and profile are influenced by the riverine system response to independent variables such as hydrologic regime, sediment conditions, and boundary conditions. Stable channel form is achieved when the physical attributes of dependent variables are maintained through time while the stream system conveys hydrologic and sediment inputs. Unstable conditions typically result when independent variables are altered, anthropogencially or naturally, and typically result in sudden changes in channel morphology through aggradation, degradation, lateral migration, or down-cutting.

The objective of the geomorphic classification is to describe channel form in order to better understand channel process. Based upon the concept that channel form reflects process, physical channel parameters are assessed in order to classify channel type, and the interpretation of channel type within the local setting enables further understanding of channel function, stability, and appropriate management approach.

A subset of sites was visited during the 2013 field season, and field assessment of channel morphology at those locations was completed in order to verify the preliminary classification results. Those sites are discussed in Section 3.4.5.1.

3.4.5.1 ROSGEN CLASSIFICATION SYSTEM (METHODS AND RESULTS)

A geomorphic classification was completed of the Green River and all major tributaries in the study area, including Beaver Creek, Cottonwood Creek, Fontenelle Creek, Gypsum Creek, Horse Creek, Klondike Creek, LaBarge Creek, Piney Creek, Rock Creek, and Tosi Creek. Channel geomorphology was described in accordance with the Rosgen Level I classification procedure, which is a broad morphological characterization of channel form based upon landform, lithology, soils, climate, basin relief, valley morphology, and general river pattern (Rosgen, 1994). The typical objective of a Level I classification is to use remote sensing technologies (with some field verification) to describe general valley and fluvial form to enable interpretation of dominant fluvial processes and identification of appropriate management strategies.

A Level I classification of channel types is a broad morphological characterization based upon landform, soils, depositional history, basin relief, valley morphology, and general river pattern. A Level II description is a more thorough morphologic description that incorporates substrate material, local slope, and field measurement of channel parameters. A Level III description incorporates riparian vegetation, depositional patterns, confinement, and channel stability to assess stream condition. A Level IV description requires direct measurement of sediment transport, bank erosion, and hydraulic conditions in order to verify classification results. A figure depicting the heierarchy of the Rosgen classification system levels is presented in Figure 3.4.5.1.3. A Level I geomorphic classification was completed during this study; the higher level classifications require thorough field investigations that are beyond the scope of this watershed assessment. The Rosgen Level I channel classification describes channel form in 8 general categories referred to by alphabetical identifiers A, G, F, B, E, C, D, and Da, as presented in Figure 3.4.5.1.3a (NRCS 2007).

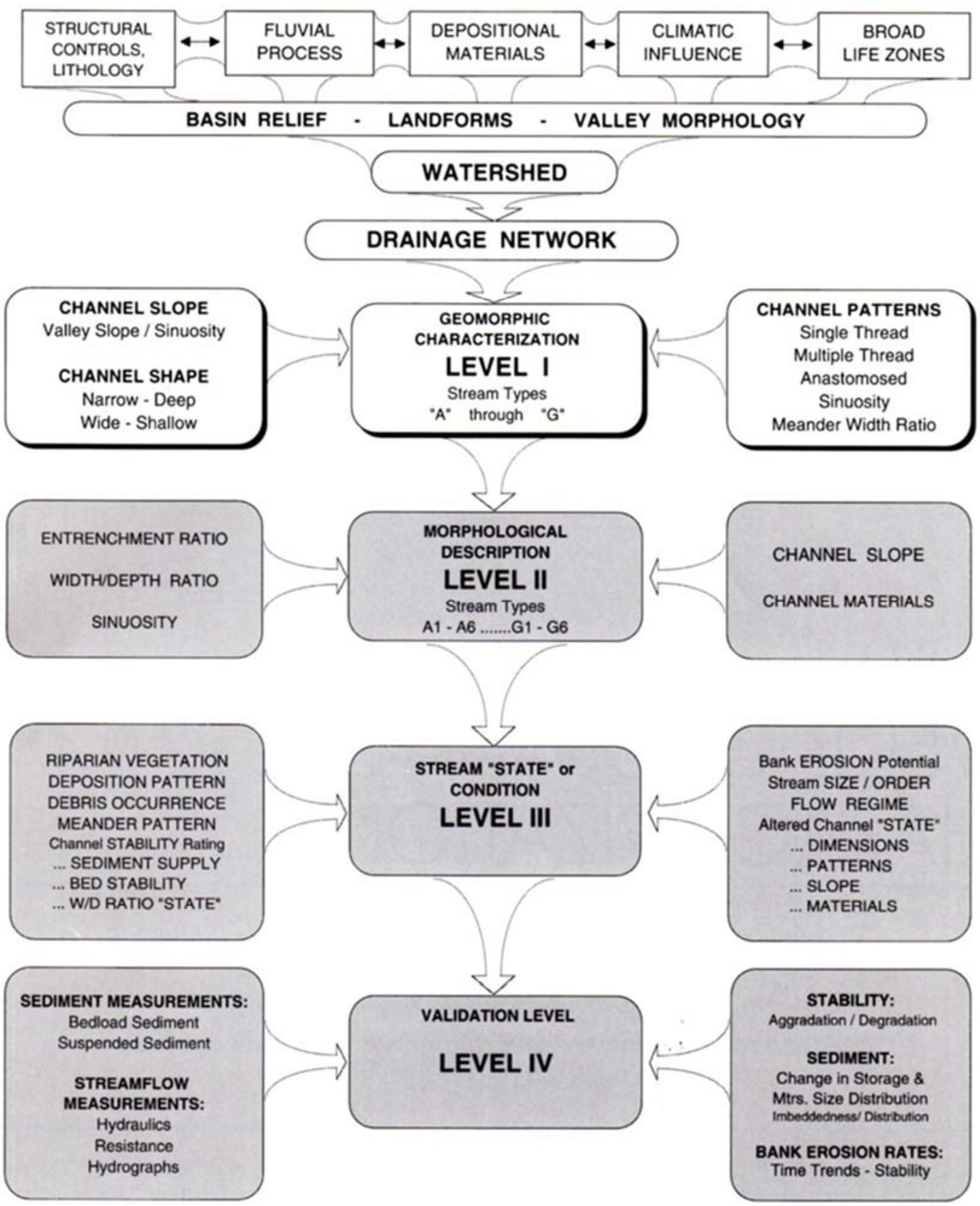


Figure 3.4.5.1.3 Schematic of the levels of Rosgen geomorphic channel classification.

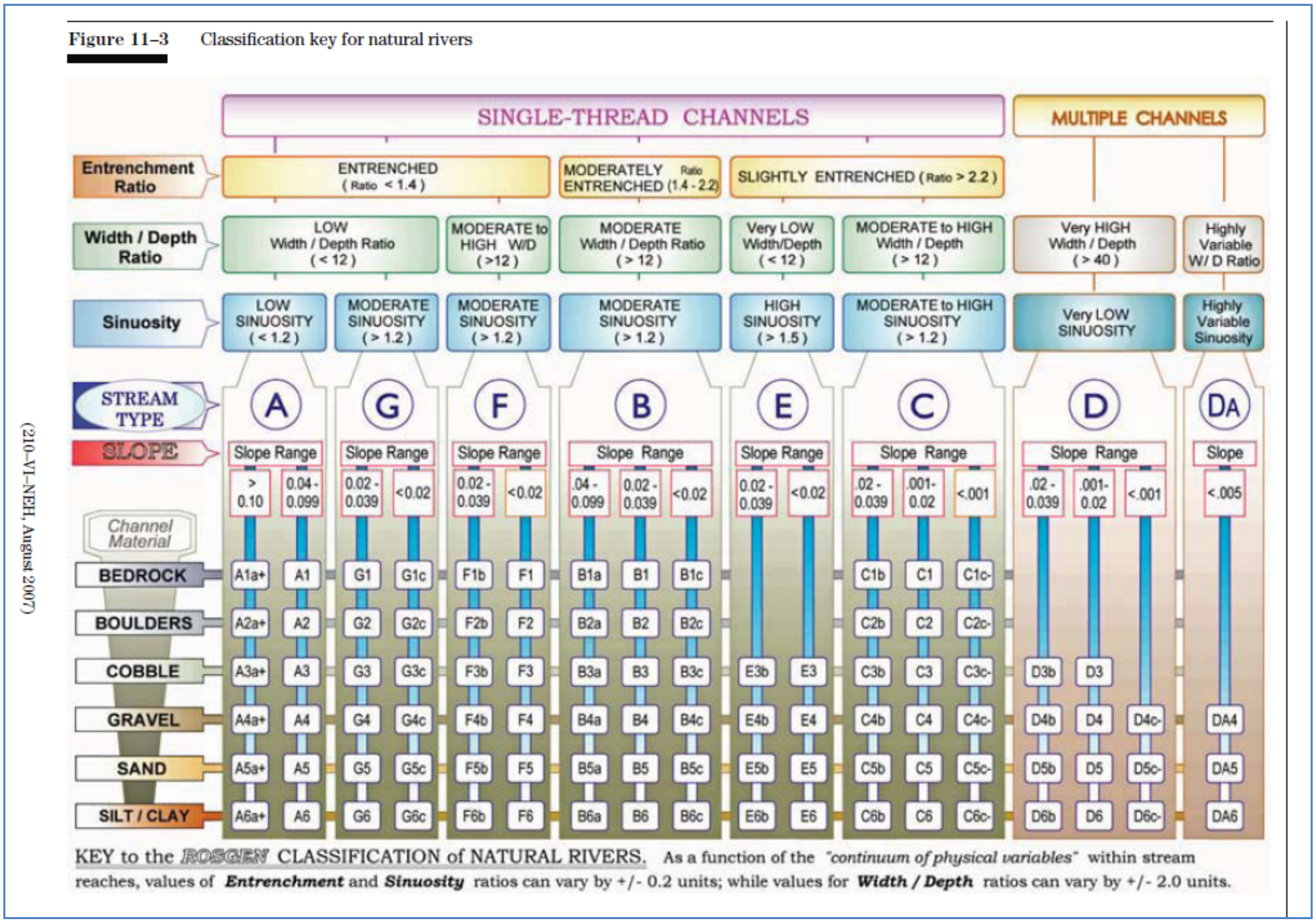


Figure 3.4.5.1.3a Rosgen Level I geomorphic channel classification schematic.

The typical relative locations of stream types within a watershed are presented in Figure 3.4.5.1.3b. Brief descriptions of the Rosgen classification system stream types are included in the following paragraphs.

“A” Stream Type. Channel slopes range from 4 to 10 percent, and typically display a step-pool morphology, with plunge or scour pools. “A” stream types are found within valley types with inherent steepness, and exhibit a high sediment transport potential and relatively low sediment storage capacity.

“B” Stream Type. The predominant landforms are narrow and moderately sloping basin, and valley side slopes result in narrow valleys that limit the development of a wide floodplain. Streams are moderately entrenched, have a moderate width/depth ratio, display low channel sinuosity, and exhibit a bed morphology dominated by rapids.

“C” Stream Type. Typically located in narrow to wide valleys constructed from alluvial deposition. Channels have a well developed floodplain, sligh entrenchment, relatively sinuous, channel slope of 2% or less, and a bedform morphology consisting of riffle/pool configuration.

“D” Stream Type. Multiple channel systems exhibiting braided, or bar-braided pattern, with high channel width/depth ratio and channel slope roughly equivalent to the local valley slope. Landorms typically consist of steep depositional fans, steep glacial trough valleys, glacial outwash valleys, broad alluviual mountain valleys, and deltas. Bank erosion rates are high, and sediment supply is generally unlimited and bed features are the result of convergence/divergence process of local bed scour and deposition.

“E” Stream Type. Channels are slightly entrenched, have low channel width/depth ratio, and high channel sinuosity. Bedform features are predominantly riffle/pool sequences. These stream types are sensitive to disturbance and rapidly adjust and convert to other stream types as the result of disturbance.

“F” Stream Type. Deepely incised in valleys of relatively low elevational relief with highly erodible materials. Channels have very high width/depth ratio, and bedform features include moderated riffle/pool sequence. Bank erosion rates, lateral extension rates, bar deposition, channel aggradation or degradation, and sediment storage capacities are high.

“G” Stream Type. Gully stream types are entrenched, narrow, and deep, with step/pool bedform and low sinuosity. Channel slopes generally exceed 2%. Channels exhibit high bank erosion rates, low channel width/depth ratios, and high bedload and suspended sediment transport rates. Channel degradation and sideslope rejuvenation processes are typical.

Table 3.4.5.1.3. Rosgen Level I geomorphic channel classification description and characteristic parameters.

Stream Type	Description	Entrenchment Ratio (ft/ft)	Width/Depth Ratio (ft/ft)	Sinuosity (ft/ft)	Slope (ft/ft)	Landform/Soils/Features
A	Steep, entrenched, stable, step pool streams with high energy and debris transport.	<1.4	<12	1.0 - 1.2	0.04 to 0.10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches, Frequently spaced, deep poosl in associated step/pool bed morphology.
B	Moderately entrenched, moderate gradient, stable, riffle dominated channels with infrequent pools.	1.4 to 2.2	>12	>1.2	0.02 to 0.039	Moderate relief, colluvial deposition, and/or structural. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate with scour pools.
C	Low gradient, meandering, point-bar, riffle-pool, alluvial channels with	>2.2	>12	>1.4	<0.02	Broad valleys with terraces, in associatation with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.

	broad defined floodplains.					
D	Braided, wide, eroding and unstable channels with longitudinal and transverse bars.	n/a	>40	n/a	<0.04	Broad valleys with alluvium, steeper fans. Glacial debris and epositional features. Active lateral adjustment, with abundance of sediment supply. Convergence/divergence bed features, aggradational processes, high bedload and bank erosion.
Da	Anastomosing (multiple channels) that are narrow and deep with well vegetated floodplains and wetlands with stable stream banks.	>4.0	<40	variable	<0.005	Broad, low gradient balleys with fine alluvium and or lacustrine soils. Anastomosed geologic control creating fine deposition with well vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high wash load sediment.
E	Low gradient, stable, meandering riffle-pool channels with low width/depth ratio and little deposition.	>2.2	<12	>1.5	<0.02	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 channels with high width-depth ratio.	<1.4	>12	>1.4	<0.02	Entrenched in highly weathered material. Gentle gradients, with a high width/depth ratio. Meandering laterally unstable with high bank erosion rates. Riffle/pool morphology.
G	Entrenched, high energy, gulley channels with low width-depth ratio.	<1.4	<12	>1.2	0.02 to 0.039	Gullies, step/pool morphology with moderate sloeps 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.

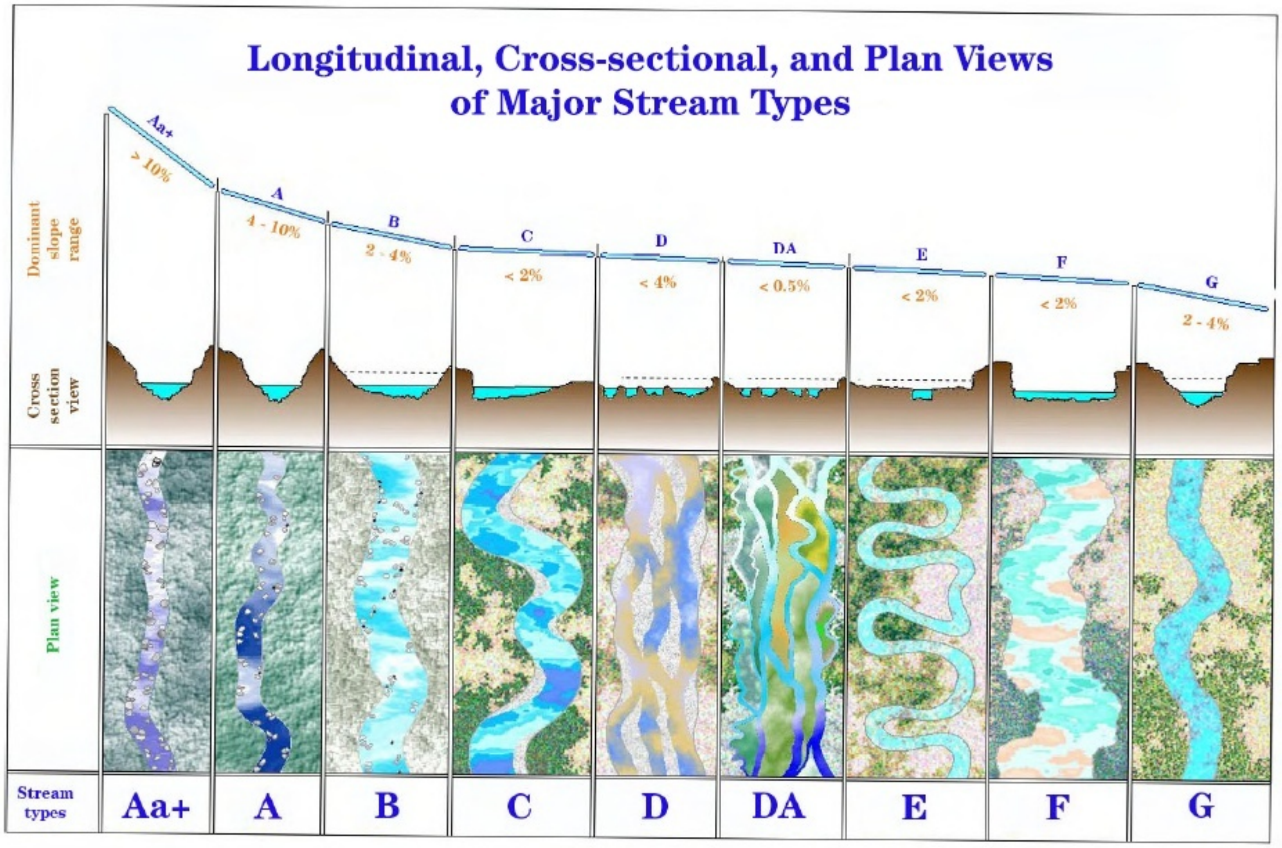


Figure 3.4.5.1.3b. Typical relative locations of stream types within a watershed.

The delineation of valley types is integral to properly classifying stream types because valley width, slope, vegetation, hill slope condition, sedimentology, and setting maintain fundamental influence over channel conditions. A given channel morphology may be considered appropriate in one valley type and inappropriate, or unstable, in another valley type; geomorphic channel classification cannot be fully interpreted without consideration of local valley type. The influence of independent variables (hydrologic regime, sediment conditions, and boundary conditions) on dependent variables of stream morphology is depicted in Figure 3.4.5.1.3c. To inform the channel geomorphic classification process and the interpretation of results, valley types within the study area were delineated through remote sensing using various GIS datasets including USGS 7.5 minute quadrangles, current and historic aerial photography, and digital elevation models. Valley types were delineated in accordance with the numerical identifiers and descriptions presented in Table 3.4.5.1.4 (Rosgen 2012).

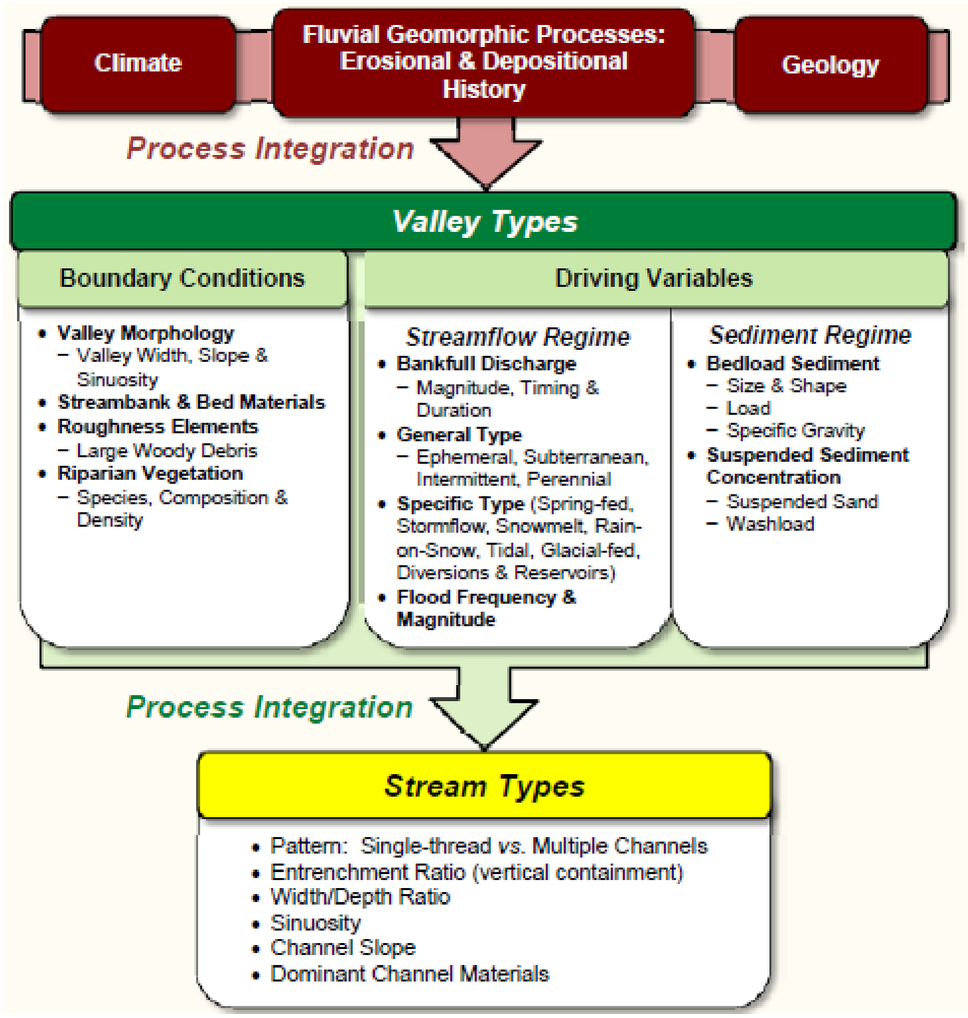


Figure 3.4.5.1.3c. The influence of independent variables on dependent variables of stream morphology.

Table 3.4.5.1.4. Valley types applied during preliminary geomorphic classification in the Upper Green River Watershed.

Valley Type	Name	Description
I	Steep, V-Notched Drainageway	Steep, confined, V-notched valley with rejuvenated side slopes
II	Colluvial	Moderately steep valley slopes with gentle to moderate side slopes associated with colluvial deposition of residual soils
IIIa	Alluvial Fan, active	Actively building fan surface with high sediment supply storage
IIIb	Alluvial Fan, inactive	Non-building stable fan with low sediment supply and generally well established riparian vegetation
IV	Inter-Gorge	Canyons, gorges and confined alluvial valleys with gentle valley floor slopes, steep valley walls, and meandering, entrenched channels
V	Glacial Trough	Moderately steep U-shaped glacial trough valleys

VI	Bedrock	Bedrock controlled valleys with gentle to moderately steep valley slopes
VII	Fluvial Dissected	Steep fluvial dissected, high drainage density, alluvial landscape
VIIIa	Alluvial, Gulch Fill	Narrow valley widths (4 channel widths) with relatively steep valley side slopes, and valley floor slopes greater than 0.5%
VIIIb	Alluvial Fill	Moderate valley widths (4 to 10 channel widths) with moderately steep valley side slopes and valley floor slopes less than 4%
VIIIc	Terraced Alluvial	Wide valley widths (10 channel widths) with gentle valley floor slopes less than 2% with river or glacial terraces
IX	Glacial Outwash	Broad, gentle valley slopes associated with glacial outwash
X	Lacustrine	Very broad and gentle valley slopes associated with glacial and non-glacial-lacustrine deposits

Preliminary remote sensing valley type delineation results were corroborated during field investigation of conditions at a randomly selected subset of sample locations. However the entire length of all classified valleys and streams within the watershed could not be visited for field verification, so results of the classification effort should be considered to be based on remote sensing and the data should be used accordingly. Preliminary valley type classification indicates that alluvial river valleys (valley type VIII) are the most prevalent valley type in the basin, comprising 705 miles (84%) of the nearly 850 total miles of stream. Table 3.4.5.1.5 depicts the total stream length of dominant valley types in the basin.

Table 3.4.5.1.5. Total stream length of dominant valley types in the Upper Green River Watershed.

Valley Type	Stream Length (mi)	Percent of Watershed
I	4	0.5%
II	36	4.3%
III	3	0.3%
IV	28	3.3%
V	34	4.1%
VIII	705	83.6%
X	34	4.0%

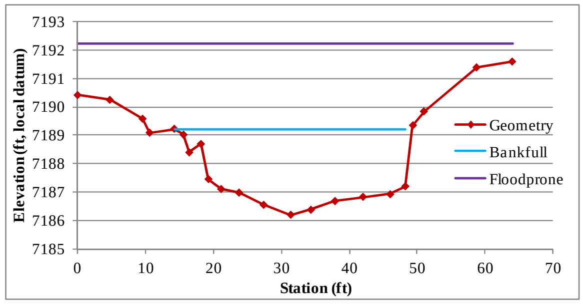
Several previous watershed studies have completed Level I geomorphic classification based primarily on channel sinuosity and slope, presumably because these channel attributes are most readily assessable using remote sensing data sets. However, the Rosgen channel classification system distinguishes channel types based upon physical parameters assessed in the following sequence: number of channels, entrenchment ratio, width/depth ratio, sinuosity, and slope. Arguably, the parameters with the most influence over channel process, and therefore channel form, are entrenchment and width/depth ratio because these parameters dictate hydraulic conditions within the channel during peak flow events, which is when the majority of sediment transport and channel maintenance occur.

A remote sensing approach was used to complete a preliminary geomorphic classification of stream channels within the study area. Assessment of primary classification attributes including entrenchment, width/depth ratio, sinuosity, and slope was conducted as possible using current and historic aerial photography, digital elevation models, and GIS data. The preliminary classification effort was completed at a standard channel assessment scale defined as approximately 20 channel widths in length; isolated changes in channel form were not considered reflective of overall channel morphology unless those changes occurred at the reach level. A randomly selected subset of sites was subsequently visited during the 2013 field season, and field assessment of channel morphology at those locations was completed in order to verify the preliminary classification results. Example photographs and surveyed channels geometry from the field verification are presented in the following figures. Generally, initial findings were found to be accurate and revisions were not necessary. However the entire length of all classified streams within the watershed could not be visited for field verification, so results of the classification effort should be considered to be based on remote sensing and the data should be used accordingly. The locations of headcuts, geologic controls, and man-made grade control structures and hard points were identified during the preliminary assessment and field verification efforts, and the results are depicted in the Watershed Management Plan.

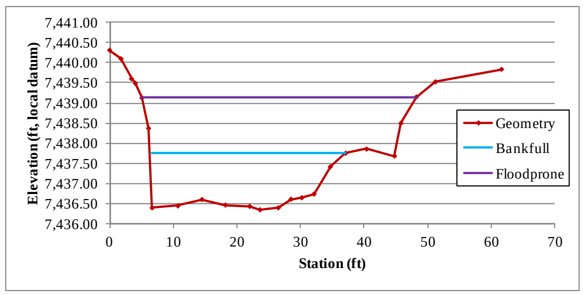
Green River (584,300E, 4,736,850N, NAD 83, UTM zone 12) example of C-type channel with entrenchment ratio greater than 2.2, width/depth ratio greater than 12, and sinuosity greater than 1.2.

Green River (584,505E, 4,742,120N, NAD 83, UTM zone 12) example of C-type channel with entrenchment ratio greater than 2.2, width/depth ratio greater than 12, and sinuosity greater than 1.2.

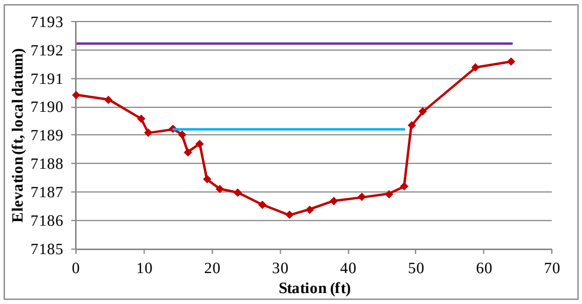
Green River at ‘old Warren Bridge’ (571,780E, 4,763,270N, NAD 83, UTM zone 12) example of C-type channel with entrenchment ratio greater than 2.2, width/depth ratio greater than 12, and sinuosity greater than 1.2.



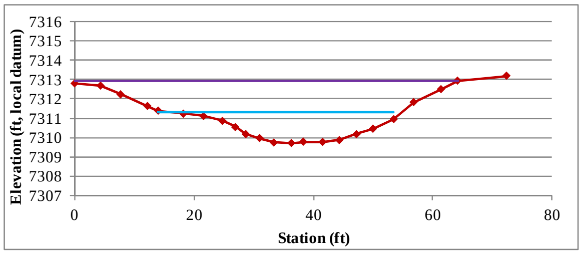
Green River at Hwy 351 (586,100E, 4,713,500N, NAD 83, UTM zone 12) example of a C-type channel with entrenchment ratio greater than 2.2, width/depth ratio of 38, sinuosity greater than 1.2, slope of 0.2%.



Beaver Creek (570,200E, 4,761,500N, NAD 83, UTM zone 12) example of an F-type channel with entrenchment ratio of 1.33, width/depth ratio of 31, sinuosity greater than 1.2, slope of 0.2%.



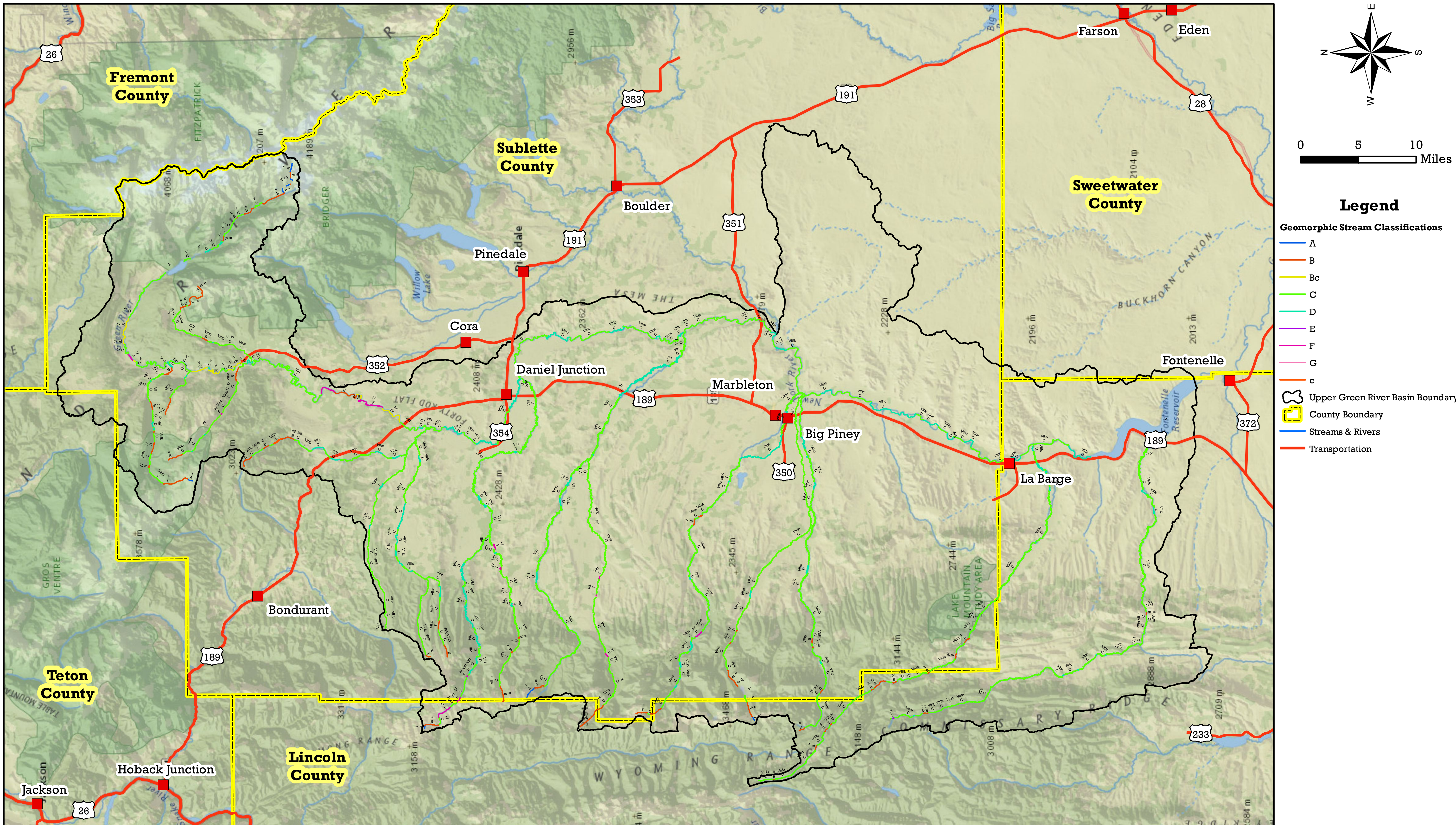
Cottonwood Creek (568,891E, 4,736,320N, NAD 83, UTM zone 12) example of a C-type channel with entrenchment ratio greater than 2.2, width/depth ratio of 20, sinuosity greater than 1.2, slope of 0.14%.



Horse Creek (566,400E, 4,752,800N, NAD 83, UTM zone 12) example of a C-type channel with entrenchment ratio of 2.2, width/depth ratio of 39, sinuosity greater than 1.2, slope of 0.4%.

The results of the geomorphic classification are contained within the project GIS, in which spatial data attributes identify valley type and channel type classifications. Channel classification data are also presented in Figure 3.4.5.1.4 and Figures 3.4.5.1-5 through 3.4.5.1.5-32 located in Appendix M. The figures depict valley type and geomorphic channel classification of the mainstem Green River and identified tributaries at the reach level. Table 3.4.5.1.6 depicts total length and relative percentages of the Upper Green River watershed streams by channel type. Table 3.4.5.1.7 presents results of the geomorphic classification by sub-basins within the watershed.

The headwater reaches of most major streams within the basin are located in steep mountainous terrain comprised of colluvial deposits, bedrock, and forested landscapes. The dominant stream types in these reaches are A and B, with some isolated C and E stream types located in alpine meadows or lacustrine features. These stream reaches are generally laterally and vertically stable, and are typically resistant to local anthropogenically caused changes in independent variables.



Upper Green River Watershed

Figure: 3.4.5.1.4
Geomorphic Stream Classifications

Projection: NAD 83 - UTM Zone 12

The headwater streams change character as they enter the lower valley reaches. In these areas lateral confinement is reduced, sediment size tends to reduce, and boundary conditions typically weaken in conjunction with a change from narrow colluvial valleys to broad riparian alluvial valleys. The common stable stream types within these settings are C and E channel types, and these channel conditions are present within much of the watershed. However, these channel types are sensitive to anthropogenic activities that alter local hydrologic regime and boundary conditions. In numerous locations within the watershed, anthropogenic and natural changes in site conditions result in shifts in channel morphology to less stable D, F, and G stream types. These areas are typically isolated within discrete stream reaches in the watershed, and include disequilibrium channel types and isolated features such as nick-points, headcuts, meander cutoffs, avulsions, and lateral migration sites. Associated conditions result in loss of aquatic and riparian habitat and reduced reliability of surface water delivery to irrigation infrastructure. These localized areas present reasonable opportunities for specific channel restoration and stabilization efforts, and are discussed in more detail in Section 4.3.1.

Table 3.4.5.1.6. Total length and relative percentage of stream types in the Upper Green River Basin study area.

Stream Type	Stream Length (miles)	Percent of Watershed (by stream length)
A	3.8	0.45%
B	59.6	7.07%
C	629.7	74.71%
D	113.4	13.46%
E	0.2	0.03%
F	11.0	1.31%
G	0.4	0.04%

Table 3.4.5.1.7. Total length and relative percentage of stream types in sub-basins of the Upper Green River study area.

Subbasin Name	Stream Type	Length (miles)	Percent of Watercourse	Subbasin Name	Stream Type	Length (miles)	Percent of Watercourse
Beaver Creek	B	5.5	6.3%	Horse Creek	A	0.3	0.3%
	C	66.0	76.4%		B	3.7	4.0%
	D	14.9	17.3%		C	68.6	75.3%
Cottonwood Creek	A	1.1	0.9%		D	14.7	16.2%
	B	3.8	3.1%		F	3.8	4.2%
	C	98.2	80.1%	Klondike Creek	B	1.6	31.9%
	D	18.3	15.0%		C	3.1	61.6%
	F	1.0	0.8%		D	0.3	6.4%
	G	0.0	0.0%	La Barge Creek	B	4.6	6.8%
Fontenelle Creek	B	0.7	1.0%		C	58.7	86.6%
	C	67.1	94.4%		D	4.4	6.6%
	D	3.0	4.2%	Rock Creek	B	2.7	20.8%
	E	0.2	0.3%		C	9.7	75.1%
Tosi Creek	A	0.4	1.8%		D	0.3	2.3%
	B	5.8	29.3%		F	0.2	1.8%
	C	10.9	55.3%	Gypsum Creek	B	4.3	27.3%
	D	2.7	13.5%		C	11.2	71.9%
Piney Creek	A	0.3	0.2%		D	0.1	0.7%
	B	9.0	5.7%	Green River	A	1.8	1.1%
	C	131.3	82.7%		B	17.9	10.7%
	D	17.3	10.9%		C	104.8	62.8%
	F	0.7	0.5%		D	37.3	22.3%
					F	5.2	3.1%

REFERENCES

Carter, R.W., and J. Davidian, General Procedure for Gaging Streams. USGS Techniques of Water-Resources Investigations, Book 3 Applications of Hydraulics

Lowham, H.W., 1988, Streamflows in Wyoming: U.S. Geological Survey Water-Resources Investigations Report 88-4045, 78 p.

Miller, K.A., 2003, Peak-flow characteristics of Wyoming streams: US Geological Survey Water Resources Investigations Report 03-4107, 79p.

NRCS (Natural Resources Conservation Service), 2007, Part 654 Stream Restoration Design, National Engineering Handbook, United States Department of Agriculture.

Osterkamp, W.R., Emmett, W.W. and Leopold, L.B. 1991. Fish Habitat Structures: A selection guide using stream classification. Journal of Hydrological Sciences, 36(4), 331-344.

Rantz, S.E. et al, 1982, Measurement and computation of streamflow: Volume 1. Measurement of stage and discharge. U.S. Government Printing Office, USGS Water-Supply Paper 2175.

Rantz, S.E. et al, 1982, Measurement and computation of streamflow: Volume 2. Computation of discharge. U.S. Government Printing Office, USGS Water-Supply Paper 2175.

Rosgen, D.L., 1994. A Stream Classification System. Catena, 22 169199. Elsevier Science, Amsterdam

Rosgen, D.L., 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado, and Ft. Collins, CO.

Rosgen, D.L., 2006. A Watershed Assessment for River Stability and Sediment Supply. Wildland Hydrology Books, Fort Collins, CO.

Rosgen, D.L. 2012. Valley Types, draft manuscript, Wildland Hydrology Books, Fort Collins, CO.

World Meteorological Organization, 2010, Manual on stream gauging. Volume I – Fieldwork, Volume II – Computation of discharge. WMO-No. 1044, Geneva.

3.4.6 WATER QUALITY

3.4.6.1 GENERAL ASSESSMENT

The following information is based on the Wyoming Department of Environmental Quality's 2012 Integrated 305(b) and 303(d) Report. The headwaters of the Upper Green are primarily comprised of hardened igneous and metamorphic rock, and the water quality is very good. Lower elevation areas are underlain by fine-grained sedimentary rocks, which are a natural source of fine sediment and TDS in surface waters. Primary land uses are grazing, recreation, irrigated hay production and oil and gas development. In the upper watershed, water quality is generally quite good, with isolated areas of increased sediment and nutrient loads. Extensive monitoring by WDEQ between Highway 191 and Green River Lakes indicates that streams in this portion of the watershed are supporting their aquatic life.

Sublette County Conservation District funded a baseline study (Marshall, 2007b) of the biological conditions of the Green River Basin in Sublette County. The study compared samples collected from 19 sites between the years 2001-05 and evaluated biological trends within sites using WDEQ's WSII benthic macroinvertebrate model. The report indicated that the macroinvertebrate communities of Middle Piney Creek and Muddy Creek were in poor condition and that wastewater treatment effluent and irrigation return flows may be having a negative effect. Credible data (chemical, physical and biological) were not reported for this study and thus no "aquatic life" other than "fish use support" determinations were made by WDEQ.

A gas processing facility and oil and gas wells are located in the upper portions of the LaBarge, Dry Piney, and South Piney Creek drainages. Oil seeps and ponds associated with oil wells and physical degradation have been identified as concerns by WDEQ. WDEQ monitoring to determine designated use support on Dry Piney Creek in 2003 was inconclusive. WDEQ suggests that seasonal dewatering of North, Middle and South Piney Creeks may limit macroinvertebrate communities.

WDEQ monitoring of LaBarge and Fontenelle Creeks indicates that their aquatic life other than fish uses are supported in the upper drainages within the Bridger-Teton National Forest and in the lower mainstem of Fontenelle Creek, just above Fontenelle Reservoir. The WGFD identifies the upper LaBarge Creek Watershed as having good Colorado River cutthroat trout habitat. WDEQ has identified physical degradation in portions of the lower drainage and seasonal dewatering for irrigation as concerns. Data collected by WDEQ in 1998 indicate that Rock Creek, a tributary to LaBarge Creek, fully supports its aquatic life other than fish use.

REFERENCES

Marshall, B.D. 2007b. Biological Baseline Condition in the Green River Basin, Sublette County, Wyoming: Biological Condition and Within Site Variability 2001-2005. Final Report prepared for Sublette County Conservation District, Pinedale, Wyoming. River Continuum Concepts, Willow Creek, MT and Eco Analysts Inc., Bozeman,MT on December 11, 2007.

3.4.6.2 STREAM CLASSIFICATION

The Wyoming Water Quality Rules and Regulations – Surface Water Standards (specifically Section 4, 33, 34, 35, and Appendix A) explains the background and process by which state classifications are assigned to waters within the state that are named on the USGS 1:500,000 scale hydrologic map or are contained in the WGFD database of state streams and lakes. Each water classification is associated with a specific combination of protected uses, including the following:

1. Agriculture – for purposes of water pollution control, agricultural uses include irrigation or stock watering;
2. Fisheries – use includes water quality, habitat conditions, spawning and nursery areas, and food sources necessary to sustain populations of game and nongame fish;
3. Industry – use protection involves maintaining a level of water quality useful for industrial purposes;
4. Drinking water – use involves maintaining a level of water quality that is suitable for potable water or intended to be suitable after receiving conventional drinking water treatment;
5. Recreation – use protection involves maintaining a level of water quality which is safe for human contact;
6. Scenic value – use involves the aesthetics of the aquatic systems themselves (odor, color, taste, 'settleable' solids, floating solids, suspended solids, and solid waste) and is not necessarily related to general landscape appearance;
7. Aquatic life other than fish – use includes water quality and habitat necessary to sustain populations of organisms other than fish in proportions which make up diverse aquatic communities common to the waters of the state;
8. Wildlife – use includes protection of water quality to a level which is safe for the contact and consumption by avian and terrestrial wildlife species;
9. Fish Consumption – use involves maintaining a level of water quality that will prevent any unpalatable flavor and/or accumulation of harmful substances in fish tissue.

Designated uses that are protected within each state water classification (identified by a unique numeric and alphabetic code) are presented in Table 3.4.6.2.1. Definitions of water classifications that are applicable to the Upper Green River watershed study area are subsequently presented, as quoted from the Water Quality Rules and Regulations, Chapter 1, Wyoming Surface Water Quality Standards (WDEQ, 2007).

Table 3.4.6.2.1. Protected uses within each Wyoming state water classification.

WYDEQ Class	Drinking Water	Game Fish	Non-Game Fish	Fish Consumption	Other Aquatic Life	Recreation	Wildlife	Agriculture	Industry	Scenic Value
1*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2AB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2A	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
2B	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2C	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
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; actual uses on each particular water must be determined independently.

***Class 1, Outstanding Waters** – waters in which no further water quality degradation by point source discharges other than from dams will be allowed. Nonpoint sources of pollution shall be controlled through implementation of appropriate best management practices. Pursuant to Section 7 of these regulations, the water quality and physical and biological integrity which existed on the water at the time of designation will be maintained and protected. In designating Class 1 waters, the Environmental Quality Council shall consider water quality, aesthetic, scenic, recreational, ecological, agricultural, botanical, zoological, municipal, industrial, historical, geological, cultural, archaeological, fish and wildlife, the presence of significant quantities of developable water and other values of present and future benefit to the people.*

__Class 2AB__ – waters 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 in 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 "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 nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic value uses.

__Class 2C__ – waters known to support or have the potential to support only nongame fish populations or spawning and nursery areas at least seasonally including their perennial tributaries and adjacent wetlands. Class 2C waters include all permanent and seasonal nongame fisheries and are considered "warm water". Uses designated on Class 2C waters include nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic value.

__Class 3B__ – waters or 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.

Stream classifications within the Upper Green River watershed study area obtained from the latest Wyoming Surface Water Classification list (WDEQ, 2001) are presented (Table 3.4.6.2.2) from downstream to upstream, and indented entries are tributary to previous entries.

Table 3.4.6.2.2. Stream classifications in the Upper Green River Watershed Study Area.

Stream	WYDEQ Classification
Fontenelle Reservoir	2AB
Fontenelle Creek	2AB
Rocky Creek	2AB
Muddy Creek	3B
LaBarge Creek	2AB
Birch Creek	3B
Fogarty Draw	3B
Reardon Draw	3B

Dry Piney Creek			2AB
	Sawmill Canyon Creek		3B
	Black Canyon Creek		2AB
		Cabin Creek	3B
South Piney Creek			2AB
	Beaver Creek		2AB
		Spring Creek	2AB
	Fish Creek		2AB
Middle Piney Creek			2AB
	North Channel Middle Piney Creek		2AB
North Piney Creek			2AB
	Red Canyon Creek		2AB
	Sixty Seven Reservoir		2AB
	Aperson Creek		2AB
Muddy Creek			2AB
Alkali Creek			3B
	Granite Wash		3B
Marsh Creek			2AB
Cottonwood Creek			2AB
	South Cottonwood Creek		2AB
	Killpekcer Creek		2C
	North Cottonwood Creek		2AB
		Spring Creek	3B
Horse Creek			2AB
	South Horse Creek		2AB
	North Horse Creek		2AB
Forty Rod Creek			2AB
Beaver Creek			2AB
	North Beaver Creek		2AB
	Middle Beaver Creek		2AB
	South Beaver Creek		2AB
Little Twin Creek			2AB
Big Twin Creek			2AB
Boulder Creek			2AB
Jim Creek			2AB
Gypsum Creek			2AB
Rock Creek			2AB
Lime Creek			2AB
Klondike Creek			2AB
Tosi Creek			2AB
	Teepee Creek		2AB
Wagon Creek			2AB

Roaring Fork	2AB
Green River (Remainder)	2AB
Green River (Above New Fork River)	1
Green River Lakes	1

3.4.6.3 WATERS REQUIRING TMDLS

Section 303(d) of the Clean Water Act requires states, territories, and authorized tribes to develop lists of impaired waters. Impaired waters are defined as those that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop Total Maximum Daily Loads (TMDLs) for these waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards.

None of the waterbodies in the Upper Green River watershed are currently listed on the 303(d) list for the State of Wyoming, and no waters within the watershed currently require TMDLs. According to the WDEQ, the lack of 303(d)-listed waterbodies in the Upper Green River watershed is primarily due to the fact that other basins around the state have been prioritized for the WDEQ monitoring and assessment that is required for 303(d)-listing (Richard Thorp, WDEQ, personal communication, March 4, 2013).

3.4.6.4 WYPDES PERMITTED DISCHARGES

The Clean Water Act authorized the creation of the National Pollutant Discharge Elimination System (NPDES) permit program in 1972. The NPDES permit program controls water pollution by regulating the discharge of pollutants from point sources into surface waters of the United States. Point sources are defined as discernible, confined, and discrete conveyances such as pipes, channels, conduits, and man-made ditches from which pollutants are or may be discharged.

The NPDES permit program is managed by the USEPA and is typically administered by authorized states and tribes. The Wyoming Pollutant Discharge Elimination System (WYPDES) Program administers the NPDES program in Wyoming. Through this program, operators of any point source discharges are required to receive coverage under a WYPDES discharge permit. The WDEQ places limitations and conditions on WYPDES permits to ensure that surface water quality standards are protected.

There are five active WYPDES permits in the Upper Green River Watershed. These permits are summarized in Table 3.4.6.4 and the associated point source locations are depicted on Figure 3.4.6.1-WYPDES Permitted Discharges. Four of these permits are for sanitary wastewater, and one is a temporary permit for the LaBarge River intake. There is one designated outfall for each of the permits. The effluent limits for these permits are based on the classification and designated uses of the receiving waterbody. Effluent from the Town of LaBarge wastewater lagoons is discharged directly to the Green River (Class 2AB). Effluent from the Mountain Village Park waste water treatment plant is discharged into Midmermac Ditch (Class 4A), which is a tributary to the Green River. Effluent from the Big Piney wasterwater lagoon is discharged into North Piney Creek (Class 2AB), which is a tributary to the Green River. Effluent from the Marbleton wastewater treatment plant is discharged into Muddy Creek (Class 2AB), which is a tributary to the Green River.

Table 3.4.6.4. Summary of WYPDES permitted discharges in the Upper Green River watershed.

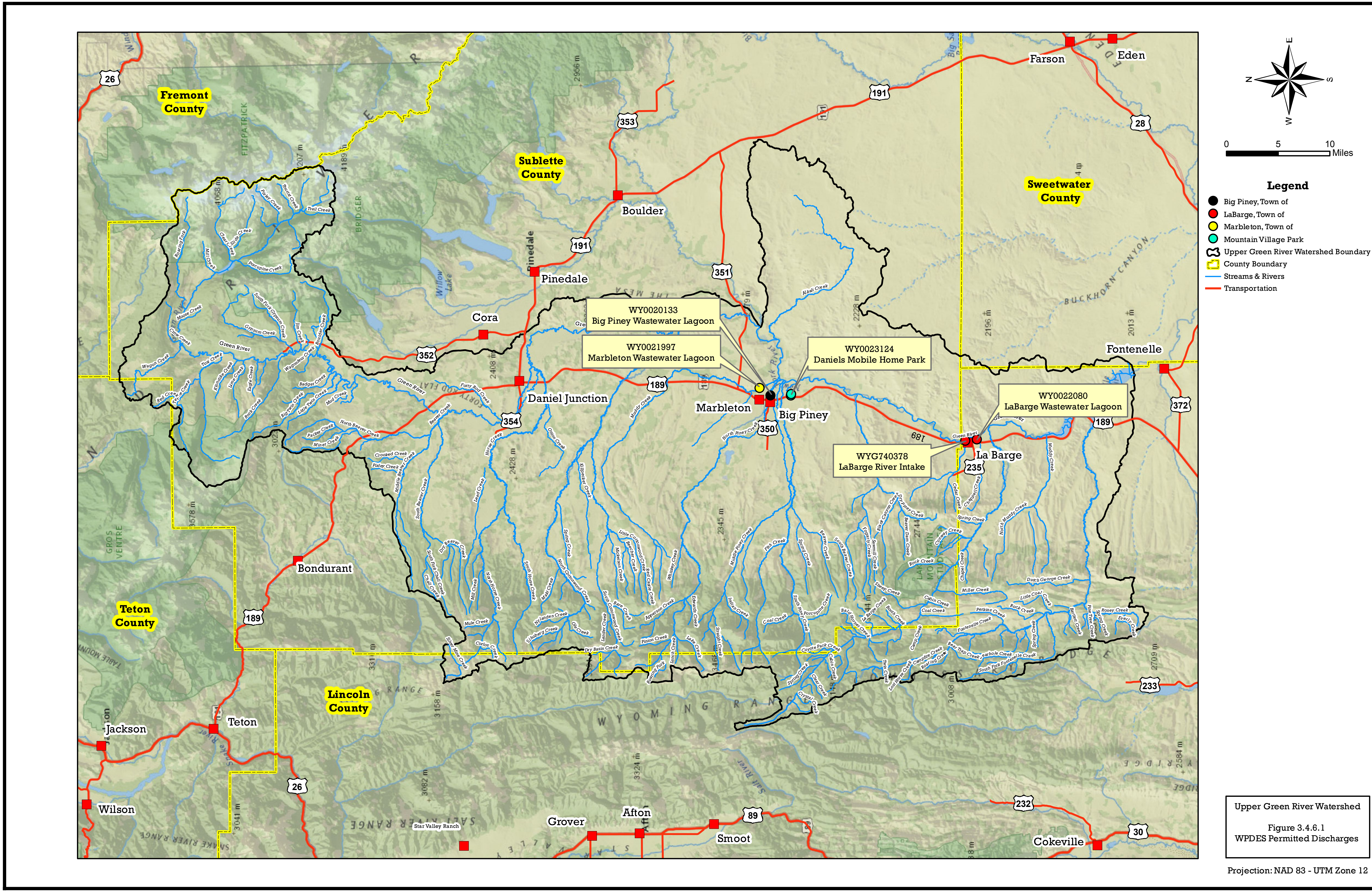
Permit Number	Permittee	Facility Name	Permit Type	Number of Outfalls
WYG740378	Town of LaBarge	LaBarge River Intake	Temporary	1
WY0022080	Town of LaBarge	LaBarge Wastewater Lagoon	Sanitary Wastewater	1
WY0023124	Mountain Village Park	Daniels Mobile Home Park	Sanitary Wastewater	1
WY0020133	Town of Big Piney	Big Piney Wastewater Lagoon	Sanitary Wastewater	1
WY0021997	Town of Marbleton	Marbleton Wastewater Lagoon	Sanitary Wastewater	1

3.4.6.5 SUITABILTY FOR IRRIGATION

The water originating in the eastern tributaries is generally of high quality. It does carry fine sediment and exhibits high seasonal turbidity. It is suited for flood irrigation and also sprinkler type systems. Water traversing high alkali and benonitic type soils in small ephemeral basins can be degraded in aesthetic quality and increase in salt content although it remains useful for stock and native grasses.

The USGS has conducted water quality tests on samples taken at the Warren Bridge Station 09188500 (point Y on Figure 3.4.4.2.1 see Section 3.4.4.2) from 1962 to 1982 and from 2008 to present. Two important parameters used to evaluate water suitability is that of sodium adsorption ration (SAR) and specific conductance measured in microsiemens/centimeter. These two parameters taken singly and together help identify potential irrigation restrictions.

Table 3.4.6.5 was taken from Water Quality for Agriculture by R.S. Ayers and D.W, Westcott and adapted with regard to salinity units to correspond with the USGS salinity records. The table illustrates water quality ranges for key indicators and associated restrictions on use.



Legend
Big Piney, Town of
LaBarge, Town of
Marbleton, Town of
Mountain Village Park
Upper Green River Watershed Boundary
County Boundary
Streams & Rivers
Transportation
0 5 10 Miles
WY0020133
Big Piney Wastewater Lagoon
WY0021997
Marbleton Wastewater Lagoon
WY0023124
Daniels Mobile Home Park
WY0022080
LaBarge Wastewater Lagoon
WYG740378
LaBarge River Intake
Fremont County
Sublette County
Sweetwater County
Teton County
Lincoln County
Boulder
Pinedale
Cora
Daniel Junction
Marbleton
Big Piney
La Barge
Fontenelle
Farson
Eden
Bondurant
Jackson
Teton
Wilson
Grover
Afton
Smoot
Cokeville
WYOMING RANGE
Upper Green River Watershed
Figure 3.4.6.1
WPDES Permitted Discharges
Projection: NAD 83 - UTM Zone 12

Table3.4.6.5 Guidelines for interpretation of water quality for irrigation

Potential Irrigation Problem	Units	Degree of Restriction on Use		
		None	Slight to Moderate	Severe
Salinity(affects crop water availability)2				
EC_w	µS/m	< 700	700 – 3000	> 3000
(or)				
TDS	mg/l	< 450	450 – 2000	> 2000
Infiltration(affects infiltration rate of water into the soil. Evaluate using ECw and SAR together)3				
SAR = 0 – 3 **and Specific Conductance** =		> 700	700 – 200	< 200
= 3 – 6 =		> 1200	1200 – 300	< 300
= 6 – 12 =		> 1900	1900 – 500	< 500
= 12 – 20 =		> 2900	2900 – 1300	< 1300
= 20 – 40 =		> 5000	5000 – 2900	< 2900
Specific Ion Toxicity *(affects sensitive crops)*				
Sodium (Na)4				
surface irrigation	SAR	< 3	3 – 9	> 9
sprinkler irrigation	me/l	< 3	> 3	
Chloride (Cl)4				
surface irrigation	me/l	< 4	4 – 10	> 10
sprinkler irrigation	me/l	< 3	> 3	
Boron (B)5	mg/l	< 0.7	0.7 – 3.0	> 3.0
Trace Elements (see Table 21)				
Miscellaneous Effects *(affects susceptible crops)*				
Nitrogen (NO3 - N)6	mg/l	< 5	5 – 30	> 30
Bicarbonate (HCO_3)				
(overhead sprinkling only)	me/l	< 1.5	1.5 – 8.5	> 8.5
pH		**Normal Range 6.5 – 8.4**		

[1] Adapted from University of California Committee of Consultants 1974.

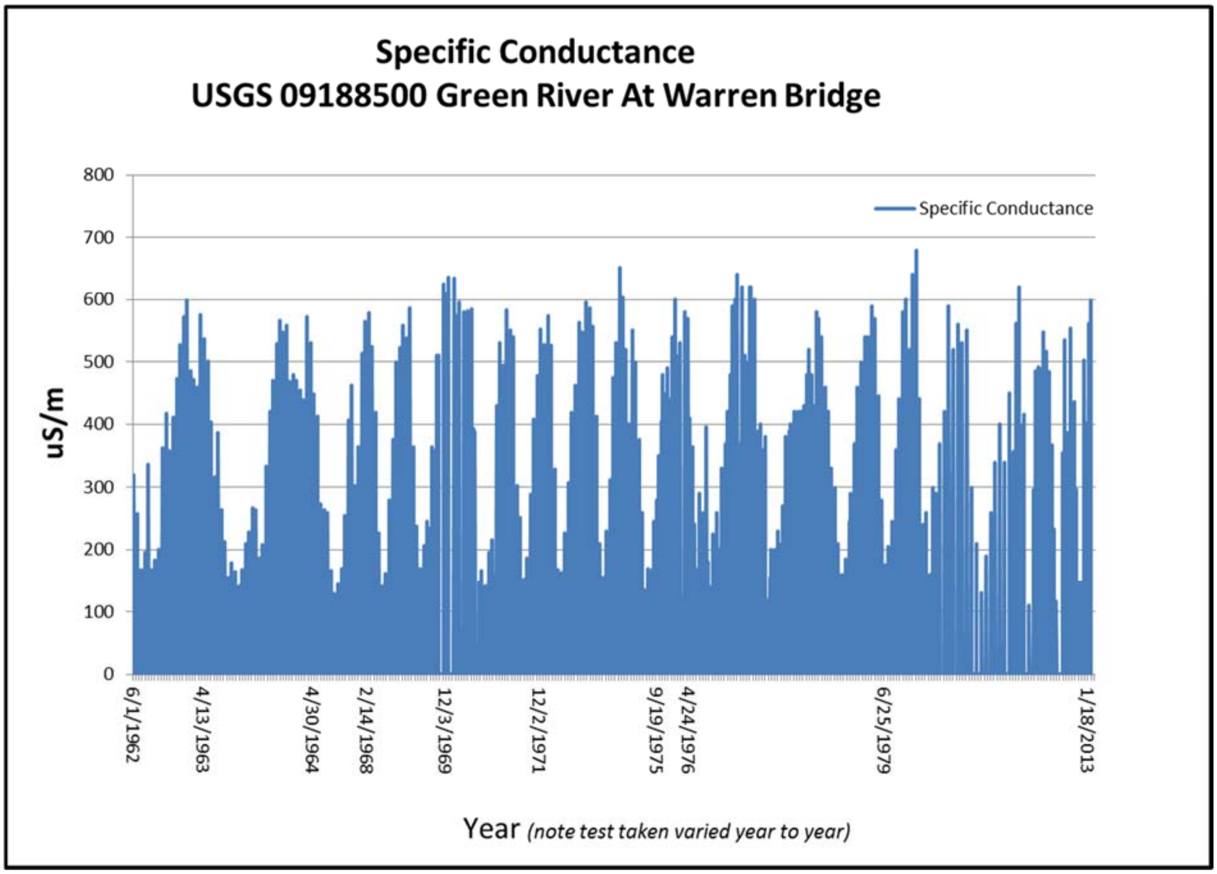
[2] ECw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per metre at 25°C (dS/m) or in units millimhos per centimetre (mmho/cm). Both are equiva-lent. TDS means total dissolved solids, reported in milligrams per litre (mg/l).

[3] SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. See Figure1 for the SAR calculation procedure. At a given SAR, infiltration rate increases as watersalinity increases. Evaluate the potential infiltration problem by SAR as modified by ECw.Adapted from Rhoades 1977, and Oster and Schroer 1979.

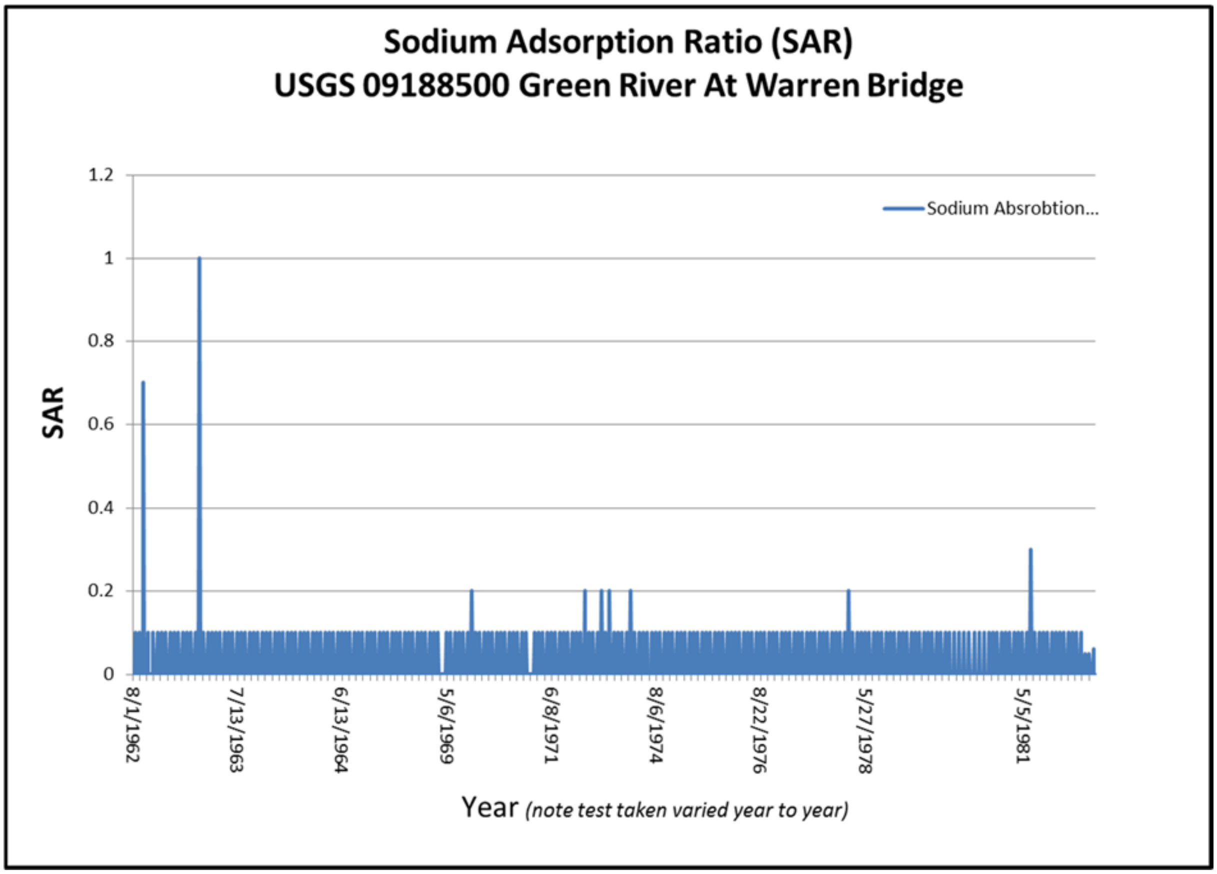
[4] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chlor-ide; use the values shown. Most annual crops are not sensitive; use the salinity tolerance tables (Tables 4 and 5). For chloride tolerance of selected fruit crops, see Table 14. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops. For crop sensitivity to absorption, see Tables 18, 19 and 20.

[5] For boron tolerances, see Tables 16 and 17.

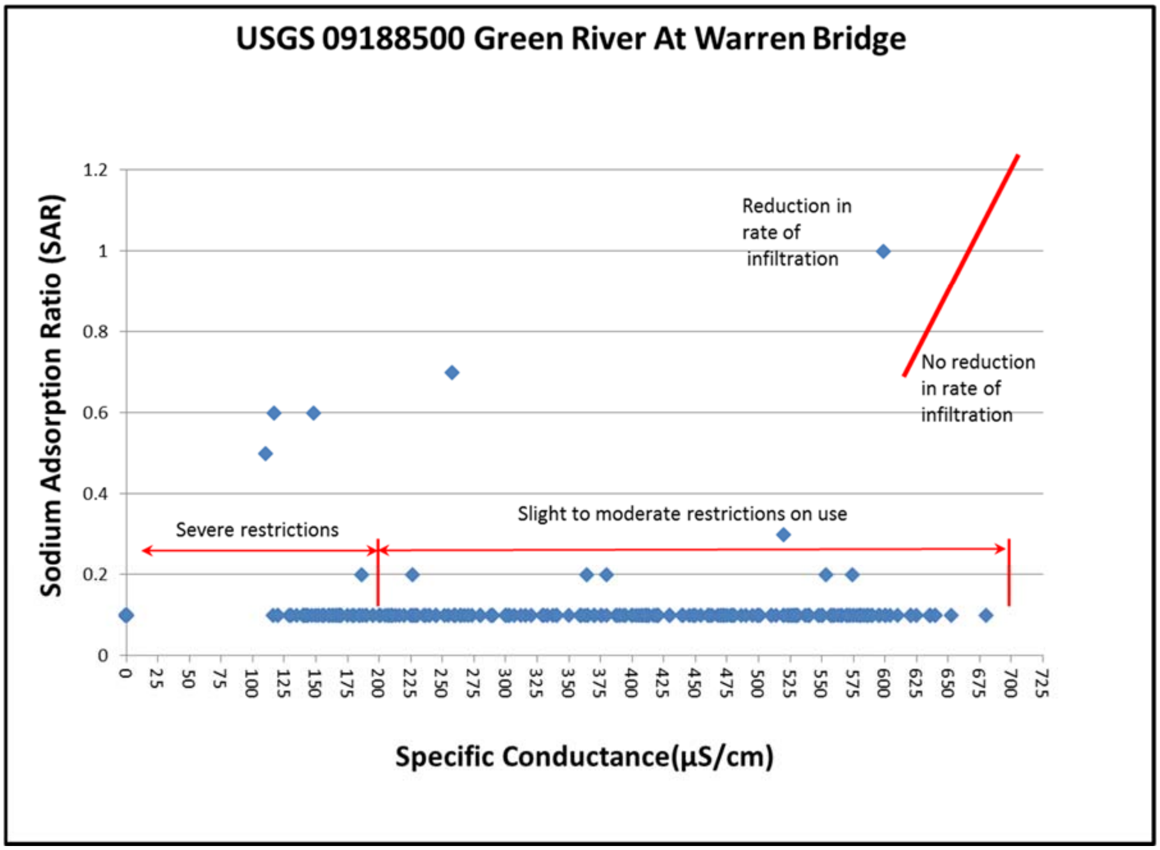
The USGS period of record at Warren Bridge indicates specific conductance generally ranges between 200 and 600 with occasional points falling as low as 130 or has high as 650 for short timespans of a few months.



The Sodium Absorption Ratio has been 0.1 for 95% of the test results with the remaining falling between 0 and 1.0.



These two parameters when taken together indicate there are likely circumstances when restrictions are warranted. The following graph plots sodium adsorption ration and specific conductance of water quality samples taken at Warren Bridge. The low specific conductance of most samples places them in the slight to moderate degree of restriction category on the second section of Table 3.4.6.5.

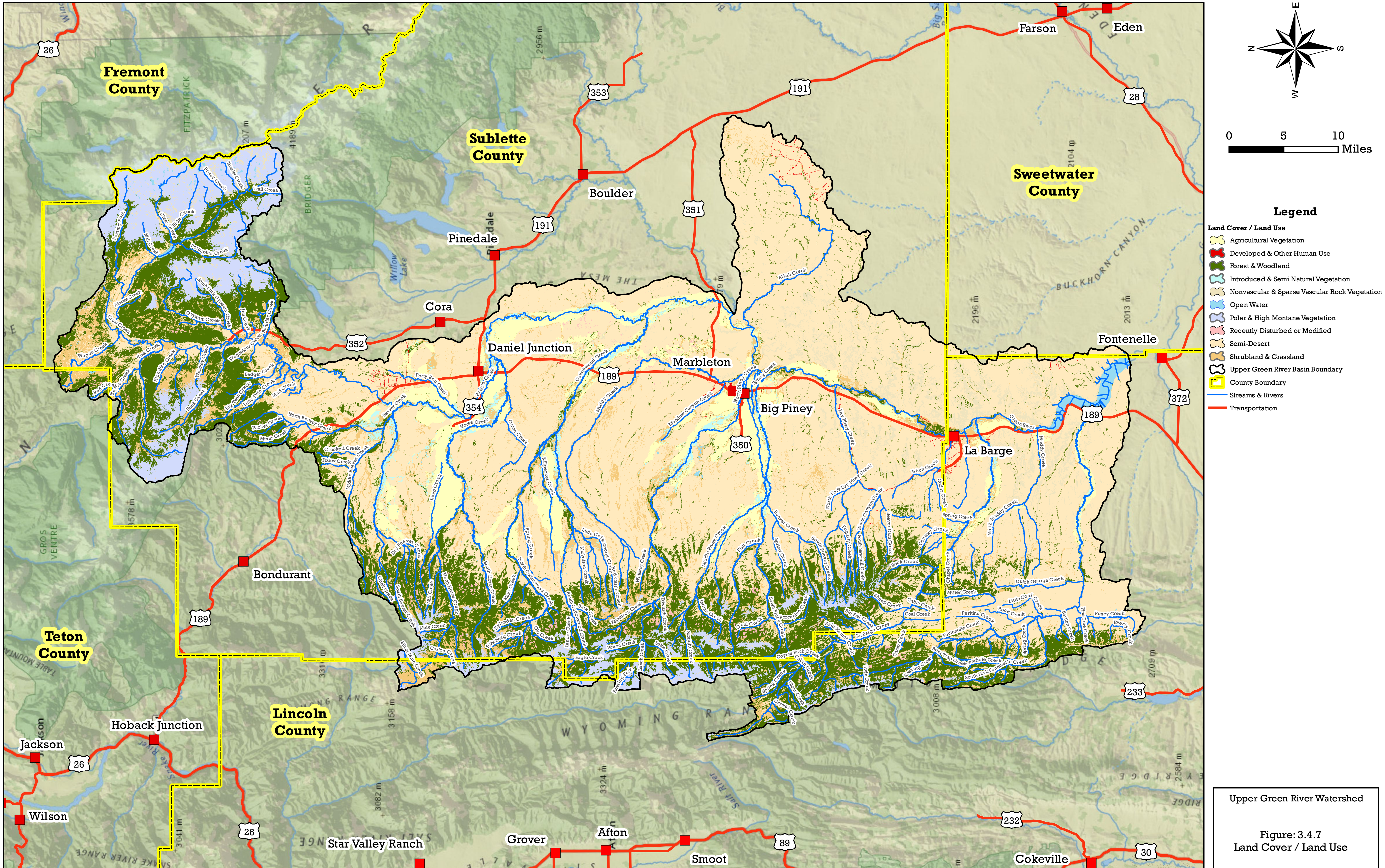


The following statement by the Water Quality for Agriculture authors regarding the use of the table provide some room for other factors.

> ***Restriction on Use:*** *The "Restriction on Use" shown in Table 1* (Table 3.4.6.5) *is divided into three degree of severity: none, slight to moderate, and severe. The divisions are somewhat arbitrary since change occurs gradually and there is no clearcut breaking point. A change of 10 to 20 percent above or below a guideline value has little significance if considered in proper perspective with other factors affecting yield. Field studies, research trials and observations have led to these divisions, but management skill of the water user can alter them. Values shown are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world.*

3.4.7 MAJOR PLANT COMMUNITIES

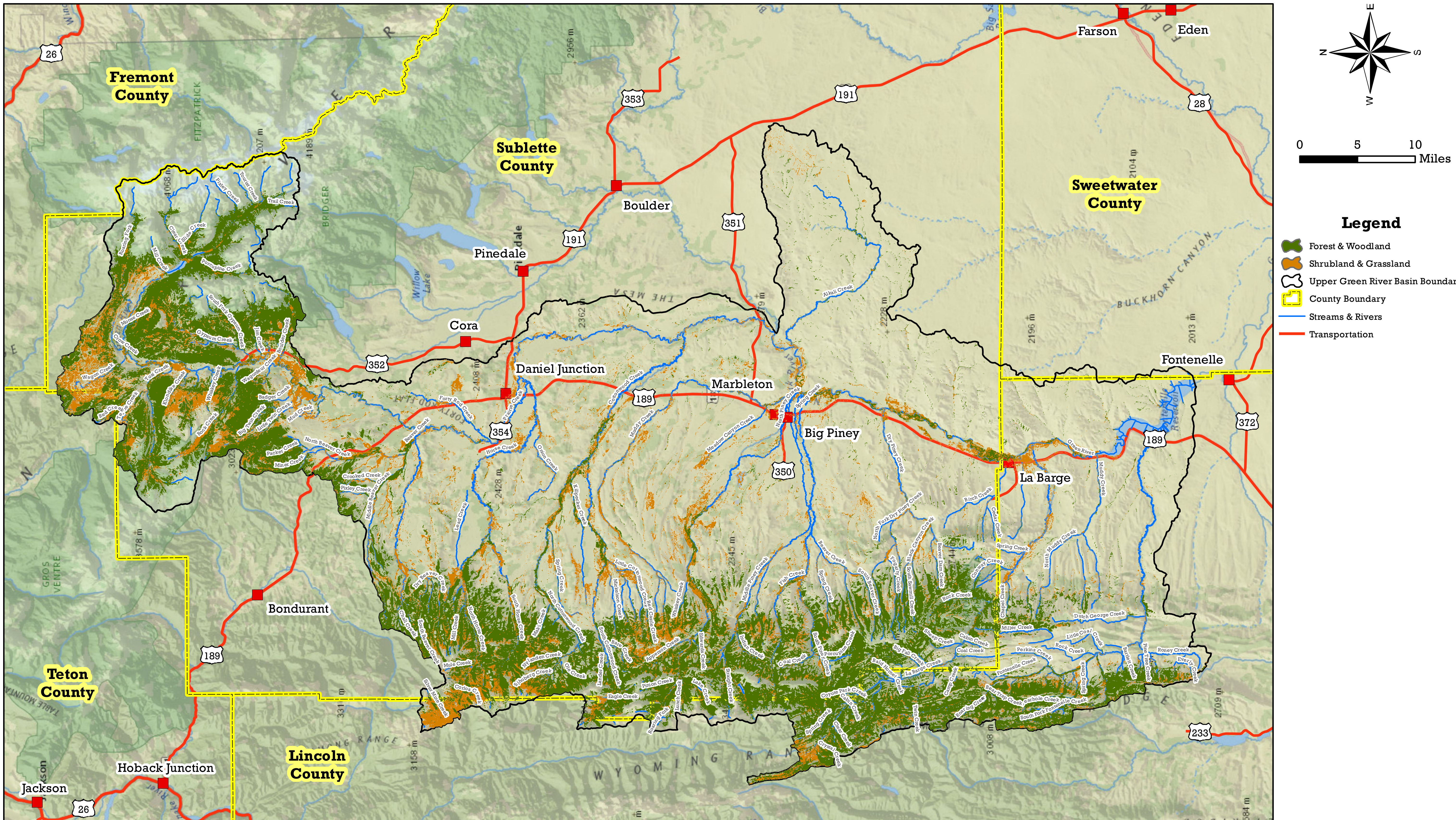
Mapping and analysis of major plant communities in the Upper Green River watershed study area was facilitated through the use of remote sensing datasets. The National Land Cover Database (NLCD) is a nationwide spatial dataset that provides a generalized characterization of 16 land surface classes at a 30-meter resolution (http://www.mrlc.gov/nlcd2006.php). All 16 land cover classes are depicted within the study area, with shrubland (1,115,051 acres) comprising more than 50% of the watershed (Figure 3.4.7-Land Cover/Land Use). A brief description of each land cover class is presented in Table 3.4.7.1.



Upper Green River Watershed

Figure: 3.4.7
Land Cover / Land Use

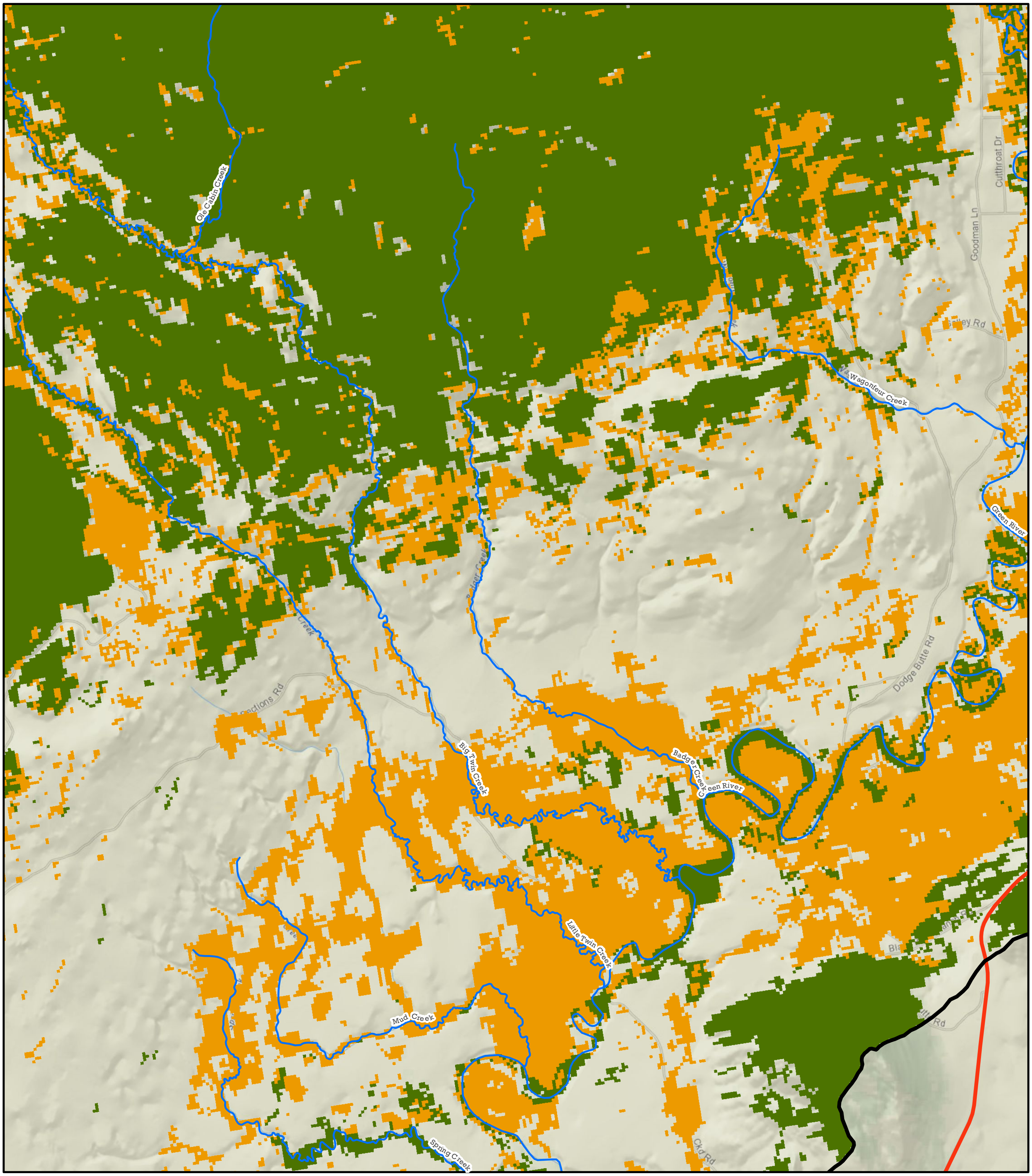
Projection: NAD 83 - UTM Zone 12



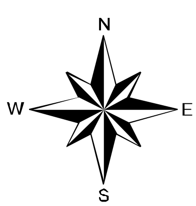
Upper Green River Watershed

Figure: 3.4.7a
NWGAP Land Cover

Projection: NAD 83 - UTM Zone 12



Legend



- Forest & Woodland
- Shrubland & Grassland
- Upper Green River Basin Boundary
- County Boundary
- Streams & Rivers
- Transportation

0 0.5 1 Miles

Upper Green River Watershed

Figure: 3.4.7b
NWG Land Cover

Projection: NAD 83 - UTM Zone 12

More descriptive and refined land cover data was derived from the Northwestern Regional Gap Analysis Project (NWGAP), which depicts 61 ecological system classes within the Upper Green River watershed study area (Figure 3.4.7a). NWGAP has a resolution of 30-meters and adheres to the Nation Vegetation Classification Standard (http://gap.uidaho.edu/index.php/nw-gap). The NWGAP dataset describes vegetation communities at a high level of thematic detail, which is typically not appropriate for display on a full watershed scale (i.e., no scales larger than 1:100,000). A zoomed-in example of NWGAP mapping in the watershed is depicted in Figure 3.4.7b-NWGAP Land Cover. According to the GAP analysis, Inter-Mountain basins big sagebrush shrubland comprises 338,843 acres (18% of the watershed) and is the most abundant ecological system in the watershed (Table 3.4.7.2). This is followed, in order of decreasing abundance, by Inter-Mountain basins montane sagebrush steppe, Inter-Mountain basins big sagebrush steppe, and Inter-Mountain basins dwarf sagebrush steppe.

LANDFIRE (Table 3.4.7.3) is another nationwide spatial dataset that provides landscape-scale vegetation and canopy characteristics (http://www.landfire.gov/). The LANDFIRE program was developed to support fire and fuels management planning, and is a shared effort between the USFS and the USDI. Similar to NWGAP, LANDFIRE datasets also describe vegetation communities at a high level of thematic detail and are not appropriate for display on a large watershed scale. According to the LANDFIRE mapping, Inter-Mountain Basins Big Sagebrush Shrubland and Artemisia tridentata ssp. vaseyana Shrubland Alliance comprise 21.6% and 18.3% of the watershed respectively. The NLCD, NWGAP, and LANDFIRE datasets are included in the project GIS.

Table 3.4.7.1. A tabulation of NLCD Land Cover classifications in the Upper Green River watershed study area.

NLCD Land Cover Classification	Description	Area	
		Acres	Percent of Watershed
Shrub/Scrub	Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.	1,115,051	59.3%
Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.	320,984	17.1%
Grassland/Herbaceous	Areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.	159,080	8.5%
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.	110,595	5.9%
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or	62,892	3.3%

NLCD Land Cover Classification	Description	Area	
		Acres	Percent of Watershed
	substrate is periodically saturated with or covered with water.		
Woody Wetlands	Areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	40,885	2.2%
Barren Land (Rock/Sand/Clay)	Areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.	26,679	1.4%
Deciduous Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.	23,647	1.3%
Open Water	Areas of open water, generally with less than 25% cover of vegetation or soil.	8,609	0.5%
Developed, Open Space	Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	7,330	0.4%
Developed, Low Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.	2,096	0.1%
Perennial Ice/Snow	Areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.	1,824	0.1%
Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.	1,329	0.1%
Developed, Medium Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.	96	<0.1%
Cultivated Crops	Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.	40	<0.1%
Developed, High Intensity	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.	5	<0.1%

Table 3.4.7.2. A tabulation of NWGAP Land Cover classifications in the Upper Green River watershed study area.

NWGAP Land Cover Classification	Area	
	Acres	Percent of Watershed
Inter-Mountain Basins Big Sagebrush Shrubland	338,843	18.0%
Inter-Mountain Basins Montane Sagebrush Steppe	211,397	11.2%
Inter-Mountain Basins Big Sagebrush Steppe	198,290	10.5%
Wyoming Basins Dwarf Sagebrush Shrubland and Steppe	149,775	8.0%
Rocky Mountain Lodgepole Pine Forest	138,440	7.4%
Pasture/Hay	122,605	6.5%
Rocky Mountain Alpine Turf	95,040	5.1%
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	91,686	4.9%
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	84,024	4.5%
Rocky Mountain Subalpine-Montane Mesic Meadow	50,748	2.7%
Rocky Mountain Aspen Forest and Woodland	42,695	2.3%
Inter-Mountain Basins Mixed Salt Desert Scrub	37,149	2.0%
Western Great Plains Saline Depression Wetland	31,805	1.7%
Inter-Mountain Basins Mat Saltbush Shrubland	29,100	1.5%
Introduced Riparian and Wetland Vegetation	29,011	1.5%
Inter-Mountain Basins Cliff and Canyon	22,972	1.2%
Western Great Plains Riparian Woodland and Shrubland	18,792	1.0%
Northwestern Great Plains Mixedgrass Prairie	16,166	0.9%
Rocky Mountain Alpine Fell-Field	14,797	0.8%
Northern Rocky Mountain Subalpine-Upper Montane Grassland	14,412	0.8%
Inter-Mountain Basins Greasewood Flat	14,170	0.8%
Rocky Mountain Alpine Dwarf-Shrubland	13,404	0.7%
Open Water	12,690	0.7%
Western Great Plains Open Freshwater Depression Wetland	12,264	0.7%
Inter-Mountain Basins Shale Badland	11,449	0.6%
Rocky Mountain Alpine-Montane Wet Meadow	9,080	0.5%
Rocky Mountain Foothill Limber Pine-Juniper Woodland	7,976	0.4%
Rocky Mountain Alpine Bedrock and Scree	7,281	0.4%
Western Great Plains Floodplain	6,673	0.4%
Developed, Open Space	5,123	0.3%
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	4,815	0.3%
Inter-Mountain Basins Active and Stabilized Dune	4,520	0.2%
Rocky Mountain Subalpine-Montane Riparian Woodland	4,060	0.2%
Harvested forest-grass regeneration	4,043	0.2%
Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland	3,790	0.2%

NWGAP Land Cover Classification	Area	
	Acres	Percent of Watershed
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	3,178	0.2%
Harvested forest-tree regeneration	3,169	0.2%
Rocky Mountain Subalpine-Montane Riparian Shrubland	2,580	0.1%
Western Great Plains Closed Depression Wetland	2,442	0.1%
Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland	2,012	0.1%
Developed, Low Intensity	1,752	0.1%
Northern Rocky Mountain Subalpine Deciduous Shrubland	1,689	0.1%
Harvested forest-shrub regeneration	1,641	0.1%
North American Alpine Ice Field	1,032	0.1%
Rocky Mountain Subalpine-Montane Fen	980	0.1%
Rocky Mountain Poor-Site Lodgepole Pine Forest	542	<0.1%
Rocky Mountain Lower Montane Riparian Woodland and Shrubland	267	<0.1%
Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	176	<0.1%
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	122	<0.1%
Columbia Plateau Vernal Pool	110	<0.1%
Developed, Medium Intensity	71	<0.1%
Rocky Mountain Cliff, Canyon and Massive Bedrock	70	<0.1%
North American Arid West Emergent Marsh	61	<0.1%
Cultivated Cropland	60	<0.1%
Western Great Plains Badland	49	<0.1%
Introduced Upland Vegetation - Perennial Grassland	19	<0.1%
Northwestern Great Plains Riparian	12	<0.1%
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	8	<0.1%
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	5	<0.1%
Great Plains Prairie Pothole	4	<0.1%
Western Great Plains Cliff and Outcrop	2	<0.1%

Table 3.4.7.3. A tabulation of LANDFIRE Land Cover classifications in the Upper Green River watershed study area.

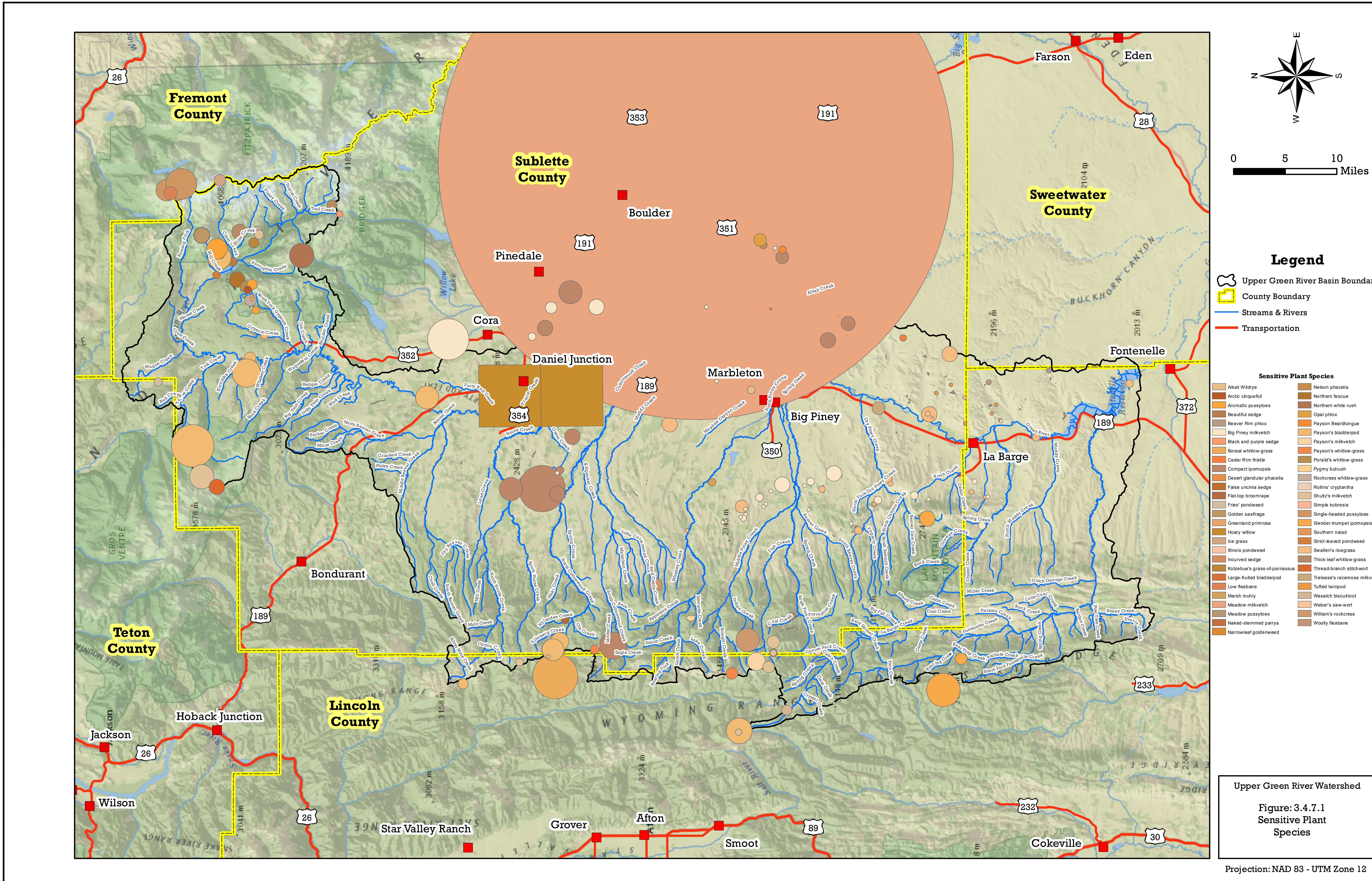
LANDFIRE Land Cover Classification	Area	
	Acres	Percent of Watershed
Inter-Mountain Basins Big Sagebrush Shrubland	406,687	21.6%
Artemisia tridentata ssp. vaseyana Shrubland Alliance	344,589	18.3%
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	153,083	8.1%
Inter-Mountain Basins Big Sagebrush Steppe	142,040	7.6%

LANDFIRE Land Cover Classification	Area	
	Acres	Percent of Watershed
Rocky Mountain Subalpine-Montane Mesic Meadow	89,286	4.7%
Northern Rocky Mountain Subalpine Woodland and Parkland	88,842	4.7%
NASS-Close Grown Crop	69,770	3.7%
Agriculture-Pasture and Hay	60,082	3.2%
Herbaceous Wetlands	59,719	3.2%
Rocky Mountain Alpine Turf	48,342	2.6%
Inter-Mountain Basins Montane Sagebrush Steppe	43,941	2.3%
Rocky Mountain Aspen Forest and Woodland	42,558	2.3%
Rocky Mountain Subalpine/Upper Montane Riparian Systems	31,162	1.7%
Barren	26,998	1.4%
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	25,147	1.3%
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	22,487	1.2%
Northern Rocky Mountain Subalpine-Upper Montane Grassland	20,091	1.1%
Western Great Plains Floodplain Systems	18,803	1.0%
Rocky Mountain Montane Riparian Systems	18,012	1.0%
Rocky Mountain Lodgepole Pine Forest	15,095	0.8%
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	14,078	0.7%
Northern Rocky Mountain Subalpine Deciduous Shrubland	13,914	0.7%
Pseudotsuga menziesii Forest Alliance	13,126	0.7%
Introduced Upland Vegetation-Annual and Biennial Forbland	11,293	0.6%
Inter-Mountain Basins Greasewood Flat	10,307	0.5%
Wyoming Basins Dwarf Sagebrush Shrubland and Steppe	10,011	0.5%
Rocky Mountain Alpine Dwarf-Shrubland	9,392	0.5%
Inter-Mountain Basins Sparsely Vegetated Systems	9,146	0.5%
Open Water	8,789	0.5%
Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	8,730	0.5%
Inter-Mountain Basins Semi-Desert Grassland	8,414	0.4%
Inter-Mountain Basins Mat Saltbush Shrubland	5,986	0.3%
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	4,919	0.3%
Northern Rocky Mountain Conifer Swamp	4,338	0.2%
Developed-Roads	3,511	0.2%
Inter-Mountain Basins Mixed Salt Desert Scrub	2,897	0.2%
Snow-Ice	2,107	0.1%
Developed-Upland Shrubland	2,071	0.1%
Developed-Upland Herbaceous	1,944	0.1%
Herbaceous Semi-dry	1,696	0.1%
Rocky Mountain Foothill Limber Pine-Juniper Woodland	1,608	0.1%
Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	1,468	0.1%

LANDFIRE Land Cover Classification	Area	
	Acres	Percent of Watershed
Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland	788	<0.1%
Colorado Plateau Pinyon-Juniper Woodland	662	<0.1%
Rocky Mountain Poor-Site Lodgepole Pine Forest	641	<0.1%
Introduced Upland Vegetation-Annual Grassland	593	<0.1%
Rocky Mountain Lower Montane-Foothill Shrubland	413	<0.1%
Recently Burned Herbaceous Wetlands	300	<0.1%
Inter-Mountain Basins Semi-Desert Shrub-Steppe	141	<0.1%
Introduced Upland Vegetation-Perennial Grassland and Forbland	138	<0.1%
NASS-Row Crop-Close Grown Crop	126	<0.1%
Southern Rocky Mountain Ponderosa Pine Woodland	96	<0.1%
Quarries-Strip Mines-Gravel Pits	87	<0.1%
Columbia Plateau Low Sagebrush Steppe	86	<0.1%
Inter-Mountain Basins Juniper Savanna	80	<0.1%
Developed-Upland Deciduous Forest	80	<0.1%
Northwestern Great Plains Mixedgrass Prairie	67	<0.1%
Western Great Plains Depressional Wetland Systems	63	<0.1%
Developed-Upland Evergreen Forest	63	<0.1%
Developed-Medium Intensity	51	<0.1%
Developed-Upland Mixed Forest	51	<0.1%
Southern Rocky Mountain Montane-Subalpine Grassland	42	<0.1%
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	33	<0.1%
Herbaceous Semi-wet	28	<0.1%
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	28	<0.1%
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	18	<0.1%
NASS-Row Crop	7	<0.1%
Recently Burned-Herb and Grass Cover	7	<0.1%
NASS-Fallow/Idle Cropland	6	<0.1%
Agriculture-Cultivated Crops and Irrigated Agriculture	2	<0.1%
Rocky Mountain Bigtooth Maple Ravine Woodland	2	<0.1%
Developed-High Intensity	1	<0.1%
Introduced Riparian Vegetation	1	<0.1%
Recently Disturbed Pasture and Hayland	1	<0.1%

3.4.7.1 SENSITIVE PLANT SPECIES

Mapping from the Wyoming Natural Diversity Database (WYNDD) depicts 55 sensitive plant species (Table 3.4.7.4) with known occurrences within the watershed (Figure 3.4.7.1-Sensitive Plant Species). Sixteen of these species are listed as critically imperiled in the state. The critically



Upper Green River Watershed

Figure: 3.4.7.1 Sensitive Plant Species

imperiled species include: meadow milkvetch (*Astragalus diversifolius*), beautiful sedge (*Carex concinna*), Rollins' cryptantha (*Cryptantha rollinsii*), woolly fleabane (*Erigeron lanatus*), northern fescue (*Festuca viviparoidea ssp. krajinae*), simple kobresia (*Kobresia simpliciuscula*), thread-branch stitchwort (*Minuartia filiorum*), southern naiad (*Najas guadalupensis*), ice grass (*Phippsia algida*), Fries' pondweed (*Potamogeton friesii*), Illinois pondweed (*Potamogeton illinoensis*), Strict-leaved pondweed (*Potamogeton strictifolius*), arctic cinquefoil (*Potentilla hyparctica*), Greenland primrose (*Primula egaliksensis*), pygmy bulrush (*Trichophorum pumilum*), and flatleaf bladderwort (*Utricularia intermedia*).

Table 3.4.7.4. Sensitive plant species mapped by Wyoming Natural Diversity Database in the Upper Green River watershed.

Scientific Name	Common Name	Global Rank	State Rank	BLM Sensitive Species	USFS Sensitive Species
Achnatherum swallenii	Swallen's ricegrass	G3G4	S2	N	N
Antennaria arcuata	Meadow pussytoes	G2	S2	Y	Y
Antennaria aromatica	Aromatic pussytoes	G4	S3	N	Y
Antennaria monocephala	Single-headed pussytoes	G4G5	S2	N	Y
Astragalus diversifolius	Meadow milkvetch	G2	S1	Y	Y
Astragalus drabelliformis	Big Piney milkvetch	G2G3	S2S3	N	N
Astragalus paysonii	Payson's milkvetch	G3	S2	N	Y
Astragalus racemosus var. treleasei	Trelease's racemose milkvetch	G5	S2	Y	N
Astragalus shultziorum	Shultz's milkvetch	G3	S3	N	N
Boechera williamsii var. williamsii	William's rockcress	G3	S3	N	N
Carex concinna	Beautiful sedge	G5	S1	N	N
Carex incurviformis var. danaensis	Incurved sedge	G4G5	S2	N	N
Carex luzulina var. atropurpurea	Black and purple sedge	G5	S2	N	Y
Carex microglochin	False uncinia sedge	G5?	S2	N	N
Cirsium aridum	Cedar Rim thistle	G2	S2	Y	N
Cryptantha rollinsii	Rollins' cryptantha	G3	S1	N	N
Draba borealis	Boreal whitlow-grass	G4	S2	N	N
Draba crassa	Thick-leaf whitlow-grass	G3G4	S3	N	N
Draba globosa	Rockcress whitlow-grass	G3	S2S3	N	Y
Draba paysonii var. paysonii	Payson's whitlow-grass	G5	S2	N	N
Draba porsildii	Porsild's whitlow-grass	G3G4	S2	N	N
Elymus simplex var. simplex	Alkali Wildrye	G3	S2	N	N
Ericameria discoidea var. linearis	Narrowleaf goldenweed	G4G5	S2	N	Y
Erigeron humilis	Low fleabane	G5	S2	N	N
Erigeron lanatus	Woolly fleabane	G3G4	S1	N	Y
Festuca viviparoidea ssp. krajinae	Northern fescue	G4G5	S1	N	N
Ipomopsis crebrifolia	Compact ipomopsis	G3G4	S3	N	N
Juncus triglumis var. albescens	Northern white rush	G5	S2	N	N
Kobresia simpliciuscula	Simple kobresia	G5	S1	N	Y
Lesquerella macrocarpa	Large-fruited bladderpod	G2	S2	Y	N
Lesquerella paysonii	Payson's bladderpod	G3	S3	N	Y
Lomatium bicolor var. bicolor	Wasatch biscuitroot	G4	S2	N	N
Minuartia filiorum	Thread-branch stitchwort	G3G4	S1	N	N

Muhlenbergia glomerata	Marsh muhly	G5	S2	N	N
Najas guadalupensis	Southern naiad	G5	S1	N	N
Orobanche corymbosa var. corymbosa	Flat-top broomrape	G4	S1S2	N	N
Parnassia kotzebuei	Kotzebue's grass-of-parnassus	G5	S2	N	Y
Parrya nudicaulis	Naked-stemmed parrya	G5	S2	N	Y
Penstemon paysoniorum	Payson Beardtongue	G3	S3	N	N
Phacelia glandulosa var. deserta	Desert glandular phacelia	G4	S2	N	N
Phacelia salina	Nelson phacelia	G3?	S2	N	N
Phippsia algida	Ice grass	G5	S1	N	N
Phlox opalensis	Opal phlox	G3	S3	N	N
Phlox pungens	Beaver Rim phlox	G3	S3	Y	N
Physaria condensata	Tufted twinpod	G2G3	S2S3	Y	N
Potamogeton friesii	Fries' pondweed	G4	S1	N	N
Potamogeton illinoensis	Illinois pondweed	G5	S1	N	N
Potamogeton strictifolius	Strict-leaved pondweed	G5	S1?	N	N
Potentilla hyparctica	Arctic cinquefoil	G4G5	S1	N	N
Primula egaliksensis	Greenland primrose	G4	S1	N	Y
Salix candida	Hoary willow	G5	S2	N	Y
Saussurea weberi	Weber's saw-wort	G2G3	S2	N	Y
Saxifraga serpyllifolia var. chrysantha	Golden saxifrage	G4	S2	N	N
Trichophorum pumilum	Pygmy bulrush	G5	S1	N	N
Utricularia intermedia	Flatleaf bladderwort	G5	S1	N	N

G = Range-wide probability of extinction (1 = critically imperiled; 2 = imperiled; 3 = vulnerable; 4 = apparently secure; 5 = secure)

S = State-wide probability of extinction (1 = critically imperiled; 2 = imperiled; 3 = vulnerable; 4 = apparently secure; 5 = secure)

3.4.7.2 THREATENED AND ENDANGERED PLANT SPECIES

According to the U.S. Fish and Wildlife Service (USFWS), the Ute ladies'-tresses orchid is the only ESA-listed plant species with known or suspected habitat within the watershed. The existing and historical range of Ute ladies'-tresses includes western Nebraska, southeastern Wyoming, northeastern and southern Utah, east-central Idaho, southwestern Montana, southeastern Nevada, and central Washington (Fertig et al. 2005). Ute ladies'-tresses have been documented at elevations between 4,300 and 7,000 feet in the central Rocky Mountains and adjacent plains. Two isolated Ute ladies'-tresses populations found in Washington State are located in considerably lower elevations (i.e., 720-1,830 feet). In response to the Ute ladies'-tresses global rarity, and current threats to this species, the USFWS listed this orchid as a threatened species under the ESA in 1992.

Ute ladies'-tresses are typically found associated with dynamic hydrologic features, including perennial and seasonally flooded watercourses and terraces, floodplains, oxbows, and sub-irrigated or spring-fed abandoned channels, and valleys. Hydrologic regimes within these riverine systems provide periodic flood events that support alluvial processes and create early successional conditions conducive to the establishment of Ute ladies'-tresses populations. Since 1992, Ute ladies'-tresses populations have been discovered along irrigation canals, berms, levees, irrigated meadows, excavated gravel pits, roadside borrow pits, reservoirs, and other modified wetlands (Fertig et al. 2005).

Extensive Ute ladies'-tresses surveys have been conducted in eastern Wyoming, where known populations have been documented. Populations have been discovered in Goshen, Laramie, Niobrara, and Converse Counties, all of which are located in southeastern Wyoming (USFWS 2005). Surveys have been conducted in numerous other locations throughout Wyoming with negative results. Despite suitable habitat, to date, no observations of this species in the Upper Green River watershed or associated counties have been recorded.

REFERENCES

Fertig, W., R. Black, and P. Wolken. 2005. Rangewide status review of Ute ladies'-tresses (*Spiranthes diluvialis*) Prepared for US Fish and Wildlife Service and Central Utah Water Conservancy District, 211 pp.

US Fish and Wildlife Service. 2005. Draft Biological Opinion for the Wyoming Statewide Transportation Improvement Program

3.4.8 WETLANDS

Wetlands are among the most important ecosystems on Earth, and they play an essential role in the landscape by providing unique habitats for a diverse array of plants and animals (Mitsch and Gosselink 1986). This is especially true in the semiarid and arid portions of the Intermountain West, where precipitation is highly variable and strongly dependent on topography and elevation. Approximately 90% of the wildlife species in Wyoming utilize wetlands and riparian habitats at some point during their life cycle, and about 70% of Wyoming bird species are wetland or riparian obligates (Nicholoff 2003).

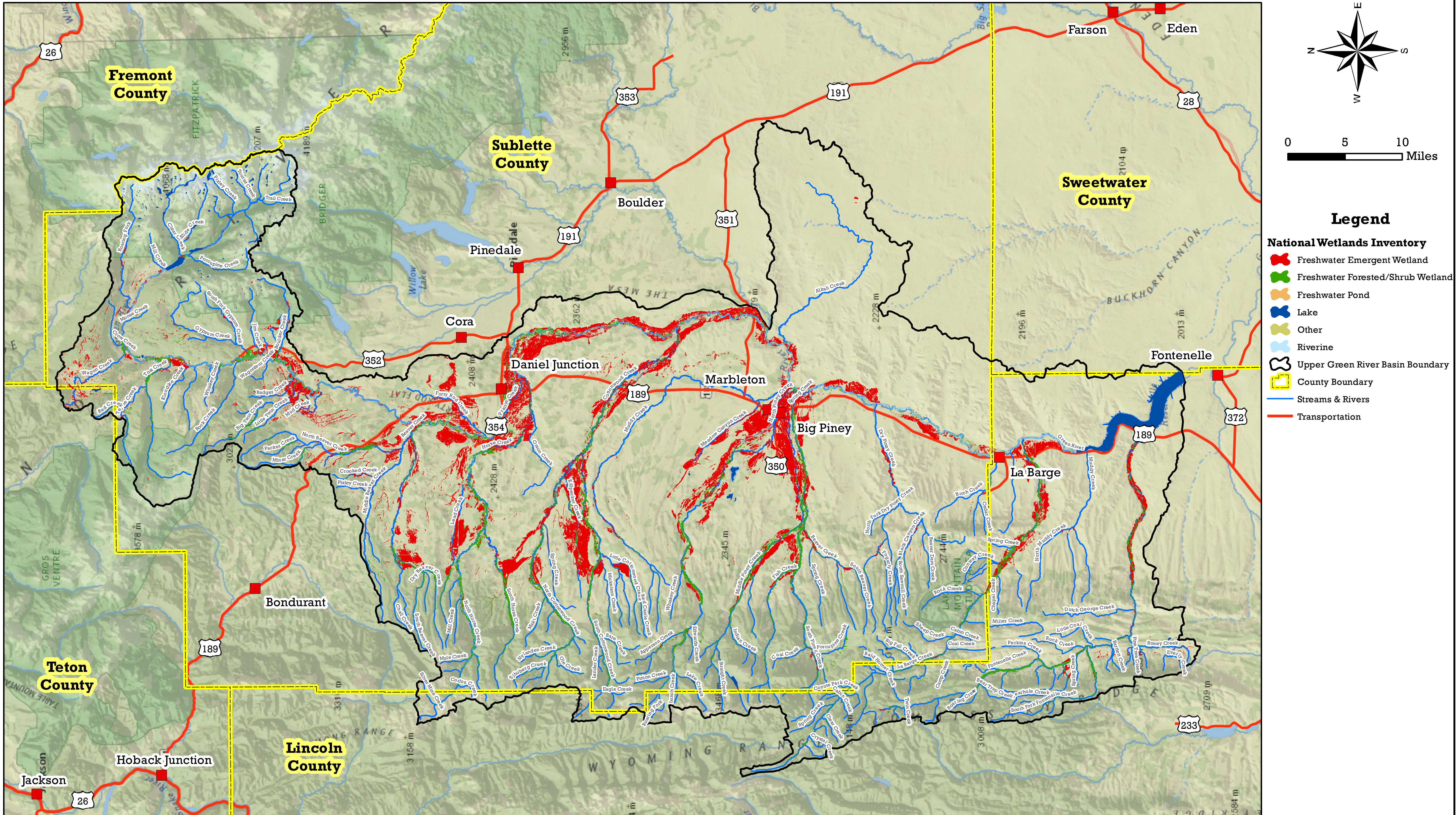
According to the WGFD, the wetland complex in the Upper Green River basin contains approximately 20% of the wetlands in Wyoming. Due in large part to the importance of these wetlands, the WGFD, along with 15 other partners, received a standard NAWCA (North American Wetland Conservation Act) grant in 2013 from the USFWS for wetland restoration, enhancement, and protection in the Upper Green River watershed. The grant will fund several projects including a large conservation easement acquisition in the Cottonwood Creek drainage and 2 large-scale wetland restoration projects on private ranches in the southern portion of the watershed. Approximately 1,500 acres of wetlands and riparian habitat will be protected and/or restored through this grant.

Ecological processes associated with wetlands provide a variety of environmental maintenance functions on global, regional, and local scales. These functions include, but are not limited to: water quality improvement (e.g., nutrient uptake and sediment retention), erosion control, groundwater recharge, flood attenuation, and fish and wildlife habitat. Landscape position helps to determine prominent functions for each particular wetland. As is common for arid basins throughout the intermountain west, wetlands in the Upper Green River watershed study area are concentrated along natural and manmade (e.g., irrigation ditches) watercourses.

3.4.8.1 WETLAND TYPES AND DISTRIBUTION

Wetland data for the watershed were obtained from the US Fish and Wildlife Service's National Wetlands Inventory (NWI) mapping and cross-referenced with the NLCD and NWGAP analysis. The USFWS established the National Wetlands Inventory (NWI) program in the mid-1970s to provide resource managers with information on the location, extent, and types of wetlands and deepwater habitats in the U.S. The program has been mapping wetlands and deepwater habitats since it was established. The objective of the mapping is to produce medium resolution information that is accurate at the product scale of 1:12,000. Recently, efforts have been made to digitize and update these wetland data. As a result, this is the most readily available and comprehensive wetland dataset in the country. NWI mapping utilizes wetland classification codes following the National Wetlands Classification Standard, which is based on Cowardin et al. (1979).

According to the NWI, 7.7% (144,743 acres) of the Upper Green River watershed study area is comprised of wetlands and deepwater habitats (Table 3.4.8.1; Figure 3.4.8.1-Wetlands and Deep Water Habitats). The NWI depicts 19 unique wetland classifications for mapped wetlands within the study area, all of which are broadly defined as freshwater emergent wetlands or freshwater forested/shrub wetlands. Wetlands primarily occur along the watercourses in the Upper Green River watershed. They are heavily concentrated in the lower portions of the tributary watersheds and along the mainstem Green River. The freshwater emergent wetlands in the watershed exist primarily as fringes along watercourses; in depressional floodplain areas; and in subirrigated or flood irrigated agricultural fields. Freshwater forested/shrub wetlands are dominated by woody shrubs and trees such as willow, dogwood, cottonwood, and alder.



Upper Green River Watershed

Figure: 3.4.8.1
Wetland
and
Deep Water Habitats

Projection: NAD 83 - UTM Zone 12

Table 3.4.8.1. A tabulation of NWI wetland and deepwater habitats in the Upper Green River watershed.

Habitat Type	Examples	Area	
		Acres	**Percent of Watershed**
Wetlands			
Freshwater Emergent Wetland	wet meadow, fen, marsh, swale	96,104	5.1%
Freshwater Forested/Shrub Wetland	scrub-shrub meadow, forested floodplain wetland	29,702	1.6%
	Subtotal	**125,807**	**6.7%**
Deepwater			
Freshwater Pond	excavated/impounded pond	2,523	0.1%
Lake	lake or reservoir	11,184	0.6%
Riverine	river or stream	5,154	0.3%
Other		75	0.0%
	Subtotal	**18,936**	**1.0%**
	Total Wetlands and Deepwater Habitat	**144,743**	**7.7%**

No site-specific field data was collected to analyze the accuracy of NWI data in the Upper Green River watershed, but several other studies in Wyoming and around the country have found that NWI mapping often underestimates the amount of wetlands (Winters et al. 2004, WWDC 2011). The NWI data was compared to the wetland/riparian classifications for both the NWGAP and NLCD datasets, and a tabulation of wetland and riparian classifications from these datasets are presented in Table 3.4.8.2. The NWI-mapped wetland area is larger (approximately 20% more area) than similar mapping in both of the other datasets, but it should be noted that the NLCD and NWGAP datasets are not specifically targeting or focusing on wetlands. The NLCD also has some significant limitations due to the large image mosaics used for areal imagery interpretation and resulting spatial resolution of 30 meters. As such, further research and ground-thruthing is necessary to determine the accuracy of NWI mapping in the watershed.

Table 3.4.8.2. A tabulation of wetland and riparian landcover classifications in the Upper Green River watershed.

Landcover Classification		Area (acres)
NLCD		
	Emergent Herbaceous Wetlands	62,892
	Woody Wetlands	40,885
	Subtotal =	**103,777**
NWGAP		
	Western Great Plains Saline Depression Wetland	31,805
	Introduced Riparian and Wetland Vegetation	29,011
	Western Great Plains Open Freshwater Depression Wetland	12,264
	Rocky Mountain Alpine-Montane Wet Meadow	9,080
	Western Great Plains Floodplain	6,673
	Rocky Mountain Subalpine-Montane Riparian Woodland	4,060
	Rocky Mountain Subalpine-Montane Riparian Shrubland	2,580
	Western Great Plains Closed Depression Wetland	2,442
	Rocky Mountain Subalpine-Montane Fen	980
	Rocky Mountain Lower Montane Riparian Woodland and Shrubland	267
	Columbia Plateau Vernal Pool	110
	North American Arid West Emergent Marsh	61
	Northwestern Great Plains Riparian	12
	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	8
	Great Plains Prairie Pothole	4
	Subtotal =	**99,358**

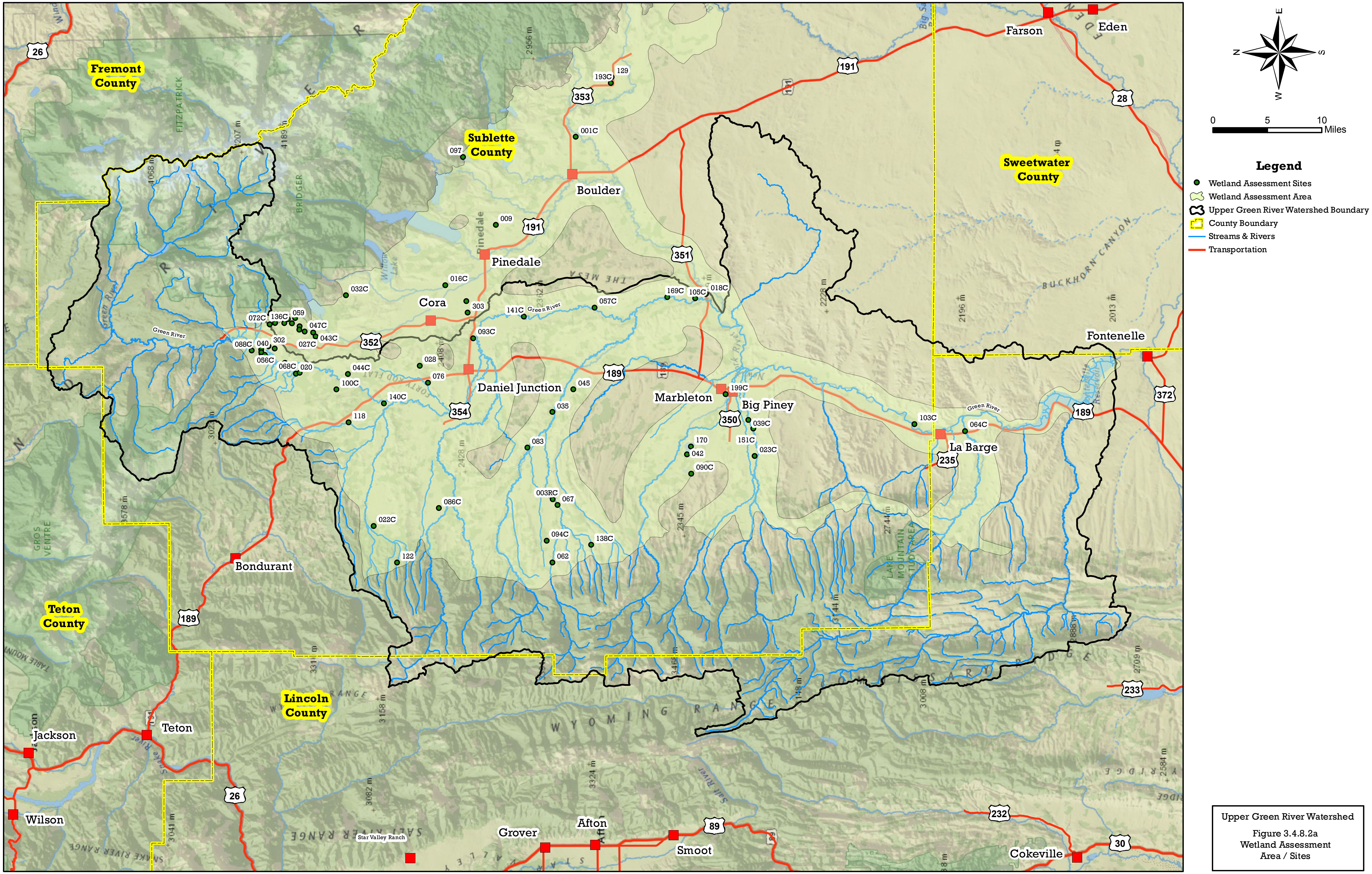
3.4.8.2 WETLAND CONDITION ASSESSMENT

Wetlands are dynamic systems that provide many important ecological services and functions, but the rate at which these services are provided is strongly dependant on landscape setting and associated level of direct or indirect anthropogenic disturbance. Wetlands play a critical role in the ecology of watersheds because they serve as the link between upland and aquatic ecosystems Wetlands provide numerous ecological functions such as water quality improvement, nutrient uptake, sediment retention, flood water attenuation, erosion control, groundwater recharge/discharge, and they provide habitat for a large majority of the fish and wildlife species that inhabit the watershed. Wetlands store precipitation and surface water and then slowly release the water into adjacent surface water resources, ground water and/or the atmosphere.

In terms of water quality, the fluctuating water levels that occur in most wetlands influence the oxidation-reduction (redox) conditions that play a key role in nutrient cycling, pH; vegetation composition; sediment and organic matter accumulation; decomposition; and metal availability. Wetland processes influence the global cycles of carbon, nitrogen, and sulfur by transforming them and releasing them into the atmosphere. The chemical transformations associated with redox conditions can substantially improve the quality of water flowing through wetlands. In addition, the vegetation growing in wetlands physically slows floodwaters and traps sediment, thereby reducing the amount of sediment in the adjacent waterbody. Wetlands with soils containing clays, peat, aluminum, iron, and/or calcium have the ability remove metals from surface and ground water. These metals bind to soil particles and are typically buried in sediment and immobilized. The rate and efficiency with which many of these ecological services are performed depends heavily on the condition or health of the wetlands.

A number of protocols have been developed to assess wetland condition in the Rocky Mountain region (e.g., Montana Wetland Assessment Method, Functional Assessment of Colorado Wetlands Methodology, Hydrogeomorphic Approach to Assessing Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains, etc.). Most of these protocols were developed for regulatory purposes, but they are also used to inform restoration and mitigation projects, assist with wetland management, and facilitate long-term monitoring projects. A comprehensive wetland condition assessment within the study area was beyond the scope and budget of this Level 1 watershed study; however, the Wyoming Game and Fish Department and the Nature Conservancy is in the process of analyzing data from a wetland condition assessment performed in the Upper Green River watershed in 2012.

The Wyoming Wetlands Conservation Strategy was developed by the Wyoming Joint Ventures Steering Committee in September 2010. One of the primary objectives of the Wetlands Conservation Strategy was to delineate important wetland and riparian habitat areas throughout Wyoming and assess their condition (Wyoming Joint Ventures Steering Committee 2010). The Upper Green River Basin was one of nine wetland complexes identified as a statewide priority in the Wetlands Conservation Strategy. Following guidance issued in the Wetlands Conservation Strategy, an assessment of wetland condition in the Upper Green River watershed was conducted by the WGFD and the Nature Conservancy (TNC) in 2012. The field work was completed in 2012, but the final project report was not available at the time this Level I watershed study was finalized. The study assessed the condition of 60 randomly-selected wetlands using a protocol that was primarily based on the USEPA's Rapid Assessment Method (USA RAM). A portion of the wetlands sampled (n=22) are located in the New Fork River watershed, which was not included in the Upper Green River watershed study area. Field sites for the wetland assessment study are depicted in Figure 3.4.8.2a-Wetland Assessment Area/Sites, and Figures 3.4.8.2b and 3.4.8.2c depict examples of wetlands included in the study.



Upper Green River Watershed

Figure 3.4.8.2a
Wetland Assessment
Area / Sites

Projection: NAD 83 - UTM Zone 12

Figure 3.4.8.2b. Photograph of a reference wetland included in the 2012 WGFD/TNC Wetland Condition Assessment for the Upper Green River Basin

Figure 3.4.8.2c. Photograph of a wetland included in the 2012 WGFD/TNC Wetland Condition Assessment for the Upper Green River Basin

3.4.8.3 WETLAND MITIGATION

In 1972, Congress enacted comprehensive national clean water legislation in response to growing public concern for water pollution. Today, the Clean Water Act is the primary federal law that protects waters, including lakes, rivers, coastal areas and wetlands in the United States. Section 404 of the Clean Water Act regulates the discharge of dredged or fill material into waters of the U.S., including wetlands. The U.S. Army Corps of Engineers and U.S. Environmental Protection Agency are jointly charged with overseeing the permitting and enforcement of the Section 404 program. The Corps is responsible for the day-to-day administration and permit review, and the EPA provides program oversight.

The rationale of the program is that no discharge of dredged or fill material into waters of the U.S. should be permitted if there is a practicable alternative that would be less damaging to our aquatic resources or if significant degradation would occur to the nation's waters. Permit review and issuance follows a sequence process that encourages avoidance of impacts, followed by minimizing impacts and, finally, requiring mitigation for unavoidable impacts to the aquatic environment.

The USACE and the USEPA issued a compensatory mitigation rule in the Federal Register in April 2008 (33 CFR Parts 325 and 332; 40 CFR Part 230; http://water.epa.gov/lawsregs/guidance/wetlands/upload/2008_04_10_wetlands_wetlands_mitigation_final_rule_4_10_08.pdf). The intent of the rule is to govern the compensatory mitigation for activities authorized by Section 404 permits issues by the USACE. According to the final rule, these regulations will improve *"the planning, implementation, and management of compensatory mitigation projects by emphasizing a watershed approach in selecting compensatory mitigation project locations, requiring measurable, enforceable ecological performance standards and regular monitoring for all types of compensation and specifying the components of a complete compensatory mitigation plan, including assurances of long-term protection of compensation sites, financial assurances, and identification of the parties responsible for specific project tasks."* The goal of the watershed approach is to maintain and improve the quality and quantity of aquatic resources in a watershed through strategic selection of mitigation sites. The watershed approach ensures that unavoidable impacts to aquatic resources are mitigated in the same watershed and target the same suite of ecological functions typically provided by the affected aquatic resource.

Activities associated with the construction of upland water developments, reservoir impoundments, and other related development in the watershed may require Section 404 permits and, if wetland impacts exceed the threshold set by the USACE (typically 0.1 acres), may require compensatory wetland mitigation. In order to gain an understanding of potential wetland mitigation opportunities in the Upper Green River watershed, the project team utilized a similar spatial analysis as that utilized in the WWDC Clear Creek watershed study to coarsely identify those lands within the watershed where wetlands could potentially be created or enhanced to satisfy any future compensatory mitigation requirements.

The spatial analysis was conducted in a GIS environment and incorporated soils, vegetation, slope, and proximity to a permanent water source. The result of the analysis coarsely identifies the geographic areas that have the physical characteristics desirable for creation of new wetlands. The following GIS datasets were mapped, and the intersection of these data was considered to be those areas with the potential for wetland creation:

- **Ecological Site Descriptions (ESD) – Soils**: Areas mapped as having clayey and loamy soils, as depicted in current, publicly-available ESD mapping were included in the analysis. Soils data from the USFS soil surveys were also included for lands administered by the USFS.
- **Ecological Site Descriptions (ESD) – Site Type**: Lowland areas, sub-irrigated areas, and wetlands were included in the analysis. ESD data were not available for lands administered by the USFS, but these lands were not excluded from the analysis. Wetland areas were included because it is possible to utilize wetland enhancement as a form of compensatory mitigation. Rocky, sandy, coarse, and saline areas were excluded from the analysis.
- **LANDFIRE Database – Existing Vegetation Type**: All vegetation types were included, with the exception of forested vegetation types, barren areas, developed areas, and snow/ice areas, which were eliminated from the analysis.
- **LANDFIRE Database – Slope**: Areas with a topographic slope of 3 degrees or less (5.2 percent or less) were included in the analysis.
- **Water Supply**: It is desirable to create wetlands in areas with shallow groundwater and/or adjacent surface waters. No comprehensive groundwater data is available, so proximity to existing surface waters was used for this coarse-level analysis. Areas within 200 m of existing, permanent water sources (including lakes, streams, and springs) were included. Although areas of shallow groundwater likely exist beyond the 200 m buffer, it was estimated that an average of 200 m would be a reasonable maximum distance from a permanent water source given the amount of earth that is necessary to move to reach the water table when creating wetlands.

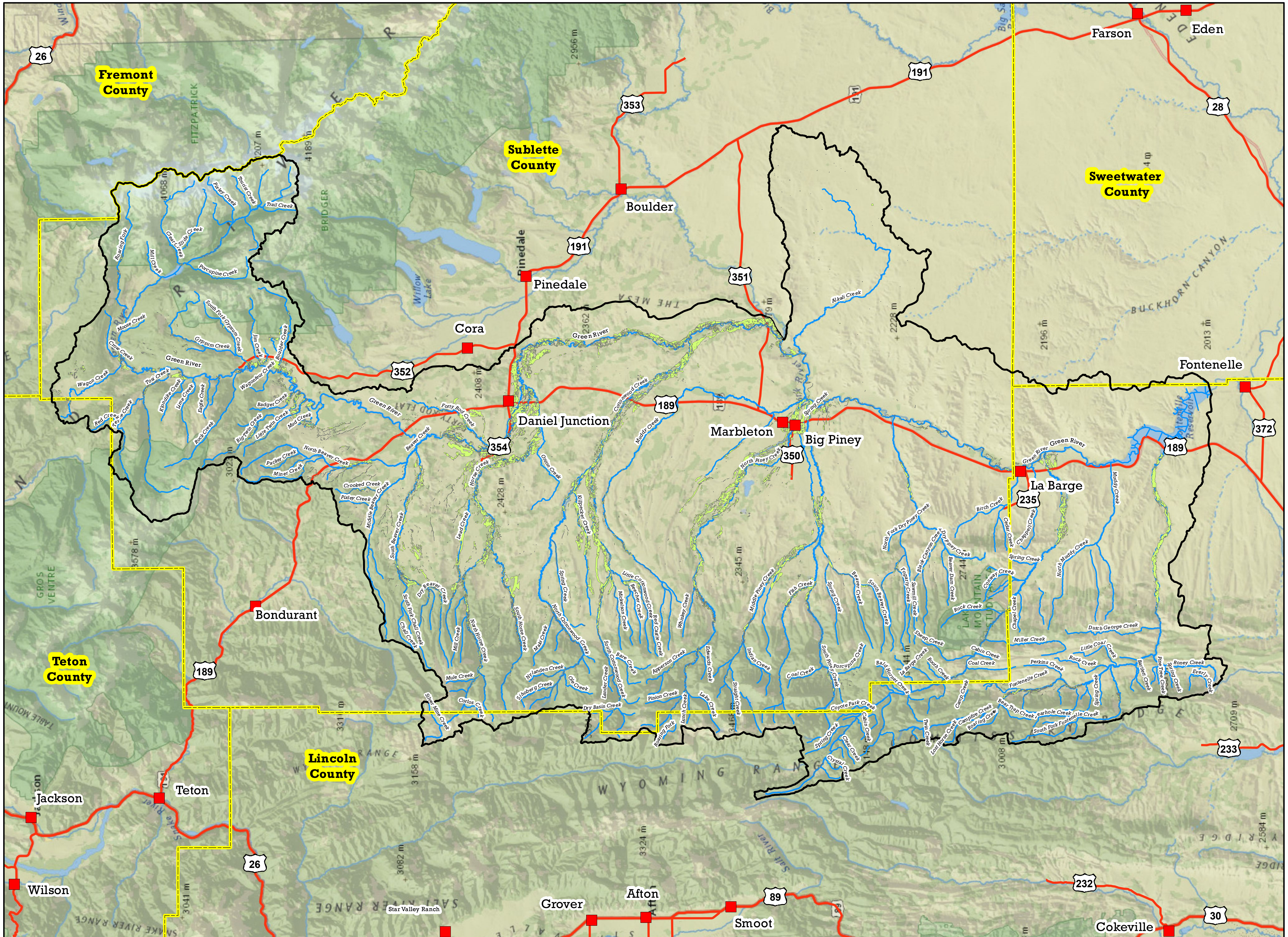
Figure 3.4.8.3-Potential Wetland Mitigation Sites depicts the results of the wetland mitigation site analysis at watershed scale. As would be expected, the potential wetland mitigation areas lie primarily within existing floodplains. Due to the scale of the analysis, the results of this analysis should only be used as a general planning tool to provide a preliminary coarse-level look at sites that might have the necessary components to support wetland creation. Site-specific investigations would be required to determine the feasibility of mitigation at any particular site.

REFERENCES

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. USDI Fish and Wildlife Service, Wash. DC. 131pp.

Mitsch, W. J. and J. G. Gosselink. 1986. Wetlands. 537 pp.

Nicholoff, S. H. 2003. Wyoming Bird Conservation Plan, Version 2.0. Wyoming Partners In Flight.



0 5 10 Miles

Legend

- Potential Wetland Mitigation Sites
- Upper Green River Watershed Boundary
- County Boundary
- Streams & Rivers
- Transportation

Upper Green River Watershed

Figure 3.4.8.3
Potential Wetland
Mitigation Sites

Projection: NAD 83 - UTM Zone 12

Wyoming Game and Fish Department, Lander, Wyoming. *http://www.blm.gov/wildlife/plan/WY/Wyoming%20Bird%20Conservation%20Plan.htm*

Wyoming Joint Ventures Steering Committee. 2010. Wyoming Wetlands Conservation Strategy. Version 1.0. 108 pp.

Winters, D.S. et al. 2004. Aquatic, riparian and wetland ecosystem assessment for the Bighorn National Forest. Report 1 of 3: Introduction and ecological driver analysis. Denver, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region.

3.4.9 INVASIVE SPECIES

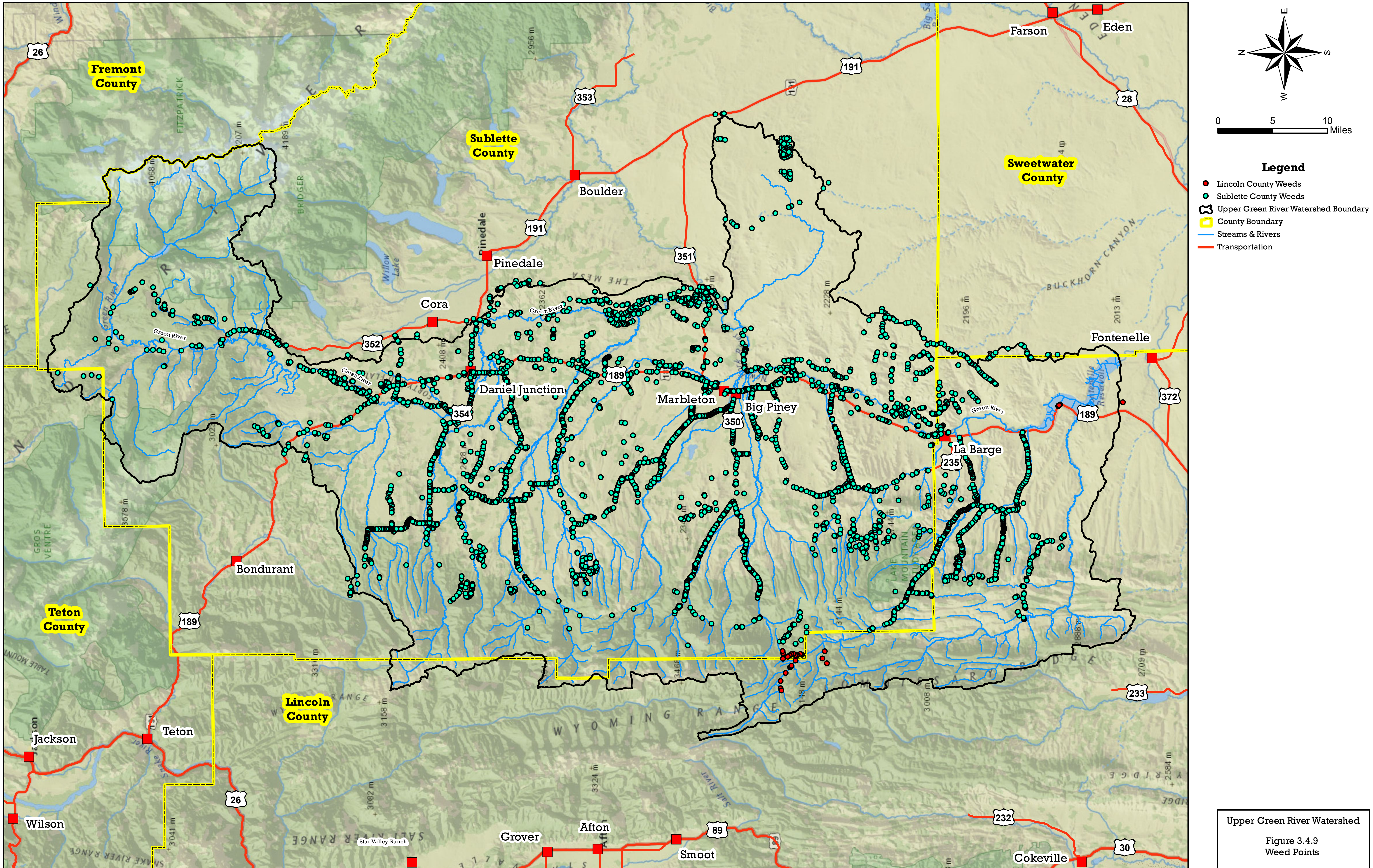
Noxious and invasive weeds inhabit approximately 1.3 million acres in the State of Wyoming (Wyoming Weed Management Strategic Plan 2003). These weeds pose a substantial threat to Wyoming's wildland, cropland, and rangeland. The Wyoming Weed Management Strategic Plan was developed in response to this threat. The strategic plan lays out three strategies to maintain healthy ecosystems in the state. These strategies include:

- cooperation among agencies, organizations, and individuals;
- development and integration of integrated weed management programs; and
- program assessment.

On a regional level, the Green River Basin Cooperative Weed Management Area (CWMA) is a consortium of private landowners and local, state, and federal agencies that have joined together to cooperatively manage invasive weeds as if there are "no fences". The CWMA allows these entities to coordinate actions and share resources. The CWMA holds several cooperative spray days each summer, where CWMA members combine forces to treat weeds in designated areas.

The 4 counties within the study area also have active weed and pest control districts, coordinated through the Wyoming Weed and Pest Council. Individual Weed and Pest Control District office information can be obtained from the state Weed and Pest Council web site (http://www.wyoweed.org/addresses.html). These weed and pest districts primarily rely on chemical application to treat Wyoming designated and County declared noxious weeds, but some alternative weed control methods, such as biocontrol with insects, are also employed. The weed and pest districts have limited staff for weed control, but most have cost-share programs that reimburse landowners for a portion of the costs associated with pesticide application. Spatial weed mapping data from Sublette and Lincoln County are depicted in Figure 3.4.9-Weed Points. Weed points depicted on the map are locations where weed infestations have been confirmed. According to the Sublette County Weed and Pest Control District (SCWPD), most of the mapped weed points in Sublette County have been or are actively being treated with herbicide.

Sublette County, in particular, has an extensive weed control program that incorporates mechanical, chemical, and biological control methods. The current noxious weed list for the State of Wyoming includes 25 species, and Sublette County has an additional 5 species on the declared county weed list (Table 3.4.9.1). The Sublette County Invasive Species Task Force was formed in



Upper Green River Watershed

Figure 3.4.9
Weed Points

Projection: NAD 83 - UTM Zone 12

2010 to study the extent of the weed problem in the county. Most recently, the task force has focused their efforts on mapping cheatgrass (Bromus tectorum) infestations. Although not on the state or county noxious weed list, cheatgrass is a priority weed species in the Upper Green River watershed. It is an aggressive, annual grass that rapidly invades disturbed sites, especially after fire. Once it has invaded an area, it spreads rapidly and prevents the native plant community reestablishing. In 2013, the Sweetwater County Weed Control District, in partnership with the BLM, has been using Plateau, a broad-spectrum herbicide, to control cheatgrass. Plateau is most effective for cheatgrass control when it is applied in the late summer or fall, and follow-up applications may be necessary in subsequent years to deplete the cheatgrass seed bank.

The SCWPD strongly promotes "early detection and rapid response", which is the process of actively searching for new weed invaders, assessing their risk potential and responding immediately with an appropriate control. According to SCWPD supervisor, Adrianne Peterson, two noxious weeds that are abundant in the Upper Green River watershed are Canada thistle and musk thistle, but the county has primarily focused management efforts (e.g., herbicide application) on treating new invaders to reduce the chance of new infestations. Canada thistle and musk thistle are both listed on the state noxious weed list and are highly invasive, covered with sharp spines, and produce abundant wind-dispersed seed. They quickly invade disturbed areas, especially in agricultural settings. They are typically controlled with herbicide

New invaders are weeds not known to be found in the county except for in isolated and containable infestations with high potential for control. These new invaders may or may not be on the state or county noxious weed lists. Three new invaders targeted in Sublette County in 2013 are knotweed (Polygonum), St. Johnswort (Hypericum perforatum), and dyers woad (Isatis tinctoria). The SCWPD states in their 2012 newsletter that perennial pepperweed (Lepidium latifolium) is the most invasive noxious weed in Sublette County and notes that it is an aggressive invader in riparian areas and irrigated meadows and may be poisonous in hay. Perennial pepperweed has an aggressive root system and can grow to heights of 6 feet. This species has invaded hundreds of acres along the Green River. The SCWPD coordinates multiple "Perennial Pepperweed Spray Days" throughout the growing season with the Green River Basin CWMA. The SCWPD also has a cost-share program available for Sublette County residents.

Pesticides purchased by a Sublette County resident from SCWPD for treatment of Wyoming Designated or Sublette County Declared Noxious Weed will get a cost share of 75%, with a cap at $1,000 per person. SCWPD will also cover 35% of contracted labor costs for the pesticide application, with a cap of $10,000. You must call ahead about your project and turn in your application record and proof of payment to SCWPD. In addition Sublette County Weed and Pest provides backpack, ATV sprayers, slide-in and hand sprayers at no cost to residents or property owners in Sublette County. See Section 4.5.3 of this report for further details on invasive species management.

Table 3.4.9.1. State of Wyoming and Sublette County noxious weed lists.

Common Name	**Scientific Name**
State of Wyoming Designated/Prohibited Noxious Weed List	
Field bindweed	*Convolvulus arvensis*

Canada thistle	*Cirsium arvense*
Leafy spurge	*Euphorbia esula*
Perennial sowthistle	*Sonchus arvensis*
Quackgrass	*Agropyron repens*
Hoary cress	*Cardaria pubescens*
Perennial pepperweed	*Lepidium latifolium*
Ox-eye daisy	*Chrysanthemum leucanthemum*
Skeletonleaf bursage	*Franseria discolor*
Russian knapweed	*Centaurea repens*
Yellow toadflax	*Linaria vulgaris*
Dalmatian toadflax	*Linaria dalmatica*
Scotch thistle	*Onopordum acanthium*
Musk thistle	*Carduus nutans*
Common burdock	*Arctium minus*
Plumeless thistle	*Carduus acanthoides*
Dyer's woad	*Isatis tinctoria*
Houndstongue	*Cynoglossum officinale*
Spotted knapweed	*Centaurea maculosa*
Diffuse knapweed	*Centaurea diffusa*
Purple loosestrife	*Lythrum salicaria*
Saltcedar	*Tamarix sp.*
Common St. Johnswort	*Hypericum perforatum*
Common Tansy	*Tanacetum vulgare*
Russian olive	*Elaeagnus angustifolia*
Sublette County Declared Noxious Weed List	
Black Henbane	*Hyoscyamus niger*
Scentless Chamomile	*Matricaria perforata*
Western Water Hemlock	*Cicuta douglasii*
Field Scabious	*Knautia arvensis*
Austrian Fieldcress	*Rorippa austriaca*

REFERENCES

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. USDI Fish and Wildlife Service, Wash. DC. 131pp.

Fertig, W., R. Black, and P. Wolken. 2005. Rangewide status review of Ute ladies'-tresses (*Spiranthes diluvialis*) Prepared for US Fish and Wildlife Service and Central Utah Water Conservancy District, 211 pp.

Mitsch, W. J. and J. G. Gosselink. 1986. Wetlands. 537 pp.

US Fish and Wildlife Service. 2005. Draft Biological Opinion for the Wyoming Statewide Transportation Improvement Program. ES-61411/W.17/WY9299BO, ES-6-WY-05-F012. 79 pp.

Wyoming State Weed Team. 2003. Wyoming Weed Management Strategic Plan. 12 pp.

Wyoming Joint Ventures Steering Committee. 2010. Wyoming Wetlands Conservation Strategy. Version 1.0. 108 pp.

3.4.10 WILDLIFE

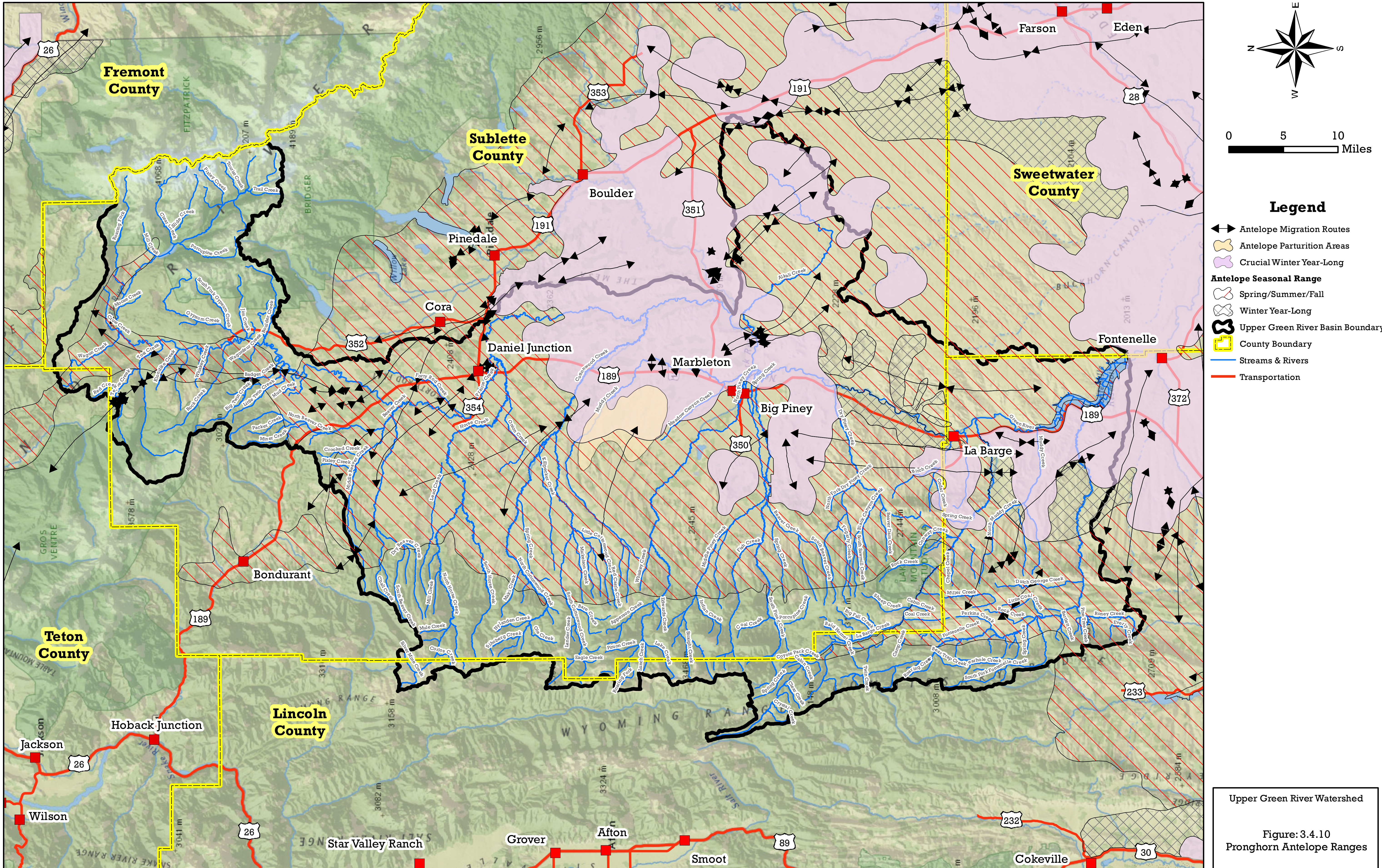
The diversity of wildlife throughout the Upper Green River watershed study area reflects a landscape of highly variable climate, terrain, and vegetation communities. The headwaters originate in alpine tundra above treeline, generally higher than 10,000 feet, to a lowland topography of mesas and buttes, characteristic of the Wyoming Basin. Mountain subalpine forests provide temperate climates and breeding habitat for many resident species, descending through the iconic sagebrush sea, a native plant community of importance to narrow endemic species, resident and migratory wildlife alike. The western ranges intercept precipitation, resulting in moister climates at higher elevations that give way to drier low-elevation desert basins as a result of the rain shadow effect. Upland snowmelt and runoff follow watercourses, where riparian vegetation including trees, shrubs and wetlands along rivers, streams, lakeshores, and reservoirs provide productive and essential habitat for nearly all native vertebrate species in the region.

To inform the wildlife component of this watershed study, the Wyoming Natural Diversity Database (WYNDD) was queried to generate a list of Species of Concern documented from the project area. Species of Concern are categorized by global and state status of species in Wyoming that are rare, endemic, disjunct, threatened, or otherwise biologically sensitive. In addition, species from the BLM or USFS Sensitive Species list are identified (Table 3.4.10.1). This report also provides the most current representations of important seasonal, crucial, parturition and migration corridors developed by the Wyoming Game and Fish Department (WGFD) for native big game species regularly occurring within the watershed study area.

3.4.10.1 BIG GAME

Sagebrush ecosystems in the study area support crucial habitats for some of the largest migratory populations of ungulates in North America. Nearly half (47%) of the upper Green River watershed provides crucial habitat for antelope, mule deer, moose, elk or bighorn sheep. Such habitat is integral to the long-term survival of populations based on various vegetation and landscape variables. Crucial ranges have been defined by the WGFD, as well as seasonal range, parturition areas, major migration routes and known migration barriers (Figures 3.4.10-3.4.14). White-tailed deer exist in small populations along cottonwood-willow river corridors and in proximity to croplands within the watershed; however, these generally sedentary, small herds are not managed by the State or promoted in this area.

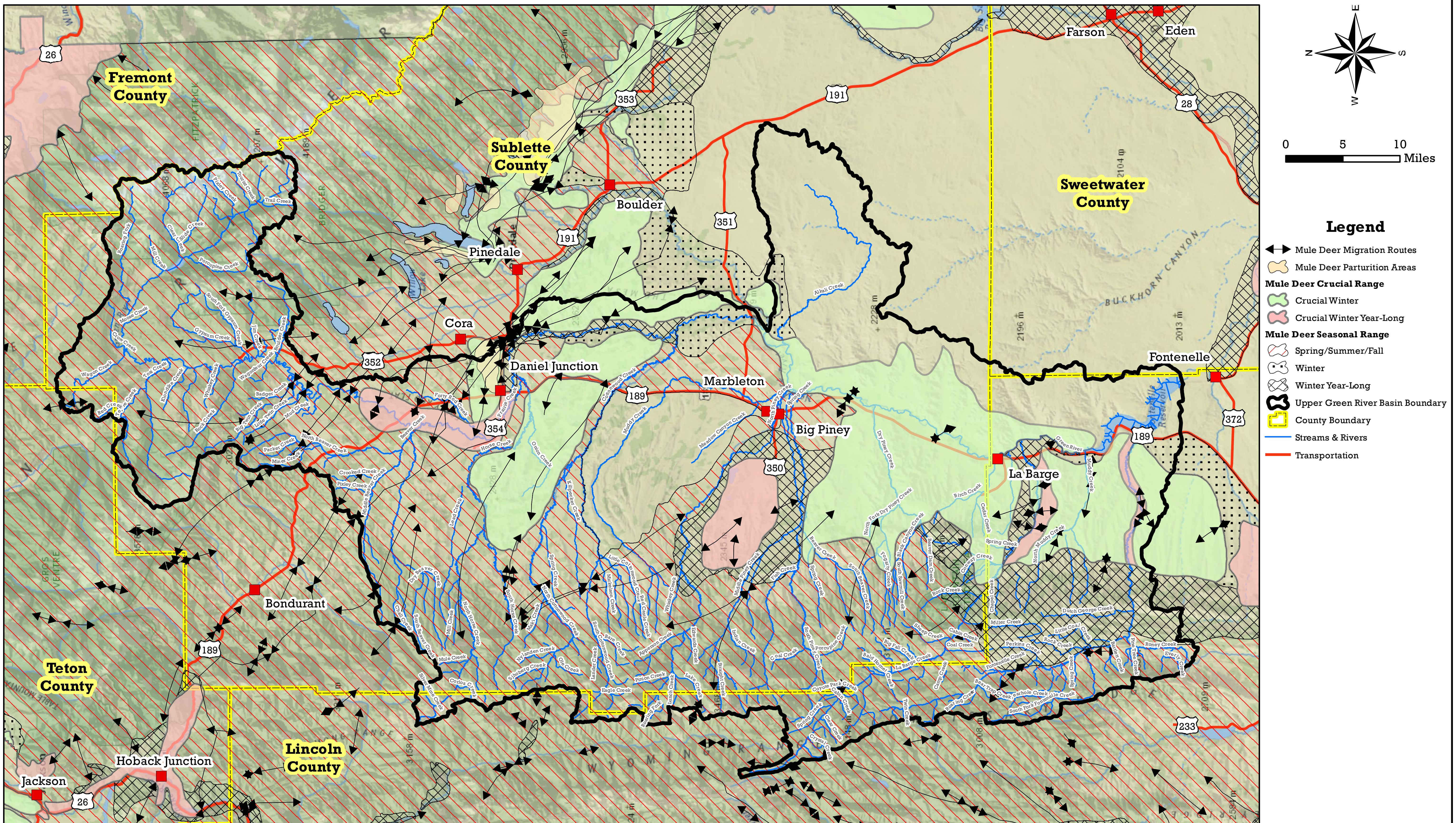
The Sublette pronghorn herd unit, occupying all of Sublette county and portions of Sweetwater, Lincoln, Fremont and Teton counties, occupies most of the Green River drainage north of Interstate Highway 80. The Upper Green River Basin provides extensive crucial winter range to pronghorn antelope where sagebrush and other plant browse species remain available on lower, sun-exposed slopes with lighter snowloads throughout the harshest winter conditions. An estimated 48,000 antelope inhabit this area from which one of the longest migrations of any North American ungulate have been documented. Trapper’s Point has a well-documented bottleneck along the eastern border of the watershed study area through which an estimated 1,500 to 2,000 pronghorn migrate twice a year (Sawyer et al. 2005). Additional migration routes and seasonal movements used by this herd are not as well understood; however, it is widely accepted that free



Upper Green River Watershed

Figure: 3.4.10
Pronghorn Antelope Ranges

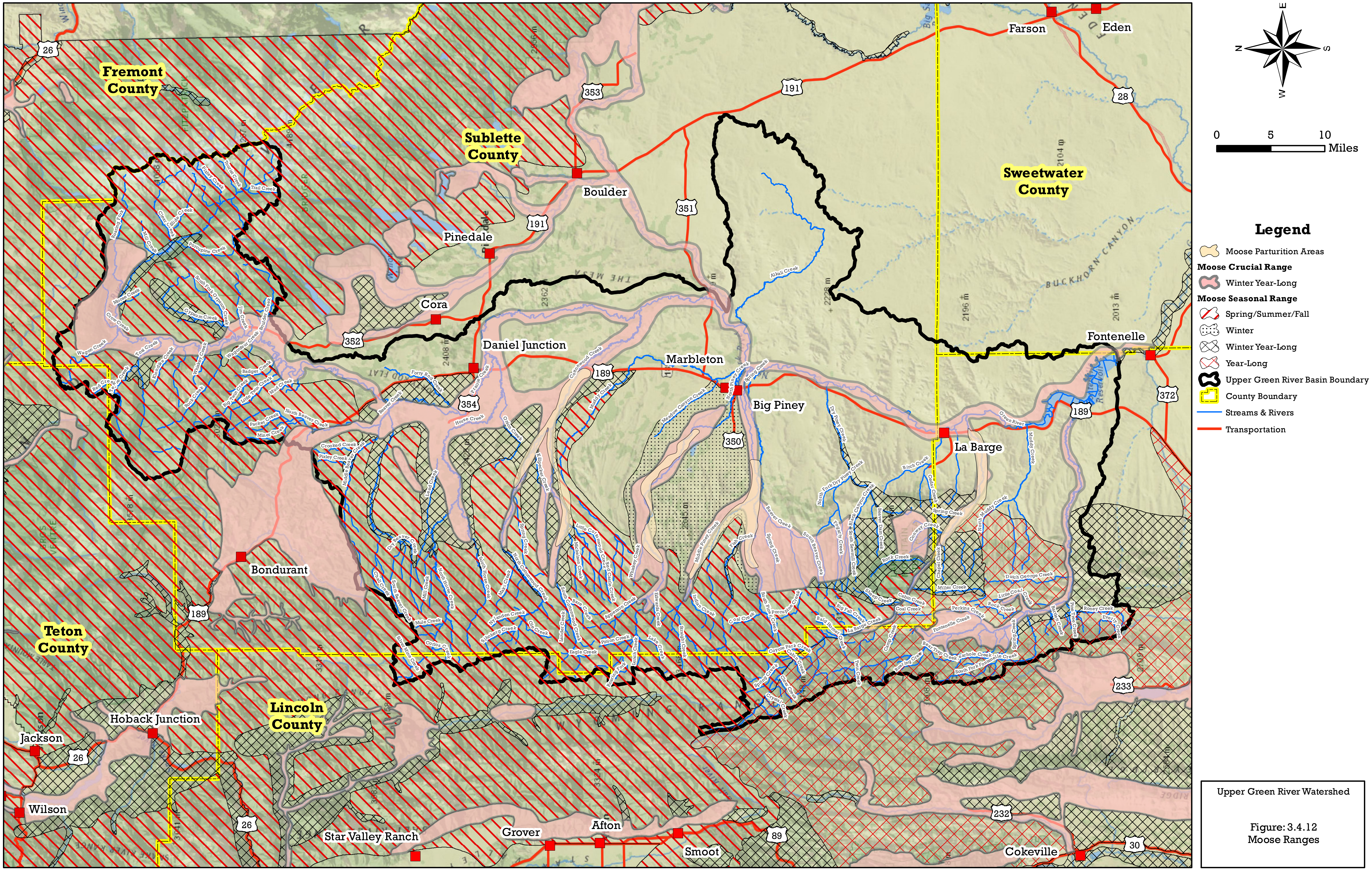
Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

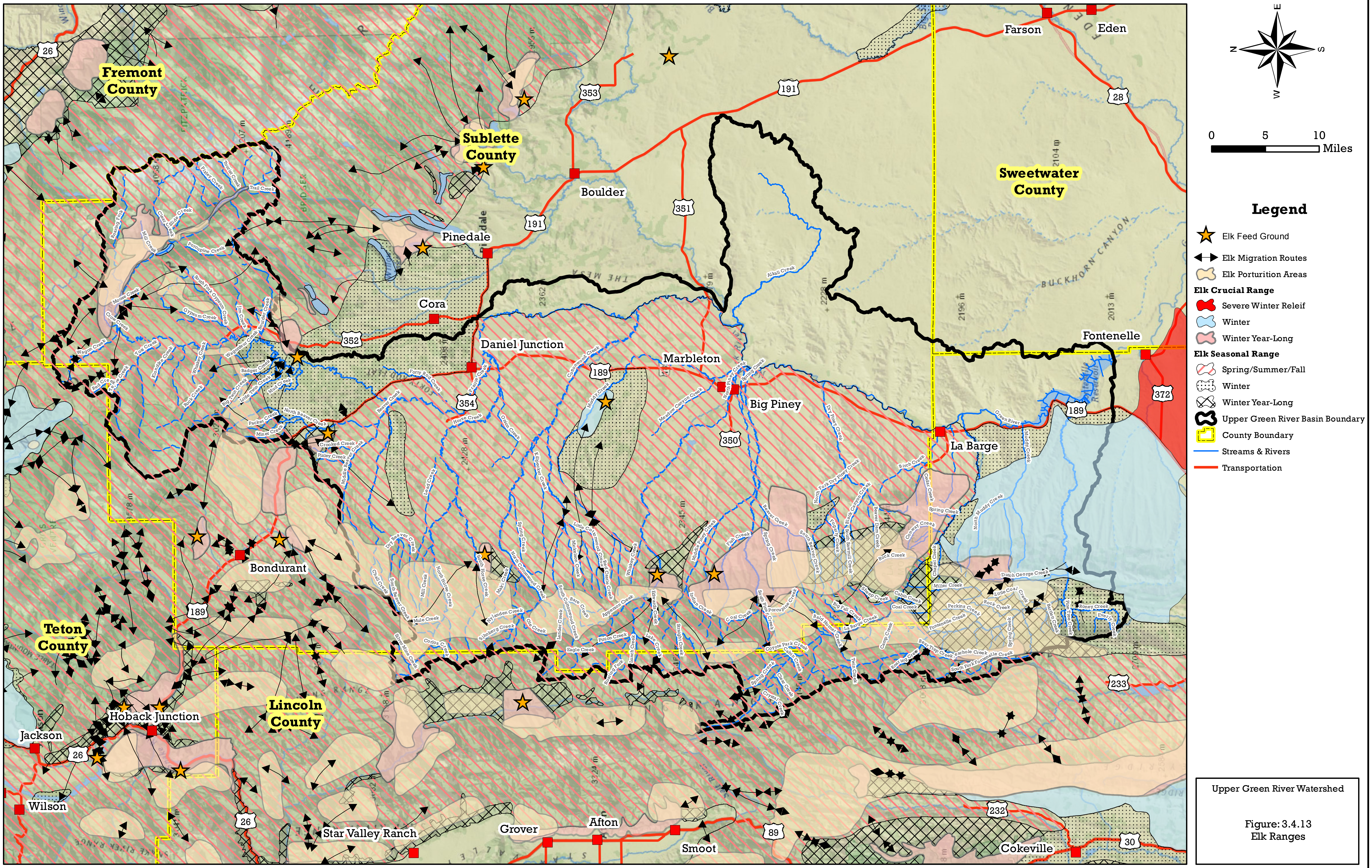
Figure: 3.4.11
Mule Deer Ranges

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

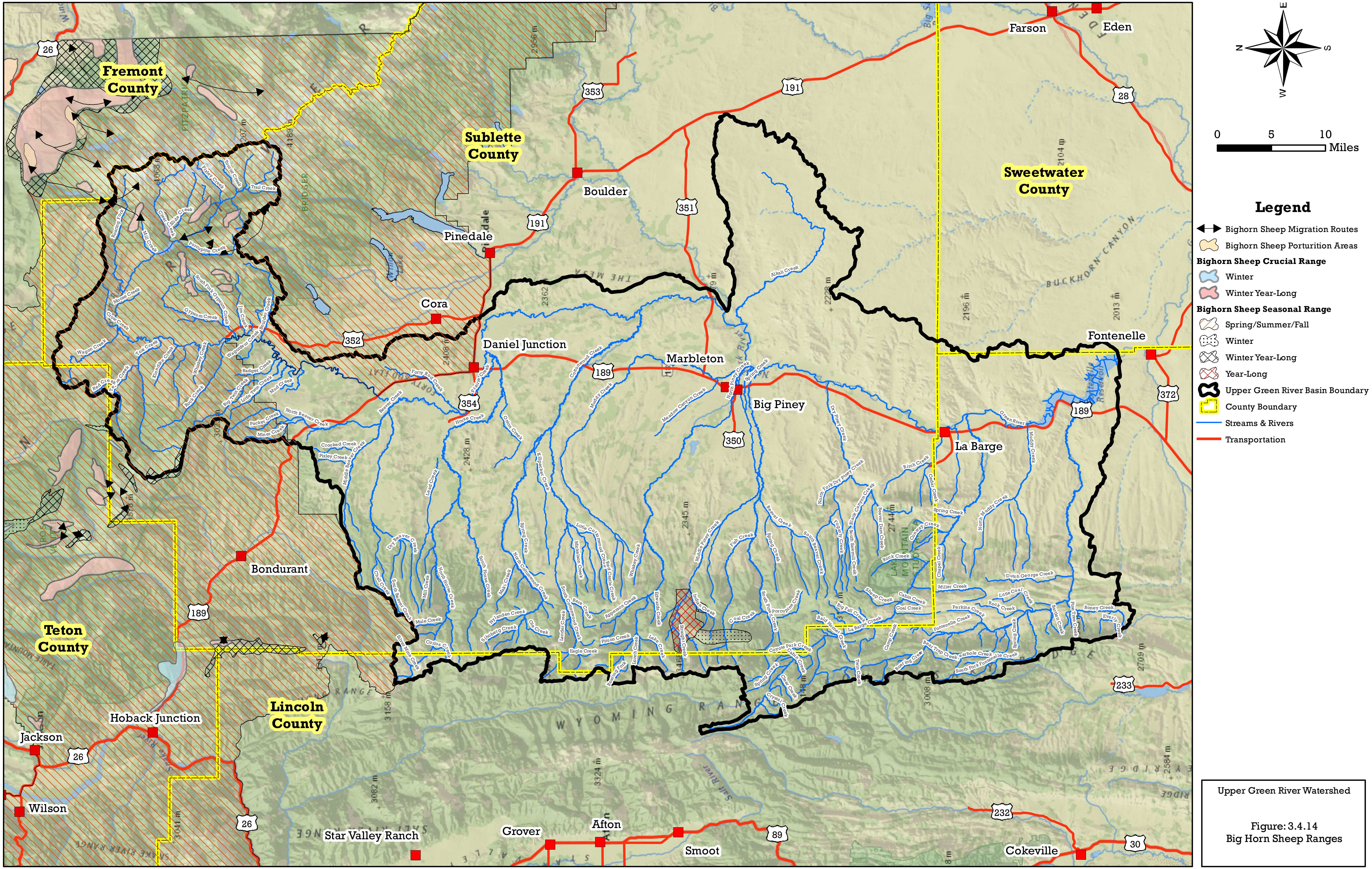
Figure: 3.4.12
Moose Ranges



Upper Green River Watershed

Figure: 3.4.13
Elk Ranges

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

Figure: 3.4.14
Big Horn Sheep Ranges

Projection: NAD 83 - UTM Zone 12

movement across habitat types and seasonal ranges is essential for pronghorn to meet their year-round energetic and nutritional requirements.

The east slope of the Wyoming Range and the upper Green River basin represent crucial winter habitat for the Wyoming Range and Sublette mule deer herd units as described by the WGFD (WGFD). The northern portion of the Wyoming Range mule deer herd winters on lower elevation foothills of the Wyoming Range in western Sublette County. This herd has remained below population objectives since the late 1990's, due to a combination of harsh winters, changes in habitat conditions and current land use including energy development on core winter ranges. Crucial winter range for the Sublette mule deer herd is located centrally within the watershed, and this subpopulation of the herd has declined by more than 15% in both 2010 and 2011, exceeding the mitigation threshold, and requiring a response by Bureau of Land Management (BLM) in accordance with the Pinedale Anticline Record of Decision (ROD; BLM 2008). Crucial winter ranges are vital to the survival of animals during critical periods of winter and mule deer will find food and/or cover here during the most inclement and difficult winter weather conditions due to physiographic and vegetative characteristics. Habitat assessments are underway to address improvements that could be implemented to improve this crucial winter range that falls partially within the watershed area.

In spring, 2,500-3,500 mule deer migrate through the Trapper's Point bottleneck, a nationally significant migration corridor, and generally move northwesterly to important transition and parturition habitat on the Hoback Rim. Trapper's Point was historically restricted to 1 mile in width and length due to riparian habitats on either side of a sagebrush dominated upland ridge. Housing and development have further narrowed this critical link between crucial winter range of the upper Green and transitional ranges farther north. The integrity of this migration corridor is significant because it insures the long-term survivability for this portion of the Sublette herd, and will sustain what is now considered the longest mule deer migration documented in the western states (Sawyer et al. 2005).

Moose populations, as managed by WGFD, are comprised primarily of the Sublette herd and to a much lesser extent, the northeast portion of the Lincoln herd unit that roughly coincides with the area of the watershed within Lincoln County. Crucial winter range for moose is found in the major river corridors and tributary drainages, where suitable riparian habitat is available. Moose in the region, according to state monitoring efforts, stabilized in mid-2000's, and have been moderately increasing, despite localized declines in southwest and northwest Wyoming. In 2011 the Sublette herd was 9% below the population objective of 5,500 for the area. However, the Lincoln herd has been dramatically impacted by the carotid artery worm (*Eleaophora schneiderii*). Prevalence rates for this parasite in hunter-harvested moose from this herd have ranged from 27-100%.

The Upper Green River watershed sustains extensive seasonal, migratory and crucial ranges for Rocky Mountain elk. Four separate herd units are managed by WGFD, all or partially within the watershed, including the Piney, Upper Green River, Pinedale and West Green River herds. Coarse post-hunt season estimates from 2011 indicate that approximately 13,000 elk were observed to use portions of the watershed. These herd sizes are all above prescribed herd objectives (9%-60%). Elk persist on grasses and forbs, though saplings and shrubs constitute important components of the diet when forbs and grasses are more difficult to access due to snow cover. Winter feedgrounds have reduced elk reliance on traditional winter ranges; however, forested ridges and unimpeded movement corridors across an elevation gradient allow necessary access to lower-elevation forage and winter range including State administered feedgrounds. The infectious disease caused by the *Brucella* bactria, Brucellosis, continues to be a significant management concern for elk populations throughout the Greater Yellowstone area, and brucellosis surveillance, in combination with vaccination efficacy and parturition ecology research, is ongoing.

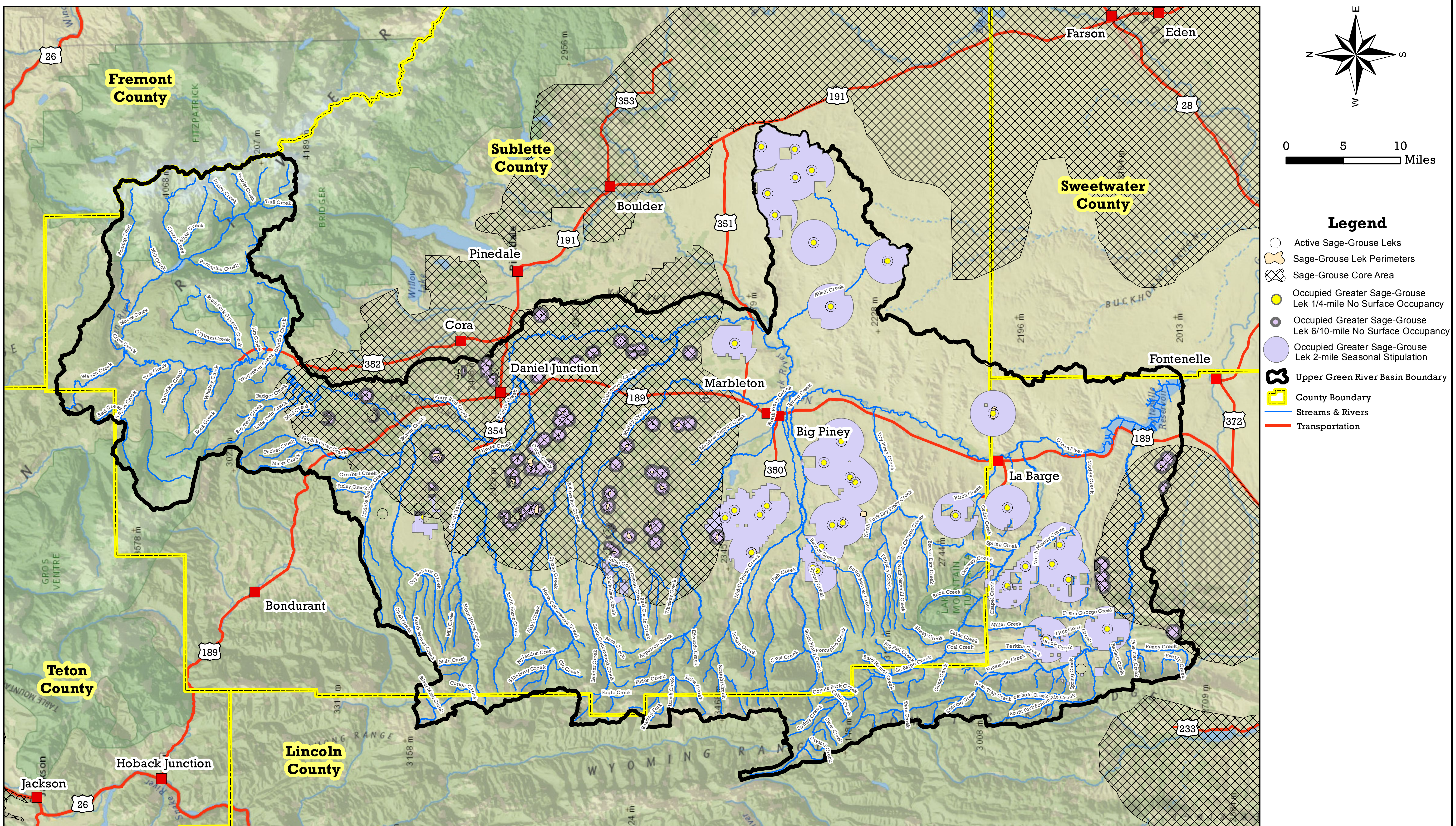
Rocky Mountain bighorn sheep within the Upper Green River watershed study area include portions of the native Whiskey Mountain and Jackson herds as well as the transplanted Darby Mountain herd in the Wyoming Range. This ungulate of primarily non-forested mountain habitat uses steep and often precipitous slopes to detect and escape predators. Loss of habitat and loss of traditional movement patterns functionally limit bighorn populations, further exacerbated by human disturbance, predation, and high incidences of several known bacteria causing pneumonia. Small, isolated areas of crucial winter yearlong range for bighorn sheep are found in the northern Wind River Range portion of the watershed study area.

3.4.10.2 GREATER SAGE-GROUSE

On March 23, 2010 the USFWS placed the greater sage-grouse on the federal list of candidate species under the Endangered Species Act of 1973, as amended (ESA). Greater-sage grouse were found to warrant the protections afforded to a listed species under ESA, but this action was precluded by higher priority listing efforts. A decision from the USFWS on whether to proceed with listing greater sage-grouse, or withdrawing the warranted finding, is due by September of 2015.

The maximum distribution of greater sage-grouse in the Western U.S. has declined to approximately 56% of their estimated historic range. However, essentially all of the historic range for this species within the Upper Green River watershed remains occupied, to a certain degree. Population declines are evident range-wide for this species, and though the Upper Green River watershed has some of the highest densities of sage-grouse in occupied habitat, observations of males at leks suggest a declining population trend in this region. In addition, recent research documents increased lek inactivity and abandonment in areas associated with gas field development. Greater sage-grouse occupy a variety of semiarid shrub-steppe habitats throughout their life cycle, and are considered obligate users of several species of sagebrush extant within the watershed study area. Greater sage-grouse are dependent on large areas of sagebrush-dominated uplands, generally below 8,500 feet. Seasonal habitats (i.e. breeding, nesting, brood rearing, and wintering areas) are predominantly sagebrush plant communities that vary in terms of vertical structure, canopy cover, understory, and herbaceous forage and insect prey availability. During the summer, late brood-rearing period (3 weeks post-hatch) broods may move to moist meadows, or streambed riparian habitats in pursuit of forbs, as arid uplands desiccate. Greater sage-grouse depend entirely on sagebrush in this region for both food and cover as forbs die off in late summer and fall, and throughout winter.

In 2008, the Governor of Wyoming implemented a Core Area Protection strategy for greater sage-grouse by executive order, designed to implement protective stipulations for sage-grouse habitats, populations and connectivity areas to conserve sage-grouse and preclude the need for listing the



Upper Green River Watershed

Figure: 3.4.15
Greater Sage Grouse
Core Population Areas

Projection: NAD 83 - UTM Zone 12

bird as a threatened or endangered species (WOG 2008). The Executive Order and associated map of Core Area protected lands were revised by Governor Mead in 2011, and the most current version (Version 3) of the Executive Order and Core Area map and stipulations are provided in Appendix H. Figure 3.4.15 illustrates known active leks, associated protective stipulation areas, and the most recent (Version 3) Core Area mapping, which constitutes 472,600 acres, or 25% of the Upper Green River watershed study area.

3.4.10.3 THREATENED, ENDANGERED, AND SENSITIVE SPECIES

A list of documented rare species occurrences from the Upper Green River watershed was solicited from the Wyoming Natural Diversity Database (WYNDD 2013; Table 3.4.10.1). The resulting list of all documented occurrences of rare or otherwise sensitive species includes wildlife species organized in seven common taxonomic groupings including reptiles (n=1), amphibians (n=6), birds (n=66), crustaceans (n=2), fish (n=8), mammals (n=24) and molluscs (n=6); Sensitive plant species that were included in the list are treated in a separate section of this report. The ranking system presented in Table 3.4.10.1 denotes the global rank (G) indicating range-wide probability of extinction and a state rank (S) reflecting degree of sensitivity assigned by WYNDD biologists for species in peril within the state. The ranks indicate a numeric score from 1-5, 1 being critically imperiled, through 5 - demonstrably secure. At least 50% of the sensitive wildlife species have life history requirements tied directly to some form of aquatic habitat, whether wetland, riparian or open water. Secondarily, species that utilize grassland or shrub steppe habitats comprise approximately 25% of the list of sensitive species occurring in the Upper Green River watershed underscoring the relative significance of sagebrush steppe to a wide range of wildlife species that are understood to be of conservation concern. Given the expansive landscape and change in elevation throughout the watershed, rare species are also documented from alpine, subalpine, cliff face and rock, montane forests, both coniferous and deciduous, as well as upland tall shrub communities.

Table 3.4.10.1 Sensitive wildlife species mapped by Wyoming Natural Diversity Database in the Upper Green River watershed.

Scientific Name	Common Name	Global Rank	State Rank	USFWS Status	WY BLM Sensitive Species	USFS Sensitive Species	WGFD Status
Amphibians							
Rana luteiventris	Columbia Spotted Frog	G4	S3		Y	Y	NSS3 Bb
Anaxyrus boreas boreas - Eastern Clade	Eastern Clade Boreal Toad	G4T1Q	S1	Petitioned		Y	NSS1 Aa
Spea intermontana	Great Basin Spadefoot	G5	S3		Y		NSSU U
Lithobates pipiens	Northern Leopard Frog	G5	S3	Listing Denied	Y	Y	NSSU U
Anaxyrus boreas boreas - Northwestern Clade	Northwestern Clade Boreal Toad	G4T4	S1		Y	Y	NSS1 Aa

Birds							
Recurvirostra americana	American Avocet	G5	S3B				
Botaurus lentiginosus	American Bittern	G4	S3B			Y	NSS3 Bb
Cinclus mexicanus	American Dipper	G5	S4				
Falco peregrinus anatum	American Peregrine Falcon	G4T4	S2	Delisted	Y	Y	NSS3 Bb
Pelecanus erythrorhynchos	American White Pelican	G4	S1B				
Haliaeetus leucocephalus	Bald Eagle	G5	S3B, S5N	Delisted	Y	Y	NSS2 Ba
Tyto alba	Barn Owl	G5	S2				
Leucosticte atrata	Black Rosy-Finch	G4	S1B, S2N				NSSU U
Picoides arcticus	Black-backed Woodpecker	G5	S1			Y	NSSU U
Nycticorax nycticorax	Black-crowned Night-Heron	G5	S3B				NSS3 Bb
Dolichonyx oryzivorus	Bobolink	G5	S2				NSS4 Bc
Aegolius funereus	Boreal Owl	G5	S2			Y	NSS3 Bb
Spizella breweri	Brewer's Sparrow	G5	S5		Y	Y	NSS4 Bc
Bucephala albeola	Bufflehead	G5	S2B				
Athene cunicularia	Burrowing Owl	G4	S4B		Y	Y	NSSU U
Larus californicus	California Gull	G5	S2B				
Selasphorus calliope	Calliope Hummingbird	G5	S3				
Catherpes mexicanus	Canyon Wren	G5	S2S3				
Hydroprogne caspia	Caspian Tern	G5	S1				NSS3 Bb
Aimophila cassinii	Cassin's Sparrow	G5	SNA			Y	
Aechmophorus clarkii	Clark's Grebe	G5	S1B				NSSU U
Spizella pallida	Clay-colored Sparrow	G5	S3B				
Tympanuchus phasianellus columbianus	Columbian Sharp-tailed Grouse	G4T3	S1	Listing Denied	Y	Y	NSS4 Bc
Bucephala clangula	Common Goldeneye	G5	S3B				
Gavia immer	Common Loon	G5	S1B, S2N			Y	NSS1 Aa
Sterna hirundo	Common Tern	G5	S1				
Spiza americana	Dickcissel	G5	S1				NSS4 Bc
Buteo regalis	Ferruginous Hawk	G4	S4B, S5N		Y	Y	NSSU U
Sterna forsteri	Forster's Tern	G5	S1				NSS3 Bb
Aquila chrysaetos	Golden Eagle	G5	S4B, S4N				
Regulus satrapa	Golden-crowned Kinglet	G5	S3B, S4N				
Ammodramus savannarum	Grasshopper Sparrow	G5	S4			Y	NSS4 Bc

Strix nebulosa	Great Gray Owl	G5	S2			Y	NSSU U
Centrocercus urophasianus	Greater Sage-Grouse	G3G4	S4	Candidate	Y	Y	NSS2 Ba
Empidonax hammondii	Hammond's Flycatcher	G5	S4				
Melanerpes lewis	Lewis Woodpecker	G4	S2			Y	NSSU U
Lanius ludovicianus	Loggerhead Shrike	G4	S3		Y	Y	
Numenius americanus	Long-billed Curlew	G5	S3B		Y	Y	NSS3 Bb
Calcarius mccownii	Mccown's Longspur	G4	S2			Y	NSS4 Bc
Falco columbarius	Merlin	G5	S3B, S4N				NSSU U
Charadrius montanus	Mountain Plover	G3	S2B, S3B	Listing Denied	Y	Y	NSSU U
Accipiter gentilis	Northern Goshawk	G5	S2B, S3N	Listing Denied	Y	Y	NSSU U
Glaucidium gnoma	Northern Pygmy-Owl	G4G5	S1				NSSU U
Pandion haliaetus	Osprey	G5	S3B				
Sitta pygmaea	Pygmy Nuthatch	G5	S2				NSSU U
Vireo olivaceus	Red-eyed Vireo	G5	S3B				
Phalaropus lobatus	Red-necked Phalarope	G4G5	S3N				
Larus delawarensis	Ring-billed Gull	G5	S2				
Aythya collaris	Ring-necked Duck	G5	S4B				
Artemisiospiza belli	Sage Sparrow	G5	S3		Y	Y	NSS4 Bc
Oreoscoptes montanus	Sage Thrasher	G5	S5		Y		NSS4 Bc
Grus canadensis	Sandhill Crane	G5	S3B, S5N				NSS4 Bc
Asio flammeus	Short-eared Owl	G5	S2			Y	NSS4 Bc
Egretta thula	Snowy Egret	G5	S3B				NSS3 Bb
Picoides dorsalis	Three-toed Woodpecker	G5	S3			Y	NSSU U
Dendroica townsendi	Townsend's Warbler	G5	SNA				
Cygnus buccinator	Trumpeter Swan	G4	S3B, S3N	Listing Denied	Y	Y	NSS2 Ba
Cygnus columbianus	Tundra Swan	G5	S2N				
Vermivora virginiae	Virginia's Warbler	G5	S1				
Megascops kennicottii	Western Screech-Owl	G5	S2				
Aphelocoma californica	Western Scrub-Jay	G5	S1				NSS3 Bb
Plegadis chihi	White-faced Ibis	G5	S1B		Y		NSS3 Bb
Lagopus leucura	White-tailed Ptarmigan	G5	S1	Petitioned		Y	
Loxia leucoptera	White-winged Crossbill	G5	S2				
Grus americana	Whooping Crane	G1	S1N	Endangered, EXPN			

Sphyrapicus thyroideus	Williamson's Sapsucker	G5	S2				
Crustacean							
Branchinecta packardi	Rock Pool Fair Shrimp	G5	SNR				NSSU U
Branchinecta lindahli	Versatile Fairy Shrimp	G5	S4				NSSU U
Fish							
Catostomus discobolus	Bluehead Sucker	G4	S3		Y	Y	NSS1 Aa
Oncorhynchus clarkii pleuriticus	Colorado River Cutthroat Trout	G4T3	S1	Listing Denied	Y	Y	NSS2 Ba
Catostomus latipinnis	Flannelmouth Sucker	G3G4	S3		Y	Y	NSS1 Aa
Rhinichthys osculus thermalis	Kendall Warm Springs Dace	G5T1	S1	Endangered			NSS1 Aa
Catostomus platyrhynchus	Mountain Sucker	G5	S5			Y	
Prosopium williamsoni	Mountain Whitefish	G5	S5			Y	NSS4 Bc
Lepidomeda copei	Northern Leatherside Chub	G1G2	S1	Listing Denied	Y	Y	NSSU U
Gila robusta	Roundtail Chub	G3	S3		Y	Y	NSS1 Aa
Mammal							
Ictidomys tridecemlineatus alleni	Allen's Thirteen-lined Ground Squirrel	G5T1Q	S1				
Bos bison	American Bison	G4	S1	Listing Denied			
Martes americana	American Marten	G5	S3			Y	NSS4 Cb
Ovis canadensis	Bighorn Sheep	G4	S3S4			Y	NSS4 Bc
Mustela nigripes	Black-footed Ferret	G1	S1	Endangered, EXPN			NSS1 Aa
Cynomys ludovicianus	Black-tailed Prairie Dog	G4	S2	Listing Denied	Y	Y	
Lynx canadensis	Canada Lynx	G5	S1	Threatened			NSS1 Aa
Martes pennanti	Fisher	G5	S1	Listing Denied		Y	NSSU U
Canis lupus	Gray Wolf	G4	S1	Delisted			
Ursus arctos arctos	Grizzly Bear	G4T3T4	S1	Threatened		Y	
Lasiurus cinereus	Hoary Bat	G5	S4			Y	
Thomomys idahoensis	Idaho Pocket Gopher	G4	S2		Y		NSS3 Bb
Myotis lucifugus	Little Brown Myotis	G5	S5				NSS4 Cb
Myotis evotis	Long-eared Myotis	G5	S4		Y		NSS3 Bb
Myotis volans	Long-legged Myotis	G5	S3B				NSS3 Bb
Lontra canadensis	North American River Otter	G5	S3			Y	NSSU U
Microtus richardsoni	North American Water Vole	G5	S2			Y	NSS3 Bb
Gulo gulo luscus	North American Wolverine	G4T4	S2	Proposed Threatened		Y	NSS3 Bb

Brachylagus idahoensis	Pygmy Rabbit	G4	S1	Listing Denied	Y	Y	NSS3 Bb
Lasionycteris noctivagans	Silver-haired Bat	G5	S3B				
Urocitellus armatus	Uinta Ground Squirrel	G5	S3S4				
Cynomys leucurus	White-tailed Prairie Dog	G4	S3	Listing Denied	Y	Y	
Urocitellus elegans	Wyoming Ground Squirrel	G5	S3S4				
Ochotona princeps princeps - Yellowstone	Yellowstone Pika	G5T5	S5	Listing Denied			
Mollusc							
Gyraulus parvus	Ash Gyro	G5	S4				NSSU U
Fluminicola coloradoensis	Green River Pebblesnail	G2G3	S4				NSSU U
Stagnicola elodes	Marsh Pondsnail	G5	S3				NSSU U
Fossaria parva	Pygmy Fossaria	G5	S3				NSSU U
Physa gyrina	Tadpole Physa	G5	S4				NSSU U
Margaritifera falcata	Western Pearlshell	G4G5	S3				NSSU U
Reptile							
Charina bottae	Northern Rubber Boa	G5	S2				NSS3 Bb

[1]Global Rank — Range-wide probability of extinction (1 = critically imperiled; 2 = imperiled; 3 = vulnerable; 4 = apparently secure; 5 = secure)

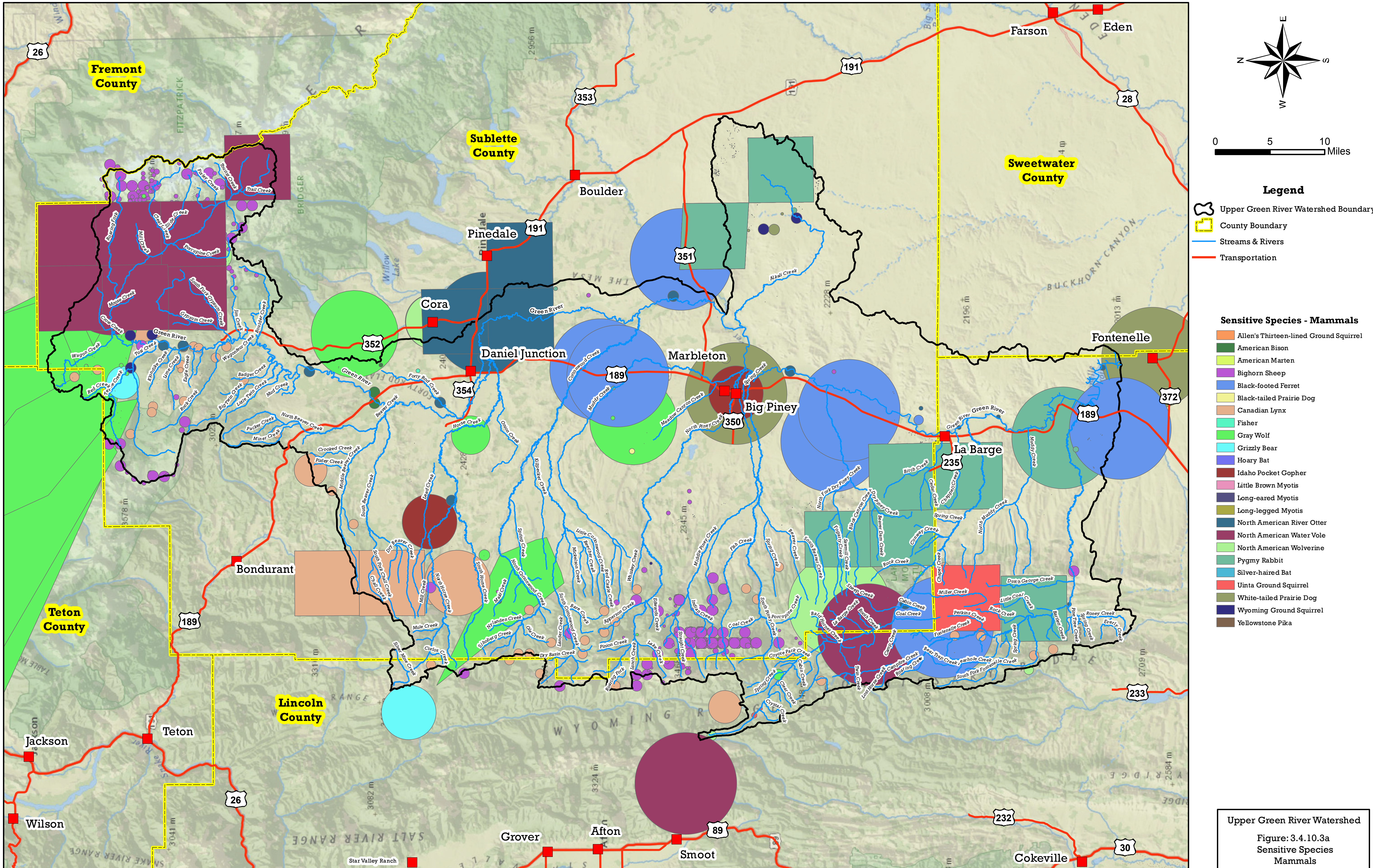
[2]State Rank — State-wide probability of extinction (1 = critically imperiled; 2 = imperiled; 3 = vulnerable; 4 = apparently secure; 5 = secure)

[3] WGFD Status — Wyoming Species of Greatest Conservation Need, *See* Appenidix for Native Species Status Matrix

[4]EXPN — Experimental Population, Non-essentail. The USFWS designation for specific reintroduced populations of listed species established outside of the species' current range, but within its historical range (experimental), yet not essential to the continued existence of the species.

A query of the US Fish and Wildlife Service Information, Planning and Conservation System (IPAC) on May 28, 2013 provided the most up-to-date information regarding federal Natural Resources of Concern including threatened and endangered species within the Upper Green River watershed. The list generated is relevant to the four Wyoming counties that overlap the watershed study area; however, the Platte River Species (ranges including SE Sublette County) are not included.

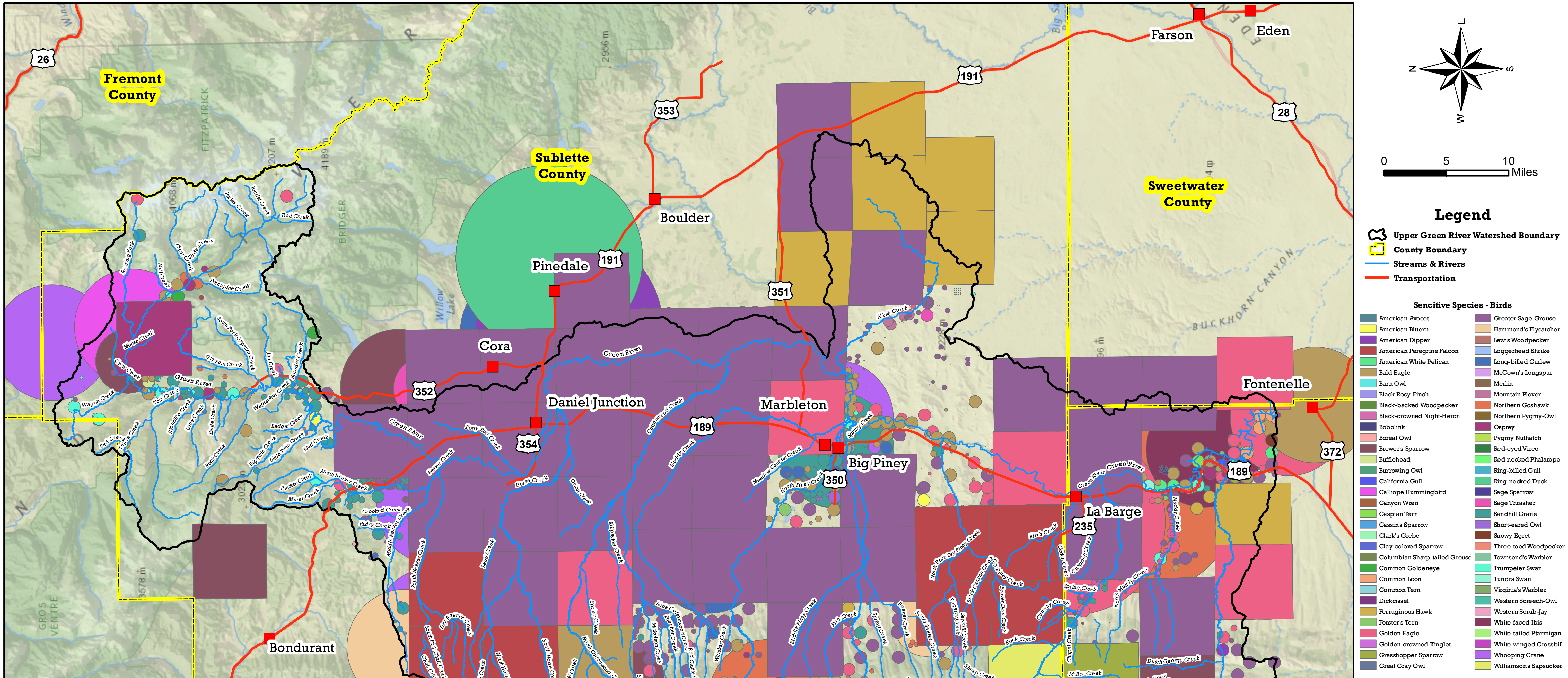
The five species listed as endangered under the Act which either occur or have protected habitat within the watershed study area, are all fish species. The Kendall Warm springs dace, a narrow endemic species, is only found in a series of small thermal springs approximately 984 feet in length, in the upper headwaters of the Green River in Sublette County. Four additional endangered fish, the bonytail chub, Colorado pikeminnow, humpback chub and razorback sucker, are Colorado River fish which may be impacted by upstream hydrological depletions or contaminations, and therefore Colorado River Fish Critical Habitat includes any tributary of the Colorado River including the Upper Green River.



Upper Green River Watershed

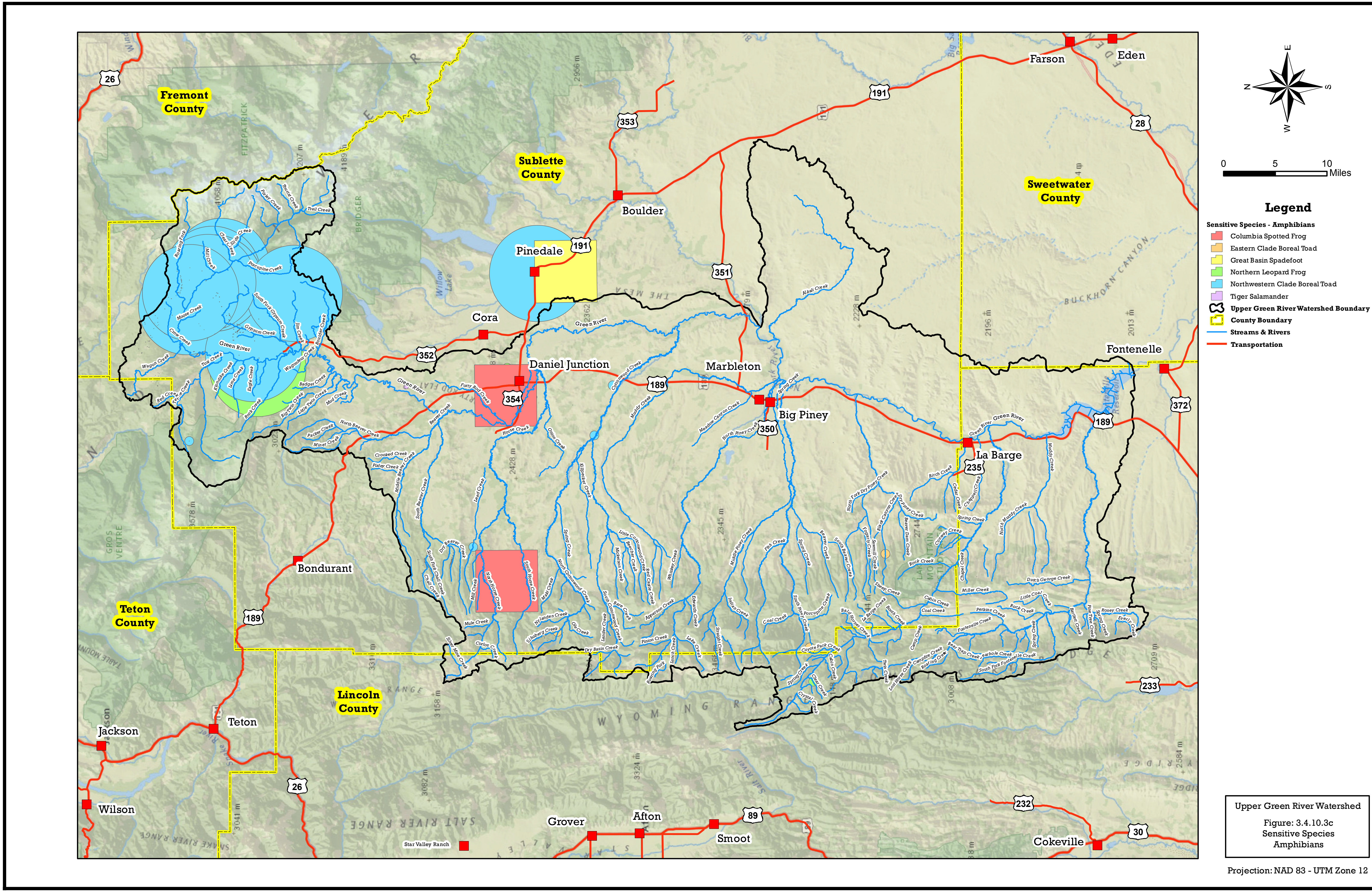
Figure: 3.4.10.3a Sensitive Species Mammals

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed
Figure: 3.4.10.3b
Sensitive Species
Birds

Projection: NAD 83 - UTM Zone 12



Legend
Sensitive Species - Amphibians
Columbia Spotted Frog
Eastern Clade Boreal Toad
Great Basin Spadefoot
Northern Leopard Frog
Northwestern Clade Boreal Toad
Tiger Salamander
Upper Green River Watershed Boundary
County Boundary
Streams & Rivers
Transportation
0 5 10 Miles
Fremont County
Sublette County
Sweetwater County
Teton County
Lincoln County
Pinedale
Boulder
Cora
Daniel Junction
Marbleton
Big Piney
La Barge
Fontenelle
Farson
Eden
Bondurant
Jackson
Teton
Wilson
Grover
Afton
Smoot
Star Valley Ranch
Cokeville
Green River
WYOMING RANGE
SALT RIVER RANGE
BUCKHORN CANYON
Upper Green River Watershed
Figure: 3.4.10.3c
Sensitive Species
Amphibians
Projection: NAD 83 - UTM Zone 12

Two threatened mammals listed under the ESA occur within the watershed study area, grizzly bear and Canada lynx. Listed as threatened under the Endangered Species Act in the lower 48 states in 1975, a Distinct Population Segment (DPS) of grizzly bears in the Yellowstone area has since been delisted and the species as a whole has recently been relisted again. The federal action vacating the original delisting rule in March of 2010 effectively eliminated the designation of a GYA grizzly bear DPS. Currently there is no critical habitat designated for this species in any of the recovery ecosystems, including the Greater Yellowstone Area. Section 7 consultations with the USFWS in consideration of potential effects to grizzly bear and grizzly bear habitat are required for proposed actions in the upper elevations of the watershed study area in portions of Lincoln, Sublette and Teton County.

The Canada lynx was first proposed for listing as a threatened species under ESA in July of 1998 and was formally listed in April 2000. The USFWS determined the lynx population in the United States was at risk as a result of human alteration and fragmentation of montane and boreal forests. Their low numbers were a result of past exploitation, inter-specific competition for prey with bobcats and coyotes, and elevated levels of human access to their habitat. Lynx are solitary carnivores generally occurring at low densities in boreal forests. Distribution and abundance of this species is closely tied to that of the snowshoe hare, their primary prey. Densely regenerating coniferous forests and regenerating burned areas in mixed species forests provide excellent habitat for snowshoe hares and, therefore, are also important habitat for lynx. Lynx are less likely to occur at lower elevations where competition with coyotes, mountain lions, bobcats, and domestic animals depletes available prey. Critical habitat for the Canada lynx (50 CFR 17.95(a)) has been designated for portions of Lincoln, Sublette, and Teton Counties within the watershed study area.

Candidate and Proposed Species

The greater sage-grouse and yellow-billed cuckoo are designated as candidate species under the Act, both of which reside within the Upper Green River watershed. The North American wolverine was proposed in 2010 for listing as threatened under the Act. Any proposed action within the Section 7 consultation area for these species should consider potential effects to these species and respective habitats.

REFERENCES

Bureau of Land Management. 2008. Record of Decision: Final Supplemental Environmental Impact Statement for the Pinedale Anticline Oil and Gas Exploration and Development Project. Pinedale Field Office, Wyoming, USA.

Sawyer, H., Lindzey, F. and D. McWhirter. 2005. Mule deer and pronghorn migration in western Wyoming. Wildl. Soc. Bulletin, 33(4):1266-1273.

Wyoming Natural Diversity Database. 2013. Data compilation for J. Mead of Wyoming Water Development Office, completed February 6, 2013. Unpublished report. Wyoming Natural Diversity Database, University of Wyoming, Laramie, Wyoming.

Wyoming Office of the Governor. 2008. “Greater Sage Grouse Core Area Protection”. Executive Order 2008-2. 1 August 2008.

3.4.10.4 FISHERIES

Fisheries within the watershed consist of a mix of native and non-native game species and a number of nongame species (Table 3.4.10.4), including several ESA listed species or species of concern. According to the WGFD, the reaches of the Green River and its tributaries are moderately productive coldwater fisheries, with some reaches having limited fisheries potential. Although game fish found within the watershed consist primarily of non-native species, two native salmonid species are present. The Colorado River cutthroat trout is the only native trout species and the mountain whitefish is the only other native salmonid. Portions of the watershed serve as key management areas for Colorado River cutthroat trout. The Snake River fine-spotted cutthroat trout, native to the nearby headwaters of the Snake River drainage, has been introduced into the watershed, as has the similar subspecies Yellowstone cutthroat trout. Other introduced salmonids include rainbow, brook, brown trout, and burbot.

Table 3.4.10.4. Fish present within the Green River Watershed Study Area. (Information provided by the WGFD.)

Native Game Fish
Colorado River Cutthroat Trout *
Mountain Whitefish*

Native Nongame Fish
Kendall Warm Springs Dace (*E)
Colorado Pikeminnnow (XE)
Razorback Sucker (XE)
Bluehead Sucker *
Mountain Sucker
Roundtail Chub *
Bonytail (XE)
Mottled Sculpin
Humpback Chub (EU)
Speckled Dace
Flannelmouth Sucker

Nonnative Game Fish
Bonneville Cutthroat Trout
Brown Trout
Rainbow Trout
Brook Trout
Snake River Cutthroat Trout
Yellowstone Cutthroat Trout
Brubot

Nonnative Nongame Fish
White Sucker
Longnose Sucker
Utah Sucker
Fathead Minnow
Utah Chub
Creek Chub
Lake Chub
Redside Shiner
Longnose Dace
Common Carp

* denotes Species of Greatest Conservation Need
X denotes extirpated from Wyoming
E denotes federally endangered species
U denotes fishes that may have been present in Wyoming, but historic presence has not been confirmed.

Colorado River cutthroat trout are widely distributed throughout much of their historic range. However, populations within the watershed (and elsewhere) have declined and this species is now limited to smaller headwater tributaries; some fish are found in the mainstem of the Green River, but probably as a result of stocking. Populations within the watershed appear relatively stable, averaging between 100 and 200 fish per mile (range 50 to more than 400 per mile) (Hirsch et al. 2006). Population stability can be attributed in part to the implementation of management objectives described in WGFD basin management plan. This includes isolating local populations, stocking and removing non-native competitors.

According to the WGFD, mountain whitefish are widely distributed throughout their historic range and are abundant in the watershed. They reside in both the Green River and in its tributaries. The brown trout population within the Green River averages about 125 per mile and this species is also present in a variety of larger and smaller tributaries and lakes within the watershed. The rainbow trout population in the Green River is estimated at about 245 fish per mile and is highest in the secont on the Forest at 1060 fish per mile. Rainbow trout are also present in various streams, creeks, ponds and lakes within the watershed. Rainbow trout continue to be stocked in the upper reaches of the mainstem of the Green River by the WGFD. The brook trout population in the Green River averages 6 to 8 fish per mile but is not actively managed on the mainstem. Brook trout are widely distributed in tributaries from the Wyoming Range.

A majority of the fish species within the watershed are nongame species (native and non-native), including mottled sculpin, five species of suckers, redside shiners, three species of dace, carp, and five species of chub. Distribution and abundance of these species varies throughout the watershed, although generally these species occupy the same waterbodies as game fish species. The nongame species are, on a relative scale, more adaptable to poorer water quality than are game fish species, but populations of both have been negatively affected by habitat degradation such as erosion and sedimentation; wide temperature fluctuation; and decreases in food sources, suitable spawning sites, and cover.

Several species of fish have been listed under the Endangered Species Act. The US Fish and Wildlife Service listed the Kendall Warm Springs dace as endangered in 1970. The Kendall Warm Springs dace is endemic to about 300 meters of Kendall Warm Springs, a small tributary to the Green River in the Bridger-Teton National Forest near Cora.

Several native species that were historically common throughout the area are either uncommon or have been extirpated. Some of the large Colorado River fishes, such as the Colorado pikeminnow, razorback sucker, bonytail, and humpback chub may have periodically been found in reaches within the watershed. However, the watershed represents the extreme northern extent of their respective ranges, and no documented collections have been located for this area. All four of these species are listed as endangered under the Endangered Species Act.

The BLM maintains a list of sensitive fish species and the following species are listed as sensitive.

Colorado River Cutthroat trout	Bluehead Sucker	Flannelmouth Sucker
Roundtail Chub	Leatherside Chub (non-native to watershed)	

The WGFD has identified six fish species as Species of Greatest Conservation Need in their State Wildlife Action Plan (SWAP).

Species	Abundance	Status
Bluehead Sucker	Extremely Rare	NSS1(Aa)
Flannelmouth Sucker	Extremely Rare	NSS1(Aa)
Roundtail Chub	Extremely Rare	NSS1(Aa)
Kendall Warm Spring Dace	Common-Extremely Limited Range	NSS1(Aa)
Colorado River Cutthroat Trout	Rare	NSS2(Ba)
Mountain Whitefish	Common	NSS4(Bc)

NSS1(Aa): Native Species Priority 1 Imperiled (extreme)
NSS1(Ba): Native Species Priority 1 Vulnerable (extreme)
NSS1(Bc): Native Species Priority 1 Vulnerable (moderate)

The majority of the watercourses within the watershed are listed as Class 2AB waters by the Wyoming DEQ Water Quality Division (WDEQ 2001a). Class 2AB waters are defined as those waters known to support game fish populations or spawning and nursery areas at least seasonally, perennial tributaries and adjacent wetlands, and areas in which game fishery and drinking water use is otherwise attainable. Additional protections of Class 2AB waters include “non-game fisheries, fish consumption, aquatic life other than fish, primary contact recreation, wildlife, industry, agriculture and scenic values”. Other water quality designations within the watershed include Class 1 and Class 3B waters. Class 1 waters are defined as “outstanding waters”. This designation is made for all waters for which water quality degradation, other than that originating from dam discharges, is not allowed. Class 3B waters include tributaries that are not known to support fisheries or drinking water supplies. They typically are intermittent or ephemeral in nature but have the hydrologic conditions necessary to support invertebrate populations, amphibians, and obligate or facultative wetland plant species.

The WGFD classifies rivers and streams within the Upper Green River watershed study area based on the relative productivity of each reach’s trout fishery. Five classifications are used to describe the quality of each river reach that has been assessed.

- Blue Ribbon: Premium trout waters and fisheries of national importance with trout production greater than 600 pounds of trout per mile
- Red Ribbon: Very good trout waters and fisheries of statewide importance with trout production of 300 to 600 pounds of trout per mile
- Yellow Ribbon: Important trout waters and fisheries of regional importance with trout production of 50 to 300 pounds of trout per mile
- Green Ribbon: Low-production water and fisheries of local importance with trout production of less than 50 pounds of trout per mile.
- Orange Ribbon: Any cool/warm water fish present.

Figure 3.4.10.4 depicts the above classifications within the Upper Green River watershed study area.

There are no reaches classified as “Blue Ribbon” within the watershed. However, three reaches of the Green River have been identified as “Red Ribbon”. The remainder of the stream and river reaches within the watershed have been classified as “Yellow Ribbon”, “Green Ribbon” or “Orange Ribbon” waters, with some waters having no classification.

Eight (8) instream flow filings involving a total of 47.3 miles have been made within the watershed.

Watercourse	Reach Distance	Year	WYSEO Permit #
LaBarge Creek	3.3 mi	1990	29 IF
South Piney Creek	7 mi	1991	28 IF
Middle Piney Creek	3.6 mi	1991	36 IF
North Piney Creek	7.6 mi	1991	35 IF
Fish Creek	4.2 mi	1991	30 IF
South Cottonwood Creek	2.9 mi	1989	74 IF
North Cottonwood Creek	8.9 mi	1989	73 IF
Green River (mainstem north of Warren Bridge)	9.8 mi	1989	6 IF

The WGFD continue stocking fish within the watershed, but most stocking for flowing water involves Colorado River cutthroat trout. Rainbow trout continue to be stocked in the Upper Green River below Green River Lake and several of the finger lakes (i.e. Fremont). The WGFD has identified the upper LaBarge Creek Watershed as having good Colorado River cutthroat trout habitat. A reintroduction project for this fish has been underway since 1999, including the removal of non-native fishes and the re-establishment of a genetically pure population of Colorado River cutthroat trout. A fish barrier has been constructed near the U.S. Forest boundary to prevent invasions of non-native trout. This was a cooperative project between WGFD, the US Fish and Wildlife Service and the Western Native Trout Initiative, and will benefit 58 contiguous miles of aquatic habitat within the LaBarge Creek drainage.

Trout Unlimited has also conducted; and is conducting; many projects in the Upper Green River Watershed Study area including the following:

Cottonwood Creek Drainage:

Essex Ditch: Replaced a diversion and head gate that was causing erosion issues and not working correctly for the land owner.

Ray Ditch: Replaced a diversion and head gate that was causing erosion issues and not working correctly for the landowner.

Future Project: Fredell Ditch Improvement project-Replace old diversion with new fish passable diversion.

Horse Creek Drainage:

Todd Ditch Diversion Improvement: This project installed a low maintenance, permanent diversion structure designed to meet operational irrigation requirements and allow upstream fish passage throughout the year. The previous diversion on Horse Creek was a barrier for fish movement throughout the majority of the year for wild trout and native fish from the Green River. This structure reconnects more than 20 miles of Horse Creek to the Upper Green River.

North Piney Creek Drainage:

North Piney Canal: Replaced a diversion and bank erosion control made up of old cars and steel.

Hat L Ditch: Replaced a diversion and head gate that was causing erosion issues and not working correctly for the land owner.

Middle Piney Creek Drainage:

Future Project: Middle Piney Diversion Improvement-Replace old high maintenance diversion with new low maintenance fish friendly diversion.

Pine Creek Drainage:

Little Colorado Ditch Fish Screen: This project installed a fish screen to the headgate of the Little Colorado Ditch to eliminate the entrainment of fish into the irrigation canal. A new fish friendly diversion structure and headgate were previously installed on Pine Creek to provide a more efficient water delivery system. The fish screen is a low cost, low maintenance, solution to the canal entrainment making the diversion entirely fish friendly.

REFERENCES

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31. USDI Fish and Wildlife Service, Wash. DC. 131pp.

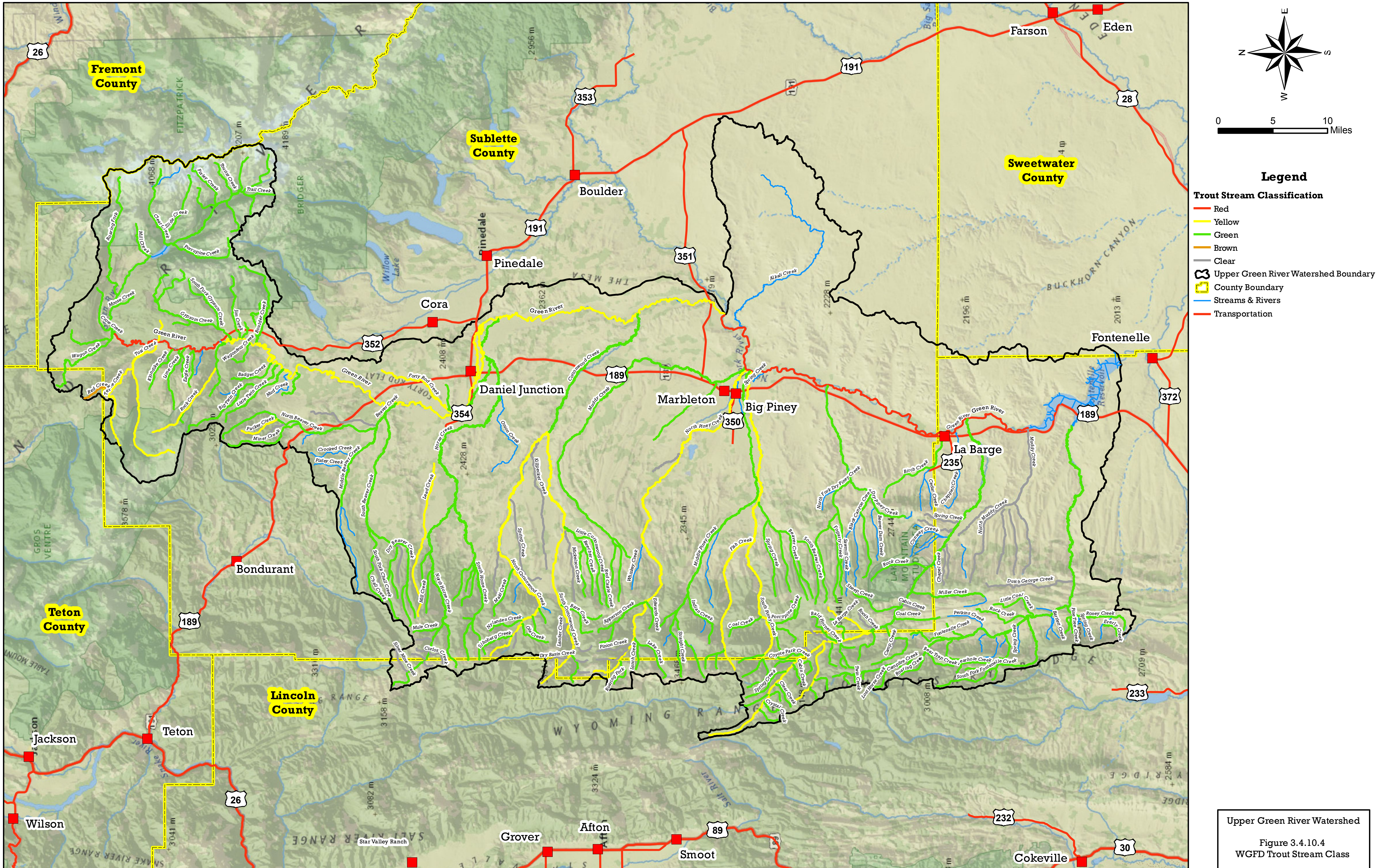
Fertig, W., R. Black, and P. Wolken. 2005. Rangewide status review of Ute ladies'-tresses (*Spiranthes diluvialis*) Prepared for US Fish and Wildlife Service and Central Utah Water Conservancy District, 211 pp.

Mitsch, W. J. and J. G. Gosselink. 1986. Wetlands. 537 pp.

US Fish and Wildlife Service. 2005. Draft Biological Opinion for the Wyoming Statewide Transportation Improvement Program. ES-61411/W.17/WY9299BO, ES-6-WY-05-F012. 79 pp.

Wyoming State Weed Team. 2003. Wyoming Weed Management Strategic Plan. 12 pp.

Wyoming Joint Ventures Steering Committee. 2010. Wyoming Wetlands Conservation Strategy. Version 1.0. 108 pp.



Upper Green River Watershed

Figure 3.4.10.4
WGFD Trout Stream Class

Projection: NAD 83 - UTM Zone 12

IV. WATERSHED MANAGEMENT AND REHABILITATION PLAN

4.1 INTRODUCTION

A primary objective of the watershed study was to develop a technically sound, practical and economically feasible watershed management plan. The investigative phase of this study focused on an assessment of the watershed characteristics and function, and the identification and evaluation of opportunities to address issues disclosed in Section 3. Opportunities include the following:

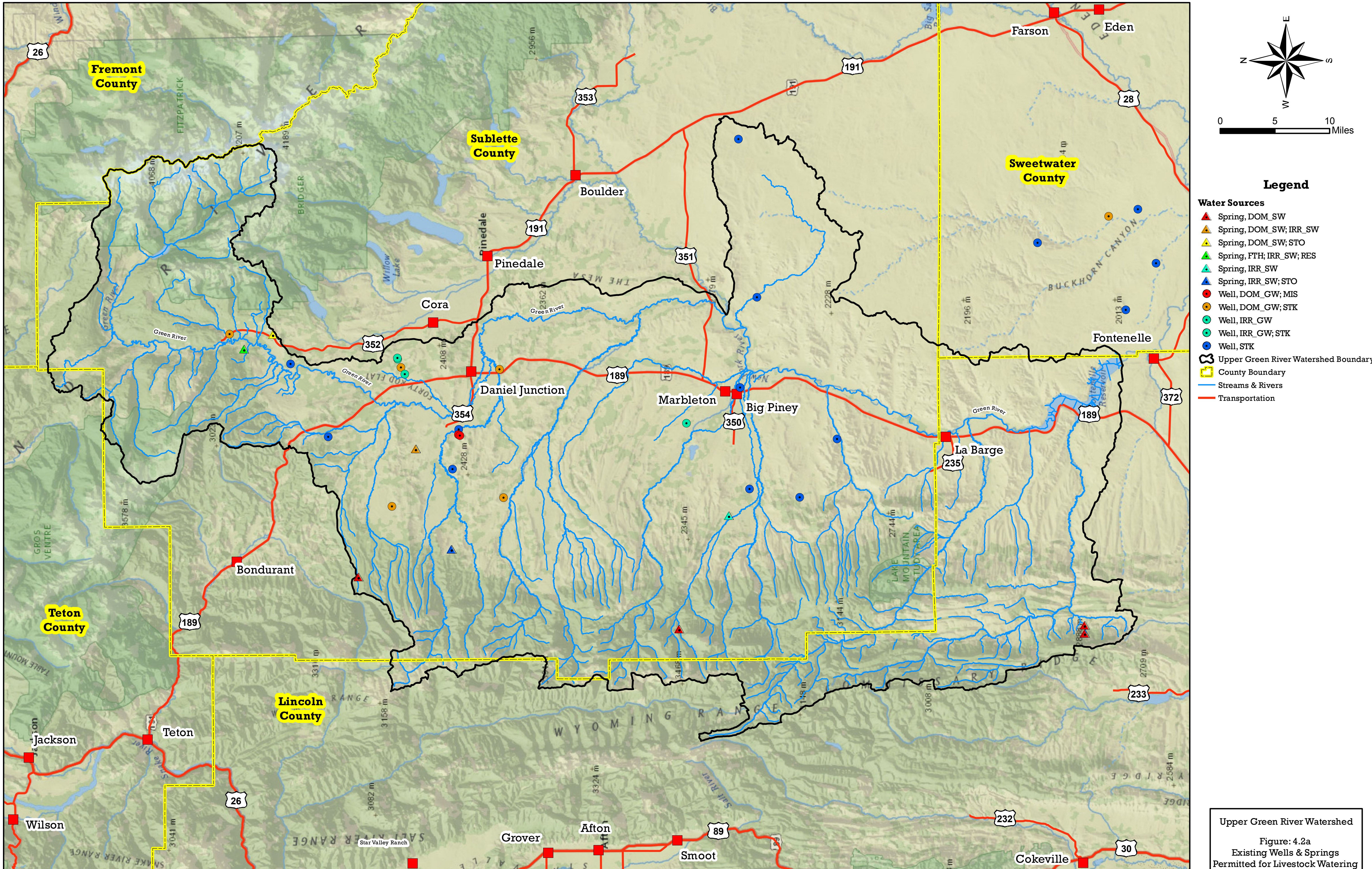
- Livestock/Wildlife Upland Watering Opportunities – Potential upland water development projects were identified based on an evaluation of existing water sources, upland grazing conditions, and input from landowners.
- Stream Channel Condition and Stability – Stream channels within the watershed were characterized with respect to their condition and stability. Impaired channels were identified for further evaluation and alternative improvements developed.
- Grazing Management Opportunities – Grazing management strategies are presented based on a review of the Ecological Site Descriptions (ESDs), vegetation, and soil conditions within the watershed.
- Other Upland Management Opportunities – Additional upland management opportunities were identified.

4.2 UPLAND WILDLIFE AND LIVESTOCK WATER SOURCES

The Upper Green River watershed study area supports numerous grazing allotments on BLM and USFS administered land. These allotments are generally adjacent to privately held ground and serve as summer and early fall range for the adjacent ranches. Extensive work has been done within the watershed to provide upland water sources for livestock and wildlife. Abundant natural water features also provide similar services; especially in the northern and western portions of the watershed. Figure 4.2a illustrates the locations of permitted springs and wells. Figure 4.2b shows stock reservoirs permitted by the SEO. Figure 4.2c Developed Water Feature Sites, and Figure 4.2d Natural Water Feature Sites depict upland water sources. Figure 4.2e Existing Upland Water Sources Stock Reservoirs illustrates upland water sources in the basin. Of note are the gaps in coverage such as North Muddy Creek and other smaller areas.

Many of the allotments have small water improvements constructed by resource agencies or the permit holder. The facilities generally group into one or more of the following categories:

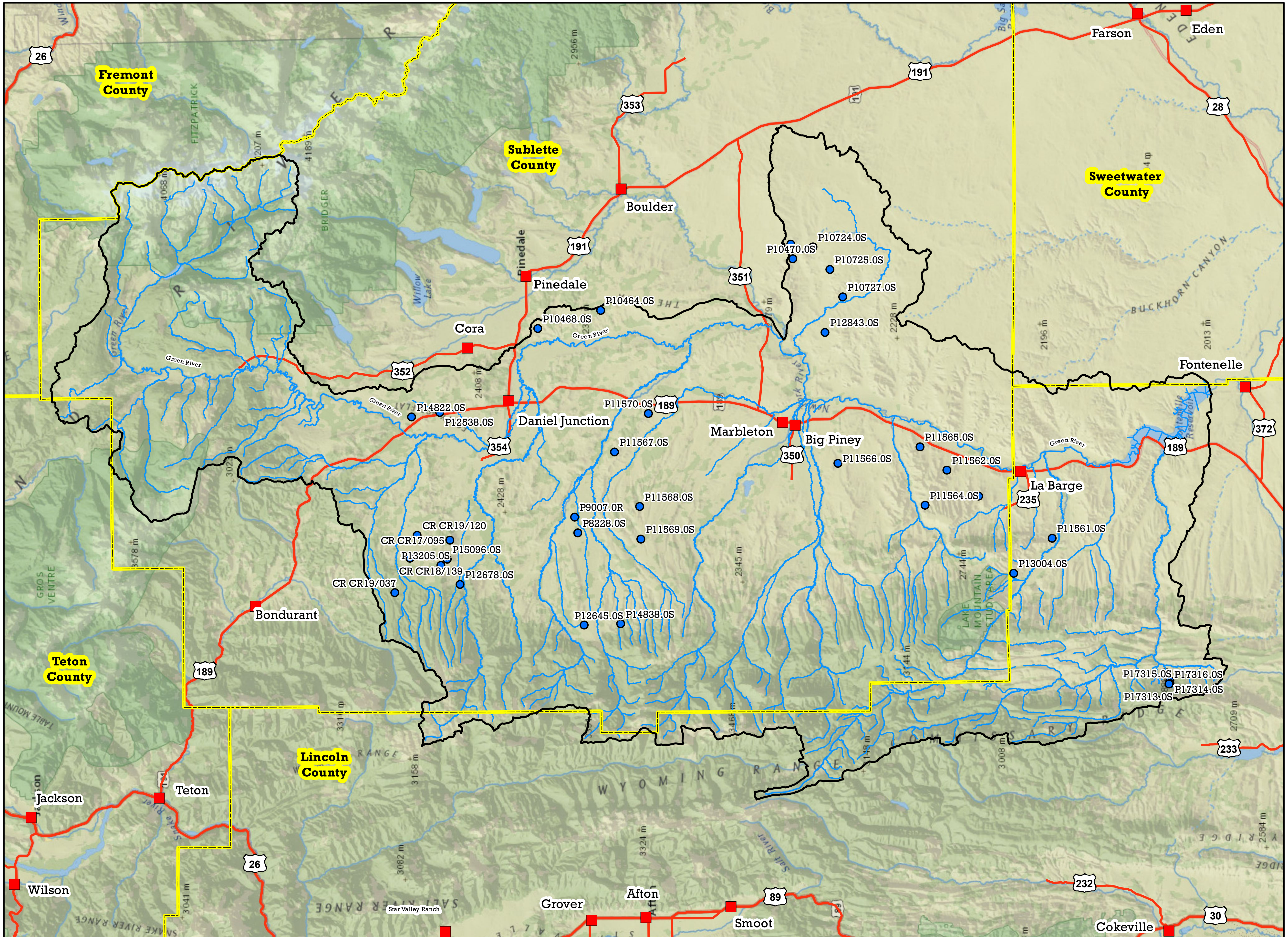
- Wells
- Springs
- Earthen Catchments (Reservoirs)
- Raintraps/Guzzlers
- Troughs
- Conveyance



Upper Green River Watershed

Figure: 4.2a
Existing Wells & Springs
Permitted for Livestock Watering

Projection: NAD 83 - UTM Zone 12



0 5 10 Miles

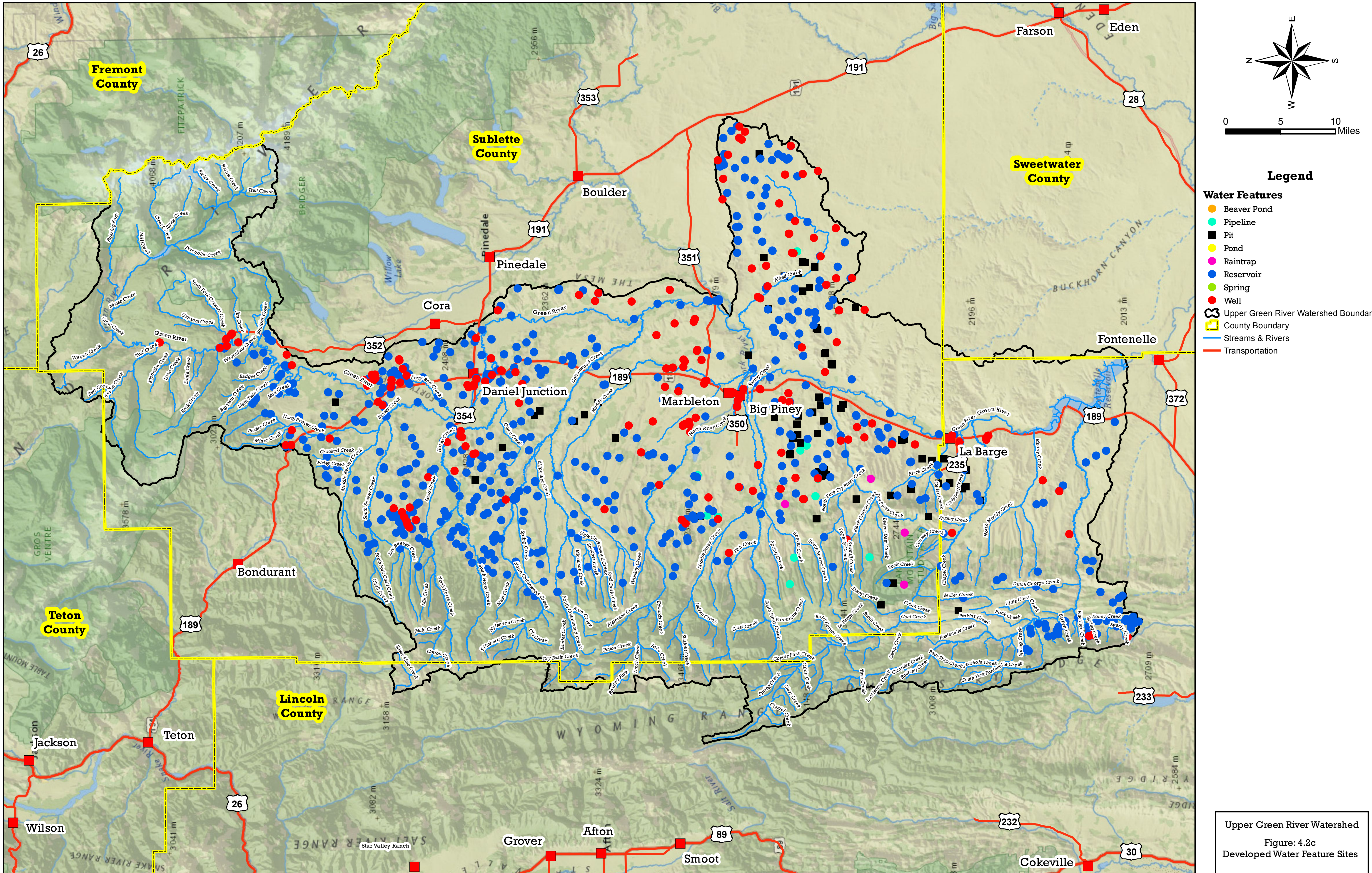
Legend

- SEO Permitted Stock Reservoirs
- Upper Green River Watershed Boundary
- County Boundary
- Streams & Rivers
- Transportation

Upper Green River Watershed

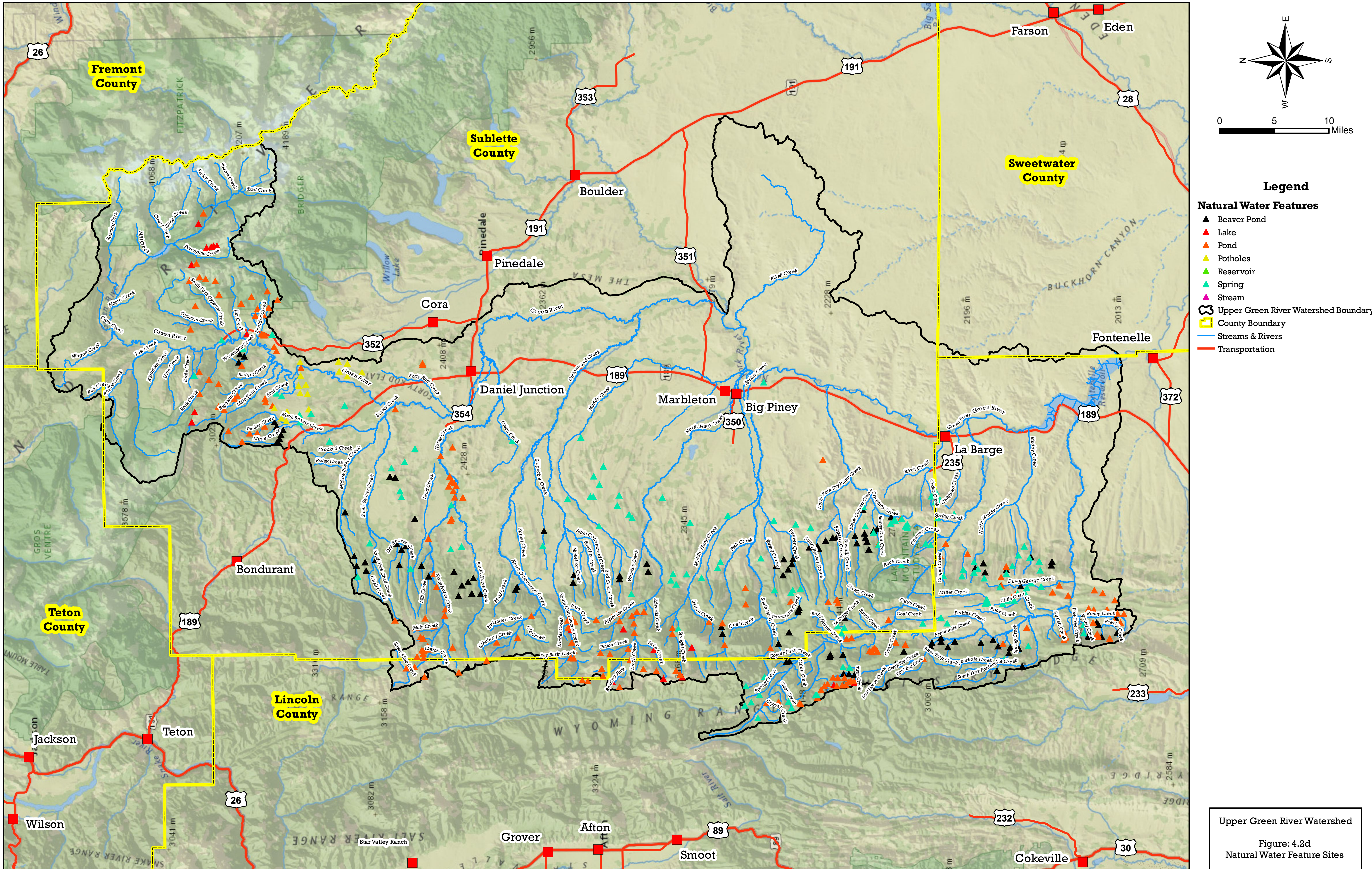
Figure: 4.2b
Stock Reservoirs Permitted by State Engineers Office

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed
Figure: 4.2c
Developed Water Feature Sites

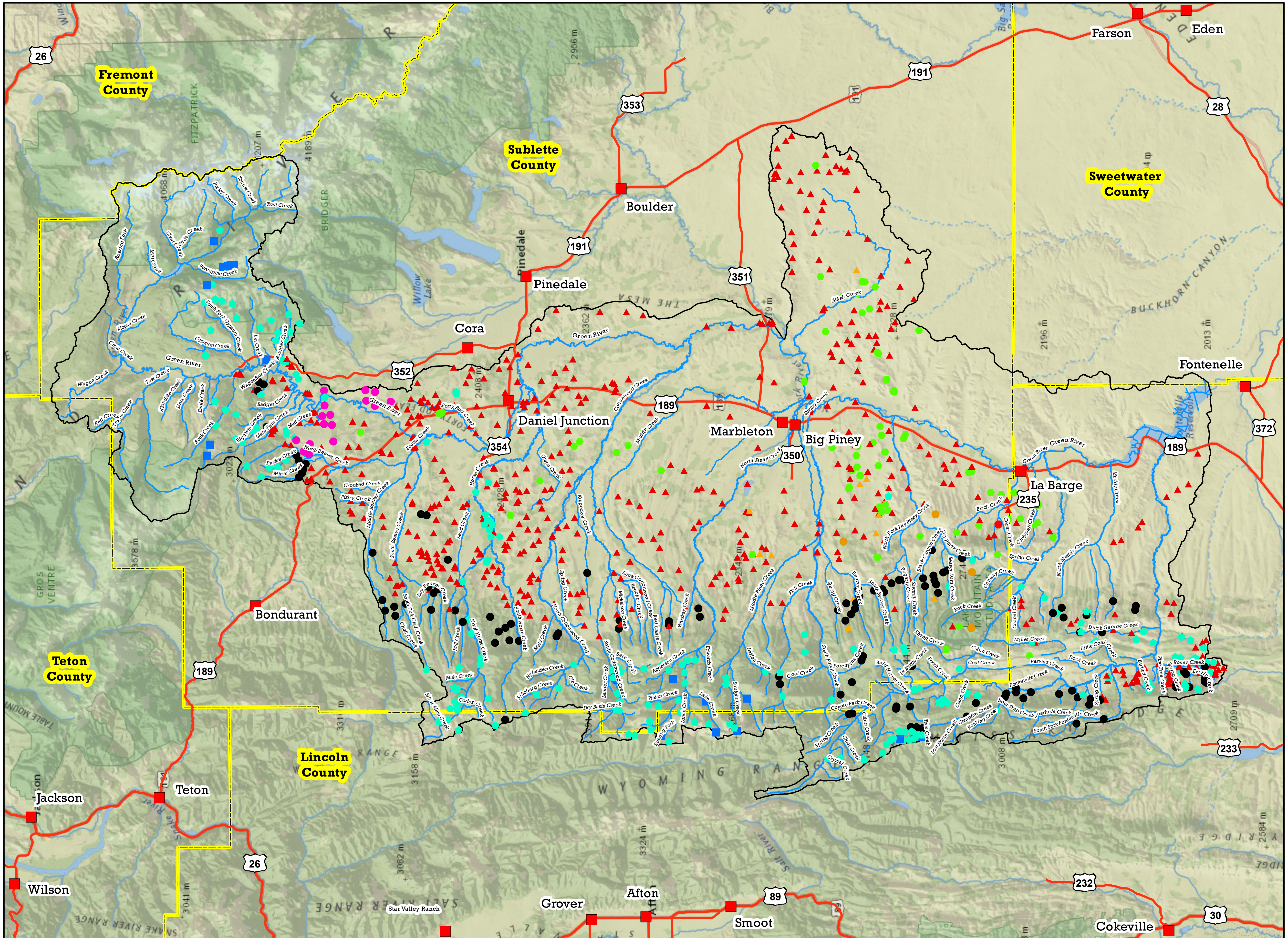
Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

Figure: 4.2d
Natural Water Feature Sites

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

Figure 4.2e
Existing Upland Water Sources
Stock Reservoirs

Projection: NAD 83 - UTM Zone 12

In the case of springs there are both developed and undeveloped springs. In addition there are some natural features such as ponds and pits that also serve to water livestock.

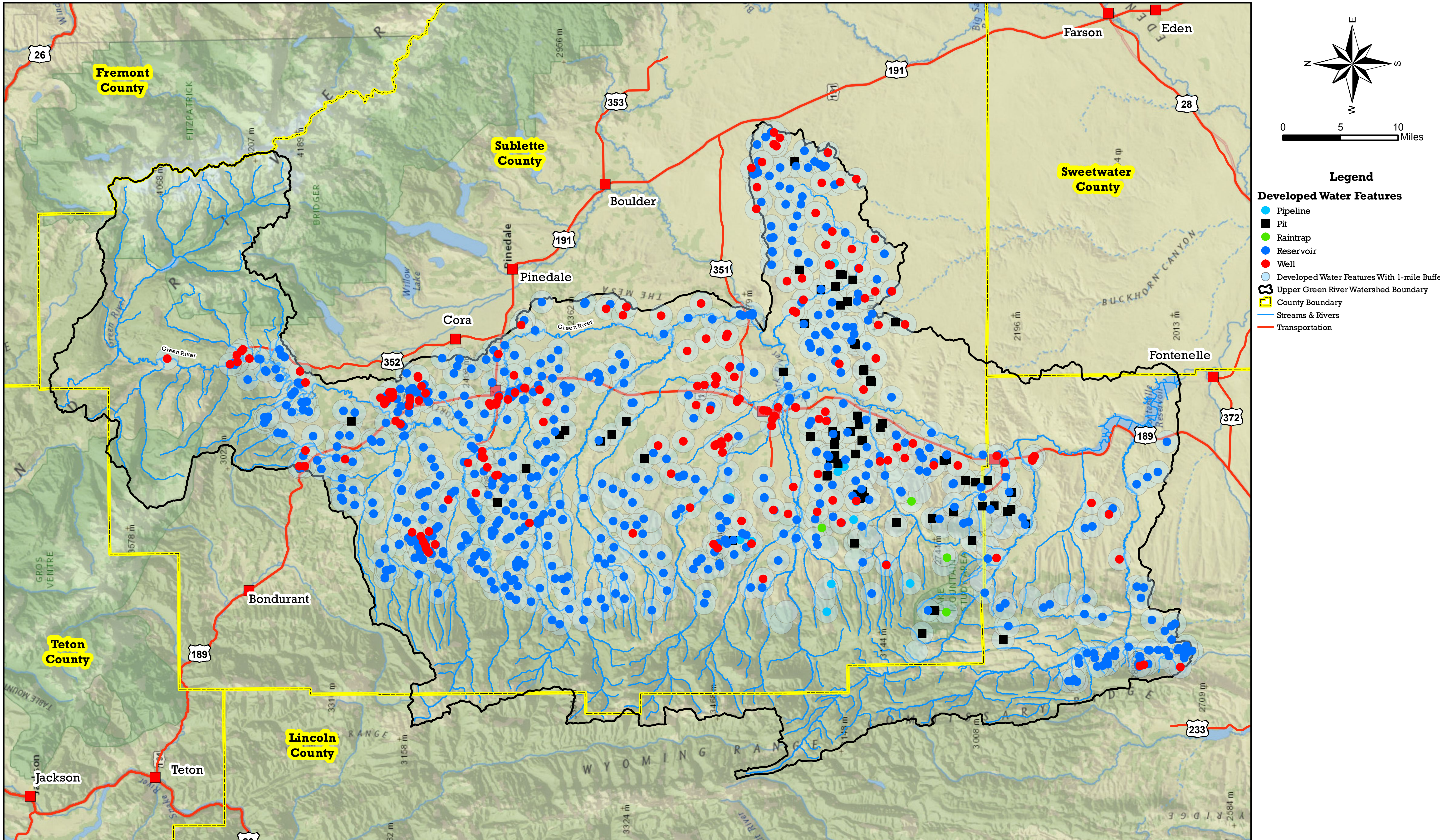
4.2.1 NEW WATERING OPPORTUNITIES

Opportunities to develop additional water sources exist in many locations. Potential water sources that would provide at least seasonal water on underutilized rangelands as well as alternative water supplies to riparian corridors include development of springs, rehabilitation of existing permitted stock reservoirs, new earthen catchments and wells. Development of springs that flow in excess of 2 gallons per minute and redevelopment of former industrial wells associated with energy development and idle or un-used domestic wells provide the greatest potential for new or expanded water sources. New or rehabilitated stock reservoirs could also provide upland water sources where wells or springs are not available, but these activities will likely require more work and are inherently more expensive to design, permit, and construct. The following is a partial list of possible upland water development projects.

- Stock ponds
- Storage reservoirs
- Spring developments
- Existing wells with conventional windmills, wind turbines and combined solar/wind systems
- New wells with solar systems
- New pipeline/tank systems and extension of existing pipelines to new trough sites

The topography throughout a substantial portion of the watershed, particularly the lower elevations within all but the extreme western and northern portions, make existing water sources (both water development and natural) capable of providing water to livestock and wildlife within a one-mile radius. This same one-mile buffer has been used in a variety of previously prepared WWDC-funded watershed studies, and for the purposes of this Level I study, this radius was assumed to be reasonable for the Upper Green River watershed study area. However, the effective radius around a given water source could be smaller depending on factors such as topography, water quality, fences, roads, and grazing allotment boundaries.

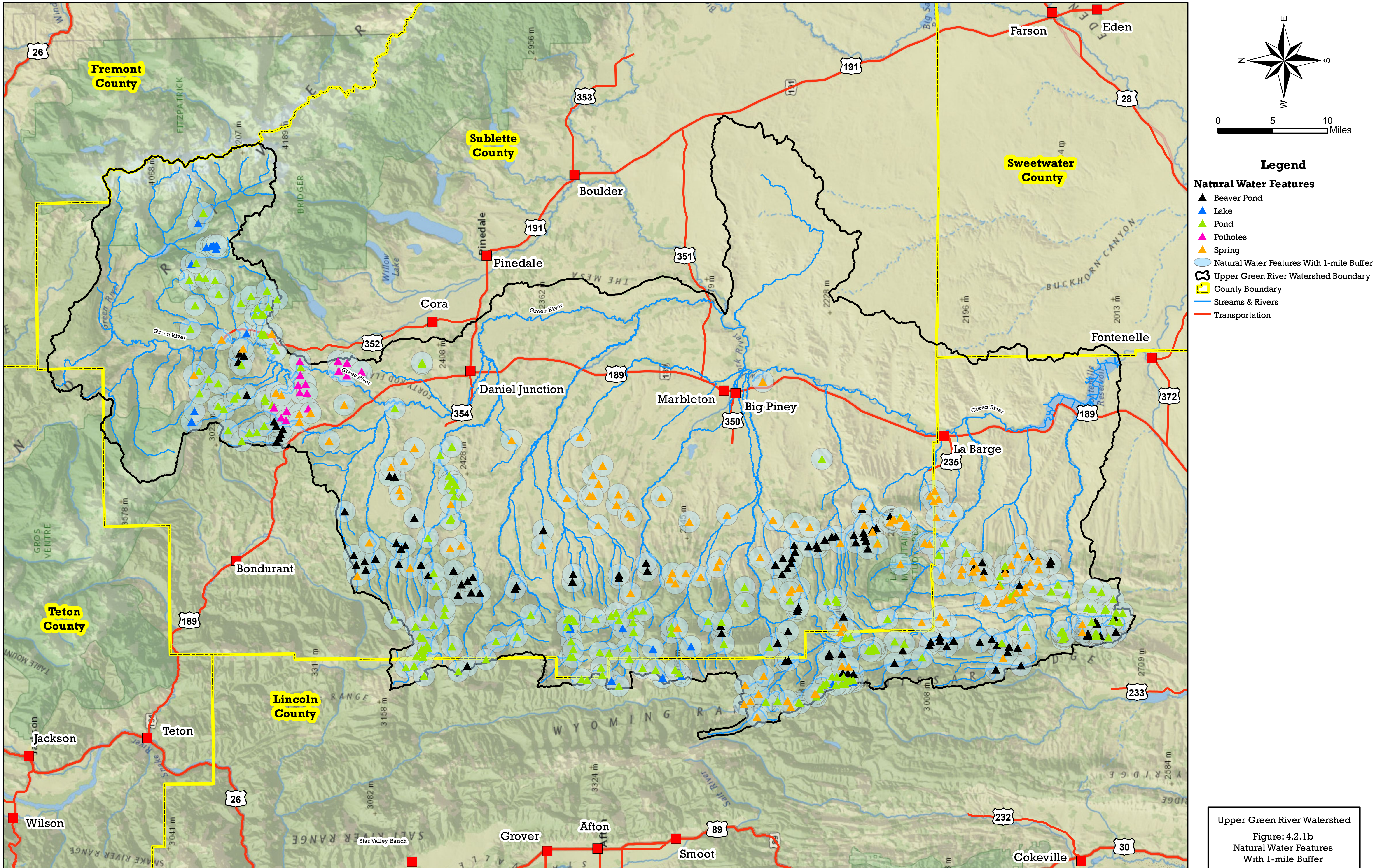
To this end, one-mile buffers were drawn around documented water sources described in Section 3 and are presented in Figures 4.2.1a for water development features, Figure 4.2.1b for natural water features. Figure 4.2.1c depicts one-mile buffers around all natural and developed water features. Water source buffers depicted in these figures, however, may not represent a complete list of all water development and natural water sources within the watershed. In addition, water co-produced during recent gas production can sometimes provide a source for upland wildlife/livestock usage depending upon its water quality character. Because one objective of this study was to evaluate alternative water sources for wildlife and livestock other than perennial and intermittent streams, these streams were not buffered in Figure 4.2.1c.



Upper Green River Watershed

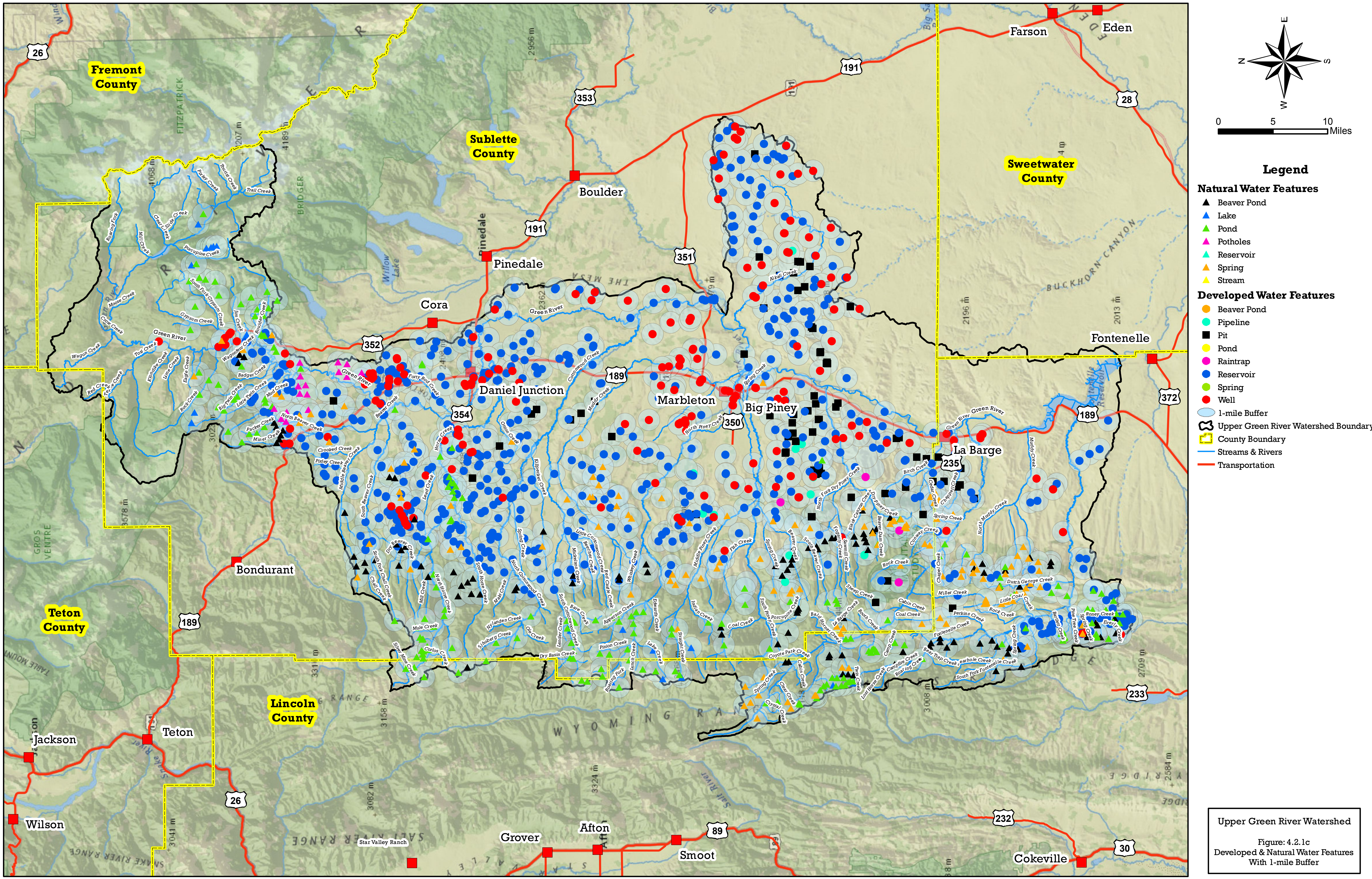
Figure: 4.2.1a
Developed Water Feature Sites
With 1-mile Buffer

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed
Figure: 4.2.1b
Natural Water Features
With 1-mile Buffer

Projection: NAD 83 - UTM Zone 12



Upper Green River Watershed

Figure: 4.2.1c
Developed & Natural Water Features
With 1-mile Buffer

Projection: NAD 83 - UTM Zone 12

An examination of these figures shows that much of the land in the watershed, including grazing land, appears to be within one mile of a water source. However, two areas appear to have fewer water sources than the remaining portion of the watershed; the southeastern portion in the vicinity of La Barge and the east-central portion between Daniel and La Barge on both sides of Highway 189. Although it is possible that some upland water features exist in these two areas, but went undetected, these figures suggest that most of the grazed portion of the watershed has upland water sources.

The 1-mile buffer is based on a relatively gentle slope that can be traversed by cattle with little difficulty. The varied and steep topography in many parts of the basin limits the effective radius a given water source may service. In addition, seasonal variability and equipment breakdowns eliminate many sources, thereby increasing travel distances and limiting the practical ability to graze certain areas. The completeness of the buffer coverage must consider the loss of certain sites through much of the year.

Each of these sites plays a critical role in the grazing management plan. Not only in terms of water being available, but also in the ability of the operator to control when this water is, or is not, available.

Future planning and design of additional upland wildlife/livestock water sources should include onsite consultation with landowners or land managers (if federal lands are involved), allotment permittees, the Natural Resource Conservation Service, Sublette County Conservation District, Lincoln Conservation District, and Sweetwater County Conservation District to verify location of the planned improvements in relation to existing sources. Additional upland water development may be desirable in areas appearing well watered because topography, physical barriers and other limiting factors were not considered during the analysis. Various types of upland water development projects identified during this study are tabulated and detailed in Appendix A of this study.

4.2.2 UPLAND WILDLIFE/LIVESTOCK WATER DEVELOPMENT PROJECTS

One of the tasks of this Level I study was to meet, on a voluntary basis, with various landowners and permit holders to tabulate and discuss their recommendations regarding upland water development.

A list of interested landowners and allotment permittees was generated based upon input obtained at project meetings and from input obtained through project team member activities and interviews conducted during the completion of the project. Individual meetings with the landowners were scheduled and completed to gain their input on the water needs of their respective geographical areas of interest. Based upon the results of these interviews, and the information presented above pertaining to existing water supplies and areas in need of upland water development, numerous conceptual water development projects were identified. The identified projects were not sourced from Allotment Management Plans. AMPs in the study area were very limited and none of the following projects are known to be in an existing AMP. Table 4.2.1 summarizes the results of the upland water landowner consultation.

Table 4.2.1 Upland Water Projects

UPLAND WATER PROJECTS Owner or Operator	Project Type and Number of Potential Projects: Spring Devel.	Water Well	Surface Catchment	Tank and Trough	Trough Only	Total	Notes	**Estimated Project Costs**
Susan and Steve Hoffman (and Jack Sims)	4	5	8	2	1	20	Includes some small pipeline	$ 439,117
Chad Espenscheid	8	3		2	3	16	Includes some small pipeline	$ 363,752
Brenda and Brad Carnahan	9	2	4	3	7	25	Includes some small pipeline	$ 778,683
Dan Budd								
Ann Budd								
Jannet Beiermann								
Bill Barney			4					$ 322,102
Jay McGinnis		2	3					$ 599,385
Freddie Botur (Cottonwood Ranches)	2		2			4	Includes some large (12" to 24") pipeline	$ 153,039
Corby McGinnis		1	1	3	15		Includes some small pipeline	$ 2,143,042
Todd	2							$ 30,105
							Total Cost All Projects	**$ 4,829,224**

The projects are identified geographically using decimal degree locations. Figure 4.2.2.1 illustrates the distribution of the potential upland water projects. Note several of the proposed projects are new installations and serve to fill in gaps while others are rehabilitation of existing projects. Appendix A contains additional maps of greater detail for the sites shown on Figure 4.2.2.1. Also found in Appendix A are detailed cost estimates for each of the individual projects.

The sites visited during this study were selected for review precisely because they could be improved. The basin also contains numerous upland sites that are operating smoothly as intended.

The condition of the facilities reviewed varies from good working order to inoperable. Even when in good condition, there may be need for improvements, better reliability and to ease operation by using modern technology. Further improvements and repairs are intended to provide higher quality and quantities of water that will reduce travel distances and allow better control over animal distribution.

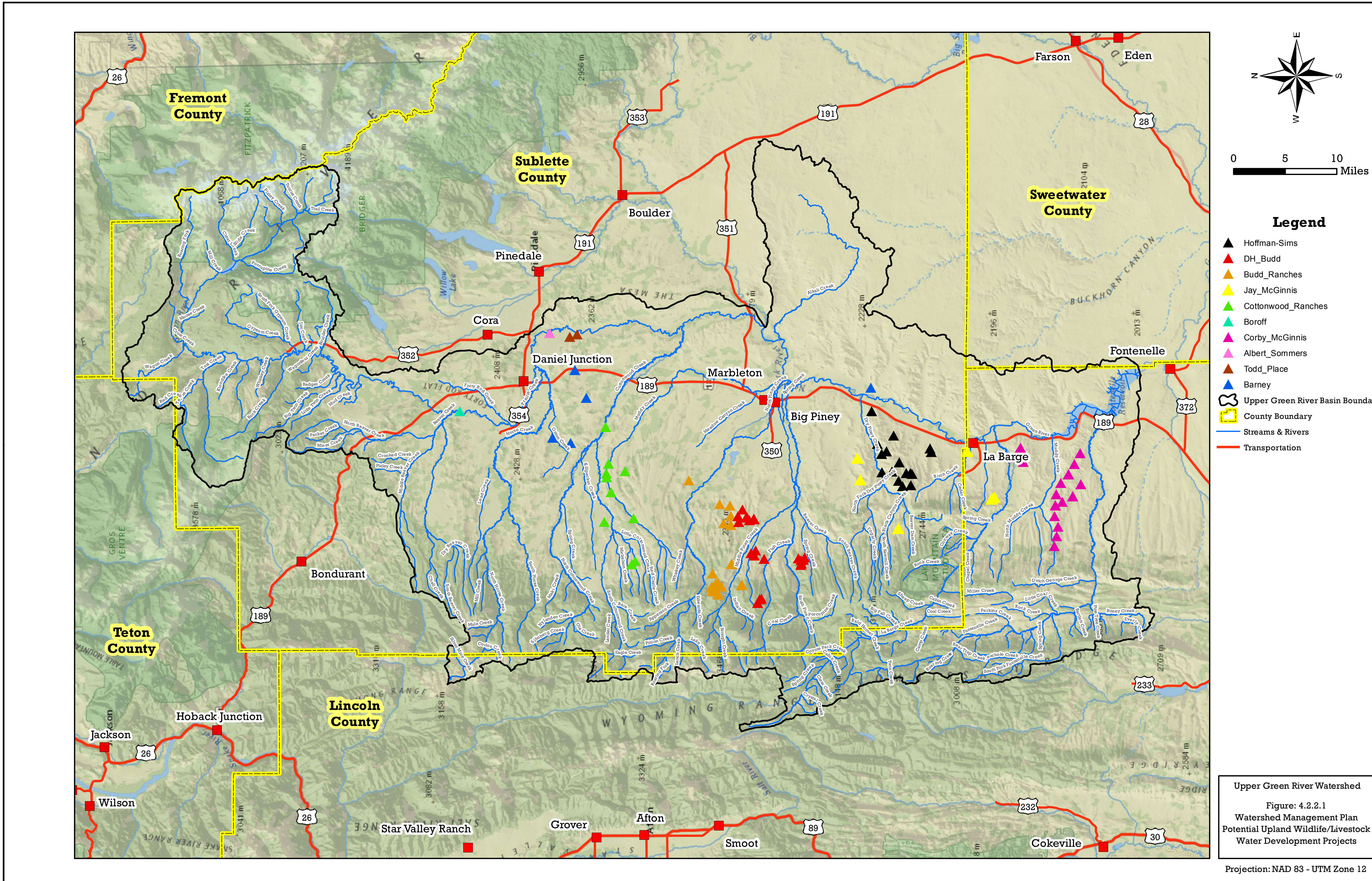
Several themes or goals are common among most of the permit holders.

Reliability:

Many of the facilities are developed to less than their potential. Consequently, the water becomes scarce sooner than it might otherwise. Springs and earthen catchments identified for improvement are examples of structures that, because of wear and tear, no longer meet their full potential, or were never originally constructed to meet their full potential. In other cases, outdated equipment and corrosion reduce the effective use of the water that is available.

Distribution of sites:

The distance to water limits the use of some areas and also causes lengthy travel distances to water. Additional reliable sources will allow better distribution of animals and reduce travel damage occurring along the current trails. Several of the proposed pipeline projects will also allow a single



Fremont County
Sublette County
Sweetwater County
Teton County
Lincoln County
Pinedale
Boulder
Cora
Daniel Junction
Marbleton
Big Piney
La Barge
Farson
Eden
Fontenelle
Bondurant
Hoback Junction
Jackson
Wilson
Star Valley Ranch
Grover
Afton
Smoot
Cokeville
WYOMING RANGE
BUCKHORN CANYON
THE MESA
0 5 10 Miles
Legend
Hoffman-Sims
DH_Budd
Budd_Ranches
Jay_McGinnis
Cottonwood_Ranches
Boroff
Corby_McGinnis
Albert_Sommers
Todd_Place
Barney
Upper Green River Basin Boundary
County Boundary
Streams & Rivers
Transportation
Upper Green River Watershed
Figure: 4.2.2.1
Watershed Management Plan
Potential Upland Wildlife/Livestock
Water Development Projects
Projection: NAD 83 - UTM Zone 12

source to serve multiple troughs and allowing isolation of certain troughs to move cattle while still using the same source. This distribution and control will facilitate more even use of natural forage, reduce over grazing and promote regeneration.

Maintenance labor and equipment costs:

Wells and tanks tend to require daily effort to perform tasks that might be performed just as well by automation. Many well sites are manually operated not only in term of starting and stopping the pump, but also use portable generators to provide power.

The automation includes pump start/stop based on tanks level control, float operated valves, solar power sources and power extensions.

Permit Risk:

Each of the allotments is at risk of being lost in the future for reasons beyond the control of the current permittee. Threats include a variety of groups with stated and unstated goals. Groups range from those with common goals of improving habitat for wildlife and the public to others with stated opposition to use of public land for grazing, development or resource extraction. Philosophies of future policy makers at the Federal level may at some point be influenced by or support those opposed to use of public lands. Consequently, the permittee may be reluctant to invest significant dollars on a project to repair or improve upland water sources. However, projects to improve watershed health and functionality could arguably help secure future use of allotments.

Wildlife:

Upland stock watering sites provide critical water to Wyoming wildlife. Big game, upland birds, song birds and predators rely on the stock water maintained by the permit holder.

It should be noted that additional opportunities for upland water development and range improvement may exist and should not be assumed to be invalid because they are not included in this report. The projects presented in this report were developed based upon input received from the interested landowners and do not represent a comprehensive list of watershed needs.

The general objective of this effort was to provide means of providing reliable sources of livestock / wildlife drinking water in water-short portions of the watershed as well as alternative water supplies to riparian corridors. In Appendix A alternatives are presented at the conceptual level. For each project, a conceptual design is also presented. It must be kept in mind that these designs are conceptual only and if implemented, detailed design would be required. Figure 4.2.2.1 displays the general location of livestock/wildlife water opportunity projects included in this report. Table 4.2-1 displays cost estimates for the potential projects.

Each of the upland water development projects could involve coordination as appropriate with the NRCS, LCCD, and/or SCCD and the USFS or BLM (if federal lands are involved) in order for construction to occur. Written agreements will be required which define the maintenance responsibility and ownership liability associated with each project.

The BLM, USFS, and State administer most of the public land on which the proposed upland water projects are located. The maintenance of existing projects generally falls on the permittee. In the case of the BLM, some funds are available to help with major BLM directed maintenance tasks such as relocation of a well or installation of power source. Typically, maintenance activities do not require National Environmental Policy Act (NEPA) review. In a phone conversation with BLM, they indicated they presently do not maintain a list or other tabulation of future upland water projects.

New projects instigated by the permittee are the permittees responsibility. The NEPA must be followed for all projects. The BLM can help with some NEPA tasks and ultimately issues the Decision, however, BLM scheduling may not meet the project goals. Use of a third party to prepare the NEPA documents is an alternative to expedite the process.

4.3 STREAM CHANNEL CONDITION AND STABILITY

The morphologic condition of major stream channels in the basin was assessed during the geomorphic classification and associated results analysis. The Level I classification was completed primarily using remote sensing techniques, and the results should accordingly be viewed as general. Additional assessment of fluvial conditions should be completed in order to precisely identify dominant system processes and inform stabilization efforts at the local scale. The watershed level classification does describe channel conditions throughout the basin, and can be used to inform stakeholders regarding general channel conditions and management strategies.

4.3.1 STREAM CHANNEL STABILITY ASSESSMENT

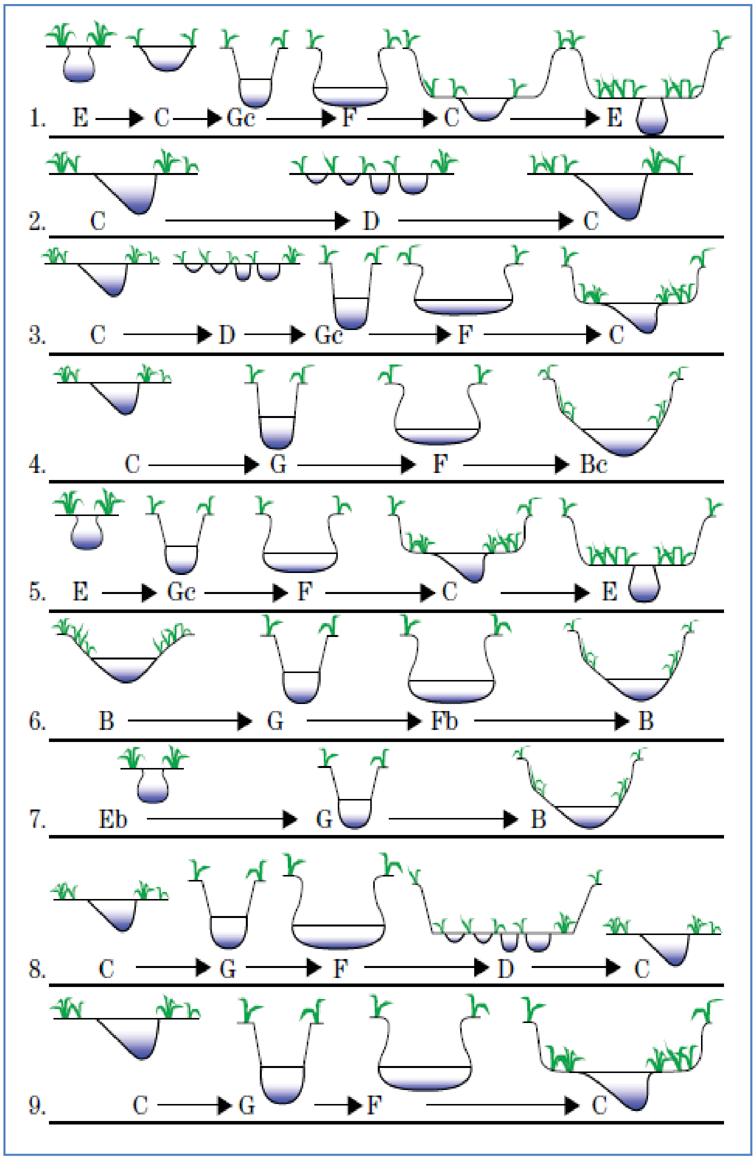
The classification of valley types provides context for the assessment of channel morphology and stability. This process is feasible because valley types describe boundary conditions, which dictate equilibrium channel conditions. For example, a braided D-type channel located on an active alluvial fan (valley type IIIa) is a typical condition representative of a system that is naturally storing excess sediment. However, a braided D-type channel located in an alluvial valley (valley type VIII) is typical of an unstable system that is not in equilibrium. Typical equilibrium and disequilibrium channel forms are identified by valley type in Table 4.3.1.1 (Rosgen 2012).

Table 4.3.1.1. Typical equilibrium and disequilibrium channel forms associated with various valley types.

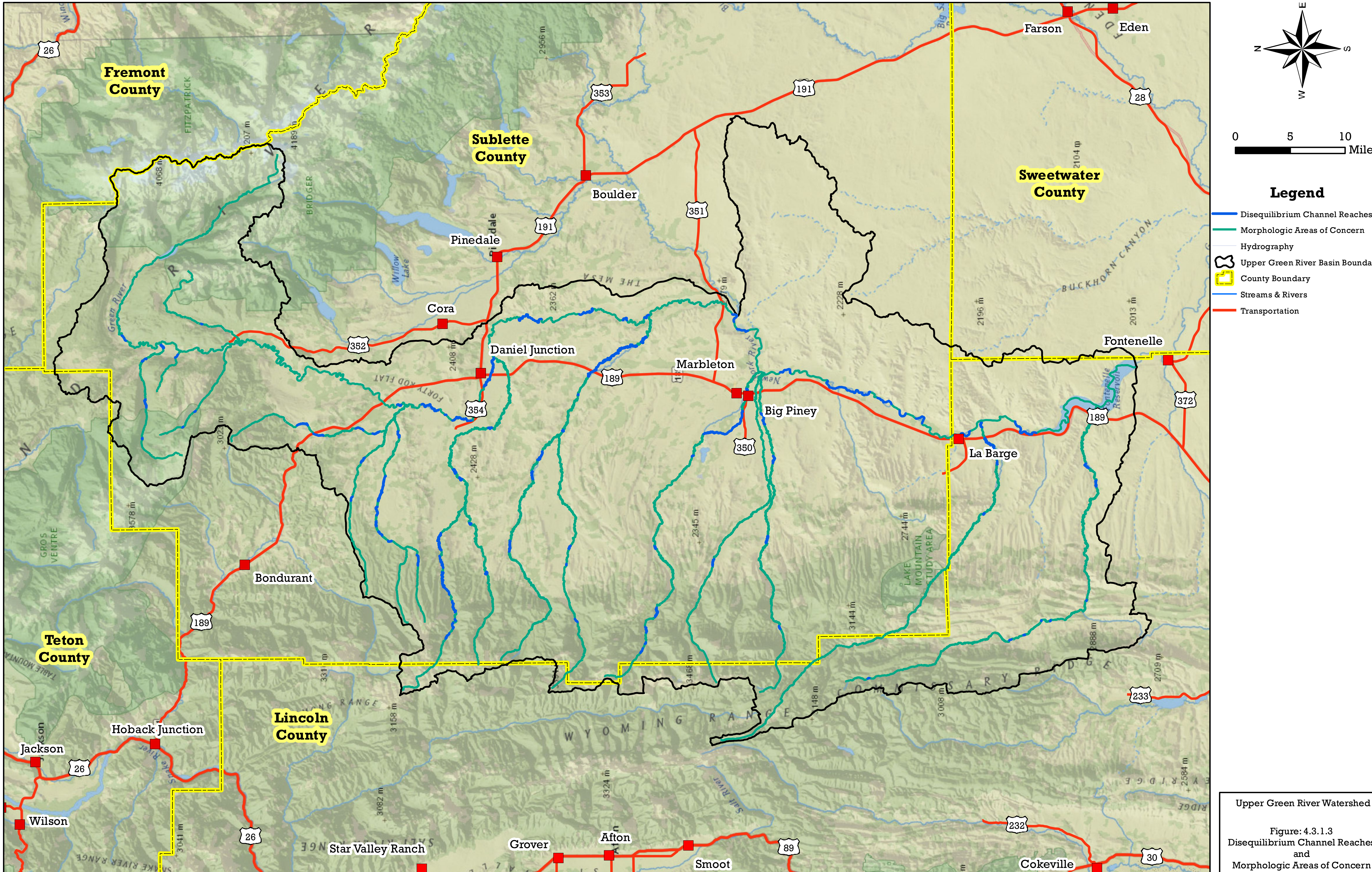
Valley Type	**Typical Equilibrium Channel Form**	**Typical Disequilibrium Channel Form**
I	A, G	-
II	B	F, G
IIIa	D	A, F, G
IIIb	B	F, G
IV	C, F	-
V	C, D	F, G
VI	A, B, C, F, G	-
VII	A, G	-
VIIIa	B, C, E	A, D, F, G
VIIIb	B, C, E	A, D, F, G
VIIIc	C, E	A, D, F, G
IX	C, D	F, G
X	C, Da, E	F, G

The stability of stream channels in the Upper Green River watershed study area can be interpreted in the context of setting, or valley type delineations. The project GIS enables review of geomorphic channel form in the context of valley type at georeferenced locations within the study area. Presented information can be used to interpret whether or not a typical equilibrium channel form exists at any given location within the study area based upon valley type. An impaired system that has lost equilibrium with hydrologic, sediment, and/or boundary conditions will undergo an evolutionary trajectory in an attempt to regain equilibrium conditions. An example would be a stable C-type channel that was altered through loss of riparian vegetation. The channel could be expected to widen and become a braided D-type channel due to loss of bank stability. The channel would likely cut through historic meanders and straighten in alignment. The increased slope of the straightened channel would then enable down-cutting and the formation of a G-type channel with excessive hydraulic forces. Additional bank erosion would ensue, and ultimately a high width/depth ratio entrenched F-type channel would result. The F-type channel would lose competence to down-cut through existing substrate, but would continue to erode banks and recruit sediment. Excessive sediment inputs would result in the formation of a constrained inset floodplain, and ultimately the regaining of equilibrium conditions through the creation of a C-type channel at the lowered elevation. This evolutionary scenario is depicted as example 3 in Figure 4.3.1.2, which depicts typical observed channel evolutionary sequences (NRCS 2007).

Figure 4.3.1.2 Example evolutionary trajectories in channel form due to initial loss of equilibrium conditions.



Reaches of stream channel that are in disequilibrium based upon interpretation of geomorphic classification in the context of valley type delineation are presented in Figure 4.3.1.3. Identified reaches have morphology indicative of impaired channel function, and are either vertically or laterally unstable. Morphologic areas of concern include nick points, headcuts, channel impingements, and areas of instability identified during the geomorphic classification. Disequilibrium channel reaches and morphologicl areas of concern are also depicted in Figure 4.3.1.3.



Upper Green River Watershed

Figure: 4.3.1.3
Disequilibrium Channel Reaches
and
Morphologic Areas of Concern

Projection: NAD 83 - UTM Zone 12

4.3.2 STREAM CHANNEL RESTORATION STRATEGIES

Extensive restoration and enhancement strategies have been developed and reviewed in the fluvial geomorphologic literature. Stream reaches identified as being in disequilibrium during the geomorphic classification represent precise locations where future channel improvement efforts could be pursued. Implementation of restoration efforts would involve the reconstruction of a specific channel form that would be in morphologic equilibrium with hydrologic and sediment inputs. Such comprehensive efforts require comprehensive survey, modeling, and design work at the reach scale, and should be conducted by practitioners with extensive experience in river restoration science. A less comprehensive approach to river restoration is to implement isolated treatments to improve and stabilize impaired conditions. However, such treatments should be designed in the context of existing channel form, the likely scenario of channel evolution, and the potential future equilibrium channel morphology. Numerous treatment strategies exist to stabilize stream channels, but all treatment types are not universally appropriate for application within all channel forms. Tables 4.3.2.1 and 4.3.2.2 describe the relative appropriateness of instream treatments based upon morphologic channel type (Rosgen 1996).

Tables 4.3.2.1 and 4.3.2.2. Applicability of instream restoration and stabilization treatments by Rosgen channel type.

Channel Type	Gravel Traps, V shaped	Gravel Traps, Log	Cross Vane	W-Weir	Root Wad Bank Stabilization	J-Hook, Hybrid Vanes
B1	Excellent	Excellent	Good	Good	n/a	n/a
B2	Good	Good	n/a	n/a	n/a	n/a
B3	Poor	Poor	Excellent	Excellent	Excellent	Excellent
B4	Poor	Poor	Excellent	Excellent	Excellent	Excellent
B5	Poor	Poor	Good	Excellent	Excellent	Good
B6	Poor	Poor	Good	Good	Excellent	Excellent
C1	Good	Good	Good	Good	Excellent	Good
C2	Excellent	Excellent	n/a	n/a	Excellent	Good
C3	n/a	n/a	Excellent	Excellent	Excellent	Excellent
C4	Poor	Poor	Excellent	Good	Excellent	Excellent
C5	Poor	Poor	Good	Fair	Excellent	Good
C6	Poor	Poor	Good	Good	Excellent	Good
D3	Poor	Poor	Poor	Poor	Fair	Fair
D4	n/a	Poor	Poor	Poor	Fair	Fair
D5	Poor	Poor	Poor	Poor	Fair	Fair
D6	Poor	Poor	Poor	Poor	Fair	Fair
E3	Fair	Fair	Good	n/a	Good	Good
E4	n/a	n/a	Good	n/a	Good	Good
E5	Poor	Poor	Good	n/a	Good	Good
E6	Poor	Poor	Good	n/a	Good	Good
F1	Poor	Poor	n/a	n/a	n/a	n/a
F2	Fair	Fair	n/a	n/a	n/a	n/a

F3	Fair	Fair	Good	Fair	Good	Good
F4	n/a	n/a	Good	Fair	Good	Good
F5	Poor	Poor	Good	Fair	Good	Good
F6	Poor	Poor	Good	Fair	Good	Good
G1	n/a	n/a	n/a	n/a	n/a	n/a
G2	n/a	n/a	n/a	n/a	n/a	n/a
G3	Poor	Poor	Good	Poor	Good	Fair
G4	Poor	Poor	Good	Poor	Good	Fair
G5	Poor	Poor	Good	Poor	Good	Fair
G6	Poor	Poor	Good	Poor	Good	Fair

Channel Type	Low Stage Check Dam	Medium Stage Check Dam	Boulder Placement	Single Wing Deflector	Double Wing Deflector	Channel Constrictor	Bank Cover
B1	Poor	Poor	Poor	Poor	Poor	Poor	Excellent
B2	Excellent	Excellent	n/a	Excellent	Excellent	Excellent	Excellent
B3	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent
B4	Excellent	Good	Excellent	Excellent	Excellent	Excellent	Excellent
B5	Good	Fair	Fair	Good	Good	Good	Excellent
B6	Good	Fair	Fair	Good	Good	Good	Excellent
C1	Poor	Poor	Poor	Poor	Poor	Poor	Excellent
C2	Good	Fair	n/a	Good	Good	Good	Good
C3	Good	Fair	Good	Good	Good	Good	Good
C4	Fair	Poor	Poor	Fair	Fair	Fair	Good
C5	Fair	Poor	Poor	Poor	Poor	Poor	Fair
C6	Fair	Poor	Poor	Poor	Poor	Fair	Good
D3	Poor	Poor	Poor	Fair	Fair	Fair	Poor
D4	Poor	Poor	Poor	Fair	Fair	Fair	Poor
D5	Poor	Poor	Poor	Fair	Fair	Fair	Poor
D6	Poor	Poor	Poor	Fair	Fair	Fair	Poor
E3	n/a	Poor	Poor	Poor	Fair	n/a	n/a
E4	n/a	Poor	Poor	Poor	Fair	n/a	n/a
E5	n/a	Poor	Poor	Poor	Fair	n/a	n/a
E6	n/a	Poor	Poor	Poor	Fair	n/a	n/a
F1	Poor	Poor	Poor	Fair	Poor	Poor	Fair
F2	Fair	Poor	n/a	Fair	Fair	Fair	Fair
F3	Fair	Poor	Fair	Good	Good	Fair	Fair
F4	Fair	Poor	Poor	Good	Fair	Fair	Fair
F5	Fair	Poor	Poor	Fair	Fair	Fair	Fair
F6	Fair	Poor	Fair	Fair	Fair	Fair	Fair
G1	n/a	n/a	Poor	n/a	n/a	n/a	Poor
G2	n/a	n/a	n/a	n/a	n/a	n/a	Poor
G3	Fair	Poor	Poor	Poor	Fair	n/a	Poor
G4	Fair	Poor	Poor	Poor	Fair	n/a	Poor
G5	Fair	Poor	Poor	Poor	Fair	n/a	Poor
G6	Fair	Poor	Poor	Poor	Fair	n/a	Poor

Instream treatment example: W-weir.

Instream treatment example: hybrid rock/log vane.

Instream treatment example: root wad revetment and rock barb.

Instream treatment example: rock cross vane.

Instream treatment example: rock J-hook vane.

4.4 GRAZING MANAGEMENT OPPORTUNITIES

4.4.1 ECOLOGICAL STATE AND TRANSITION MODELS

NRCS ecological site descriptions provide state and transition models for each ecological site. These models illustrate the plant communities that typically occur on the site and transitions between these communities (states) due to ecological disturbances or changes in management practices. State and transition models for the Historic Climax Plant Community (HCPC) in each of the 3 most prominent ecological sites within the watershed are provided below along with a brief description from the respective ESD. The HCPC is typically determined by expert study of rangeland relic areas, or areas protected from excessive disturbance, as well as trends in plant communities going from heavily grazed areas to lightly grazed areas, seasonal use pastures, and historical accounts.

The most abundant ecological site in the watershed is **Loamy 10-14" Foothills and Basins West**. The full report for this ecological site can be found at https://esis.sc.egov.usda.gov/ESDReport/fsReport.aspx?approved=yes&id=R034AY222WY.
The HCPC for this site is a Mixed Grass/Big Sagebrush community. This community (state) evolved with grazing by large herbivores and is well suited for grazing by domestic livestock. Potential vegetation is estimated at 75% grasses or grass-like plants, 10% forbs, and 15% woody plants. As this site deteriorates because of a combination of frequent and severe grazing, species such as big sagebrush, rabbitbrush, phlox, and yarrow will increase. Cool-season bunchgrasses such as bluebunch wheatgrass, Indian ricegrass, and needle-and-thread will decrease in frequency and production. Big sagebrush will become dominant on some areas with an absence of fire.

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

- Nonuse and No Fire will convert this plant community to the Big Sagebrush/Bunchgrass State.
- Heavy Continuous Season-long Grazing and No Fire will convert this plant community to the Big Sagebrush/Rhizomatous Wheatgrass State.
- Wildfire with Heavy Continuous Season-long Grazing will convert this plant community to the Rabbitbrush/Rhizomatous Wheatgrass State.

A graphical depiction of the model for this ecological site is depicted in Figure 4.4.1.1.

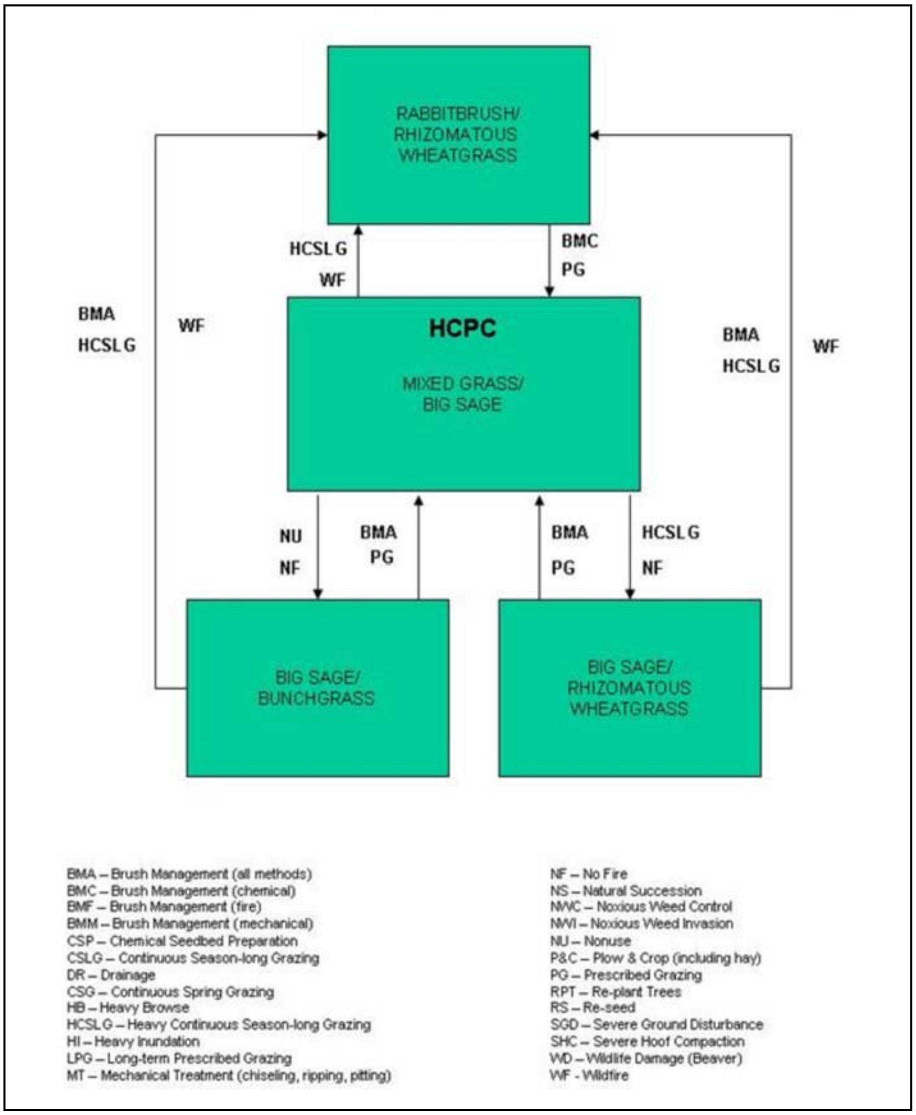


Figure 4.4.1.1. A graphical depiction of the state and transition model for the Loamy 10-14” Foothills and Basins West site.

The HCPC for **Loamy 15-19" Foothills and Mountains West** ecological site is a Mixed Grass/Mountain Big Sagebrush community. The full report for this ecological site can be found at https://esis.sc.egov.usda.gov/ESDReport/fsReport.aspx?approved=yes&id=R043BY222WY.
This community (state) evolved with grazing by large herbivores and is well suited for grazing by domestic livestock. Potential vegetation is estimated at 75% grasses or grass-like plants, 15% forbs, and 10% woody plants. This plant community is extremely stable and well adapted to the Central Rocky Mountains climatic conditions. The diversity in plant species allows for high drought tolerance. As this site deteriorates because of a combination of frequent and severe grazing, species such as mountain big sagebrush, buckwheat, and yarrow will increase. Less palatable grasses such as Letterman needlegrass, Idaho fescue, rhizomatous wheatgrass, and Sandberg bluegrass also increase. Kentucky bluegrass often invades. Cool-season grasses such as bluebunch wheatgrass, blue wildrye, mountain brome, Columbia needlegrass, and spike fescue will decrease in frequency and production. Mountain big sagebrush will become dominant with the absence of fire.

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

- Nonuse and No Fire will convert this plant community to the Mountain Big Sage/Bunchgrass State.
- Heavy Continuous Season-long Grazing and No Fire will convert this plant community to the Mountain Big Sage/Idaho Fescue State.
- Wildfire with Heavy Continuous Season-long Grazing will convert this plant community to the Kentucky Bluegrass/Idaho Fescue State.

A graphical depiction of the model for this ecological site is depicted below in Figure 4.4.1.2.

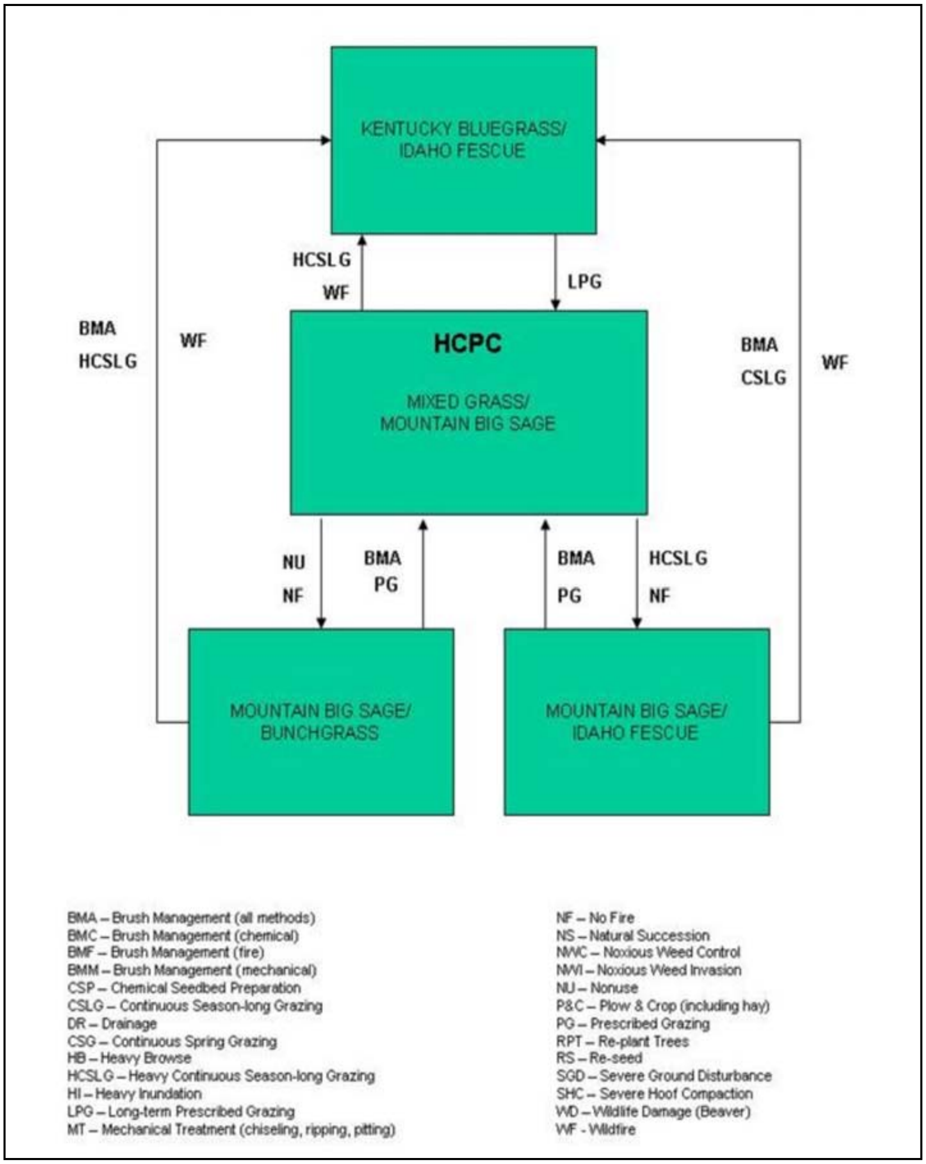


Figure 4.4.1.2. A graphical depiction of the state and transition model for the Loamy 15-19” Foothills and Mountains West site.

The HCPC for **Loamy 7-9” Green River and Great Divide Basins** ecological site is a Mixed Grass/Big Sagebrush community. The full report for this ecological site can be found at https://esis.sc.egov.usda.gov/ESDReport/fsReport.aspx?approved=yes&id=R034AY122WY. This community (state) evolved with grazing by large herbivores and is well suited for grazing by domestic livestock. Potential vegetation is estimated at 75% grasses or grass-like plants, 10% forbs, and 15% woody plants. This plant community is extremely stable and well adapted to the Cool Central Desertic Basins and Plateaus climatic conditions. The diversity in plant species allows for high drought tolerance. As this site deteriorates because of a combination of frequent and severe grazing, species such as big sagebrush, rabbitbrush, phlox, and yarrow will increase. Cool-season bunchgrasses such as bluebunch wheatgrass, Indian ricegrass, and needle and thread will decrease in frequency and production.

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

- Nonuse and No Fire will convert this plant community to the Big Sagebrush/Bunchgrass State.
- Heavy Continuous Season-long Grazing and No Fire will convert this plant community to the Big Sagebrush/Rhizomatous Wheatgrass State.
- Wildfire with Heavy Continuous Season-long Grazing will convert this plant community to the Douglas Rabbitbrush/Rhizomatous Wheatgrass State.

A graphical depiction of the model for this ecological site is depicted below in Figure 4.4.1.3.

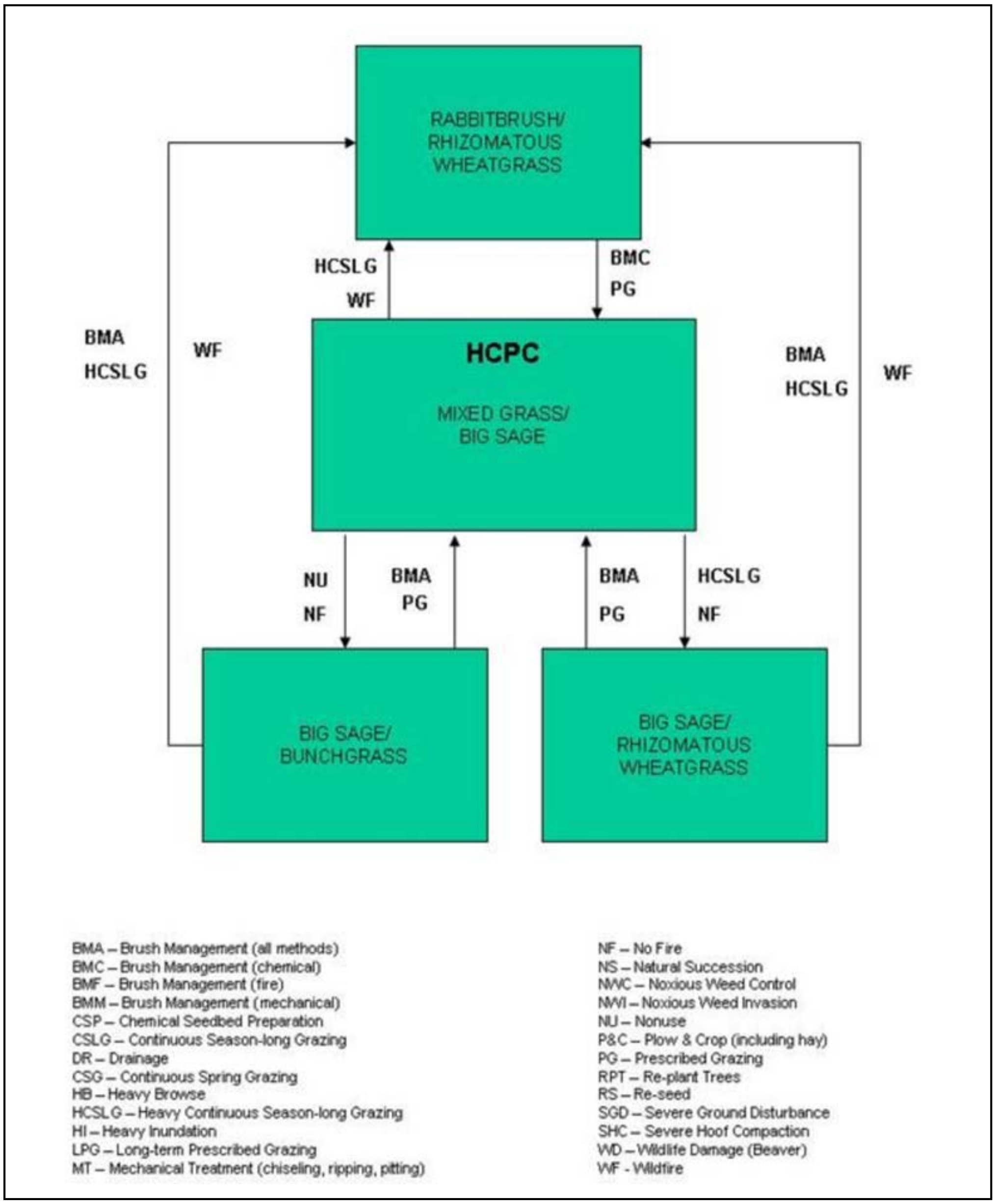


Figure 4.4.1.3. A graphical depiction of the state and transition model for the Loamy 7-9” Green River and Great Divide Basins site.

4.4.2 RANGE AND GRAZING MANAGEMENT CONSIDERATIONS

In the sagebrush grasslands of the arid west, livestock use is often concentrated around watering areas and lush palatable vegetation (i.e., riparian zones). Implementing certain Best Management Practices (BMPs) can help to disperse livestock, graze underutilized areas, and reduce pressure on riparian zones. Environmental conditions and constraints vary amongst allotments, but the following BMPs can be implemented in concert with the ESD state and transition models to improve range health:

1. Upland (i.e., off-site) livestock watering systems;
2. Strategic salting and/or herding;
3. Riparian fences to exclude livestock from, or manage livestock use of, riparian areas;
4. Pasture fences or cross-fences to facilitate rotational grazing systems;
5. Prescribed fire; and
6. Chemical brush control.

Many of these management practices are mutually beneficial for livestock, range condition, and wildlife. It is important to consider the impacts of any range improvement project on wildlife and wildlife habitat, especially in sensitive habitats. Some range improvement projects can unintentionally have adverse effects on wildlife habitat. For example, the installation of certain types of fence can increase the chance of certain species of wildlife becoming entangled. Adding a smooth top wire or rail to the fence will help to mitigate these impacts. Another example of a wildlife friendly range improvement project involves the addition of escape ramps to stock watering tanks.

There are many different types and applications of upland water developments for livestock, and the particular design that is selected depends on needs, local conditions, and available funding. Upland livestock watering systems typically include spring developments, wells, pumps, tanks, diversions, or gravity feed systems.

Strategic salting and active herding can be used to direct livestock to the most underutilized areas in a pasture of allotment. The most desirable areas are often grazed so heavily that individual plants do not have time to replenish nutrients and energy reserves between grazing episodes. Strategic salting and active herding can reduce grazing pressure on the areas that have the most concentrated use, and allow root system reserves to be replenished in these areas.

4.5 OTHER UPLAND MANAGEMENT OPPORTUNITIES

4.5.1 PRESCRIBED FIRE

The native vegetation communities of the entire watershed study area evolved as dynamic landscapes influenced to varying degrees of intensity by wildland fire. Active fire suppression and historic land management including intensive livestock grazing, have impacted stand diversity and productivity in both forested as well as shrub steppe and grassland-dominated community types. Dense, often monotypic stands of vegetation with depleted understory diversity and herbaceous productivity have resulted. Large stand replacing fires historically were an important source of landscape heterogeneity, introducing a mosaic of unburned patches interspersed through burned or partially burned areas. Unburned, mature even-aged forested communities have also proven to be more susceptible to epidemics of mountain pine beetle, bark beetle and budworm infestations.

Where fire suppression has been the presiding management option, natural wildland fires, when they do occur, burn uncharacteristically hot and turn normally forested areas into sparsely vegetated areas lacking sufficient seed sources and lack potential for cool or moist microclimates necessary for native plant establishment and growth. The primary forest communities within the watershed (Douglas-fir, lodgepole pine, whitebark pine, limber pine, subalpine fir/Engelmann spruce and aspen) are all underrepresented by the youngest age classes (<5" dbh); representing a lack of regeneration in these important forest communities. Prescribed fire can address habitat improvement criteria to maintain healthy ecosystems, while reducing hazardous fuels to mitigate potential for future severe wildland fires.

Prescribed burns in the shrub steppe vegetation community are also recommended where sagebrush canopy cover exceeds 25 percent, in more than 30-45 percent of the sagebrush community. Under these conditions, soil water retention is reduced and growth of important understory species, such as forbs and perennial bunchgrasses, is suppressed. The use of prescribed burns as a management technique in sagebrush-dominated communities must be applied very carefully, as such areas are susceptible to conversion to non-native annual species such as cheatgrass, limiting the habitat value for sagebrush obligate species that require shrub cover. Prescribed burns in sagebrush-dominated shrublands should be applied on a small scale, and designed to allow gradual reestablishment of sagebrush from peripheral stands or direct seeding. Early spring and late fall burns are preferable, as hot season fires eradicate native perennial grasses and forbs, and favor invasive species. Fire, applied appropriately can reduce cheatgrass invasion, however, evaluation of potential prescribed burn size and severity is integral to preserving extant sagebrush habitats, and implementation of natural or mechanical firebreaks may be necessary to avoid excessive impacts to important sagebrush habitat.

If used properly, prescribed burns can increase production of desirable forage, benefiting both livestock and wildlife. Watershed values improve overall by decreasing bare ground, decreasing runoff, and improving infiltration, again to the benefit of wildlife and stock. Base flows in creeks sustained by groundwater discharges can extend later into the summer, benefiting the riparian environment and aquatic habitat in these reaches. Disadvantages of prescribed fire include; temporary increases in rates of soil erosion and decreases in water quality, increases in soil temperature extremes, initial loss of vegetative productivity, reduction in soil moisture level, and requires a minimum of one growing season rest (BLM Rangeland Mechanical Treatment Guide).

4.5.2 MECHANICAL TREATMENT

Upland vegetation may benefit in special circumstances from mechanical treatments where passive management practices may not achieve long-term habitat goals. Mechanical treatments are generally specific to a community type, and have proven successful in rapid landscape alterations that allow for restoration to a desired plant community composition or age-structure, within an accelerated time frame.

Upland shrub-steppe communities dominated by sagebrush may benefit from localized mechanical treatments including mowing, roto-beating, chaining, disking, roller harrowing, railing, and blading. As an example of achievable project goals through mechanical treatment, recent mowing of 300-400 acres within USFS allotments near Daniel, WY were designed with the following objectives: 1) Remove decadent and dead sagebrush. 2) Increase age class diversity of sagebrush in a mosaic pattern. 3) Increase the vigor and production of the existing perennial grass and forb species. 4) Maintain or increase herbaceous diversity. 5) Improve wildlife habitat for mule deer, antelope, elk and sage-grouse. Important considerations include maintaining sufficient mature shrub component to the landscape such that natural regeneration of forbs, perennial grasses and native shrubs will occur.

Regional aspen declines have been tied directly to replacement by seral conifers, fire suppression, and excessive herbivory. Disturbance through fire or other means reduces competition from conifers and creates conditions conducive for reproduction and recruitment of early seral stages of aspen. Mechanical treatments in aspen that can be used independently or in conjunction with a prescribed fire management plan include thinning of mature aspen, removal of conifers, and aspen root separation, or severing of lateral roots near the soil surface with bulldozer-mounted ripper attachment, to stimulate regeneration. In some areas, successful regeneration of aspen cannot be accomplished without clone or stand protection with fencing.

Pastureland, rangeland, grazed forest and native pastures where slopes are less than 30 percent may benefit from pitting, contour furrowing, and chiseling, ripping of subsoiling. These mechanical treatments for grazing lands are designed to fracture compacted soil layers, and improve soil permeability. Additional benefits include reduction in runoff and increased infiltration, increased plant vigor, and consequently increased plant productivity and yields. Site-specific considerations and specifications for these applications can be obtained from the NRCS.

4.5.3 INVASIVE SPECIES TREATMENT

State Weed and Pest administrative areas are contiguous with county boundaries in Wyoming. Therefore, portions of 4 county Weed and Pest Districts are within the Upper Green River watershed study area, led in area of representation by Sublette County and Lincoln County Weed and Pest Districts. Weed and pest districts focus on education outreach, as well as active identification and treatment of noxious weeds to maintain low levels of invasive and noxious weeds in the region. The district weed and pest offices are responsible for noxious weed control on Federal, State and County road right-of-ways, as well as collaborative weed control with state and federal agencies and through cost share agreements with private landowners and oil and gas production companies. Cost share opportunities are available through the local Weed and Pest Districts, and the best information outlet for broader funding and coopertative invasive species management information is the Wyoming Weed and Pest Council (http://www.wyoweed.org). The Weed and Pest districts have established guidelines for assuming some or all of the cost of weed prevention and detection on private property, including weed control consultation, reduced price herbicides, and spray equipment. Sublette County Conservation District has also developed a Wildlife and Habitat Program, wherein funds are allotted for conservation planning and engaging in environmentally of socially beneficial activities (Payment for Ecosystem Services Program). More information is available at the following web address: http://sublettecd.com/pid/63/wildlife-and-habitat-program.aspx .

In 2010, the Invasive Species Taskforce of Sublette County was formed to investigate and understand the extent of invasive species problems in the County. Taskforce membership includes agency and private industry partners, including Sublette County Weed and Pest, BLM, WGFD, NRCS, and the Sublette County Conservation District. BLM has made controlling noxious weeds a priority, and the taskforce collaborative effort has allowed BLM to focus biological, chemical, and manual removal techniques on impacted areas within grazing allotments, oil and gas leases, adjacent lands (USFS, private, State), and prime recreational hunting areas. The Pinedale Field Office Noxious Weed Management project and the Boulder Jonah Cheatgrass project are examples of two regional collaborative efforts led by BLM to eradicate and otherwise control the spread of invasive plant species.

Forested lands on the Bridger-Teton National Forest have not been identified as high-risk weed management areas; however, an inventory of noxious weeds does indicate an increase in acres infested and in the number of species present. Recent or prolonged surface disturbing activities are the greatest contributors to the spread of noxious weeds, and demand the highest level of proactive control of weed dispersal. The Forest Service National Strategic Framework for Invasive Species Management (2013) prioritizes and guides prevention, detection, and control of invasive plants, insects, pathogens, wildlife and fish.

(http://www.fs.fed.us/foresthealth/publications/Framework_for_Invasive_Species_FS-1017.pdf).

The most cost effective way to manage weeds is through early detection and small-scale infestation control. Wyoming State laws require landowners to control noxious weeds, and integrate weed control Best Management Practices for any project as identified in the Upper Green River Sage Grouse Management Plan (WGFD 2007) and outlined here:

1. Identify invasive/noxious plants of concern within the project area.
2. Map areas where invasive/noxious plants of concern already exist, and weed free areas.
3. Implement strategies to assist in prevention of the spread of noxious weeds or invasive plants.
4. Prioritize and aggressively treat invasive/noxious plants in identified areas of concern.
5. Employ appropriate site preparation techniques and timely reseeding, with approved seed mixes, of any disturbed areas to prevent establishment and encroachment of invasive/noxious plants.
6. Maintain cumulative records for invasive/noxious plants treatment.
7. Educate public on invasive weeds and how to control them.
8. Encourage use of wash stations or vehicle cleaning for vehicles or equipment that have a high potential to spread weeds.
9. Encourage enforcement of travel plans on public lands.

Noxious weed management and control can be cost and labor intensive, especially when particularly invasive species become established. Support for landscape-level habitat restoration and noxious weed control through cooperative efforts with State and Federal agencies, such as the Sublette County Invasive Species taskforce, is recommended. Focal treatment of target species such as perennial pepperweed, cheatgrass, Canada thistle, and musk thistle should be coordinated through the local Weed and Pest Districts. Typical treatment of these species employs the use of herbicide such as Roundup or Plateau. Local Weed and Pest Districts have cost-share programs that reimburse landowners for a portion of the costs associated with pesticide application.

As an example, pesticides purchased by a Sublette County resident from SCWPD for treatment of Wyoming “Designated” or Sublette County “Declared” noxious weeds will get a cost share of 75%, with a cap at $1,000 per person. SCWPD will also cover 35% of contracted labor costs for the pesticide application, with a cap of $10,000. You must call ahead about your project and turn in your application record and proof of payment to SCWPD. In addition Sublette County Weed and Pest provides backpack, ATV sprayers, slide-in and hand sprayers at no cost to residents or property owners in Sublette County.

V. IRRIGATION SYSTEM INVENTORY AND REHABILITATION

5.1 AGRICULTURAL WATER USE

Agricultural Water use in the Upper Green River Basin consists primarily of irrigation and to a lesser degree stock watering. Although a few irrigation wells exist in the Upper Green River Basin, the predominant source of irrigation supply is surface water. Historically, a network of canals and ditches were constructed by producers to convey water from the natural tributaries and main stream Green River to the meadows and cultivated lands. Flood irrigation remains the principal method of applying water to the fields. In recent years, through the NRCS Environmental Quality Incentives Program (EQIP), center pivot irrigation systems have emerged as an alternative to flood irrigation. Center pivot irrigation is being utilized in the LaBarge, Big Piney, and 40 Rod Flat area(s) of the Upper Basin.

5.1.1 IRRIGATION SYSTEM INVENTORY

Approximately 287 diversions to ditches or pipline intakes exist in the Upper Green River watershed atudy area. The diversion priority dates range from 1882 to 1988. Table 5.1.1 Irrigation/Surface Water Rights Tabulation in Appendix J contains the conveyance name along with the appropriator, permit number, priority date, diversion rate, acreage and source creek.

During the course of this study the public meetings discussed in Section II were used to identify potential landowners/managers with projects. Several landowners/managers at these meetings later proposed projects. In addition, the SCCD was able to gain several referrals by word of mouth. Meetings were held with these landowners and concept projects were produced. Section 5.1.2 and Appendix A identify the particular projects discussed along with cost and locations.

5.1.2 POTENTIAL IRRIGATION IMPROVEMENT PROJECTS

Much of the project need within the Upper Green River waterhed study area is associated with aging headgate structures constructed of wood; headgates being stranded as the main channel drops in elevation; and diversion revetments that are difficult to maintain. One of the projects also included piping of a ditch section and one project proposal involves the abandonment of a troublesome ditch section in favor of a downstream pumped irrigation diversion.

Removal of headgates and combining ditches was the goal of the most expensive project. This project on Cottonwood Ranches involves abandonment of two headgates and short ditch extensions from upstream headgates to maintain the same irrigated acreage. This project will aid fish passage and also remove some recurring maintenance demands.

The following Table 5.1.2 summarizes the project types and cost. More detailed evaluations and detailed cost estimates for each project are found in Appendix A – (Irrigation Rehabilitation Projects) under the respective owner or operator name.

Table 5.1.2 Potential Irrigation Projects

IRRIGATION PROJECTS	Project Type and Number of Potential Projects							
Owner or Operator	Ditch Improvements	Headgate Modifications				Total	Notes	**Estimated Project Costs**
Bill Barney	1							$ 32,171
Dave Pape		1				1	Same Headgate as Jon Boroff	
Jon Boroff		1				1	Same Headgate as Dave Pape	$ 51,460
Freddie Botur (Cottonwood Ranches)	3	5				8	Includes some large (12" to 24") pipeline	$ 730,222
Albert Summers		1				1		$ 57,088
Wapika Ranches		1				1		$ 38,056
Aaron Wilson/Joc Saxton	1	1				2		$ 140,214
							Total Cost All Projects	**$ 1,049,210**

5.1.3 IRRIGATED ACREAGE

Irrigated acreage has been reported a number of different ways in studies completed for the Green River Basin since 1970. The area of interest for this study, the Upper Green River Basin, includes lands within WYSEO Division 4, Districts 5, 10 and 11.

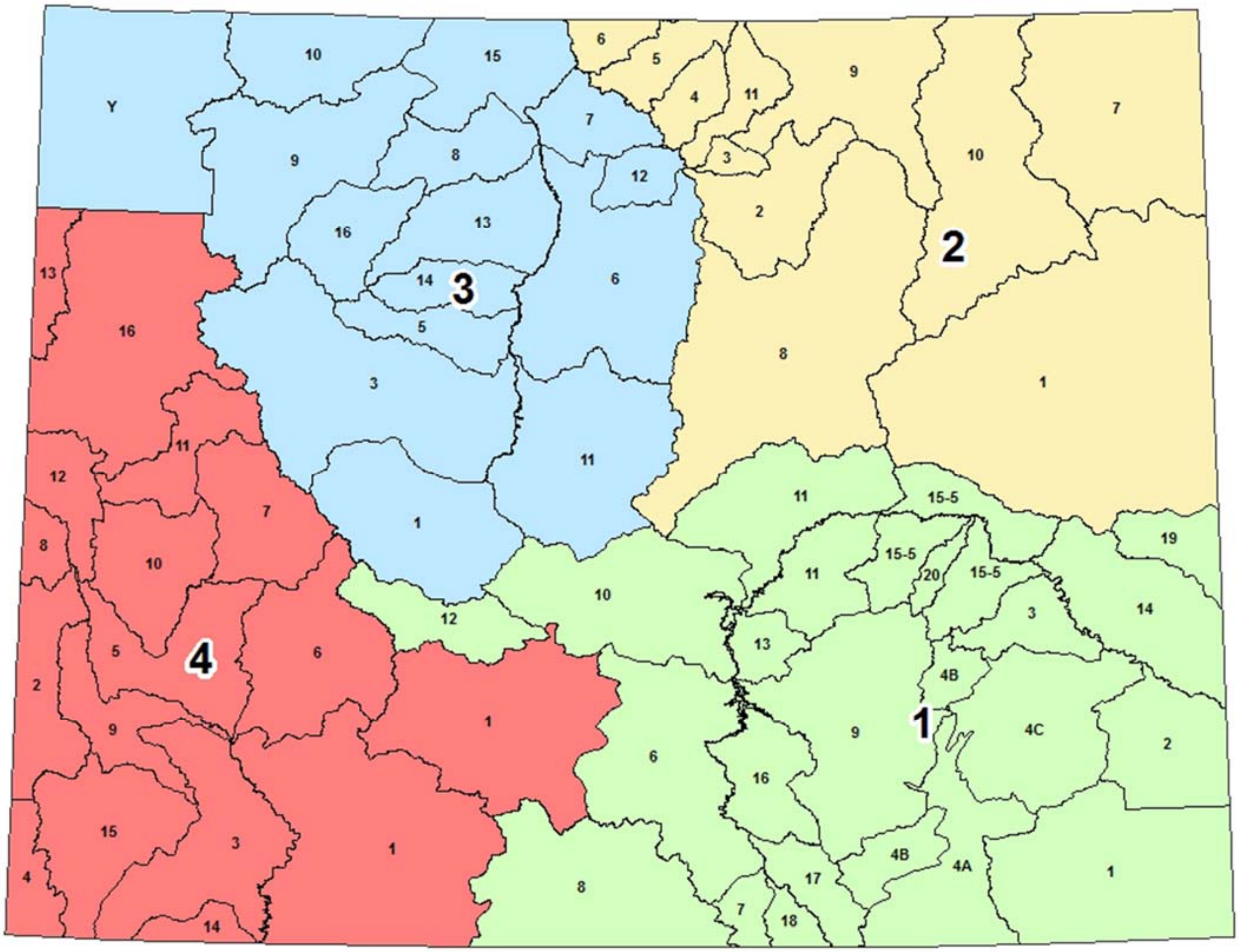


Figure 5.1.3 SEO Water Divisions (map provided by SEO)

The most pertinent method of reporting irrigated acreages for the Upper Green River Basin was completed by Leonard Rice Engineers, Inc. in the Wyoming Water Rights Attribution Geodatabase (WYWRAG) memorandum dated June 27, 2009(Appendix I). Excerpts of the data relevant to the Upper Basin is illustrated in Table 5.1.3. In the table, assigned acreages were tied to a specific source structure, while unassigned acreage was not tied to a source structure. Unassigned acreage could be lands irrigated by return flows or man made riparian areas caused by seepage.

Table 5.1.3 - Irrigated Acreage By Water District

Water District	Wet Year (1997) Acreage			Dry Year (2002) Acreage		
	Assigned	Unassigned	Total	Assigned	Unassigned	Total
5	7,680	5,679	13,360	6,770	5,275	12,045
10	100,357	15,259	115,616	88,347	13,593	101,940
11	11,540	4,151	15,691	10,214	3,742	13,956
Total	**119,577**	**25,089**	**144,667**	**105,331**	**22,610**	**127,941**

The average of the Wet Year and Dry Year values is 136,304 acres.

5.1.4 AGRICULTURAL CROPS

Grass hay and alfalfa are the primary crops in the upper Green River Basin. (WWC Engineering 2010). Small grains and cash crops are grown only in the very southwestern portion of the Green River Basin. Table 5.1.4 illustrates the percentage of acreage used for grass hay and alfalfa in each of the Upper Green River Basin water districts of interest.

Table 5.1.4 Crop Type by Water District Upper Green River Basin

Water District	Grass Hay and Pasture	Alfalfa
05	100%	0
10	95%	5%
11	95%	5%

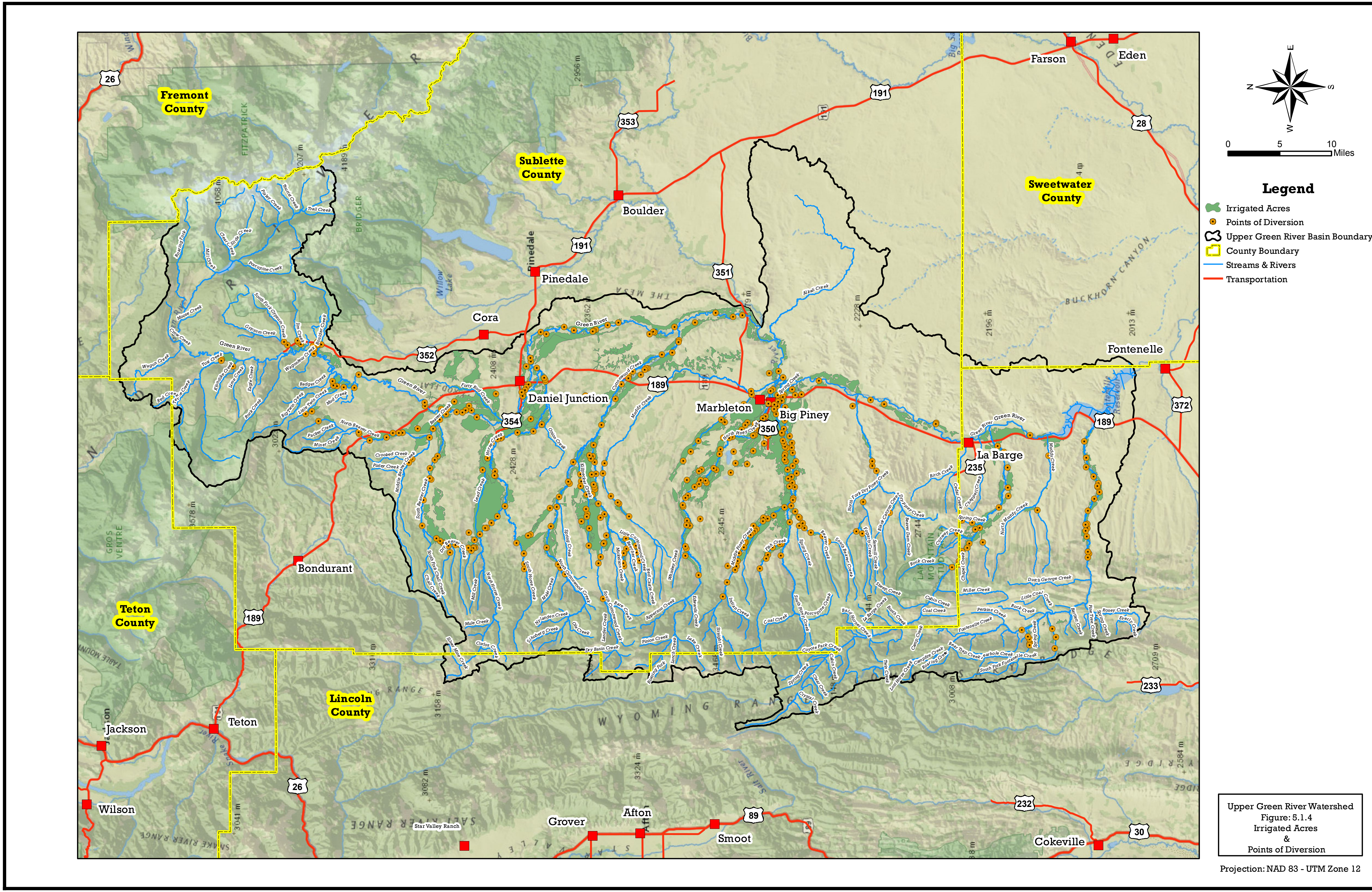
5.1.5 IRRIGATION DIVERSIONS

Based on 2012 WYSEO Hydrographer Annual Reports there are 287 active surface water diversions in Districts 5, 10 and 11 of the Upper Green River Basin. A breakdown of the location and source of the 287 active diversions is illustrated in Table 5.1.5.

Table 5.1.5 Irrigation Diversion by District Upper Green River Basin

Water District	Number of Diversions	Main Stem	Tributary
05	44	6	38
10	218	9	209
11	25	10	15
Total	287	25	262

Of the 287 active diversions, 9 had sufficiently long diversion records to warrant use for calculating consumptive use by Leonard Rice Engineers, Inc. in 2009. Since 2009, additional continuous recorders have been installed and short term records at these monitoring points are now available. Table 5.1.5.2 illustrates Average Monthly Diversions for a number of diversions with varying periods of record. Data for the first 9 sites is taken from Table 7 WYWRAG Memorandum (working draft) by Leonard Rice Engineers, Inc. June 2009 (Appendix I). The remaining data is derived from compilations completed by the WYSEO for 2012 only. Based on records to date from the SEO, these diversions are the ones with continuous recorders at this time (May 2013). Figure 5.1.4 identifies irrigated acreage and points of diversion for the study area. Appendix I contains single line diagrams for the main basin river reaches showing the relative order of diversions along the stream.



Legend
Irrigated Acres
Points of Diversion
Upper Green River Basin Boundary
County Boundary
Streams & Rivers
Transportation
0 5 10 Miles
Fremont County
Sublette County
Sweetwater County
Teton County
Lincoln County
Farson
Eden
Boulder
Pinedale
Cora
Daniel Junction
Marbleton
Big Piney
La Barge
Fontenelle
Bondurant
Jackson
Teton
Wilson
Grover
Afton
Smoot
Cokeville
Star Valley Ranch
Green River
WYOMING RANGE
BUCKHORN CANYON
Upper Green River Watershed
Figure: 5.1.4
Irrigated Acres
&
Points of Diversion
Projection: NAD 83 - UTM Zone 12

Table 5.1.5.2 Upper Green River Basin Average Monthly Diversions by Diversion

Model ID	SEO ID	Structure Name	Division	District	Pattern Gage Assignment	April	May	June	July	Aug	Sept	Total
						Acre-Feet						
5005005		Anderson & Howard Canal	4	5	9210500	274	1,768	3,166	2,234	1,076	333	8,851
5005085		La Barge No. 2 Ditch	4	5	9210500	239	1,144	1,153	733	555	165	3,989
10000301		Homestake Ditch	4	10	9188500	307	1,255	2,388	1,623	593	270	6,436
10000471		Musselman Ditch (District 10)	4	10	9188500	0	464	791	407	166	98	1,926
10000610		South Piney Ditch	4	10	9188500	35	758	2,015	1,169	272	54	4,302
10000715		Yankee Ditch	4	10	9188500	82	410	737	587	495	242	2,553
10000917		Reardon Ditch	4	10	9188500	256	1,344	1,990	1,178	408	192	5,368
10000943		North Piney Ditch	4	10	9188500	50	852	1,742	1,223	712	429	5,007
11000124		Canyon Ditch (Green River)	4	10	9188500	0	1,306	2,692	3,190	1,847	801	9,836
		Structure Name				**2012 Monthly Diversion (Rounded)**						
						April	**May**	**June**	**July**	**Aug**	**Sept.**	**Total**
	197	Alpha	4	10				82	425	59	64	630
	201	Aurora	4	10			118	182	7	2		309
	204	Beaver-IV(10)	4	10				84	369	35		488
	222	Deway	4	10			254	632	244			1,130
	795	Empire (No. 2)	4	10		1	80	182				263
	797	Essex	4	10				12	8			20
	801	Finnegan	4	10		522	277	300	10			1,109
	802	Fish Creek Ditch	4	10			491	663	387	200	240	1,981
	809	Green River Supply	4	10			3510	7030	8150	4970	2310	25,970
	811	H, McKay	4	10		120	458	547	463	56	30	1,674
	1388	Homestake (Middle Piney)	4	10		626	1530	1580	621	70		4427
	1386	Homestake (South Piney)	4	10								
	851	Midmermac	4	10		553	632	558	151			1,894
	1233	Muir No. 2	4	10			80	278	223	155		736
	858	Munn (D10)*	4	10				369	906	1240	1090	3,605
	870	North Piney Canal	4	10		132	853	1440	322	635	65	3,447
	883	Ranchero	4	10				460	104			564
	888	Red Bluff	4	10		18	156	362	64	3		603
	895	S. McKay No. 2	4	10		327	511	1230	961	33		3,062
	971	South Piney Canal	4	10								
	973	South Piney Canal (Middle Piney)	4	10		454	1180	1250	519			3,403
	975	Spencer	4	10				549	260	235	259	1,303
	986	Vermillion	4	10		252	273	191	56			772
	1410	Ballou- Plank*	4	11			194	270	73	56	65	658

*Bad Sensor – Values are estimated.

5.2 CONSUMPTIVE USE IN THE UPPER GREEN RIVER BASIN

Water use for irrigation in the Green River basin has been estimated in several previous publications commissioned by the state of Wyoming, notably described in a draft memo issued by Leonard Rice Engineers, Inc. 2009. These results were incorporated into the Green River Basin Plan (WWC Engineers, 2010). This section presents a summary of that work, specific to the Upper Green River Basin, Districts 5, 10, and 11.

Irrigation water in the Upper Green River Basin is mostly obtained from surface water diversions (Leonard Rice Engineers, Inc. 2009). The 2010 Green River Basin Plan shows only 7 irrigation wells in Districts 5, 10, and 11. Crops grown in the Upper Green River Basin are almost exclusively grass hay, with minor amounts of alfalfa (see Table 5.1.3). Flood irrigation remains the most common method, with limited use of sprinklers.

Crop irrigation requirement (CIR) is the amount of water required by the crop to meet evapotranspiration throughout the growing season. It can be viewed as the maximum amount of water that could be used by a specific crop. Consumptive use (CU) is the amount of water that the crop actually uses. When it is less than CIR, it is most often because water is not available to irrigators for the entire irrigation season.

To fully meet the CIR at the field level, additional water must be diverted from the source. A significant portion of the diverted flow is typically lost to seepage from canals and ditches; inefficiencies at head gates; scheduling inefficiencies; and on-farm losses. On-farm losses can include evaporation from sprinklers; runoff and tail water from fields; deep percolation out of the root zone and inefficient and lack of uniformity in application of water.

The 2010 Green River Basin Plan presents estimates of consumptive use and crop irrigation requirement, based specifically on the Leonard Rice Engineers, Inc. 2009 memo. These values are shown in the table below, as presented in the 2010 basin plan for the Upper Green River Basin districts.

The LRE / Basin Report CIR analysis represented in Table 5.2.1 is reporting a) Average year shortages over the entire 1971 - 2007 study period assuming the amount of acreage irrigated in a Dry Year is irrigated every year, and b) Average year shortages over the entire 1971 - 2007 study period assuming the amount of acreage irrigated in a Wet Year is irrigated every year.

Table 5.2.1 Average Annual Upper Basin Results (1971-2007)
for Representative Wet and Dry Year Acreage

	Water District	Consumptive Irrigation Requirement (Acre-Feet)	Actual Consumptive Use (Acre-Feet)	Percent Short
WET YEAR	5	16,804	16,558	1%
	10	133,172	113,629	15%
	11	20,527	20,527	0%
	Total	**170,503**	**150,714**	**12%**
DRY YEAR	5	15,162	15,044	1%
	10	118,455	106,650	10%
	11	17,260	17,260	0%
	Total	**150,877**	**138,954**	**8%**

Source: WWC Engineering (2010), Leonard Rice Engineers, Inc.(2009)

In the table above, Wet Year and Dry Year are based upon water use data for 1997 and 2002, respectively. The crop irrigation requirement was calculated using a modified Blaney-Criddle method, with TR-21 coefficients, and with a standard adjustment for the higher elevations of the project area. The LRE / Basin Report CIR analysis represented in Table 5.2.1 is reporting a) Average year shortages over the entire 1971 - 2007 study period assuming the amount of acreage irrigated in a Dry Year is irrigated every year, and b) Average year shortages over the entire 1971 - 2007 study period assuming the the amount of acreage irrigated in a Wet Year is irrigated every year. Irrigated acreage is less in a dry year, but in actuality, shortages are more in a dry year because irrigators can't irrigate the acreage they'd like to or would irrigate in a normal or wet year. So this doesn't represent the 100% shortage on those acres not irrigated in a dry year.

Actual consumptive use within each district attempts to define the amount of water used for irrigation, for comparison with the consumptive irrigation requirement. It is based upon monthly diversion records rather than climate data or crop needs. Flow records were available for a limited number of structures within each district. The structures with long term flow records are shown in the table below. For the many systems within each district with no diversion records, diversion flows were extrapolated from the known flows based upon irrigated acres. As shown in the table above, District 11 CIR and CU values are equal. It is assumed this is because there is sufficient water available to meet the CIR even during dry years in this district. The source documents do not provide further clarification.

Table 5.2.2 Explicit Structures with Available Diversion Flow Data

Water District	Model ID	Structure Name	Conveyance Efficiency
05	05005005	Anderson and Howard Canal	90%
05	05005085	LaBarge No. 2 Ditch	80%
10	10000471	Musselman Ditch (Dist 10)	90%
10	10000917	Reardon Ditch	90%
10	10000610	South Piney Ditch	90%
10	10000715	Yankee Ditch	75%
10	10000301	Homestake Ditch	90%
10	10000943	North Piney Ditch	90%
11	11000124	Canyon Ditch (Green River)	90%

Source: Leonard Rice (2009)

Conveyance efficiency for each of these sites is a best-case scenario, implicitly assuming improvements to the ditch system (see pg 9, LRC 2009, and pg 7, Tyrell et al, 2000). This efficiency was used to determine the amount of water delivered to irrigated land at the farm level. Because actual conveyance efficiencies in upper basins of Wyoming are typically less than 90% (pg 8, Tyrell et al, 2000), the amount of water available at the field is likely less than the volume predicted.

The following table summarizes irrigation withdrawals from Districts 5, 10, and 11 of the Green River basin. The most recent estimate of consumptive irrigation requirement is about 161,000 ac-ft per year.

Table 5.2.3 Irrigation Water Use, Average of Wet and Dry Years

District	Consumptive Irrigation Requirement (ac-ft)	Actual Consumptive Use (ac-ft)
05, 10, & 11	160,690	144,834

Source: Leonard Rice (2009)

Total irrigated area in the Upper Basin Districts is shown in the table below. The water duty for each district has been calculated as the actual consumptive use divided by the irrigated area, and is shown in the following table.

Table 5.2.4 Irrigated Area by Sub-basin (acres)

Water District	Wet Year (1997)	Dry Year (2002)	Average
05	13,360	12,045	12,703
10	115,616	101,940	108,778
11	15,691	13,956	14,824
Total	**144,667**	**127,941**	**136,304**

Source: Leonard Rice (2009)

Table 5.2.5 Water Duty by Sub-basin (ac-ft/ac)

Water District	Wet Year (1997)	Dry Year (2002)	Average
05	1.24	1.25	1.24
10	0.98	1.05	1.01
11	1.31	1.24	1.27
Total	**1.04**	**1.09**	**1.06**

5.3 STRUCTURE CONVEYANCE EFFICIENCY

As noted in the Green River Basin plan of 2010 (WWC Engineering), 23 agricultural diversion structures had sufficiently long diversion records to enable determination of actual or supply limited consumptive use. Of those 23, nine diversions are situated in the Upper Basin. Of the nine diversions in the Upper Basin, three have been identified as having conveyance efficiencies of less than 90%. As discussed in the Technical Memorandum "Water Conservation" of the 2001 Green River Basin Plan and the WYWRAG Memorandum, June 2009, conveyance efficiencies in the remaining diversions were assumed at 90%. This assumption deserves refined review as more long term diversions records become available. An illustrative example is the Green River Supply Canal where monitoring in 2002-2003 indicated losses in the 12-15% range along a 5.5 mile reach of the 35 mile long canal. In addition, ditches and canals in the Upper Basin tend to be excavated through more porous and coarse grained soils. These sections of ditches and canals exhibit higher seepage loss than ditches and canals in lower and down gradient parts of the Green River Basin.

Table 5.4 Explicit Structure Conveyance Efficiencies

Water District	Model ID	Structure Name	Conveyance Efficiency
5	5005005	Anderson & Howard Canal	90%
5	5005085	La Barge No. 2 Ditch	80%
10	10000471	Musselman Ditch (District 10)	90%
10	10000917	Reardon Ditch	90%
10	10000610	South Piney Ditch	90%
10	10000715	Yankee Ditch	75%
10	10000301	Homestake Ditch	90%
10	10000943	North Piney Ditch	90%
11	11000124	Canyon Ditch (Green River)	90%

REFERENCES

Leonard Rice Consulting Water Engineers, Inc. WYRAG Memorandum (working draft) – Consumptive use analysis, Green River Basin. June 27, 2009. 18 pp.

Pochop, L., T. Teegarden, G. Kerr, R. Delaney, and V. Hasfurther. Consumptive use and consumptive irrigation requirements in Wyoming. University of Wyoming Cooperative Extension Service, Wyoming Water Research Center. WWRC Publication No. 92-06. October 1992. 59 pp.

Tyrell, P., R. Vore, S. Lowry. Water Conservation – Technical memorandum. States West Water Resources Corporation and Wyoming State Engineer's Office, Green River Basin Plan. December 7, 2000. 11 pp.

Western Water Consultants. Green River Basin Plan. December 2010. 189 pp.

Wyoming State Engineer's Office. 2012 Hydrographers' Annual Report – Water Division 4. 2012. 204 pp.

VI. WATER SUPPLY AND STORAGE OPPORTUNITIES

6.1 INTRODUCTION

This section of the report involved investigation and analysis of water supply issues and storage needs and opportunities in the Upper Green River basin. This work involved hydrological analysis and initial screening of storage alternatives. Permitting, economic analysis, cost estimates and funding opportunities were also investigated for various water storage projects. The potential opportunities for water supply and storage were comparatively ranked. Recommendations for advancement of projects were made.

The storage alternatives all have the primary purposes of supplemental agricultural irrigation water and stock water supply. However, economic feasibility is substantially enhanced with a multi-purpose project.

6.2 UPPER GREEN RIVER BASIN HYDROLOGY

A number of hydrological models have been developed for the Upper Green River basin. A Basin Plan spreadsheet model for the entire Green River basin within Wyoming was developed in 2001. The Basin Plan spreadsheet model was updated in 2010. The spreadsheet models have been used to estimate available flow over one year, on a monthly time step. Three spreadsheet models have been developed – one each for a representative wet, dry, and average hydrologic year.

A StateMod format model was developed for the Green River Basin above Fontenelle Reservoir to support the Upper Green River Level II Storage Study Model (Kleinfelder, 2005). The StateMod model incorporated the monthly variability in streamflows and demands over a 34-year study period. Unlike the spreadsheet models, the StateMod model distributes water to meet demands per Wyoming Water Law, based on user input water rights.

The study period of the Upper Green StateMod model was extended and representation of the Piney Creek tributary basin was refined to support the Upper Green River Level II Westside Storage Study Model (Short Elliott Hendrickson, 2007). The geographic extent of the Upper Green StateMod model was extended down to the Town of Green River to support the 2009 planning effort by WWC Engineering and AECOM. The 2007 and 2009 models both represented a 1971 through 2006 study period.

Although the geographic focus of the Watershed Study is the Upper Green River basin (excluding the New Fork River), the 2007 StateMod model and 2009 StateMod model were combined to develop one complete StateMod format model for use in the Watershed Study and future efforts.

6.2.1 GREEN RIVER MODELS

Two StateMod models were integrated for use in this study. The study period was extended and the water availability results have been updated to include the 1971 through 2011 period. The 41-year study period adequately represents a mixture of wet, dry, and average hydrologic years evidenced in the Green River basin. The additional years of 2007 through 2011 are typically characteristic of the 1971 through 2006 study period; therefore, the estimates of available flows have not changed significantly from the shorter study period.

The StateMod model is based on a river network representing streamflows, diversions, reservoirs, and instream flows within the area of interest. Natural flows absent man's impact ("baseflows") are estimated by the model based on historical streamflows, diversions, reservoir storage contents, monthly efficiencies, and the timing and locations of return flows. Irrigation structures with historical diversion records are represented explicitly, where one model node represents one use. Irrigation structures that do not have historical diversion records are aggregated into diversion systems. Diversion systems represent irrigation structures that operate similarly and serve a common purpose. The diversions systems are aggregated by geographic area (e.g., upper North Fork Piney River). Historical diversions for the aggregate structures are estimated based on water shortages estimated at nearby explicitly-modeled structures.

A Baseline data set was developed with irrigation demands based on a full water supply to meet the crop irrigation water requirement. The model network includes Middle Piney Lake, Willow Lake, and Fontenelle Reservoir. Fontenelle Reservoir is operated in the model to release water to meet downstream municipal and industrial demands. Operations with Fontenelle Reservoir are potentially limited by a 415 cfs bypass flow requirement included in the model. The bypass is included to represent the reservoir FERC permit requirement to bypass 50 cfs to the Town of Green River. A total of 10 instream flows, representing permitted and pending water rights, are included in the model network.

The StateMod model is set up and operated assuming full utilization of existing water rights to meet demands on currently irrigated lands over the 41-year hydrologic period. In addition, the interplay of the physical supply, demands, and water rights above and below Fontenelle Reservoir impacts the estimated flows available for diversion.

The complete report on the models and results are included in Appendix F.

6.2.2 AVAILABLE FLOWS

The StateMod model is divided into a number of main stem and tributary reaches, each composed of several nodes (e.g., inflows, diversions, reservoirs, and instream flows). Streamflow is simulated by the model and reported at every model node for every time step within the study period.

The model output at each node includes inflows, including natural gains and return flows; demand; water supply, including the amount that is consumed and that returns to the system; shortage to demand; and outflows. The inflow and outflow at each node represents the physical supply of water for each time step.

The amount of water simulated past a headgate, though, does not represent the amount of water available for diversion. This is because some of the physical supply may be “pulled” downstream to meet the demands under a senior water right. StateMod also outputs the portion of the outflow that is available to a junior diversion. This represents the legally available flow for diversion by a junior water right (or present day water right) after all input water rights and demands in the model have been simulated.

The model results were utilized to estimate the available flows at the bottom of particular tributaries and main stem locations. The results of the physical flow estimates and available flow estimates are summarized in Tables 6.2.2.1a (annual) and 6.2.2.1b (monthly). Note the Available Flow values are NOT additive. The Available Flow represents the flow available for diversion at a certain location based on the minimum flow available for diversion at all downstream locations.

Table 6.2.2.1a Simulated Flows for Tributary and Main Stem Locations (ac-ft/yr)

#	Gage ID	Name	Simulated Stream Flow 1971 – 2011 Average	
			Physical Flow	Available Flow
1	09188500	Green River at Warren Bridge	347,993	292,089
2	09189000	Beaver Creek near Daniel	26,524	25,106
3	09190000	Horse Creek near Daniel	37,142	20,166
4	09191500	Cottonwood Creek near Daniel	54,126	26,086
5	09205500	North Piney Creek near Mason	39,496	10,228
6	09206000	Middle Piney Creek below South Fork	16,131	1,179
7	09207500	South Piney Ck near Big Piney	40,767	15,414
8	09205000	New Fork R near Big Piney	551,977	499,502
9	09209400	Green River near La Barge	1,202,673	852,439

Table 6.2.2.1b Simulated Flows for Tributary and Main Stem Locations (ac-ft/Month)

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
09188500	Green River at Warren Bridge	Physical Flow	6,699	6,016	8,022	17,183	56,926	104,007	73,710	29,893	17,145	12,110	8,756	7,528	347,993
		Available Flow	6,670	5,980	8,022	10,376	34,629	96,585	62,706	24,116	15,320	11,705	8,567	7,414	292,089
09189000	Beaver Creek near Daniel	Physical Flow	372	334	444	1,170	4,138	7,549	5,639	3,017	1,764	1,185	556	357	26,524
		Available Flow	372	334	444	706	3,250	7,483	5,639	3,017	1,764	1,185	556	357	25,106
09190000	Horse Creek near Daniel	Physical Flow	404	367	500	2,319	8,924	11,409	5,428	3,804	1,955	1,132	574	326	37,142
		Available Flow	404	367	500	1,827	4,973	7,219	1,145	837	861	1,132	574	326	20,166
09191500	Cottonwood Creek near Daniel	Physical Flow	734	661	891	1,990	8,416	15,938	12,167	6,698	3,465	1,670	834	664	54,126
		Available Flow	734	661	891	1,449	3,509	8,734	4,527	1,203	1,211	1,670	834	664	26,086
09205500	North Piney Creek near Mason	Physical Flow	701	633	839	1,789	6,534	12,030	8,705	3,657	1,821	1,167	845	777	39,496
		Available Flow	701	633	839	1,352	603	2,451	345	72	444	1,167	845	777	10,228
09206000	Middle Piney Creek below South Fork	Physical Flow	235	203	300	740	2,768	5,190	3,663	1,421	768	241	326	277	16,131
		Available Flow	30	21	71	404	22	346	0	0	25	90	112	59	1,179
09207500	South Piney Ck near Big Piney	Physical Flow	449	374	602	1,656	7,008	13,164	9,592	4,165	1,810	888	547	512	40,767
		Available Flow	449	374	602	1,274	2,240	5,405	2,383	196	546	888	547	512	15,414
09205000	New Fork R near Big Piney	Physical Flow	27,849	26,753	45,595	78,949	175,972	350,549	231,102	103,644	53,787	40,823	37,885	29,766	1,202,673
		Available Flow	19,262	19,874	37,229	22,985	51,764	290,332	187,369	95,810	46,303	32,057	29,124	20,329	852,439
09209400	Green River near La Barge	Physical Flow	12,627	11,704	17,390	25,238	74,979	183,176	108,480	39,969	23,872	21,620	18,356	14,568	551,977
		Available Flow	12,442	11,582	17,390	16,915	42,136	178,873	104,163	39,969	23,479	20,507	18,170	13,878	499,502

6.2.3 SHORTAGE ESTIMATES

The results of the modeling were reviewed to identify the extent of shortages to demands at individual ditches and groups of ditches on tributary systems. It is recognized that almost every area of the Green River basin within Wyoming can be considered water short during severe dry years. The purpose of this investigation is to identify the extent of shortages in the basin.

The shortages were classified during dry, wet, and normal years. The wet years were defined as the highest 20 percent of annual flows recorded at the Green River near La Barge stream gage (USGS ID 09209400) over the 1971 through 2011 study period. The dry years were defined as the lower 20 percent of annual flows recorded at the stream gage. The remaining 60 percent of years in the middle define the normal years.

The areas listed in Table 6.2.3.1 were identified based on their locations with certain water districts in the Green River basin. The table values represent total shortages on the tributaries and the Green River main stem within the Districts. Note the contribution of shortages to main stem nodes is minimal.

Table 6.2.3.1 Water Short Areas during Various Hydrologic Conditions

Water District	Location	Percent Demand is Shorted		
		Dry Year	Avg. Year	Wet Year
11	Green River above Cottonwood Ck	20%	10%	5%
10	Green River from Cottonwood Ck to below Piney Ck	49%	23%	8%

Water District	Location	Percent Demand is Shorted		
		Dry Year	Avg. Year	Wet Year
5	Green River from Piney Ck to Fontenelle Reservoir	15%	2%	0%

Dry year based on average of 1977, 1981, 1988, 1992, 1994, 2001, 2002, and 2007
Wet year based on average of 1971, 1972, 1982, 1983, 1986, 1997, 1999, and 2011
Average year based on remaining years between 1971 and 2011

6.2.4 GREEN RIVER BASIN INSTREAM FLOWS

Several rivers and streams in the Green River basin are permitted for instream flow water rights and several are in the process of being studied by the WGFD to determine appropriate flows.

The instream flow process in Wyoming involves three State agencies: the Game and Fish Department (WGFD), the Water Development Commission (WWDC), and the State Engineer's Office (SEO). The WGFD identifies stream reaches where instream flows are critical and unappropriated surface water appears available. The WGFD conducts field studies and prepares a biological report that identifies the minimum flows necessary to maintain or improve existing fisheries. A water right application with the requested minimum flows is then prepared by the WGFD that lists the WWDC as the applicant. The application is submitted to the SEO along with the biological report. The date that the application is submitted establishes the priority date of the water right. The WWDC then completes a hydrologic study on the feasibility of unappropriated water in the stream supporting the application's requested flows. Upon completion, the WWDC study is supplied to the State Engineer for his consideration. The State Engineer then conducts a public hearing to present WGFD and WWDC information and receive public comments. Following the public input period, the State Engineer determines whether or not to approve the application or approve with modifications to the requested flows. The State Engineer issues a decision and permits the instream flow right. The instream flow appropriation goes into effect the date the State Engineer approves the permit. It then becomes the Board of Control's job to finalize or "proof" the water right by physically measuring stream flows to validate that the permitted flows are present. However, the water right cannot be fully finalized, or adjudicated, by the Board of Control for at least three years after the permit is granted.

WWDC's hydrologic study primarily involves a collection of data, a water rights inventory, flow measurements, and a hydrology analysis. Data collection entails gathering available time-series records of stream flow, diversions, reservoir storage, and other pertinent information. During the water rights inventory, SEO records are researched, and all existing water rights are inventoried that encompass areas located upstream from the downstream end of each instream flow segment. Stream flows are verified during the course of the study by periodic flow measurements and the installation and monitoring of stage recording equipment. A comprehensive hydrology analysis is performed to estimate virgin flow in the basin during a dry, average, and wet year. The analysis typically involves the use of stream flow data, diversion records, consumptive use estimates, depletions and return flows, return flow patterns, and return flow timing. Available unappropriated flows are then determined for the dry, average, and wet year classifications based on the water rights inventory and the hydrology analysis. If shortages are indicated, the feasibility of placing storage above the instream flow segment is evaluated. Lastly, exceedance flows are determined along with the percent of time the requested instream flows are equaled or exceeded and compared to unappropriated flows.

As of the date of this report, a total of 8 instream flow segments reside within the Upper Green River Basin study area, and the WWDC has completed a separate hydrologic study for each. One of these segments is located on the Green River mainstem and is fully adjudicated. The other 7 have been issued permits by the State Engineer's Office and are in the process of being proofed by Division 4 of the State's Board of Control. A summary of these 8 instream flow segments is presented in Table 6.2.4. Additional information along with the flow rates for these segments is presented in Appendix F. Further information and maps pertaining to instream flow filings in Wyoming can be found on the WWDC's website: http://wwdc.state.wy.us/instream_flows/instream_flows.html.

Table 6.2.4 Instream Flow Segments within the Upper Green River Basin Study Area

Stream Name	Stream Length (mi)	Temp Filing No.	Priority Date	SEO Hearing Date	Approval Date	Permit No.	Adjudicated Date	County	Current Status
Green River	9.84	26 2/328	1/10/1989	8/7/1990	1/7/1992	6 IF	8/15/2012	Sublette County	Adjudicated
South Cottonwood Creek	2.93	26 6/383	6/27/1989	11/9/1993	1/16/2008	74 IF		Sublette County	BOC Proofing Stage
North Cottonwood Creek	8.90	26 4/388	7/12/1989	11/9/1993	1/15/2008	73 IF		Sublette County	BOC Proofing Stage
LaBarge Creek	3.30	27 3/146	12/17/1990	11/8/1993	12/3/2003	29 IF		Lincoln County	BOC Proofing Stage
North Piney Creek	7.60	27 5/185	3/11/1991	11/9/1993	2/10/2004	35 IF		Sublette County	BOC Proofing Stage
Middle Piney Creek	3.60	27 6/185	3/11/1991	11/9/1993	2/23/2004	36 IF		Sublette County	BOC Proofing Stage
South Piney Creek	7.00	27 1/186	3/11/1991	11/9/1993	12/3/2003	28 IF		Sublette County	BOC Proofing Stage
Fish Creek	4.20	27 2/186	3/11/1991	11/9/1993	12/1/2003	30 IF		Sublette County	BOC Proofing Stage

6.2.5 WATER AVAILABILITY

The model input includes full supply water demands to meet crop water requirements for lands identified as currently irrigated in the 2009 AECOM model. The model input includes full supply water demands to meet crop water requirements for lands currently under irrigation. The full utilization of water rights, though, to meet demands on the permitted acreage associated with the water rights would further limit flow available for upland storage or in a new storage facility.

6.3 PRELIMINARY RESERVOIR SCREENING

6.3.1 PREVIOUS STUDIES AND PLANNING DOCUMENTS

This present study was designed to be a review of existing studies with reservoir storage components. This study does not pursue new detailed analysis of previously identified reservoir sites or attempt to identify new sites. This study compiles the previously identified sites along with basic site information and study results.

Numerous studies have addressed storage opportunities in the Upper Green. Of the planning document reviewed, the following studies (included in the digital library) had reservoir planning components.

- Report on Green River Basin In Wyoming and Proposed New Project Therein, 1919 Department of the Interior, United States Reclamation Service
- Water Resources of Colorado River Basin, Feb, 1938; Workers on WPA Project 65-83-107
- 142707 US Bureau of Reclamation, 1938
- Proposed Unit Plan, Development of Water Resources Green River Basin in Wyoming, April, 1938, State Planning Board
- Appendix To The Report On Green River Basin Wyoming-Utah, May 1944; Bureau of Reclamation
- Summary of Available Information on Water Development Projects, Green River Basin in Wyoming, 1965, Bureau of Reclamation
- Report on Preliminary Reconnaissance of Potential Reservoir Green River Basin Wyoming, July 1969; JT Banner and Associates, Inc.
- Reconnaissance Geologic Report, New Fork Damsite, Upper Green River Investigations, Wyoming, Report No. G-271, 1970 Bureau of Reclamation
- Water and Related Land Resources of the Green River Basin, Wyoming, 1970, Wyoming Water Planning Program
- Development of Presently Unused Water Supplies of the Green River Basin In Wyoming, 1972 Tipton and Kalmbach for State of Wyoming Department of Economic Planning and Development
- Alternative Plans for Water Resource Developments Green River Basin, Wyoming, 1972, Bureau of Reclamation
- A Plan for Study of Water and its Relation to Economic Development in the Green River and Great Divide Basins in Wyoming, 1976 US Geological Survey
- Green River Basin, Wyoming, Cooperative River Basin Study, 1978, USDA

- WWDC Pre-Feasibility Study of the Upper Green River Drainage Potential Reservoir Sites, January 12, 1983, ARIX

- Green River Basin Plan 2001, States West

- Green River Ground Water Recharge and Alternate Storage, Level I Project, December 2001, States West for WWDC.

- Upper Green River Storage Level II Study, February 2007; Klienfelder, Inc.

- Kendall Reservoir, Upper and Lower Sites Near Warren Bridge, "WWDO, 2007

- Middle Piney Reservoir Level II Study, 2009 States West Water Resources Corporation

- Upper Green River Westside Storage Study, Level II, February 2009, Short Elliott Hendrickson Inc.

- Green River Basin Plan, December 2010 WWC Engineering

- Green River Basin Summary of Potential Dam and Reservoir Projects Literature

Other documents cited by the Green River Basin: Summary of Potential Dam and Reservoir Project Literature also mention the following additional studies:

- Summary of Available Information On Water Development Projects, Green River Basin Wyoming, USBR 1965

- Reconnaissance Geologic Report New Fork Dam Site, Upper Green River Investigations, WY, USBR 1970

- Report 3, Water and Related Land Resources of the Green River Basin, WY State Engineers Office 1970.

- Development of Presently Unused Water Supplies of the Green River Basin, WY, USBR 1972

- Alternative Plans for Water Resource Development Green River Basin WY, USBR 1972

- A Plan for Study of Water and its Relation to Economic Development in the Green River and Great Divide Basins in Wyoming, 1976 US Geological Survey

Most studies focused on the entire Green Basin and included broader water planning issues and concepts. However, a few studies of note focused exclusively on reservoirs and storage. The above studies reviewed 60 to 70 potential reservoir sites in the Upper Basin area. Of these sites approximately 40 passed one or more levels of screening. More popular sites were reviewed by multiple studies. The potential sites range in size from 340,000 acre-feet (Kendall) down to about 1,400 acre-feet (Fish Creek and Cottonwood Creek sites). The exact size at any given site can vary between studies. Since the earliest (1938) study, to the present, environmental and social changes, along with physical land development, have changed expectations of reservoir sizes and locations. The additional years of hydrologic data have also better defined what is possible and practical. Earlier documents tend to have fewer, but larger (Kendall Sites, New Fork Narrows Site) and more aggressive storage proposals, while later documents tend to focus on multiple smaller off channel sites. Of note on the table below is the inclusion of the Kendall Reservoir review from 2007 (study #18 on following Table 6.3.1.1). This was an "in house" study conducted by the Wyoming Water Development Office and focused only on the Kendall Sites. The fact that the Kendall sites were not identified in most recent studies reflects the improbability anticipated with permitting of a reservoir of the magnitude of the Kendall sites on the main stem of the Green River. The NEPA process necessitates the consideration of a range of reasonable alternatives that would achieve the objective of the purpose and need for the project. The intent of the process is to identify the Least Environmentally Damaging Practicable Alternative (LEDPA). In addition to the dam and reservoir impact of the Kendall alternatives, construction of a costly conveyance system would be required, consisting of 135 miles of canal ranging in size from 1,100 cfs to 100 cfs, and from 10,000-15,000 linear feet of tunnel. The environmental impacts of the conveyance system are unknown. In addition, the cost of the project, willingness and ability to pay for a portion of such a project by the limited number of beneficiaries and the lack of interest in pursuing the Kendall alternatives by local sponsors has led to the study of more viable tributary and off-channel storage sites. Due to elevation and climate, crops grown in the area are limited to forage crops where the associated revenue is not capable of servicing a sponsor's debt and operation and maintenance obligations for a large dam and reservoir project. Table 6.3.1.1 is a matrix illustrating which studies addressed various sites and the ranking of the top sites in the respective study. Those matrix squares highlighted in green indicate a particular side was studied by which study. Table 6.3.1.2 show the sites and various site characteristics.

No.	Previous Studies Containing Reservoir Components*	Site: 1 Fish Creek	2 Fontenelle No. 1	3 Fontenelle Creek	4 Green River Lakes Enl.	5 Green River Supplemental Supply Project	6 Kendall	7 LaBarge Meadows	8 Lower Kendall	9 McNinch Wash	10 Middle Piney Lake	11 North Piney Cr	12 Sand Hill	13 Sixty-Seven Enl.	14 Snider Basin	15 South Cottonwood	16 Warren Bridge Res	17 Cottonwood No.1	18 Fogarty Creek	19 Horse Creek	20 LaBarge Reservoir	21 Middle Beaver Creek	22 North Cottonwood Creek	23 South Beaver Creek	24 South Cottonwood Creek	25 South Horse Creek	26 Straight Creek	27 Cottonwood Creek	28 Fontenelle Res. #1	29 Big Piney and LaBarge	30 Horse Pasture Draw	31 Mickleson Creek Res	32 Cow Gulch	33 North Horse Creek	34 Haines Flat	35 North Cottonwood Creek SEH -5	36 North Cottonwood Creek SEH - 7	37 Wiskey Creek	38 Fish Creek SEH-12	39 New Fork Narrows	40 Green River Lakes Enl/
1	Report on the Green River Basin In Wyoming and Proposed New Project Therein, 1919 Department of the Interior, United States Reclamation Service																																								
2	Water Resources of Colorado River Basin, Feb, 1938; Workers on WPA Project 65-83-107																																								
3	142707 US Bureau of Reclamation, 1938						1																																		
4	Proposed Unit Plan, Develoment of Water Resources Green River Basin in Wyoming, April, 1938, State Planning Board											2						1																							
5	Appendix To The Report On Green River Basin Wyoming-Utah, May 1944, Bureau of Reclamation																																								
6	Summary of Available Information on Water Development Projects, Green River Basin in Wyoming, 1965 Bureau of Reclamation																																								
7	Report on Prelimiary Reconnaissance of Potential Reservoir Green River Basin In Wyoming, July 1969; JT Banner and Associates, Inc.						1		2																																
8	Reconnaissance Gelogic Report, New Fork Damsite, Upper Green River Investigations, Wyoming, Report No. G271, 1970 Bureau of Reclamation																																							Only Dam	
9	Water and Related Land Resources of the Green River Basin Wyoming, 1970, Wyoming Water Planning Program						1																																	2	
10	Development of Presently Unused Water Supplies of the Green River Basin in Wyoming, 1972, Tipton and Kalmbach for State of Wyoming Department of Economic Planning and Development																																								
11	Alternative Plans for Water Resource Developments Green River Basin, Wyoming, 1972, Bureau of Reclamation						1																																	2	
12	A Plan for Study of Water and Its Relation to Economic Development in the Green River and Great Divide Basins in Wyoming, 1976, US Geological Survey																																								
13	Green River Basin, Wyoming, Cooperative River Basin Study, 1978, USDA											2								1																					
14	WWDC Pre-Feasibility Study of the Upper Green River Drainage Potential Reservoir Sites, Jan, 1983, ARIX Corporation												1		2	3																									
15	Green River Basin Plan, 2001, States West Water Resources Corporation										1			2																											
16	Green River Ground Water Recharge and Alternate Storage Level I Project, Dec, 2001, States West Water Resources Corporation																																								
17	Final Report for Upper Green River Storage Level II Study, Feb, 2007, Kleinfelder, Inc.																														2	3	1								
18	Kendall Reservoir, Upper and Lower Sites near Warren Bridge, WWDO, 2007						2		1																																
19	Middle Piney Reservoir Level II Study, 2009, States West Water Resources Corporation										1																														
20	Upper Green River Westside Storage Study, Level II, Final Report, Feb, 2009, Short Elliott Hendrickson Inc.,											3				2										1						2			1			3			
21	Green River Basin Plan, Dec, 2010, WWC Engineering												2																		3		1								
22	Green River Basin Summary of Potential Dam and Reservoir Projects Literature																																								

Table 6.3.1.1 Previous Reservoir Studies

Potential Reservoir sites

Site #	Proposed Reservoir Site Name	Comment	Status	Drainage/River	Section	Township	Range	Volume in Acre Feet	Use	Priority ranking from 2001 Basin Plan	*Previous Studies Addressing Site
1	Fish Creek		Proposed	Fish Creek, South Piney Creek	26	30	115	1,400	irr	2	13, 14, 15, 22
2	Fontenelle No. 1		Proposed	Fontenelle Creek	4	24	115	2,500	irr	2	2, 15, 22
3	Fontenelle Creek		Proposed	Fontenelle Creek	30	26	115	15,950	irr	2	13, 15, 22
4	Green River Lakes Enl.		Proposed	Green River	32	39	108	80,000 to 250,000	irr, pow	2	2, 15, 22
5	Green River Supplemental Supply Project		Proposed	Green River	4	33	110		irr	2	15
6	Kendall		Proposed	Green River	34	36	111	100,000	irr, ind, mun	3, 4	2, 3, 4, 5, 6, 7, 9, 11, 12, 15, 18, 22
7	LaBarge Meadows		Proposed	LaBarge Creek	8	29	116	4,800	irr	2	4, 13, 14, 15, 22
8	Lower Kendall		Proposed	Green River	4	35	111	77k-810k	irr, rec, wl, pow	3, 4	1, 2, 7, 18, 22
9	McNinch Wash		Proposed	North Piney Creek	10	30	113	5,600	irr	2	14, 15, 17, 21, 22
10	Middle Piney Lake		Proposed	Middle Piney Creek	8	30	115	4,200	irr	1	2, 4, 15, 19, 21, 22
11	North Piney Cr		Proposed	North Piney Creek	24	31	115	5,600	irr	2	2, 4, 13, 14, 15, 22
12	Sand Hill		Proposed	Middle Piney Creek or Middle Piney and S. Piney	36	30	113	14,100	irr	2	14, 15, 17,20, 21, 22
13	Sixty Seven Enl.		Proposed	North Piney Creek	17	30	112	5,600	irr	1	4, 14, 15, 22
14	Snider Basin		Proposed	South Piney Creek	11	29	115	4,300	irr	2	13, 14, 15, 22
15	South Cottonwood		Proposed	Cottonwood Creek	12	32	115	6,000	irr	2	14, 15, 21
16	Warren Bridge Res.		Proposed	Green River	4	35	111	33,400	irr	2	15, 22
17	Cottonwood No. 1		Proposed	South Cottonwood Creek	16	32	115	1,465	irr	2	4, 15, 22
18	Fogarty Creek		Proposed	Dry Piney Creek	24	28	114	700	irr	2	13, 15
19	Horse Creek		Proposed	Horse Creek	7	34	114	36,660	irr	2	13, 15, 22
20	LaBarge Reservoir		Proposed	LaBarge Creek	12	29	116	4,030	irr	2	2, 4, 15, 22
21	Middle Beaver Creek		Proposed	Middle Beaver Creek	29	36	112	5,905	irr	2	13, 15, 22
22	North Cottonwood Creek		Proposed	North Cottonwood Creek	24	33	115	10,805	irr	2	13, 15, 22
23	South Beaver Creek		Proposed	South Beaver Creek	24	35	114	5,905	irr	2	13, 15, 22
24	South Cottonwood Creek		Proposed	South Cottonwood Creek	11	32	115	10,805	irr	2	13, 15, 22
25	South Horse Creek		Proposed	South Horse Creek	30	34	114	36,660	irr	2	13, 15, 22
26	Straight Creek		Proposed	Straight Creek	4	30	115	4,815	irr	2	13, 15
27	Cottonwood Creek		Proposed	Cottonwood Creek		30 & 31	110 & 111	1,465	irr		2, 22
28	Fontenelle Res. #1		Proposed	Fontenelle Creek		24	115	2,507	irr		2, 22
29	Big Piney and LaBarge		Proposed			26 to 29	111 to 113				2
30	Horse Pasture Draw	North Horse Creek Drainge Off Channel Site	Proposed	North Horse Creek and South Horse Creek	16	34	113	5710 - 7,670	irr		17, 20, 21, 22
31	Mickleson Creek Res	South Cottonwood Creek Off Channel Site	Proposed	South Cottonwood Creek	11	32	114	6,010 -15,000	irr		17, 20, 21, 22
32	Cow Gulch Res	Beaver Creek Drainage Off Channel Site	Proposed	South Beaver Creek and Middle Bea ver Creek	4	35	112	13,330	irr		17, 21, 22
33	North Horse Creek		Proposed	North Horse Creek	1	34	114				20, 22
34	Haines Flat	Captures S Horse direct and North Horse Via Canal	Proposed	South Horse Creek	33	34	113	40,000	irr		20
35	North Cottonwood Creek SHE-5		Proposed	North Cottonwood Creek	14	33	114		irr		20
36	North Cottonwood Creek SHE-7		Proposed	North Cottonwood Creek	29	33	114		irr		20
37	Wiskey Creek	Off Channel	Proposed	North Piney Creek	19	31	113	20,000	irr		20
38	Fish Creek SEH-12		Proposed	Fish Creek and South Piney	35	30	110	20,000	irr		20
39	New Fork Narrows	Just Outside Basin	Proposed	New Fork	14	30	110	200,000	irr		7, 8, 9, 11, 12, 22
40	Geen River Lakes Enl		Proposed	Green River	2	39	109	100,000	irr		4,22

Table 6.3.1.2 Characteristics of Potential Reservoir Sites

6.3.2 POTENTIAL RESERVOIR SITES ELIMINATED

In order to narrow the large field of potential reservoir sites identified in existing documents; this study first identified the top 1 to 3 sites recommended in previous studies. These top sites were then reviewed to identify the twelve sites that have consistently ranked high in past work. The next step was to compare these top sites in terms of current siting standards including environmental, cultural and permitting issues, cost, yield, ownership, and other issues that may impact feasibility.

This method of narrowing the field does have shortcomings, including 1) not all past studies include the same sites, 2) current selection priorities may not match historical priorities, 3) reservoir sizes have varied for given sites. Additional weight was given to the more recent studies that focused on storage. Of particular mention are the following:

- Upper Green River Westside Storage Study, Level II, February 2009;
- Middle Piney Reservoir Level II Study, 2009
- Kendall Reservoir, Upper and Lower Sites Near Warren Bridge, WWDO, 2007
- WWDC Pre-Feasibility Study of the Upper Green River Drainage Potential Reservoir Sites, 1983
- Green River Basin Plan, December 2010

These studies reflect the most recent findings, evaluations, and sentiments regarding storage in the upper basin.

6.3.3 RESERVOIR SITES ADVANCED TO FURTHER ANALYSIS

Studies of the past decade have tended to rank about 12 to 13 sites high in the respective scoring. The changes in the sites studied reflect a trend toward finding permittable sites. These sites include several off channel sites and a few main channel sites:

Off Channel	On Channel
Horse Creek/Cottonwood Creek (Haines Flat Res)	Middle Piney Rehab
Cottonwood Creek (Mickelson Creek Res)	North Piney Creek
North Piney Creek (Wiskey Creek Res)	Snider Basin (South Piney Creek)
Sixty Seven Enlargement	Kendall Reservoir Sites
Beaver Creek (Cow Gulch Res)	
North Horse Creek (Horse Pasture Draw)	

McNinch Wash

S. Piney and Middle Piney Creek (Sand Hill Res)

Mickleson Creek

Sand Hill

6.3.4 STORAGE EVALUATION MATRIX

The following Table 6.3.4 shows a short list of potential reservoir sites along with issues and features gleaned from previous studies that could impact feasibility. The Kendall and Lower Kendall reservoir sites will also be included in this review of sites because they offer a large reservoir option located high in the basin with available flow although they both have considerable hurdles and negatives. The blank spaces on the matrix are due to limited information in previous studies.

The costs taken from recent studies then updated to 2014 dollars reflect the cost of the reservoir and identified conveyance canals. Costs for additional laterals, ditches, headgates, siphons, energy dissipation, etc., associated with delivery, have not been included. In addition, analysis of impacts and disruptions to transportation, recreation, land access, wildlife, etc. have not been evaluated for the conveyance infrastructure.

Table 6.3.4 Potential Reservoir Storage Sites

Site #	6	8	9	10	11	12	13
Proposed Reservoir Site Name	**Upper Kendall**	**Warren Bridge (Lower Kendall)**	**McNinch Wash**	**Middle Piney Lake**	**North Piney Cr**	**Sand Hill**	**Sixty Seven Enl.**
Location	On Channel	On Channel	Off Channel	On Channel but Existing	On Channel	Off Channel	Off Channel
Status	Proposed	Proposed	Proposed	Proposed	Proposed	Proposed	Proposed
Drainage/River	Green River	Green River	North Piney Creek	Middle Piney Creek	North Piney Creek	Middle Piney Creek or Middle Piney and S. Piney	North Piney Creek
Section	34	4	10	8	24	36	17
Township	36	35	30	30	31	30	30
Range	111	111	113	115	115	113	112
Volume in Acre Feet	340,000	77,000	5,600	4,200	5,600	14,500	5,600
Use	irr, ind, mun	irr, rec, wl, pow	irr	irr	irr	irr	irr
Priority ranking from 2001 Basin Plan	3, 4	3, 4	2	1	2	2	1
*Previous Studies Addressing Site	2, 3, 4, 5, 6, 7, 9, 11, 12, 15, 18, 22	1, 2, 7, 18, 22	14, 15, 17, 21, 22	2, 4, 15, 19, 21, 22	2, 4, 13, 14, 15, 20, 22	14, 15, 17,20, 21, 22	4, 14, 15, 22
Source	Green	Green	North Piney Creek	Middle Piney Creek	North Piney Creek	Piney Creek Drainage	North Piney Creek
Surface Elevation (NWS)	7680	7620	7230	8840	8118		
Irrigated Acres	71000[b]	71000[b]	6,000	8,827			
Average Annual Shortages							
Other Benefits	Flood Control, Recreation	Flood Control, Recreation	Recreation	Flood Control, Recreation	Flood Control, Recreation	Recreation	Recreation
Dam Type	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill
Conveyance	135 miles of canal and 15,000' tunnel crossing private and public land, roads, fences and other improvements.	135 miles of canal and 11,700' tunnel crossing private and public land, roads, fences and other improvements.	5 miles of canal to off channel site	Existing	None Required	3 miles of canal to off channel site	Existing
Geology	Glacial till-potentially unfavorable	Glacial till-potentially unfavorable	generally favorable	generally favorable	generally favorable	unknown	generally favorable
Land Ownership	BLM, Private	BLM, Private	BLM, Private	USFS	USFS	State- BLM-Private	Private and BLM
Inudated Acreage	9500	1100		250	264		
Inundated Infrastructure	Canyon Ditch headgate will be flooded. Service to this ditch could be lost during low water if headgate is damaged. Loss of productive meadows in pool area.	Canyon Ditch headgate will be flooded. Service to this ditch could be lost during low water if headgate is damaged. Loss of productive meadows in pool area.		None	Road innundation	Significant transportation, energy, and utility infrastructure	None
Cultural or Archaelological Impacts	One or more sites eligible for NRHP	One or more sites eligible for NRHP	No Mapped Sites	No Mapped Sites	No Mapped Sites	Lander Trail	One or more sites eligible for NRHP
Wetlands[a]	Significant impacts to riparian and wetland area along Green River; 4,700 acres	Loss of some riparian and wetland area along Green River; 75 to 120 acres	Few to None	1.5 acres innundated	Yes	minimal impact	Limited - 26 potential acreas created by lake
Threatened and Endangered	Some Sensitive Species	Some Sensitive Species	Some Sensitive Species	No impact on Whooping Crane or Canada Lynx, Potential T&E amphibians	Canada Lynx, Potential T&E amphibians	Limited Impact	Limited Impact
Sage Grouse	Core Area	Core Area	LEK in area	No impact	No Impact	LEK in area	No Mapped LEK, No mapped Core Area
Big Game Impacts	Yes; Pronghorn migration, Mule Deer Crucial Winter Habitat, Elk Winter Range, Year long Moose range	Yes; Pronghorn migration, Mule Deer Crucial Winter Habitat, Elk Winter Range, Year long Moose range	Moose Winter Range, Crucial Mule Deer Winter Range	Few to none	Moose Crucial Range	Mule Deer and Pronghorn Crucial Winter Range; Moose Winter Range	Moose Winter Range, Mule Deer Crucial Winter Range
Fish	Migration along Green, Colorado River Cutthroat, Innudation of adjudicated instream flow segment	Migration along Green, Colorado River Cutthroat, Innudation of adjudicated instream flow segment	Fish entrainment, Colorado River Cutthroat,	Fish Passage, Colorado River Cutthroat	Fish Passage, Colorado River Cutthroat	Fish entrainment, Colorado River Cutthroat, flanel Mouth Suckers, Bluehead Suckers, and Roundtail Chub	Fish entrainment,
Year of Most Recent Cost Estimate	2007	2007	2010	2009	1983	2007	1983
Cost at Date of Estimate	386,500,000[c]	247,000,000[c]	28,600,000	2,930,000	4,501,000	32,800,000	3,514,000
$ Cost in 2014 @3%/annum inflation	475,346,249	303,778,845	32,189,552	3,396,673	11,252,862	40,339,863	8,785,282
2014 $ Cost/ Acre Ft	1,398	3,945	5,748	809	2,009	2,782	1,569

Favorable for Project	
Minimal Difficulty	
Cost Permitting Impact	
Caution Could be Potentitally Cost Prohibitive	
Potential Fatal Flaw	

[a] Some wetlands will be replaced at a ratio higher or lower than 1:1 such as 710 acres @30% = 210 mitigated acres

[b] These are not all existing irrigated acres but include 34,000 new potential acres that would be brought into production, which would trigger additional environmental scrutiny that may trigger additonal mitigation expense.

[c] Estimates ingnore costs of conveyance system appurtenances (farm turnouts, canal drops/energy dissapaters, inverted siphons, flumes or bridges and culverts at county or ranch road crossings), endangered species depletion fee assessment and easement and land acquisition costs.

Table 6.3.4 Potential Reservoir Storage Sites (Continued)

Site #	14	30	31	32	34	37
Proposed Reservoir Site Name	**Snider Basin**	**Horse Pasture Draw**	**Mickelson Creek Res**	**Cow Gulch Res**	**Haines Flat**	**Wiskey Creek**
Location	On Channel	North Horse Creek Drainge Off Channel Site	South Cottonwood Creek Off Channel Site	Beaver Creek Drainage Off Channel Site	Captures S Horse direct and North Horse Via Canal	Off Channel
Status	Proposed	Proposed	Proposed	Proposed	Proposed	Proposed
Drainage/River	South Piney Creek	North Horse Creek and South Horse Creek	South Cottonwood Creek	South Beaver Creek and Middle Beaver Creek	South Horse Creek	North Piney Creek
Section	11	16	11	4	33	19
Township	29	34	32	35	34	31
Range	115	113	114	112	113	113
Volume in Acre Feet	4,300	7,670	15,000	13,330	40,000	20,000
Use	irr	irr	irr	irr	irr	irr
Priority ranking from 2001 Basin Plan	2					
*Previous Studies Addressing Site	13, 14, 15, 22	17, 20, 21, 22	17, 20, 21, 22	17, 21, 22	20	20
Source	South Piney Creek	North Horse Creek	South Cottonwood Creek	Beaver Creek	Horse Creek/Cottonwood Creek	North Piney Creek
Surface Elevation (NWS)	7948	7635	7740 or 7795	7640	7659	7544
Irrigated Acres		15,151	20,200	11,500	35,100	17,900
Average Annual Shortages			7,950	2,793	21,000	11,100
Other Benefits	Flood Control, Recreation	Recreation	Recreation	Recreation	Recreation	Recreation
Dam Type	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill	Earth Fill
Conveyance	None Required	Off channel site requires canal	Canal from South Cottonwood to Reservoir Water delivered to Cottonwood Creek via 100 cfs canal	Supply canal from Beaver Creek and Supply canal from Cottonwood Creek for 5 total miles	Canals to Reservoir from Horse Ck (240 cfs) and Cottonwood (Ck 165 cfs)	None Required
Geology	unknown	Favorable but Cautious	Favorable but Cautious	Favorable but Cautious	Favorable	Marginal slope stablity surrounding pool
Land Ownership	USFS , State	State, Private	Private	Private	Private	Private
Inudated Acreage	180		576		1408	640
Inundated Infrastructure	USFS Road	Limited access two track inundated	Limited (one fence)	Shorth Access Road and Culvert Crossing	Slight to roads and some 707 acres of irrigated lands	Roads; 1.5 miles of power and phone; 403 irrigated acres
Cultural or Archaelological Impacts	One or more sites eligible for NRHP	No Mapped Sites	Few known sites	Few known sites	Few known sites	Few known sites
Wetlands[a]	Yes	Few to None	NWI = 407 acres @40%; 163 mitigated acres	92 acres	NWI = 710 acres @30%; 210 mitigated acres	NWI = 279 acres @60%; 167 mitigated acres
Threatened and Endangered	Potential T&E amphibians	Marginal Impacts to several species	Marginal Impacts to several species	Marginal Impacts to several species	Marginal Impacts to several species	Marginal Impacts to several species
Sage Grouse	No Mapped LEK, No mapped Core Area	Inside Fringe of Core Area	Core Area; one LEK at 1.4 miles	Core Area but no mapped LEK	Core Area but no mapped LEK	Core Area
Big Game Impacts	Elk Proturition	Year Long Moose Habitat, Elk Porturition	Some impacts to Moose	Potential Pronghorn Migration Issues	Few to None	Moderate impacts to Moose
Fish	Fish Passage, Colorado River Cutthroat	Fish entrainment	Fish entrainment	Fish entrainment	Fish entrainment	Fish entrainment
Year of Most Recent Cost Estimate	1983	2007	2009	2007	2009	2009
Cost at Date of Estimate	1,940,000	20,600,000	40,278,000	19,500,000	87,657,000	49,058,967
$ Cost in 2014 @3%/annum inflation	4,850,156	25,335,402	46,693,241	23,982,540	101,618,488	56,872,789
2014 $ Cost/ Acre Ft	1,128	3,303	3,113	1,799	2,540	2,844

Favorable for Project	
Minimal Difficulty	
Cost Permitting Impact	
Caution Could be Potentitally Cost Prohibitiv	
Potential Fatal Flaw	

[a] Some wetlands will be replaced at a ratio higher or lower than 1:1 such as 710 acres @30% = 210 mitigated acres
The wetland acreages shown may include irrigated acres that will not qualify as jurisdictional wetlands.

6.3.5 SUMMARY OF RESULTS

Model simulations conducted during the Upper Green River Westside Storage Study, Level II, February 2009 indicate average demand shortages of approximately 87,000 acre-feet or 32%. These shortages are greatest in the upper reaches on tributaries such as Cottonwood Creek, and the North, Middle, and South Piney Creek.

The Kendall reservoir sites are large and do offer the ability for a single project to potentially supply shortages if the required conveyance infrastructure is also built. These sites will require significant canals, tunnels, turnouts, drops/energy dissipaters, siphons, flumes, bridges and culverts and are very expensive. The irrigated lands in the upper reaches of the tributaries such as Cottonwood Creek, Horse Creek, and the Piney Creeks cannot be supplied by gravity from the Kendall site. Through an adjustment of water rights, it is believed the Kendall sites could provide water above the needed conveyance canal by supplying water to existing senior diversions below the canal and allowing existing water from those diversions to be diverted higher in the tributaries by exchange (provided there is water physically available in the tributaries to divert at the times of the year it's needed, and provided there is not injury to other appropriators).

Based on purpose and need, the final size of a reservoir at the Kendall site would be much smaller than the 340,000 acre-feet of earlier studies with a corresponding increase in the unit cost per acre-foot of storage. Even with a smaller dam at the site, the cost of the conveyance infrastructure and most of the difficulty with mitigation, and permitting remain.

Due to impacts associated with wetlands, migration corridors and conveyance ditches, instream flow, endangered species, depletion, etc., and expected permitting difficulty with mainstem sites such as the Kendall sites, and the relatively large cost of the project, the Kendall sites are not a favored alternative after reviewing the recent studies.

Recent studies have demonstrated off channel sites and enlargement of existing reservoirs appear most favorable, largely due to environmental and permitting difficulties associated with damming mainstem channels. In addition, the tributary storage is located on drainages where shortages exist and the supplemental water can be put to beneficial use without the additional conveyance infrastructure. The early spring flow can be stored for use later in the season, when physical water in the steams is lacking for exchanges. The sites are located in the tributary drainages of South Cottonwood Creek, Middle Piney Creek, South Piney Creek, South Horse Creek, and South and Middle Beaver Creek. Based on preliminary data, the Middle Piney Lake project actually turned out to be the lowest cost project in terms of $/acre-foot. On Table 6.3.4 the top four sites in terms of $ per acre-foot are:

1) Middle Piney Lake $809/ac.ft.
2) Snider Basin $1,128/ac.ft.
3) Upper Kendall $1,398/ac.ft.*
4) Sixty Seven Enl. $1,569/ac.ft.

Other off channel sites that should be considered further due to favorable permitting and/or the potential for beneficial yeild include:

5) Cow Gulch Res. $1,799/ac.ft.
6) Sand Hill $2,782/ac.ft.
7) Mickleson Creek $3,113/ac.ft
8) McNinch Wash $5,748/ac.ft.

**The low cost is due to an economy of scale that will likely not be realized due to a lack of purpose and need for the full volume of 340,000 acre-feet. The final size of the Kendall project will be smaller with a corresponding increase in per acre ft. cost. Also, estimates ignore costs of conveyance system appurtenances such as turnouts, drops, inverted siphons, flumes or bridges, culverts on road crossings, easements and land acquisition costs.*

The top five sites in terms of anticipated permitting ease are:

1) Middle Piney Lake
2) Sixty Seven Enlargement (McNinch Wash)
3) Horse Pasture Draw
4) Mickleson Creek
5) Sand Hill

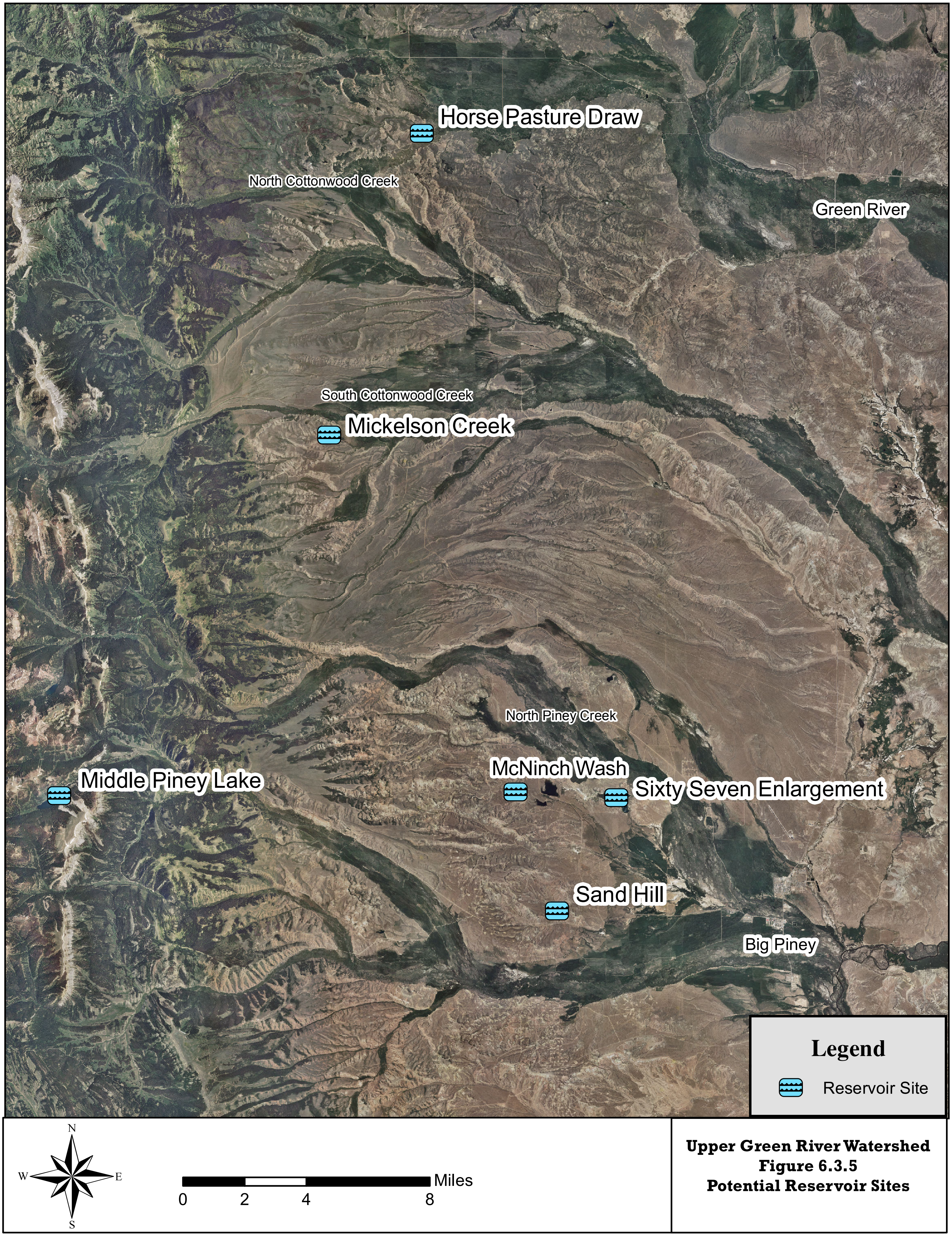
This cursory analysis is not meant to be a substitute for a detailed reservoir study of a particular site. Each site has a variety of issues, impacts and benefits. In general terms, enlargement of existing facilities and off-channel sites appear to be most likely to be permitted and constructed.

As stated in the conclusions of the Upper Green River Westside Storage Study, Level II:

- Each subbasin (North and South Horse, North and South Cottonowood, and North, Middle and South Piney Creeks) would generally benefit from some amount of storage in the basin to capure legally available flows (typically spring runoff) and release captured flow in the irrigation season or as carryover to subsequent drier years, if possible. Thus, at least one or more alternatives should be included to provide storage and/or supplemental supply to each of the sub-basins.

- More promising storage alternatives generally lie within a discernible North-South corridor. Sites within the Wyoming Range (generally defined as sites lying within the Bridger-Teton National Forest) tend to exhibit generally less favorable characteristics such as difficulty of permitting and less favorable geologic and geotechnical conditions. These sites are also located below the area of highest unit runoff in the study area (i.e., the high elevation Wyoming Range). Conversely, sites lying far downstream in the study area, while having the ablity to capture even more of the physically and legally available flow in the subbasin, miss opportunities to satisfy present demand and shortages by gravity release. The most favorable locations are generally above the majority of the irrigation demands and below the Wyoming Range/ National Forest.

Previous studies have identified both public and private lands are involved with most projects when one considers the reservoir site proper, the conveyance into, and the conveyance out of the reservoirs. The Horse Pasture Draw site and Cow Gulch site have been identified as being exclusively on private ground in the Upper Green River Westside Storage Study, Level II. Figure 6.3.5 illustrates the relative location of the leading sites.



Upper Green River Watershed
Figure 6.3.5
Potential Reservoir Sites

6.4 RESERVOIR ECONOMIC ANALYSIS

6.4.1 PROJECT BENEFITS

Several previous studies include detailed economic analysis for their respective reservoir sites. Increased hay production and fall growth in winter pasture is viewed as the primary direct benefit of the water. The Upper Green River Westside Storage Study, Level II established the increased hay production value of each additional acre foot of evapotranspiration (ET) at 1.48 tons per acre. Accounting for a 35% conveyance efficiency, also established by the Upper Green River Westside Storage Study, the actual increased crop production will be (0.35 x 1.48) or 0.52 tons per acre. The marginal cost of producing an additional ton was estimated in the Upper Green River Westside Storage Study, Level II at $39.06 per ton in 2008 dollars. The Cattle Business Weekly suggested as high as $60 per ton in 2012. For purposes of this analysis we will used a production cost of $60 per ton July 3, 2013 USDA Market news placed the market value of grass/alfalfa mix at $180 to $200 per ton. By using a market price of $180 per ton, and a production cost of $60 per ton, the value of the increased production of 0.52 tons per acre achieved by adding 1 acre-foot of water water is valued at $62.40.

Based on this analysis, a 5,000 acre-foot active capacity reservoir will produce $312,000 per year in direct benefits.

Indirect benefits are a result of a locally produced “on-ranch” dollars being spent locally and circulating locally and resulting in income in other sectors that support agriculture. In 1992 the US Department of Commerce estimated the indirect multiplier for the Wyoming agriculture sector to be 3.36 meaning every $1.00 produced on the ranch generates $2.36 in indirect benefits. Consequently the $312,000 in direct benefit from a 5,000 acre-foot active capacity reservoir grows to $736,320 in the local economy.

Other potential project benefits include recreation, flood control, hydropower and wildlife. Few of these beneficiaries have the organization or means to directly pay significant project costs. However, these benefits will be considered by the State when analyzing project funding and should be considered with potential reservoir planning. The benefits identified in previous studies include:

- Late season flows benefiting aquatic wildlife and riparian habitat
- Tailwater fisheries
- Sediment control
- Direct wildlife and stock watering opportunity at reservoir
- Flood control capability
- Waterfowl habitat
- Flat water recreational opportunities
- General shore recreational opportunities
- Water quality

6.4.2 PROJECT FINANCING

Spending all or most of the benefit on the project debt service negates the benefit. The beneficiary of the reservoir will spend part of the benefit (perhaps up to 50%) on the reservoir project debt service. This leaves the remaining 50% for operations and maintenance and as potential increased income to the beneficiary.

Each reservoir project requires significant grant resources in order for the project to be financially affordable to the end user. The Upper Green River Westside Storage Study, Level II established that grant levels on the order of 90% are required before the end user has the ability to pay the outstanding 10%. At lower grant levels, such as the standard 67% grant, the end user can only pay a portion of the outstanding debt payment.

The most recent Middle Piney Reservoir Level II Study, 2009, places the sponsor ability to pay at between 5% and 10% of the project cost.

None of the projects can finance and carry their entire cost as a loan paid by the subscribers to the system. All projects will require grants on the order of 90% in order for the irrigators to afford the user rates. The WWDC realizes the value of storage projects and has adopted special criteria specific to the Dam and Reservoir Program to address affordability. See Project Financing Section 8.3.4.1

6.4.3 OPERATION AND MAINTENANCE COSTS

After project completion, there will be ongoing maintenance tasks associated with the operation of the facility. These operational costs will be the responsibility of the beneficiaries (irrigators that have formed a district). On-going maintenance costs include annual special use permit payments (if on USFS or BLM), vegetation control, debris removal, slope maintenance, inspections, mechanical components, etc.

The estimated annual costs for these expenses are tied to the size, location and complexity of the facility. The USFS ties their fees to the surface acreage of the facility and bases the Annual Use Payment on the number of inundated acres. A general liability policy may also be required of the permittee. Permit fees on USFS lands have been in the $500 per acre per year range. Inundated lands, embankments, and roads all count in the fee estimation. These fees alone can be a significant hurdle and potential fatal flaw when considering storage feasibility.

Maintenance costs are site dependent. As an example, Cottonwood Lake in the Bridger Teton National Forest, with one to two acres of embankment to maintain, annual fees were estimated by Sunrise Engineering as follows:

Maintenance Costs

Debris Removal	$ 1,000 (as needed)
Vegetation Control	$ 600 (once every other year)

Slope Maintenance	$ 800	(once every 5 years)
Drain Inspections	$ 200	(once per year)
Gate Maint./Operation	$ 500	(five to seven visits per season)
Subtotal	$ 3,100	(annual cost)

Larger embankments will be more expensive based on the number of acres that must be maintained and the complexity of the dam infrastructure. The above costs for two acres could be prorated to larger acreages for an approximation of the operation and maintenance costs.

VII. PERMITTING

Permitting can become a complex, lengthy and expensive process. The Upper Green River Watershed study area contains lands administered by the USFS, BLM, State, and private individuals. The projects identified in this study range from maintenance or replacement of existing and permitted facilities; to new reservoirs. Depending on the location and type of project, permitting may be as simple as a water rights application to a full Environmental Impact Statement (EIS). The following sub-sections detail various permitting requirements.

7.1. IRRIGATION SYSTEM REHABILITATION PROJECTS

For the most part, the U.S. Army Corps of Engineers will allow irrigation system rehabilitation projects to proceed with the acquisition of a Nationwide Permit. This includes replacement of irrigation diversion structures in the same location. The process for applying for and receiving a Nationwide Permit involves providing a project description, preliminary design documents and photos of the area involved. Once the Corps has received these documents they simply issue a letter to proceed.

7.2 NEW RESERVOIR PERMITTING

Permitting requirements will vary depending upon whether the proposed project is situated upon private, State or Federal lands. The only exception relates to Section 404 permitting through the U.S. Army Corps of Engineers. An Army Corps of Engineers Section 404 permit will be needed regardless of land ownership. A summary of new reservoir permitting is presented below.

7.3 FEDERAL PERMITTING REQUIREMENTS

7.3.1 NEPA PROCESS FOR RESERVOIR PROJECTS

One of the first steps in the National Environmental Policy Act (NEPA) process is to develop an accurate and defensible Purpose and Need statement for the project. The Purpose and Need statement consists of three parts: the purpose, the need, and goals and objectives. The purpose defines the problem. The need provides data to support the problem. The goals and objectives describe other issues and possible opportunities that could be realized as part of the potential solutions to the problem. The Purpose and Need statement should provide enough information to develop and support a “reasonable range” of alternatives and guide the alternative development and screening process. The NEPA process requires analysis of the “No Action” alternative and a reasonable range of alternatives that fully address the project's purpose and need.

7.3.2 U.S. ARMY CORPS OF ENGINEERS SECTION 404 PERMITTING

For any new reservoir, the Applicant must submit a Section 404 permit application to the U.S. Army Corps of Engineers office. Prior to submitting the application, the Applicant should address the proposed project's Purpose and Need and any other alternatives considered and the reasons for their elimination.

Most of the current alternatives for the Upper Green River watershed study area are proposed "off-channel" storage options, some of which have significant wetlands present. The Applicant must address these wetlands and also be prepared to discuss the potential impact of the new diversion structures and the impacts on current flow patterns in the designated water source (Upper Green or tributaries).

Due to the requirements of the National Environmental Policy Act (NEPA), the Corps of Engineers will require an Environmental Assessment (EA) for those projects that have minimal impacts identified. Most EA's can be completed within a year from the date of application. Those projects that have identified impacts to aquatic resources greater than 0.5 acres or have impacts to threatened or endangered (T&E) species will likely require that an Environmental Impact Statement (EIS) be prepared. The time requirements for completing an EIS can range from 2-5 years and be quite expensive. For this reason, it becomes imperative that the Applicant investigate thoroughly those projects with the least damaging impacts to area wildlife, fisheries and aquatic resources.

Once the Application package has been accepted, the Corps of Engineers (COE) will prepare a Public Notice of the pending Application and announce Public Scoping meetings to be held in the area of interest. Public notices will be sent to most local, State and Federal agencies along with all surrounding land owners. Upon the completion of Public Scoping meetings, a Scoping Document will be prepared summarizing all comments received regarding the proposed project. The COE will then finalize the Scope of Work for conducting the environmental analysis. Unlike most Federal land management agencies, the COE does not require reimbursement of their NEPA/404 participation costs.

7.3.3 BUREAU OF LAND MANAGEMENT (BLM) PERMITTING

For those potential projects located upon BLM lands, the Bureau of Land Management will become the Lead Federal Agency and to initiate the process for permitting a new reservoir or upland development projects, the Applicant must submit a Right-of-Way application. This application requires the completion of a thorough project description and a summary of alternatives investigated and the reasons for their elimination. The application also requires an explanation of all the environmental effects anticipated from the construction and operation of the proposed reservoir. As the Lead Federal Agency, the BLM will manage and direct the preparation of all environmental documentation (EA/EIS). The BLM will also manage all NEPA requirements for the proposed project. In most cases, projects on Public Lands will also include the U.S. Army Corps of Engineers as a Cooperating Federal Agency. The process for providing Public Notice and comments is nearly identical to the COE process outlined above. Upon initiating the NEPA environmental process the Applicant will agree to pay all costs of the EA/EIS preparation and will also sign a "Cost Collection Agreement", whereby the Applicant agrees to reimburse the BLM for all their costs associated with the NEPA document preparation process.

7.3.4 UNITED STATES FOREST SERVICE (USFS) PERMITTING

Much like the BLM, the USFS becomes the Lead Federal Agency for all projects located upon Forest Service lands. To initiate this process with the USFS, the Applicant must complete a Special Use Permit application. The application process is nearly identical to the BLM right-of-way application process. The USFS will also then be responsible for all NEPA compliance issues and the COE will become a Cooperating entity, The USFS also requires the Applicant to pay all EA/EIS preparation costs and to reimburse the Agency for all their project related NEPA compliance and document preparation expenses.

Although the Applicant pays all NEPA EA/EIS and agency expenses related to Applications, this does not allow the Applicant to direct the work product of the 3rd Party consultants selected by the agency to prepare the NEPA documentation. Third Party environmental consultants work directly for the Federal agency involved.

7.3.5 UNITED STATES FISH AND WILDLIFE SERVICE (USFWS)

On new projects, the Applicant is required to consult with the USFWS under Section 7 of the Endangered Species Act to make certain that the project is in compliance. The lead agency will prepare a biological assessment to determine project effects on threatened and endangered plant and animal species listed or proposed for listing under the Endangered Species Act. The USFWS will then issue an opinion on whether federal actions are likely to jeopardize the continued existence of a threatened or endangered species, or adversely modify critical habitat. The USFWS must approve the preparation of a biological assessment to comply with the Endangered Species Act in order to render its decision. lf the USFWS determines that the proposed project could adversely impact a protected species, mitigation measures or changes to the project scope, location and methods will be required.

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.

7.3.6 U.S. DEPARTMENT OF INTERIOR - ADVISORY COUNCIL ON HISTORIC PRESERVATION (SECTION 106)

Section 106 of the National Historic Preservation Act of 1966 (NHPA) requires Federal agencies to take into account the effects of their undertakings on historic properties, and afford the Advisory Council on Historic Preservation a reasonable opportunity to comment. Laws and regulations addressing cultural resources include: the National Historic preservation Act(NHPA) of 1966; the National Environmental Policy Act (NEPA) of 1969; the Archaeological Resources Protection Act (ARPA) of L979; the National Park Service (NPS) procedures concerning the National Register of Historic Places (NR); the Advisory Council on Historic Preservation's Procedures for the Protection of Cultural Properties; the Treatment of Archaeological Properties of 1980: Determination of Eligibility of Inclusion in the NR; the Secretary of Interior's Standards and Guidelines for Archaeological Historical Preservation of1983; Reservoir Salvage Act of 1960; and the 1974 Amendment to the Reservoir Salvage Act of 1960.

The Wyoming State Historic Preservation Office (SHPO) is the point of contact to meet compliance with NHPA requirements. SHPO should be contacted early in the planning stages for their comments that could impact project approach and cost.

7.4 STATE OF WYOMING PERMITTING

In addition to the Federal permits outlined above, there are a host of additional permits/approvals required for any new dam construction. Outlined below are the State of Wyoming permits required for new dam construction.

7.4.1 WYOMING STATE ENGINEER'S OFFICE (WSEO) SURFACE WATER STORAGE PERMITS

- The Applicant must obtain the necessary water rights storage permits from the WSEO for the diversion and storage of the State's surface water. If an existing ditch is utilized for reservoir supply, an enlargement permit for this ditch would be required. Stock reservoirs constructed in existing draws and or ephemeral streams will require completion of Forms S.W. 3 and/or S.W. 4.

- The Wyoming Dam Safety Law (W.S.41-3) requires that any proposed 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 cfs must obtain approval by the Wyoming State Engineer's Office. The Applicant must provide plans and specifications to the WSEO for a Permit to construct through the Dam Safety office. Design, construction, and operation of jurisdictional dams must also comply with dam safety regulations pursuant to the Dam Safety Act. The upland water development projects identified in this plan utilize dams that fall under the 20’ height limit and the 50 acre foot threshold.

7.4.2 WYOMING STATE DEPARTMENT OF ENVIRONMENTAL QUALITY (WDEQ) PERMITTING

- National Pollution Discharge Elimination System (NPDES) permit and corresponding Section 401 Certification. The NPDES permit controls the discharge of storm water pollutants associated with construction activities. The Section 401 Certification is the State's approval to insure that the activities authorized under Section 404 (COE) meet State water quality standards and do not degrade water quality.

7.4.3 WYOMING HISTORIC PRESERVATION OFFICE (SHPO) ARCHAEOLOGICAL CLEARANCE

- SHPO coordinates with federal agencies in determining the significance of cultural resources potentially affected by ground disturbing activities. Contact with SHPO should be made early in the planning process.

7.4.4 WYOMING BOARD OF LAND COMMISSIONERS

- The Wyoming Board of Land Commissioners through the State Lands and Investments Board (SLIB) is responsible for regulating all activities on state lands, including granting of rights-of-way. Any facility ,utility, road, ditch, or reservoir 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).

7.4.5 WYOMING GAME AND FISH

- Coordination with the WGFD is encouraged when planning and implementing upland water resource projects. Many of the upland water projects identified in this study fall on private ground and coordination may not be mandatory, however coordination may bring expertise and funding that will enhance the scope of the project.

7.5 NEPA PROCESS FOR OTHER PROJECT TYPES

The applicability of NEPA to projects other than reservoir storage (non-stock pond) must be determined on a case-by-case basis. For example, proposed new wildlife/livestock watering developments including tank/pipeline systems that cross and/or serve federal or state land 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 possible that an EA process will be found appropriate rather than a full EIS. Most of the upland water projects identified in this plan have some component that crosses or is located on federal or state land.

BLM

At the time of this reporting, compliance with NEPA will be guided in large part by the Approved Resource Management Plan (RMP) for Public Lands Administered by the BLM Pinedale Field Office (BLM 2008) and any subsequent new or additional guidance and/or updates. The RMP was developed on the basis of a NEPA-compliant EIS. Currently, the BLM is in the process of completing a revision to the RMP and associated EIS.

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. For example, a project proposed within the BridgerTeton National Forest would presumably be led by the U.S. Forest Service, most likely from the Jackson Regional Office or in the case of small projects the Big Piney Ranger District. 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, these plans will guide these agencies' NEPA process for any applicable proposed projects.

Watershed Wide Environmental Analysis

In other watershed studies a watershed wide approach to the environmental permitting of upland stock and wildlife water projects has been propsed as a way to establish baseline data for all sites. This baseline data could then be supplemented by additional data on a case by case basis. The approach is intended to eliminate duplicate and repetitive work and in the long term reduce overall costs for environmental analysis. While certain aspects of this approach are attractive for the Upper Green Watershed Study Area, there are some considerations that indicate a case by case basis may be the best approach. The Upper Green River Basin Study Area includes lands with varied topography, administration, ownership, climate, and other characteristics. Many of the proposed projects will require unique work based on location and adminstration that will not translate directly to other sites. If baseline work could be funded and completed independently of individual projects, the watershed wide environmental analysis approach may work well provided individual assessments are not required to reanalyze the established watershed wide baseline conclusions.

Non-Reservoir Project Permits, Clearances, and Approvals

The permits, clearances and approvals required for projects other than dam and reservoir projects will depend on the specific nature and location of the project. The various permits and clearances discussed above in Sections 7.3 and 7.4 may also apply to other types of projects. For example, if a new groundwater well is associated with a proposed wildlife/livestock watering development, then the applicant must obtain the necessary groundwater right permits from the Wyoming State Engineer's Office (WSEO), which includes Forms U.W. 5 & 6. New wildlife/livestock watering development projects that utilize existing groundwater wells must include stock as a use in the associated water right. 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 possible re-design during project implementation. Additionally, coordination with the Wyoming Game and Fish Department is encouraged when planning and implementing natural and water resource improvement projects.

7.6 MITIGATION

Mitigation could be required at any of the identified reservoir projects or other potential projects described in Sections 4 and 5 to address impacts to wetlands, riparian vegetation, cultural resources, fish and wildlife resources, and possibly threatened or endangered species. Potential environmental impacts associated with potential reservoir sites are identified in Table 6.3.4.

If wetland impacts associated with any future projects are above the threshold set by the USACE (typically 0.1 acres), detailed compensatory mitigation plans to replace lost wetland functions will need to be prepared and approved. The ratio of wetland replacement mitigation would be determined during the permitting process. Any required mitigation plans will follow guidance provided by the 10 April 2008 “Compensatory Mitigation for Losses of Aquatic Resources; Final Rule” in 33 CFR Parts 325 and 332 and 40 CFR Part 230, which requires compensatory mitigation plans to contain 14 elements as outlined in Part 332 Section 332.4.

Prior to constructing a project, surveys for sensitive wildlife and plant species would likely be required. If any sensitive species are found, mitigation measures would likely be required. Mitigation of potential raptor and big game impacts would generally involve stoppage of certain construction activities during sensitive time periods and avoidance of direct disturbance of the subject species. Impacts to crucial big game habitat will likely have more significant mitigation requirements. If any T&E species were encountered at a given site, special studies would be required to determine if appropriate mitigation could be implemented.

The greater sage-grouse has been petitioned for listing as threatened or endangered under the Endangered Species Act. The Wyoming Game and Fish Department recently revised a map showing sage grouse "Core Population Areas" within the state of Wyoming (Figure 3.4.15), and Governor Freudenthal issued an Executive Order (updated in Order 2011-5 by Governor Mead) mandating that new development within Core Population Areas should be authorized or conducted only when it can be demonstrated that the activity will not cause declines in greater sage-grouse populations. Current recommendations limit surface disturbances to 5% of suitable sage-grouse habitat per 640 acres in core areas. Given the Governor’s executive order, it may be difficult to obtain state approval for projects within the core area if significant areas of sage-grouse habitat are impacted. The executive orders can be found at:

http://www-wsl.state.wy.us/sis/wydocs/execorders.html. The most recent executive order can be found in Appendix H.

The BLM and WGFD have developed restrictions and recommendations to help protect the species, see Appendix H for BLM and WGFD policy on greater sage-grouse. Many upland water projects identified in section 4 will serve to enhance sage grouse habitat. This enhancement angle may be viewed as a multiuse benefit that will ease permitting. In addition most upland projects will occur on areas already disturbed and occupied by development.

Impacts to fishery resources will require mitigation. Impacts related to reservoir projects could potentially be mitigated through minimum reservoir release requirements and creation of a minimum pool for aquatic habitat. Fish passage on main-stem sites will likely be required as well as fish screening on major intakes or diversions to canals or off channel storage sites.

Cultural and historic resource fieldwork will need to be completed to identify and document any such resources that will be impacted. This would include 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 will be developed culminating in a Memorandum of Agreement (MOA) between the Wyoming SHPO and the lead federal agency with concurrence by the project sponsor, and possibly affected Native American tribes. The agreement would require approval from the Advisory Council on Historic Preservation.

7.7 LAND OWNERSHIP AND PROPERTY OWNERS

All upland projects are on land owned by the sponsor proposing the project or on State, BLM, or USFS administered lands. Most upland projects will be permitted by working with one or more of these entities. Potential reservoir projects in the basin and ancillary canals can span multiple land owners and agencies. No upland projects were identified that involved easements across more than one private land owner, however, most upland project involve state and/or federal lands and possibly the private land of the project sponsor.

VIII. FUNDING OPPORTUNITIES

8.1 OVERVIEW

Multiple funding sources exist to assist with the cost of project implementation. Selection of the proper program(s) can result in a significant portion of the cost being covered by complimentary sources.

This section briefly describes some of the programs available and provides details regarding where more information can be obtained regarding these programs. In general, most of the future watershed improvement projects can reasonably expect to tap into the funding sources identified here within.

An investigation of federal, state and local funding sources was conducted to identify potential opportunities for watershed improvement projects.

Within this section, other recent watershed studies were referenced on the behalf of the Wyoming Water Development Commission. Specifically, the Clear Creek Watershed Study (States West Water Resource Corporation, 2011) was reviewed and several sections reproduced and/or modified herein where appropriate.

The following documents provide extensive information pertaining to project funding opportunities for projects investigated within this Level I study:

- **Water Management & Conservation Assistance Programs Directory, Fourth Edition** (WWDC May 2009). This directory provides funding agency direct contacts to assist with potential project funding throughout the area. http://wwdc.state.wy.us/wconsprog/WtrMgntConsDirectory.html
- **Catalog of Federal Funding Sources for Watershed Protection.** This EPA website provides information pertaining to numerous funding sources including grants, loans, and cost sharing programs which are applicable to watershed projects. The document is available at: http://cfpub.epa.gov/fedfund/
- **Habitat Extension Bulletin No. 50 - Fisheries and Wildlife Habitat Cost Share Programs and Grants (Wyoming Game & Fish Department, August 2007)** The Wyoming came & Fish department has developed this informative bulletin pertaining to financial assistance programs available for fisheries and wildlife habitat projects. http://gf.state.wy.us/habitat/ExtBulletinsCont/index.asp

As government programs frequently change according to the available budgets of the funding agencies the grants, loans, and cost share opportunities presented herein are subject to change. As such, it is recommended that additional inquires be made if interested parties wish to pursue the opportunities presented in this section.

Significant competition for funding associated with many of the opportunities presented is frequently encountered by applicants. To increase the potential for success in obtaining funding from other sources, applicants may wish to have other funds available to leverage against these opportunities. By showing the financial commitment to projects, funding agencies may look more favorably to fund specific projects that have a higher likelihood of timely implementation. Contacts for key local groups who can provide current information on funding sources relevant to watershed projects include:

- Bureau of Land Management/Pinedale Field Office (307-367-5300)
- NRCS - Pinedale Office (307-367-2257 #110)
- Sublette Conservation District (307-367-2257)
- Wyoming Water Development Office (307-777-7626)

8.2 LOCAL AGENCIES

8.2.1 SUBLETTE COUNTY CONSERVATION DISTRICT

Sublette County Conservation District (SCCD) serves as the local liaison between local landowners and resource users and state and federal government agencies. In addition to their many other roles and responsibilities, this district can also provide funding assistance as follows:

- In-kind technical assistance as local resources, capacity and expertise allow.
- Administration of programs, projects and grants on behalf of recipients of state and federal natural resources program funding.
- Assistance in development of leveraged, partnered programs and projects.
- Assistance in preparation of grant applications

8.2.2 SUBLETTE COUNTY WEED AND PEST DISTRICT

Wyoming Weed and Pest Districts provide financial and in-kind support to landowners and other agencies/entities including, but not necessarily limited to:

- Cost-share in the control of noxious weeds.
- Assistance in the identification of noxious weeds and other undesirable plants.
- Organization and/or participation in local meetings, seminars and field trips to educate local landowners and agencies on the problems and potential solutions for weed and other undesirable plant control, and
- Facilitating weed control work days attended by a broad base of stakeholders.

8.3 STATE PROGRAMS

8.3.1 WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY

The Wyoming Department of Environmental Quality (WDEQ) provides funding for implementation of best management practices (BMPs) to address non-point sources of pollution under Section 319 of the Clean Water Act. Section 319 grant funding requires a non-federal (i.e., local) match of 40 percent from the applicant. These matching funds may be provided by landowners, a conservation district, other quasigovernmental entities (e.g., watershed improvement district, irrigation district, etc.), and/or nonprofit organizations (e.g., Trout Unlimited, Ducks Unlimited, and the Rocky Mountain Elk Foundation). Applications (proposals) conforming to a specified format are required. The proposal describes in some details the issues to be addressed and the proposed methods/BMPs to be implemented, as well as providing all other information required to evaluate the proposed project and matching fund entity(ies). These proposals are normally due in August or September of each year.

Projects located within watersheds of streams on the 303d list are eligible for the 319 - Incremental Funds, which has historically been a larger amount. Projects located within watersheds which are not listed on the 303d list, such as the Upper Green are only eligible for 319-base funds.

See (http://deq.state.wy.us/wqd/watershed/Downloads/305b/2012/WY2012IR.pdf) for the latest Water Quality Assessment and Impaired Waters List (2012)

Quote taken from Wyoming DEQ website:

"After water quality problems have been identified, objectives have been set and BMPs have been planned, the next step is to obtain funding so that the BMPs can be implemented. Funding sources will likely be different depending on whether the BMPs are to be implemented on private land or public land.

Several organizations, including DEQ, provide funds for BMPs on private land. DEQ funding is provided through section 319 of the Clean Water Act. A 40 percent non-federal match is required. Proposals are usually due in August or September. While most 319 funding for BMPs goes for projects on private land, these funds can also be used on public land if a nonfederal match is provided. In addition to BMPs, other eligible 319 activities include information and education and a limited amount of problem identification.

For projects where the problem has not yet been clearly identified, DEQ provides 205j funding for planning and assessment. Eligible activities include: problem identification; goal and objective development; public participation; and education. A 25 percent nonfederal match is required. Proposals are usually due in January.

Periodically, DEQ conducts workshops on how to apply for 319 and 205j funds. Contact the Water Quality Division for dates and locations (307 777-7781).

A Nonpoint Source Task Force has been appointed by the Governor to review and rank 319 and 205j proposals. Awards range from a few thousand dollars to a couple hundred thousand dollars. Chances of approval are greater if the proposal addresses a problem identified on the 303d list (included in the 305b report).”

8.3.2 WYOMING GAME AND FISH DEPARTMENT

Wyoming Game & Fish Department funding assistance can best be summarized by the following:

'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." (WWDC, 2005)

Current programs offered by the Wyoming Game & Fish Department include: Riparian Habitat Improvement Grant, Water Development/Maintenance Habitat Project Grant, Upland Development Grant, Fish Wyoming, and Wyoming Sage Grouse Conservation Fund. These programs are described below.

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 contribution required from the 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 rights are responsibilities of the grantee. There is a maximum of $7,500/project and 50% cash or in-kind contribution required from the grantee.

Upland Development Grant

The purpose of this program is to develop upland wildlife habitat. Example projects include management, grazing systems, prescribed burning, and 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.

Wyoming Sage Grouse Conservation Fund

WGFD administers the Wyoming Sage-Grouse Conservation Fund (WSGCF).

http://gf.state.wy.us

The WSGCF is a special fund established by the Wyoming State Legislature to support the efforts of Local Sage-Grouse Working Groups (LWGS). The WSGCF funding is intended to promote conservation of sage grouse populations and habitat (sagebrush ecosystems), including socio-economic and human use of the habitat.

Requests for WSGCF funding must be made on a Project Proposal Form.

Funding is normally considered for projects ranging between $5,000 and $50,000, with priority given to those with matching funds, established partnerships, multi-species benefits, management relevance and consistency with the local sage-grouse conservation plan, highest wildlife impact, appropriate budgets, landscape scale, and a lasting legacy of benefits. Evaluation criteria include: consistency with the local plan, likelihood of project success, project readiness, and availability of matching funds, multiple species benefits, significance at local/state/regional level, duration of benefits, and adequacy of funding. Application may be made at any time, but should be made by February 1 to receive first round consideration. Funds awarded must be expended between July 1 of the year received and September 30 of the second year after award. The funds are normally distributed as reimbursable grants (i.e., payments are made for expenses incurred and not "up-front"). Requests for funding of habitat improvement projects, including water developments, must include a livestock grazing management plan. A Project Close-out Report must also be submitted upon completion to allow tracking of expenditures and tracking of results.

8.3.3 WYOMING OFFICE OF STATE LANDS AND INVESTMENTS

As the administrative advisory arm of the Board of Land Commissioners and State Loan and Investment Board, the Office of State Lands and Investments (OSLI) administers Regular Farm Loans and Small Water Development Project Loans that are applicable to potential projects identified in Sections 4 and 5.

Regular Farm Loans

These loans are made for a wide range of agricultural purposes, including as most applicable to the potential projects identified in Sections 4 and 5, purchasing, constructing or installing equipment and/or improvements necessary to maintain or improve the earning capacity of the farming operation. Eligible applicants include individuals whose primary residence is in Wyoming and legal entities with a majority of the ownership meeting the individual residency requirements. Single loans or combinations of loans cannot exceed an outstanding principal balance of $600,000. Loan rates are 8% for loans up to 50 percent of the appraised value of the security land and improvements and 9% for loans between 50 and 60 percent of the security. The term of a given loan is limited to 30 years.

Small Water Development Project Loans

These loans are authorized for projects for development and use of water upon agricultural lands for agricultural purposes. These projects may convert dry land into irrigated land or lead to more efficient use of water and/or increased crop or forage production. Eligible recipients may include court approved water districts, agencies of state and local government, persons, corporations, associations, and other legal entities recognized under state law. Individual loans up to $150,000 may be made. Interest is currently set at 4% to 6% percent and the maximum term of loan is 15 years.

8.3.4 WYOMING WATER DEVELOPMENT COMMISSION

The mission of the Wyoming Water Development Commission (WWDC), as defined in the enabling legislation, is to:

"provide, through the commission, procedures and policies for the planning, selection, financing, construction, acquisition and operation of projects and facilities for the conservation, storage, distribution and use of water, necessary in the public interest to develop and preserve Wyoming's water and related land resources, The program shall encourage development of water facilities for irrigation,..for abatement of pollution, for preservation and development of fish and wildlife resources...and shall help make available the waters of the state for all beneficial uses..," (W.S. 41-2-112(a)).

Key aspects of the Wyoming Water Development Program and the Small Water Project Program administered by WWDC are described in the following subsections.

8.3.4.1 WYOMING WATER DEVELOPMENT PROGRAM

The main Wyoming Water Development Program encompasses new development, dams and reservoirs, rehabilitation, water resources planning and master planning. Of most relevance to the Upper Green watershed in terms of implementing alternative projects are the New Development, Rehabilitation Programs and Dams and Reservoirs Program described below. This information was abstracted in the Clear Creek Watershed Study from the Operating Criteria of the Wyoming Water Development Program available at:

http://wwdc.state.wy.us/opcrit/final_opcrit.pdf

It is very important to ensure that the most current information on funding is reviewed prior to making an application as WWDC's policies and procedures can and do change over time in response to legislative direction and/or Commission action. Review of information available at the above website and contact with the staff of the WWDC (307-777-7626) is recommended prior to beginning the application process.

Water Resource Planning

The Wyoming Water Development Commission serves as the water development planning agency for the State of Wyoming. In this capacity, the WWDC can provide assistance for both Basin Wide Plans and Master Plans. These two types of plans are further described below:

Basin Wide Plans- The program serves to develop basin wide plans for each of the state's major drainage basins.

Master Plans -The program provides a service to municipalities, districts and other entities to assist in the preparation of planning documents which serve as master plans for future water supply systems and improvements. The plans serve as a framework for the entities to establish project priorities and to perform the financial planning necessary to meet those priorities. These plans can assist entities in preparing the reports necessary to achieve federal funding assistance for water development and other water related projects.

Groundwater Grant Program

The primary purpose of the program is to inventory the available groundwater resources in the state. The program also serves to assist communities in developing efficient water supplies. Municipalities and special districts that purvey drinking water are eligible to receive up to $400,000 in grant funds if 25% of the total project costs will be paid by local marching funds.

New Development Program

This program provides technical assistance and funding to develop waters of the state that are unused and/or un-appropriated at present. It deals with a wide range of projects, including as most relevant to the Upper Green watershed the following types of projects:

- Multiple Purpose - including among other uses two or more of the following: agriculture, recreation, and environmental;
- New Storage - dams and reservoirs less than 2,000 acre-feet;
- New Supply - diversion dams;
- Watershed Improvement - for components whose primary function or benefit is water development; and
- Recreation

These project types are listed above in the order of preference assigned by WWDC when determining what projects to pursue among all of the applications received for funding.

Rehabilitation Program

The Rehabilitation Program addresses the improvement of water projects completed and in use for at least fifteen years in order to assist in keeping existing water supplies effective and viable for the future. Relative to the Upper Green watershed, the Rehabilitation Program can improve existing agricultural facilities and conveyance systems to insure safety, decrease operation and maintenance (O&M) costs, and increase the efficiency of agricultural water use. The types of projects supported relevant to this watershed are essentially the same as listed above for the New Development Program.

Note that on-farm improvements (e.g., gated pipe, side rolls, center pivots and related facilities and/or equipment such as pumps, power lines) are excluded from WWDC funding under both the New Development and Rehabilitation Programs.

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. The source of revenue for the program is Water Development Account No. III [W.S. 41-2-12a (iii), which has received Water Development Account No. I appropriations and budget reserve account appropriations on occasion, as approved by the legislature; the interest earnings that have accrued to the Water Development Account No. III; and a percentage (0.5%) of the revenues which accrue to the state's severance tax distribution account. Legislative approval must be granted prior to allocating funds to a particular purpose or project. 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.

Key Criteria and Procedures

An application for funding under either the New Development or Rehabilitation Programs must meet the following key criteria most applicable to potential projects as identified in Section 4 above:

- "'The project sponsor shall be a public entity that can legally receive state funds, incur debt, generate revenues to repay state loan, hold title and grant a minimum of a parity position mortgage on the existing water system and improvements or provide other adequate security for the anticipated state construction loan."
- "The proposed project must serve 2,000 or more acres of irrigated cropland, or must rehabilitate watershed infrastructure, which will develop or preserve the beneficial use of water in a watershed. The watershed rehabilitation projects must possess an estimated minimum useful life span of twenty-five (25) years and demonstrate that sufficient public benefits will accrue to justify construction of the anticipated improvements..."

Important procedures, deadlines and requirements for applications to the New Development and Rehabilitation Programs include but are not necessarily limited to the following:

- A fee of $1,000 must be submitted with initial project applications; the fee does not apply to projects advanced to the next level of stud or to construction. A certified resolution passed by the governing body of the sponsoring entity must accompany an application for a Level II study or Level III construction. This requirement may be deferred if the applicant is in the process of forming a public entity.
- A public entity must be in place before a Level II study or Level III construction can commence, with certain exceptions discussed below.
- The due date for new project applications is August 15 of each year; the due date for applications for advancing to the next study level or construction funding is October 1 of each year.

Two important criteria that apply specifically to dam and reservoir projects are:

- "For projects that enlarge existing storage projects by 1,000 acre-feet or greater or for proposed new dam and reservoirs with a capacity of 2,000 acre-feet or greater, expenses associated with final engineering design and required National Environmental Policy Act reviews, including, but not limited to, environmental assessments and environmental impact statements, are eligible components of a Water Development Program Level II, Phase III Study Project."
- "For dam and reservoir projects, the Commission may wave sponsor eligibility requirements through Level II, Phase II. However the eligible entity requirements shall be met prior to initiation of Level II, Phase III activities described herein."

Financial Plan

The current standard terms of the Wyoming Water Development Program financial plan are summarized as follows:

- Sixty-seven (67) percent grant to thirty-three (33) percent loan mix.
- Minimum four (4) percent loan interest rate (current rate is 4 percent, but legislature may increase rate).
- Maximum 50-year term of loans; term shall not exceed economic life of project,
- Payment of loan interest and principal may be deferred up to 5 years after substantial completion at WWDC's discretion under special circumstances.

In the document entitled "Information for New Applicants" the following additional relevant information is provided regarding financial terms:

- "The best available project financial terms include a grant for Level I and Level II expenses, a grant of 75% of the Level III costs, a loan of 25% of the Level III costs with an interest rate of four percent (4%) and a term equal to the economic life of the project/improvements or fifty (50) years whichever is less. Principal and interest payments may be deferred for five (5) years after project completion. However, these favorable terms will be granted when a project is essential and the project sponsor has a very limited ability to pay."

- "Those sponsors, who feel more favorable terms are warranted due to a limited ability to pay, must make a formal presentation to the Commission documenting their case. Sponsors electing to pursue this option should be aware that the Commission is reluctant to deviate from this standard and such requests will be denied unless they are clearly documented and justified."

The Commission will evaluate whether or not a project will be funded for Level III construction following review of the results of Level II studies. If the Commission determines that the project should not advance due to high repayment costs (as determined by an analysis of the sponsor's ability-to-pay and after other funding sources have been considered), the sponsor has the option of making a formal presentation to WWDC relative to the sponsor's ability and willingness to pay. This presentation must address the need for the project, the direct and indirect benefits of the project, and any other information the sponsor feels is relevant to the Commission's final decision.

The WWDC may waive the requirement that the project sponsor be a public entity under the following exceptions:

1. The WWDC may accept applications for Level I studies from applicants that are not public entities. This will allow the applicant to know if there is a viable project prior to becoming a public entity. However, the applicant must be a public entity before applying for a Level II study. Under these circumstances, the Level I process will have a two-year duration with the study being completed the first year and the sponsor forming a public entity the second year.

2. The WWDC may accept applications related to the construction of dams and reservoirs from applicants that are not public entities. As the evaluations of the feasibility of new dams are complex, this will allow the applicant to know if the proposed reservoir is feasible prior to becoming a public entity. However, the applicant must be a public entity before applying for Level II, Phase III funding.

The Wyoming State Legislative Services Office maintains current district formation information principly found in the Wyoming State Statues, Title 22, Chapter 26 – Special District Elections Act. This chapter can be viewed at the following web address:

http://legisweb.state.wy.us/statutes/statutes.aspx?file=titles/Title22/T22CH29.htm

8.3.4.2 SMALL WATER PROJECT PROGRAM

As outlined by the WWDC website; *"The purpose of the Wyoming Water Development Commission (WWDC) Small Water Project Program (SWPP) is to participate with land management agencies and sponsoring entities in providing incentives for improving watershed condition and function. Projects eligible for SWPP grant funding assistance include the construction or rehabilitation of 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 Wyoming Water Development Office. 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 management and rehabilitation plan outlining site specific projects that may remediate existing watershed impairments or address opportunities beneficial to the watershed is required for access to the SWPP. Activities should improve watershed condition and function and provide benefit for wildlife, livestock and the environment. Projects may provide improved water quality, riparian habitat, habitat for fish and wildlife and address environmental concerns by providing water supplies to support plant and animal species or serve to improve natural resource conditions."

The Small Water Project Program (SWPP) is intended to be compatible with the conventional WWDC program described above. Small water projects are defined as providing multiple benefits where the total estimated project costs (including construction, permitting, construction engineering, and land procurement) are less than $135,000 or where WWDC's maximum financial contribution is thirty-five thousand dollars or less. SWPP funding is a "one-time" grant so that ongoing operation and maintenance costs are not included. Loans are not available under SWPP.

Eligibility

The kinds of projects eligible for SWPP funding include, but are not necessarily limited to:

- Small reservoirs and stock watering ponds (up to 20 feet high and 20 acre-feet capacity);
- Wells;
- Pipelines and conveyance facilities;
- Irrigation
- Spring developments;
- Solar platforms
- Windmills; and
- Wetland developments

Benefits associated with SWPP projects may include, but are not necessarily limited to:

- improved water quality;
- Habitat and water for fish and wildlife
- improved riparian habitat; and
- Increased recreational opportunities.

These projects may address environmental concerns by providing water supplies to support plant and animal species, and serve as instruments to improve rangeland conditions.

Funding can only be provided to eligible public entities including but not necessarily limited to conservation districts, watershed improvement districts, water conservancy districts, and irrigation districts.

Application, Evaluation and Administration

Details of the application and evaluation process and program administrative procedures are provided in the Small Water Project Program Operating Criteria available online as noted previously. Some key aspects of the process and procedures applicable to the potential projects identified in Sections 4 and 5 include the following:

1. 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. A watershed study may identify one or more projects that may qualify for SWPP funding. A professional engineer and/or geologist, as appropriate, shall certify any analysis submitted unless generated by a federal agency.

2. Applications shall be received by January l of each calendar year. Applications Meeting criteria requirements will be considered during the regularly scheduled WWDC meeting in March. Applications shall include a project application, sponsor project referral, project location map, project cost estimates and any letters of authorization or commitment of participation that may be available from other funding sources.

3. Projects that improve watershed condition and function, provide multiple benefits, and meet the funding criteria specified in W.S. 99-3-703(j)(vii) or W.S. 99-3-704(g)(vii), as described in 8.4 herein, are eligible for consideration.

4. The sponsoring entity will be required to address the WWDC and provide testimony and other additional supporting evidence that justifies SWPP funding whenever the public benefit documentation, submitted with the application, is deemed to be insufficient by the WWDO.

8.3.5 WYOMING WILDLIFE AND NATURAL RESOURCE TRUST

The Wyoming Wildlife and Natural Resource Trust (WWNRT) was formed by the state legislature in 2005 to preserve and enhance Wyoming's wildlife and natural resources. Projects funded by WWNRT must provide a public benefit such as continued agricultural production to maintain open space and healthy ecosystems, enhancements to water quality, and maintenance or enhancement of wildlife habitat.

Wildlife and Natural Resource Trust funding is available for a wide variety of projects throughout the state, including natural resource programs of other agencies. Some examples include the following:

- 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.
- Preservation of open space by purchase or acquisition of development rights contractual obligations, or other means of maintaining open space.
- Improvement and maintenance of aquatic habitats, including wetland creation or enhancement, stream restoration, water management or other methods.
- Acquisition of terrestrial or aquatic habitat when existing habitat is determined crucial / critical, or is present in minimum amounts, and acquisition presents the necessary factor in attaining or preserving desired wildlife or fish population levels.
- Mitigation of impacts detrimental to wildlife habitat, the environment and the multiple use of renewable natural resources, or mitigation of conflicts and reduction of potential for disease transmission between wildlife and domestic livestock.

Allowable projects under this program that are potentially relevant to this watershed management plan study include:

- Improvement and maintenance of existing aquatic habitat necessary to maintain optimum fish populations.
- Conservation, maintenance, protection and development of wildlife resources, the environment, and Wyoming's natural resource heritage.
- Participation in water enhancement projects to benefit aquatic habitat for fish populations and allow for other watershed enhancements that benefit wildlife.

Funding is by grant with no matching funds required. Non-profit and governmental organizations (including watershed improvement districts, conservation districts, etc.) Are eligible for funding by WWNRT- Projects will be funded in July and January. Applications may be filed any time, but must be filed within 90 days of the next funding cycle to receive consideration in that cycle.

8.4 FEDERAL AGENCIES

8.4.1 BUREAU OF LAND MANAGEMENT

BLM's Riparian Habitat Management Program

This program offers the opportunity to coordinate with outside interests on riparian improvement projects. The goal of BLM's riparian-wetland management is to maintain, restore, improve, protect, and expand these areas so they are in proper functioning condition for their productivity, biological diversity, and sustainability. The overall objective is to achieve an advanced ecological status, except where resource management objectives, including proper functioning condition, would require an earlier successional stage. The goal includes aggressive riparian-wetland information, inventory, training, and research programs as well as improving the partnerships and cooperative management processes.

Partnerships have been available for riparian improvement projects and for research into riparian issues. Funding is available on an annual basis subject to budget allocations from Congress. All submitted cooperative projects compete for the funds available in the riparian program, For information on the riparian habitat program wìthin BLM, please contact Shane Deforest (307) 367-5300.

Range Improvement Planning and Development

This 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. These plans outline a management strategy for an area and identify the type of range improvements needed to accommodate that management. Examples of these plans are Coordinated Resource Plans, Allotment Management Plans, and Wildlife Habitat Management Plans.

All rangeland improvement projects on lands administered by the Bureau of Land Management require the execution of a Permit. Although there are a couple of methods for authorizing range improvements on the 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 Bureau of Land Management's share comes from the range improvement fund which is generated from the grazing fees collected. There, also is a limited amount of funding from the general rangeland management appropriations. If the cooperator is a livestock operator; their contributions come generally in the form of labor. There are times they also provide some of the material costs as well. Contributions from the conservation/environmental interests is monetary and often come in the form of grants, they also contribute labor on occasion. For information on the range improvement program within BLM, please contact Shane Deforest (307) 367-5300.

BLM’s Watershed and Water Quality Improvement

Under this program, 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.

It is anticipated that as the Wyoming Department of Environmental Quality (WDEQ) continues the inventory of waters of the State and the identification of impaired and/or threatened water bodies, BLM will be partnering with the WDEQ to improve water quality in water bodies on Public Lands. In the course of developing watershed plans or TMDL's for these watersheds, BLM will be routinely involved in watershed health assessments, planning, project implementation and Best Management Practice (BMP) monitoring.

Now, and in the future, the goals of cooperative watershed projects will typically be the restoration and maintenance of healthy watershed function. These goals will typically be accomplished through approved BMP's, e.g. prescribed burns, vegetation treatments, in-stream structures, too enhance vegetation cover, control accelerated soil erosion, increase water infiltration and enhance stream flows and water quality.

8.4.2 BUREAU OF RECLAMATION

The Bureau of Reclamation (BOR) administers the Water 2025 Challenge Grant Program. This program provides funding on a competitive basis for projects focused on water conservation, efficiency and water marketing. Preference is given to projects that can be completed within 24 months that will help to prevent crises over water in areas identified as "hot spots" where potential for conflict is judged to be moderately to highly likely by 2025.

8.4.3 ENVIRONMENTAL PROTECTION AGENCY

The Targeted Watershed Grants Program administered by the Environmental Protection Agency (EPA) "*…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.*" as described in the following program website: http://water.epa.gov/grants_funding/twg/twg_basic.cfm

8.4.4 FARM SERVICE AGENCY

The Farm Service Agency (FSA) administers two potential programs that may be applicable to some of the alternative projects identified in Sections 4 and 5. Technical assistance for the FSA programs is provided by NRCS. Each of these two programs is briefly discussed below.

Conservation Reserve Program (CRP-C)-Continuous

From the USDA Farm Service Agency; "*Conservation Reserve Program (CRP) is a voluntary program that helps agricultural producers safeguard environmentally sensitive land. CRP* *participants plant long-term, resource-conserving covers to improve the quality of water, control soil erosion, and enhance wildlife habitat. In return, FSA provides participants with rental payments and cost-share assistance."*

"Environmentally desirable land devoted to certain conservation practices may be enrolled in CRP at any time under continuous sign-up. Offers are automatically accepted provided the land and producer meet certain eligibility requirements. Continuous sign-up contracts are 10 to 15 years in duration."

Land in the Upper Green watershed would qualify for this program under marginal pastureland.

Emergency Conservation Program (ECP)

This program provides emergency funding and technical assistance for implementing emergency livestock watering conservation measures during periods of severe drought and rehabilitating farmland damaged during natural disasters. Cost share assistance up to 75 percent of the cost to implement the emergency measure(s) is available.

The damage from the natural disaster or severe drought must create new conservation problems that if not dealt with would:

- Further damage the land
- Significantly affect the land's productive capacity
- Represent damage from a natural disaster unusual for the area (an exception to this is damage from wind erosion)
- Be too costly to repair without Federal assistance in order to return the land to agricultural production

8.4.5 FISH AND WILDLIFE SERVICE

Technical and financial assistance are available to private landowners, profit or nonprofit entities, public agencies and public-private partnerships under several programs addressing the management, conservation, restoration or enhancement of wildlife and aquatic habitat (including riparian areas, streams, wetlands and grasslands). These programs include:

Partners for Wildlife Habitat

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 Wildlife Extension Agreements, 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.

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 50/50 with non-federal monies. *Small Grants may not exceed $50,000.*

Wildlife Conservation and Appreciation Program

This program, under the Pittman-Robertson Wildlife Restoration Act, provided grants to state fish and wildlife agencies to fund projects that bring together USFWs, state agencies and 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. FY 2009 Budget Justification eliminated further funding for this program. It will not be available at this time.

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 too 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.

Landowner Incentive Program (Non-Tribal)

This program provides funding directly to the lead state wildlife service agency (WGFD in Wyoming) for programs addressing the issues noted previously. To provide technical or financial assistance, including habitat protection and restoration. Up 50% Federal grant is available.

8.4.6 NATURAL RESOURCES CONSERVATION SERVICE

The Natural Resources Conservation Service (NRCS) administers a number of funding and technical assistance programs applicable to many of the alternative projects identified in Sections 5 and 6. These programs are briefly described below and summarized in Table 8.5.

Environmental Quality Incentives Program

The Environmental Quality incentives Program (EQIP) is a voluntary program available to agricultural producers that provides technical assistance, cost sharing and incentive payments for projects and practices that improve water quality, enhance grazing lands, and/or increase water conservation.

Non-federal landowners (including American Indian tribes) that engage in livestock operations or agricultural production are eligible for funding. Eligible land includes cropland, rangeland, pasture, forestland, and other farm and ranch lands. Eligibility also requires that the applicant develop an EQIP plan of operations that becomes the basis of the cost-sharing agreement between NRCS and the participant.

EQIP provides payments up to 75 percent of the incurred costs and income foregone of certain conservation practices and activities. In most cases a 25 percent nonfederal match is required. Farmers and ranchers may elect to use a certified Technical Service Provider (TSP) for technical assistance needed for certain eligible activities and services. Participants may not receive, directly or indirectly, payments that, in the aggregate, exceed $300,000 for all program contracts entered during any six year period. Projects determined as having special environmental significance may, with approval of the NRCS Chief, have the payment limitation raised to a maximum of $450,000.

Detailed information about the Wyoming EQIP program is available at the following website:

http://www.nrcs.usda.gov/wps/portal/nrcs/main/wy/programs/financial/eqip/

Watershed Protection and Flood Prevention Program

Also known as the "Small Watershed Program" or the "PL 566 Program," this program provides technical and financial assistance to address resource and related economic problems on a watershed basis. Projects related to watershed protection, flood prevention, water supply, water quality, erosion and sediment control, wetland creation and restoration, fish and wildlife habitat enhancement, and public recreation are eligible for assistance. Technical and financial 8-18assistance is also available for planning and installation of works of improvement to protect, develop, and use land and water resources in small watersheds.

Applicants eligible for funding through this program that are potentially relevant to the Upper Green Watershed include: local or state agencies, counties, conservation districts, or other Sub-units of state government (e.g., watershed improvement, water conservancy and irrigation districts) with the authority and capacity to carry out, operate, and maintain installed works of improvement. Projects are limited to watersheds containing less than 250,000 acres.

The assistance provided consists of technical assistance and cost sharing (amount varies) for implementation of NRCS-authorized watershed plans. Technical assistance is provided on watershed surveys and planning.

Other NRCS Programs

Other programs administered through NRCS that may be relevant to certain alternative projects discussed in Sections 4 and 5 include, but are not necessarily limited to the following:

Wildlife Habitat Incentive Program (WHIP)

Through WHIP, technical and financial assistance is provided to landowners and others to develop and improve wildlife habitat on private lands. The Natural Resources Conservation Service administers WHIP to provide both technical assistance and up to 75 percent cost-share assistance to establish and improve fish and wildlife habitat. WHIP cost-share agreements between NRCS and the participant generally last from one year after the last conservation practice is implemented but not more than 10 years from the date the agreement is signed.
NRCS has established the following national priorities:

- Promote the restoration of declining or important native fish and wildlife habitats
- Protect, restore, develop or enhance fish and wildlife habitat to benefit at-risk species
- Reduce the impacts of invasive species on fish and wildlife habitats; and
- Protect, restore, develop or enhance declining or important aquatic wildlife species' habitats
- Protect, restore, develop or enhance important migration and other movement corridors for wildlife

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 conversion.

Farm and Ranch Lands Protection Program (FRPP)

FRPP 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 environment and standard of living for residents of those communities.

Emergency Watershed Protection (EWP)

From the NRCS website: *"The purpose of the Emergency Watershed Protection Program (EWP) was established by Congress to respond to emergencies created by natural disasters. The EWP Program is designed to help people and conserve natural resources by relieving imminent hazards to life and property caused by floods, fires, drought, windstorms, and other natural occurrences. The U.S. Department of Agriculture's Natural Resources Conservation Service*

(NRCS) administers the EWP Program; EWP-Recovery, and EWP–Floodplain Easement (FPE).” Public and private landowners are eligibile but must be represented by a legal subdivision of the State. The program provides up to 75% of project costs.

Watershed Rehabilitation Program

The purpose of the Small Watershed Rehabiltation Program is, "…to assist project sponsors with rehabilitation of aging project dams. Only dams installed under PL-566, the Pilot Watershed Program, PL-534, or RC&D Programs are eligible. The purpose of PL-472 is to extend the service life of dams and meet applicable safety and performance standards. Priority is given to those structures that pose the highest risk to life and property. Projects are eligible when hazard to life and property increases due to downstream development and when there is need for rehabilitation to extend the planned life of a structure. Rehabilitation Program work can consist of repairing or replacing deteriorated components, repairing damages from catastrophic events, upgrading the structure to meet state dam safety laws, or to decommission a structure."

Sage Grouse Restoration Project (SGRP)

From the USDA NRCS; "*The purpose of SGRP was the identification, integration, evaluation, and documentation of effects of 2002 Farm Bill conservation technologies and strategies on sage-grouse and other sagebrush-steppe obligates. This information has been used to assist NRCS, SCDs, state wildlife agency field staff, and private landowners in the planning and implementation of habitat projects and practices on private lands to benefit sage-grouse and other sagebrush-steppe obligate species. The projects contributed to range-wide sage-grouse conservation efforts. This project provided current information on the role of existing conservation practices and technologies relative to conserving sage-grouse and other sagebrush obligate species. The information gained from the multi-state experiments also assisted local sage-grouse working groups in complying with the conservation plan reporting requirements set forth in the U. S. Fish and Wildlife Service (USFWS) Policy for Evaluation of Conservation Efforts (PECE) When Making Listing Decisions.”*

Grazing Lands Conservation Initiative (GLCI) Grants

From the USDA NRCS; "*GLCI is a nationwide consortium of individuals and organizations working together with NRCS to maintain and improve the management and the health of the nation's grazing lands, mostly private but also public. The Initiative is driven by agricultural producer, conservation, and environmental organizations for the benefit of America's grazing lands resource. GLCI seeks to carry out its activities through local, state and national partnerships. It informs the public of the contributions well-managed grazing lands make to the quality of life of every citizen. GLCI is founded on the principles of voluntary action by those who own and manage grazing lands, and a respect for private property rights. GLCI emphasizes high quality, voluntary technical assistance, expanded grazing lands research and education, and a more knowledgeable and informed public.”* The GLCI Strategic Plan can be reviewed at the following website: https://prod.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043496.pdf

Cooperative Conservation Partnership Initiative (CCP)

From the USDA NRCS; *"The Cooperative Conservation Partnership Initiative (CCPI) is a voluntary conservation initiative that enables the use of certain conservation programs along with resource of eligible partners to provide financial and technical assistance to owners and operators of agricultural and nonindustrial private forest lands. Under CCPI, the Natural Resources Conservation Service (NRCS) enters into partnership agreements with eligible entities that want to enhance conservation outcomes on agricultural and nonindustrial private forest lands."* Additional information and criterial can be found at the following web site: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/ccpi/

Agricultural Water Enhancement Program (AWEP)

AWEP is not a grant program, and no funds are transferred to the partner through the agreement once the Chief approves and announces the proposals selected, agricultural producers within the approved project areas may submit an application directly to NRCS for EQIP. The Upper Green has not been an AWEP priority area in years past, however an application is still possible.

8.4.7 US ARMY CORPS OF ENGINEERS

The Army Corps of Engineers has civil responsibilities for flood damage reduction, hydroelectric power generation and navigational improvement as well as other water and land resource problems and needs including environmental preservation and enhancement, ecosystem management and comprehensive flood plain management. The Corps is responsible for a worldwide military construction program, an extensive environmental program and a broad national civil works program.

The Corps of Engineers is authorized to provide technical assistance to local communities, States and federally recognized Indian Tribes in support of their efforts to alleviate flooding impacts, reduce erosion and otherwise plan for the wise and prudent use of the nation's water and related land resources. They also have authority to construct certain water resources related projects and respond to water resource needs. These programs have limited application for the types of upland water projects but could find application for bank stabilization or should a larger reservoir type project be considered. The programs are a follows:

Planning Assistance to States

This program provides for assistance in preparation of plans for the development, utilization and conservation of water and related land resources. The Corps provide technical planning assistance in all areas related to water resources development such as bank stabilization, sedimentation, water conservation, ecosystem and watershed planning and water quality. Assistance is limited to $500,000 per state and studies are cost-shared on a 50-50 basis with a non-federal sponsor such as a state, public entity or an Indian Tribe.

Flood Plain Management Services

This program provides technical services and planning guidance for support and promotion of effective flood plain management. Flood and flood plain data are developed and interpreted with assistance and guidance provided in the form of "Special Studies" on all aspects of flood plain management planning. All services are provided free of charge to local, regional, state or non-federal public agencies. Federal agencies and private entities have to cover 100% of costs.

Flood Damage Reduction Projects

This program provides structural and non-structural projects to reduce damages caused by flooding and focuses on solving local flood problems in urban areas, towns and villages. The Corps works with the project sponsor to define the flood problem, evaluate solutions, select a plan, develop the design and construct a project. A feasibility study is conducted to identify potential projects with the first $100,000 of the cost Federal. Any cost above this amount is cost-shared 50-50 with the sponsor in the form of cash and in-kind services. Construction lands, easements, rights-of-way, relocations and disposal and 5% of the projects costs are the sponsor's responsibility. Operation and maintenance and a maximum of 50% of total project cost are the sponsor's responsibility.

Project Modification for Improvement of Environment

The purpose of this program is to modify structures or operation of previously constructed water resources projects to improve environmental quality, especially fish and wildlife values, a study, at federal expense, is initiated followed by a feasibility plan that is cost-shared 25% by the sponsor.

Aquatic Ecosystem Restoration

This effort is for restoration of historic habitat conditions to benefit fish and wildlife resources. This is primarily to provide structural or operational changes to improve the environment such river channel reconnection, wetland creation or improving water quality. Conditions are similar to the Project Modification program with sponsor cost share being 35%.

Water Resources Projects

The purpose of this program is to construct larger projects for flood damage reduction and to provide technical assistance in resolving more complex water resource problems. It is used to evaluate projects costing more than $10 million that include purposes of flood control, water supplies, water quality, environmental protection and restoration, sedimentation or recreation. This would include reservoirs, diversions, levees, channels or flood plain parks as examples. The Corps works with a non-federal sponsor to define the flood or water resource related problem or opportunity, evaluate flood control or solutions, select a plan, develop a design and construct a project. This requires special authorization and funding from Congress with a reconnaissance study being federal cost. A feasibility study to establish solutions is cost-shared 50% by the non-federal sponsor with 35 to 50% of construction cost the responsibility of the sponsor.

Support for Others Program

This program provides for environmental protection and restoration or facilities and infrastructure. This includes Environmental Planning and Compliance, Economic and Financial Analyses, Flood Plain Management, Cultural Resources and General Planning. All costs for these programs are provided by the customer agency.

Regulatory Authority/Responsibility

The Corps of Engineers has regulatory authority under the Clean Water Act and the River and Harbor Act. The purpose of these laws is to restore and maintain the chemical, physical and biological integrity of waters of the United States. Section 404 of the Clean Water Act authorizes the Corps to regulate the discharge of dredged or fill material into waters. This would include dams and dikes, levees, riprap, bank stabilization and development fill. There are three kinds of permits issued by the Corps. They are individual, nationwide and Regional General Permits.

8.4.8 USDA FOREST SERVICE

A number of Federal laws direct or authorize watershed management on National Forest Service lands. Some of these laws provide broad authority while others deal more narrowly with specific watershed management activities.

The objectives of the Forest Service watershed management program are to protect and enhance soil productivity, water quality, water quantity and timing of water flows and to maintain favorable conditions of stream flow and continuous production of resources from National Forest System watersheds.

It is the policy of the Forest Service to implement watershed management activities on National Forest System lands in accordance with general objectives of multiple use and the specific objectives in the forest land management plans for the area involved. It is also the intent to design management activities of other resources to minimize short term impacts on soil and water resources and to maintain or enhance long term productivity, water quality and water quantity.

The Clean Water Action Plan provides broad water quality direction for the Forest Service. Specific direction for water quality is contained in the Land and Resource Management Plan for each National Forest. The forests in Wyoming are in the process of completing the Inland West Water Reconnaissance which will provide a classification of watersheds and stream reach conditions. Forest Service water quality programs are coordinated with Wyoming Department of Environmental Quality and other appropriate agencies. The Forest Service also has a water rights program that is coordinated with the Wyoming State Engineer.

The Forest Service, in conjunction with other federal, state and local agencies, provides watershed management and condition training. T-WALK and Proper Functioning Condition surveys are field methods used to assess stream reach and other water body conditions.

8.4.9 RURAL UTILITIES SERVICE

The United States Department of Agriculture, Rural Development's utilities program is authorized to provide financial assistance for water and waste disposal facilities in rural areas and towns of up to 10,000 people. This program is intended for Non-profit corporations and public bodies such as municipalities, counties, and special purpose districts and authorities.

Funding may be obtained through Rural Development only when the applicant is unable to secure funding from other sources at reasonable rates and terms. The applicant must have legal capacity to borrow and repay loans, to pledge security for loans and to operate and maintain the faculties. The applicant must be financially sound and able to manage the facility effectively as well as have a financially sound facility based upon taxes, assessments, revenues, fees or other satisfactory sources of income to pay costs of operating, debt service and reserve. Grants are also available and are used to supplement loans to reduce debt service where necessary to achieve reasonable user rates. Assistance is also available on how to assemble information concerning engineering, financing and management of proposed improvements.

Loans and grants may be used to construct, repair, improve, expand or modify rural water supplies and distribution facilities such as reservoirs, pipelines, wells and pumping stations, waste collection, pumping, treatment or other disposal facilities. This assistance may also be used to acquire a water supply or water right or finance facilities in conjunction with funds from other agencies or those provided by the applicant. These funds can be used to pay legal and engineering fees connected with the development of a facility or pay other costs related to development including rights-of-way or easements and relocation of roads or utilities. Loan terms are a maximum of 40 years, State statute, or the useful life, whichever is less with interest rates based on current market yields for municipal obligations.

USDA Rural Development also guarantees loans to eligible commercial lenders to improve, develop, or finance water or waste disposal facilities in rural areas. This guarantees ¡s a warrant to protect the lender and may cover up to 90% of the principal advanced. The guarantee fee is 1% of the loan amount multiplied by the percent of the guarantee. Interest rates will be negotiated between the lender and the borrower.

8.5 NON-PROFIT AND OTHER ORGANIZATIONS

8.5.1 DUCKS UNLIMITED

Ducks Unlimited, Inc. (DU) is a potential funding source for wetlands and waterfowl restoration projects. Although direct grant funding is limited (to the extent that there is generally about $20,000 to $30,000 available annually statewide), in-kind assistance may be available from the local chapter of DU. Additional information on DU's funding programs and opportunities is available in the Water Management & Conservation Assistance Program Directory referenced previously.

8.5.2 NATIONAL FISH AND WILDLIFE FOUNDATION

The National Fish and Wildlife Foundation (NFWF) is a private, non-profit, tax exempt organization chartered by Congress in 1984 to sustain, restore and enhance the Nation's fish, wildlife, plants and habitats. NFWF provides grant funding on a competitive basis through their Keystone Initiative Gants and Special Grant Program. Some of the grants/programs that may be applicable to potential projects in the Upper Green watershed include, but are not limited to the following:

Pulling Together Initiative

Provides support on a competitive basis for the formation of local Weed Management Area (WMA) partnerships that engage federal resource agencies, state and local governments, private landowners, and other interested parties in developing long-term weed management projects within the scope of an integrated pest management strategy; minimum 1:1 non-federal match is required.

Funding priorities for this program include:

- Projects that focus on a particular well-defined Weed Management Area, such as a watershed, ecosystem, landscape, or county
- Projects supported by private landowners, state and local governments, and the regional/state offices of federal agencies
- Projects with a Steering Committee composed of local cooperators who are committed to working together to manage invasive and noxious plants across their jurisdictional boundaries
- Long-term weed management plans which are based on an integrated pest management approach using the principles of ecosystem management
- Inclusion of a public outreach and education component, as appropriate

Native Plant Conservation Initiative

This program has funding preference for "on-the-ground" projects that involve local communities and citizen volunteers in the restoration of native plant communities.

Funding priorities for this program include:

- Projects that directly address plant conservation priorities established by one or more of the federal agency partners
- On-the-ground work that involves local communities and citizen volunteers in restoration or protection of native plant communities
- Inclusion of a project component focused on pollinator conservation.

Bring Back the Natives Grant Program

This funding source can be used to restore damaged or degraded reverine habitats and their native aquatic species provided by BLM, Bureau of Reclamation, FWS, Forest Service, and NFWF; minimum 2:1 nonfederal match required. Colorado cutthroat trout are one the targeted species.

Five-Star Restoration Program

This 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; grants in 2012 ranged from $12,000 to $152,000.

Information about all of these and other NFWF grants/programs is available at their website:

http://nfwf.org/

8.5.3 TROUT UNLIMITED

The Wyoming Council of 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 on a 1:1 matching basis. Partnerships are encouraged and can include local conservation districts and state and federal agencies. The grant application is prepared in coordination with the local TU Chapter and submitted by the Chapter. Objectives are to protect, restore, reconnect, and sustain habitat for the conservation of trout. Additional instructions and application can be found at the following website:

http://www.tu.org/sites/default/files/2013-14_tu_embrace-a-stream_rfp_final.pdf

8.6 FUNDING SUMMARY

The following Table 8.5 summarized the potetntial funding sources discussed above with contact information where available.

Table 8.5 Funding Sources

Agency / Entity	Program Name	Project Type	Internet Site	Telephone	E-mail
		Local			
Sublette County Conservation District		Technical assistance, state and federal grant partnering, grant applications	http://www.sublettecd.com/	307-367-2257	sccd@sublettecd.com
Sublette County Weed and Pest District		Technical assistance and cost share in the control of noxious and invasive weeds	http://sublettecountyweed.com/	Ph: (307) 367-4728	
		State			
Wyoming Department of Environmental Quality	Watershed Protection Program	Implementation of BMP's	http://deq.state.wy.us/wqd/watershed/	307-777-5985	kevin.frederick@wyo.gov
Wyoming Game and Fish Department	Riparian Habitat Improvement Grant	Stream bank protection and stabilization	http://wgfd.wyo.gov/	307 777-4600	n/a
	Water Development/Maintenance Habitat Project Grant	Upland water development for fish and wildlife			
	Upland Development Grant	Upland habitat, prescribed burns, feed plots and range seeding			
	Fish Wyoming	Public fishing			
	Wyoming Sage Grouse Conservation Fund	Protection and enhancement of sage grouse habitat	http://wgfd.wyo.gov/web2011/wildlife-1000382.aspx	307 777-4506	
Wyoming Office of State Lands and Investments	Regular Farm Loans	Improvements related to improving farm earning capacity	http://lands.state.wy.us/	307-777-7331	slfmail@wyo.gov
	Small Water Development Project Loans	Water development for agriculture			
Wyoming Water Development Commission - Wyoming Water Development Program	Water Resource Planning	Basin wide plans and master planning of water resource development	http://wwdc.state.wy.us/	307-777-7626	jon.wade@wyo.gov
	Groundwater Grant Program	Ground water inventory and development			
	New Development Program	Storage, supply, watershed and recreation projects			
	Rehabilitation Program	Rehab of old (>15yrs) water source and conveyance systems			
	Dam and Reservoir Program	New dams and expansion of existing dams			mike.besson@wyo.gov
Wyoming Water Development Commission - Small Water Project Program		Watershed condition and function, upland water, small reservoirs, wells, pipelines, springs, solar, windmills, and wetlands			ron.vore@wyo.gov
Wyoming Wildlife and natural Resource Trust Fund		Preservation of open space, ecosystem health, water quality, wildlife habitat	http://wwnrt.wyo.gov/	307 777-8024	n/a
		Federal			
Bureau of Land Management	Riparian Habitat Management Program	Wetland function and health	http://www.blm.gov/wyoming1/	307-367-5300	sdefores@blm.gov
	Range Improvement Planning and Development	Rangeland health, watershed BMP's			
	Watershed and Water Quality Improvement				
Bureau of Reclamation	Water Challenge Grant	Water conservation and marketing	http://www.usbr.gov/gp/wyao/	307 261-5671	jdallman@usbr.gov
Environmental Protection Agency	Watershed Grants Program	Watershed restoration	http://water.epa.gov/grants_funding/twg/twg_basic.cfm	303 312-6312	r8eisc@epa.gov
Farm Service Agency	Conservation Reserve Program (CRP-C)-Continuous	Marginal pastureland qualifies; watershed restoration riparian buffers, shelter belts, erosion control	http://www.fsa.usda.gov/FSA/	307 261-5231	gregor.goertz@wy.usda.gov
	Emergency Conservation Program (ECP)	Emergency watering, disaster rehabilitation			
Fish and Wildlife Service	Partners for Wildlife	Riparian, wetland, and grassland restoration	http://www.fws.gov/wyominges/	307 772-2374	genevieve_skora@fws.gov
	North American Wetlands Conservation Act Grant Program	Wetlands conservation			
	Wildlife Conservation and Appreciation Program	Habitat and conservation studies (presently un-funded)			
	Cooperative Endangered Species Conservation Fund	Habitat surveys, planning, management, land acquisition, public education			
	Landowner Incentive Program (Non-Tribal)	Habitat protection and restoration			

Table 8.5 Funding Sources (Continued)

Natural Resources Conservation Service	Environmental Quality Incentives Program (EQIP)	Water Quality, Land Enhancement, Water Conservation	http://www.nrcs.usda.gov/wps/portal/nrcs/main/wy/programs/financial/eqip/	Pinedale 307 367-2257 #110 State 307 233-6768	Local - jennifer.hayward@wy.usda.gov State - shelly.thomas@wy.usda.gov
	Watershed Protection and Flood Prevention Program	Watershed protection, Flood prevention, water supply, water quality, erosion, sediment, wetlands, fish and wildlife and recreation	http://www.nrcs.usda.gov/wps/portal/nrcs/main/wy/programs/		
	Wildlife Habitat Incentive Program (WHIP)	Wildlife Habitat			
	Wetlands Reserve Program (WRP)	Wetland, soil, and wildlife habitat on private lands			
	Grassland Reserve Program (GRP)	grazing operation support, grassland and range health			
	Farm and Ranch Lands Protection Program (FRPP)	land conservation			
	Resource Conservation and Development (RC&D)	conservation and development of natural resources			
	Emergency Watershed Protection (EWP)	Emergency conservation			
	Watershed Rehabilitation Program	Dam rehabilitation			
	Sage Grouse Restoration Project (SGRP)	Sage grouse related conservation and land enhancements			
	Grazing Lands Conservation Initiative (GLCI) Grants	Grazing and range health	https://prod.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1043496.pdf		
	Cooperative Conservation Partnership Initiative (CCP)	Conservation of agricultural and non-industrial forest lands	http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/ccpi/		
	Agricultural Water Enhancement Program (AWEP)	Water resources - (Not a grant program)			
US Army Corps of Engineers	Planning Assistance to States	Planning for conservation of water and land resources, sediment control, watershed planning, water quality	http://www.nwo.usace.army.mil/Missions/RegulatoryProgram/Wyoming.aspx	(307) 772-2300	
	Flood Plain Management Services	Flood plain guidance and special studies			
	Flood Damage Reduction Projects	Flood control in developed areas such as Towns or villages			
	Project Modification for Improvement of Environment	Water resource structure modifications for fish and wildlife benefit			
	Aquatic Ecosystem Restoration	Water resource development modifications for fish habitat enhancement			
	Water Resources Projects	Large projects >$10 million; levees, channels, flood plains			
USDA Forest Service	Watershed Management Program	Soil productivity, water quality, water quantity			
USDA Rural Utilities Service	Rural Utilities Program	Water and waste water in rural communities			
Private					
Ducks Unlimited		Wetlands and waterfowl restoration projects	https://www.ducks.org/wyoming	307-856-4903	djgroathouse@yahoo.com
National Fish and Wildlife Foundation	Pulling Together Initiative	Weed and invasives management	http://www.nfwf.org/	503-417-8700	info@nfwf.org
	Native Plant Conservation Initiative	Restoration and preservation of native plant communities			
	Bring Back the Natives Grant Program	Restoration of riverine habitats and native aquatic species			
	Five-Star Restoration Program	Wetlands and riparian habitat restoration			
Trout Unlimited		Erosion control, habitat restoration, fish passage, habitat enhancements	http://www.tu.org/sites/default/files/2013-14_tu_embrace-a-stream_rfp_final.pdf	307-332-7700 ex. 12	

REFERENCES

Clear Creek Watershed Level I Study, States West Water Resource Corporation for the Wyoming Water Development Commission.

IX. CONCLUSIONS AND RECOMMENDATIONS

This study collected and inventoried various data sets and previous studies related to the Upper Green watershed study area and its resources, challenges and potential with regard to watershed improvements. Potential improvements include both projects and management strategies related to rangeland health, irrigation potential, livestock watering, wildlife watering, wildlife habitat and general stream health. The following conclusions and recommendations summarize the findings.

9.1 UPLAND/WILDLIFE WATERING OPPORTUNITIES

"The number one resource concern associated with range management in the study area is water availability" (Pers. Comm. Karen Clause, Pinedale NRCS Field Office, 2013). There are many different types and applications of upland water developments, and the particular design that is selected is highly dependent on local needs, conditions, and available funding. Upland livestock watering systems typically include spring developments, wells, pumps, tanks, diversions, or gravity feed systems. These types of water projects can be mutually beneficial for range health, wildlife, and livestock.

Within the Upper Green River watershed study area additional opportunities exist to improve upland water availability for livestock and wildlife. The potential projects range from simple spring developments to reservoirs with piped distribution to multiple tanks and troughs. Many opportunities lie on public lands and agency involvement is required for permitting. Agencies may also present opportunity for partnering on projects that improve range and offer wildlife watering opportunities. Partnering could take the form of design and permitting support or even financial participation.

The small upland water projects included in this study are likely eligible for the WWDC's Small Water Project Program. The total project cost cap for eligibility is $135,000. If eligible, a grant up to a maximum of $35,000, is available to help with the project. The SCCD can serve as the legal engity sponsor making the program responsive to individual landowners.

With approximately 65 potential projects totaling $4.5 million dollars, some prioritization of project by the landowner/lessee will be required to provide parity with project dollars that may be available. Working with the resource agencies, the best projects in terms of benefits can be identified using the documents contained in Appendix A.

9.2 STREAM CHANNEL CONDITION AND STABILITY

1. Stream channel morphologic classification results must be interpreted within the context of local valley type and condition. Some channel classifications are considered appropriate in some valley settings and inappropriate or unstable in other valley settings.
2. The basin-wide channel morphology classification identified numerous disequilibrium channel reaches and areas of morphologic concern based upon channel condition and

valley setting. The effort generated a list of warranted treatment areas that watershed managers can utilize to identify meaningful channel restoration and stabilization projects across the watershed.

3. The Level I morphologic channel classification was completed at a large scale using remote sensing and limited field verification; individual restoration projects can be weighed in terms of watershed value based upon the results, but each local project should be designed by experienced practitioners based upon local field data and site analysis.
4. High width/depth ratio Rosgen C-type channels are prevalent within the Upper Green River watershed study area. These channel segments are not highlighted during the identification of disequilibrium channel reaches and morphologic areas of concern because the initial channel classification is appropriate in the context of local valley conditions even though the width/depth ratio may be excessive. These stream reaches may benefit from aquatic habitat enhancement projects that incorporate bank stabilization, channel narrowing, and/or width/depth ratio reduction.
5. Numerous diversions within the study area incorporate instream structures or require regular channel manipulations to maintain diversion function. These locations present an opportunity where watershed managers and landowners could pursue alternative structure configurations that maintain year-round diversion functionality while minimizing the need for periodic channel manipulations or site maintenance. Such efforts would benefit water users and the aquatic ecology of the proximate watercourse.

9.3 GRAZING MANAGEMENT OPPORTUNITIES

Environmental conditions and constraints vary by location, but the following general BMPs for range management can be implemented in concert with the ESD state and transition models to accomplish management objectives:

1. Upland (i.e., off-site) livestock watering systems;
2. Strategic salting and/or herding;
3. Riparian fences to exclude livestock from, or manage livestock use of, riparian areas;
4. Pasture fences or cross-fences to facilitate rotational grazing systems;
5. Prescribed fire; and
6. Chemical brush control.

Many of these management practices are mutually beneficial for livestock, range condition, and wildlife. Financial and technical assistance for these practices are available through the NRCS and other federal, state, and local agencies (see Section VIII).

9.4 INVASIVE SPECIES TREATMENT

Noxious weed and invasive plant species management should be integrated into planning, funding, and implementation of any surface disturbing projects. Recent or prolonged surface disturbing activities are the greatest contributors to the spread of noxious weeds, and demand the highest level of proactive control of weed dispersal. All sponsored projects shall integrate coordination with County Weed and Pest, and when applicable, representatives of the Interagency Green River Basin Coordinated Weed Management Area to prevent the inadvertent spread of invasive plant species.

Weed control Best Management Practices as described in this study are strongly recommended as the most cost effective way to manage weeds in coordination with any development projects. In addition, cost share funding opportunities should be explored during project planning to defray weed management expenses for private landowners or industry partners.

9.5 IRRIGATION SYSTEM OPPORTUNITIES

Potential opportunities for irrigation projects identified in this study are associated with primary conveyance systems. Identified projects included piping canal sections, combining head gates, and repairs to troubled spots on canals.

Four headgate structures were identified as needing reconfiguration. Two of the structures required repair due to aging wood material in the wing walls and headwalls. One of the structures (in reasonable condition) is being stranded as the river down cuts, and the final structure requires repairs to its pushup diversion rock weir.

One new diversion location project was also identified that will support a center pivot type irrigation system on a meadow.

Based on the projects identified by landowners, downcutting of the river is a major challenge requiring higher and longer diversion revetments. The wood constructed diversions are also reaching the end of their expected life and replacement with concrete structures is recommended.

In total, 14 irrigation related projects were identified totaling $980,000 in estimated cost.

As with upland water projects, the small irrigation improvement projects included in this study are likely eligible for the WWDC's Small Water Project Program. The total project cost cap for eligibility is $135,000. If eligible, a grant up to a maximum of $35,000, is available to help with the project. The SCCD can serve as the legal engity sponsor making the program responsive to individual landowners. Larger scale projects could be eligible for funding under WWDC's rehabilitation program.

9.6 WATER SUPPLY AND STORAGE OPPORTUNITIES

The Upper Green Watershed produces excess water that could be beneficially utilized with additional storage capability. Reservoir sites range from small sites (4,000 acre-feet) of local significance to larger sites (over 100,000 acre-feet) with potential for regional benefit to the entire Green River Basin. The smaller sites tend to be located in tributary basins and off the channel of the tributaries. The larger sites (Kendall Upper and Lower) are located on the main-stem of the Green River. The smaller off channel sites are favored in terms of permitting. Permitting of any of the sites will be rigorous with the main stem sites being the most difficult. Mitigation measures will be required for any site. In terms of cost and permitting ease, Middle Piney Lake ranks as the best opportunity with the Sixty Seven Enlargement ranking second.