A Comprehensive Watershed Management Plan for the Moab Area

2014

Moab Area Watershed Partnership

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Canyonlands Watershed Council
City of Moab
Grand County
Grand County Conservation District
Grand County Trail Mix
Grand Water and Sewer Service Agency
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San Juan County
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And
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Acronym Reference List

BLM:	Bureau of Land Management
BMP:	Best Management Practice
DO:	Dissolved Oxygen
GIS:	Geographic Information System
GWSSA:	Grand Water and Sewer Service Agency
NGO:	Non-Government Organization
NPDES:	National Pollution Discharge Elimination System
NPS:	Non-Point Source
NRCS:	National Resource Conservation Service
OHV:	Off Highway Vehicle
SITLA:	School and Institutional Trust Lands Administration
STORET:	Storage and Retrieval information system
TDS:	Total Dissolved Solids
TMDL:	Total Maximum Daily Load
TSS:	Total Suspended Solids
UDWQ:	Utah Division of Water Quality
USDA:	United States Department of Agriculture
USU:	Utah State University

Executive Summary

Water quality is an important issue that affects all people within a watershed. Resolving water quality issues will require local people making and implementing local solutions. This Watershed Management Plan (WMP) for Spanish and Castle Valley is a planning tool for developing local solutions. Although a WMP is required for project funding through the EPA 319 program, this WMP was written to support the mission of the MAWP which is "*The Moab Area Watershed Partnership is a collaboration of diverse stakeholders who share knowledge and develop, and facilitate implementation of, a holistic watershed plan that conserves and enhances water quality and quantity in the Mill Creek (including Pack Creek) and Castle Creek watersheds."* This WMP and the MAWP go beyond addressing the total maximum daily load issues of the EPA 319 program and will support local solutions to the various water quality and quantity issues in Spanish and Castle Valley.

Section 1 of the WMP identifies and defines MAWP and the watershed boundaries it focuses on. It also identifies in detail the partnership goals, the planning process and the desired uses of the plan. More importantly, it stresses the value of stake holder participation: "A successful water quality management plan relies as much on voluntary stakeholder participation and buy-in as on the rigor of technical analysis."

Section 2 of the WMP is a characterization of the two watersheds. The Section describes in depth the hydrology and topography of Spanish and Castle Valley watersheds and the six sub-watersheds. The section also includes a detailed analysis of climate, vegetation, soils, wildlife, demographic trends, water rights, and land uses. These sub-sections are important to the stakeholders because they recognize the connections between uplands and water quality. Anthropogenic influences on uplands and riparian areas can impact water quality and opportunities are available to improve water quality by improving upland and riparian land uses and conditions.

Section 3 provides a comprehensive compilation of water quality data that have been collected in the watersheds and a detailed analysis of the chemical and physical water quality issues in the watershed. The analysis indicates that water quality issues are not widespread. They are different in different sub-watersheds and the analysis identifies stream segments where improvements would be most beneficial. The section also includes a detailed compilation of groundwater quality resources because the stakeholders recognize the close connection between groundwater and surface water resources in these watersheds. The communities in these watersheds are dependent on the groundwater resources and improvements in groundwater quality are not only beneficial to the community, they are beneficial to surface water quality also.

Section 4 and 5 meld the three previous sections into a set of resources concerns and opportunities to address those concerns. The process described in Section 1 used the characteristics described in Sections 2 to address the water quality concerns in Section 3. The specific concerns listed in Section 4 are addressed by several broad project types and policies in

Section 5 that the MAWP supports. Before and during the WMP development, MAWP members recognized there isn't one solution to the water quality issues in our watersheds. The issues, concerns and remedies are inter-related and changes to water quality will only be realized through a combination of improvement projects.

The MAWP realizes that community support for water quality improvements coupled with cultural or behavioral changes will be necessary to realize long term improvements in water quality. Section 6 outlines several promotional mediums and educational programs that will be enlisted by the MAWP to garner that support. The MAWP also realizes that one of the best ways to garner support is through successful projects and documented improvement in water quality. The WMP addresses this component in Section 7 through an in-depth sampling plan and reporting policy.

The MAWP realizes the monitoring and reporting policy could drive changes in this WMP, the projects, and the policies the MAWP supports. This is Version 1. This document is a working and living document that the MAWP has agreed to review and revise on an annual basis. At the very least projects will be completed and new projects developed and started. The Moab Area Watershed Management Plan will change with those projects and the focus of the MAWP. This is not a final document, there will never be a final document, but this a great place to start.

Chapter 1. Introduction

What is a watershed/watershed approach?

1.1 Overview of Watershed

The Moab Area Watershed is made up of Mill Creek and Castle Creek watersheds, which encompass the most populated areas in Grand County and combined, consist of 126,506 acres (almost 200 Square miles). Approximately 65% of these watersheds lie in Grand County with the other 35% in San Juan County. Both Mill Creek and Castle Creek are tributaries to the Colorado River and have had Total Maximum Daily Loads (TMDL's) completed on them by the Utah Division of Water Quality.

1.2 Watershed Group Profile

The Moab Area Watershed Partnership began meeting informally as the Moab Area Watershed Council in the Grand County Public Library in 2010 to discuss the mission, purpose and need for a watershed group. Working with UDWQ, the group evolved into a diverse partnership that includes most land and water management entities in the Moab area, conservation group representatives, recreationists, local business owners, ranchers and other Non-Governmental Organizations (NGO's). The group held a governance session in January of 2011 and began meeting monthly to develop its organizational structure. Once a set of By-Laws were listed for the group they began drafting this comprehensive management plan.

Mission Statement of the
Moab Area Watershed Partnership (MAWP)

"The Moab Area Watershed Partnership is a collaboration of diverse stakeholders who share knowledge and develop, and facilitate implementation of, a holistic watershed plan that conserves and enhances water quality and quantity in the Mill Creek (including Pack Creek) and Castle Creek watersheds."

Stakeholders

State of Utah

- Division of Water Quality
- Utah State University Extension
- Utah Division of Forestry Fire and State Lands
- School and Institutional Trust Lands
- Utah Department of Agriculture and Food

Federal

- USDI Bureau of Land Management, Moab Field Office
- USDA Manti-La Sal United States National Forest Service
- USDA Natural Resource and Conservation Service

Local

- Grand County
- San Juan County
- Moab City
- Town of Castle Valley
- Grand County Conservation District
- Grand Water and Sewer Service Agency
- Moab Irrigation Company
- Canyonlands Watershed Council
- Grand County Trail Mix

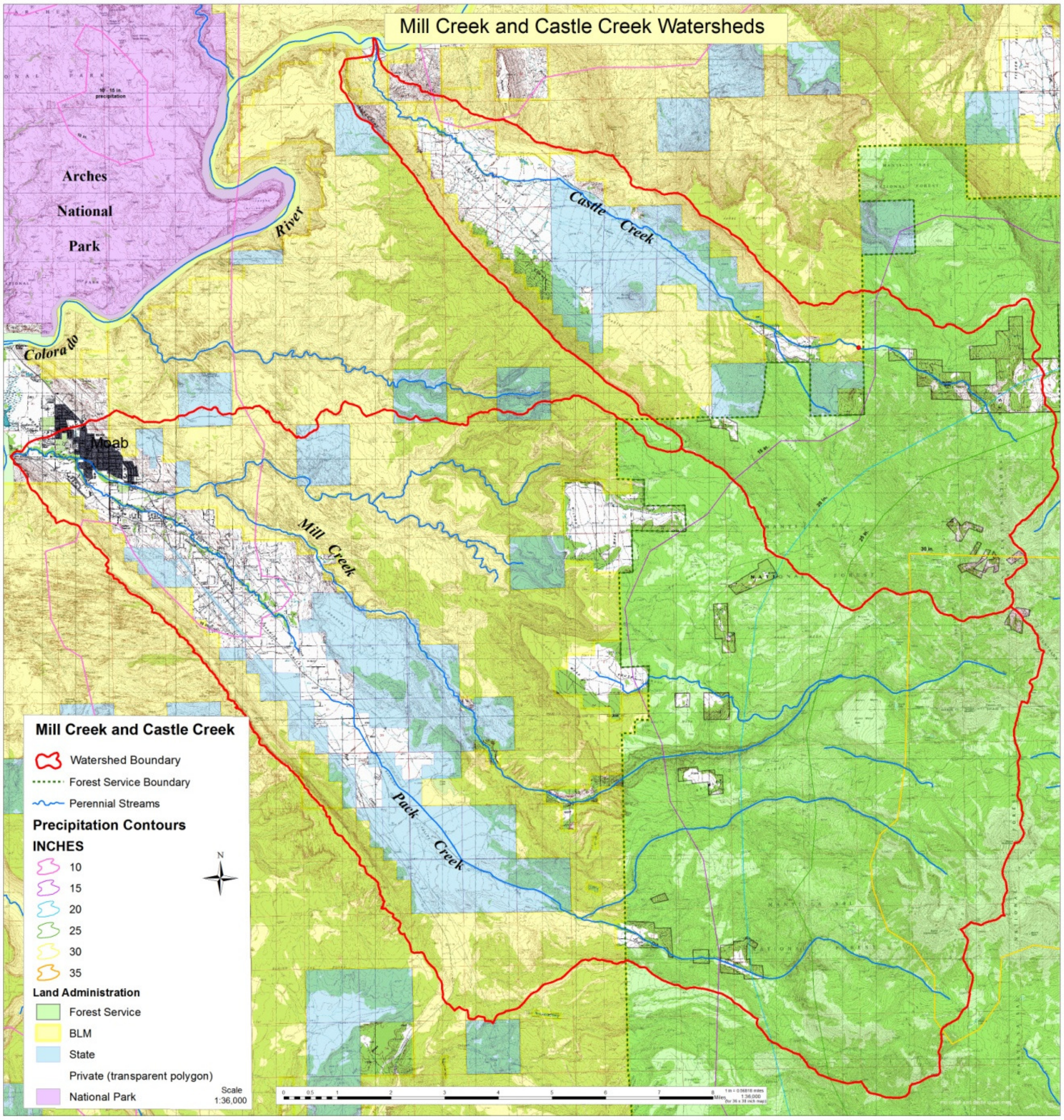

Figure 1.2.1: Moab area watershed boundaries as defined by the hydrological unit codes for Mill and Castle Creek.

1.3 Watershed Management Planning Process and Utah's Watershed Approach

Watershed-based planning promotes individuals, groups, and institutions with a stake in the watershed to participate in identifying and addressing issues that affect the quality of their water. Looking at issues on a watershed scale allows for more holistic planning, since water does not follow political boundaries. Watershed planning is an adaptive, collaborative, inclusive and participatory process that aims to protect water quality standards by allowing those at a local level to actively contribute to the assessment and management of their watershed.

Utah's Watershed Approach

Utah's watershed approach is aimed at improving and protecting the State's surface and groundwater resources. Characteristics of the approach include a high level of stakeholder involvement, water quality monitoring and information gathering, problem targeting and prioritization, and integrated solutions that make use of multiple agencies, local citizens and groups. Federal and state regulations charge DWQ with the task of preventing, controlling, and abating water pollution. Other state and local agencies have associated responsibilities. Utah's watershed approach is to form partnerships with accountable government agencies and interested groups to combine resources and increase the effectiveness of existing programs.

Throughout the State of Utah a series of ten management units provide spatial focus to watershed management activities, thereby improving coordination. Watershed management units in the State may contain more than one stream system, or watershed, defined as the entire area drained by a stream and its tributaries. Delineated watershed units are consistent with the hydrologic basins defined by the Utah Department of Natural Resources. The watershed management units provide boundaries for evaluating the impact of various stressors on commonly shared resources, provide boundaries for evaluating the impacts of management actions, and provide a better perspective for DWQ and stakeholders to determine environmental objectives and to develop management strategies that account for local and regional considerations.

Each watershed plan will establish management actions at several spatial scales ranging from the watershed scale to specific sites that are influenced by unique environmental conditions. Watershed plans consider a holistic approach to watershed management in which groundwater, hydrologic basins and eco-regions encompassed within the units are considered. The goal of Utah's watershed approach is better coordination and integration of the State's existing resources and water quality management programs to improve protection for surface and groundwater resources. Better coordination and integration extends beyond the tiers of government agencies to include all stakeholders in the watershed.

Utah's watershed approach is based on hydrologically defined watershed boundaries and aims to de-emphasize jurisdictional delineations in watershed management efforts. This approach is expected to accelerate improvements in water quality as a result of increased coordination and sharing of resources. Statewide watershed management is not a new regulatory program, it is a means of operating within existing regulatory and non-regulatory programs to more efficiently and effectively protect, enhance, and restore aquatic resources. The Statewide watershed management approach has been introduced to establish a framework to integrate existing programs and coordinate management activities geographically.

In addition to the technical components, Utah's watershed approach is dependent on the critical role stakeholders play in watershed water quality management. The success of the implementation plan, and ultimately the restoration of water quality, depends on the voluntary participation of the stakeholders in Utah's watersheds. Therefore, to be successful, the TMDL development approach must ensure public participation and input at critical points throughout the process.

A successful water quality management plan relies as much on voluntary stakeholder participation and buy-in as on the rigor of technical analysis. The advantages of involving stakeholders throughout the TMDL development and implementation process are numerous. Through their voluntary participation, the stakeholders can become more comfortable that the monitoring and modeling programs generate reliable data that are scientifically defensible. Further, effluent limits and Best Management Practices (BMPs) developed by the Stakeholders are less prone to credibility challenges and litigation. Stakeholders are more apt to agree to pollutant reduction or habitat improvement schemes that they helped to formulate.

The boundaries of watershed management units in Utah were drawn so that stakeholders would be aggregated or grouped into areas sharing common environmental characteristics. Defining watershed management units in this way is intended to encourage a sense of ownership in the resident stakeholders and to encourage involvement in stewardship activities. Based on a model successfully used by other states, the program draws on the expertise of those involved in or affected by water quality management decisions. These stakeholders help gather information and design BMPs, then become involved in stewardship activities.

In the Moab Area watershed, both governmental and non-governmental entities work to achieve a skillful and honest presentation of technical information to the Moab Area Watershed Partnership. These efforts have resulted in a Watershed Management Plan that assures control of nonpoint source pollution and is acceptable to those living and working in the watershed.

1.4 Use and Purpose of Watershed Management Plan

The Mill Creek and Castle Creek watersheds have been included in other water quality studies over the last 10 years in response to significant water quality concerns. Many of these studies speak to various aspects of water quality issues and remedies proposed for this watershed. This Watershed Management Plan (WMP) will bring together the previous studies and reports into a cohesive picture of the water quality issues and opportunities in both the Mill Creek and Castle Creek watersheds. In addition, the WMP will provide a cohesive strategy for implementing needed water quality improvements for the watershed such that state water quality standards are restored and maintained in Mill Creek, Castle Creek and all tributaries.

Prior reports have identified some non-point sources of pollution that are causing water quality impairments. The problems listed in these reports include high total dissolved solids and elevated water temperatures. The U.S. Environmental Protection Agency (EPA) regulations require that states develop Total Maximum Daily Loads (TMDL) for those watersheds that have impaired beneficial uses. A TMDL for Mill Creek was completed in 2002 and one for Castle Creek was completed in 2004.

The procedure for improving water quality involves the development of a Watershed Plan that identifies impairment sources and makes improvements on a watershed scale. The purpose of the watershed plan is to provide tools, resources and guidance to local decision makers and stakeholders in order to assist them with management activities affecting the protection or restoration of the watershed's aquatic resources.

Chapter 2. Watershed Inventory

2.1 Location Boundaries and Topography

2.1.1 Location

This plan covers the area delineated by Moab Area Watershed Partnership (MAWP) boundaries. The MAWP covers the Mill Creek and Castle Creek watersheds near Moab, Utah (See Figure 1.1). The Castle Creek Watershed is located entirely within Grand County and encompasses 34,154 acres. The Mill Creek Watershed encompasses 92,352 of which approximately 60% is in Grand County and the other 40% in San Juan County

2.1.2 Topography

The topography of the Mill Creek and Castle Creek watersheds are very similar. Both streams originate in the La Sal Mountains, a laccolithic intrusion located in the southeastern part of the watersheds, with elevations of over 12,000ft and travel across the desert and canyons below eventually discharging into the Colorado River at an elevation of approximately 4,000 ft. The mountain valleys provide contrast to the panoramic views of the deserts and canyons below. Mesas, buttes and sandstone fins with dramatically vertical rims create obvious watershed boundaries for both creeks and their tributaries.

The Mill Creek and Castle Creek watersheds are nested within a larger watershed known as the Southeast Colorado River Basin in Southeastern Utah. This area is often referred to as "Canyon Country" because of the varied landscape that includes high plateaus, buttes, igneous intrusive mountains, innumerable incised sandstone canyons and long narrow valleys resulting from the collapse of ancient salt anticlines. The rugged desert terrain defining these watersheds is the result of the erosional processes that are commonly associated with the Colorado Plateau and since these erosional processes are still taking place, canyons continue to increase in depth and number.

2.1.3 Sub-Watersheds

There are six 12 digit Hydrologic Units or sub-watersheds in the MAWP area (see Figure 2.1).

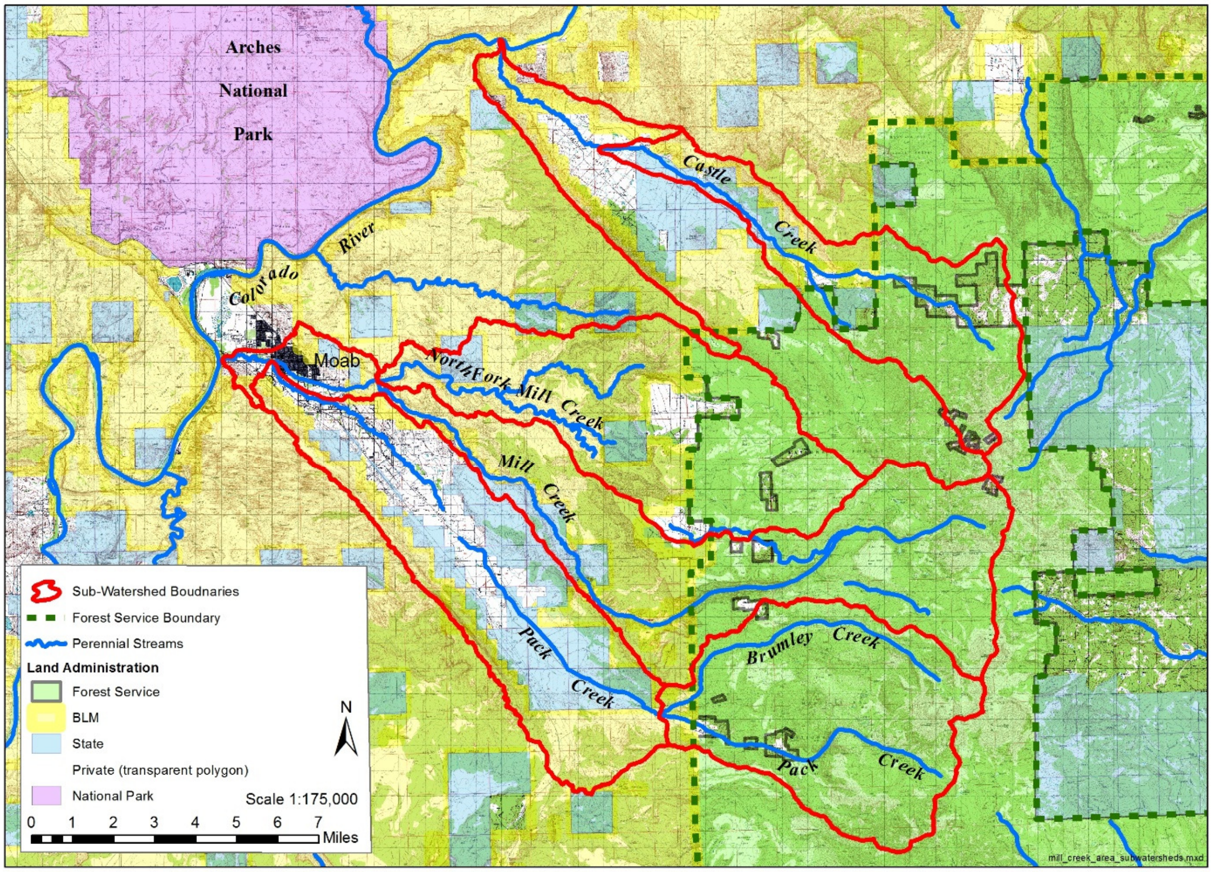

Figure 2.1.1: Sub-Watersheds in the MAWP area.

2.1.3.1 Sub-Watershed 140300050401 Upper Pack Creek

The Upper Pack Creek watershed contains the drainage from the confluence of Brumley Creek and Pack Creek to their headwaters (see Figure 3). The elevation ranges from 5,750 feet at the confluence to 12,482 at the top of Mount Tukuhnikivatz. The area is almost entirely USFS Land with some small in private inholdings and a small amount of BLM land near the confluence of the two creeks. Both Brumley Creek and Pack Creek are perennial streams prior to their diversion for beneficial use. The entire sub-watershed resides in San Juan County.

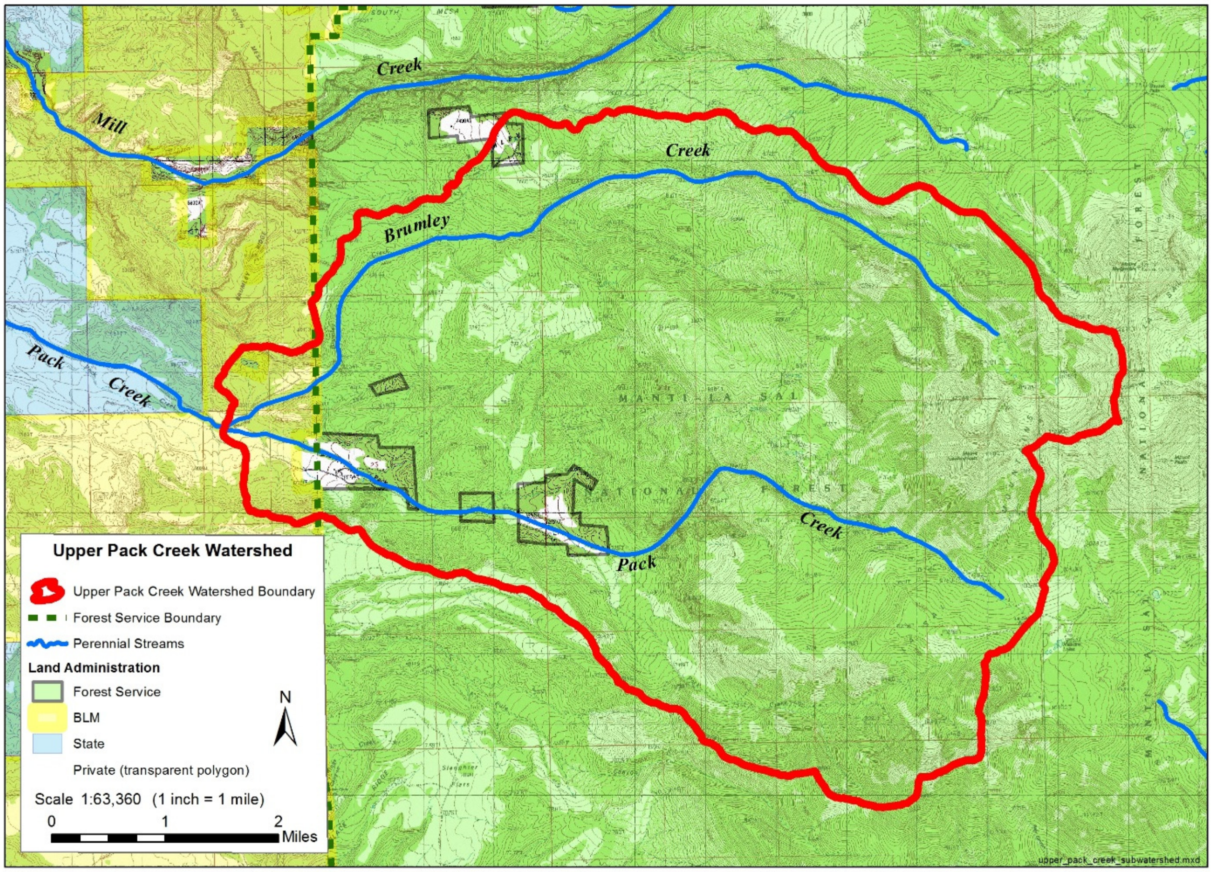

Figure 2.1.2: Sub-Watershed 140300050401 Upper Pack Creek

2.1.3.2 Sub-Watershed 140300050402 North Fork of Mill Creek

The North Fork Mill Creek contains the drainage of the North Fork Mill Creek from its confluence with Mill Creek to its headwaters (see Figure 4). The elevation ranges from 4,300 feet at the confluence to about 9,500 feet near Wilcox Flat on the west slope of the La Sal Mountains. The area is about 60% BLM Land, 20% Forest Service Land, 10 % SITLA Land, and 10% private inholdings. Some of the SITLA land resides within the BLM and Grand County managed Sand Flats Recreation Area and is effectively managed by the BLM and Grand County. A large portion of the watershed is managed as wilderness because it is in the BLM Mill Creek Wilderness Study Area. The stream is perennial through the wilderness study area. The entire watershed resides in Grand County.

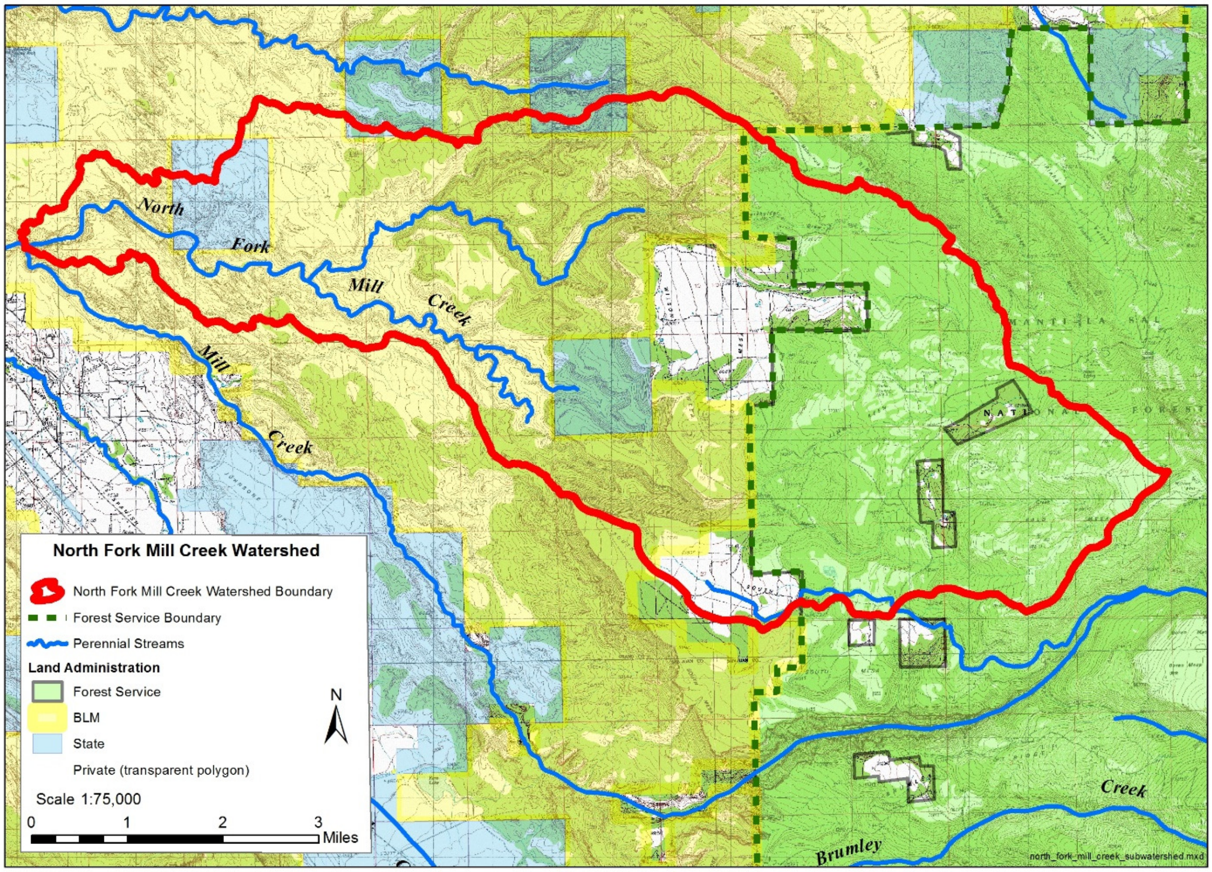

Figure 2.1.3: Sub-Watershed 14030005402 North Fork Mill Creek

2.1.3.3 Sub-Watershed 140300050403 Lower Pack Creek

The Lower Pack Creek sub-watershed contains all the area drained by Pack Creek from its confluence with Mill Creek to the confluence of Pack Creek and Brumley Creek (see Figure 5). The elevation ranges from 4,000 feet at the confluence of Mill Creek to 5,750 feet at the confluence of Brumley Creek. The property ownership is almost evenly split between the BLM, SITLA and Private Property. The stream itself is generally dry below the confluence with Brumley creek because of diversions. The creek becomes perennial south of Spanish Trail Road with the addition of water from springs in the area. The stream has several other springs along its water course that add to its volume. The sub-watershed is shared almost equally between Grand and San Juan Counties, but the stream is perennial only in Grand County. The majority of the human development occurs in this sub-watershed.

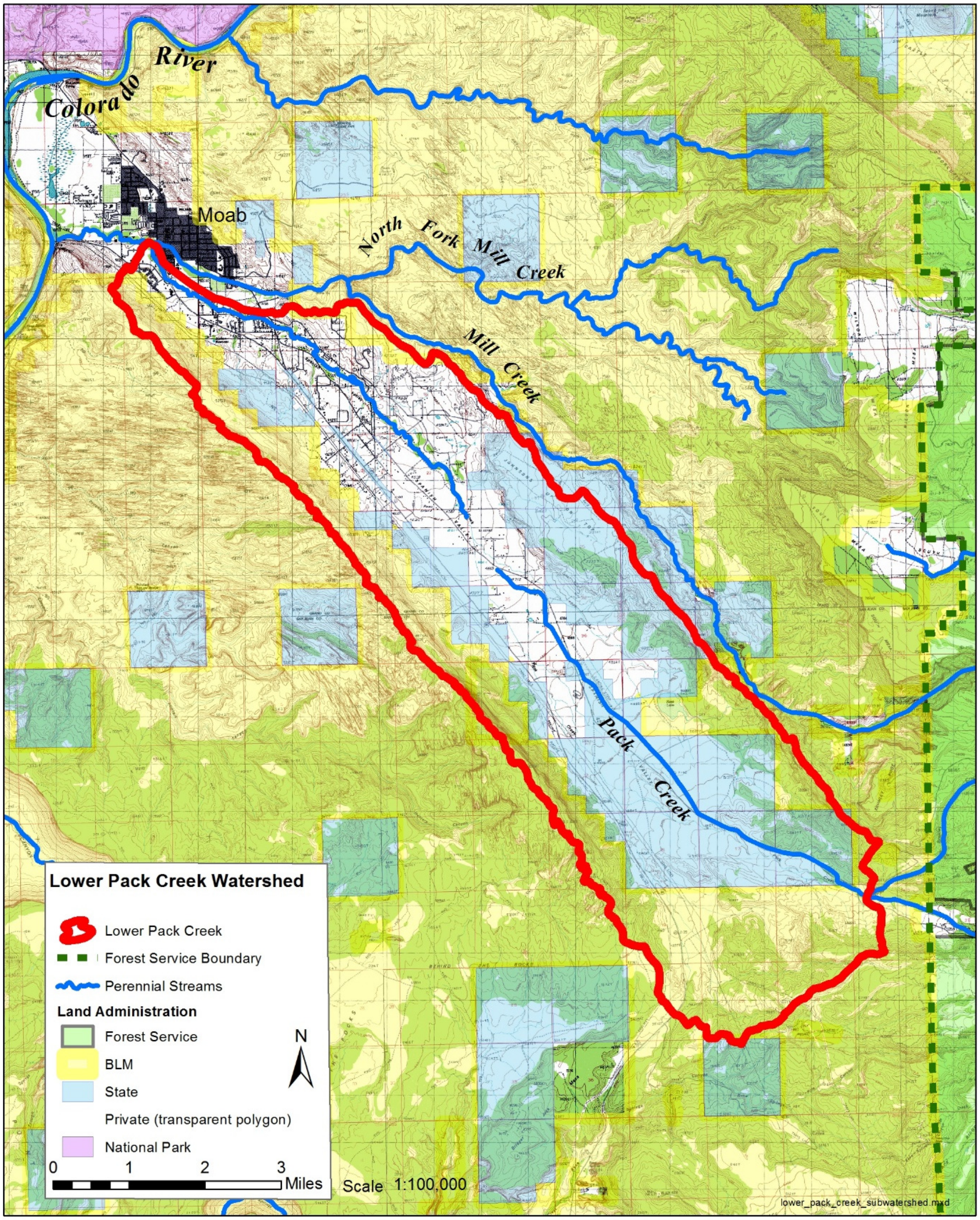

Figure 2.1.4: Sub-Watershed 140300050403 Lower Pack Creek

2.1.3.4 Sub-Watershed 140300050404 Mill Creek/Horse Creek

The Mill Creek sub-watershed consists of Mill Creek from its confluence with the Colorado River to its headwaters on Mount Mellenthin with the exclusion of the three previously mentioned sub-watersheds (see Figure 6). The elevation ranges from 3,950 feet at the Colorado River to 12,645 feet at the top of Mount Mellenthin. About 50% of the watershed is on USFS lands. The rest of the drainage is approximately 25% BLM, 15% private property, and 10% SITLA land. The portion of Mill Creek from about the confluence with North Fork to a private inholding near Spring Canyon is managed as wilderness in the Mill Creek Wilderness Study Area. The stream is perennial. About 60% of the watershed is in Grand County and the other 40% is in San Juan County. The stream runs through Moab and the City has established a green zone near the creek. There is also a parkway along the majority of its course through the town of Moab.

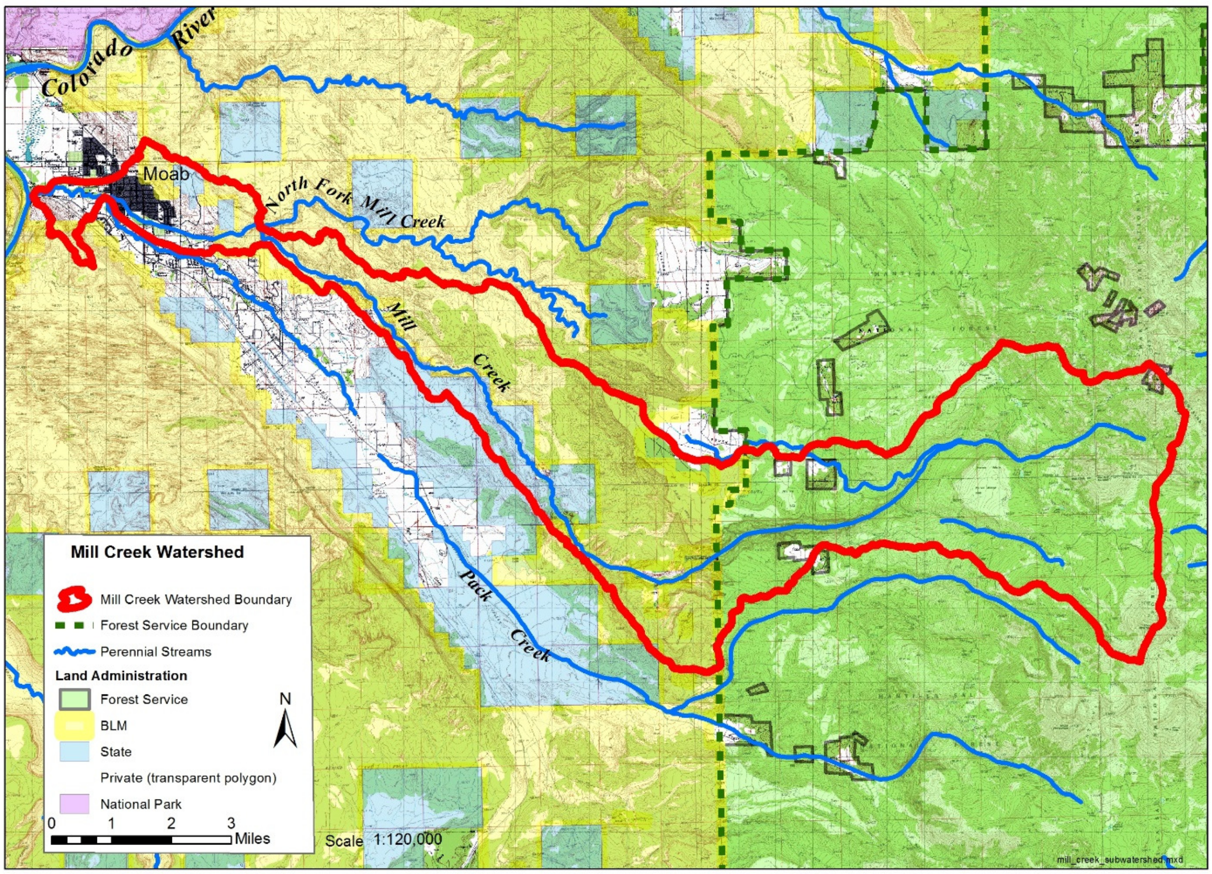

Figure 2.1.5: Sub-Watershed 140300050404: Mill Creek/Horse Creek

2.1.3.5 Sub-Watershed 140300050304 Castle Creek

The sub-watershed Castle Creek contains Castle Creek from its confluence with Placer Creek to its headwaters at Mount Waas (See Figure 7). The elevation ranges from 4,640 feet and the confluence with Placer Creek to 12,331 at the top of Mount Waas. About 40% of the area is USFS managed land with the rest being split almost evenly at 20% for BLM, SITLA and Private Land ownership. The private land upstream from the confluence with Placer Creek has been developed. Castle Creek is perennial above a diversion in the area known as Castleton. The creek is in Grand County.

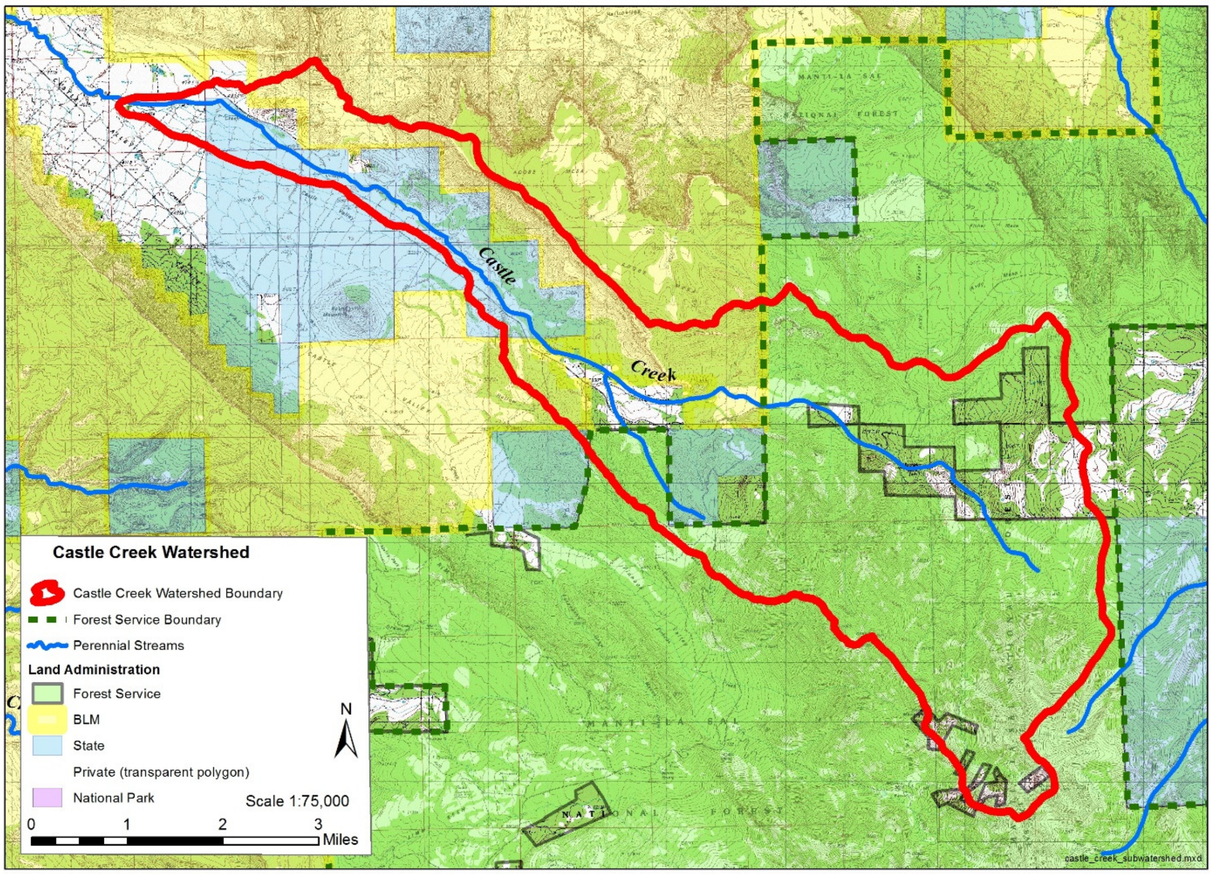

Figure 2.1.6: Sub-Watershed 140300050304 Castle Creek

2.1.3.6 Sub-Watershed 140300050305 Placer Creek

The sub-watershed Placer Creek contains Castle Creek to its confluence with the Colorado River to the confluence of Placer and Castle Creek and then the Placer Creek drainage to its headwaters (see Figure 8). The name of this sub-watershed is somewhat misleading because Placer Creek is and intermittent stream that is dry most of the year. There is a perennial stream high in the drainage, mostly on USFS land called Pinhook Creek. The sub-watershed is about 30% BLM, 30 % USFS, 15% SITLA and 15% Private land. The majority of private property has been developed to some extent. Most of the Town of Castle Valley is in this sub-watershed. The entire sub-watershed resides in Grand County.

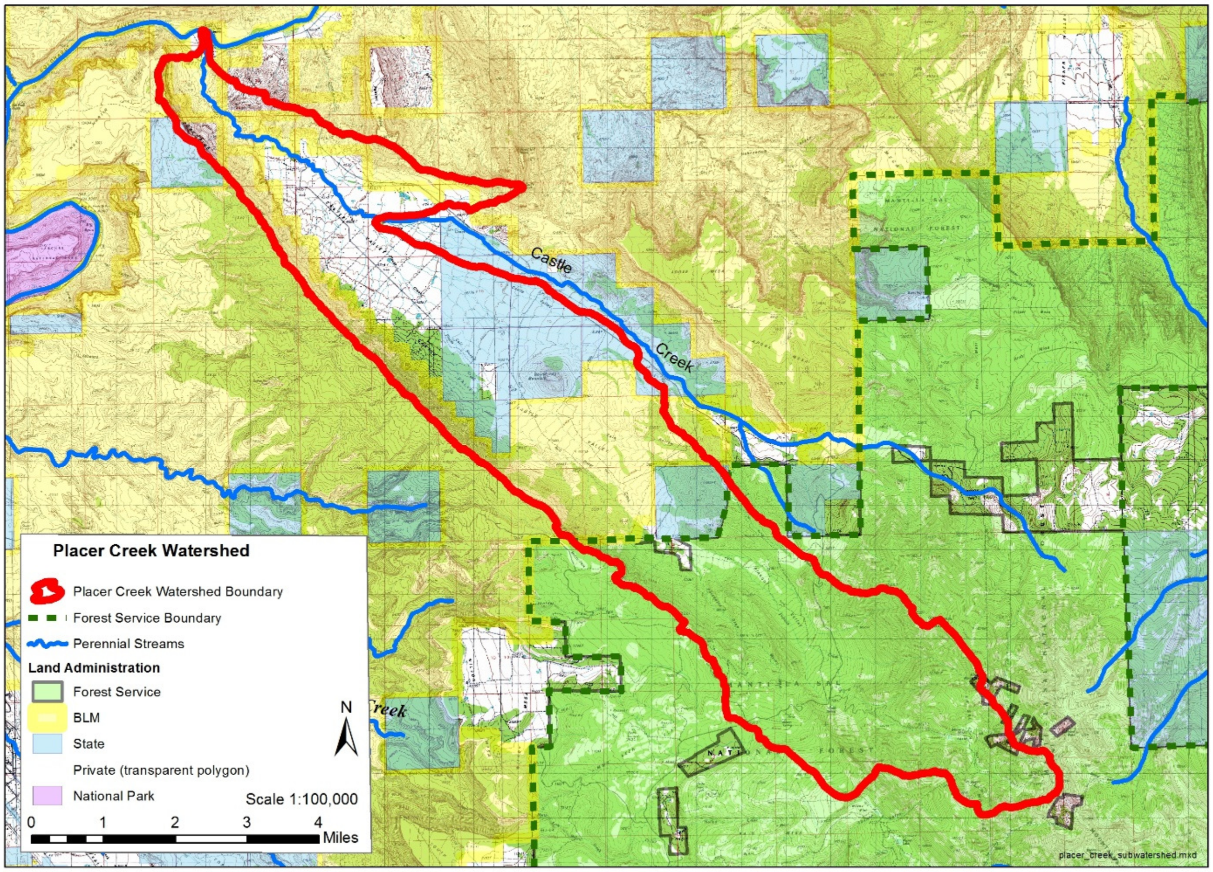

Figure 2.1.7: Sub-Watershed 1403000050305 Placer Creek

2.2 Hydrology

The hydrology of the Castle Creek and Mill Creek watersheds (refer to watershed area map in introduction) includes all relationships between precipitation falling on these basins, surface evaporation, transpiration by plants, intermittent and perennial streams, canals and ditches, diversions and return flows, irrigation and consumptive use by crops, evapotranspiration in riparian and wetland areas, reservoirs and lakes, springs, infiltration of surface water into the underlying soil and rock, water in the vadose zone above the water table, and the movement of water in the saturated zone(s) or aquifers. These relationships have not been exhaustively researched and many are, as yet, poorly defined. What is partially understood is described in Sections 2.2.1 *Surface Water* and 2.2.2 *Ground Water.*

Numerous publications and online databases address the hydrology of the Castle Creek and Mill Creek watersheds. Appendix B contains a partial list of these information sources, which were used in the descriptions presented in the following sections.

2.2.1 Surface Water

Annual precipitation on the Mill and Castle Creek watersheds varies from less than 8 inches in their lower reaches near the Colorado River to more than 30 inches at the headwaters in the La Sal Mountains (Figure 2.2.1). The quantity of precipitation falling on the Castle Creek watershed is estimated at 50,000 acre-feet per year. The quantity of precipitation falling on the Mill Creek watershed is estimated at 130,000 acre-feet per year. These quantities can vary substantially from year to year depending on changing weather patterns and climatic conditions.

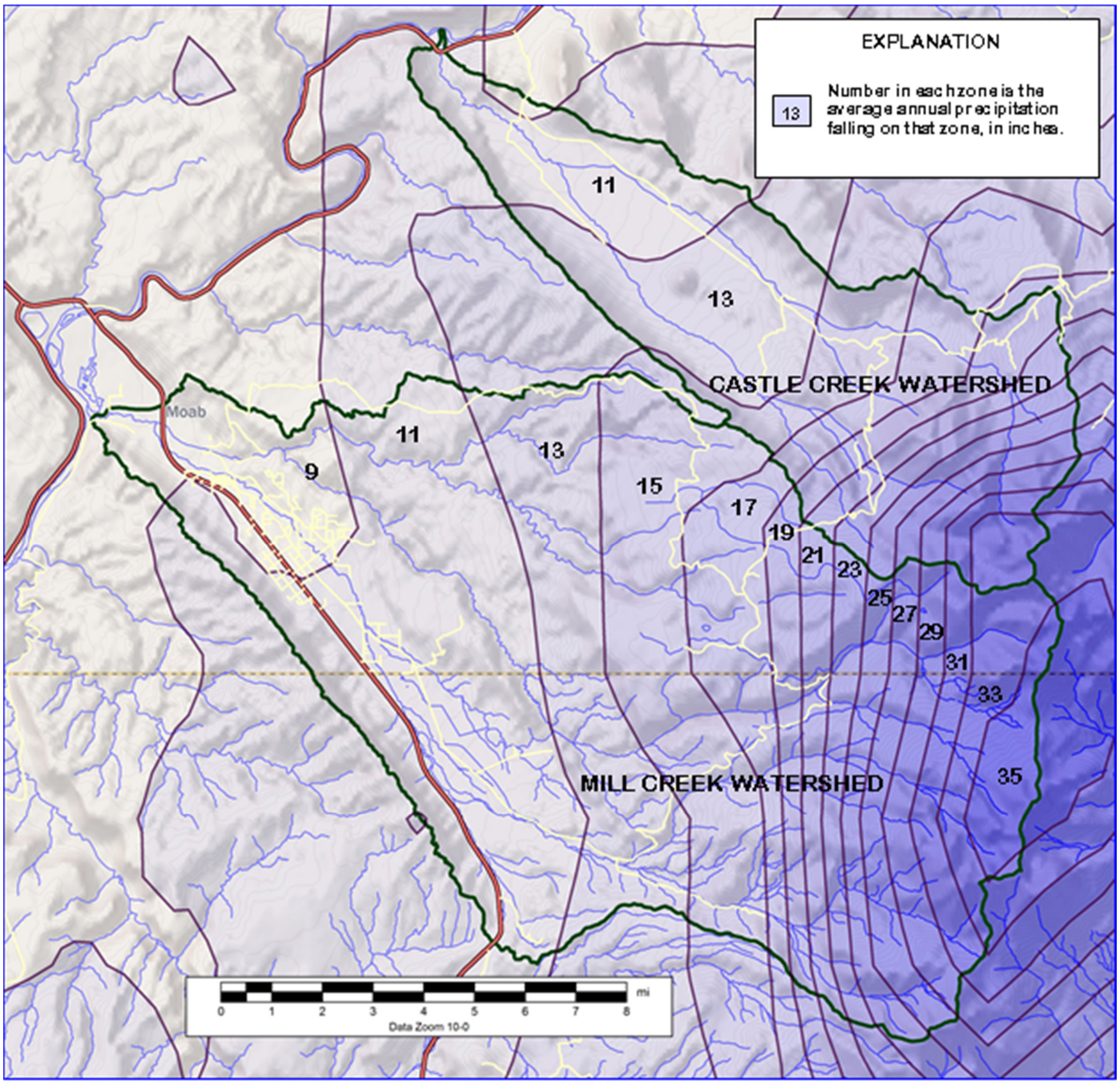

Figure 2.2.1 Average annual precipitation in the Castle Creek and Mill Creek watersheds

2.2.1.1 Castle Creek Watershed

Although the majority of precipitation that falls on the watershed is returned to the atmosphere by evaporation or intercepted and used by vegetation, the remaining runoff and snowmelt along with base flow supports perennial flow in most of Castle Creek and the upper reaches of Placer Creek (Ford, 2006, p. 7). Flow records from gaging stations on Castle Creek (Castle Creek near Moab (1950-1958) and Castle Creek below Castle Valley (1992-2011) indicate that surface flow from the watershed averages about 4,100 acre-feet/year (Figure 2.2.2). This is about 8 percent of total annual precipitation on the watershed. Surface flow peaks in November after riparian-zone plants have ceased water uptake and diversions for irrigation are shut down. Surface flow out of the watershed is the least in mid-summer when evaporation, transpiration, and irrigation use are the greatest.

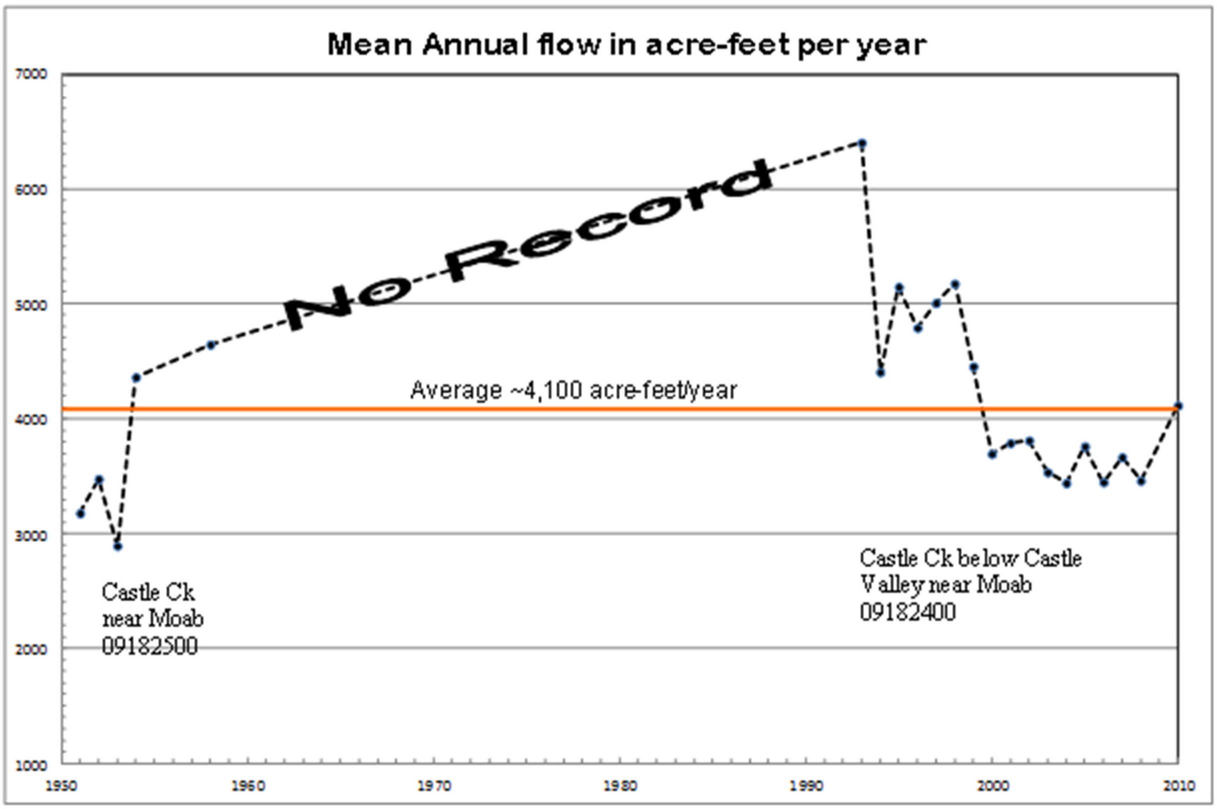

Figure 2.2.2 Mean annual flow in Castle Creek and average for period of record

The main tributary to Castle Creek, Placer Creek, is an intermittent stream in its lower reach, but mostly perennial above diversions. Springs discharging into the drainage in the Manti-La Sal National Forest support perennial flow at higher altitudes. The area drained by Placer Creek and Castles Creek above the confluence is about the same (Placer Creek --~15,500 acres and Castle Creek--~14,500 acres). No long-term stream flow records are available for Placer Creek.
There are 26 approved or perfected surface flow/spring diversions for the Castle Creek drainage area listed in the Utah Division of Water Rights data base. There are 7 approved or perfected flow/spring diversions listed for the Placer Creek drainage area. The quantity of surface water being diverted for use at present (2012) is uncertain.

Peak flows can cause considerable erosion and destruction of property. From 1993 to 2012 the highest recorded flow at the gage on Castle Creek was greater than 3,000 cubic feet per second (cfs). Flows of more than 100 cfs have occurred in 9 out of the 18 years of record available (USGS Gaging Station 09182400).

2.2.1.2 Mill Creek Watershed

The north part of the Mill Creek watershed is drained by Mill Creek and tributaries and the south part of the watershed, including Spanish Valley, is drained by Pack Creek (see watershed map). The area of these 2 principal drainages is ~50,000 acres for Mill Creek and ~41,000 acres for Pack Creek. A larger portion of the Mill Creek drainage is above 6,000 feet where more precipitation occurs.

Several streams or portions of streams in the Mill Creek watershed are perennial. The Main Fork of Mill Creek is perennial beginning at the headwaters near Manns Peak. Smaller tributary basins like Schumann Gulch, Horse Creek, and Wet Fork of Mill also likely support perennial reaches of stream. The North Fork of Mill Creek is perennial in its lower 7 miles before joining the Main Fork. This consistent flow at altitudes lower than 6,000 feet is the result of ground water discharging from the formations of the Glen Canyon Group (Navajo Ss., Kayenta Fm., and Wingate Ss). Pack Creek is perennial above its confluence with Brumley Creek probably owing to the numerous springs in the Hell Canyon drainage. Where Pack Creek begins traversing the alluvial sediments in Spanish Valley, during low runoff periods, surface flow ceases because it either percolates into the unconsolidated sediments, is diverted for irrigation, or is consumed by riparian vegetation.

From limited stream flow records (Pack Creek near Moab - 1955-1959; and Mill Creek near Moab - 1982-1993) annual surface flow from the Mill Creek watershed is about 12,000 acre- feet (Figures 2.2.3 & 2.2.4) or about 9 percent of total annual precipitation on the watershed.

There are 47 approved surface flow/spring diversions in the Mill Creek drainage and 45 diversions in the Pack Creek drainage. Most are for irrigation and stock watering. The historic Moab Irrigation Company owns the right to divert water at numerous points in the Mill Creek drainage for irrigation, and in 2010 the company's total estimated diversion from Mill Creek or tributaries was about 6,380 acre-feet. The largest single diversion is for storing water in Ken's Lake, which is used for summer irrigation in Spanish Valley. In 2010 that quantity was estimated to be 3,290 acre-feet. The total quantity of surface flow now (2012) being diverted at all points of diversion in the Mill Creek watershed is uncertain.

High flows in Mill Creek has caused damage to Moab residences and destroyed the old power dam several times during the early 1900's. Peak flows in Mill Creek exceeded 1,000 cfs 18 times from 1949 to 1994 and exceeded 6,000 cfs twice during that period (USGS Gaging Station 09184000). Flows in Pack Creek exceed 100 cfs four times from 1954 to 1958 (USGS Gaging Station 09185000)

2.2.2 Ground Water

Ground water is stored in the pores and fractures of unconsolidated and consolidated formations throughout the Castle Creek and Mill Creek watersheds. The formations that readily yield potable ground water via wells and springs are the valley fill deposits in Castle Valley and Spanish Valley, the sandstone formations of the Glen Canyon Group, and the sandstone at the top of the Permian Cutler Formation (refer to section 3.7 for geologic details). The fractured igneous rocks of La Sal Mountain intrusion support small spring discharges suitable for stock watering.

The quantity of ground water stored in geologic formations has not been determined; however, on the basis of the available pore space in the Glen Canyon Group formations (~15%) and the thickness and areal extent of these rocks, the quantity could be substantially more than the water stored above ground in reservoirs.

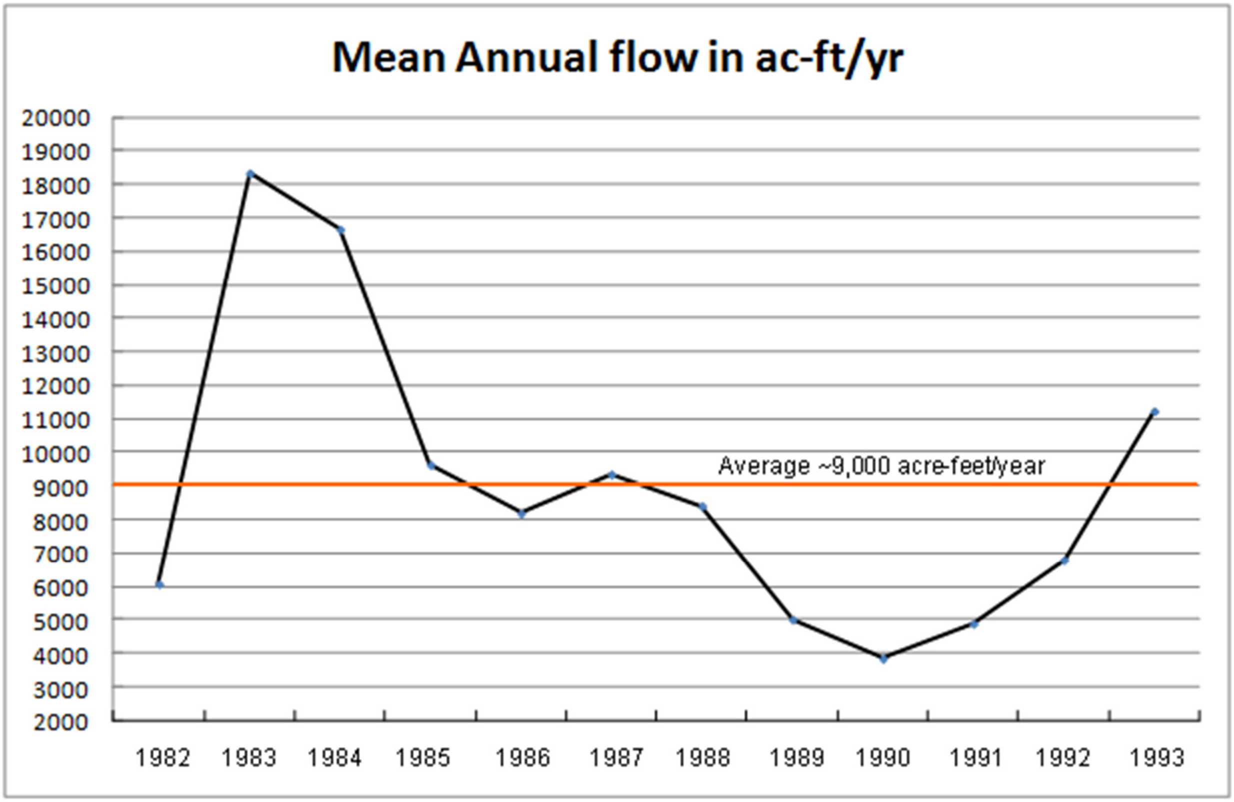

Figure 2.2.3. Mean annual flow in Mill Creek, 1982-1993 and average for period of record.

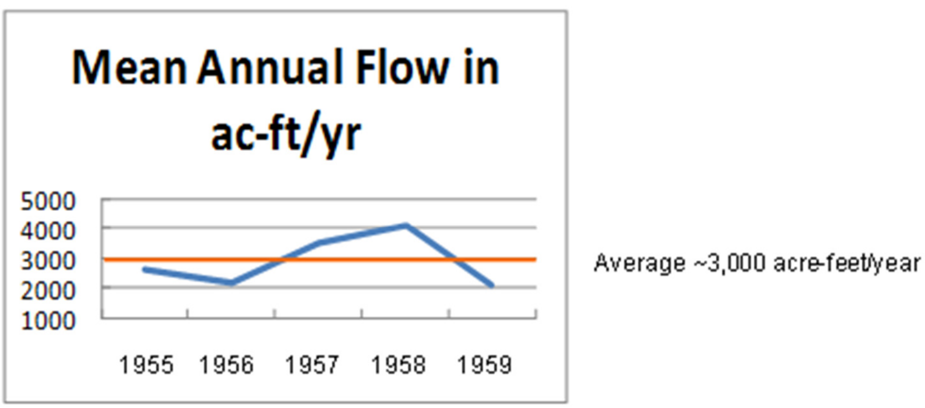

Figure 2.2.4. Mean annual flow in Pack Creek, 1955-1959 and average for period of record.

Figure 2.2.3 and Figure 2.2.4

2.2.2.1 Castle Creek Watershed

Ground water in the Castle Creek watershed occurs primarily in the valley fill sediments of Castle valley (alluvial aquifer) and in the Cutler Formation (Cutler aquifer) along the western side of the valley. It has been presumed that ground water in the Cutler aquifer originates from precipitation infiltrating into the rocks of the La Sal Mountains, and that ground water in the alluvial aquifer of Castle Valley originates from stream flow, excess applied irrigation, and direct precipitation infiltrating into the unconsolidated sediments. On the basis of water levels in wells that penetrate the alluvial aquifer and the Cutler aquifer and from chemical analysis of water from these wells, ground water in the Cutler aquifer moves laterally into the alluvial aquifer on the southwest border of Castle valley.

A potentiometric contour map (altitude of the top of the saturated zone of an aquifer) generally shows direction of ground-water movement. The potentiometric contours depicted in Figure 4 of Snyder (1996, p. 16) indicate ground water moves northwest from higher altitudes in the valley to lower altitudes at an average gradient of 0.026 ft/ft. The shape of the contours as they cross Castle Creek indicate the stream loses water to the aquifer in the upper reaches (between the altitude of 4,750 ft and 4,650 ft) and gains water from the aquifer in the lower reaches (between the altitude of 4,560 ft to 4,320 ft).

Ground water in the alluvial aquifer of the Castle Creek watershed exits the aquifer in several ways. Ground water discharges into the lower reaches of Castle Creek; is used by riparian vegetation where their roots can penetrate to the top of the saturated zone; or is pumped to supply households, water livestock, or irrigate crops. Ford (2006, p. 10) estimated that household use of ground water in 2005 was about 63 acre-feet.

The quantity of water entering and exiting the aquifers of the Castle Creek watershed has not been determined. A numerical model of the flow system was developed by Downs and Lasswell (undated), but the inflow and outflow quantities used in the simulation were not reported.

2.2.2.2 Mill Creek Watershed

Ground water in the Mill Creek watershed occurs primarily in the valley fill sediments of Spanish Valley (alluvial aquifer) and in the formations that make up the Glen Canyon Group (Glen Canyon aquifer) (Navajo Sandstone, Kayenta Formation, and the Wingate Sandstone). It has been presumed that ground water in the Glen Canyon aquifer originates from precipitation infiltrating into the rocks of the La Sal Mountains and into outcrops of the formations found on the lower slopes of the La Sal Mountains, and that ground water in the alluvial aquifer of Spanish Valley originates from stream flow, excess applied irrigation, and direct precipitation infiltrating into the unconsolidated sediments. Ken's Lake was once a source of recharge to the alluvial aquifer, but recent repairs to the reservoir have negated that source. The alluvial aquifer overlies and abuts the Glen Canyon aquifer in Spanish Valley, which leads to the presumption that ground water moves from the Glen Canyon into the alluvial aquifer.

The potentiometric contours showing the altitude of the top of the saturated zone for the alluvial aquifer and Glen Canyon aquifer in Spanish Valley on Plate 2 of Sumsion (1971) and Figure 19 of Blanchard (1990) indicate ground water moves west from the La Sal Mountains toward Spanish valley, then northwest down Spanish Valley toward the Colorado River. The ground-water flow gradient in the intensely fractured part of the Glen Canyon aquifer is approximately 0.03 ft/ft and the average gradient in the alluvial aquifer in Spanish Valley is 0.011 ft/ft in the southeastern end of the valley and 0.20 ft/ft in the northwestern end of the valley. The shape of the contours near the surface contact between the alluvial fill and the Glen Canyon Group sandstone depicts ground water moving across this interface from the west. The shape of the potentiometric contours for the alluvial aquifer indicates Pack Creek is gaining flow from the aquifer in a 2 mile reach downstream from the Moab Golf course, and that the principal discharge area for the ground-water system is the Matheson Wetlands Preserve and the Colorado River.

Ground water in the Glen Canyon aquifer of the Mill Creek watershed exits the aquifer in several ways. Ground water discharges into the Main Fork of Mill Creek in a deep canyon between Brumley Ridge and South Mesa; ground water discharges into the North Fork of Mill Creek along a 7-mile reach upstream from the confluence of North Fork and Main Fork Mill Creek; ground water discharges from springs along the northeast side of Spanish Valley; ground water discharges into the alluvial aquifer of Spanish Valley; ground water is used by riparian vegetation where the roots of these plants extend to the top of the saturated zone; and groundwater is pumped from Moab City wells, Grand County Water Conservancy District wells, and private wells for household and irrigation use by Moab and Spanish Valley residents. The 2 public suppliers (Moab City and Grand County Water Conservancy District) pumped about 1,460 acre-feet of water in 2010. The quantity pumped by private well owners is not known.

Ground water in the alluvial aquifer exits the aquifer by discharging into Pack Creek, by discharging at springs on the southwest side of Spanish Valley, through consumption by riparian vegetation, by withdrawals through private wells, and by movement into the Colorado River.

The quantity of water entering and exiting the aquifers of the Mill Creek watershed have been inferred using indirect methods. On the basis of stream base flow, measured spring discharge, consumptive use, evapotranspiration, and calculated subsurface flow using Darcy's Law, Sumsion (1971, p. 20) estimated total recharge to both aquifers in the watershed to be 22,000 acre-feet per year or about 17% of the precipitation that falls on the watershed. New methods of measuring various hydrologic parameters are available and this 40-year old estimate could be improved upon with additional investigation.

2.3 VEGETATIVE COVER IN MILL CREEK AND CASTLE CREEK WATERSHEDS

2.3.1 Current Vegetative Cover and General Conditions

2.3.1.1 GENERAL DESCRIPTION OF VEGETATION IN THE WATERSHEDS

The Mill Creek watershed includes about 76500 acres, while the Castle Creek watershed is approximately 36000 acres. The watersheds share a boundary, and it is unsurprising that the vegetation types in the watersheds are similar. Information about vegetation cover is taken from the SE Region GAP database – the overall categories are generally descriptive of the various areas within the watershed, although the actual condition of the vegetation in these areas is not outlined in this database. A detailed table of the acres of each vegetation type, and descriptions of what those vegetation types include, is included in the appendix. A map of the watershed vegetation cover is included in this section.

In Mill Creek 32% of the watershed is Pinyon-Juniper Woodland and Shrubland, and nearly 15% is Rocky Moutain Gambel Oak mixed montane shrub land. The remaining areas are of sagebrush and desert grasslands, as well as various Mountain vegetation types, with small percentages of bedrock and slickrock. Approximately 4% of the watershed is categorized as Aspen forest and woodland, and 4.2% is Intermountain West Aspen Mixed Conifer and Woodland Complex. Only 2.5%of the watershed is in Agriculture, with 1.1% developed at medium to high density. Nearly 1% of the Mill Creek watershed is categorizes at recently chained Pinyon-Juniper, which likely means bullhogged fire fuel treatments.

In Castle Creek, only 1.75% of the watershed is Agricultural, and 3.5% is developed, mostly rated at low density.   34% is Pinyon Juniper Woodland and Shrubland, with 6% Intermountain West Aspen Mixed Conifer and Woodland Complex, and 2% Rocky Moutain Aspen Forest and Woodland. . The remaining areas are of sagebrush and desert grasslands, as well as various Mountain vegetation types, with small percentages of bedrock and slickrock. No areas in the Castle Creek Watershed are categorized in this data set as being recently chained Pinyon-Juniper.

See Appendix E for a meticulous description of vegetation cover.

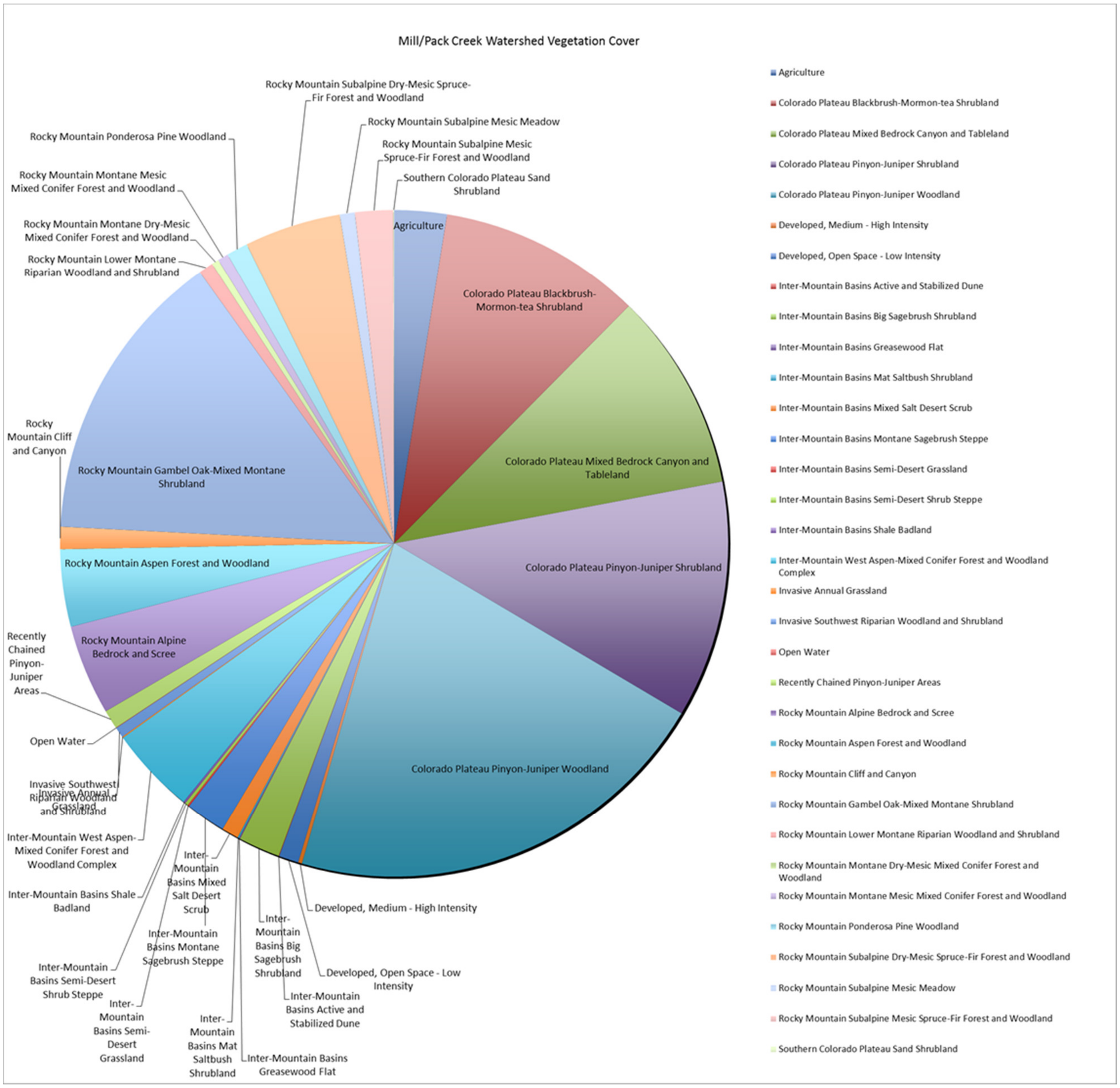

Figure 2.3.1: Pie chart of percent land cover by vegetation type in Spanish Valley

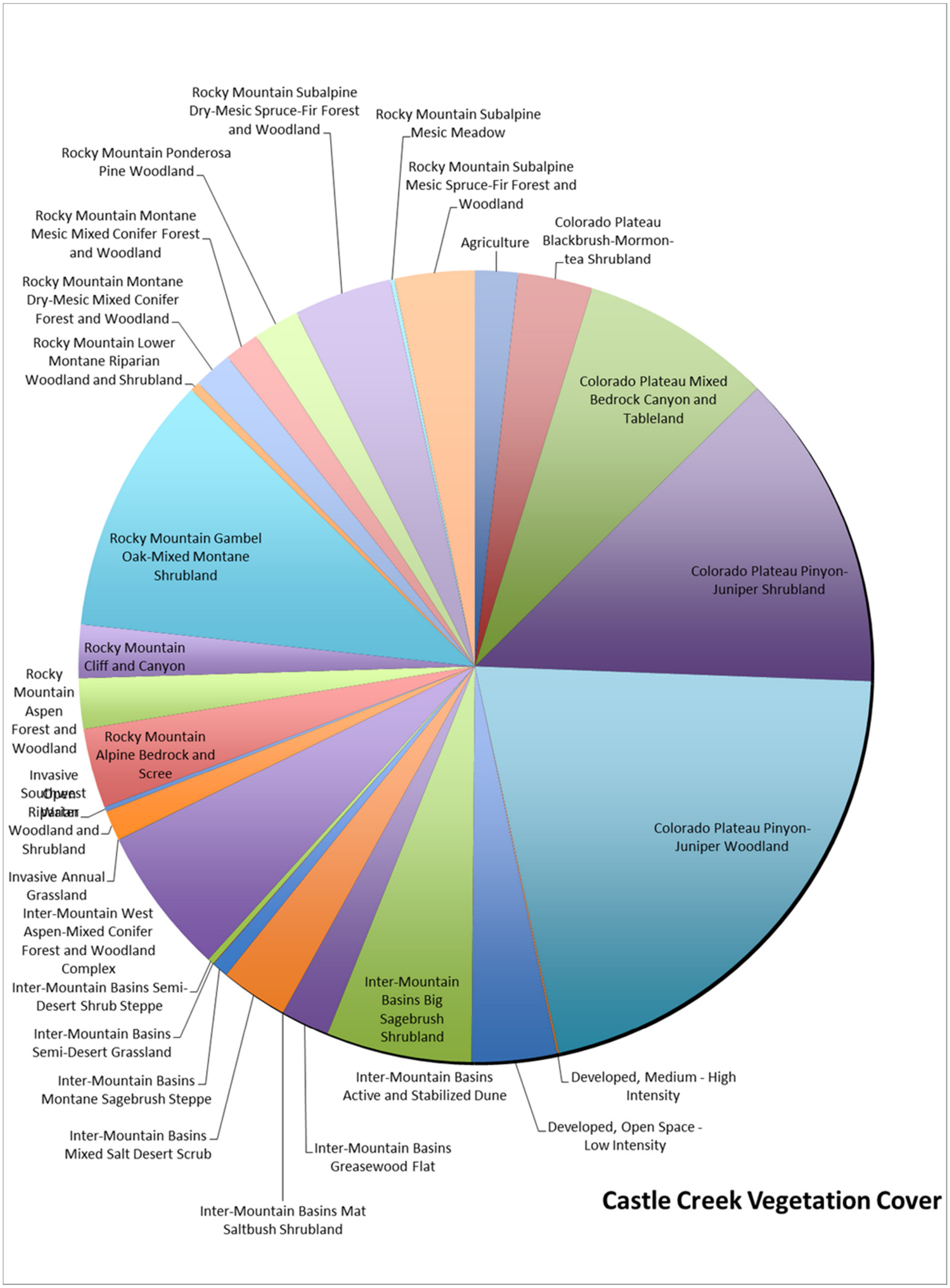
Castle Creek Vegetation Cover
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
Rocky Mountain Subalpine Mesic Meadow
Rocky Mountain Ponderosa Pine Woodland
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
Agriculture
Colorado Plateau Blackbrush-Mormon-tea Shrubland
Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland
Rocky Mountain Lower Montane Riparian Woodland and Shrubland
Colorado Plateau Mixed Bedrock Canyon and Tableland
Rocky Mountain Gambel Oak-Mixed Montane Shrubland
Colorado Plateau Pinyon-Juniper Shrubland
Rocky Mountain Cliff and Canyon
Rocky Mountain Aspen Forest and Woodland
Rocky Mountain Alpine Bedrock and Scree
Invasive Southwest Riparian Woodland and Shrubland
Open Water
Colorado Plateau Pinyon-Juniper Woodland
Invasive Annual Grassland
Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex
Inter-Mountain Basins Semi-Desert Shrub Steppe
Inter-Mountain Basins Big Sagebrush Shrubland
Inter-Mountain Basins Semi-Desert Grassland
Inter-Mountain Basins Montane Sagebrush Steppe
Inter-Mountain Basins Active and Stabilized Dune
Developed, Medium - High Intensity
Developed, Open Space - Low Intensity
Inter-Mountain Basins Mixed Salt Desert Scrub
Inter-Mountain Basins Greasewood Flat
Inter-Mountain Basins Mat Saltbush Shrubland

Figure 2.3.2: Pie Chart of percent land cover by vegetation type for Castle Valley.

2.3.1.2 GENERAL VEGETATION COMMUNITY CONDITION

The GAP data does not evaluate the health of the vegetative communities throughout the watershed. For this watershed management plan we have divided the area into three categories based upon land management for assessment. The categories are the United States Forest Service (USFS), the Bureau of Land Management (BLM), and all other land we are calling non-federal lands. Although the Federal Agencies do not have a detailed assessment for the area, they do have some assessment documentation on vegetative condition. There is also some assessment data available for the non-federal lands through the rim to rim project in Spanish and Castle Valley. That assessment information will be presented in Section 2.3.2.

However, some general vegetative conditions for both watersheds are available. According to the GAP data, all the riparian areas, however, are rated as INVASIVE SOUTHWEST RIPARIAN WOODLAND AND SHRUBLAND (1.24% of Castle Creek and .5% of the Mill Creek Watersheds vegetation cover). This is likely due to the presence of Russian Olive and tamarisk throughout the waterways. These riparian areas do also support healthy stands of native trees, shrubs and grasses.

Invasive annual grasslands are estimated to be less than 1% of either watershed. It is likely that non-native and other less desirable species make up far more than 1% of the watersheds. Not only is cheat grass prevalent throughout some of the vegetation communities, but other non-native species including crested wheat and others are problematic in various locations.

Less clearly mapped and understood are areas where vegetation has been changing over the years to increaser species (eg Iris and mountain goldenpea and others) that are not generally browsed by livestock or wildlife. Shifts in certain areas to increasing species puts graze pressure on other areas, and can result in larger areas of increasing species that are not useful for grazing which in turn increases grazing pressures.

In some of the sagebrush dominated areas vegetation between the sagebrush is absent. Not only does this reduce available food for wildlife or livestock, but it results in erosion which not only further damages the mesa tops, but also impacts downstream riparian areas by increasing the sediment load in the lower watershed.

2.3.1.3 LAND USES THAT IMPACT VEGETATION COMMUNITIES

In relation to water quality and quantity, there are some areas of concern that may need further exploration as a part of the overall watershed planning process. In the lower elevations of the watersheds, development and recreation have an impact on vegetation communities including in riparian areas. The prevalence of invasive species in the riparian areas is of concern as these plants impact flood flows and their removal, if not done carefully, may result in enormous changes in erosion in the watershed.

Two significant impacts on vegetation condition in the upper areas of the watershed include grazing and recreation. Grazing rotation has been occurring in the mountain areas due to recent drought. It is agreed within the MAWP that there are some locations, most notably springs and some riparian areas, where fencing and water diversions may be important to protecting water quality.

Recreation activities have noticeably increased in these watersheds in recent years. Springs and riparian areas sensitive to these impacts are also highly attractive recreation areas. This raises concern related to soil compaction, loss of vegetation, spread of noxious weed seeds, and increases in erosion. The Forest Service and BLM have been addressing these issues by creating concentrated use areas that include toilet facilities as well as parking areas, within a network of planned designated trails.

Wildfire and the fuels treatments to reduce wildfire impact are the last major category of impacts viewed by the MAWP as important to address. Fire prevention efforts like fuels thinning, or using fire to help regenerate species dependent on fire for reproduction have been performed in the MAWP watershed. How they are implemented can affect water quality. Furthermore, the use of non-selective herbicides with long soil persistence that are transportable in waterways is a topic for further discussion in MAWP.

The GAP data does not show areas of land uses like grazing or recreation, but a GIS analysis could easily show areas of active grazing and recreation use overlaid on to vegetation types. That type of analysis or similar analyses could be useful in determining areas where land uses may be impacting vegetation health.

2.3.2 Vegetation Assessments

2.3.2.1 United States Forest Service Assessments

The United States Forest Service completed a watershed condition classification in May of 2011. The results for all USFS lands are available at http://www.fs.fed.us/biology/watershed/condition_framework.html . Five of the 12 digit HUC sub-watersheds in the MAWP area were classified by the USFS. A sixth sub-watershed, Lower Pack Creek/140300050403 was not classified because it does not contain any USFS land. The classifications by the USFS only refer to USFS lands within each sub-watershed. Private or lands managed by another agency were not considered by the USFS. The watershed classification refers to general conditions in each watershed and does not imply that the entire watershed is in a certain condition. There may be local areas that deviate substantially from the classification for the entire watershed.

This section of the Watershed Management Plan does not intend to explicate the USFS watershed classification process. The technical guide used for determining classification can be found at http://www.fs.fed.us/publications/watershed/watershed_classification_guide.pdf . This document will only provide a brief summary of the process and the results of the classification.

The USFS conceptual model for classification breaks down the USFS lands into the four major components of their basic watershed condition model as shown in Figure 2.3.3.

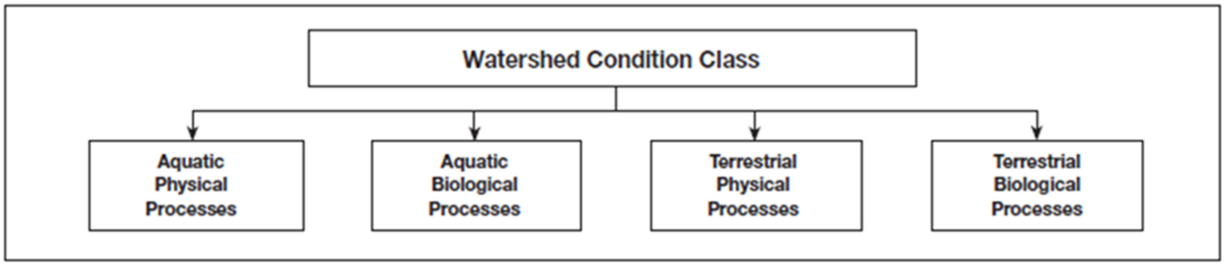

Figure 2.3.3 USFS Basic watershed condition model four major components

The four class components are weighted and the core national watershed condition indicators used to classify watersheds are shown in Figure 2.3.4

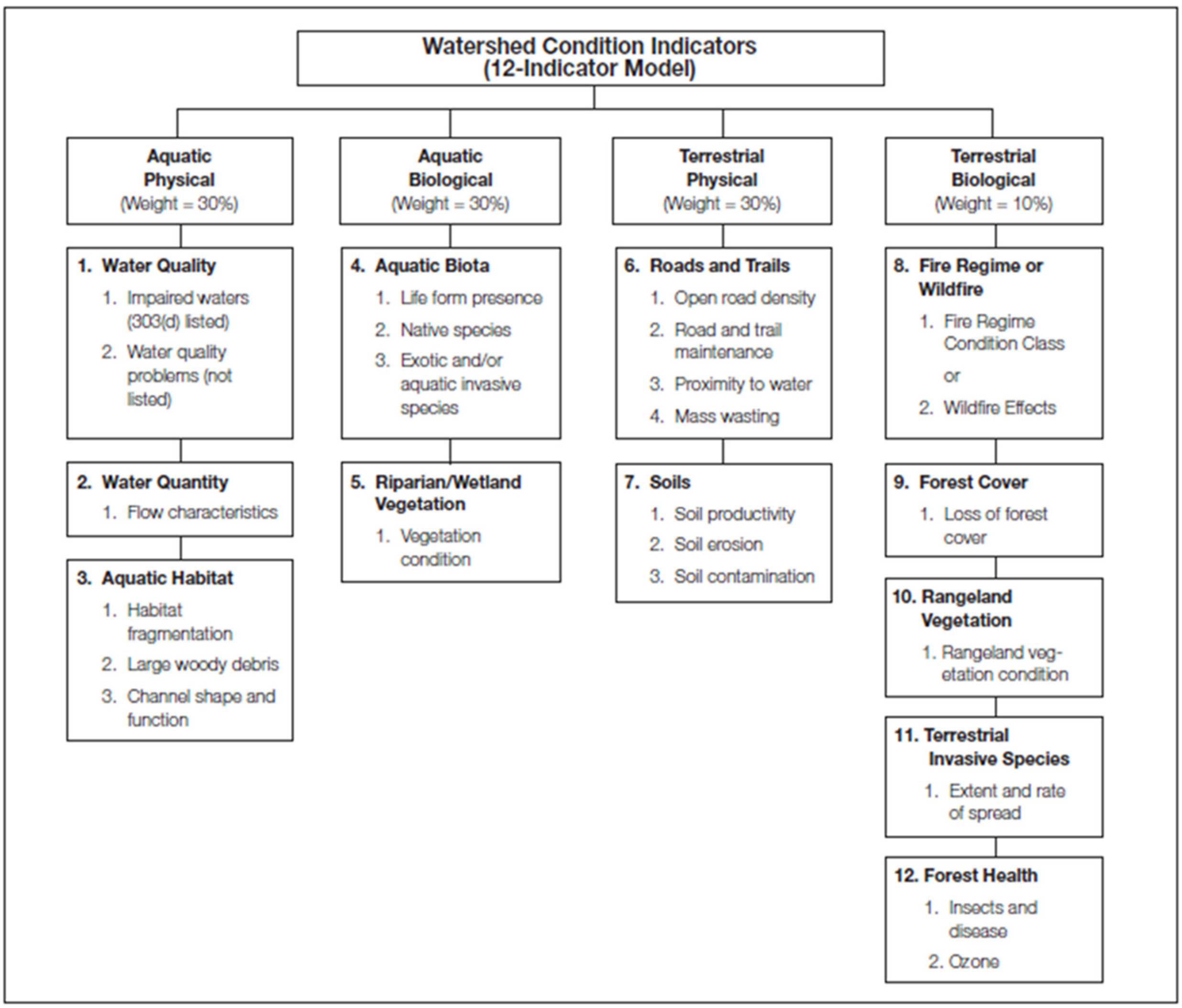

Figure 2.3.4 USFS National watershed condition indicators

The core watersheds conditions indicators are rated good, fair or poor, given a value of 1, 2 or 3 respectively, weighted as shown if Figure 2 for a final score. The watershed is classified as functioning properly for scores from 1 through 1.6, functioning at risk for scores from 1.7 through 2.2, and impaired function for scores from 2.3 to 3. The results for the 12 core components and total watershed classification for the five watersheds in the MAWP area are shown in Table 1.

Table 2.3.1: USFS Watershed Classification and core component scores for MAWP Sub-hydrobasins

WATERSHED_NAME	Castle Creek	Placer Creek	Upper Pack Creek	North Fork Mill Creek	Horse Creek-Mill Creek
WATERSHED_CODE	140300050304	140300050305	140300050401	140300050402	140300050404
WATERSHED_CONDITION_FS_AREA	Functioning Properly	Functioning Properly	Functioning at Risk	Functioning Properly	Functioning Properly
TOTAL_WATERSHED_AREA_ACRES	14423.7	19832.9	19410.5	21941	28052.3
FS_OWNERSHIP_PERCENT	51	39	94	35	49
NONFS_AREA_PERCENT	50	62	6	65	51
AQUATIC_BIOTA_CONDITION	Good	Good	Fair	Good	Fair
RIPARIAN_WETLAND_VEG_CONDITION	Fair	Fair	Fair	Fair	Good
WATER_QUALITY_CONDITION	Good	Fair	Good	Good	Good
WATER_QUANTITY_CONDITION	Good	Good	Good	Good	Fair
AQUATIC_HABITAT_CONDITION	Good	Good	Fair	Good	Fair
ROADS_AND_TRAILS_CONDITION	Fair	Poor	Poor	Poor	Poor
SOIL_CONDITION	Fair	Fair	Fair	Fair	Good
FIRE_EFFECTS_REGIME_CONDITION	Fair	Fair	Fair	Fair	Fair
FOREST_COVER_CONDITION	Good	Poor	Fair	Good	Good
FOREST_HEALTH_CONDITION	Fair	Fair	Fair	Good	Fair
INVASIVE_SPECIES_CONDITION	Good	Good	Good	Good	Good

RANGELAND_VEGETATION_CONDITION	Fair	Fair	Fair	Fair	Good

2.3.2.2 Bureau of Land Management Assessments

Not available at time of publication

2.3.2.3 Other Non-Federal Lands Assessments

Not available at time of publication

2.4 Climate

The Mill Creek and Castle Creek watersheds are situated in the region known as the Colorado Plateau Province. This region is described as a high altitude and high latitude semi-arid desert and is defined by its cold winters and hot summers. Temperatures for the region can range from below 0° Fahrenheit in the winter to over 100° F during summer months leading to an annual average temperature of 55.9° F. Due to extreme fluctuations in temperature, freezing and thawing often occurs and is partly responsible for the high degree of erosion that takes place on the Colorado Plateau.

Table 2.4.1 Monthly Climate Summaries for Moab, UT 1889-2006

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
Average Max Temp (F)	42.4	50.8	62.1	72.1	82.2	92.5	98.1	95.2	86.6	73.4	56.9	44.4	71.4
Average Min Temp (F)	18.2	24.6	32.8	40.8	48.5	56	62.8	62	51.5	39.5	28.2	20.3	40.3
Average Precipitation (in.)	0.67	0.61	0.83	0.81	0.72	0.43	0.78	0.86	0.85	1.01	0.7	0.75	9.01

(Western Regional Climate Center, 2010)

In Utah, there is about a 3° Fahrenheit decrease in mean annual temperature for each 1,000-foot increase in altitude and approximately 1.5 to 2° F decrease in average yearly temperature for each one degree increase in latitude. The elevation of the Moab Valley is 3,967 feet and the elevation of the highest point in the area, Mt. Peale, is 12,721 feet. The vertical relief between Moab and Mt. Peale is 8,754 feet. The average precipitation at the Colorado River Bridge at Hwy 191 in Moab is about 9 inches per year. The average rainfall on the slopes of the La Sal Mountains is not precisely known, but is thought to be somewhere between 35 and 40 inches per year. The wettest month for the Moab region is October, which receives over one inch on average and the driest month is June receiving less than ½ inch on average.

These watersheds also experience monsoonal cloudbursts that consistently occur in the summer and fall. The moisture for these summer storms in usually derived from evaporation off the Gulf of Mexico. Summer and fall storms often consist of heavy localized rainstorms that are short lived resulting in flash floods. Flash flooding occurs as precipitation rapidly flows off higher plateaus, mostly formed of solid rock, into dry washes and low lying areas without enough time to infiltrate into the soils. This type of flooding can bring down large amounts of sediment and debris.

Utah is the 2nd driest state in the nation, which increases the potential risk of the region being affected by climate change. Increases in temperatures and evaporation, as well as decreases in precipitation, are potential risks that land and resource managers in the region should be aware of, and plan for, accordingly.

2.5 Geology, Geomorphology, and Soils

Soil Survey of Canyonlands Area, Utah, Parts of Grand and San Juan Counties

The following information was taken in whole or part from the 1991 NRCS Soil Survey of Canyonlands Area, Utah, Parts of Grand and San Juan Counties, pages 1 through 5.

The survey area is in the southeastern part of Utah (see Figure 1). It includes the southeastern part of Grand County and the northern part of San Juan County. It has a total area of about 2.785 square miles, or 1,782,490 acres. Moab, the county seat of Grand County, and the adjacent Spanish Valley area are the only urban areas in the survey area.

Most of the survey area is public land, including parts of Canyonlands National Park, Manti-La Sal National Forest, Glen Canyon National Recreation Area, and Dead Horse Point State Park and land administered by the Bureau of Land Management. Land administered by the State of Utah is in Spanish Valley, in Castle Valley, near Potash, on the eastern side of the La Sal Mountains, and in small areas scattered throughout the survey area. Most of the privately owned land is in the Moab-Spanish Valley area, in Castle Valley, near La Sal, and on the eastern side of the La Sal Mountains.

The survey area consists of entrenched red rock canyon systems carved on a stepped sequence of nearly level benches and mesas, high alpine tundra, snow-capped mountains, and anticlines of sedimentary rock. The area is a result of the forces of gravity, wind, and running water rhythmically eroding and depositing sediment over time.

The survey area, which is part of the Canyon Lands section of the Colorado Plateaus physiographic province, is an erosional landscape. Nearly one-fourth of the area is exposed bedrock, mostly sandstone. The material in which the soils formed is in areas that have a stony surface, a gravel pavement, or a windward barrier; are gently sloping; have a cemented layer; support vegetation; or are bypassed by drainage ways.

The soils in the survey area vary widely in their characteristics. The soils at low elevations on canyon floors, on structural benches, and in salt valleys are dry and hot. The soils on the high mountains are cold and moist. The soils on strath terraces, alluvial fans, glacial outwash fans, moraines, and talus slopes have a high content of rock fragments. The soils that formed in eolian deposits, alluvium derived from sedimentary rock, and shale landslide material have few if any rock fragments. The soils that formed in recent eolian deposits commonly are sandy loam, loamy sand, or sand, and the soils that formed in material derived from shale are clay loam or clay. Deep soils are on mountainsides, alluvial fans, valley fills, and gently sloping mesas, benches, and cuesta dip slopes. Shallow soils and exposed sandstone are on escarpments. rims, desert benches, and sloping to moderately steep dip slopes of anticlines and synclines.

An older survey, "San Juan Area, Utah," was published in 1962 *(16).* This earlier survey covers a small part of the present survey, in the vicinity of La Sal. The 1991 survey, however, updates the earlier survey and provides additional information and larger maps that show the soils in greater detail. NRCS is currently working to update and expand the 1991 soil survey.

Geology

From the ancient Precambrian era 570 million years ago to the Late Cretaceous period about 80 million years ago, the survey area was low and relatively flat. Some areas were under shallow seas, and some were coastal plains. Many layers of marine, coastal, and freshwater deposits accumulated during this time. The climate varied from tropical to arid. The only major feature to develop above the general surface of the land was the Uncompahgre upwarp, which started rising about 310 million years ago and has continued to do so, with the last rise occurring about 1 million years ago *(1, 2, 5, 8, 10, 11).*

As the Uncompahgre upwarp lifted, it divided a large shallow basin in the sea called the Paradox Basin. This basin gradually sank lower, and thousands of feet of salts accumulated in the basin as the sea water evaporated *(14).* Sediment that eroded from the Uncompahgre highland was deposited in the southwest, depressing and warping the underlying salt beds. The resulting subsurface salt flows and salt domes eventually led to the formation of "salt valleys" in the survey area. The Monument upwarp, which extends into the southwestern part of the area, was uplifted at the end of the Cretaceous period.

During the late Tertiary period, about 20 million years ago, the La Sal and Abajo Mountains were formed by laccolithic igneous intrusion *(17).* The overlying sedimentary beds were lifted, warped, and fractured, which accelerated erosion of the previously flat rock. Upturned hogbacks that flank the La Sal Mountains and sedimentary rock remnants interfingered with the intruded igneous rock on the mountain peaks. A gradual rise of the entire intermountain region began about 11 million years ago during the late Tertiary and eventually left the area lying more than a mile higher than it had been.

The slow but consistent uplift of the Colorado Plateau allowed the Green, Dolores, and Colorado Rivers to maintain their course and become progressively more entrenched in deep canyons *(6, 7).* Subsurface drainage along the crest of salt anticlines flowed toward the entrenched canyons and removed the soluble salt, which resulted in the collapse of the salt domes. Erosion then excavated the salt valleys common to the Paradox Fold and Fault Belt *(2, 9).*

The La Sal Mountains were glaciated at least nine times during the ice age, which was during the Pleistocene epoch of the Quaternary *(13).*

During the last 1 million years, cyclical climatic changes have resulted in periods of colluvial, fluvial, and eolian deposition alternating with periods of accelerated erosion. The soils that formed in these deposits have been greatly influenced by their relative age, the erosion and deposition, and the fluctuating climate. The canyons have continued to deepen at the rate of 500 to 800 feet per million years during the Quaternary, and the rate of scarp retreat has been about 800 to 1,800 feet during the same period.

Physiography, Drainage, and Relief

The survey area is near the center of the Canyon Lands section of the Colorado Plateaus physiographic province in southeastern Utah. Several distinct physiographic features occur within the survey area. Knowledge of these is important in understanding the soils and other natural resources of the area.

In general, the nearly horizontal sedimentary rock was deformed locally by anticlines, synclines, monoclines and igneous intrusions. Uplift of the Colorado Plateau and concurrent erosion has produced extensive canyon systems.

The dominant physiographic features are deep canyons, canyon walls of alternating erosion-resistant benches and highly erodible slopes, and broad benches that dip at a low angle to the northeast. Other distinctive features include salt anticlines and laccolithic mountains. The salt anticlines consist of linear, flat interior valleys bounded by steep escarpments with eroded hogbacks. The La Sal Mountains include three mountain masses around which the sedimentary rocks of the adjoining areas are sharply upturned. Aretes, cirques, moraines, U-shaped valleys, outwash fans, solifluction mantles, and landslides are common features of the once-glaciated mountains *(7)*.

The major drainageways in the survey area are the Green, Dolores, and Colorado Rivers. The Green River flows in a southeasterly direction along the western boundary of the survey area to its confluence with the Colorado River. The Dolores River flows to the northwest. It is north of the La Sal Mountains and flows along the toe of the Uncompahgre upwarp, from the Utah-Colorado state line in the northeastern tip of the survey area to the southwestern corner of the survey area. The Colorado River forms the survey area boundary from the Utah-Colorado state line to the San Juan County line and from its confluence with the Green River to the southwestern corner of the survey area. These major rivers and many of the tributaries flow through deep, narrow canyons. Other tributaries follow the broader salt valleys and are extensions of radial drainageways from the La Sal Mountains, which typify both Mill Creek and Placer Creek.

A unique drainage situation exists where a major river flows perpendicular to a salt anticline valley. The name "Paradox" was given to such a valley just east of the survey area in Colorado where the Dolores River flows across the valley rather than along its axis. The Moab-Spanish Valley area is a similar contradiction to the usual drainage pattern in a valley. Most of the drainageways in the survey area are intermittent. Runoff from intense summer thunderstorms is rapidly shed from barren Rock outcrop and produces flash floods in the dry washes and canyon bottoms. Drainageways in the La Sal Mountains have developed radially around the mountain groups. Several small perennial streams originate in these mountains and drain into the Colorado and Dolores Rivers. Most of these streams have been diverted for irrigation, leaving downstream areas dry in summer.

Elevation ranges from less than 4,000 feet on the canyon floors to nearly 13,000 feet at the peaks of the La Sal Mountains. The canyons have steep walls that vary from a few hundred feet to 2,000 feet high or more. The broad, nearly level benches extend for miles before being interrupted by a canyon more than 1,000 feet deep. The La Sal Mountains have rugged, steep slopes that grade to moraines and outwash fans that are deeply dissected by V-shaped canyons that extend to the surrounding tablelands.

Natural Resources

Soil, surface and ground water, natural vegetation, oil, natural gas, uranium, gold, silver, copper, potash, and scenic beauty are the major natural resources of the survey area.

Soil is the most widely used natural resource in the area. During summer, surface runoff from the La Sal Mountains is used extensively for irrigation of alfalfa, small grain, corn, and orchard crops. Water is pumped from the Colorado and Dolores Rivers to irrigate crops on adjacent flood plains. Wells and springs are important sources of water for domestic uses and for irrigation. Small seeps, springs, ephemeral streams, and potholes in the slickrock are important sources of water for livestock and wildlife.

The arid canyon floors and lower benches support sparse natural vegetation that provides limited livestock grazing if properly managed. The production of forage is much higher on the high mesas and mountainsides within the La Sal Mountains. Pinyon and Utah juniper woodlands provide firewood and fence posts. Engelmann spruce, subalpine fir, ponderosa pine, and quaking aspen on the La Sal Mountains historically provided some merchantable timber. Vegetation resources within the Manti-La Sal National Forest are now managed to support watershed function and other multiple uses.

In 1960 oil and gas were discovered in the Lisbon Field south of La Sal, in San Juan County. This field has produced 40 million barrels of oil and 300 billion cubic feet of gas *(3).* Gold, silver, and copper have been mined in the La Sal Mountains, in Lisbon Valley, and in the alluvium along the Colorado and Dolores Rivers, but they are of little economic importance at present *(15).* Large deposits of uranium are present in the survey area. More than 40,000 tons of uranium oxide has been produced, about 75 percent of which was extracted in the Lisbon Valley mining district *(4).* Potash is mined from the evaporite deposits of the Paradox Formation on the northeastern flank of the Cane Creek anticline, about 7 miles southwest of Moab *(12).*

The scenic and recreational value provided by the natural rock formations, the rivers flowing through the deep canyons, and the snow-capped mountains attracts thousands of visitors to the survey area each year. Campsites, picnic areas, biking and hiking trails, four-wheel drive trails, and other facilities have been developed in the Canyonlands National Park, Dead Horse Point State Park, and Manti- La Sal National Forest and on lands administered by the Bureau of Land Management. Many people float on the Green and Colorado Rivers through Cataract and Westwater Canyons and in other sections of these rivers each year.

General Soil Map Units

The following discussion for General Soil Map Units is taken with slight modification from the 1991 NRCS Soil Survey of Canyonlands Area, Utah, Parts of Grand and San Juan Counties, pages 7 through 15.

The General Soil Map for the Moab Area Watersheds for Mill Creek and Placer Creek is shown in Figure 2. The General Soil Map shows broad areas that have a distinctive pattern of soils, relief, and drainage. Each soil map unit on the general soil map is a unique natural landscape. Typically, a map unit consists of one or more major soils or miscellaneous areas and some minor soils or miscellaneous areas. It is named for the major soils or miscellaneous areas. The soils or miscellaneous areas making up one unit can occur in other units but in a different pattern.

The general soil map can be used to compare the suitability of large areas for general land uses, such as managing land resource functions for watershed planning. Areas of suitable soils or miscellaneous areas can be identified on the map. Likewise, areas that are not suitable can be identified.

Because of its small scale, the map is not suitable for small scare planning (e.g., the management of a farm or field or for selecting a site for a road or building or other structure). The soils in any one map unit differ from place to place in slope, depth, drainage, and other characteristics that affect management.

The general map units in this survey (Figure 2) have been grouped into general kinds of landscape for broad interpretive purposes. Each of the broad groups and the map units in each group are described below:

FIGURES

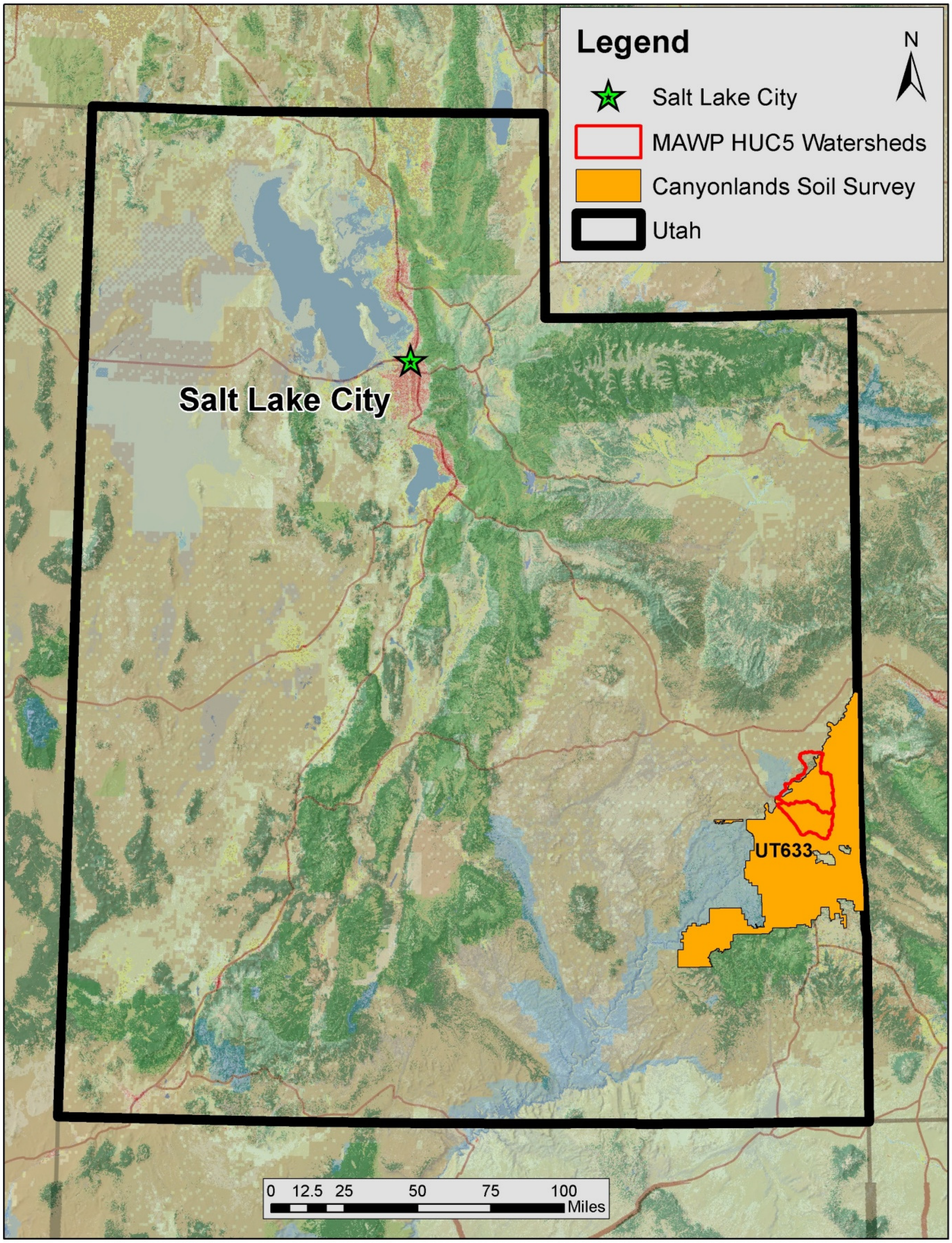

Figure 2.5.1: Location of UT633 Soil Survey of Canyonlands Area, Utah, Parts of Grand and

San Juan Counties

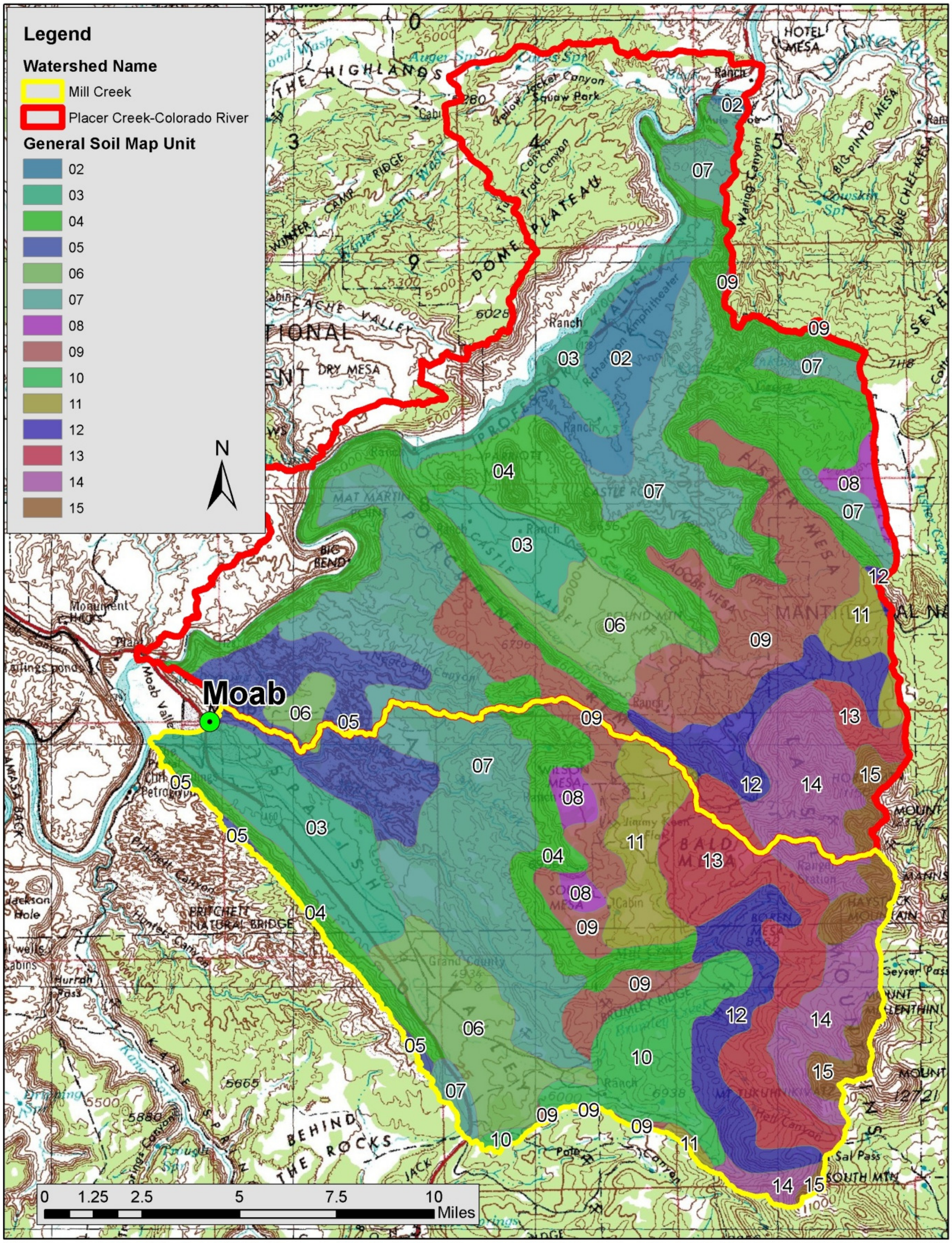

Figure 2.5.2: Moab Area Watersheds, NRCS Canyonlands, Parts of Grand and San Juan

Counties Soil Survey General Soil Map Units.

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Section 2.6 Wildlife

The Mill Creek and Castle Creek watersheds are home to diverse wildlife due to the varied zones of vegetation (habitat) and elevations found across this unique landscape. The headwaters begin at elevations over 11,000 feet which is considered the alpine community. The habitat found in this community supports marmots, blue grouse, weasels, American pika and other small wildlife and is often used seasonally in the summer by deer, elk, coyote, and bobcat. Descending the watershed to the mixed conifer community, black bear, red crossbill, warbling vireo, yellow-rumped warbler, chipmunk, mountain chickadee and pine siskin can be found in addition to the species listed above. Entering the aspen community, even more diversity can be found with supportive habitat for northern goshawk, three-toed woodpecker, house wren and downy woodpecker. Descending even further, below 9,000 feet, the ponderosa pine and mountain brush communities are home to pygmy nuthatch, spotted towhee, Stellar's jay, Virginia's warbler, western bluebird, flammulated owl, Williamson's sapsucker, spotted bat, Townsend's big eared bat, Abert's squirrel, porcupine, chipmunk, white-crowned sparrow, kestrel, band-tailed pigeon, northern flicker, scrub jay, coyote, mule deer, bobcat and weasel. Below the mountain brush community is the juniper/pinyon community and desert shrub habitat. While many of the species already listed are also found in these communities, especially in winter, there a few that are unique to these lower areas. For instance the habitat provided in the juniper/pinyon community supports black-throated gray warbler, blue-gray gnatcatcher, broad-tailed hummingbird, common bushtit, dusky flycatcher, green-tailed towhee, mountain lion and jackrabbit. The lowest vegetation zone of the watershed is known as the desert shrub habitat where typical wildlife residents include collared lizards, whiptail lizards, side-blotched lizard, gopher snake, cottontail rabbit, bushytail woodrat, ord kangaroo rat, rock squirrel and a variety of birds such as the robin, vesper sparrow, golden eagle and the red-tailed hawk. [1]

It is also very important to note that the riparian zones of both Mill Creek and Castle Creek provide wildlife corridors, habitat and water supply for all wildlife. Common species of the riparian zone include kingfisher, killdeer, western wood-pewee, yellow warbler, red-wing blackbird, black-headed grosbeak, lazuli bunting, song sparrow, raccoon, beaver, pheasants and garter snakes. Wild turkeys can also be seen along these riparian corridors and in some areas there are populations of leopard frogs and other native amphibians.

In early September 2013 the State of Utah Division of Wildlife Resources introduced Rocky Mountain Goat into the La Sal Mountains at the headwaters of Mill Creek and Castle Creek watershed.

2.6.1 Scott M. Matheson Wetlands Preserve

The 895-acre Scott M. Matheson Wetlands Preserve is located in the Mill Creek watershed at the confluence of Mill Creek and the Colorado River. This wetland is a result of a flooded bottomland meander and is the largest intact wetlands along the Colorado River in Utah.[2] The preserve is maintained by the Nature Conservancy of Utah and the Utah Division of Wildlife Resources. This wetland houses over 200 species and is an important habitat for migratory birds. The Nature Conservancy's 2003 Fire Response Plan states "Over 247 terrestrial vertebrates have

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[1] Moab Face Landscape Assessment. Moab Ranger District. Manti-La Sal National Forest Continuing Education in Ecosystem Management Team. May 7-May 18, 2001. Pg. 26-27

[2] Scott M. Matheson Wetlands Preserve Wildfire Response Plan. The Nature Conservancy of Utah 2003. Pg 2.

been recorded in the preserve with the majority being avian species. The avian fauna changes seasonally and is defined by wintering species, seasonal migrations of waterfowl and shorebirds, summer nesting neotropical migrants, and year-round residents." [3]

2.6.2 Endangered, Threatened and Sensitive Species of the Moab Area Watershed

The Mill Creek and Castle Creek watersheds provide habitat for species listed as endangered, threatened, species of special concern and species listed on the *Utah Sensitive Species List*. The following tables compile the animals (Table 2.6.1) and plants (Table 2.6.2) acknowledged on lists provided by the Utah Division of Wildlife Resources (UDWR) for the planning area identified as Township 24-27 South, Range 21-24 East, SLB&M, in Grand County and San Juan County, Utah (2013) and by the U.S. Fish and Wildlife (2011). The tables were then further developed based on observations and recommendations from land managers in the Mill Creek and Castle Creek watersheds. All species listed in these tables must be taken into consideration during planning and project implementation.

Except for the threatened plant, Jones cycladenia, none of the following species are known to have breeding populations in the Mill Creek or Castle Creek watersheds. The four endangered Colorado River fish occur downstream in the larger rivers.

[3] Scott M. Matheson Wetlands Preserve Wildfire Response Plan. The Nature Conservancy of Utah 2003. Pg 3.

Table 2.6.1 Animal Species list as endangered, threatened or sensitive.

Scientific Name	Common Name	Listing	Listing Type
Coccyzus Americanus	Yellow-billed cuckoo	Candidate	Federal
Empidonax Traillii Extimus	Southwestern willow flycatcher	Endangered	Federal
Xyrauchen Texanus	Razorback sucker	Endangered	Federal
Strix Occidentalis Lucida	Mexican spotted owl	Threatened	Federal
Gila Cypha	Humpback chub	Endangered	Federal
Ptychocheilus Lucius	Colorado pikeminnow	Endangered	Federal
Gila Elegans	Bonytail chub	Endangered	Federal
Idionycteris Phyllotis	Allen's big-eared bat	Sensitive Species	State
Picoides Tridactylus	American three-toed woodpecker	Sensitive Species	State
Pelecanus Erythrorhynchos	American white pelican	Sensitive Species	State
Nyctinomops Macrotis	Big free-tailed bat	Sensitive Species	State
Catostomus Discobolus	Bluehead Sucker	Sensitive Species	State
Elaphe Guttata	Cornsnake	Sensitive Species	State
Buteo Regalis	Ferruginous Hawk	Sensitive Species	State
Catostomus Latipinnis	Flannelmouth Sucker	Sensitive Species	State
Cynomys Gunnisoni	Gunnison prairie-dog	Sensitive Species	State
Melanerpes Lewis	Lewis's woodpecker	Sensitive Species	State
Accipiter Gentilis	Northern goshawk	Sensitive Species	State
Gila Robusta	Roundtail chub	Sensitive Species	State
Euderma Maculatum	Spotted bat	Sensitive Species	State
Mustela Nigripes	Black-footed ferret	Sensitive Species	State
Opheodrys Vernalis	Smooth greensnake	Sensitive Species	State

http://dwrcdc.nr.utah.gov/ucdc/viewreports/sscounty.pdf

Table 2.6.2 Plant species list as endangered, threatened or sensitive.

Scientific Name	Common Name	Listing	Listing Type
Cycladenia Jonesii	Jones Cycladenia	Threatened	Federal

http://dwrcdc.nr.utah.gov/ucdc/viewreports/te_cnty.pdf

Other Links
http://wildlife.utah.gov/education/newsletters/95winter-gw.pdf
http://extension.usu.edu/utahrangelands/files/uploads/RRU_Section_Seven_Zones.pdf
http://www.ut.nrcs.usda.gov/technical/nri/RA-data/Grand_Res_Assmnt.pdf (pg14)
Scott M. Matheson Wetlands Preserve Wildfire Response Plan
http://www.tncfiremanual.org/MoabWildfireResponsePlan.pdf (pg 2-3)

2.7 Regional Demographic Trends

A better understanding of the area's water needs/impacts can be gained with an awareness of local and regional demographic patterns. Grand and San Juan counties' populations are generally small and rural in zero to low growth conditions. These populations are expected to expand only slightly during the 2014 to 2030 period. In Grand County approximately 1/3 of the population is less than 25 years of age. Grand County's active seniors (ages 55 to 64 years) are expected to double during the 2014 to 2018 period. Long term population growth projections suggest that slight to moderate increases will occur during the next 20 years. An additional 5,000 residents in Grand and San Juan counties are expected to be added from 2014 to 2030.

Source: Governor's Office of Planning and Budget

Population Projections by Component

Population growth by component yields a more accurate understanding of the influences on growth. During the 2014 to 2030 period population increases in Grand and San Juan counties will come at a very slight pace. During the next several years growth in Grand County comes primarily from inbound migration to the county. In ensuing years growth occurs primarily due to the relatively consistent natural rate of births amongst county residents. In San Juan County, an out-flux of migration from the county will lessen overall growth through 2020. From 2020 to 2030 the natural birth rate will be account for the growth expected in the county. Once again, population growth in both counties is projected to be less that 1% annually.

Births Deaths Migration Source: Governor's Office of Planning and Budget & LatentSEA

Household Projections

The number of households in Grand County is expected to increase by approximately 60 households per year through 2030. In San Juan County the annual increase in households from 2014 to 2030 is projected to be 80 to 90 households. However, only a small amount of the San Juan County household increase will take place in Spanish Valley. Thus, there will be a slight demand in the housing inventory in both counties over the next 20 years.

Source: Governor's Office of Planning and Budget

Statewide Tourism Indicators

Tourism is a major part of the economic vitality and growth to areas of interest. Grand and San Juan counties are host to national parks of national and international interest. Two dominant drivers of tourism and visitation to the state of Utah are ski destinations and unique geological features found in and around national parks. National parks visitation in Utah has consistently exceeded 5 million visitors during the last decade; with some decline the year Salt Lake City hosted the Olympics. As expected hotel room rents in Utah have increased at an annual increase of 5 percent since 1998.

Source: Governor's Office of Planning and Budget

Regional Tourism

Grand and San Juan counties are the homes of two popular national parks, Arches National Park and Canyonlands National Park. Arches National Park has consistently hosted from 700,000 to 800,000 visitors annually during the last decade. The City of Moab has benefitted from its proximity to Arches and the presence of Slickrock, perhaps the most renowned mountain bike destination in the world. Canyonlands National Park annual visitation trends are consistently above 350,000 visitors. The impact of tourism on the local economy in Grand County is demonstrated in traveler spending with in excess of $250 million occurring annually. According to recent adjusted economic models, tourism and travel are responsible for 5,000 jobs in the county. Hotel accommodation room tax collections have exceeded $1 million in Grand County; further verifying the impact of travel and tourism in Grand County. Although on a smaller scale, travel and tourism has a positive impact on the local economy. Traveler spending in San Juan County has exceeded $60 million annually in recent years. Tourism and travel is also responsible for 1,200 + jobs in San Juan County in recent years. Hotel accommodation revenues have been growing since 2003 and contribute more than $200,000 in tax collections annually.

Source: Governor's Office of Planning and Budget

2.8 Water Rights and Owners

Not available at time of publication

2.9 Land Use

2.9.1 Historical Use

Not available at time of publication

2.9.2 Current Land Use and Trends

Not available at time of publication

Chapter 3. Water Quality Summary

Water quality refers to the physical, chemical and biological characteristics of water. Water quality information can be used to assess the ability of surface water to meet requirements for a variety of beneficial uses ranging from drinking water, contact recreation, and aquatic wildlife habitat requirements. Water quality is often framed in context of measureable concentrations of contaminants. (See Section 3.2 for more information on beneficial uses).

Water quality is evaluated and affected by a complex web of chemical, physical and biological processes. A diverse variety of human activities can affect water quality in ways that aren't always obvious. The impacts to water quality from human activities are dependent on the type of activity, its timing, location, duration and intensity. All activities within the watershed have the potential to affect water quality and contribute wide-ranging pollutants to the stream system. Pollutant concentrations can vary by season, by day, and sometimes from hour to hour making it difficult to measure water quality. This makes it critical to build a data set over time in order to assess water quality under varied conditions.

3.1 Water Quality Regulations

Utah is the second driest state in the nation making water a highly valued and sought after resource. As a public resource, it is the responsibility of the State to evaluate and maintain water quality. Public Law 92-500, the Federal Water Pollution Control Act (commonly referred to as the Clean Water Act), enacted by Congress in 1972 and amended in 1977 and 1981, provides a national framework for water quality protection. The Clean Water Act recognizes that it is the primary responsibility of the States to prevent, reduce and eliminate water pollution; to determine appropriate uses for their waters and to set water quality criteria to protect those uses. Section 303(d) of the Clean Water Act requires that each state reviews and, if necessary, revises its Water Quality Standards at least once every three years. This serves to ensure that the requirements of State and Federal law are met and that water quality criteria are adequate to protect designated water uses. A list of water quality standards and pollutant criteria can be found in Rule R317-2 of the Utah Administrative Code.

3.2 Beneficial Use

The Division of Water Quality is responsible for assessing all streams, rivers, lakes and reservoirs in the state and categorizing them according to their beneficial use. Water quality standards are directly associated with these uses and therefore limitations for pollutants are created according to each waterbody's beneficial use.

Mill Creek and its tributaries from the confluence with the Colorado River to the headwaters are protected for the following beneficial uses: 1C – domestic source water, 2B-secondary contact recreation, 3A-coldwater fishery and 4-agriculture. Castle Creek from its confluence with the Colorado River to the headwaters is protected for the following beneficial uses: 2B-secondary contact recreation, 3B-warmwater fishery and 4-agriculture. Ken's Lake is protected for the following beneficial uses: 2B-secondary contact recreation, 3A-coldwater fishery and 4-agriculture (Standards of Quality for Waters of the State §R317-2, UAC). A full description of all beneficial uses is provided below in Table 3.2.1.

Table 3.2.1 Use designations for the State of Utah and their definitions

Use Designation	**Definition of Uses**
Class 1	Protected for use as a raw water source for domestic water systems
Class 1C	Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water
Class 2	Protected for recreational use and aesthetics.
Class 2A	Protected for frequent primary contact recreation where there is a high likelihood of ingestion of water or a high degree of bodily contact with the water. Examples include, but are not limited to, swimming, rafting, kayaking, diving, and water skiing.
Class 2B	Protected for infrequent primary contact recreation. Also protected for secondary contact recreation where there is a low likelihood of ingestion of water or a low degree of bodily contact with the water. Examples include, but are not limited to, wading, hunting, and fishing.
Class 3	Protected for use by aquatic wildlife.
Class 3A	Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Class 3B	Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain.
Class 3C	Protected for nongame fish and other aquatic life, including the necessary aquatic organisms in their food chain.
Class 3D	Protected for waterfowl, shore birds and other water-oriented wildlife not included in Classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain.

Class 3E	Severely habitat-limited waters. Narrative standards will be applied to protect these waters for aquatic wildlife.
Class 4	Protected for agricultural uses including irrigation of crops and stock watering.

3.3 Known and Potential Pollutants

Both Mill Creek and Castle Creek, the two main drainages in the watersheds being assessed in this plan, have been listed on Utah's 303(d) list. As shown in Table 3.3.1, Mill Creek, along with its main tributary Pack Creek, have been listed for exceeding standards set for total dissolved solids and temperature. A Total Maximum Daily Load (TMDL) was completed in 2002. Castle Creek was listed on Utah's 303(d) list for total dissolved solids and a TMDL was completed in 2004.

Table 3.3.1 303 (d) listed streams in the Mill Creek and Castle Creek Watersheds

Management Unit	Water Body Name	HUC Unit	Impaired Beneficial Use	Perennial Stream Miles	Cause
Southeast Colorado	Mill Creek	14030005-005	3A	41.14	Temperature
Southeast Colorado	Mill Creek	14030005-005	4	41.14	Total Dissolved Solids
Southeast Colorado	Castle Creek	14030005-009	4	11.88	Total Dissolved Solids

In addition to these main drainages in the two watersheds, Ken's Lake, a water storage reservoir in the Mill Creek Watershed has been listed for exceeding the temperature standards for cold water fisheries (See Table 3.3.2). A TMDL was completed for this reservoir in 2002.

Table 3.3.2 303 (d) listed reservoirs

Management Unit	Type of Water Body	Water Body Name	HUC Unit	Impaired Beneficial Use	Cause
Southeast Colorado	Reservoir	Ken's Lake	14030005	3A	Temperature

3.3.1 Point Source and Non-Point Source Pollution

Pollutants come from a variety of sources within a watershed, some of which are more easily identifiable and some which are not. Point source pollution refers to contaminants that are directly discharged into a waterbody through an obvious point of disposal. Waste water, or grey water, from industrial manufacturing, sewer treatment facilities and mining operations are commonly used as examples for point source pollution. Because these sources are more easily identifiable they are also more easily and heavily regulated by federal, state and local laws. Point source discharge permits must be obtained from the Utah Division of Water Quality and strict monitoring is required to ensure all beneficial uses are being met.   No point source inputs have been identified as contributing to the impairments in the Mill Creek or Castle Creek watersheds.

Non-point source (NPS) pollution refers to contaminants that come from a wide range of diffuse sources. NPS pollution can be natural or human-caused. Natural sources are often referred to as "background" sources and include naturally occurring salts in local soils, geology and springs.[4] Human-caused nonpoint sources of pollution can include storm water runoff and erosion caused by recreational activities.

Non-point source pollution is the result of a variety of activities taking place across the whole watershed and is harder to regulate. The main mechanism for pollutants entering Mill Creek and Castle Creek is through NPS inputs. Despite the widespread concern over toxic substances in our streams, the leading pollution concerns in the Moab area watersheds are total dissolved solids (TDS) and increasing water temperatures. The cumulative effects of excessive amounts of these naturally occurring substances/conditions are exacerbated by the reduction in stream flows. Sediment and diminishing summertime flows are also an issue for this watershed and could potentially be contributing to these impairments

3.3.2 Water Quality Standards

Utah water quality standards (State of Utah, 2000, UAC R317-2) and the 303(d) listing criteria provide the criteria to make an initial assessment of water quality conditions.

Utah's Standards of Quality for Waters of the State (§R317-2, UAC) establishes numeric criteria for beneficial use 3A (cold water game fish) including; pH, dissolved oxygen, and temperature. The temperature criterion for cold water game fish is a maximum of 20 degrees Celsius. (See Table 3.3.3)

Table 3.3.3 Numeric Criteria for Aquatic Life

Parameter	Aquatic Wildlife 3A
Maximum Temperature (C◦)	20
Maximum Temperature Change (C◦)	2

Additional criteria are used to determine the degree of beneficial use support. Utah's 303d List provides guidance on how to apply the numeric water quality criteria for determining the degree of beneficial use support. These criteria are used to evaluate the listing and delisting of a water body. The 303(d) criterion for assessing the degree of support for beneficial use Class 3A is provided in Table 3.3.4

Table 3.3.4 303(d) Criteria for Assessing Aquatic Life - Beneficial Support Class 3A

Degree of Use Support	Conventional Parameters (pH, DO, Temperature)
Full Support	For any one pollutant, no more than one exceedence of a criterion or criterion exceeded in <10% of the samples, if there were two or more exceedences.
Partial Support	For any one pollutant, criterion was exceeded two times, and criterion was exceeded in more than 10% but not more than 25% of the samples.
Non-Support	For any one pollutant, criterion was exceeded two times, and criterion was exceeded in more than 25% of the samples.

The Utah water quality standards establish a numeric criterion of 1,200 mg/L TDS for Class 4 waters, for protection of their agricultural beneficial use. In addition, the Utah water quality standards also provide numeric criteria for pH, boron, and metals as summarized in Table 3.3.5

Table 3.3.5Utah 303(d) Criteria for Class 4 Waters

Parameter	Criterion Maximum Concentration
Target Parameters*	
Total Dissolved Solids	1,200 mg/L
Secondary Parameters**	
PH	6.5-9.0 pH units
Boron	0.75 mg/L
Arsenic	0.10 mg/L
Cadmium	0.01 mg/L
Chromium	0.10 mg/L
Copper	0.20 mg/L
Lead	0.10 mg/L
Selenium	0.05 mg/L

Notes: * Utah WQS clarify that TDS limits may be adjusted if such adjustment does not impair the designated beneficial use of the receiving water.

** Metals criteria as dissolved maximum concentration.

Additional criteria are used to determine the degree of beneficial use support. Utah's 303d List provides guidance on how to apply the numeric water quality criteria for determining the degree of beneficial use support. These criteria are used to evaluate the listing and delisting of a water body. The 303(d) criterion for assessing the degree of support for beneficial use Class 4 is provided in Table 3.7

Table. 3.3.6 303 (d) Criteria for Assessing Agricultural Beneficial Use Support

Degree of Use Support	Conventional Parameter (TDS-1,200 mg/L)	Toxic Parameters
Full	Criterion exceeded in less than two samples and in <10% of the samples if there were two or more exceedences.	For any one pollutant, no more than one violation of criterion.
Partial	Criterion was exceeded two times, and criterion was exceeded in more than 10% but not more than 25% of the samples.	For any one pollutant, two or more violations of the criterion, but violations occurred in less than or equal to 10% of the samples.
Non-support	Criterion was exceeded two times, and criterion was exceeded in more than 25% of the samples.	For any one pollutant, two or more violations of the criterion, and violations occurred in more than 10% of the samples.

3.3.2.1 Relation of Total Dissolved Solids to Beneficial Uses

TDS is listed as a criterion for protection of agricultural uses because of the negative effect of high salinity on crop production. The major components of salinity are the cations: calcium, magnesium, and sodium; and the anions: chlorine, sulfate, and bicarbonate. The potassium and nitrate ions are minor components of salinity. Salinity reduces crop growth by reducing the ability of plant roots to absorb water, and is evaluated by the relationship of salt tolerance to crops. Unlike salinity hazard, excessive sodium does not impair the uptake of water by plants, but does impair the infiltration of water into the soil. The growth of plants is, thus, affected by an unavailability of water. The reduction in infiltration of water can usually be attributed to surface crusting, the dispersion and migration of clay into the soil pores, and the swelling of expandable clays. The hazard from sodium is evaluated using the Sodium Absorption Ratio (SAR), a ratio of sodium to calcium and magnesium in the irrigation water; in relation to the irrigation water TDS (Tanji, 1990). Boron is the primary toxic element of concern in irrigation waters. Boron is an essential trace element at low concentrations, but becomes toxic to crops at higher concentrations. Other trace elements, as listed in the table above, are potentially toxic to plants and animals. High pH (pH > 9.0) directly and adversely affects infiltration as well as limiting calcium concentrations and high SAR. Therefore, in addition to evaluating TDS, the listed TMDL pollutant, a water quality assessment for protecting the agricultural beneficial use may also consider assessment of sodium, SAR, boron, pH, and other toxic metals. This additional assessment may be of particular interest if the source of TDS is primarily a natural source and does not impair agricultural uses. As identified in the Utah Water Quality Standards, the 1,200 mg/L limit "may be adjusted if such adjustment does not impair the designated beneficial use of the receiving water".

3.4 The TMDL Process

Water quality standards are set by States, Territories, and Tribes. They identify the scientific criteria to support a waterbody's beneficial uses such as for drinking water supply, contact recreation (swimming), and agricultural uses (including irrigation of crops and stock watering). A TMDL or Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. As part of the TMDL process, the maximum amount of the parameter of concern is allocated to its contributing sources. Therefore, a TMDL is the sum of the allowable loads of the parameter of concern from all contributing point and nonpoint sources. The calculation must include a margin of safety to account for future growth and changes in land use, uncertainties in data collection, analysis, and interpretation.

The Clean Water Act, Section 303(d), establishes the TMDL program. Section 303(d) and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130), requires that States report waterbodies (i.e., lakes, reservoirs, rivers, and streams) that currently do not meet water quality standards for their designated beneficial use(s). EPA regulations require that each State submit a prioritized list of waterbodies to be targeted for improvement to EPA every two years. These regulations also require States to develop TMDLs for those targeted waterbodies. Thus, those waterbodies that are not currently achieving, or are not expected to achieve, applicable water quality standards are identified as water quality limited. Waterbodies can be water quality limited due to point sources of pollution, nonpoint sources of pollution, or both. Examples of pollutants that can cause use impairment include chemicals, pathogens, and other load parameters (e.g., TDS) for which there are numeric standards. In addition to pollutants, impairments may originate from sources such as habitat alteration or hydrologic modification that have associated narrative standards. Section 303(d)(1)(A) and the implementing regulations (40 CFR 130.7(b)) provide States with latitude to determine their own priorities for developing and implementing TMDLs.

Once a waterbody is identified as water quality limited, the State, Tribe, or EPA is required to determine the source(s) of the water quality problem and to allocate the responsibility for controlling the pollution. The goal of the TMDL is reduction in pollutant loading necessary for a waterbody to meet water quality standards and support its beneficial uses. This process determines: 1) the amount of a specific pollutant that a waterbody can receive without exceeding its water quality standard or impair a beneficial use; 2) the allocation of the load to point and nonpoint sources; and 3) a margin of safety. While the term TMDL implies that the target load (loading capacity) is determined on a daily time scale, TMDLs can range from meeting an instantaneous concentration (e.g., an acute standard) to computing an acceptable load to a water body.

Mill Creek was listed on Utah's 1998 303d list for waters requiring the development of a TMDL due to the exceedances of the coldwater fishery temperature criteria for beneficial use 3A and the exceedance of Total Dissolved Solids (TDS) criteria for beneficial use 4 (agricultural use). Castle Creek was listed due to the exceedances of Total Dissolved Solids criteria for beneficial use 4 and Ken's Lake was listed for exceedances of coldwater fishery temperature criteria for beneficial use 3A.

3.5 Current Quality Monitoring Programs

3.5.1 Intensive Monitoring Program

The State of Utah Division of Water Quality conducts targeted intensive chemical and physical ambient water monitoring in the State's five major watersheds. The program rotates annually between the five basins sampling each basin October through September every five years. The Southeast or Colorado River Basin was sampled intensively in 1997 -1998, 2002 – 2003, 2007 – 2008, and 2012 - 2013. Mill Creek and Castle Creek watersheds were included in those sampling efforts. The sites are sampled monthly for field parameters, flow, nutrients anions, cations, and standard water characteristics. Metals are sampled for quarterly. Sites varied over the years as data needs and issues varied. The sites that have been sampled and the periods they were sampled are shown in Table 3.5.1. A summary of the results for all sampling periods through 2008 is presented in Appendix A. The results from the 2012-2013 sampling period are not available at this time.

Table 3.5.1 Intensive monitoring stations and their sampling period					
Station Id #	Station Description	1997-1998	2002-2003	2007-2008	2012-2013
Mill Creek Watershed					
4956360	Mill Ck Bl Cnfl / Pack Ck at 500W Xing		X		X
4956390	Mill Ck at 100 S & 100 W Moab	X	X	X	
4956393	Mill Ck at Mill Creek Drive Xing				X
4956395	Mill Ck Above Moab				X
4956430	South Fk Mill Creek ab North Fk				X
4956410	North Fk Mill Creek ab South Fk				X
4956399	Mill Ck 3/4 MI ab Ken's Lake Diversion				X
4956400	Mill Ck at USFS Bndy	X	X		
4956435	Mill Ck 1 Mile Ab La Sal Loop Rd				X

4956440	Mill Ck at Power Dam				
4956455	Pack Ck ab CNFL w/ Mill Ck @ end of 200 S				X
4956460	Pack Ck at U91 Xing	X	X	X	
4956480	Pack Ck at USFS Bndy and Brumley rd	X	X	X	
4956490	Pack CK at Mill Creek Drive Xing				X
4956485	Pack CK 2 MI ab cnfl/ Brumley CK				X
4956510	Pack Ck at Pack Creek Campground				X
4956530	Pack Ck at Spanish Trail Drive Xing		X	X	X
Castle Creek Watershed					
4958030	Castle Ck at U128 Xing	X	X	X	X
4958070	Castle Valley Ck at Castleton		X	X	X
4958085	Castle CK at Bridge Crossing of Castle Valley				X
4958075	Castle CK ab USFS Rd Xing to CO				X

3.5.2 Bacteriological Monitoring

The State has encouraged a cooperative bacteriological monitoring program for targeted waterbodies that have high recreational (swimming) use. Sampling occurs bi-weekly from May through September and are collected and analyzed locally for total coliform and escheria coliform. Samples from the Mill Creek watershed and Kens Lake are collected by the Grand and San Juan County Watershed Coordinator and analyzed at the Bureau of Land Management office in Moab. Sites that were collected in 2013 are listed in Table 3.5.2.

Table 3.5.2 2103 Bacteriological Monitoring sites	
Station Id	Station Description
5958510	Kens Lake West Side
5958510	Kens Lake South East Side
4959440	Mill Creek @ Power Dam
4956393	Mill Creek At Mill Creek Drive Xing
4956455	Pack Creek Above Confluence with Mill Creek
4956510	Pack Ck @ Pack Creek Campground on Murphy Lane
4956530	Pack Creek At Spanish Trail Drive Xing

3.5.2.1 Bacteriological Monitoring Data Summary

The bacteriological data for sites sampled in 2013 are summarized in the tables below. Kens Lake and Mill Creek are classified as recreational use class 2B; protected for infrequent primary contact recreation. Also protected for secondary contact recreation where there is a low likelihood of ingestion of water or a low degree of bodily contact with the water. Examples include, but are not limited to, wading, hunting, and fishing. As such the Escheria Coliform standards are a geometric mean of 206 and a maximum of 668 coliforms per 100 ml.

Table 3.5.3 2013 Escheria Coliform Data Summary				
Station Name	Station Id	Geometric Mean Escheria Coliform	Max Escheria Coliform	Min Escheria Coliform

Kens Lake West Side	5958510	3	25	0
Kens Lake South East Side	5958510	5	61	0
Mill Creek At Mill Creek Drive Xing	4956393	318	770	216
Mill Creek @ Power Dam	4959440	25	118	10
Pack Creek Above Confluence with Mill Creek	4956455	>1605	>2419	816
Pack Ck @ Pack Creek Campground Murphy Ln	4956510	962	1733	613
Pack Creek At Spanish Trail Drive Xing	4956530	275	517	172

The State also conducted bacteriological monitoring in September 2013. During the last intensive monitoring run they sampled all the sites on the run. The E. Coliform results are listed in the Table 3.5.4 below.

Table 3.5.4 2013 Intensive Sampling Escheria Coliform Results

Station Name	Station Id	Escheria Coliform
Mill Ck bl Pack Ck	4956360	>2419.6
Mill Ck ab Moab	4956395	104.6
Mill Ck ab N Fk Mill Ck	4956430	88.6
N Fk Mill Ck ab Mill Ck	4956410	95.9
Mill ck ab Sheely Tunnel	4956399	21.3
Mill Ck 1 Mi ab La Sal Loop Rd	4956435	12.2
Pack ck @ mill Ck Dr	4956490	1553.1
Pack Ck ab Cnfl/ Brumley Ck	4956485	11
Castle Ck @ Bridge to CV	4958085	>2419.6
Castle Ck at Castleton	4958070	51.2
Castle Ck at USFS BNDY	4958075	16.9

In 2011 and 2012 coliform sampling in the MAWP watershed was performed by the Watershed Coordinator in cooperation with the BLM. The results of that sampling are summarized in Table 3.5.5 below.

Table 3.5.5 2011 and 2012 Escheria Coliform Result Summary

Station Name	Station Id	Geometric Mean Escheria Coliform	Max Escheria Coliform	Min Escheria Coliform
Kens Lake West Side	5958510	1.82	884.63	0
Kens Lake South East Side	5958510	2.26	666.20	0
Mill Ck Bl Sheley Div	4956400	14.80	37.90	8.60
Mill Creek ab Power Dam	4956440	>72.43	>1463.80	16.00
Mill Creek bl Power Dam	4956395	73.14	1413.60	16.10

Prior to 2011 the BLM was sampling for Fecal Coliform in the MAWP watershed. The results of that sampling are summarized in Table 3.5.6 below.

Table 3.5.6 2006 Through 2009 Fecal Coliform Result Summary				
Station Name	Station Id	Geometric Mean Fecal Coliform	Max Fecal Coliform	Min Fecal Coliform
Kens Lake West Side	5958510	1.74	30.00	0
Kens Lake South East Side	5958510	4.68	312.00	0
Mill Ck Bl Sheley Div	4956400	12.08	77.00	5.00
Mill Creek bl Power Dam	4956395	17.14	124.00	1.00

3.5.3 Other Monitoring Programs

There are several other monitoring programs that have sampled sites in the Mill Creek and Castle Creek watersheds. The EPA sponsored Environmental Monitoring and Assessment Program (EMAP) began sampling in 2001. The EMAP program involved several western states and the document "An Ecological Assessment of Western Streams and Rivers" can be found at: http://www.epa.gov/region8/water/emap/EMAP_West_Assessment_100305.pdf. The EMAP monitoring protocol consists of sampling water for chemical and physical parameters, macroinvertebrate sampling, algal sampling, coliform sampling, fish counts and tissue sampling, and physical habitat sampling. The EMAP program was a demonstration project and was replaced by the National River and Stream Assessment program.

The National River and Stream Assessment program was initiated by the EPA and modeled after the EMAP program. The program samples the same constituents as the EMAP program and uses the same protocols for monitoring. The EPA is the caretaker for the data for both programs. The EPA uses the data from these programs to assess water quality on a regional basis. The data is not used to assess individual waterbodies. Both EMAP and NRSA have probabilistic monitoring strategies that pick sites randomly as opposed to the targeted sampling strategies.

The Utah Classification and Stream Assessment program (UCASE) is modeled after the EMAP and NRSA program. The sampling strategy is probabilistic and similar constituents are monitored. The DWQ is the caretaker for that data and uses it to assess waterbodies in the State. Currently the macroinvertebrate community is compared to "reference sites" that have similar climate and geographic characteristics and have not been subjected to anthropogenic disturbance. Monitoring locations associated with these sampling programs are listed in Table 3.5.7

Table 3.5.7 EMAP, NRSA, and UCASE Sampling locations in Mill Creek and Castle Creek				
SITE ID	Site Description	Date Sampled	Program	Comments
4956395	Mill Ck Above Moab	8/1/2001	EMAP	
4956435	Mill CK 1 Mile Ab La Sal Loop Rd	10/5/2004, 10/8/2009, 9/14/2011	UCASE	
4956399 /RUT9089	Mill CK 3/4 MI ab Ken's Lake Diversion	9/20/2006, 10/24/2007, 6/3/2009	UCASE/ NRSA	Same coordinates as 4956399

4956480	Pack Ck at USFS Boundary and Brumley rd	10/24/2007	UCASE	
UT070	Pack Ck	6/4/2009	NRSA	N 38.54468, W -109.50484; Boger Property
4956485	Pack CK 2 MI ab cnfl/ Brumley CK	8/31/2009, 9/14/2011	UCASE	
4958075	Castle Ck ab USFS Rd Xing to CO	10/5/2004	UCASE	
4958032	Castle Ck 1/4 mi ab U128 Xing	9/20/2005	UCASE	

3.5.3.1 Fish Tissue Sampling

Fish tissue from some of the EMAP, NRSA, and UCASE sampling was analyzed for mercury. The results for mercury in fish are summarized in Table 3.5.8. The brown trout collected at 4956395, Mill Creek above Moab contained levels of mercury above the EPA significant value of .3ug/g. The State of Utah Department of Health in cooperation with UDWQ issued a fish advisory for Brown Trout for that stream section in August of 2005.

Table 3.5.8 Fish tissue data summary

STORET	Site Description	Year Sampled	Mean ug/g	Species
4956395	Mill Ck ab Moab (EMAP)	2001/2005	0.342	Brown trout
4956399	Mill Ck 3/4 mi ab Kens Lk Diversion	2006	0.133	Brown trout
4956399	Mill Ck 3/4 mi ab Kens Lk Diversion	2006	0.098	Rainbow trout
4956435	Mill Ck 1mi ab LaSal Loop Rd	2004	0.044	Brown trout
4958075	Castle Ck ab USFS Rd Xing to Colorado	2004	0.023	Brown trout
5958500	Kens Lake 001 ab Dam	2005	0.256	Largemouth bass
5958500	Kens Lake 001 ab Dam	2005	0.129	Rainbow trout
5958510	Kens Lake Upper End 002	2005	0.196	Largemouth bass
5958510	Kens Lake Upper End 002	2005	0.207	Brown trout
5958510	Kens Lake Upper End 002	2005	0.121	Rainbow trout

3.6 Water Quantity

3.6.1 Water Quantity Gages

The United States Geological Survey (USGS) has historically established several stations in the Mill Creek and Castle Creek Drainages. Several sites were maintained for a limited time. All the sites in the Mill and Castle Creek drainages and their corresponding period of record are shown in Table 3.6.1.

Water rights in the State of Utah allow for complete dewatering of streams if conditions require it. The Right of Way contract between the BLM and GWSSA require the GWSSA to leave 3CFS or the entire flow if less than 3CFS in Mill Creek below the Sheley Diversion.

Table 3.6.1 USGS Stations in the Mill Creek and Castle Creek Watersheds					
Station Id	Station Name	Start	End	Latitude	Longitude
09183600	MILL CREEK BELOW SHELEY TUNNEL, NEAR MOAB, UT	2003-10	Present	38°29'09"	109°24'38"
09183500	MILL CREEK AT SHELEY TUNNEL, NEAR MOAB, UT	1954-10	Present	38°28'59"	109°24'12"
09184000	MILL CREEK NEAR MOAB, UT	1947-07	1993-10	38°33'44"	109°30'48"
09184500	PACK CREEK AT M4 RANCH, NEAR MOAB, UTAH	1954-10	1959-09	38°26'10"	109°21'15"
09185000	PACK CREEK NEAR MOAB, UTAH	1954-10	1959-09	38°32'25"	109°30'00"
09182000	CASTLE CREEK ABOVE DIVERSIONS, NEAR MOAB, UTAH	1950-07	1975-10	38°35'34"	109°15'54"
09182200	CASTLE CREEK BELOW CASTLETON NEAR MOAB, UT	1992-04	2001-09	38°36'45"	109°19'54"
09182400	CASTLE CREEK BELOW CASTLE VALLEY NEAR MOAB, UT	1992-04	Present	38°40'26"	109°26'58"
09182500	CASTLE CREEK NEAR MOAB, UTAH	1950-07	1958-09	38°40'45"	109°26'55"

3.6.2 Water Quantity Gage Data Summary for Active Gages

There are three active gages in the Mill Creek and Castle Creek watersheds. A summary of mean monthly flows are presented in the following tables.

Table 3.6.2 USGS 09183500 MILL CREEK AT SHELEY TUNNEL,												
YEAR	Monthly mean in ft3/s (Calculation Period: 1954-10-01 -> 2012-12-31)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1954										7.41	4.44	4.30
1955	4.88	4.61	5.07	7.59	21.6	15.9	10.0	9.37	6.60	5.15	4.58	4.79
1956	4.96	4.48	5.02	6.71	11.9	10.9	7.46	5.72	5.40	4.84	3.89	5.01
1957	4.60	4.89	4.88	7.44	23.1	67.9	33.7	16.3	12.7	12.1	9.49	8.79
1958	8.06	7.41	6.87	22.2	70.5	49.0	15.6	12.9	11.6	8.28	6.94	6.97
1959	6.16	5.83	6.17	8.24	10.3	7.08	5.32	5.77	5.00			
1987										12.0	15.6	11.0
1988	8.82	8.06	9.43	18.4	42.3	34.0	15.0	10.3	11.1	9.82	7.60	7.63
1989	6.89	6.70	7.88	10.7	10.6	9.13	8.16	8.99	6.56	6.81	5.80	5.55
1990	5.75	5.20	5.37	5.42	8.03	7.34	5.71	4.69	7.87	8.34	7.49	6.77

1991	5.94	6.23	5.22	10.1	22.1	20.9	11.5	9.56	7.02	6.79	7.14	6.61
1992	6.31	5.88	7.65	15.9	33.1	23.4	14.0	8.55	7.10	6.49	5.96	6.13
1993	6.22	5.87	7.13	13.2	68.4	65.4	26.7	18.7	13.5	12.0	9.40	7.91
1994	6.56	5.99	6.55	13.2	27.6	19.7	8.77	6.11	6.08	5.45	5.83	5.66
1995	5.41	5.35	7.45	9.34	28.1	55.2	40.7	16.3	10.3	9.68	9.41	7.50
1996	6.29	5.62	5.62	9.09	21.5	14.5	7.80	5.40	10.8	7.61	5.90	5.14
1997	5.02	4.65	5.95	10.5	35.6	32.5	13.0	11.9	11.2	15.4	10.3	8.77
1998	8.30	7.14	8.34	13.2	37.9	34.5	21.4	12.2	9.22	11.0	9.09	7.86
1999	6.39	6.04	6.33	7.43	13.0	19.5	14.1	15.3	10.6	7.20	6.98	6.70
2000	6.50	5.69	6.13	12.8	22.5	13.2	6.99	6.51	5.79	5.38	5.53	4.93
2001	4.68	4.50	4.80	7.93	26.4	13.5	10.1	12.2	7.36	5.55	5.65	5.21
2002	4.72	4.38	4.30	6.87	6.54	4.40	2.78	2.48	3.92	3.63	3.63	3.71
2003	3.66	3.59	3.85	7.43	21.0	18.0	6.16	5.57	4.36	3.85	4.47	4.48
2004	4.19	4.03	4.79	6.20	18.0	15.5	7.83	5.97	6.38	6.39	5.85	4.73
2005	4.43	4.04	4.75	14.5	56.3	63.5	26.1	13.0	9.00	7.45	7.40	6.32
2006	5.59	4.99	4.87	8.67	14.8	9.84	5.51	6.05	5.10	18.2	7.67	6.46
2007	5.70	5.65	6.97	9.73	21.7	13.6	6.28	6.18	8.63	7.60	5.23	4.31
2008	4.15	4.36	4.77	7.17	17.2	22.9	9.28	6.65	4.89	5.68	5.93	5.44
2009	5.29	5.28	5.45	8.38	19.9	12.0	6.64	5.05	5.28	5.11	5.31	4.93
2010	4.77	4.78	4.90	9.47	14.3	21.2	8.97	13.1	6.70	6.50	5.74	5.42
2011	4.89	4.84	5.73	9.81	22.0	48.2	27.2	12.4	11.3	8.31	7.12	5.82
2012	5.23	5.05	6.42	8.02	6.02	4.42	3.42	2.99	2.61	2.94	4.30	4.20
Mean of monthly Discharge	5.7	5.4	6.0	10	25	25	13	9.2	7.8	7.8	6.8	6.1

** Incomplete data have been used for statistical calculation

Table 3.6.3 USGS 09183600 MILL CREEK BELOW SHELEY TUNNEL,

YEAR	Monthly mean in ft3/s (Calculation Period: 2003-10-01 -> 2012-10-31)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003										3.41	2.58	2.16
2004	1.22	1.06	2.35	3.28	4.27	3.90	4.21	4.72	3.60	3.64	3.98	3.86
2005	3.56	3.58	2.67	3.18	19.3	39.4	9.17	4.73	4.22	4.65	5.18	4.26
2006	3.43	3.14	3.28	3.72	3.43	3.52	3.24	3.50	3.18	8.84	3.58	3.58
2007	3.02	3.05	3.19	3.61	5.26	3.71	3.23	3.50	5.13	3.49	3.37	2.91
2008	2.79	2.74	2.93	2.28	5.14	4.40	4.35	4.43	3.22	3.27	3.10	2.78
2009	2.65	3.63	2.98	2.72	3.88	3.34	3.55	3.49	3.93	3.29	3.19	2.91

2010	2.71	3.03	2.53	3.50	3.94	4.72	3.93	7.86	3.79	2.86	3.86	2.52
2011	2.19	2.53	3.35	2.88	5.03	18.2	11.8	3.97	6.16	4.37	5.03	4.33
2012	3.10	3.23	3.58	3.83	3.58	3.21	3.30	3.01	2.79	2.88		
Mean of monthly Discharge	2.7	2.9	3.0	3.2	6.0	9.4	5.2	4.4	4.0	4.1	3.8	3.3
** Incomplete data have been used for statistical calculation												

Table 3.6.4 USGS 09182400 CASTLE CREEK BELOW CASTLE VALLEY,												
YEAR	Monthly mean in ft3/s (Calculation Period: 1992-04-01 -> 2012-10-31)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992				6.13	6.43	6.15	5.20	5.26	5.84	6.64	8.56	7.75
1993	8.53	7.48	8.36	8.43	17.2	15.4	6.96	5.51	5.13	7.93	7.57	7.72
1994	7.44	7.07	6.85	7.36	5.62	4.44	3.31	3.56	4.13	5.85	6.87	6.93
1995	6.46	6.45	6.46	6.13	6.80	12.2	9.85	5.45	5.82	6.97	8.52	8.36
1996	8.37	7.98	8.30	6.52	4.69	4.65	4.24	4.46	6.35	7.71	8.63	6.89
1997	6.79	6.68	6.57	5.56	7.35	7.20	5.31	6.72	7.50	8.33	8.95	8.19
1998	8.19	8.37	8.77	7.00	4.67	6.18	5.89	5.14	6.11	6.28	8.16	7.23
1999	5.64	6.49	6.69	5.72	5.20	5.36	5.79	5.59	5.66	5.30	6.71	6.71
2000	6.52	6.19	6.28	5.16	3.93	3.48	3.76	3.57	3.62	4.09	6.32	6.62
2001	6.80	6.89	6.80	5.71	4.11	3.74	3.75	3.65	4.41	4.62	6.08	6.80
2002	6.80	6.78	6.83	5.60	4.09	3.96	3.64	3.45	4.57	4.61	5.62	6.27
2003	6.38	6.55	5.06	4.07	4.17	4.22	3.78	3.65	4.27	4.59	5.63	6.78
2004	6.45	6.26	5.99	4.44	3.80	3.24	3.32	3.32	3.17	3.52	4.52	5.75
2005	5.65	5.31	5.09	4.62	5.71	6.82	4.95	4.61	5.78	5.04	6.41	5.71
2006	5.48	5.20	5.75	4.82	3.90	3.19	3.21	4.20	4.29	7.72	5.52	5.40
2007	5.55	5.26	5.09	5.47	5.38	3.57	3.81	4.09	3.78	4.41	5.14	5.46
2008	5.52	6.04	5.64	4.56	4.69	5.05	3.35	4.02	3.50			
2009										5.11	6.94	6.75
2010	7.31	7.15	6.86	5.68	5.05	5.01	3.74	4.10	4.57	5.74	7.31	6.97
2011	6.52	6.55	6.07	5.15	4.89	8.39	5.75	4.71	5.14	6.10	8.02	6.72
2012	5.74	5.76	5.08	4.18	3.69	3.46	3.86	3.08	2.91	3.77		
Mean of monthly Discharge	6.6	6.6	6.4	5.6	5.6	5.8	4.7	4.4	4.8	5.7	6.9	6.8
** Incomplete data have been used for statistical calculation												

3.7 Water Quality Data Assessment

The State of Utah compares water chemistry data to the numeric criteria associated with the use designations of a waterbody. The numerical criteria and use classifications can be found it R317-2 of the Utah Administrative Code. The use designations for the Mill Creek and Castle Creek waterbodies were discussed earlier in Section 3.1 and 3.2. The tables in Appendix B provide a list of exceedances for the sites sampled as part of the intensive monitoring program from 1997 through 2008.

The exceedance report highlights the numerous water quality standard exceedances for the three intensive surveys previously completed. The report demonstrates that only a small number of characteristics are responsible for the majority of those exceedances. The characteristics that are violating water quality standards are listed in Table 3.7.1 starting with the characteristic with the highest percentage of exceedances for all sampling locations in the watershed.

Table 3.7.1 Characteristic exceedance summary for the Mill and Castle Creek Watershed

Characteristic	Number of Exceedances	Number of Samples	Percentage of Exceedances
Selenium	15	101	14.9%
Total Phosphorus	27	222	12.2%
Temperature	24	246	9.8%
Escheria Coliform	13	133	9.8%
Total Dissolved Solids	23	241	9.5%
DO Saturation	15	177	8.5%
Dissolved Oxygen (DO)	13	240	5.4%
pH	5	234	2.1%

Individually each stream section has different water chemistry and therefore exceedances vary with stream segment. Table 3.7.2 lists the exceedances at each intensive site.

Table 3.7.2 Percentage of Characteristic Exceedances by Station

Station ID	Station Location	Selenium	Total Phosphorus	Temperature	E Coli	Total Dissolved Solids	DO Saturation	Dissolved Oxygen (DO)	pH
4956360	Mill Ck Bl Cnfl/ Pack Ck	0.0%	12.5%	18.8%	N/A	0.0%	18.8%	12.5%	0.0%
4956390	Mill Ck @ U191 Xing	0.0%	9.3%	29.2%	N/A	2.5%	15.4%	9.5%	2.6%
4956393	Mill Ck @ Mill Dr	N/A	N/A	N/A	20.0%	N/A	N/A	N/A	N/A
49956440	Mill Ck @ Powerdam	N/A	N/A	N/A	5.7%	N/A	N/A	N/A	N/A

4956400	Mill Ck ab Shelley Diversion	0.0%	15.8%	12.0%	0.0%	0.0%	0.0%	4.0%	4.0%
4956460	Pack Ck @ U191 Xing	78.6%	27.3%	13.2%	83.3%	35.9%	11.5%	7.9%	2.6%
4956510	Pack Ck @ Pack Ck CMPGD	N/A	N/A	N/A	50%	N/A	N/A	N/A	N/A
4956530	Pack Ck @ Spanish Trail Rd	44.4%	12.0%	0.0%	0.0%	0.0%	0.0%	4.2%	0.0%
4953480	Pack Ck bl Brumley Ck	0.0%	9.7%	2.8%	N/A	0.0%	0.0%	5.6%	2.8%
4958030	Castle Ck @ U128 Xing	0.0%	0.0%	0.0%	N/A	2.7%	16.7%	0.0%	2.8%
4958070	Castle Ck @ Castleton	0.0%	16.7%	0.0%	N/A	29.2%	4.3%	0.0%	0.0%

3.8 Ground Water Quality Monitoring

The ground water in Spanish and Castle Valley's has been the subject of several studies over numerous years. In general the more recent studies build upon previous studies, using both their findings and data. The most recent studies that consider groundwater quality, transport, and availability are from the Utah Geological Survey (UGS). In recent years the UGS has published planning documents that suggest septic tank density, ground water protection strategies, and classified the ground water according to Administrative Rules for Ground Water Quality Protection R317-6. The following sections summarize their findings for Spanish Valley and Castle Valley.

3.8.1 Spanish Valley Ground Water Quality Summary

The following information and figures were taken in whole or part from the 2007 Utah Geological Survey Special Study 120 "The Hydrogeology of Moab-Spanish Valley, Grand and San Juan Counties, Utah with Emphasis on Maps for Water-Resource Management and Land-Use Planning.", and references therein.

Ground water Quality in Moab-Spanish Valley is generally good and is suitable for most uses. Ground water in Moab-Spanish Valley occurs in two types of aquifers: (1) fractured bedrock, and (2) valley-fill deposits. Most of the fractured bedrock groundwater occurs in what is known as the Glen Canyon Group aquifer. The valley-fill aquifer has been labeled the alluvial aquifer. Groundwater is the principle source of drinking water in Moab-Spanish Valley. Most public water supply is from the Glen Canyon aquifer. The Glen Canyon aquifer, northeast of Moab-Spanish Valley, generally yields groundwater of Pristine quality as total dissolved solids (TDS) concentrations are predominantly below 500 mg/l. Ground water quality data compiled from 24 water wells completed in the Glen Canyon aquifer in the Moab-Spanish Valley indicate 83 percent of the Glen Canyon aquifer samples had TDS concentrations of less than 250 mg/l. Nitrate-plus-nitrite concentrations in ground water from wells completed in the Glen Canyon aquifer ranged from 0.2 to 15.2. Ground water quality in the Glen Canyon aquifer along the northeastern margin of Moab-Spanish Valley has been designated a Sole Source Aquifer by the U.S. Environmental Protection Agency, and is therefore classified as Class IB, Irreplaceable ground water.

The alluvial aquifer was once the most important source of culinary water in Moab-Spanish Valley and is now primarily used for domestic and agricultural purposes. Ground water in the alluvial aquifer is classified as Class IA (Pristine; 13 percent) and Class II (Drinking Water Quality; 87 percent). Class II groundwater predominates the throughout most of the valley. Class IA ground water is generally confined to the northeastern margin of Moab-Spanish Valley where recharge from the sandstone aquifer to the alluvial aquifer occurs. TDS concentrations in the alluvial aquifer range from 140 to 1818 mg/l, and average 690 mg/l. Nitrate-as-Nitrogen concentrations in Moab-Spanish Valley's alluvial aquifer ranged from 0.06 to 7.37, with an average (background) nitrate concentration of 2.1 mg/l. The ground water classification map for the Moab-Spanish valley is shown as Figure 3.8.1 is Plate 2 from the UGS publication. The data for the alluvial and Glen Canyon group aquifer is summarized in a fashion similar to the chemistry data for water quality stations in Appendix 3C.

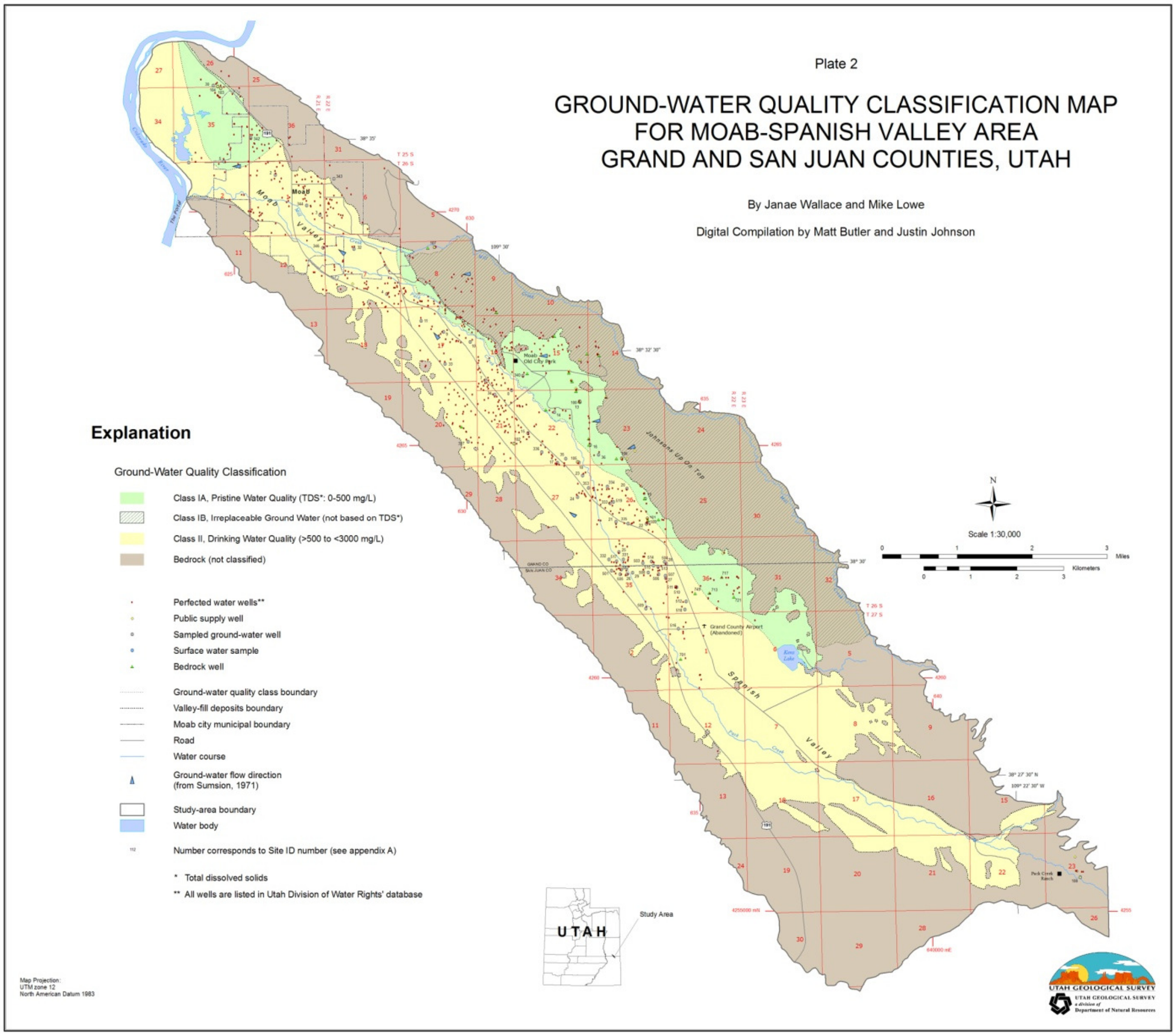

Figure 3.8.3 Groundwater classification map for Spanish Valley

The generalized ground water flow in the Moab Spanish Valley shown in Figure 3.8.2 is also from the UGS publication.

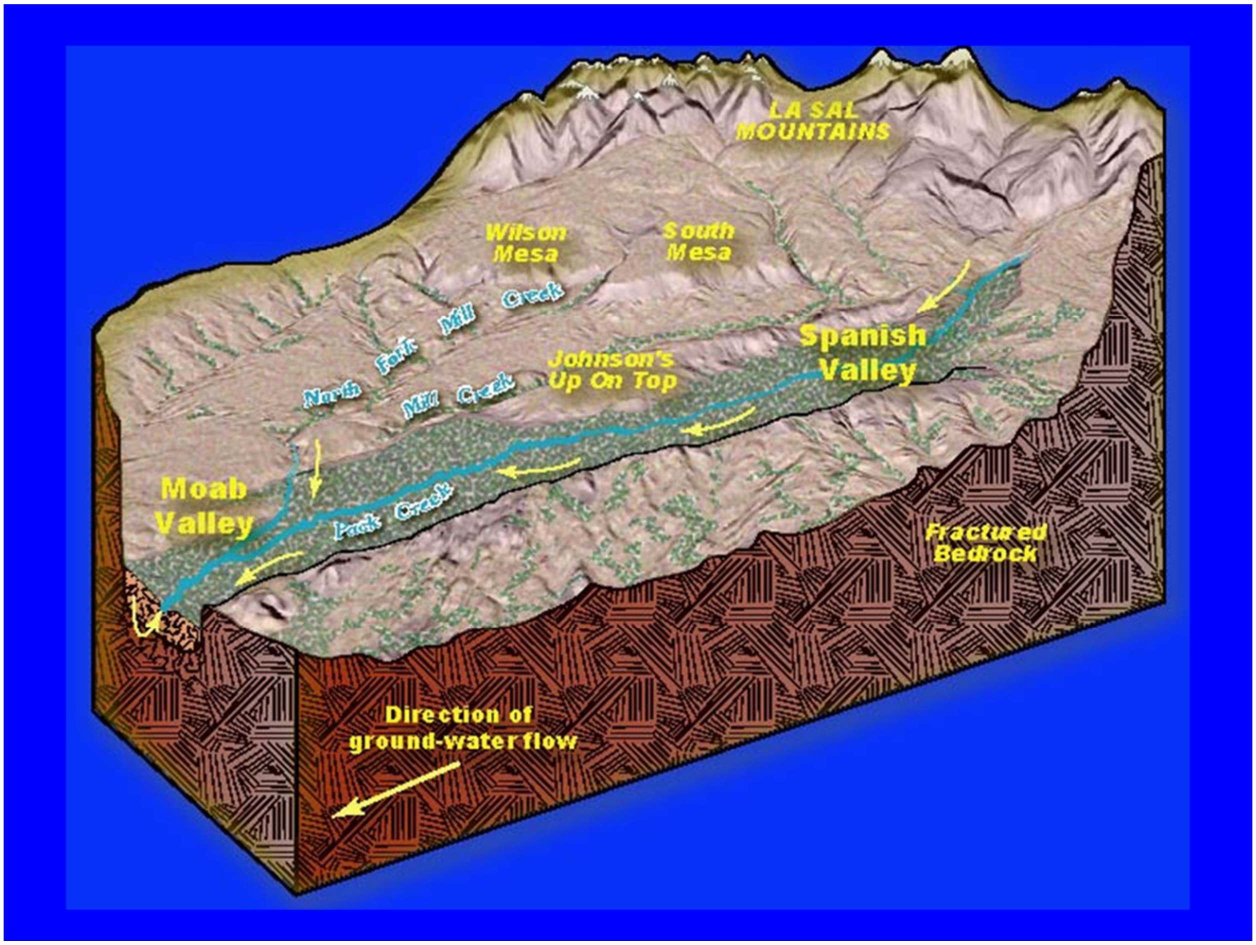

Figure 3.8.2. Schematic block diagram showing ground water flow in Moab-Spanish Valley.

3.8.1.1 Total Dissolved Solids in Moab-Spanish Valley Groundwater

As stated earlier, TDS in the alluvial aquifer of Moab-Spanish Valley range from 140 to 1818, with only four wells exceeding 100 mg/L TDS and an overall average of TDS concentration of 690 mg/l. Higher TDS concentrations exist in the central part of the Moab-Spanish Valley on the west side of Pack Creek; the higher TDS concentrations may be due to (1) upward leakage of higher TDS ground water along the Moab fault, (2) contact with pre-Jurassic rocks that contain more soluble materials than the Glen Canyon Group which underlies the valley fill in most other areas of Moab-Spanish Valley, or (3) a combination of 1 and 2. The lower TDS concentrations found on the east side of Moab-Spanish Valley are likely the result of higher quality water discharging from the Glen Canyon aquifer and mixing locally with water in the alluvial aquifer. Figure 3.8.3 which is Plate 8 from the UGS publication depicts TDS concentrations in Moab-Spanish Valley wells.

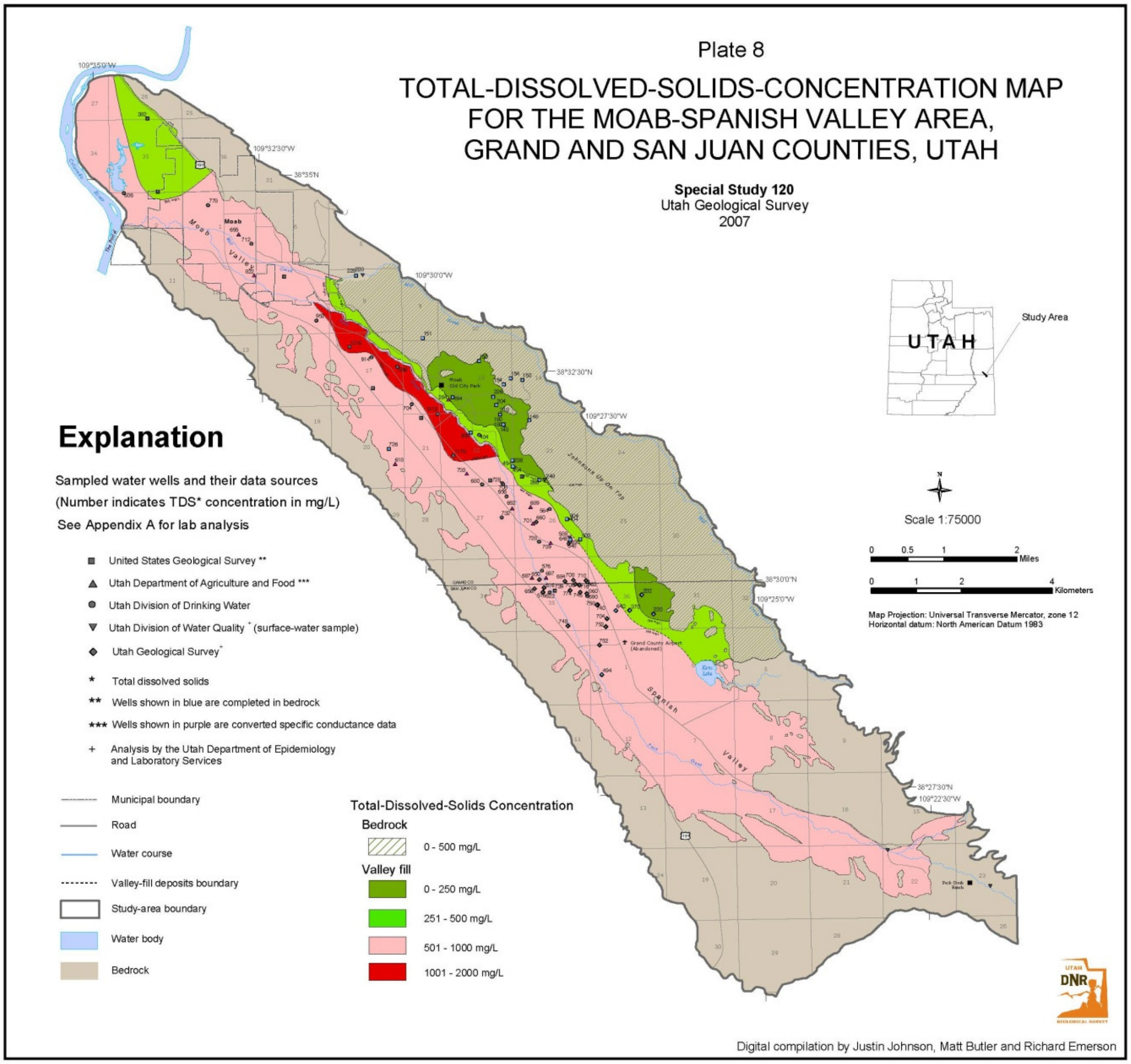

Figure 3.8.3 Total Dissolved Concentration map for Spanish Valley groundwater

3.8.1.2 Nitrate in Moab-Spanish Valley Groundwater

The ground water quality (health) standard for nitrate as nitrogen is 10 mg/L. The nitrate as nitrogen concentrations in Moab-Spanish Valley wells range from 0.06 to 7.37 mg/L, with 16 wells yielding ground water above 3 mg/L, and an overall average nitrate concentration of 2.1 mg/l. Nitrate concentrations above 3 mg/L are mostly in ground water from wells in the central part of Moab-Spanish Valley, and are likely the result of human activity, possibly domestic wastewater disposal via septic-tank systems. Figure 3.8.4 which is Plate 9 from the UGS publication depicts nitrate concentrations in Moab-Spanish Valley Wells.

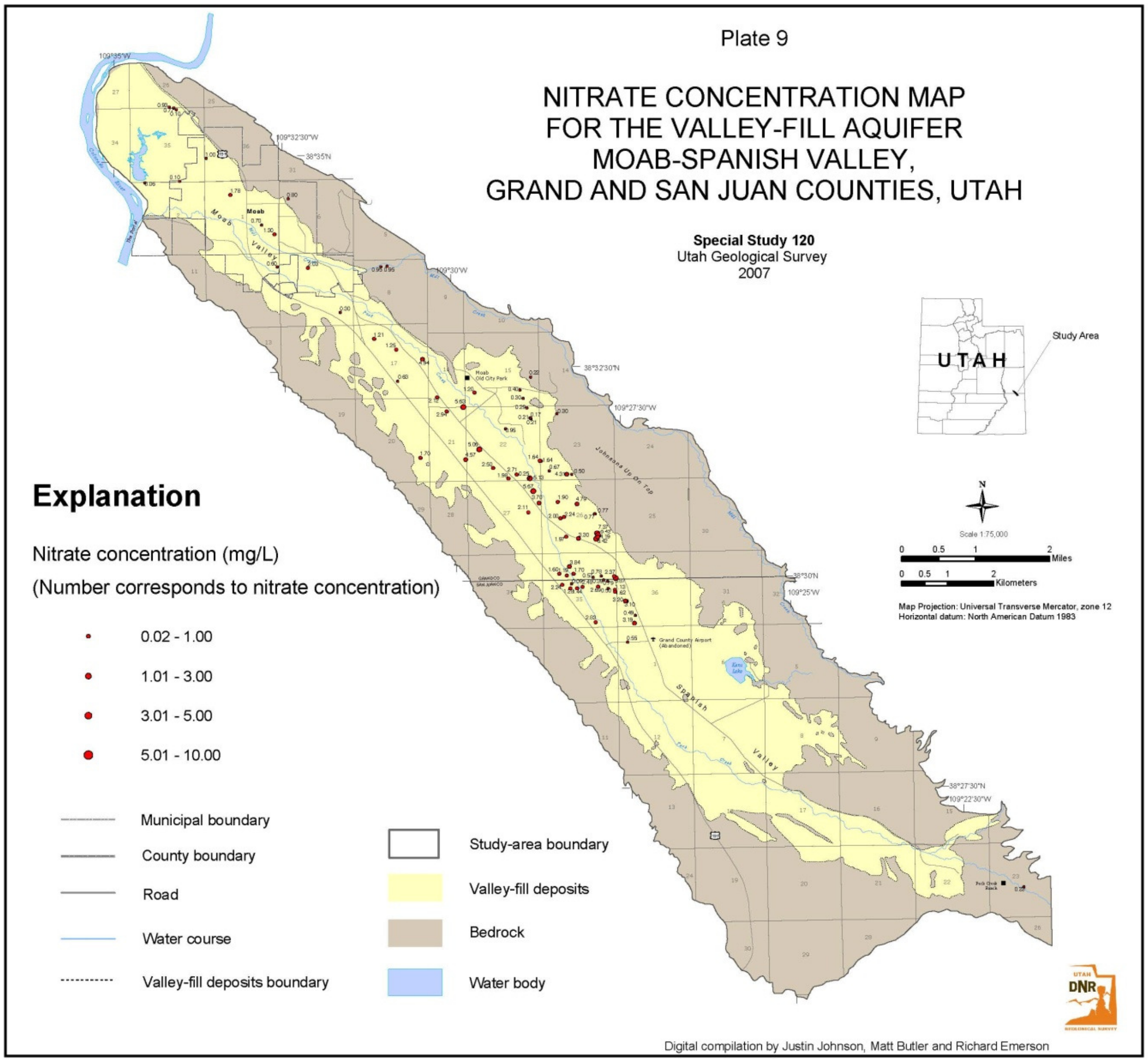

Figure 3.8.4 Nitrate concentration map for Spanish Valley groundwater

3.8.1.3 Other Constituents in Moab-Spanish Valley Wells

Three wells exceeded the primary water quality standards for the metals lead, silver, and selenium; four wells exceeded water quality standards for radionuclides, alpha (three wells), beta (two wells), radium (one well), and uranium (one well). No pesticides from any of the wells sampled were detected.

Sixteen wells exceeded secondary water quality standards. One well for iron, and fifteen wells for sulfate.

3.8.1.4 Potential for Ground Water Degradation

The UGS mapped potential ground water contaminant sources including some facilities related to mining, agricultural practices, and junkyard/salvage areas. A primary objective was to identify potential contaminant sources to establish a relationship between water quality and land-use practices. The UGS mapped approximately 400 potential contaminant sources in the following categories in Moab-Spanish Valley:

(1) mining, which includes abandoned and active gravel mining operations and uranium tailings;
(2) agricultural practices, which consist of irrigated and non-irrigated farms, active and abandoned animal feed lots, corrals, stables/barnyards, and animal wastes that are dominantly produced from feeding facilities, water transported by runoff, and excrement on grazing or pasture land that potentially contribute nitrate;
(3) junkyard/salvage areas that potentially contribute metals, solvents, and petroleum products;
(4) government facility/equipment storage associated with a variety of sources such as salt storage facilities, transportation/equipment storage, and mosquito abatement equipment that may contribute metals, solvents, and petroleum;
(5) cemeteries, nurseries, greenhouses, and a golf course that may contribute chemical preservatives, fertilizer and pesticides; and
(6) storage tanks that may contribute pollutants such as fuel and oil.

In additions to the above-described potential contaminants, Figure 3.8.5 which is Plate 11 from the UGS publication show the distribution of septic-tank soil absorptions systems in the Moab-Spanish Valley. Historically, approximately 1600 septic-tank systems exist in Moab-Spanish Valley. The current number is estimated to be approximately 210. In 1979-81 sanitary sewer services were extended throughout the Spanish Valley Water and Sewer Improvement District to an area which had 1314 septic tanks, and extended again in 1995-97 to an area which had 162 septic tanks. All building owners within 600 feet of a sewer line are assessed a hook-up fee and charged the monthly fee for wastewater treatment once sanitary services are available. Septic-tank systems may contribute contaminants such as nitrate and solvents. All approved water wells are also considered potential contaminant sources.

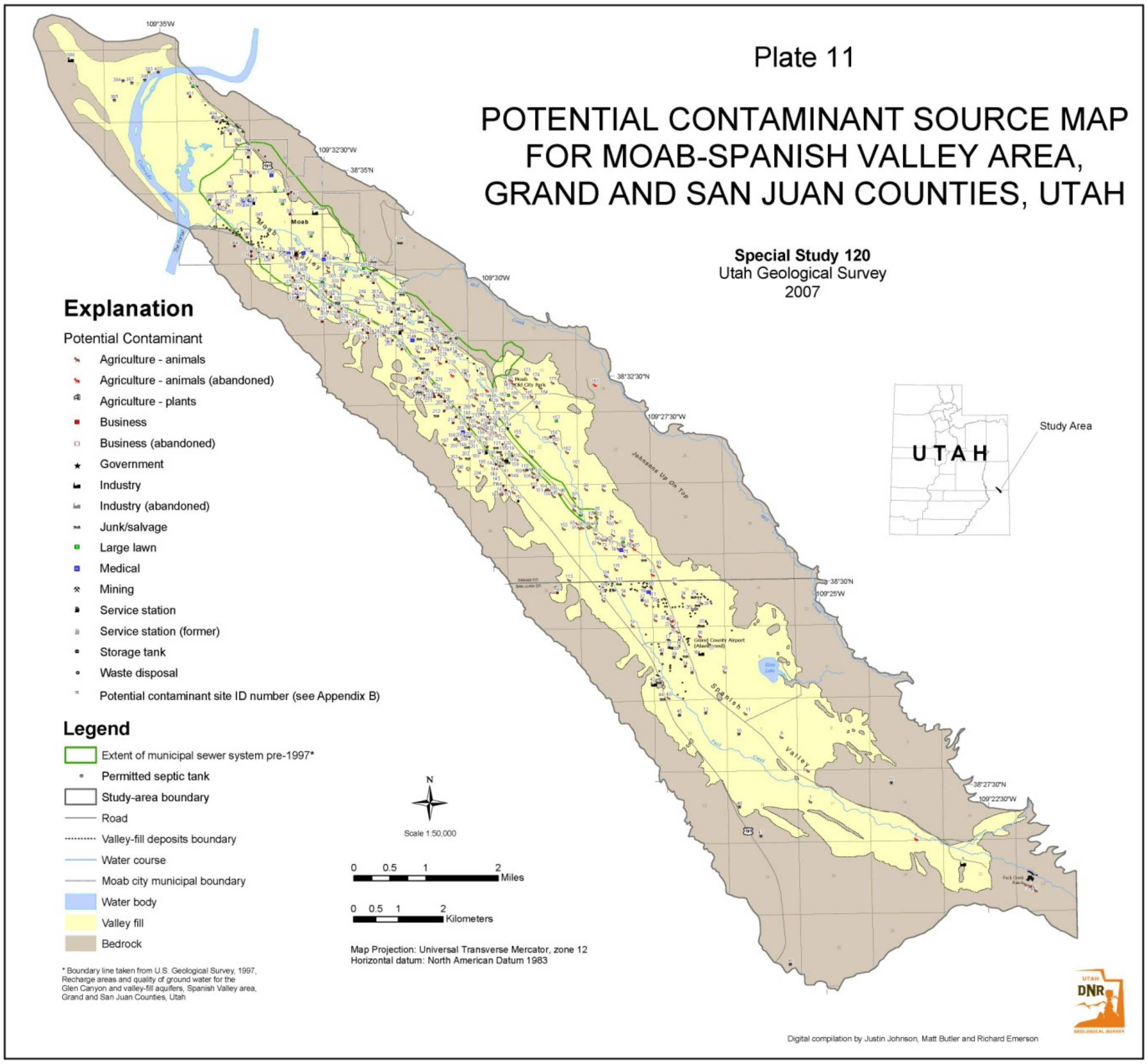

Figure 3.8.5 Potential contaminant source map for Spanish Valley groundwater

3.8.2 Castle Valley Ground Water Quality Summary

The following information and figures were taken in whole or part from the 2012 Groundwater quality classification/reclassification, Castle Valley, Grand County, Utah by Wallace, J. and Lowe, M. and from the 2004 Utah Geological Survey Special Study 113 "Ground-Water Quality Classification and Recommended Septic Tank Soil-Absorption-System density Maps, Castle Valley, Grand County, Utah.", and references therein.

The UGS classified ground water in Castle Valley as generally good. Ground water in Castle Valley occurs in two types of aquifers: (1) fractured bedrock and (2) valley-fill deposits. The fractured bedrock aquifer is referred to as the Cutler aquifer and valley fill deposit aquifer is also known as the alluvial aquifer. The alluvial aquifer is the most important source of drinking water in Castle Valley. Groundwater from wells completed in the Cutler Formation is generally higher in TDS than groundwater wells completed in the alluvial aquifer. Previous investigations reported that groundwater samples from the Cutler Formation near the Town of Castle Valley had TDS concentrations ranging from 1420 to 3450 mg/L. Some studies also found wells in the Cutler Formation also had significant concentrations of Selenium. Previous investigations reported groundwater from wells and springs in the alluvial aquifer had smaller concentrations of TDS than the Cutler Formation based upon specific conductance values.

The northwestern part (40%) of the alluvial aquifer was classified in 2003 by the Utah Division of Water Quality. The majority of the aquifer was not classified at that time due to insufficient data. The aquifer was divided into the Class IA and Class II. The class 1A TDS concentrations range from 204 to 480 mg/L. Class 1A (Pristine) areas were mapped primarily in the central part of northwestern Castle Valley near the confluence of Castle and Placer Creeks where recharge from the surface water is sufficient to keep TDS in ground water diluted below 500 mg/l, oor are pristine due to the presence of less-soluble minerals in the alluvium there. Areas having Pristine water quality covered about 48% of the classified part of the valley fill material in the northwestern Castle Valley. TDS concentrations in the Class II (Drinking Water Quality) area of the alluvial aquifer ranged from 602 to 2,442 mg/L. Class II areas were defined by the TDS data and represent about 52% of the classified part of the valley fill material in northwestern Castle Valley, and are found along the western margin and northern end of the valley.

The alluvial aquifer was reclassified in 2007 after sufficient data was collected in areas that were data pauperate in 2003. The Class 1A (Pristine) alluvial aquifer TDS concentrations range from 196 to 500 mg/l. In Castle Valley, 1A areas are still primarily in the central part of the valley along Castle and Placer Creeks where recharge from surface water is sufficient to keep groundwater diluted below 500 mg/l TDS, or where less soluble minerals are present in the alluvium. Areas having pristine water quality cover about 74% of the valley fill material. UGS also recognized that areas near the less soluble igneous rocks of the La Sal Mountains, in the southeastern part of the valley may yield pristine water. The TDS concentrations for the Class II alluvial aquifer range from 560 to 2442 mg/l. Class II areas represent about 26% of the total valley fill material and are along the western margin, northwestern end and locally in the northern arm of the eastern end of the valley near the community of Castleton. UGS projected Class II groundwater quality along the western margin of the valley based on extrapolated geologic conditions. Because the Paradox Formation underlies valley fill material, UGS believes any proposed water wells adjacent to or tapping into this unit may potentially yield water having a TDS between 500 and 3000 mg/l (Drinking Water Quality) or greater, similar to water quality reported from bedrock wells. The current ground water classification map for Castle Valley is shown in Figure 3.8.6 which is Plate 2 from the UGS publication. The water chemistry data for Castle Valley groundwater is summarized in a fashion similar to the chemistry data for stream water quality stations in Appendix 3C.

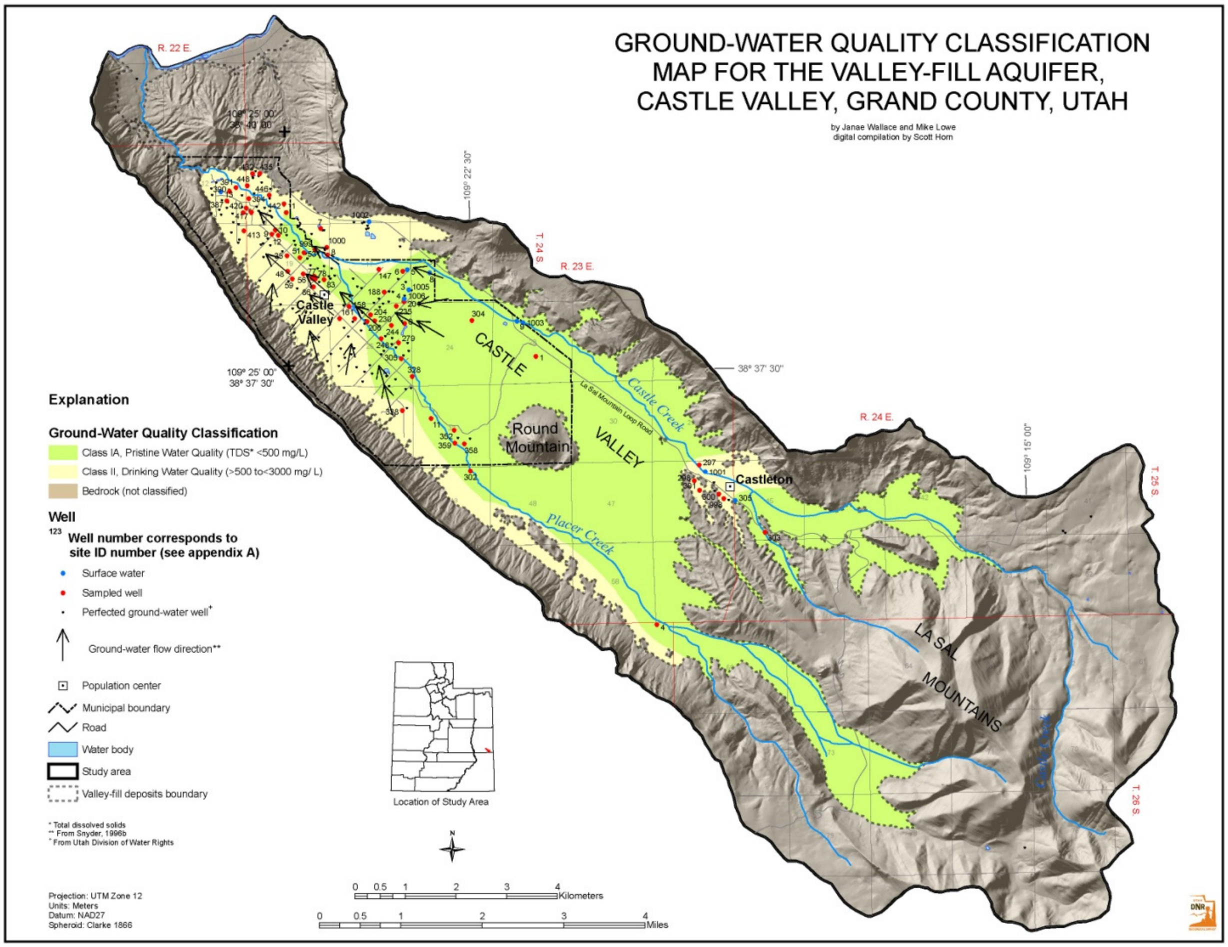

Figure 3.8.6 Groundwater classification map for Castle Valley groundwater

The generalized ground water flow in Castle Valley as shown in Figure 3.8.7 is also from the UGS publication.

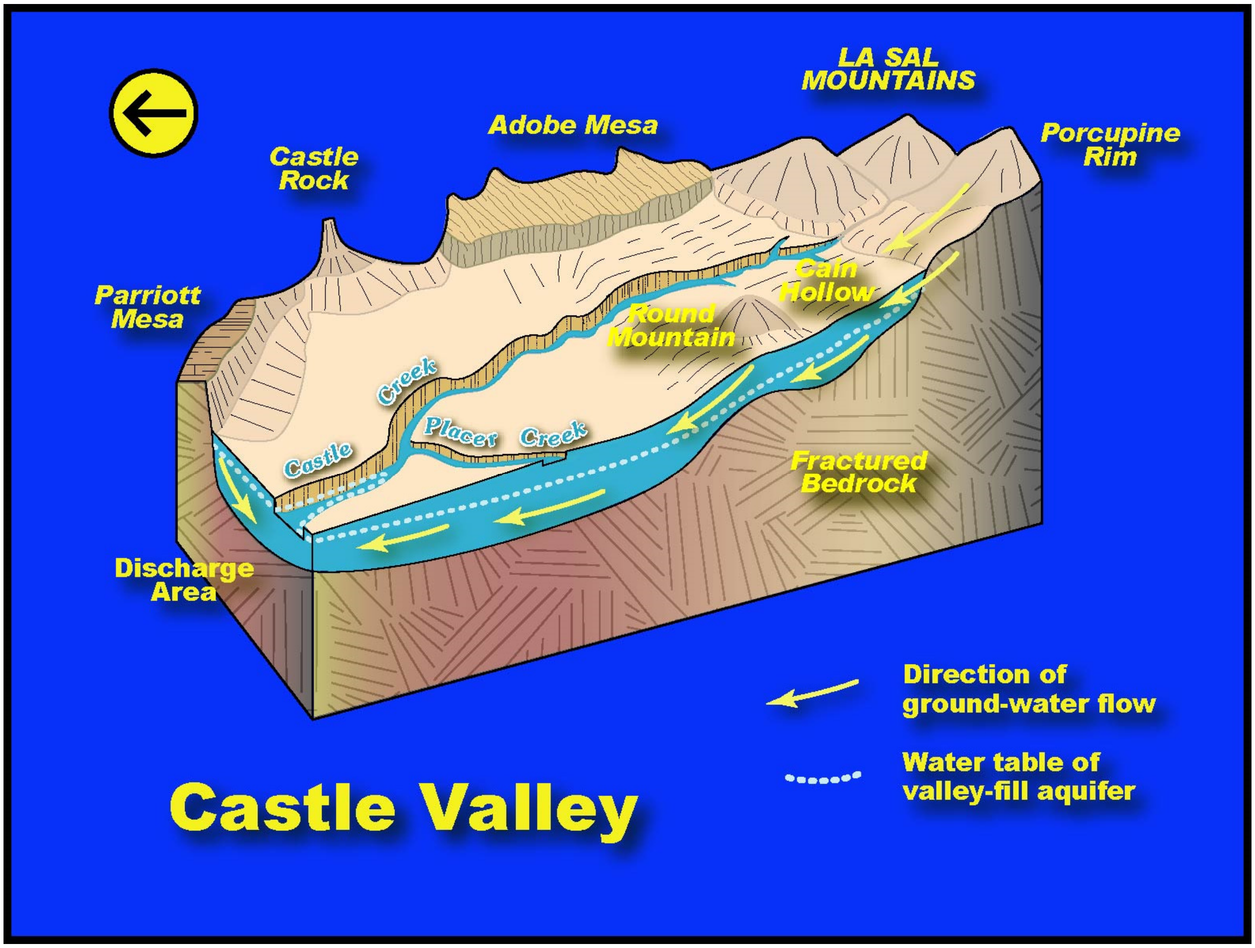

Figure 3.8.7. Schematic block diagram showing ground water flow in Castle Valley

3.8.2.1 Total Dissolved Solids in Castle Valley Groundwater

As stated earlier the TDS concentrations in Castle Valley ground water range from 196 to 2442 mg/L. Only 17 wells exceed 1,000 mg/L TDS concentration and the overall average in the 2003 study of 54 wells was 785 mg/L. Higher TDS concentrations exist along the northwest margins of Castle Valley where the Cutler Formation is encountered at relatively shallow depths and where negligible mixing of ground and surface water occurs. Relatively high TDS concentrations are also present around Castleton and the northwest end of of the valley where the Paradox Formation is exposed. Figure 3.8.8 which is Plate 4 from the UGS publication depicts TDS concentrations in Castle Valley wells.

Not available at the time of publication

Figure 3.8.8 Total Dissolved Solids concentrations in Castle Valley groundwater

3.8.2.2 Nitrate in Castle Valley Groundwater

The ground water quality (health) standard for nitrate as nitrogen is 10 mg/L. The nitrate as nitrogen concentrations from the 20003 study of Castle Valley wells range from less than 0.1 to

4.27 mg/L. Six wells yield ground water above 1.0 mg/l and the overall average nitrate concentration for the 52 wells was .052 mg/L. No apparent trend in the distribution of nitrate concentrations exist; the highest concentrations (1.54 and 4.27 mg/L) are likely attributed to proximity to stables/corrals. Figure 3.8.9 which is Plate 5 from the UGS publication depicts nitrate concentrations in Moab-Spanish Valley Wells.

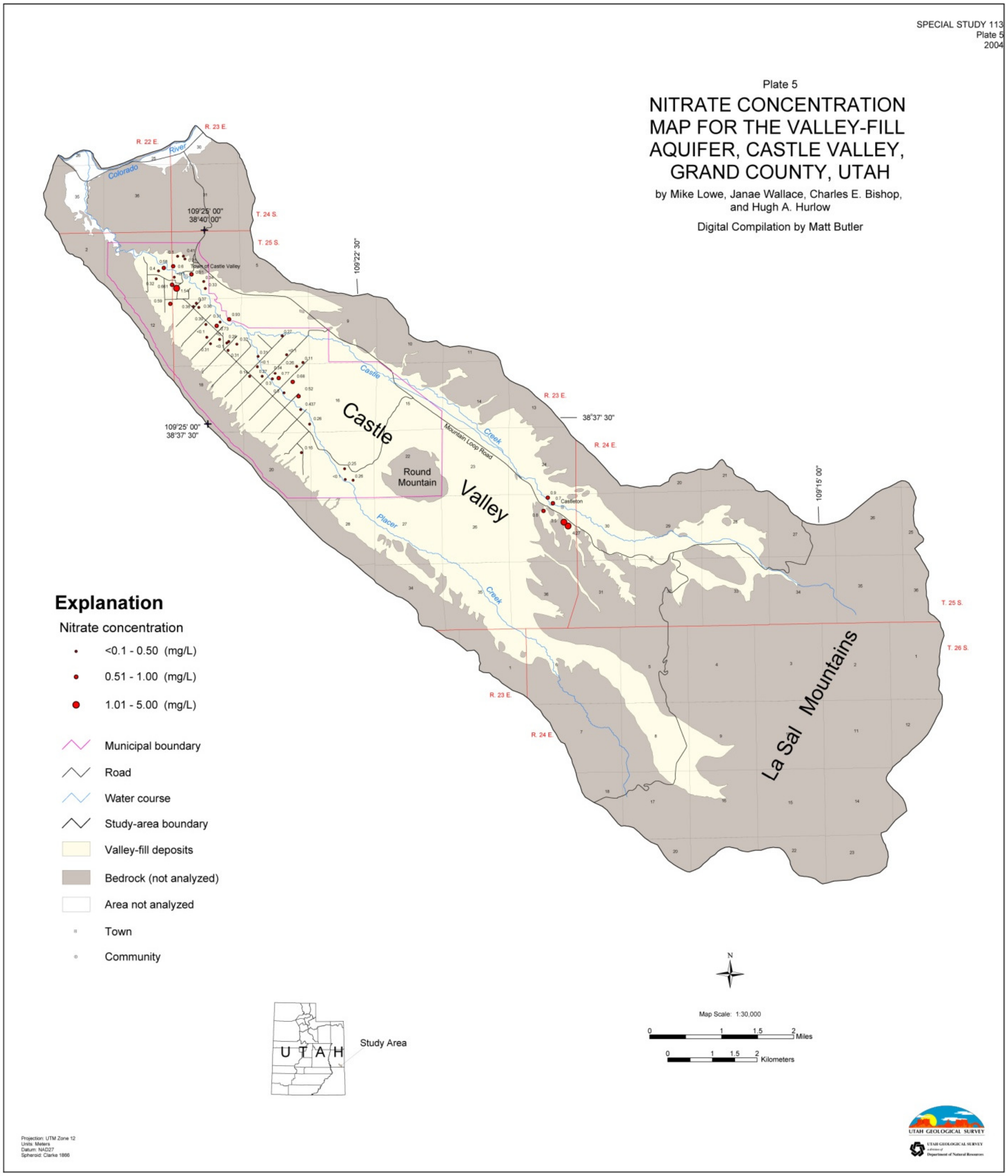

Figure 3.8.9 Nitrate concentrations in Castle Valley groundwater

3.8.2.3 Other Constituents in Castle Valley Wells

Based on the data, no wells exceeded primary water quality standards for any chemical constituent, and not pesticides were detected. However, one well exceeded the secondary ground water quality standards for iron and chloride, and 25 wells exceeded the secondary ground water quality standard for sulfate.

3.8.2.4 Potential for Ground Water Degradation

The UGS mapped potential ground water contaminant sources including some facilities related to mining, agricultural practices, and junkyard/salvage areas. A primary objective was to identify potential contaminant sources to establish a relationship between water quality and land-use practices. The UGS mapped approximately 85 potential contaminant sources in the following categories in Castle Valley:

(1) mining, which includes abandoned and active gravel mining operations and uranium tailings;
(2) agricultural practices, which consist of irrigated and non-irrigated farms, active and abandoned animal feed lots, corrals, stables/barnyards, and animal wastes that are dominantly produced from feeding facilities, water transported by runoff, and excrement on grazing or pasture land that potentially contribute nitrate;
(3) junkyard/salvage areas that potentially contribute metals, solvents, and petroleum products;
(4) government facility/equipment storage associated with a variety of sources such as salt storage facilities, transportation/equipment storage, and mosquito abatement equipment that may contribute metals, solvents, and petroleum;
(5) cemeteries, nurseries, greenhouses, and a golf course that may contribute chemical preservatives, fertilizer and pesticides; and
(6) storage tanks that may contribute pollutants such as fuel and oil.
(7) Oil and gas wells that ma also contribute pollutants such as petroleum and oil.

In additions to the above-described potential contaminants, Figure 3.8.10 which is Plate 7 from the UGS publication show the distribution of septic-tank soil absorptions systems in the Castle Valley. Castle Valley currently has approximately 235 septic-tank systems. Septic-tank systems may contribute contaminants such as nitrate and solvents. All approved water wells are also considered potential contaminant sources.

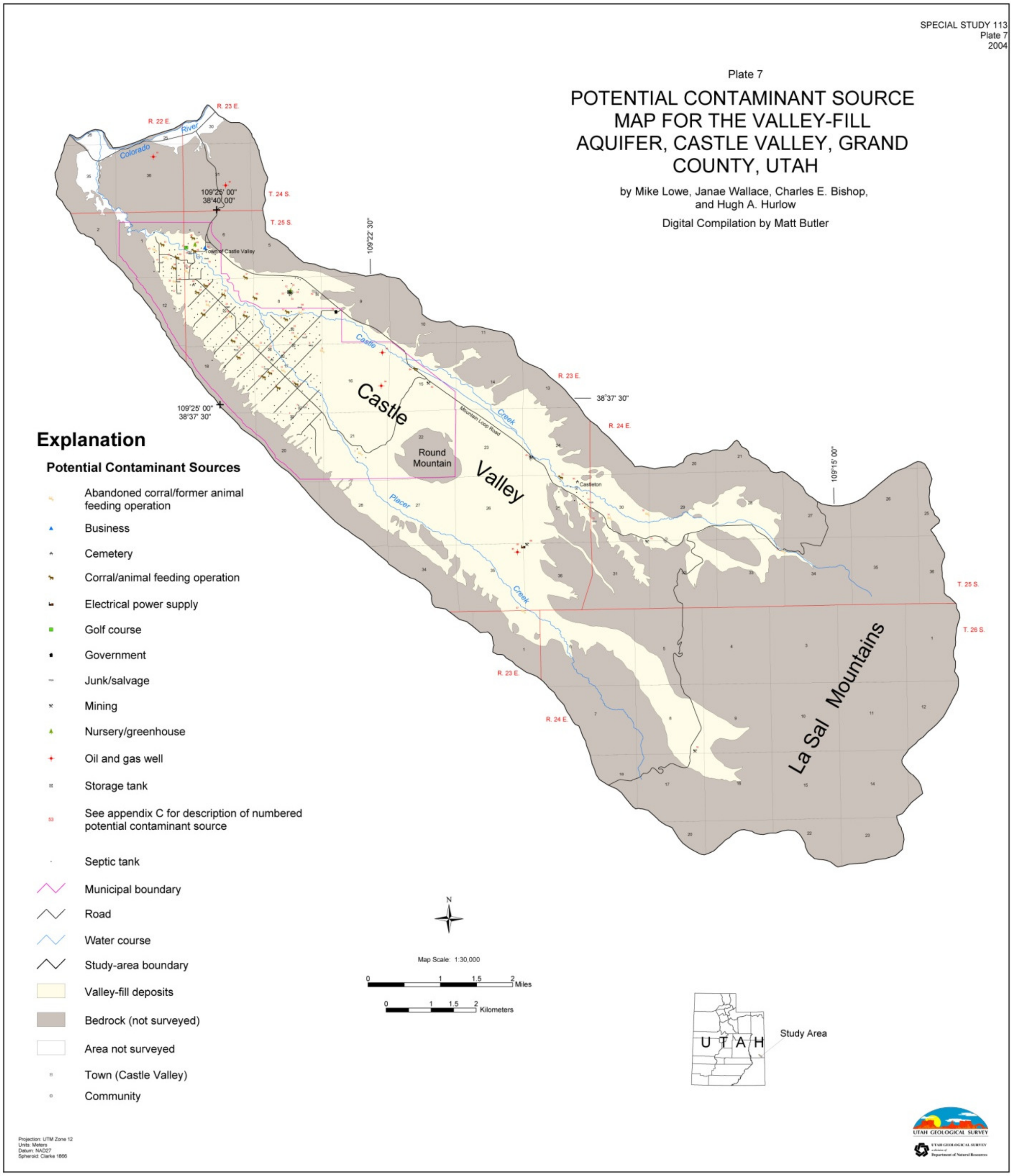

Figure 3.8.10 Potential contamination source map for Castle Valley groundwater

3.9 Conclusion

The foregoing compilation of water quality sampling and data indicates there has been a large and wide variety of sampling in the Mill Creek and Castle Creek watersheds. There appears to be a small number of problem constituents that are impairing the watershed.

Chapter 4 Watershed Concerns and Resource Issues

4.1 Water Quality

4.1.1 Surface Water

The MAWP considers the following current identified surface water impairments of:

Total Dissolved Solids (TDS)
Temperature
Nutrients
Dissolved Oxygen
Selenium
Escheria coliform and
Mercury in fish

to be a concern for the MAWP watersheds. The MAWP is also concerned with maintaining current surface water quality beneficial uses for constituents that are not identified as being impairments.

4.1.2 Groundwater

The MAWP regards the maintenance of groundwater protections zones and groundwater source protection practices as a concern for MAWP watersheds. Specific constituents of concern include:

Total Dissolved Solids (TDS)
Selenium and
Nitrate.

The MAWP believes that groundwater in the MAWP watershed should meet or exceed the State's drinking water standards. The MAWP considers the maintenance and improvement of current groundwater quality a priority for the watershed.

4.2 Water Quantity

4.2.1 Surface Water

Water quantity and water quality are intricately related in MAWP watersheds and the MAWP considers adequate flows necessary to maintain healthy riparian corridors and maintain water quality. The MAWP also recognizes that maintaining in-stream flow must be balanced with maintaining both water storage capacity and current water right users' appropriations in the watersheds.

4.2.2 Groundwater

Surface water and ground water are intricately related in our watersheds. The connectivity of surface and ground water in our watersheds is not thoroughly understood, and the MAWP considers understanding those connections as critical to maintaining groundwater levels and adequate flows in surface water. The MAWP believes the State Division of Water Rights and other public officials need to know how much water we actually have and what the sustainable yield is.

4.3 Watershed Conditions

The MAWP believes maintaining healthy upland and riparian conditions is critical to maintaining water quality and quantity. The MAWP considers maintaining and improving soil ecology and vegetative cover in uplands areas as critical for water infiltration and reducing erosion. The MAWP is concerned that activities and events that reduce vegetative cover, such as catastrophic fire, will negatively impact the watersheds.

4.4 Industrial, Recreational and other Economic Activities

Numerous anthropogenic activities are currently taking place that effect water quality in MAWP watersheds. There are also numerous proposed activities that could potentially affect water quality and the MAWP watersheds. The MAWP is concerned with how these current and proposed activities effect water quality and water quantity and what can be done to mitigate their impacts.

4.5 Wetland maintenance

Wetlands are critical resource in all environs, but their scarcity in the MAWP watershed's arid environment makes their conservation critical. The MAWP considers maintaining wetlands and associated habitat essential for maintaining water quality, quantity and a healthy watershed.

Chapter 5 Recommendations and Management Implementation Strategies (Watershed Action Plan)

5.1 Goals and Objectives

The previous section, resource issues and concerns, emphasizes the interrelationship of water issues in the Spanish and Castle Valley Watersheds. It is fitting that the mission of the Moab Area Watershed Partnership is "*to facilitate implementation of, a holistic watershed* *plan that conserves and enhances water quality and quantity in the Mill Creek (including Pack Creek) and Castle Creek watersheds."* The goal of this watershed management plan is to facilitate and support the development of plans, projects, and land uses that support the beneficial uses of water in these watersheds.

The goals of this watershed plan are congruent with several other completed management plans. These other management plans include:

- Land and Resource Management Plan, Manti- La Sal National Forest 1986
- http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5383373.pdf
- Moab Resource Management Plan, Bureau of Land Management, 2008
- http://www.blm.gov/ut/st/en/fo/moab/planning/rod_approved_rmp.html
- School and Institutional Trust Lands Policy Statements and Resolutions
- http://trustlands.utah.gov/our-agency/board-of-trustees-members/board-policy-statements-resolutions/
- Grand County Utah General Plan, 2012
- http://www.grandcountyutah.net/DocumentCenter/Home/View/200
- San Juan County Master Plan, 2008
- http://www.sanjuancounty.org/documents/2008%20SJC%20Materplan.pdf
- City of Moab General Plan, 2002
- http://moabcity.org/DocumentCenter/View/68
- Town of Castle Valley, Utah General Plan, 2014
- http://www.castlevalleyutah.com/pdfs/GeneralPlanFinal31914.pdf
- Grand County Conservation District Resource Needs Assessment
- http://www.uacd.org/pdfs/RA/12%20Grand%20County%202012%20Resource%20Assessment.pdf
- State of Utah Division of Water Resources Utah State Water Plan Southeast Colorado River Basin
- http://www.water.utah.gov/Planning/SWP/SEastcol/SeCol2000.pdf

The objectives of this plan are:

- Support projects that reduce loading to surface water from constituents that are not meeting State numerical standards.
- Support projects that reduce or protect groundwater from TDS, Selenium, and nitrogen.
- Support projects that benefit in-stream uses and protect current water right holders.
- Support determination of safe yield for both surface and groundwater sources in times of plenty and during droughts.
- Support projects and policies that maintain and improve soil ecology and vegetative cover in uplands
- Support projects that alleviate the possibilities of catastrophic wild fire.
- Support projects and land uses that protect the riparian corridors and stream ecology.
- Support projects, land uses, and water allocation policy that protect wetlands.

5.2 Current Watershed Projects

There have been several watershed restoration initiative projects performed historically in the Spanish and Castle Valley watersheds. Some of the current projects are extensions of ongoing improvement efforts being made by several organizations. Moab City, the Bureau of Land Management, Moab Solutions and Rim to Rim Restoration have an ongoing effort to improve habitat and manage recreation in Spanish Valley. In Castle Valley prior projects have been implemented by USFS and DFFSL. There are also several ongoing information and educational projects in the MAWP watersheds.

5.2.1 Spanish Valley Projects

Currently three projects supported by the MAWP have received funding.

5.2.1.1 Pack Creek Flood Plain Restoration

The Pack Creek Flood Plain Restoration Project includes restoration of the natural streambank through removal and disposal of concrete and other construction debris that was dumped in this area, regarding the streambank to match the historical slope, and construction of a berm to properly direct drainage. Once all he earthwork has been completed, the area will be revegetated with a native grass seed mix to reduce erosion potential.

The City of Moab is working with the property owner to resolve this longstanding issue. City Staff will handle all of the administrative responsibilities for the project including but not limited to administering the grant funding, obtaining appropriate permits, providing construction oversight, and writing the final report. It is anticipated that City crews will assist with the removal of dirt and other non-concrete debris from the project area as part of the in-kind match. The property owner may also be assisting with some of the soil removal ad revegetation activities. A contractor will responsible for removal and proper disposal of the concrete.

For many years prior to purchase by the current owner, this area was used to dump significant amounts of concrete and other construction debris as well as the dumping of appliances and other household trash. The current owner has cleaned up much of the trash. However removal of the concrete was cost prohibitive. The property owner attempted to remedy the situation by covering the concrete with soil, but this created steep slopes that readily erode and exacerbated the constriction of the floodway previously caused by the historic dumping. This project will clean up the debris, revegetate to reduce he erosion potential, and restore the floodway capacity of the Pack Creek channel.

5.2.1.2 Mill and Pack Creek Active Revegeation 2015

Since 1998 collaborators including the City of Moab have been working to remove Russian olive and tamarisk in the Mill and Pack Creek watersheds in an effort to reduce fire fuels loads, recover habitat and improve flood capacity through these riparian areas. Over the last 6 years much of this work has been funded through the UPCD Watershed Restoration Initiative. The project proposals, before and after photos, and completion reports can be accessed through the WRI web site, project numbers 1157, 1419, 1645, 1982, 2225 and 2568.

In many areas the clearing has passively revegetated with native plants including woods rose, three leaf sumac, new mexico privet and various grasses in a short time. In other areas, however, native vegetation is not regenerating passively and needs some assistance including seeding, planting, and some other site follow up. This project will target active revegetation in the riparian and some adjacent upland zones on sites where passive plant regeneration is not occurring. Work will occur primarily in spring and fall months – with some site preparation work in the summer months.

Equally important, this project will also provide opportunities to work with land owners, Moab City, the School District, and residents of Moab during planting days along the creeks. Water quality issues including the high coliform levels in Mill Creek below Power house Lane through town may be able to be addressed in a manner that can change habits in this watershed.

5.2.1.3 Mill Creek Riparian Restoration Project 2015

The Mill Creek riparian restoration project involves multiple actions on BLM lands within the Mill Creek Watershed which have been recently identified through detailed inventory work. Restoration activities include:

-close multiple trails in high use recreation areas
-reduce size of several parking areas along the Steelbender Jeep Trail
-remove up to 50% of the woody invasive plants in phase 1 treatment area
-apply herbicide treatments on recently cut woody invasive plant stumps and
-replant locally sourced native plants in treatment areas.

Multiple partners will coordinate closely to accomplish this workload, with oversight and organization provided by BLM staff. The local non-profit group "Moab Solutions" would organize regular volunteer days to control social trailing and vehicle pullouts within the riparian corridor in Mill Creek Canyon, in coordination with BLM staff, using BLM equipment and supplies as needed. This group is well established and has been working with volunteers in Mill Creek Canyon for several years. Work would be ongoing through most of the year as appropriate.

The National Park Service Weeds Team would provide labor and herbicide to control Ravenna Grass, an invasive species which is starting to dominate the riparian corridor near the Power Dam area. This would be accomplished during the summer months by applying herbicide on the leaves and leaving the plant in place to help stabilize the stream banks. Once the plants are dead, some would be removed and native plants installed to keep stream banks stable.

The Canyon Country Youth Corps would provide labor and tools to cut down woody invasive plants including Tamarisk, Russian Olive and Elms. The brush would be piled up nearby for removal by volunteer groups. Herbicides would be applied to the cut stumps immediately after cutting to prevent regrowth. BLM would plan and supervise this work. This work would be done in the fall months, when the herbicides are most successful.

Moab Solutions would organize volunteer days to plant locally sourced native plants in areas where invasive species were removed. Plants would be purchased from a local nursery by the BLM for this project. This work would be ongoing during fall months when the chance of revegetation success is highest.

5.2.2 Castle Valley Projects

5.2.2.1 Porcupine Fire Bare Ground Stabilization 2014

Castle Creek runs through the Town of Castle Valley, Utah on its way to the Colorado River from the north side of La Sal Mountains in Grand County, Utah. Placer Creek, an intermittent stream, is the main tributary of Castle Creek. I t joins Castle Creek within the Town of Castle Valley residential area. Both creeks are prone to flash flooding during monsoon season. In 2008, the Porcupine Ranch catastrophic wildfire burned approximately 4,000 acres in upper Placer Creek drainage. In 2009 the area received an estimated 4 -5 inches of rain overnight. The resulting debris flow was estimated by the NRCS, by the size of boulders carried in the flow, to have been 6-8,000 cfs. The system has been plagued by debris flows and heavy sediment loads since the fire. The area has a high percentage of bare ground and cheatgrass (*Bromus tectorum)* is present in high concentration in the system. The idea is to selectively hand seed a native grass, forb and sagebrush (2%) mix selectively on areas with a high percentage of bare ground (Figs. 6 – 7) or suffer from cheatgrass dominance.

We propose to selectively hand seed 100 of 195 acres identified on map in the green outlined areas with a seed mix recommended by the Moab-Monticello Ranger District Biologist Barb Smith. It is similar to the mix used, in limited application, after the fire. This mix replaces the basin wildrye with squirreltail (*Elymus elymoides*) which has been found in the project area to compete well with cheatgrass (*Bromus tectorum*).

5.2.2.2 Castle Creek Bank Stabilization 2015

The State Division of Forestry, Fire and State Lands removed Russian-olive (*Elaeagnus augustifolia* L.) and Saltcedar (*Tamarix* ramosissima Ledeb.) from this section of Castle Creek over the last few years under the supervision of Allison Lerch. The combination of clearing along with a heavy monsoon season last summer resulted in several large flow events which caused some slumping of the incised channel.

The Castle Creek Bank Stabilization and Sediment Reduction Project includes:

1) Planting willow wattles (horizontal and/or vertical) and cottonwood and willow pole-plantings to stabilize eroding sections of the incised stream channel and
2) Transplanting rushes and sedges in appropriate locations in order to vegetate bare areas adjacent of the stream channel

The combination of these treatments in appropriate locations will prevent bank slumping and re-vegetatation of bare soils areas within the drainage the project will reduce large influxes of sediment in time of high flows by stabilizing banks and putting deep-rooted vegetation back in the system which will help stabilize the system immediately and provide long-term debris retention as they mature. These plantings are also likely to spread and will keep invasive plants such as the ones removed from getting a foothold back in the system. Project results can be measured through the current Division of Water Quality monitoring program for Castle Creek.

5.2.3 Spanish and Castle Valley Projects

5.2.3.1 Manti-La Sal United States National Forest Spring Development Projects 2013

This project is actually several spring development and protection projects on the Manti-La Sal National Forest. In 2013, Webb Hollow Spring, South Mesa Spring/Seep, Oowah Bench Spring, and Geyser Pass Spring are scheduled for development. Currently unprotected or inadequately protected springs are being effected, mainly through trampling by permitted livestock and wildlife. Development and protection are designed to protect spring source and surrounding wet area while providing needed water to livestock and wildlife.

The projects essentially build an exclosure to livestock and wildlife, install a headwork gathering system for the spring water and pipe the water to a trough outside the exclosure and spring area.

5.2.3.2 Manti-La Sal United States National Forest Spring Development Projects 2014

This project is actually several spring development and protection projects on the Manti-La Sal National Forest. In 2014, Lower Brumely Spring, Wilcox Flat Spring, and four springs on Bald Mesa are scheduled for development. Currently unprotected or inadequately protected springs are being effected, mainly through trampling by permitted livestock and wildlife. Development and protection are designed to protect the spring source and surrounding wet area while providing needed water to livestock and wildlife.

The projects essentially build an exclosure to livestock and wildlife, install a headwork gathering system for the spring water and pipe the water to a trough outside the exclosure and spring area.

5.3 Land Use Stipulations and Plans Supported by the MAWP

Land management agencies, local and state government through zoning and land use stipulations have protected and enhanced the MAWP watersheds. The MAWP supports, at a minimum the following existing land use stipulations and plans.

- The Bureau of Land Management’s Oil and Gas Development stipulation for no surface occupancy within the Mill Creek, Spanish Valley and Castle Valley watersheds
- Moab City’s Green Belt Zoning around Mill and Pack Creek.
- Drinking water source protection zones in Spanish and Castle Valley
- Moab City’s groundwater protection plan

The MAWP encourages similar land use protections that enhance our watersheds.

5.4 Proposed Watershed Projects

The MAWP is currently working with land owners and political entities for future projects in the Spanish and Castle Valley watersheds. However, there are currently three proposed projects that the MAWP supports.

The 2015 Mill Creek Riparian Restoration Project is a continuation of projects that have been ongoing in Mill Creek for several years. It is considered Phase 1 of a three phase project. The Phase 1 project extends geographically from the downstream BLM property boundary below the Power Dam to the confluence of the North Fork and Main Fork of Mill Creek. Phase 2 will consist of the same efforts on the North Fork from the confluence with Mill Creek to the confluence of Rill and North Fork Mill Creek. Phase 3 will consist of the same efforts as Phase 1 on the Main Fork Mill Creek from the confluence with North Fork to the eastern end of property owned by the BLM.

In 2006 the Utah Legislature provided some new legislation to help manage groundwater resources in a specific basin by adopting a groundwater management plan. The objectives of a groundwater management plan are to limit groundwater withdrawals to safe yield, protect he physical integrity of the aquifer and protect water quality.

Current water right appropriation policy in the Moab-Spanish Valley allows for the development of new water right applications and movement of existing approved water right applications into the valley via change applications. A recent large change application moving water rights into the valley highlighted the need for a better understanding of the extent and availability of existing groundwater resources.

The principle study estimating groundwater recharge to the Moab-Spanish Valley was completed in 1971. Recent studies on particular components of the groundwater system have raised questions concerning the accuracy of the recharge estimate made in 1971. The construction of Kens Lake has also changed certain flow patterns in the groundwater system within the valley. The Division of Water Rights (UDWRi) in coordination with the United States Geologic Service and all of the major water users/stakeholders in the valley have initiated a new comprehensive study of groundwater resources. The new study will be utilized in developing a Groundwater Management Plan for the valley. The MAWP is encouraged by this opportunity and is planning on cooperating and helping with this study and plan

The Town of Castle Valley is also concerned with the sustainable yield from their groundwater resources. The Town is proposing a study that will be implemented with the use of a private contractor to determine the extent of groundwater resources in Castle Valley. The findings of the study will be used by DWRi and stakeholders to create a Groundwater Management Plan for Castle Valley. The MAWP is encouraged by this opportunity and is planning on cooperating and helping with this study and plan.

Chapter 6 Public Information and Education

6.1 Goals of Informational and Educational Activities

The status of Mill and Pack Creek water quality and their connection to the ground water are not well known to the general public in Spanish Valley. This is surprising because portions of the creeks are heavily used recreational areas for the local population and they are also relied upon for irrigation. In contrast, the populace of Castle Valley is generally informed of Castle Creek's and the valley groundwater quality.

The MAWP information and education goals include educating the populace on:
1: The relationship of the Groundwater and Surface Water.
2: The sensitivity of the aquifer to contamination
3: Drinking water comes from that aquifer
4: The limited resources of that Ground and Surface Water
5: The status of surface and groundwater quality.

6.2 Planned Informational and Educational Activities

The MAWP intends to inform and educate the communities of Spanish Valley and Castle Valley through:

1: The MAWP website
2: Press releases
3: The Utah Water Watch website and educational outreach efforts
4: An educational kiosk along the Mill Creek Parkway
5: Booths at community events when appropriate
6: Lectures at educational institutions
7: Updates delivered through utility bills
8: Presentations to local governments when appropriate.

Chapter 7 Monitoring and Evaluation

The intent of this watershed management plan is to develop means and practices that will benefit watersheds. A monitoring program and criteria to evaluate improvements in the watershed are necessary to determine success and document achievement of milestones.

7.1 Water Quality Monitoring

Water quality monitoring in Spanish and Castle Valley is performed by the Division of Water Quality (DWQ) and volunteers with Utah Water Watch. DWQ samples the Spanish Valley Watershed on a monthly basis for one year every five years. Crews collect field data and water samples for analysis at the State Health Laboratory. DWQ collects a variety of constituents that are used to determine support of Castle Creek's beneficial uses. Visit the DWQ Website for the SAP associated with their intensive monitoring

Utah Water Watch, the Moab Area Watershed Partnership, and the watershed coordinator have teamed up to monitor a select group of sites in Spanish and Castle Valley. Several of the constituents of concern in these watersheds can be monitored with typical field measurements and the use of a chemical laboratory is not necessary. The Moab BLM's office contains and incubator for coliform analysis and has agreed to allow access to coliform analysts and participate in the analyses if necessary. This monitoring program allows the MAWP to track constituents of concern as projects on a long term basis as projects are implemented.

7.1.1 Sample and Analysis Plan for Spanish Valley Utah Water Watch Volunteer Monitoring

Utah Water Watch and their volunteers have a Sampling Analysis Plan (SAP) that will be used to evaluate project successes and ongoing improvements in the watershed. The SAP is as follows:

1. Monitoring Goals and Objectives

The goal of this SAP is to document the overall monitoring plan and provide clear documentation for how Utah Water Watch (UWW) volunteers will provide assistance monitoring.

Monitoring objectives for this project are related to the UDWQ and Watershed Coordinator roles of monitoring water quality for assessment and long term data collection related to TMDLs.

Specific Objectives:

- Monitor total coliform and *E. coli* in streams to assess whether recreation and drinking source beneficial uses are met as part of the UDWQ's coliform monitoring program.
- Monitor temperature and total dissolved solids (TDS) to establish baseline conditions and track watershed improvement as part of the identified TMDL.

2. Background & Project Area Description

This project is taking place in the Spanish Valley surrounding Moab, UT. The two main streams are Pack and Mill Creek. The creeks start in the La Sal Mountains and flow through city of Moab before Pack Creek joins Mill Creek. Mill Creek empties directly into the Colorado River.

Name	Assessment Unit	Beneficial Uses	2010 Assessment	TMDL
Mill Creek – 1	14030005-005	1C, 2B, 3A, 4	Impaired 3A Temp; 4 TDS	Yes, TMDL
Mill Creek – 2	14030005-006	1C, 2B, 3A, 4	Not impaired; not all assessed	
Pack Creek	14030005-011	1C, 2B, 3A, 4	Impaired 3A Selenium & Temp; 4 TDS	Required; Linked in with Mill Creek TMDL

Impairments were initially detected in 1997 and the DWQ has developed an approved TMDL. The area has a Watershed Coordinator (WC) and a watershed group "Moab Area Watershed Partnership"

3. UWW volunteer role

The UWW volunteer will help with water quality sampling. The volunteer will serve as additional help for the watershed coordinator to monitor their many water bodies. Specifically, they will collect qualitative data about the site (water clarity, water color, number of dead fish, etc.), will measure several field parameters using calibrated field probes (temperature, TDS, pH, etc.), and they will collect an *E. coli* sample for IDEXX testing. The volunteers will also assist the WC with the continuous monitoring (deploying, checking, and downloading the probe). The volunteer will work with the local WC to schedule times for sampling. UWW volunteer will record and enter all data in the appropriate locations. If the volunteer needs more supplies they will contact the UWW program coordinator in time to ensure delivery of supplies before the next scheduled sampling event. UWW volunteers will also share photos, stories, and potential problems with the local WC and UWW program coordinator.

4. Sampling Locations

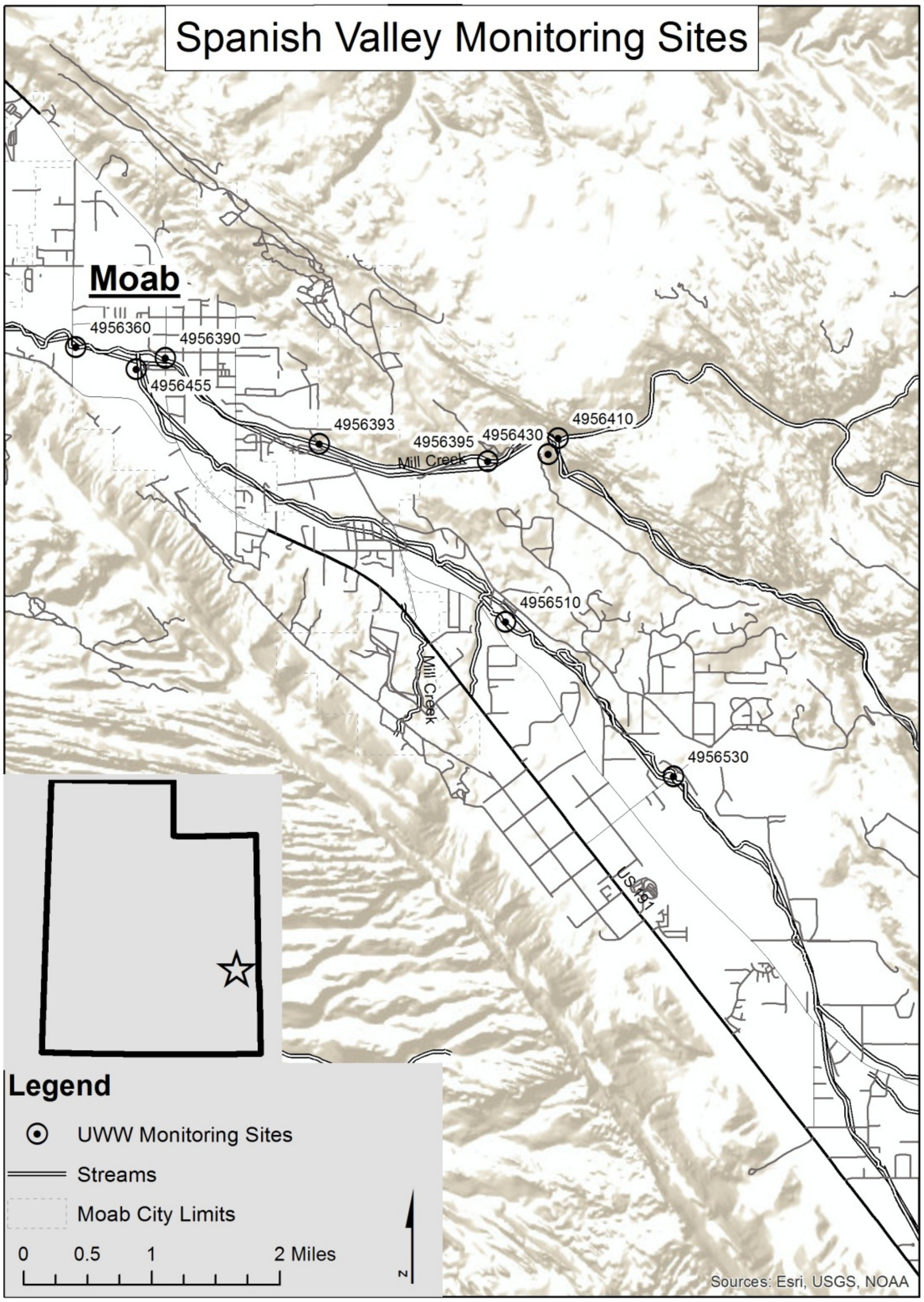

Fig. 7.1.1 Monitoring Locations – Visit the UWW Map for an interactive map.

DWQ Assessment Unit Name / UWW Stream Name	AWMQS Monitoring ID	UWW ID	Description	Latitude Longitude
Mill Creek -1 / Mill Creek Grand County	4956360	MICG-02-S	Mill Creek bl Confluence w Pack Ck at 500 West	38°34'19.936"N 109°33'39.422"W
Mill Creek -1 / Mill Creek Grand County	4956390	MICG-03-S	Mill Creek @ HWY 191 Xing	38°34'16.436"N 109°33'2.922"W
Mill Creek -1 / Mill Creek Grand County	4956393	MICG-04-S	Mill CK at Mill Creek Drive Xing	38°33'49.183"N 109°32'0.360"W
Mill Creek -1 / Mill Creek Grand County	4956395	MICG-05-S	Mill Creek bl Power Dam (EMAP)	38°33'40.509"N 109°31'19.604"W
Mill Creek -1 / Mill Creek Grand County	4956410	NA	North Fork Mill Creek ab cnfl Mill Creek	38°33'50.937"N 109°30'23.420"W
Mill Creek -1 / Mill Creek Grand County	4956430	NA	Mill Creek ab cnfl/ N Fk Mill Creek	38°33'45.937"N 109°30'27.420"W
Mill Creek -1 / Mill Creek Grand County	Not Available at this time	NA	Mill Creek 1 mi ab Spring Canyon	Not Available at this time
Pack Creek / Pack Creek	4956455	PACG-02-S	Pack Creek ab cnfl Mill Ck @ west end of 200 S	38°34'12.858"N 109°33'14.731"W
Pack Creek / Pack Creek	4956510	PACG-03-S	Pack Creekk at Pack Creek Campground	38°32'52.740"N 109°30'44.850"W
Pack Creek / Pack Creek	4956530	PACG-04-S	Pack Creek at Spanish Trail Drive Xing	38°32'3.439"N 109°29'36.619"W

5. Sample Parameters

Qualitative Parameters: UWW Field Observations – Observed Flow, Water Surface, Water Clarity, Water Color, Water Odor, Visual Algae Cover, # of Dead Fish, Present Weather, Past 24 HR weather, Estimated Inches of Rain fall in past 72 hours, Comments

Field Parameters: Temperature, pH, Conductivity, Salinity, & TDS; Turbidity & Total Depth;

Biological Parameters: Coliforms and *E. coli*

Continuous monitoring: Hobo Temperature loggers and Pressure Transducers (Pressure Transducers also measure temperature concurrently)

DWQ Assessment Unit Name / UWW Stream Name	AWMQS Monitoring ID	UWW ID	Monitoring
Mill Creek -1 / Mill Creek Grand County	4956360	MICG-02-S	Qualitative parameters Field Parameters Biological Parameters Continuous monitoring: Pressure Transducer
Mill Creek -1 / Mill Creek Grand County	4956390	MICG-03-S	Qualitative parameters Field Parameters Biological Parameters Continuous monitoring: Hobo Temperature
Mill Creek -1 / Mill Creek Grand County	4956393	MICG-04-S	Qualitative parameters Field Parameters Biological Parameters
Mill Creek -1 / Mill Creek Grand County	4956395	MICG-05-S	Qualitative parameters Field Parameters Biological Parameters
Mill Creek -1 / Mill Creek Grand County	4956410	NA	Continuous Monitoring: Pressure Transducer
Mill Creek -1 / Mill Creek Grand County	4956430	NA	Continuous Monitoring: Pressure Transducer
Mill Creek -1 / Mill Creek Grand County	Not Available at this time	NA	Continuous Monitoring: Pressure Transducer
Pack Creek / Pack Creek	4956455	PACG-02-S	Qualitative parameters Field Parameters Biological Parameters Continuous monitoring: Pressure Transducer
Pack Creek / Pack Creek	4956510	PACG-03-S	Qualitative parameters Field Parameters Biological Parameters
Pack Creek / Pack Creek	4956530	PACG-04-S	Qualitative parameters Field Parameters Biological Parameters Continuous monitoring: Pressure Transducer

6. Sampling Frequency

Parameters	Responsible Party	Frequency	Timeline
Qualitative Parameters and Field Parameters	UWW volunteer	Once a month	December 2013 – December 2014
Biological Parameters	UWW volunteer & WC	Once a month Oct – April Twice a month May – Sept	December 2013 – December 2014
Continuous monitoring	WC	Collecting data every 30 min.	Mar. 2013 – Mar. 2014

7. Methodologies

All UWW volunteers have attended a training where they were instructed on proper techniques for sampling. Please refer to the UDWQ or UWW SOPs if additional review is needed.

The UDWQ SOPs are managed by UDWQ staff. For latest versions visit their website or contact their staff. The WC will be provided with a hard copy of the current SOPs at the time of this document's creation. The UWW SOPs are managed by USU Water Quality Extension Staff. Generally they are hosted on the UWW website and are publicly available.

UDWQ *E.coli* field sampling and processing SOPs
UDWQ Pressure Transducer SOP
UDWQ Temperature Logger SOP

UWW Tier II Stream SOP

- Qualitative Field Observations
- Oakton PCS 35 Testr Field Probe Calibration for conductivity and pH
- Field Probe Measurements

8. Field Equipment

Qualitative Parameters:
UWW Datasheet (Appendix)
Notebook
Pencil

Field Parameters:
Oakton PCS 35 Testr
Calibration Solutions for pH (4, 7, & 10) and conductivity (1413 µs/cm)
60 cm Turbidity Tube
UWW Datasheet (Appendix)
Biological Parameters:

UDWQ *E.coli* Datasheet (Appendix)
Sterile *E.coli* sample bottles
Marker
Cooler with wet ice
Thermometer

Continuous Monitoring:
Hobo Temperature Pendent Logger

Rugged TROLL 100 Pressure Transducer
Supplies to install and secure probes in the stream
UDWQ Continuous Monitoring Data Sheet (Appendix)

9. Health & Safety

Safety is a primary concern at all times and in all sampling situations for field personal. All UWW volunteers are trained to minimize risk and sample in a safe manner. In any marginal or questionable situation, monitoring personnel (samplers) are required to assume worst case conditions and use safety precautions and equipment appropriate to that situation. Samplers who encounter conditions which in their best professional judgment may exceed the protection of their safety equipment (PFD, waders, boat, etc.) or may in any way represent a potential hazard to human health (high water levels, ice, etc.) and safety should immediately leave the area and sample at another safer time.

There should be a minimum of two sampling personnel present in the field. Samplers will wash hands and arms thoroughly with bacterial soap after sampling, before eating and drinking and at the end of the sampling run.

Before heading out to sample, samplers will inform a family member or friend when they are leaving for the field and their estimated time of return. Samplers are strongly encouraged to carry a cell phone. In case of emergency call 911.

General safety steps should be followed when on site. Wearing proper equipment (proper shoes or waders, PFD, etc.) and bringing a first aid kit is essential. Identify potential hazards (steep cliffs, barbed wire, broken glass, etc.) both on land and in the water. Follow the general standard that water flows above 1 cfs or that are deeper than knee depth can be hazardous.

10. QAQC

All UWW volunteers have attended a training where they were instructed on proper techniques for sampling. Please refer to the UTDWQ or UWW SOPs if additional review is needed.

Parameter	QC Check	Frequency	Acceptable Range	Correction Actions
E. coli	8 hour holding time; Replicates at 10 % of sites or 1 per trip if less than 10 sites. 1 Field Blank per trip	Each sampling trip	NA	Audit and train
pH	3 point meter calibration; written record of calibration	Within 24 hours prior to sampling	± 0.1	Repeat field check; if not correct return meter to manufacturer for repair

Temperature	Annual calibration against NIST thermometer	Annually	On the calibration mark	Repeat measurement with different thermometer; if not correct return meter to manufacturer for repair
Conductivity	1-point calibration; Written record of calibration	Within 24 hours prior to sampling	± 5% of standard (70 µs/cm)	Repeat field check; if not correct return meter to manufacturer for repair

Data entry QAQC – UWW volunteer double check data when they enter it on the online UWW database. The database also has internal quality control for extreme values and data entry limitations. All data submitted to the UWW database is examined by WQE staff with a QAQC checker to examine high values and data entry errors. 10% of copies of original field datasheets are submitted annually to check for data accuracy. The local watershed coordinator should also look over reports submitted on the UWW database to ensure correct data.

11. Data Documentation and Storage

Field Observations & Parameters: UWW volunteer will record all field data on the UWW Tier II datasheet. UWW volunteer will submit the electronic data online on the Utah Water Watch Database. The original field datasheets will be stored with the local watershed coordinator who can provide copies to the UWW volunteer if needed. The WC will be provided with a filing system to store all data sheets, SOPs, and SAPs in a clearly identifiable location. The UWW program coordinator will work with the UDWQ to transfer the formatted data to UDWQ's AQWMS database.

Coliform data will be sent electronically by the WC to UDWQ for entry into the AQWMS data base. The WC will also maintain hard copies of bench sheets for three years after analysis.

Continuous temperature probe and pressure transducer data will be maintained by the WC.

12. Decontamination

All Utah Water Watch volunteers are educated about the importance of proper decontamination to prevent the spread of aquatic invasive species. This is especially important for volunteers who travel to different watersheds or lakes.

Utah Water Watch follows the Utah Division of Wildlife Resources recommended strategy of cleaning, draining, and drying all equipment. For further instructions visit the Utah Water Watch's decontamination webpage.

13. Participants

Name	Role	UWW Volunteer ID	Email	Phone
Arne Hultquist	Watershed Coordinator	SE Colorado Watershed Coordinator	arnehultquist@gmail.com	435-259-7558
Mike Allred	DWQ Scientist	N/A	mdallred@utah.gov	801-536-4331
Ann Marie Aubry	BLM / UWW Volunteer	13-45	aaubry@blm.gov	435-259-2173
Brian Greene	UWW program coordinator	1	Brian.greene@usu.edu	435-797-2580

7.1.2 Sample and Analysis Plan for Castle Valley Utah Water Watch Volunteer Monitoring

Utah Water Watch and their volunteers have a Sampling Analysis Plan (SAP) that will be used to evaluate project successes and ongoing improvements in the watershed. The SAP is as follows:

1. Monitoring Goals and Objectives

The goal of this Sample and Analysis Plan (SAP) is to document the overall monitoring plan and provide clear documentation for how Utah Water Watch volunteers will provide assistance monitoring.

Monitoring objectives for this project are related to the UDWQ and watershed coordinator roles of monitoring water quality for assessment and long term data collection related to TMDLs.

Specific Objectives:

- Monitor total coliform and *E. coli* in streams to assess whether recreation and drinking source beneficial uses are met as part of the UDWQ's coliform monitoring program.
- Monitor temperature and total dissolved solids (TDS) to establish baseline conditions and track watershed improvement as part of the identified TMDL.

2. Background & Project Area Description

This project takes place along Castle Creek which flows through the town of Castle Valley. Castle Creek has its headwaters in the La Sal Mountains on USFS land and flows through the rural residential community of Castle Valley before it empties directly into the Colorado River.

Name	Assessment Unit	Beneficial Uses	2010 Assessment	TMDL
Castle Creek – 1	14030005-009	1C, 2A, 3B, 4	Impaired for 3B: Benthic Macroinvertebrate	Required, but not yet created

Castle Creek – 2	14030005-012	1C, 2A, 3B, 4	Not impaired; not all assessed	None

The area has a watershed coordinator and is part of the watershed group "Moab Area Watershed Partnership"

3. UWW volunteer role

The UWW volunteer will help with water quality sampling. The volunteer will serve as additional help for the watershed coordinator to monitor their many water bodies. Specifically, they will collect qualitative data about the site (water clarity, water color, number of dead fish, etc.), will measure several field parameters using calibrated field probes (temperature, TDS, pH, etc.), and they will collect an *E. coli* sample for IDEXX testing. The volunteers will also assist the WC with the continuous monitoring (deploying, checking, and downloading the probe). The volunteer will work with the local WC to schedule times for sampling. UWW volunteer will record and enter all data in the appropriate locations. If the volunteer needs more supplies they will contact the UWW program coordinator in time to ensure delivery of supplies before the next scheduled sampling event. UWW volunteers will also share photos, stories, and potential problems with the local WC and UWW program coordinator.

4. Sampling Locations

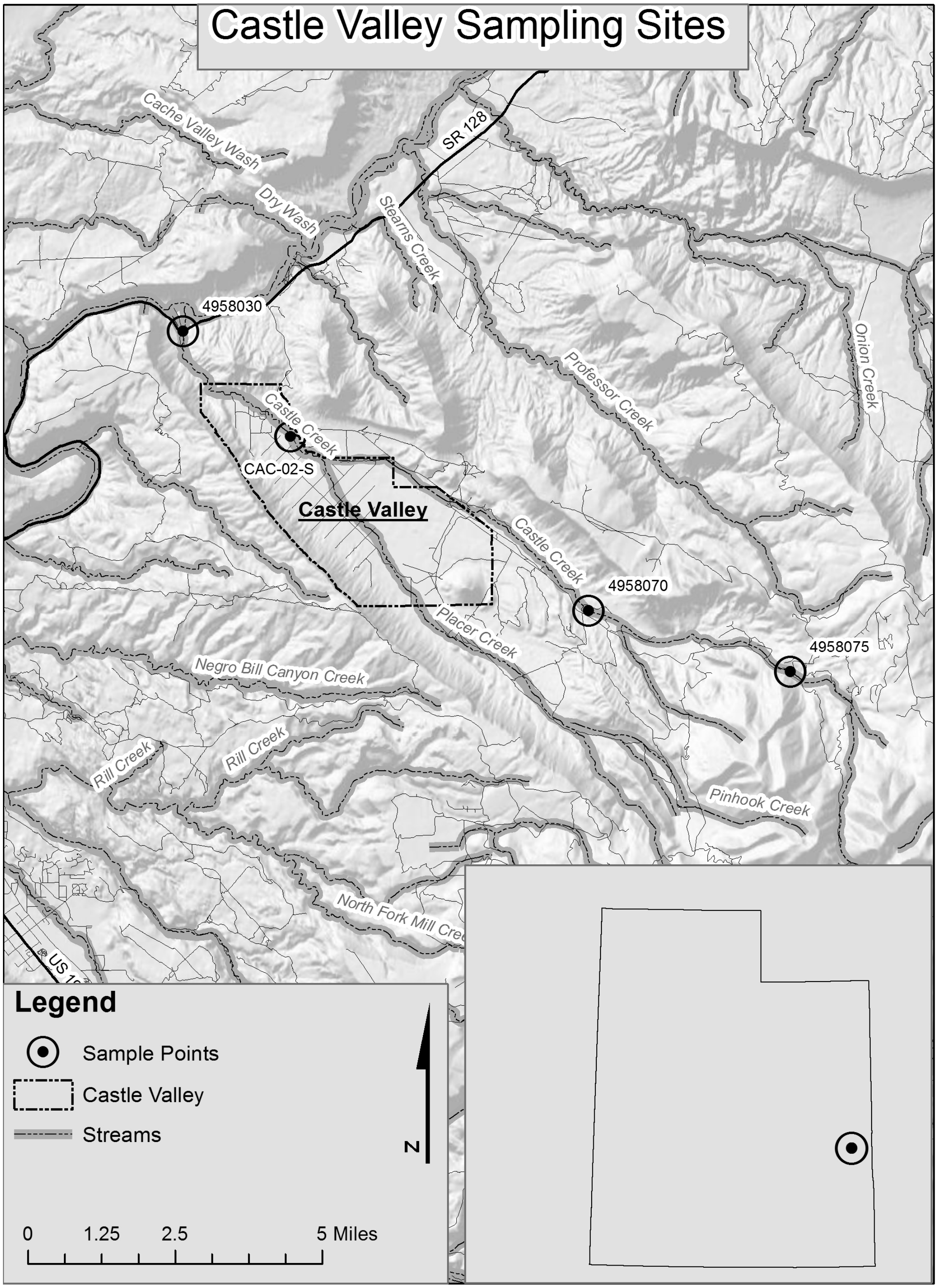

Figure 7.1.2 2014 Monitoring Sites for Castle Valley. Visit the [UWW Map]() for an interactive map.

DWQ Assessment Unit Name / UWW Stream Name	AWMQS Monitoring ID	UWW ID	Description	Latitude Longitude
Castle Creek -1 / Castle Creek	4958030	CAC-01-S	Castle Creek at U128 Xing	38°40'38.936"N 109°26'57.423"W
Castle Creek -1 / Castle Creek	4958080	CAC-02-S	Castle Creek ab Diversion in town	38°39'3.19"N 109°24'57.67"W
Castle Creek -1 / Castle Creek	4958070	CAC-03-S	Castle Valley Creek @ Castleton	38°36'23.946"N 109°19'23.417"W
Castle Creek -2 / Castle Creek	4958075	CAC-04-S	Castle Ck ab USFS Rd Xing to CO	38°35'25.950"N 109°15'36.415"W

5. Sample Parameters

Qualitative Parameters: UWW Field Observations – Observed Flow, Water Surface, Water Clarity, Water Color, Water Odor, Visual Algae Cover, # of Dead Fish, Present Weather, Past 24 HR weather, Estimated Inches of Rain fall in past 72 hours, Comments

Field Parameters: Temperature, pH, Conductivity, Salinity, & TDS; Turbidity & Total Depth;

Biological Parameters: Coliforms and *E. coli*

Continuous monitoring: Pressure Transducers (Pressure Transducers also measure temperature concurrently)

DWQ Assessment Unit Name / UWW Stream Name	AWMQS Monitoring ID	UWW ID	Monitoring
Castle Creek -1 / Castle Creek	4958030	CAC-01-S	Qualitative parameters Field Parameters Biological Parameters (USGS has a continuous gauging station at this location)
Castle Creek -1 / Castle Creek	4958088	CAC-02-S	Qualitative parameters Field Parameters Biological Parameters
Castle Creek -1 / Castle Creek	4958070	CAC-03-S	Qualitative parameters Field Parameters Biological Parameters Continuous monitoring: Pressure Transducer
Castle Creek -2 / Castle Creek	4958075	CAC-04-S	Qualitative parameters Field Parameters Biological Parameters

6. Sampling Frequency

Parameters	Responsible Party	Frequency	Timeline
Field Observations and Field Parameters	UWW volunteer	Once a month	December 2013 – December 2014
Biological Parameters	UWW volunteer & WC	Once a month Oct – April Twice a month May – Sept	December 2013 – December 2014
Continuous monitoring	WC	Collecting data every 30 min.	March 2013 – March 2014

7. Methodologies

All UWW volunteers have attended a training where they were instructed on proper techniques for sampling. Please refer to the UDWQ or UWW SOPs if additional review is needed.

The UDWQ SOPs are managed by UDWQ staff. For latest versions visit their website or contact their staff. The WC will be provided with a hard copy of the current SOPs at the time of this document's creation. The UWW SOPs are managed by USU Water Quality Extension Staff. Generally they are hosted on the UWW website and are publicly available.

UDWQ *E.coli* field sampling and processing SOPs
UDWQ Pressure Transducer SOP

UWW Tier II Stream SOP

- Qualitative Field Observations
- Oakton PCS 35 Testr Field Probe Calibration for conductivity and pH
- Field Probe Measurements

8. Field Equipment

Qualitative Parameters:
UWW Datasheet (Appendix)
Notebook
Pencil
Field Parameters:
Oakton PCS 35 Testr
Calibration Solutions for pH (4, 7, & 10) and conductivity (1413 µs/cm)
60 cm Turbidity Tube
UWW Datasheet (Appendix)
Biological Parameters:

UDWQ *E.coli* Datasheet (Appendix)
Sterile *E.coli* sample bottles
Marker
Cooler with wet ice
Thermometer

Continuous Monitoring:
Rugged TROLL 100 Pressure Transducer
Supplies to install and secure probes in the stream
UDWQ Continuous Monitoring Data Sheet (Appendix)

9. Health & Safety

Safety is a primary concern at all times and in all sampling situations for field personal. All UWW volunteers are trained to minimize risk and sample in a safe manner. In any marginal or questionable situation, monitoring personnel (samplers) are required to assume worst case conditions and use safety precautions and equipment appropriate to that situation. Samplers who encounter conditions which in their best professional judgment may exceed the protection of their safety equipment (PFD, waders, boat, etc.) or may in any way represent a potential hazard to human health (high water levels, ice, etc.) and safety should immediately leave the area and sample at another safer time.

There should be a minimum of two sampling personnel present in the field. Samplers will wash hands and arms thoroughly with bacterial soap after sampling, before eating and drinking and at the end of the sampling run.

Before heading out to sample, samplers will inform a family member or friend when they are leaving for the field and their estimated time of return. Samplers are strongly encouraged to carry a cell phone. In case of emergency call 911.

General safety steps should be followed when on site. Wearing proper equipment (proper shoes or waders, PFD, etc.) and bringing a first aid kit is essential. Identify potential hazards (steep cliffs, barbed wire, broken glass, etc.) both on land and in the water. Follow the general standard that water flows above 1 cfs or that are deeper than knee depth can be hazardous.

10. QAQC

All UWW volunteers have attended a training where they were instructed on proper techniques for sampling. Please refer to the UTDWQ or UWW SOPs if additional review is needed.

Parameter	QC Check	Frequency	Acceptable Range	Correction Actions
E. coli	8 hour holding time; Replicates at 10 % of sites or	Each sampling trip	NA	Audit and train

	1 per trip if less than 10 sites. 1 Field Blank per trip			
pH	3 point meter calibration; written record of calibration	Within 24 hours prior to sampling	± 0.1	Repeat field check; if not correct return meter to manufacturer for repair
Temperature	Annual calibration against NIST thermometer	Annually	On the calibration mark	Repeat measurement with different thermometer; if not correct return meter to manufacturer for repair
Conductivity	1-point calibration; Written record of calibration	Within 24 hours prior to sampling	± 5% of standard (70 µs/cm)	Repeat field check; if not correct return meter to manufacturer for repair

Data entry QAQC – UWW volunteer double check data when they enter it on the online UWW database. The database also has internal quality control for extreme values and data entry limitations. All data submitted to the UWW database is examined by WQE staff with a QAQC checker to examine high values and data entry errors. 10% of copies of original field datasheets are submitted annually to check for data accuracy. The local watershed coordinator should also look over reports submitted on the UWW database to ensure correct data.

11. Data Documentation and Storage

Field Observations & Parameters: UWW volunteer will record all field data on the UWW Tier II datasheet. UWW volunteer will submit the electronic data online on the Utah Water Watch Database. The original field datasheets will be stored with the local watershed coordinator who can provide copies to the UWW volunteer if needed. The WC will be provided with a filing system to store all data sheets, SOPs, and SAPs in a clearly identifiable location. The UWW program coordinator will work with the UDWQ to transfer the formatted data to UDWQ's AQWMS database.

Coliform data will be sent electronically by the WC to UDWQ for entry into the AQWMS data base. The WC will also maintain hard copies of bench sheets for three years after analysis.
Continuous pressure transducer data will be maintained by the WC.

12. Decontamination

All Utah Water Watch volunteers are educated about the importance of proper decontamination to prevent the spread of aquatic invasive species. This is especially important for volunteers who travel to different watersheds or lakes.

Utah Water Watch follows the Utah Division of Wildlife Resources recommended strategy of cleaning, draining, and drying all equipment. For further instructions visit the Utah Water Watch's decontamination webpage.

13. Participants

Name	Role	UWW Volunteer ID	Email	Phone
Arne Hultquist	Watershed Coordinator	SE Colorado Watershed Coordinator	arnehultquist@gmail.com	435-259-7558
Mike Allred	DWQ Scientist	N/A	mdallred@utah.gov	801-536-4331
Dave Erley	GCT/ UWW Volunteer	13-44	dderley@frontiernet.net	435-259-4859
Mary O'Brien	GCT / UWW Volunteer	13-43	maryobrien10@gmail.com	435-259-6205
Brian Greene	UWW program coordinator	1	Brian.greene@usu.edu	435-797-2580

7.2 Habitat and Riparian Monitoring

The MAWP has agreed to use Multiple Indicator Monitoring (MIM) for riparian projects. The MAWP recognizes the protocol is designed to measure impacts from cattle grazing and cattle are not grazed in a large portion of riparian areas in Spanish and Castle Valley. However, several of the streams are high use recreational areas where trampling and social trailing occur in riparian areas. The MAWP also considers the monitoring geared toward stream side vegetation and canopy which directly affect temperature, one of our critical physical parameters.

For each project, the project sponsor will assemble a team of personnel trained in MIM monitoring. Pre and post MIM will occur at all project sites as a minimum for project monitoring.

The MAWP considers MIM the primary tool to be used in our watersheds for riparian monitoring assessment. The MAWP envisions monitoring appropriate reference locations at definable stream reaches to use as a comparison to project sites. A team of MIM trained personnel will define stream sections by differing hydrogeomorphic conditions, determine a reference reach, and perform MIM in stream reaches that have riparian projects associated with them.

7.3 Watershed Management Evaluation Criteria

The MAWP considers evaluation of ongoing monitoring and improvements from initiatives in the watershed a critical component of the watershed management plan. Evaluation will help reinforce practices and projects that are beneficial to the watershed.

7.3.1 Water Quality Evaluation

Water Quality characteristics will be compared to State of Utah Water Quality Standards (r317-2) and evaluated per DWQ guidelines.

7.3.2 Habitat and Riparian Evaluation

Although MIM will be used for monitoring riparian projects, MIM is not an assessment tool. The MAWP has considered using the Stream Visual Assessment Protocol developed by the Department of Agriculture and used by the NRCS. The MAWP is also considering using Proper Functioning Condition assessment developed by the BLM

7.4 Reporting

At a minimum of once per year the Watershed Coordinator will provide a summary and evaluation of water quality data collected during the previous water year. The report should be presented at the MAWP monthly meeting in November. The MAWP can use the data to evaluate the monitoring plan and document improvements. If the MAWP partners or the Watershed Coordinator considers any new data critical to the MAWP, he can report on current monitoring activities as necessary.

Project sponsors who have completed or are working on projects in the MAWP watershed will also provide an update on project progress at the same meeting.

Appendix A: Intensive Monitoring Program Data Summary

The general water chemistry data for sites sampled in 1997-1998, 2002-2003, and 2007-2008 are presented in the tables below. The analyses for water chemistry of sites sampling in the 2012-2013 intensive monitoring period has not been completed at this time.

Table A.1 Mill Ck Bl Cnfl / Pack Ck at 500W Xing (4956360)									
Characteristic	97-98 Mean	97-98 High	97-98 Low	02-03 Mean	02-03 High	02-03 Low	07-08 Mean	07-08 High	07-08 Low
Aluminum ug/l				<30	<30	<30			
Ammonia mg/l N				<.05	<.05	<.05			
Arsenic ug/l				<5	<5	<5			
Barium ug/l				94	120	69			
Boron ug/l				NA	NA	NA			
Cadmium ug/l				<1	<1	<1			
Calcium mg/l				122	170	38			
$CaCO_3$ (Alkalinity)				204	298	103			
Chloride mg/l				<32.5	57.6	<10			
Chromium ug/l				<5.7	9.3	<5			
Copper ug/l				<12	<12	<12			
Dissolved oxygen mg/l				8.7	10.3	6.4			
Flow ft3/sec				7	13.2	0.01			
Hardness mg/l				489	725	135			
nitrate and nitrite mg/l				0.92	2.5	0.32			
Iron ug/l				<20.4	22.1	<20			
Lead ug/l				<3	<3	<3			
Magnesium mg/l				44.6	66.5	10			
Manganese ug/l				98	166	43			
Mercury ug/l				<0.2	<0.2	<0.2			
Nickel ug/l				NA	NA	NA			
pH Units				8.1	8.5	7.5			
Dissolved Phosphate mg/l P				<0.021	0.03	<.02			
Total Phosphate mg/l P				0.099	0.91	<.02			
Potassium mg/l				3.6	4.7	1.8			
Selenium ug/l				2.6	3.1	2.1			
Silver ug/l				<2	<2	<2			

Sodium mg/l				55	79	23			
Specific conductance umho/cm				1034	1546	258			
Sulfate mg/l				310	604	41			
Temperature, water deg C				14.3	27.4	5.1			
Total dissolved solids mg/l				727	1146	208			
Total suspended solids mg/l				22	144	<4			
Turbidity NTU				125	1449	1.5			
Zinc ug/l				<30	31	<30			

Table A.2 Mill Creek at US 191 Xing (4956390)									
Characteristic	97-98 Mean	97-98 High	97-98 Low	02-03 Mean	02-03 High	02-03 Low	07-08 Mean	07-08 High	07-08 Low
Aluminum ug/l	<35	54	<30	<41	85	<30	<12.84	18.6	<10
Ammonia mg/l N	<0.06	0.18	<0.05	<0.05	<0.05	<0.05	.0<.05 2	0.08	<0.05
Arsenic ug/l	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<1.0	1.04	<1.0
Barium ug/l	128	150	120	170	194	150	161.2	183	136
Boron ug/l	NA	NA	NA	NA	NA	NA	<32.1	40.5	<30
Cadmium ug/l	<1	<1	<1	<1	<1	<1	<0.1	<0.1	<0.1
Calcium mg/l	39	55	28	55	86	34	42	70	31
$CaCO_3$ (Alkalinity)	111	156	80	160	210	123	147	236	112
Chloride mg/l	<4	7.5	<3	<10.8	17.9	<10	<13.5	49.8	<10
Chromium ug/l	<5	<5	<5	<5.5	7.4	<5	<2.5	3.9	<2
Copper ug/l	<12	<12	<12	<12	<12	<12	<1.2	1.7	<1.0
Dissolved oxygen mg/l	8.9	11.8	7.4	8.3	11.6	3.25	9.32	12.5	5.5
Flow ft3/sec	11.6	50	1.5	5.2	45.5	0	3.1	10.2	0.13
Hardness mg/l	140	90	206	209	315	121	201	725	120
nitrate and nitrite mg/l	0.13	0.26	0.03	0.15	0.37	<0.1	<0.41	0.72	<0.1
Iron ug/l	<26.7	37.5	<20	<22.4	32	<20	<22.8	30.6	<20
Lead ug/l	<3	<3	<3	<3	<3	<3	0.115	0.157	<0.1
Magnesium mg/l	10.6	17	5	17.5	24.3	13	14	22.1	10.1
Manganese ug/l	32	53	18	37	58	18	24	61	10
Mercury ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel ug/l	NA	NA	NA	NA	NA	NA	<5	<5	<5
pH Units	8.4	8.8	7.8	8.2	8.7	7.4	8.2	8.5	6.8
Dissolved Phosphate mg/l P	<0.029	0.43	<0.02	<0.023	0.04	<0.02	<0.02	<0.02	<0.02

Total Phosphate mg/l P	0.071	0.241	<0.02	0.106	1.01	<0.02	<0.02	0.02	<0.02
Potassium mg/l	1.4	2.3	1	2.2	3.6	1.4	1.6	2.8	1
Selenium ug/l	<1	<1	<1	<1	<1	<1	<1	<1	<1
Silver ug/l	<2	<2	<2	<2	<2	<2	<0.5	<0.5	<0.5
Sodium mg/l	6.9	12.3	3	12	19.9	4.4	9.1	27	5.5
Specific conductance umho/cm	287	429	172	417	543	216	421	1548	250
Sulfate mg/l	27.6	54.4	10.5	<58	97.6	<20	<39	120	<20
Temperature, water deg C	14.1	25.2	3.9	14.5	24.3	4.7	12.4	21.5	2.9
Total dissolved solids mg/l	172	264	122	274	388	174	277	1220	130
Total suspended solids mg/l	<56	477	<4	<6	31	<4	<7	20	<4
Turbidity NTU	30.6	225	0.8	86.7	1001	0.5	2.5	10.9	0.06
Zinc ug/l	<30	31	<30	<30	<30	<30	<12	16.5	<10

Table A.3 Mill Creek at USFS Boundary (4956400)									
Characteristic	97-98 Mean	97-98 High	97-98 Low	02-03 Mean	02-03 High	02-03 Low	07-08 Mean	07-08 High	07-08 Low
Aluminum ug/l	<39.5	68	<30	<30	<30	<30			
Ammonia mg/l N	<0.05	0.05	<.05	<0.05	<0.05	<.05			
Arsenic ug/l	<5	<5	<5	<5	<5	<5			
Barium ug/l	131	190	88	104	121	85			
Boron ug/l	NA	NA	NA	NA	NA	NA			
Cadmium ug/l	<1	<1	<1	<1	<1	<1			
Calcium mg/l	31	53	23	31	36	21			
$CaCO_3$ (Alkalinity)	85	147	65	83	95	62			
Chloride mg/l	<3	<3	<3	<10	<10	<3			
Chromium ug/l	<5	<5	<5	<5	<5	<5			
Copper ug/l	<12	<12	<12	<12	<12	<12			
Dissolved oxygen mg/l	10	12.1	8.1	9	11.4	5.8			
Flow ft3/sec	17.6	56	6.3	n/t	n/t	n/t			
Hardness mg/l	99	153	72	99	114	65			
nitrate and nitrite mg/l	<.2	0.31	0.02	<.15	0.36	<.1			
Iron ug/l	<22.8	30.9	<20	<20	<20	<20			
Lead ug/l	<3	<3	<3	<3	<3	<3			
Magnesium mg/l	5	6.7	3.5	5.7	6.9	3.3			
Manganese ug/l	12	16	6	21	39	10			

Mercury ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2			
Nickel ug/l	NA	NA	NA	NA	NA	NA			
pH Units	8.4	9.6	7.9	8.3	8.7	7.6			
Dissolved Phosphate mg/l P	<.016	0.031	<.01	<.021	0.035	<.02			
Total Phosphate mg/l P	0.068	0.31	<.02	0.069	0.097	<.02			
Potassium mg/l	<1.1	1.6	<1	<1.0	1.2	<1			
Selenium ug/l	<1	<1	<1	<1	<1	<1			
Silver ug/l	<2	<2	<2	<2	<2	<2			
Sodium mg/l	3.1	5	2.3	3.3	4.2	2.2			
Specific conductance umho/cm	186	296	123	198	250	144			
Sulfate mg/l	<12.4	21	<10	<21.1	31.3	<20			
Temperature, water deg C	8.3	24.1	2.7	10.7	21	3.5			
Total dissolved solids mg/l	124	174	96	130	174	84			
Total suspended solids mg/l	<68.2	618	<4	<15.7	42.7	<4			
Turbidity NTU	35.4	353	0.9	12.2	86.8	0.7			
Zinc ug/l	<30	31	<30	<30	<30	<30			

Table A.4 Pack Ck at U191 Xing (4956460)									
Characteristic	97-98 Mean	97-98 High	97-98 Low	02-03 Mean	02-03 High	02-03 Low	07-08 Mean	07-08 High	07-08 Low
Aluminum ug/l	<30	<30	<30	<30	<30	<30	<12.3	19.2	<10
Ammonia mg/l N	<0.05	0.07	<.05	<0.05	<.05	<.05	<0.08	0.46	<.05
Arsenic ug/l	<5	<5	<5	<5	<5	<5	<1.2	1.5	<1
Barium ug/l	37	42	33	39	65	26	<122	188	<100
Boron ug/l	NA	NA	NA	NA	NA	NA	122	162	103
Cadmium ug/l	<1	<1	<1	<1	<1	<1	<0.16	0.33	<0.1
Calcium mg/l	159	173	52	155	188	64	162	240	113
$CaCO_3$ (Alkalinity)	194	225	99	188	213	95	217	251	132
Chloride mg/l	50	78	6	<43	52	<10	<40	54	<10
Chromium ug/l	<5	<5	<5	<6.4	9.2	<5	<2.9	4.1	<2
Copper ug/l	<12	<12	<12	<12	<12	<12	<2.5	5	<1
Dissolved oxygen mg/l	8.9	11.6	7.7	8.8	12.7	5.9	9.5	15.5	5.5
Flow ft3/sec	4.3	8	2	2.7	11.7	0.05	2.2	10.8	0
Hardness mg/l	643	777	174	633	742	223	611	843	128

nitrate and nitrite mg/l	2.27	8.44	0.3	1.56	2.07	<.1	1.72	2.89	0.18
Iron ug/l	23.6	34.4	<20	<20	<20	<20	<20	<20	<20
Lead ug/l	<3	<3	<3	<3	<3	<3	0.16	0.28	<0.1
Magnesium mg/l	60	72	23	60	70	15	61	72	44
Manganese ug/l	28	40	11	14	21	<5	11	22	5
Mercury ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel ug/l	NA	NA	NA	NA	NA	NA	5.2	5.8	<5
pH Units	8.3	9.1	7.8	8.2	8.6	7.6	8.2	8.4	8
Dissolved Phosphate mg/l P	<.015	0.021	<.01	<.021	0.032	<0.02	<0.021	0.029	<0.02
Total Phosphate mg/l P	0.09	0.259	0.015	<.037	0.056	<0.02	<.069	0.47	<0.02
Potassium mg/l	4.9	7	1.9	4.7	5.6	1.6	5.8	11.4	4.2
Selenium ug/l	5.7	6.2	5.2	5.2	6	4.4	6.5	11.4	4.7
Silver ug/l	<2	<2	<2	<2	<2	<2	<0.5	<0.5	<0.5
Sodium mg/l	88	109	14	87	100	22	82	99	62
Specific conductance umho/cm	1462	1796	340	1346	1557	500	1375	1638	297
Sulfate mg/l	589	788	84	581	1530	48	460	667	226
Temperature, water deg C	13.4	22.2	6.3	13.6	24.3	4.3	11.1	22	2.5
Total dissolved solids mg/l	1111	1304	252	1110	1356	322	1025	1290	176
Total suspended solids mg/l	<69.3	440	<4	<22.5	173	<4	<122	896	<4
Turbidity NTU	30.4	228	1	18	114	0.9	159	1769	0.9
Zinc ug/l	<30	<30	<30	<30	<30	<30	<15	23	<10

Table A.5 Pack Ck at Spanish Trail Drive Xing (4956530)									
Characteristic	97-98 Mean	97-98 High	97-98 Low	02-03 Mean	02-03 High	02-03 Low	07-08 Mean	07-08 High	07-08 Low
Aluminum ug/l				<30	<30	<30	<13.6	28	<10
Ammonia mg/l N				<0.05	<0.05	<0.05	<0.052	0.08	<0.05
Arsenic ug/l				<5	<5	<5	<1.04	1.07	<1
Barium ug/l				43	63	31	<100	<100	<100
Boron ug/l				NA	NA	NA	106	144	86
Cadmium ug/l				<1	<1	<1	<0.1	<0.1	<0.1
Calcium mg/l				134	159	55	144	164	91
$CaCO_3$ (Alkalinity)				202	223	84	239	272	177
Chloride mg/l				<27.8	32.6	<10	29.1	35.4	16.2
Chromium ug/l				<7.3	28	<5	<3.1	5.1	<2

Copper ug/l				<12	<12	<12	<1.7	2.5	<1
Dissolved oxygen mg/l				8.6	10.3	7.4	8.5	11.3	5.3
Flow ft3/sec				2.1	4	0	1.5	2.2	0
Hardness mg/l				520	602	184	559	637	340
nitrate and nitrite mg/l				1.96	2.36	0.32	2	2.4	1.2
Iron ug/l				<32	75	<20	<26	33	<20
Lead ug/l				<3	<3	<3	<.26	0.73	<0.1
Magnesium mg/l				45	50	11	49	56	28
Manganese ug/l				32	38	25	47	62	34
Mercury ug/l				<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel ug/l				NA	NA	NA	<5	<5	<5
pH Units				8.1	8.3	7.4	8	8.1	7.8
Dissolved Phosphate mg/l P				<0.022	0.035	<0.02	<0.02	<0.02	<0.02
Total Phosphate mg/l P				<0.029	0.093	<0.02	<0.028	0.073	<0.02
Potassium mg/l				3.8	4.8	1.2	4.3	6.1	2.7
Selenium ug/l				4.9	5.9	4	4.7	5.6	4.3
Silver ug/l				<2	<2	<2	<0.5	<0.5	<0.5
Sodium mg/l				59	69	15	60	69	34
Specific conductance umho/cm				1081	1217	417	1259	1338	1221
Sulfate mg/l				332	607	24	307	453	35
Temperature, water deg C				13.8	19.2	8.3	12.3	16.5	7.3
Total dissolved solids mg/l				841	992	258	886	984	552
Total suspended solids mg/l				<34	359	<4	<45	366	<4
Turbidity NTU				6.6	53.6	0.9	28.5	206	1.1
Zinc ug/l				<30	<30	<30	18.4	25	10.9

Table A.6 Pack Ck BL Brumley Ck at Rd to Pack Ck Ranch (4956480)									
Characteristic	97-98 Mean	97-98 High	97-98 Low	02-03 Mean	02-03 High	02-03 Low	07-08 Mean	07-08 High	07-08 Low
Aluminum ug/l	<30	<30	<30	<30	<30	<30	<11	15	<10
Ammonia mg/l N	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic ug/l	<5	<5	<5	<5	<5	<5	<1	<1	<1
Barium ug/l	32	40	26	37	45	18	<100	<100	<100
Boron ug/l	NA	NA	NA	NA	NA	NA	36	61	<30

Cadmium ug/l	<1	<1	<1	<1	<1	<1	<0.1	<0.1	<0.1
Calcium mg/l	117	152	35	145	175	53	149	174	52
$CaCO_3$ (Alkalinity)	125	151	76	134	213	73	170	195	94
Chloride mg/l	<8.5	11	<3	<9.3	10.6	<3	<11.1	14.5	<10
Chromium ug/l	<5	<5	<5	<5.4	6.6	<5	2.6	3.9	<2
Copper ug/l	<12	<12	<12	<12	<12	<12	<1.9	2.6	<1
Dissolved oxygen mg/l	9.4	11.4	8.3	8.5	11.6	5.6	9.1	12.1	5.4
Flow ft3/sec	6.5	24.4	0	2	4.5	0.5	0.8	1.2	0.2
Hardness mg/l	376	486	119	472	559	167	504	651	159
nitrate and nitrite mg/l	<0.035	0.16	<.02	<0.11	0.19	<0.1	<.11	0.24	<0.1
Iron ug/l	<20	<20	<20	<26	54	<20	<20.6	23	<20
Lead ug/l	<3	<3	<3	<3	<3	<3	<0.12	0.21	<0.1
Magnesium mg/l	21	27	5.2	27	41	8.7	29	35.5	7.3
Manganese ug/l	<7.6	10	<5	<41.6	210	<5	<47.0	105	<5
Mercury ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel ug/l	NA	NA	NA	NA	NA	NA	<5	<5	<5
pH Units	8.5	10	7.9	8.2	8.5	7.1	8.3	8.5	8.1
Dissolved Phosphate mg/l P	<.014	0.02	<.01	<0.021	0.033	<0.02	<0.02	<0.02	<0.02
Total Phosphate mg/l P	<0.06	0.221	<0.015	<0.03	0.054	<0.02	<0.02	<0.02	<0.02
Potassium mg/l	2	2.4	1	<2.1	2.4	<1	<2.1	2.7	<1
Selenium ug/l	<1	<1	<1	<1	<1	<1	<1.0	1.1	<1
Silver ug/l	<2	<2	<2	<2	<2	<2	<0.5	<0.5	<0.5
Sodium mg/l	31	42	6	37	44	11	39	49	10
Specific conductance umho/cm	816	1058	222	936	1091	345	1100	1262	925
Sulfate mg/l	279	453	45	325	647	29	395	609	86
Temperature, water deg C	8.9	14.4	4.2	11.3	20.8	3.9	10.1	16.4	2.8
Total dissolved solids mg/l	587	738	154	747	918	240	800	946	226
Total suspended solids mg/l	<24.8	174	<4	<5.5	18	<4	<9.7	32.4	<4
Turbidity NTU	17.4	159	0.5	9	66.7	0.2	3.5	19.2	0.23
Zinc ug/l	<30	<30	<30	<30	<30	<30	<14.6	19.2	<10

Table A.7 Castle Ck at U128 Xing (4958030)									
Characteristic	97-98 Mean	97-98 High	97-98 Low	02-03 Mean	02-03 High	02-03 Low	07-08 Mean	07-08 High	07-08 Low

Aluminum ug/l	<30	<30	<30	<30	<30	<30	<11.2	14.9	<10
Ammonia mg/l N	<0.06	0.067	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic ug/l	<5	<5	<5	<5	<5	<5	<1.1	1.2	<1
Barium ug/l	39	50	28	40	64	17	<100	<100	<100
Boron ug/l	NA	NA	NA	NA	NA	NA	115	157	86
Cadmium ug/l	<1	<1	<1	<1	<1	<1	<0.1	<0.1	<0.1
Calcium mg/l	121	147	94	163	184	140	147	183	125
$CaCO_3$ (Alkalinity)	163	172	153	131	182	99	177	194	163
Chloride mg/l	337	530	275	407	884	88	380	515	291
Chromium ug/l	<5	<5	<5	<5.9	7.8	<5	<2.5	3.2	<2
Copper ug/l	<12	<12	<12	<12	<12	<12	1.8	2.6	1.1
Dissolved oxygen mg/l	8.9	10.1	7.6	9.3	11.4	8	9.7	13.2	7.2
Flow ft3/sec	7.1	9.1	5	2.8	3.8	1.5	6	9.3	3
Hardness mg/l	446	555	352	598	655	501	524	669	280
nitrate and nitrite mg/l	0.29	0.23	0.36	0.5	1.07	0.3	0.62	3.1	0.27
Iron ug/l	<22	28.7	<20	<20	<20	<20	<20	<20	<20
Lead ug/l	<3	<3	<3	<3	<3	<3	<0.15	0.21	<0.1
Magnesium mg/l	34	46	28	47	51	37	44	52	36
Manganese ug/l	33	71	8.8	<9.3	14.2	<5	<11.2	16.8	<5
Mercury ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nickel ug/l	NA	NA	NA	NA	NA	NA	<5	<5	<5
pH Units	8.5	9.1	8.3	8.2	8.6	7.3	8.3	8.5	8.1
Dissolved Phosphate mg/l P	<0.015	0.015	<0.01	<0.021	0.035	<0.02	<0.02	<0.02	<0.02
Total Phosphate mg/l P	<0.024	0.035	<0.01 5	<0.024	0.042	<0.02	<0.024	0.039	<0.02
Potassium mg/l	9.6	9.65	3.9	13.3	15.3	9.9	11.9	16.1	7.4
Selenium ug/l	3	3.8	2.5	3.3	3.8	2.9	3	3.1	2.6
Silver ug/l	<2	<2	<2	<2	<2	<2	<0.5	<0.5	<0.5
Sodium mg/l	220	343	78	298	345	219	262	324	198
Specific conductance umho/cm	1969	2733	1661	2383	2758	1914	2322	3692	1894
Sulfate mg/l	341	433	264	437	649	56.4	397	570	274
Temperature, water deg C	13.5	20.9	7.5	12.1	19.3	7.9	11.8	19.3	7.1
Total dissolved solids mg/l	1214	1686	1042	1586	1810	1258	1422	1674	1176
Total suspended solids mg/l	<47.5	218	<4	<4.2	6.4	<4	<47.1	171	<4
Turbidity NTU	14.4	58.4	0.6	5.6	36.8	0.2	8.4	62.8	0.7

Zinc ug/l	<30	<30	<30	<30	<30	<30	<13.5	19.2	<10

Table A.8 Castle Valley Ck at Castleton (4958070)									
Characteristic	97-98 Mean	97-98 High	97-98 Low	02-03 Mean	02-03 High	02-03 Low	07-08 Mean	07-08 High	07-08 Low
Aluminum ug/l				<30	<30	<30	<13	22.1	<10
Ammonia mg/l N				<0.05	<0.05	<0.05	<0.05	0.05	<0.05
Arsenic ug/l				<5	<5	<5	<1	<1	<1
Barium ug/l				68	78	55	<100	<100	<100
Boron ug/l				NA	NA	NA	<49	89	<30
Cadmium ug/l				<1	<1	<1	<0.1	<0.1	<0.1
Calcium mg/l				152	218	70	97	240	43
$CaCO_3$ (Alkalinity)				186	207	151	150	209	101
Chloride mg/l				109	188	41	81	187	23
Chromium ug/l				<6.6	9.6	<5	<2	<2	<2
Copper ug/l				<12	<12	<12	<1.4	2.2	<1
Dissolved oxygen mg/l				9	10.3	7.2	9.8	13.8	6.9
Flow ft3/sec				0.6	1.5	0	2.3	4.1	0.3
Hardness mg/l				563	849	250	343	905	138
nitrate and nitrite mg/l				0.4	0.55	0.2	0.19	0.63	<0.1
Iron ug/l				<20	<20	<20	<20	<20	<20
Lead ug/l				<3	<3	<3	<0.13	0.18	<0.1
Magnesium mg/l				44	74	18	24	74	7.7
Manganese ug/l				35.9	47	24	25	38	14
Mercury ug/l				<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nickle ug/l				NA	NA	NA	<5	<5	<5
pH Units				8.2	8.4	7.8	8.3	8.6	8.1
Dissolved Phosphate mg/l P				<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Total Phosphate mg/l P				<0.033	0.077	<0.02	<0.031	0.152	<0.02
Potassium mg/l				2.7	3.8	1.7	2.4	4.3	1.2
Selenium ug/l				2.3	3.7	1.5	1.8	3.5	1.2
Silver ug/l				<2	<2	<2	<0.5	<0.5	<0.5
Sodium mg/l				83	138	33	69	153	24
Specific conductance umho/cm				1276	2130	598	970	2192	549
Sulfate mg/l				310	725	29	236	775	49
Temperature, water deg C				11.1	19.5	7.3	9.2	20.2	3.3

Total dissolved solids mg/l				953	1320	394	613	1566	226
Total suspended solids mg/l				<4.8	8	<4	<38	272	<4
Turbidity NTU				14.5	118	0.2	11.4	99.8	0.7
Zinc ug/l				<30	<30	<30	13.1	19.7	10.4

Appendix B: Number of Exceedances per Location Report

Report Criteria

01-01-1997 to 09-10-2010

Location: Utah Department Of Environmental Quality 4956360 ~ MILL CK BL CNFL / PACK CK

Date	Characteristic	Fraction	Value	Units	Lower Threshold	Upper Threshold	%Diff
7/19/2002	Dissolved oxygen (DO)	Total	6.38	mg/l	6.5		2%
7/19/2002	Temperature, water		21.19	deg C		20.0	6%
8/21/2002	Dissolved oxygen saturation	Total	132.60	%		110	21%
8/21/2002	Temperature, water		27.44	deg C		20.0	37%
9/18/2002	Phosphate-phosphorus as P	Total	0.91	mg/l		.05	1720%
1/22/2003	Dissolved oxygen saturation	Total	112.90	%		110	3%
3/26/2003	Dissolved oxygen saturation	Total	113.10	%		110	3%
6/5/2003	Phosphate-phosphorus as P	Total	0.0860	mg/l		.05	72%
6/19/2003	Dissolved oxygen (DO)	Total	6.28	mg/l	6.5		3%

8/26/2008	Temperature, water		24.21	deg C		20.0	21%

Location Exceedance Count: 10

Location: Utah Department Of Environmental Quality 4956390 ~ MILL CK AT U191 XING

Date	Characteristic	Fraction	Value	Units	Lower Threshold	Upper Threshold	%Diff
7/31/1997	Temperature, water		25.20	deg C		20.0	26%
8/28/1997	Temperature, water		20.61	deg C		20.0	3%
9/18/1997	Temperature, water		20.30	deg C		20.0	2%
4/7/1998	Phosphate-phosphorus as P	Total	0.1490	mg/l		.05	198%
5/21/1998	Phosphate-phosphorus as P	Total	0.2410	mg/l		.05	382%
6/24/1998	Temperature, water		21.23	deg C		20.0	6%
4/7/1999	pH	Total	6.20	None	6.5	9.0	5%
6/28/1999	Temperature, water		26.70	deg C		20.0	34%
7/29/1999	Phosphate-phosphorus as P	Total	0.1930	mg/l		.05	286%
7/29/1999	Temperature, water		22.50	deg C		20.0	13%
6/29/2000	Temperature, water		26.70	deg C		20.0	34%

8/21/2002	Dissolved oxygen (DO)	Total	3.25	mg/l	6.5		50%
8/21/2002	Temperature, water		24.28	deg C		20.0	21%
9/18/2002	Phosphate-phosphorus as P	Total	1.01	mg/l		.05	1920%
5/21/2003	Dissolved oxygen (DO)	Total	5.31	mg/l	6.5		18%
5/21/2003	Temperature, water		21.70	deg C		20.0	9%
6/5/2003	Dissolved oxygen saturation	Total	132.90	%		110	21%
6/5/2003	Temperature, water		21.34	deg C		20.0	7%
6/19/2003	Dissolved oxygen (DO)	Total	6.10	mg/l	6.5		6%
7/31/2007	Temperature, water		21.11	deg C		20.0	6%
8/30/2007	Dissolved oxygen saturation	Total	123.30	%		110	12%
8/30/2007	Temperature, water		21.48	deg C		20.0	7%
10/31/2007	Dissolved oxygen saturation	Total	111.30	%		110	1%
11/28/2007	Dissolved oxygen saturation	Total	112.80	%		110	3%
2/19/2008	Total dissolved solids		1220	mg/l		1200	2%
4/16/2008	Dissolved oxygen (DO)	Total	5.54	mg/l	6.5		15%
8/26/2008	Temperature, water		24.77	deg C		20.0	24%

Location Exceedance Count: 27

Location: Utah Department Of Environmental Quality 4956400 ~ MILL CK AT USFS BOUNDARY AB KENS LAKE DIVERSION

Date	Characteristic	Fraction	Value	Units	Lower Threshold	Upper Threshold	%Diff
7/31/1997	Temperature, water		24.10	deg C		20.0	21%
5/21/1998	Phosphate-phosphorus as P	Total	0.31	mg/l		.05	520%
6/3/1998	pH	Total	9.59	None	6.5	9.0	7%
7/18/2002	Dissolved oxygen (DO)	Total	5.75	mg/l	6.5		12%
7/18/2002	Temperature, water		20.98	deg C		20.0	5%
8/21/2002	Temperature, water		20.08	deg C		20.0	0%
9/18/2002	Phosphate-phosphorus as P	Total	0.0970	mg/l		.05	94%
11/20/2002	Phosphate-phosphorus as P	Total	0.55	mg/l		.05	1000%

Location Exceedance Count: 8

Location: Utah Department Of Environmental Quality 4956460 ~ PACK CK AT U191 XING

Date	Characteristic	Fraction	Value	Units	Lower Threshold	Upper Threshold	%Diff
7/31/1997	Selenium	Dissolved	5.20	ug/l		4.6	13%

7/31/1997	Temperature, water		22.20	deg C		20.0	11%
8/28/1997	Total dissolved solids		1304	mg/l		1200	9%
9/18/1997	Total dissolved solids		1288	mg/l		1200	7%
10/29/1997	Selenium	Dissolved	5.60	ug/l		4.6	22%
10/29/1997	Total dissolved solids		1302	mg/l		1200	9%
11/19/1997	Total dissolved solids		1284	mg/l		1200	7%
1/14/1998	Inorganic nitrogen (nitrate and nitrite) as N	Dissolved	8.44	mg/l		4	111%
1/14/1998	Selenium	Dissolved	6.20	ug/l		4.6	35%
1/14/1998	Total dissolved solids		1292	mg/l		1200	8%
2/18/1998	Total dissolved solids		1298	mg/l		1200	8%
4/1/1998	Total dissolved solids		1270	mg/l		1200	6%
5/6/1998	Selenium	Dissolved	5.80	ug/l		4.6	26%
5/21/1998	Phosphate-phosphorus as P	Total	0.08	mg/l		.05	60%
5/21/1998	Total dissolved solids		1206	mg/l		1200	1%
6/3/1998	Phosphate-phosphorus as P	Total	0.2590	mg/l		.05	418%
6/3/1998	pH	Total	9.10	None	6.5	9.0	1%
6/24/1998	Phosphate-phosphorus as P	Total	0.0650	mg/l		.05	30%

7/19/2002	Dissolved oxygen (DO)	Total	5.85	mg/l	6.5		10%
7/19/2002	Temperature, water		21.55	deg C		20.0	8%
8/21/2002	Temperature, water		24.31	deg C		20.0	22%
9/18/2002	Phosphate-phosphorus as P	Total	0.07	mg/l		.05	40%
11/20/2002	Phosphate-phosphorus as P	Total	0.12	mg/l		.05	140%
1/22/2003	Dissolved oxygen saturation	Total	118.30	%		110	8%
1/22/2003	Selenium	Dissolved	5.60	ug/l		4.6	22%
1/22/2003	Total dissolved solids		1292	mg/l		1200	8%
3/26/2003	Selenium	Dissolved	6	ug/l		4.6	30%
3/26/2003	Total dissolved solids		1356	mg/l		1200	13%
4/16/2003	Selenium	Dissolved	5.70	ug/l		4.6	24%
4/16/2003	Total dissolved solids		1208	mg/l		1200	1%
6/5/2003	Phosphate-phosphorus as P	Total	0.0560	mg/l		.05	12%
7/31/2007	Phosphate-phosphorus as P	Total	0.1040	mg/l		.05	108%
7/31/2007	Temperature, water		20.22	deg C		20.0	1%
9/19/2007	Phosphate-phosphorus as P	Total	0.1640	mg/l		.05	228%
10/31/2007	Selenium	Dissolved	5.15	ug/l		4.6	12%
11/28/2007	Dissolved oxygen saturation	Total	120.90	%		110	10%

1/23/2008	Dissolved oxygen saturation	Total	141.50	%		110	29%
1/23/2008	Selenium	Dissolved	4.68	ug/l		4.6	2%
4/16/2008	Dissolved oxygen (DO)	Total	5.47	mg/l	6.5		16%
4/16/2008	Total dissolved solids		1244	mg/l		1200	4%
4/30/2008	Selenium	Dissolved	4.75	ug/l		4.6	3%
4/30/2008	Total dissolved solids		1230	mg/l		1200	3%
8/26/2008	Dissolved oxygen (DO)	Total	6.25	mg/l	6.5		4%
8/26/2008	Phosphate-phosphorus as P	Total	0.47	mg/l		.05	840%
8/26/2008	Selenium	Dissolved	11.40	ug/l		4.6	148%
8/26/2008	Temperature, water		21.99	deg C		20.0	10%
8/26/2008	Total dissolved solids		1290	mg/l		1200	8%

Location Exceedance Count: 47

Location: Utah Department Of Environmental Quality 4956480 ~ PACK CK BL BRUMLEY CK @ RD TO PACK CK RANCH

Date	Characteristic	Fraction	Value	Units	Lower Threshold	Upper Threshold	%Diff
5/20/1998	Phosphate-phosphorus as P	Total	0.2210	mg/l		.05	342%

6/3/1998	pH	Total	10.01	None	6.5	9.0	11%
7/18/2002	Temperature, water		20.78	deg C		20.0	4%
9/18/2002	Phosphate-phosphorus as P	Total	0.0540	mg/l		.05	8%
10/16/2002	Dissolved oxygen (DO)	Total	5.55	mg/l	6.5		15%
5/21/2003	Phosphate-phosphorus as P	Total	0.0740	mg/l		.05	48%
4/16/2008	Dissolved oxygen (DO)	Total	5.44	mg/l	6.5		16%

Location Exceedance Count: 7

Location: Utah Department Of Environmental Quality 4956530 ~ Pack Ck at Spanish Trail Drive Xing

Date	Characteristic	Fraction	Value	Units	Lower Threshold	Upper Threshold	%Diff
1/22/2003	Selenium	Dissolved	5	ug/l		4.6	9%
3/26/2003	Selenium	Dissolved	5.40	ug/l		4.6	17%
4/16/2003	Selenium	Dissolved	5.90	ug/l		4.6	28%
6/5/2003	Phosphate-phosphorus as P	Total	0.0930	mg/l		.05	86%
4/16/2008	Dissolved oxygen (DO)	Total	5.28	mg/l	6.5		19%
5/14/2008	Phosphate-phosphorus as P	Total	0.0730	mg/l		.05	46%

8/26/2008	Phosphate-phosphorus as P	Total	0.062750	mg/l	.05	26%
8/26/2008	Selenium	Dissolved	5.63	ug/l	4.6	22%

Location Exceedance Count: 8

Location: Utah Department Of Environmental Quality 4958030 ~ CASTLE CK AT U128 XING

Date	Characteristic	Fraction	Value	Units	Lower Threshold	Upper Threshold	%Diff
6/4/1998	pH	Total	9.06	None	6.5	9.0	1%
8/22/2002	Total dissolved solids		1810	mg/l		1800	1%
1/23/2003	Dissolved oxygen saturation	Total	111.10	%		110	1%
11/1/2007	Dissolved oxygen saturation	Total	112.40	%		110	2%
11/28/2007	Dissolved oxygen saturation	Total	115.90	%		110	5%
1/24/2008	Dissolved oxygen saturation	Total	110.30	%		110	0%

Location Exceedance Count: 6

Location: Utah Department Of Environmental Quality 4958070 ~ CASTLE VALLEY CK AT CASTLETON

Date	Characteristic	Fraction	Value	Units	Lower Threshold	Upper Threshold	%Diff
8/22/2002	Total dissolved solids		1730	mg/l		1200	44%
9/19/2002	Total dissolved solids		1320	mg/l		1200	10%
5/8/2003	Total dissolved solids		1228	mg/l		1200	2%
5/22/2003	Total dissolved solids		1270	mg/l		1200	6%
6/19/2003	Total dissolved solids		1308	mg/l		1200	9%
7/31/2007	Total dissolved solids		1400	mg/l		1200	17%
8/30/2007	Dissolved oxygen saturation	Total	110.50	%		110	0%
8/30/2007	Total dissolved solids		1566	mg/l		1200	31%

Location Exceedance Count: 8

Appendix C: Water Quality Summary of Aquifers in Moab-Spanish Valley and Castle Valley

Watershed	Castle Valley			Spanish Valley					
Aquifer	Alluvial Aquifer			Alluvial Aquifer			Glen Canyon Group Aquifer		
Charateristic	Mean	High	Low	Mean	High	Low	Mean	High	Low
Aluminum ug/l	<30	<30	<30	<30	<30	<30	<30	<30	<30
Ammonia mg/l N	NA	NA	NA	<0.052	0.09	<.05	NA	NA	NA
Arsenic ug/l	<5.0	<5.0	<5.0	<1.6	10	<1	<2.7	10	<1
Barium ug/l	<30.2	174	<5.0	22.8	49	15	48.2	100	21
Boron ug/l	160	282	85	53	110	0	NA	NA	NA
Cadmium ug/l	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Calcium mg/l	143	486	38.6	132	379	9	49.4	100	30
$CaCO_3$ (Alkalinity)	139	228	112	199.2	321	128	120.2	161	97
Chloride mg/l	65	282	5	<23.3	177.5	6.5	17	110	1
Chromium ug/l	<6	29.6	<5	<5.1	6.46	<5	<5	<5	<5
Copper ug/l	<21.9	331	<12	<15.05	53.2	<12	<18.5	100	<12
Dissolved oxygen mg/l	5.47	2.4	8.0	NA	NA	NA	NA	NA	NA
Flow ft3/sec	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hardness mg/l	490.6	1378.3	151.4	482.3	969.4	110	201.3	372.9	120
nitrate and nitrite mg/l	0.464	4.27	<0.1	<2.05	7.37	0.06	2.56	15.2	0.02
Iron ug/l	<65.1	338	<20	<128.3	1300	<20	<27.2	90	7
Lead ug/l	<3.1	8.5	<3.0	<3.4	15	<3	<5	14	<3
Magnesium mg/l	<38.4	132.6	<1	37.7	106.5	7.3	20	35	11
Manganese ug/l	<6.6	23.4	<5.0	<55.2`	680	<5	<6.2	10	<5
Mercury ug/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nickle ug/l	NA	NA	NA	NA	NA	NA	NA	NA	NA
pH Units	7.69	9.33	7.0	7.63	8.75	7.2	7.8	8.4	7.3
Dissolved Phosphate mg/l P	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Phosphate mg/l P	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Potassium mg/l	3.3	14.2	1.14	7.2	230.4	1.6	2.4	18	1
Selenium ug/l	<2.6	9.9	<1	<3.0	347	<1	2.9	21	0.2
Silver ug/l	<2.0	<2.0	<2.0	<2	156	<2	<2.0	3	<2.0
Sodium mg/l	54.6	270	15	45.1	170	12	24.4	140	5.7
Specific conductance umho/cm	977	2800	213	1027	2081	400	502	1170	255
Sulfate mg/l	330	1090	39.6	341	1062	43	115	280	28
Temperature, water deg C	16.1	27.9	7.5	17.7	26.6	10	14.3	18	5.5
Total dissolved solids mg/l	801	2442	204	703	1818	140	324	736	148
Total suspended solids mg/l	<4	<4	<4	<4.76	19	<4	<20	68	<4
Turbidity NTU	1.8	17.5	0.07	2.61	18	0.16	1.52	2.05	0.58
Zinc ug/l	<47.8	145	<30	<67	240	<30	<42.6	120	<2

Appendix D: Online Information and Hydrologic Investigations References

URLs

http://waterdata.usgs.gov/ut/nwis/current/?type=flow

http://waterdata.usgs.gov/ut/nwis/sw/

http://waterdata.usgs.gov/ut/nwis/gw/

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http://www.landsat.com/utah-free-gis-data.html

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http://grandwater.org/ReportsandLinks.aspx

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Appendix E

MILL CREEK WATERSHED VEGETATION COVER
According to the SE REGION GAP database, vegetation cover in the Mill/Pack Watershed is dominated by PJ woodland and scrubland, as well as blackbrush/mormon tea shrubland and bedrock canyon and table lands.

Only a little over 1% of the entire watershed is classified as developed – either high or low intensity, and approximately 2.5% of the watershed is in agricultural production. The bulk of the private lands in the watershed fall into one of these categories.

ACRES	%	CATEGORY
1942.83	2.54%	Agriculture
7544.44	**9.86%**	**Colorado Plateau Blackbrush-Mormon-tea Shrubland**
7361.04	**9.62%**	**Colorado Plateau Mixed Bedrock Canyon and Tableland**
8789.36	**11.49%**	**Colorado Plateau Pinyon-Juniper Shrubland**
16019.52	**20.94%**	**Colorado Plateau Pinyon-Juniper Woodland**
140.55	0.18%	Developed, Medium - High Intensity
731.10	0.96%	Developed, Open Space - Low Intensity
20.09	0.03%	Inter-Mountain Basins Active and Stabilized Dune
1542.16	**2.02%**	**Inter-Mountain Basins Big Sagebrush Shrubland**
43.16	0.06%	Inter-Mountain Basins Greasewood Flat
56.19	0.07%	Inter-Mountain Basins Mat Saltbush Shrubland
629.80	0.82%	Inter-Mountain Basins Mixed Salt Desert Scrub
1483.24	**1.94%**	**Inter-Mountain Basins Montane Sagebrush Steppe**
64.74	0.08%	Inter-Mountain Basins Semi-Desert Grassland
116.67	0.15%	Inter-Mountain Basins Semi-Desert Shrub Steppe
76.44	0.10%	Inter-Mountain Basins Shale Badland
3228.42	**4.22%**	**Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex**
39.17	0.05%	Invasive Annual Grassland
392.09	0.51%	Invasive Southwest Riparian Woodland and Shrubland
17.73	0.02%	Open Water
704.43	0.92%	Recently Chained Pinyon-Juniper Areas
3341.82	**4.37%**	**Rocky Mountain Alpine Bedrock and Scree**
2859.94	**3.74%**	**Rocky Mountain Aspen Forest and Woodland**
841.85	1.10%	Rocky Mountain Cliff and Canyon
10946.27	**14.31%**	**Rocky Mountain Gambel Oak-Mixed Montane Shrubland**
538.84	0.70%	Rocky Mountain Lower Montane Riparian Woodland and Shrubland
267.29	0.35%	Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland
393.68	0.51%	Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
791.25	1.03%	Rocky Mountain Ponderosa Pine Woodland
3573.90	**4.67%**	**Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland**
556.12	0.73%	Rocky Mountain Subalpine Mesic Meadow
1409.11	**1.84%**	**Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland**
31.32	0.04%	Southern Colorado Plateau Sand Shrubland

76494.56	TOTAL ACRES IN THE MILL/PACK CREEK WATERSHED

CASTLE CREEK WATERSHED VEGETATION COVER

According to the SE REGION GAP database, the Castle Creek Watershed is under ½ the size of the Mill Creek Watershed. The vegetation composition is similar to the Mill Creek Watershed except that more of the land is categorized as developed – mostly in low density, and a similar amount is in agricultural production. Grazing is not noted on the vegetation cover maps.

ACRES	%	CATEGORY
629.59	1.75%	Agriculture
1090.64	**3.03%**	**Colorado Plateau Blackbrush-Mormon-tea Shrubland**
2819.88	**7.84%**	**Colorado Plateau Mixed Bedrock Canyon and Tableland**
4670.79	**12.98%**	**Colorado Plateau Pinyon-Juniper Shrubland**
7557.42	**21.00%**	**Colorado Plateau Pinyon-Juniper Woodland**
27.35	0.08%	Developed, Medium - High Intensity
1246.15	3.46%	Developed, Open Space - Low Intensity
1.18	0.00%	Inter-Mountain Basins Active and Stabilized Dune
2134.31	**5.93%**	**Inter-Mountain Basins Big Sagebrush Shrubland**
711.67	**1.98%**	**Inter-Mountain Basins Greasewood Flat**
0.89	0.00%	Inter-Mountain Basins Mat Saltbush Shrubland
987.25	**2.74%**	**Inter-Mountain Basins Mixed Salt Desert Scrub**
240.37	0.67%	Inter-Mountain Basins Montane Sagebrush Steppe
6.86	0.02%	Inter-Mountain Basins Semi-Desert Grassland
93.29	0.26%	Inter-Mountain Basins Semi-Desert Shrub Steppe
2172.31	**6.04%**	**Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex**
2.64	0.01%	Invasive Annual Grassland
445.39	1.24%	Invasive Southwest Riparian Woodland and Shrubland
70.09	0.19%	Open Water
1171.75	**3.26%**	**Rocky Mountain Alpine Bedrock and Scree**
738.22	2.05%	Rocky Mountain Aspen Forest and Woodland
780.84	2.17%	Rocky Mountain Cliff and Canyon
3822.54	**10.62%**	**Rocky Mountain Gambel Oak-Mixed Montane Shrubland**
139.39	0.39%	Rocky Mountain Lower Montane Riparian Woodland and Shrubland
565.39	1.57%	Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland
514.46	1.43%	Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland
675.23	1.88%	Rocky Mountain Ponderosa Pine Woodland
1433.38	**3.98%**	**Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland**
64.81	0.18%	Rocky Mountain Subalpine Mesic Meadow
1173.02	**3.26%**	**Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland**
35987.08		TOTAL ACRES IN CASTLE CREEK WATERSHED

The vegetation classifications do not reflect condition of vegetation in each area, but rather the expected vegetation type in the area. There are some inconsistencies and inaccuracies in the SWgap date, however these data do provide some basis for understanding the vegetative cover found in the watershed.

The following category descriptions are taken from the SWReGAP Legend Description Database.

Agriculture

An aggregated landcover type that includes both Pasture/Hay (N81): 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, where pasture/hay vegetation accounts for greater than 20 percent of total vegetation, and Cultivated Crops (N82): 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, where crop vegetation accounts for greater than 20 percent of total vegetation. N82 also includes all land being actively tilled.

Colorado Plateau Blackbrush-Mormon-tea Shrubland

This ecological system occurs in the Colorado Plateau on benchlands, colluvial slopes, pediments or bajadas. Elevation ranges from 560-1650 m. Substrates are shallow, typically calcareous, non-saline and gravelly or sandy soils over sandstone or limestone bedrock, caliche or limestone alluvium. It also occurs in deeper soils on sandy plains where it may have invaded desert grasslands. The vegetation is characterized by extensive open shrublands dominated by Coleogyne ramosissima often with Ephedra viridis, Ephedra torreyana, or Grayia spinosa. Sandy portions may include Artemisia filifolia as codominant. The herbaceous layer is sparse and composed of graminoids such as Achnatherum hymenoides, Pleuraphis jamesii, or Sporobolus cryptandrus.

Colorado Plateau Mixed Bedrock Canyon and Tableland

The distribution of this ecological system is centered on the Colorado Plateau where it is comprised of barren and sparsely vegetated landscapes (generally <10% plant cover) of steep cliff faces, narrow canyons, and open tablelands of predominantly sedimentary rocks, such as sandstone, shale, and limestone. Some eroding shale layers similar to Inter-Mountain Basins Shale Badland (CES304.789) may be interbedded between the harder rocks. The vegetation is characterized by very open tree canopy or scattered trees and shrubs with a sparse herbaceous layer. Common species includes Pinus edulis, Pinus ponderosa, Juniperus spp., Cercocarpus intricatus, and other short-shrub and herbaceous species, utilizing moisture from cracks and pockets where soil accumulates.

Colorado Plateau Pinyon-Juniper Shrubland

This ecological system is characteristic of the rocky mesatops and slopes on the Colorado Plateau and western slope of Colorado, but these stunted tree shrublands may extend further upslope along the low-elevation margins of taller pinyonjuniper woodlands. Sites are drier than Colorado Plateau Pinyon-Juniper Woodland (CES304.767). Substrates are shallow/rocky and shaley soils at lower elevations (1200-2000 m). Sparse examples of the system grade into Colorado
Plateau Mixed Bedrock Canyon and Tableland (CES304.765). The vegetation is dominated by dwarfed (usually <3 m tall) Pinus edulis and/or Juniperus osteosperma trees forming extensive tall shrublands in the region along low-elevation margins of pinyon-juniper woodlands. Other shrubs, if present, may include Artemisia nova, Artemisia tridentata ssp. wyomingensis, Chrysothamnus viscidiflorus, or Coleogyne ramosissima. Herbaceous layers are sparse to moderately dense and typically composed of xeric graminoids

Colorado Plateau Pinyon-Juniper Woodland

This ecological system occurs in dry mountains and foothills of the Colorado Plateau region including the

Western Slope of Colorado to the Wasatch Range, south to the Mogollon Rim and east into the northwestern corner of New Mexico. It is typically found at lower elevations ranging from 1500-2440 m. These woodlands occur on warm, dry sites on mountain slopes, mesas, plateaus, and ridges. Severe climatic events occurring during the growing season, such as frosts and drought, are thought to limit the distribution of pinyon-juniper woodlands to relatively narrow altitudinal belts on mountainsides. Soils supporting this system vary in texture ranging from stony, cobbly, gravelly sandy loams to clay loam or clay. Pinus edulis and/or Juniperus osteosperma dominate the tree canopy. In the southern portion of the Colorado Plateau in northern Arizona and northwestern New Mexico, Juniperus monosperma and hybrids of Juniperus spp may dominate or codominate the tree canopy. Juniperus scopulorum may codominate or replace Juniperus osteosperma at higher elevations. Understory layers are variable and may be dominated by shrubs, graminoids, or be absent. Associated species include Arctostaphylos patula, Artemisia tridentata, Cercocarpus intricatus, Cercocarpus montanus, Coleogyne ramosissima, Purshia stansburiana, Purshia tridentata, Quercus gambelii, Bouteloua gracilis, Pleuraphis jamesii, or Poa fendleriana. This system occurs at higher elevations than Great Basin Pinyon-Juniper Woodland (CES304.773) and Colorado Plateau shrubland systems where sympatric.

Developed, Medium - High Intensity

Developed, Medium Intensity: Includes areas with a mixture of constructed materials and vegetation. Impervious surface accounts for 50-79 percent of the total cover. These areas most commonly include single-family housing units. Developed, High Intensity: Includes 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 percent of the total cover

Developed, Open Space - Low Intensity

Open Space: Includes areas with a mixture of some construction materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include largelot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes. Developed, Low Intensity: Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include singlefamily housing units.

Inter-Mountain Basins Active and Stabilized Dune

This ecological system occurs in Intermountain West basins and is composed of unvegetated to moderately vegetated (<10-30% plant cover) active and stabilized dunes and sandsheets. Species occupying these environments are often adapted to shifting, coarse-textured substrates (usually quartz sand) and form patchy or open grasslands, shrublands or steppe composed of Achnatherum hymenoides, Artemisia filifolia, Artemisia tridentata ssp. tridentata, Atriplex canescens, Ephedra spp., Coleogyne ramosissima, Ericameria nauseosa, Leymus flavescens, Prunus virginiana, Psoralidium anceolatum, Purshia tridentata, Sporobolus airoides, Tetradymia tetrameres, or Tiquilia spp.

Inter-Mountain Basins Big Sagebrush Shrubland

This ecological system occurs throughout much of the western U.S., typically in broad basins between mountain ranges, plains and foothills between 1500 and 2300 m elevation. Soils are typically deep, well-drained and non-saline. These shrublands are dominated by Artemisia tridentata ssp. tridentata and/or Artemisia tridentata ssp. wyomingensis. Scattered Juniperus spp., Sarcobatus vermiculatus, and Atriplex spp. may be present in some stands. Ericameria nauseosa, Chrysothamnus viscidiflorus, Purshia tridentata, or Symphoricarpos oreophilus may codominate disturbed stands. Perennial herbaceous components typically contribute less than 25% vegetative cover. Common graminoid species include Achnatherum hymenoides, Bouteloua gracilis, Elymus lanceolatus, Festuca idahoensis, Hesperostipa comata, Leymus cinereus, Pleuraphis jamesii, Pascopyrum smithii, Poa secunda, or Pseudoroegneria spicata.

Inter-Mountain Basins Greasewood Flat

This ecological system occurs throughout much of the western U.S. in Intermountain basins and extends onto the western Great Plains. It typically occurs near drainages on stream terraces and flats or may form rings around more sparsely vegetated playas. Sites typically have saline soils, a shallow water table and flood intermittently, but remain dry for most growing seasons. The water table remains high enough to maintain vegetation, despite salt accumulations. This system usually occurs as a mosaic of multiple communities, with open to moderately dense shrublands dominated or codominated by Sarcobatus vermiculatus. Atriplex canescens, Atriplex confertifolia, or Krascheninnikovia lanata may be present to codominant. Occurrences are often surrounded by mixed salt desert scrub. The herbaceous layer, if present, is usually dominated by graminoids. There may be inclusions of Sporobolus airoides, Distichlis spicata (where water remains ponded the longest), or Eleocharis palustris herbaceous types.

Inter-Mountain Basins Mat Saltbush Shrubland

This ecological system occurs on gentle slopes and rolling plains in the northern Colorado Plateau and Uinta Basin on Mancos Shale and arid, wind-swept basins and plains across parts of Wyoming. Substrates are shallow, typically saline, alkaline, fine-textured soils developed from shale or alluvium and may be associated with shale badlands. Infiltration rate is typically low. These landscapes that typically support dwarf-shrublands composed of relatively pure stands of Atriplex spp. such as Atriplex corrugata or Atriplex gardneri. Other dominant or codominant dwarf-shrubs may include Artemisia longifolia, Artemisia pedatifida, or Picrothamnus desertorum, sometimes with a mix of other low shrubs such as Krascheninnikovia lanata or Tetradymia spinosa. Atriplex confertifolia or Atriplex canescens may be present, but do not codominate. The herbaceous layer is typically sparse. Scattered perennial forbs occur, such as Xylorhiza glabriuscula and Sphaeralcea grossulariifolia, and the perennial grasses Achnatherum hymenoides, Bouteloua gracilis, Elymus elymoides, Elymus lanceolatus ssp. lanceolatus, Pascopyrum smithii, or Sporobolus airoides may dominate the herbaceous layer. In less saline areas, there may be inclusions grasslands dominated by Hesperostipa comata, Leymus salinus, Pascopyrum smithii, or Pseudoroegneria spicata. In Wyoming and possibly elsewhere, inclusions of non-saline, gravelly barrens or rock outcrops dominated by cushion plants such as Arenaria hookeri and Phlox hoodii without dwarf-shrubs may be present. Annuals are seasonally present and may include Eriogonum inflatum, Plantago tweedyi, and the introduced annual grass Bromus tectorum.

Inter-Mountain Basins Mixed Salt Desert Scrub

This extensive ecological system includes open-canopied shrublands of typically saline basins, alluvial slopes and plains across the Intermountain western U.S. This type also extends in limited distribution into the southern Great Plains. Substrates are often saline and calcareous, medium- to fine-textured, alkaline soils, but include some coarser-textured soils. The vegetation is characterized by a typically open to moderately dense shrubland composed of one or more Atriplex species such as Atriplex confertifolia, Atriplex canescens, Atriplex polycarpa, or Atriplex spinifera. Other shrubs present to codominate may include Artemisia tridentata ssp. wyomingensis, Chrysothamnus viscidiflorus, Ericameria nauseosa, Ephedra nevadensis, Grayia spinosa, Krascheninnikovia lanata, Lycium spp., Picrothamnus desertorum, or Tetradymia spp. Sarcobatus vermiculatus is generally absent, but if present does not codominate. The herbaceous layer varies from sparse to moderately dense and is dominated by perennial graminoids such as Achnatherum hymenoides, Bouteloua gracilis, Elymus lanceolatus ssp. lanceolatus, Pascopyrum smithii, Pleuraphis jamesii, Pleuraphis rigida, Poa secunda, or Sporobolus airoides. Various forbs are also present.

Inter-Mountain Basins Montane Sagebrush Steppe

This ecological system includes sagebrush communities occurring at montane and subalpine elevations across the western U.S. from 1000 m in eastern Oregon and Washington to over 3000 m in the southern Rockies. In British Columbia, it occurs between 450 and 1650 m in the southern Fraser Plateau and the Thompson and Okanagan basins. Climate is cool, semi-arid to subhumid. This system primarily occurs on deep-soiled to stony flats, ridges, nearly flat ridgetops, and mountain slopes. In general this system shows an affinity for mild topography, fine soils, and some source of subsurface moisture. It is composed primarily of Artemisia tridentata ssp. vaseyana (mountain sagebrush) and related taxa such as Artemisia tridentata ssp. spiciformis (= Artemisia spiciformis). Purshia tridentata may codominate or even dominate some stands. Other common shrubs include Symphoricarpos spp., Amelanchier spp., Ericameria nauseosa, Peraphyllum ramosissimum, Ribes cereum, and Chrysothamnus viscidiflorus. Most stands have an abundant perennial herbaceous layer (over 25% cover), but this system also includes Artemisia tridentata ssp. vaseyana shrublands. Common graminoids include Festuca arizonica, Festuca idahoensis, Hesperostipa comata, Poa fendleriana, Elymus trachycaulus, Bromus carinatus, Poa secunda, Leucopoa kingii, Deschampsia caespitosa, Calamagrostis rubescens, and Pseudoroegneria spicata. In many areas, frequent wildfires maintain an open herbaceous-rich steppe condition, although at most sites, shrub cover can be unusually high for a steppe system (>40%), with the moisture providing equally high grass and forb cover.

Inter-Mountain Basins Semi-Desert Grassland

This widespread ecological system occurs throughout the intermountain western U.S. on dry plains and mesas, at approximately 1450 to 2320 m (4750-7610 feet) elevation. These grasslands occur in lowland and upland areas and may occupy swales, playas, mesatops, plateau parks, alluvial flats, and plains, but sites are typically xeric. Substrates are often well-drained sandy or loamy-textured soils derived from sedimentary parent materials but are quite variable and may include fine-textured soils derived from igneous and metamorphic rocks. When they occur near foothill grasslands they will be at lower elevations. The dominant perennial bunch grasses and shrubs within this system are all very drought-resistant plants. These grasslands are typically dominated or codominated by Achnatherum hymenoides, Aristida spp., Bouteloua gracilis, Hesperostipa comata, Muhlenbergia sp., or Pleuraphis jamesii and may include scattered shrubs and dwarfshrubs of species of Artemisia, Atriplex, Coleogyne, Ephedra, Gutierrezia, or Krascheninnikovia lanata.

Inter-Mountain Basins Semi-Desert Shrub Steppe

This ecological system occurs throughout the intermountain western U.S., typically at lower elevations on alluvial fans and flats with moderate to deep soils. This semi-arid shrub-steppe is typically dominated by graminoids (>25% cover) with an open shrub layer. Characteristic grasses include Achnatherum hymenoides, Bouteloua gracilis, Distichlis spicata,
Hesperostipa comata, Pleuraphis jamesii, Poa secunda, and Sporobolus airoides. The woody layer is often a mixture of shrubs and dwarf-shrubs. Characteristic species include Atriplex canescens, Artemisia tridentata, Chrysothamnus greenei, Chrysothamnus viscidiflorus, Ephedra spp., Ericameria nauseosa, Gutierrezia sarothrae, and Krascheninnikovia lanata. Artemisia tridentata may be present but does not dominate. The general aspect of occurrences may be either open shrubland with patchy grasses or patchy open herbaceous layer. Disturbance may be important in maintaining the woody component. Microphytic crust is very important in some stands.

Inter-Mountain Basins Shale Badland

This widespread ecological system of the intermountain western U.S. is composed of barren and sparsely vegetated substrates (<10% plant cover) typically derived from marine shales but also includes substrates derived from siltstones and mudstones (clay). Landforms are typically rounded hills and plains that form a rolling topography. The harsh soil properties and high rate of erosion and deposition are driving environmental variables supporting sparse dwarf-shrubs, e.g., Atriplex corrugata, Atriplex gardneri, Artemisia pedatifida, and herbaceous vegetation.

Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex

Invasive Annual Grassland

Areas that are dominated by introduced annual grass species such as: Avena spp., Bromus spp., Schismus spp.

Invasive Southwest Riparian Woodland and Shrubland

Areas that are dominated by introduced riparian woody species such as: Tamarix spp. and Elaeagnus angustifolius.

Open Water

Areas of open water, generally with less than 25% cover of vegetation or soil.

Recently Chained Pinyon-Juniper Areas

Areas that have recently been chained to remove Pinyon-Juniper and are clearly evident in the imagery (images acquired between 1999-2001).

Rocky Mountain Alpine Bedrock and Scree

This ecological system is restricted to the highest elevations of the Rocky Mountains, from Alberta and British Columbia south into New Mexico, west into the highest mountain ranges of the Great Basin. It is composed of barren and sparsely vegetated alpine substrates, typically including both bedrock outcrop and scree slopes, with nonvascular- (lichen) dominated communities. Exposure to desiccating winds, rocky and sometimes unstable substrates, and a short growing season limit plant growth. There can be sparse cover of forbs, grasses, lichens and low shrubs.

Rocky Mountain Aspen Forest and Woodland

This widespread ecological system is more common in the southern and central Rocky Mountains, but occurs throughout much of the western U.S. and north into Canada, in the montane and subalpine zones. Elevations generally range from 1525 to 3050 m (5000-10,000 feet), but occurrences can be found at lower elevations in some regions. Distribution of this ecological system is primarily limited by adequate soil moisture required to meet its high evapotranspiration demand, and secondarily is limited by the length of the growing season or low temperatures. These are upland forests and woodlands dominated by Populus tremuloides without a significant conifer component (<25% relative tree cover). The understory structure may be complex with multiple shrub and herbaceous layers, or simple with just an herbaceous layer. The herbaceous layer may be dense or sparse, dominated by graminoids or forbs. Associated shrub species include Symphoricarpos spp., Rubus parviflorus, Amelanchier alnifolia, and Arctostaphylos uva-ursi. Occurrences of this system originate and are maintained by stand-replacing disturbances such as avalanches, crown fire, insect outbreak, disease and windthrow, or clearcutting by man or beaver, within the matrix of conifer forests.

Rocky Mountain Cliff and Canyon

This ecological system of barren and sparsely vegetated landscapes (generally <10% plant cover) is found from foothill to subalpine elevations on steep cliff faces, narrow canyons, and smaller rock outcrops of various igneous, sedimentary, and metamorphic bedrock types. It is located throughout the Rocky Mountains and northeastern Cascade Ranges in North America. Also included are unstable scree and talus slopes that typically occur below cliff faces. There may be small patches of dense vegetation, but it typically includes scattered trees and/or shrubs. Characteristic trees includes species from the surrounding landscape, such as Pseudotsuga menziesii, Pinus ponderosa, Pinus flexilis, Populus tremuloides, Abies concolor, Abies lasiocarpa, or Pinus edulis and Juniperus spp. at lower elevations. There may be scattered shrubs present, such as species of Holodiscus, Ribes, Physocarpus, Rosa, Juniperus, and Jamesia americana, Mahonia repens, Rhus trilobata, or Amelanchier alnifolia. Soil development is limited, as is herbaceous cover.

Rocky Mountain Gambel Oak-Mixed Montane Shrubland

This ecological system occurs in the mountains, plateaus and foothills in the southern Rocky Mountains and Colorado Plateau including the Uinta and Wasatch ranges and the Mogollon Rim. These shrublands are most commonly found along dry foothills, lower mountain slopes, and at the edge of the western Great Plains from approximately 2000 to 2900 m in elevation, and are often situated above pinyon-juniper woodlands. Substrates are variable and include soil types ranging from calcareous, heavy, fine-grained loams to sandy loams, gravelly loams, clay loams, deep alluvial sand, or coarse gravel. The vegetation is typically dominated by Quercus gambelii alone or codominant with Amelanchier alnifolia, Amelanchier utahensis, Artemisia tridentata, Cercocarpus montanus, Prunus virginiana, Purshia stansburiana, Purshia tridentata, Robinia neomexicana, Symphoricarpos oreophilus, or Symphoricarpos rotundifolius. There may be inclusions of other mesic montane shrublands with Quercus gambelii absent or as a relatively minor component. This ecological system intergrades with the lower montane-foothills shrubland system and shares many of the same site characteristics. Density and cover of Quercus gambelii and Amelanchier spp. often increase after fire.

Rocky Mountain Lower Montane Riparian Woodland and Shrubland

This system is found throughout the Rocky Mountain and Colorado Plateau regions within a broad elevation range from approximately 900 to 2800 m. This system often occurs as a mosaic of multiple communities that are tree-dominated with a diverse shrub component. This system is dependent on a natural hydrologic regime, especially annual to episodic flooding. Occurrences are found within the flood zone of rivers, on islands, sand or cobble bars, and immediate streambanks. They can form large, wide occurrences on mid-channel islands in larger rivers or narrow bands on small, rocky canyon tributaries and well-drained benches. It is also typically found in backwater channels and other perennially wet but less scoured sites, such as floodplains swales and irrigation ditches. Dominant trees may include Acer negundo, Populus angustifolia, Populus balsamifera, Populus deltoides, Populus fremontii, Pseudotsuga menziesii, Picea pungens, Salix amygdaloides, or Juniperus scopulorum. Dominant shrubs include Acer glabrum, Alnus incana, Betula occidentalis, Cornus sericea, Crataegus rivularis, Forestiera pubescens, Prunus virginiana, Rhus trilobata, Salix monticola, Salix drummondiana, Salix exigua, Salix irrorata, Salix lucida, Shepherdia argentea, or Symphoricarpos spp. Exotic trees of Elaeagnus angustifolia and Tamarix spp. are common in some stands. Generally, the upland vegetation surrounding this riparian system is different and ranges from grasslands to forests.

Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland

This is a highly variable ecological system of the montane zone of the Rocky Mountains. It occurs throughout the southern Rockies, north and west into Utah, Nevada, western Wyoming and Idaho. These are mixed-conifer forests occurring on all aspects at elevations ranging from 1200 to 3300 m. Rainfall averages less than 75 cm per year (40-60 cm) with summer "monsoons" during the growing season contributing substantial moisture. The composition and structure of overstory is dependent upon the temperature and moisture relationships of the site, and the successional status of the occurrence. Pseudotsuga menziesii and Abies concolor are most frequent, but Pinus ponderosa may be present to codominant. Pinus flexilis is common in Nevada. Pseudotsuga menziesii forests occupy drier sites, and Pinus ponderosa is a common codominant. Abies concolor-dominated forests occupy cooler sites, such as upper slopes at higher elevations, canyon sideslopes, ridgetops, and north- and east-facing slopes which burn somewhat infrequently. Picea pungens is most often found in cool, moist locations, often occurring as smaller patches within a matrix of other associations. As many as seven conifers can be found growing in the same occurrence, and there are a number of cold-deciduous shrub and graminoid species common, including Arctostaphylos uva-ursi, Mahonia repens, Paxistima myrsinites, Symphoricarpos oreophilus, Jamesia americana, Quercus gambelii, and Festuca arizonica. This system was undoubtedly characterized by a mixed severity fire regime in its "natural condition," characterized by a high degree of variability in lethality and return interval.

Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland

These are mixed-conifer forests of the Rocky Mountains west into the ranges of the Great Basin, occurring predominantly in cool ravines and on north-facing slopes. Elevations range from 1200 to 3300 m. Occurrences of this system are found on cooler and more mesic sites than Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland (CES306.823). Such sites include lower and middle slopes of ravines, along stream terraces, moist, concave topographic positions and north- and east-facing slopes which burn somewhat infrequently. Pseudotsuga menziesii and Abies concolor are most common canopy dominants, but Picea engelmannii, Picea pungens, or Pinus ponderosa may be present. This system includes mixed conifer/Populus tremuloides stands. A number of cold-deciduous shrub species can occur, including Acer glabrum, Acer grandidentatum, Alnus incana, Betula occidentalis, Cornus sericea, Jamesia americana, Physocarpus malvaceus, Robinia neomexicana, Vaccinium membranaceum, and Vaccinium myrtillus. Herbaceous species include Bromus ciliatus, Carex geyeri, Carex rossii, Carex siccata, Muhlenbergia virescens, Pseudoroegneria spicata, Erigeron eximius, Fragaria virginiana, Luzula parviflora, Osmorhiza berteroi, Packera cardamine, Thalictrum occidentale, and Thalictrum fendleri. Naturally occurring fires are of variable return intervals, and mostly light, erratic, and infrequent due to the cool, moist conditions.

Rocky Mountain Ponderosa Pine Woodland

This very widespread ecological system is most common throughout the cordillera of the Rocky Mountains, from the Greater Yellowstone region south. It is also found in the Colorado Plateau region, west into scattered locations in the Great Basin, and in the Black Hills of South Dakota and Wyoming. These woodlands occur at the lower treeline/ecotone between grassland or shrubland and more mesic coniferous forests typically in warm, dry, exposed sites. Elevations range from less than 1900 m in northern Wyoming to 2800 m in the New Mexico mountains. Occurrences are found on all slopes and aspects; however, moderately steep to very steep slopes or ridgetops are most common. This ecological system generally occurs on igneous, metamorphic, and sedimentary material derived soils, with characteristic features of good aeration and drainage, coarse textures, circumneutral to slightly acid pH, an abundance of mineral material, rockiness, and periods of drought during the growing season. Northern Rocky Mountain Ponderosa Pine Woodland (CES306.030) in the eastern Cascades, Okanagan and northern Rockies regions receives winter and spring rains, and thus has a greater spring "green-up" than the drier woodlands in the central Rockies. Pinus ponderosa (primarily var. scopulorum and var. brachyptera) is the predominant conifer; Pseudotsuga menziesii, Pinus edulis, and Juniperus spp. may be present in the tree canopy. The understory is usually shrubby, with Artemisia nova, Artemisia tridentata, Arctostaphylos patula, Arctostaphylos uva-ursi, Cercocarpus montanus, Purshia stansburiana, Purshia tridentata, Quercus gambelii, Symphoricarpos oreophilus, Prunus virginiana, Amelanchier alnifolia, and Rosa spp. common species. Pseudoroegneria spicata and species of Hesperostipa, Achnatherum, Festuca, Muhlenbergia, and Bouteloua are some of the common grasses. Mixed fire regimes and ground fires of variable return intervals maintain these woodlands, depending on climate, degree of soil development, and understory density.

Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland

This is a high-elevation system of the Rocky Mountains, dominated by Picea engelmannii and Abies lasiocarpa. It extends eastward into the northeastern Olympic Mountains and the northeastern side of Mount Rainier in Washington Occurrences are typically found in locations with cold-air drainage or ponding, or where snowpacks linger late into the summer, such as north-facing slopes and high-elevation ravines. They can extend down in elevation below the subalpine zone in places where cold-air ponding occurs; northerly and easterly aspects predominate. These forests are found on gentle to very steep mountain slopes, high-elevation ridgetops and upper slopes, plateau-like surfaces, basins, alluvial terraces, well-drained benches, and inactive stream terraces. In the Olympics and northern Cascades, the climate is more maritime than typical for this system, but due to the lower snowfall in these rainshadow areas, summer drought may be more significant than snowpack in limiting tree regeneration in burned areas. Picea engelmannii is rare in these areas. Mesic understory shrubs include Menziesia ferruginea, Vaccinium membranaceum, Rhododendron albiflorum, Amelanchier alnifolia, Rubus parviflorus, Ledum glandulosum, Phyllodoce empetriformis, and Salix spp. Herbaceous species include Actaea rubra, Maianthemum stellatum, Cornus canadensis, Erigeron eximius, Gymnocarpium dryopteris, Rubus pedatus, Saxifraga bronchialis, Tiarella spp., Lupinus arcticus ssp. subalpinus, Valeriana sitchensis, and graminoids Luzula glabrata var. hitchcockii or Calamagrostis canadensis. Disturbances include occasional blow-down, insect outbreaks and stand-replacing fire.

Rocky Mountain Subalpine Mesic Meadow

This Rocky Mountain ecological system is restricted to sites in the subalpine zone where finely textured soils, snow deposition, or wind-swept dry conditions limit tree establishment. It is found typically above 3000 m in elevation in the southern part of its range and above 1500 m in the northern part. These upland communities occur on gentle to moderategradient slopes. The soils are typically seasonally moist to saturated in the spring, but if so will dry out later in the growing season. These sites are not as wet as those found in Rocky Mountain Alpine-Montane Wet Meadow (CES306.812). Vegetation is typically forb-rich, with forbs contributing more to overall herbaceous cover than graminoids. Important taxa include Erigeron spp., Asteraceae spp., Mertensia spp., Penstemon spp., Campanula spp., Lupinus spp., Solidago spp., Ligusticum spp., Thalictrum occidentale, Valeriana sitchensis, Balsamorhiza sagittata, Wyethia spp., Deschampsia caespitosa, Koeleria macrantha, and Dasiphora fruticosa. Burrowing mammals can increase the forb diversity.

Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland

This is a high-elevation system of the Rocky Mountains, dominated by Picea engelmannii and Abies lasiocarpa. It extends eastward into the northeastern Olympic Mountains and the northeastern side of Mount Rainier in Washington**.** Occurrences are typically found in locations with cold-air drainage or ponding, or where snowpacks linger late into the summer, such as north-facing slopes and high-elevation ravines. They can extend down in elevation below the subalpine zone in places where cold-air ponding occurs; northerly and easterly aspects predominate. These forests are found on gentle to very steep mountain slopes, high-elevation ridgetops and upper slopes, plateau-like surfaces, basins, alluvial terraces, well-drained benches, and inactive stream terraces. In the Olympics and northern Cascades, the climate is more maritime than typical for this system, but due to the lower snowfall in these rainshadow areas, summer drought may be more significant than snowpack in limiting tree regeneration in burned areas. Picea engelmannii is rare in these areas. Mesic understory shrubs include Menziesia ferruginea, Vaccinium membranaceum, Rhododendron albiflorum, Amelanchier alnifolia, Rubus parviflorus, Ledum glandulosum, Phyllodoce empetriformis, and Salix spp. Herbaceous species include Actaea rubra, Maianthemum stellatum, Cornus canadensis, Erigeron eximius, Gymnocarpium dryopteris, Rubus pedatus, Saxifraga bronchialis, Tiarella spp., Lupinus arcticus ssp. subalpinus, Valeriana sitchensis, and graminoids Luzula glabrata var. hitchcockii or Calamagrostis canadensis. Disturbances include occasional blow-down, insect outbreaks and stand-replacing fire.

Southern Colorado Plateau Sand Shrubland

This large-patch ecological system is found on the south-central Colorado Plateau in northeastern Arizona extending into southern and central Utah. It occurs on windswept mesas, broad basins and plains at low to moderate elevations (1300- 1800 m). Substrates are stabilized sandsheets or shallow to moderately deep sandy soils that may form small hummocks or small coppice dunes. This semi-arid, open shrubland is typically dominated by short shrubs (10-30 % cover) with a sparse graminoid layer. The woody layer is often a mixture of shrubs and dwarf-shrubs. Characteristic species include Ephedra cutleri, Ephedra torreyana, Ephedra viridis, and Artemisia filifolia. Coleogyne ramosissima is typically not present. Poliomintha incana, Parryella filifolia, Quercus havardii var. tuckeri, or Ericameria nauseosa may be present to dominant locally. Ephedra cutleri and Ephedra viridis often assume a distinctive matty growth form. Characteristic grasses include Achnatherum hymenoides, Bouteloua gracilis, Hesperostipa comata, and Pleuraphis jamesii. The general aspect of occurrences is an open low shrubland but may include small blowouts and dunes. Occasionally grasses may be moderately abundant locally and form a distinct layer. Disturbance may be important in maintaining the woody component. Eolian processes are evident, such as pediceled plants, occasional blowouts or small dunes, but the generally higher vegetative cover and less prominent geomorphic features distinguish this system from Inter-Mountain Basins Active and Stabilized Dune (CES304.775).

Appendix F Soil Map Unit Descriptions

Dominantly Well Drained and Somewhat Excessively Drained, Nearly Level to Moderately Steep Soils on Low Benches, Terraces, Cuestas, and Valleys in an Arid Climatic Zone

2. Moenkopie-Rock Outcrop-Hoskinnini

Shallow, well drained, nearly level to moderately steep soils that formed in residuum derived from sandstone and limestone, and Rock outcrop; on low benches and cuestas

This map unit is in the west-central and northwestern parts of the survey area. Slopes are 1 to 30 percent. The vegetation on the Moenkopie and Hoskinnini soils is mainly shadscale, blackbrush, horsebrush, and Mormon tea.

This unit makes up about 5 percent of the Castle/Placer Creek watershed. It is about 50 percent Moenkopie and similar soils, 20 percent Rock outcrop, and 10 percent Hoskinnini soils. The remaining 20 percent is components of minor extent.

The Moenkopie soils formed in residuum derived dominantly from sandstone. The surface layer is reddish brown gravelly loamy sand. The underlying material to a depth of 8 inches is reddish brown sandy loam. Sandstone is at a depth of 8 inches.

Rock outcrop consists of exposed areas of sandstone in the form of ledges, cliffs, monoliths, and slickrock.

The Hoskinnini soils formed in residuum derived dominantly from limestone and sandstone. The surlace layer is reddish yellow very gravelly fine sandy loam. The subsoil is reddish brown sandy clay loam and cobbly clay loam. Sandstone is at a depth of 14 inches.

Of minor extent in this unit are Trail, Arches, Nepalto, Cataract, Moab, and Thoroughfare soils and Badland.

This unit is used as rangeland, wildlife habitat, and recreation areas.

The main limitations for rangeland are the depth to bedrock, low available water capacity, and low annual precipitation.

3. Thoroughfare-Sheppard-Nakai

Very deep, well drained and somewhat excessively drained, nearly level and gently sloping soils that formed in alluvium and eolian deposits derived from sandstone and shale; on valley floors and low benches

This map unit is in the south-central and northwestern parts of the survey area. Slopes are 0 to 8 percent. The vegetation on the Thoroughfare soils is mainly greasewood, shadscale, and big sagebrush. The vegetation on the Sheppard soils is mainly Indian ricegrass, Mormon tea, and sand dropseed. The vegetation on the Nakai soils is mainly galleta, Mormon tea, and shadscale.

This unit makes up about 10 percent of Mill/Pack Creek watershed, and 7 percent of the Castle/Placer Creek watershed. It is about 35 percent Thoroughfare and similar soils, 20 percent Sheppard and similar soils, and 15 percent Nakai and similar soils. The remaining 30 percent is soils of minor extent.

The Thoroughfare soils are on valley floors. These soils are well drained. They formed in alluvium derived dominantly from sandstone and shale. The surface layer is dark red fine sandy loam. Below this to a depth of 60 inches or more is red, stratified fine sandy loam and gravelly loamy sand.

The Sheppard soils are on structural benches. These soils are somewhat excessively drained. They formed in eolian deposits derived dominantly from sandstone. The surface layer is red fine sand. The underlying material is red and reddish yellow fine sand, loamy fine sand, and loamy sand.

The Nakai soils are on structural benches. These soils are well drained. They formed in eolian deposits derived dominantly from sandstone. The surface layer is yellowish red fine sand. The underlying material is yellowish red and reddish yellow fine sandy loam and fine sand.

Of minor extent in this unit are Moab, Trail, Bluechief, Cataract, Nepalto, and Moenkopie soils on benches, and Ustic Torrifluvents and Typic Ustifluvents on flood plains.

This unit is used as rangeland, wildlife habitat, irrigated cropland, and recreation areas.

The main limitations for rangeland are the low annual precipitation and the moderately low available water capacity of the Sheppard soils. The main limitations for growing irrigated crops are the hazard of erosion on the Thoroughfare soils and the hazard of soil blowing, rapid permeability, and moderately low available water capacity of the Sheppard soils.

Dominantly Well Drained, Gently Sloping to Extremely Steep Soils on Benches, Cuestas, Mesas, Escarpments, and Canyon Walls in a Semiarid Climatic Zone

4. Ustlc Torriorthents-Lithic Torriorthents-Rock Outcrop

Shallow to very deep, strongly sloping to extremely steep soils that formed in colluvium and residuum derived from sedimentary rock, and Rock outcrop; on escarpments and canyon walls

This map unit is throughout the survey area, along the Colorado and Green Rivers and their tributaries. Slopes are 10 to 80 percent. The vegetation on this unit is mainly blackbrush, galleta, and Mormon tea.

This unit makes up about 10 percent of the Mill/Pack Creek watershed, and 26 percent of the Castle/Placer Creek watershed. It is about 35 percent Ustic Torriorthents, 20 percent Lithic Torriorthents, and 20 percent Rock outcrop. The remaining 25 percent is components of minor extent.

The Ustic Torriorthents are on talus cones. These soils are moderately deep to very deep. They formed in colluvium derived dominantly from sandstone and shale. The surface layer is yellowish red very cobbly loamy fine sand. The underlying material is yellowish red extremely stony fine sandy loam.

The Lithic Torriorthents are on escarpments and ledges. These soils are shallow. They formed in colluvium and residuum derived dominantly from sandstone. The soils are yellowish red gravelly fine sandy loam throughout. Sandstone is at a depth of 15 inches.

Rock outcrop consists of exposed areas of sandstone in the form of ledges, cliffs, and monoliths.

Of minor extent in the unit are Badland on shale escarpments, Nepalto soils on alluvial fans, and Thoroughfare soils on alluvial bottoms.

This unit is used as recreation areas, wildlife habitat, and rangeland.

5. Rock Outcrop-Rizno, Dry-Mido

Rock outcrop, and shallow and very deep, gently sloping to steep soils that formed in residuum and eolian deposits derived from sandstone and shale; on escarpments, mesas, benches, and cuestas

This map unit is in the southern and west-central parts of the survey area. Slopes are 2 to 35 percent. The vegetation on the Rizno, dry, soils is mainly blackbrush, snakeweed. galleta, and Mormon tea. The vegetation on the Mido soils is mainly fourwing saltbush, blue grama, and galleta. Elevation is 4,800 to 6,500 feet.

This unit makes up about 6 percent of the Mill/Pack Creek watershed, and 5 percent of the Castle/Placer Creek watershed. It is about 55 percent Rock outcrop, 17 percent Rizno, dry, soils, and 13 percent Mido soils. The remaining 15 percent is soils of minor extent.

The Rock outcrop consists of exposed areas of sandstone in the form of ledges, cliffs, fins, and slickrock.

The Rizno, dry, soils are on benches, escarpments, and cuestas. These soils are shallow. They formed in residuum and eolian deposits derived dominantly from sandstone and shale. The surface layer is light reddish brown gravelly fine sandy loam. The underlying material is reddish brown and pinkish gray fine sandy loam. Sandstone is at a depth of 8 inches.

The Mido soils are on sand drifts and sand shadows on benches, mesas, and cuestas. These soils are very deep. They formed in eolian deposits derived dominantly from sandstone. The surface layer is light brown loamy fine sand. The underlying material is yellowish red loamy fine sand and light reddish brown fine sand.

Of minor extent in the unit are Arches, Begay, Ignacio, and Leanto soils.

This unit is used as wildlife habitat, recreation, and rangeland.

The main limitations for rangeland are the shallow depth to bedrock and low available water capacity of the Rizno soils, the sandy texture and severe hazard of soil blowing on the Mido soils, and the low annual precipitation.

Dominantly Well Drained, Gently Sloping to Moderately Steep Soils on Benches, Cuestas, Fans, Mesas, Alluvial Bottoms, Stream Terraces, and Valley Floors in a Semiarid Climatic Zone

6. Begay-Moab-Redbank

Very deep, gently sloping to moderately steep soils that formed in alluvium and eolian deposits derived from sandstone and diorite; on benches, cuestas, alluvial fans, alluvial bottoms, stream terraces, and valley floors

This map unit is in the central and southern parts of the survey area. Slopes are 2 to 30 percent. The vegetation on the Begay soils is mainly fourwing saltbush. galleta. Indian ricegrass, and blue grama. The vegetation on the Moab soils is mainly blackbrush, galleta. and Indian ricegrass. The vegetation on the Redbank soils is mainly basin big sagebrush, fourwing saltbush. Galleta, and Mormon tea.

This unit makes up about 8 percent of the Mill/Pack Creek watershed, and 6 percent of the Castle/Placer Creek watershed. It is about 50 percent Begay and similar soils, 15 percent Moab and similar soils, and 15 percent Redbank and similar soils. The remaining 20 percent is soils of minor extent.

The Begay soils are on benches and cuestas. They formed in eolian deposits derived dominantly from sandstone. The surface layer is yellowish red fine sandy loam. The subsoil is yellowish red fine sandy loam. The substratum is reddish yellow fine sandy loam and loamy fine sand.

The Moab soils are on alluvial valley floors and alluvial fans. They formed in alluvial deposits derived dominantly from sandstone and diorite. The surface layer is brown gravelly fine sandy loam. The subsoil is brown gravelly fine sandy loam. The substratum to a depth of 60 inches or more is pinkish white and pink very gravelly fine sandy loam.

The Redbank soils are on alluvial bottoms and stream terraces. They formed in alluvium derived dominantly from sandstone. The surface layer is reddish brown fine sandy loam. The underlying material is stratified, yellowish red very fine sandy loam and loam with thin lenses of sandy clay loam and sand.

Of minor extent in this unit are Mido soils on sand drifts; Sazi, Ignacio, and Newsrock soils on benches; and Strych soils on alluvial fans.

This unit is used mainly as rangeland, wildlife habitat, and recreation areas. Small areas of the Redbank soils are used as irrigated cropland.

The main limitations for rangeland management are the hazard of erosion and low annual precipitation.

7. Rizno, Dry-Rock Outcrop

Shallow, gently sloping to strongly sloping soils that formed in eolian deposits and residuum derived dominantly from sandstone and shale, and Rock outcrop; on benches, cuestas, and mesas

This map unit is throughout the survey area. Slopes are 2 to 15 percent. The vegetation on the Rizno, dry, soils is mainly blackbrush, galleta, Mormon tea, and Utah juniper.

This unit makes up about 17 percent of the Mill/Pack Creek watershed, and 18 percent of the Castle/Placer Creek watershed. It is about 45 percent Rizno, dry, and similar soils and 25 percent Rock outcrop. The remaining 30 percent is soils of minor extent.

The Rizno, dry, soils formed in eolian deposits and residuum derived dominantly from sandstone. The surface layer is light reddish brown gravelly fine sandy loam. The underlying material is reddish brown fine sandy loam. Sandstone is at a depth of 8 inches.

The Rock outcrop consists of exposed areas of sandstone in the form of ledges, cliffs, monoliths, and slickrock.

Of minor extent in this unit are Arches, Ignacio, Leanto, Begay, Mivida, Sazi, Windwhistle, Barx, and Mido soils on benches, cuestas, and mesas and Moab soils on fans.

This unit is used as rangeland, wildlife habitat, and recreation areas.

The main limitations for rangeland are the shallow depth to bedrock, very low available water capacity, and low annual precipitation.

Dominantly Well Drained, Gently Sloping to Very Steep Soils on Upland Benches, Landslides, Cuestas, Hillsides, and Escarpments in a Dry, Subhumid Climatic Zone

8. Cahona-Begay-Hagerman

Moderately deep and very deep, gently sloping soils that formed in eolian deposits derived from sandstone; on upland benches and cuestas

This map unit is in the eastern and southern parts of the survey area. Slopes are 2 to 8 percent. The vegetation is mainly Wyoming big sagebrush, blue grama, western wheatgrass, and muttongrass.

This unit makes up about 2 percent of the Mill/Pack Creek watershed, and 1 percent of the Castle/Placer Creek watershed. It is about 30 percent Cahona and similar soils, 25 percent Begay and similar soils, and 20 percent Hagerman and similar soils. The remaining 25 percent is soils of minor extent.

The Cahona soils are very deep. The surface layer is yellowish red fine sandy loam. The subsoil is reddish brown sandy clay loam and yellowish red silty clay loam. The substratum is pink fine sandy loam and loam.

The Begay soils are very deep. The surface layer is yellowish red fine sandy loam. The subsoil is yellowish red fine sandy loam. The substratum to a depth of 60 inches or more is yellowish red fine sandy loam and loamy fine sand.

The Hagerman soils are moderately deep. The surface layer is brown very fine sandy loam. The subsoil is yellowish red very fine sandy loam and brown sandy clay loam. The substratum is brown and strong brown sandy clay loam. Sandstone is at a depth of 33 inches.

Of minor extent in this unit are Redbank and Barnum soils on valley bottoms, Mido soils on sand drifts, Strych and Sedillo soils on alluvial fans, and Ignacio, Leanto, Shalako, Bond, and Rizno soils on benches and cuestas.

Most areas of this unit are used as rangeland and wildlife habitat. A few areas are used as irriga ed cropland and for homesite development.

The main limitations of this unit for homesite development and cropland are low soil strength and the hazards of soil blowing and water erosion.

9. Rizno-Rock Outcrop

Shallow, gently sloping to moderately steep soils that formed in residuum and eolian deposits derived from sandstone and shale, and Rock outcrop; on upland benches and cuestas

This map unit is in the eastern, central, and southern parts of the survey area. Slopes are 3 to 15 percent. The vegetation is mainly pinyon, Utah juniper, big sagebrush, Mormon tea, and antelope bitterbrush.

This unit makes up about 7 percent of the Mill/Pack Creek watershed, and 14 percent of the Castle/Placer Creek watershed. It is about 45 percent Rizno and similar soils and 35 percent Rock outcrop. The remaining 20 percent is soils of minor extent.

The Rizno soils have a surface layer of light reddish brown fine sandy loam. The underlying material is pinkish gray and reddish brown fine sandy loam. Sandstone is at a depth of 8 inches.

Rock outcrop is exposed areas of sandstone. It occurs mainly as slickrock.

Of minor extent in this unit are Anasazi, Begay, Bond, Mido, and Ignacio soils on cuestas and Bluehon and Strych soils on alluvial fans.

This unit is used as woodland, rangeland, wildlife habitat, and recreation areas.

The main limitations for rangeland are the shallow depth to bedrock and low available water capacity.

10. Ustic Torrlorthents-Ustolllc Calciorthlds-Ustolllc Haplarglds

Moderately deep to very deep, strongly sloping to very steep soils that formed in residuum and colluvium derived from shale and sandstone; on hillsides, landslides, and escarpments

This map unit is in the east-central and southeastern parts of the survey area. Slopes are 10 to 60 percent. Vegetation is mainly Utah juniper, pinyon, Indian ricegrass, serviceberry, and Mormon tea.

This unit makes up about 8 percent of the Mill/Pack Creek watershed. It is about 50 percent Ustic Torriorthents, 15 percent Ustollic Calciorthids, and 15 percent Ustollic Haplargids. The remaining 20 percent is components of minor extent.

The Ustic Torriorthents are on escarpments and landslides. The surface layer is yellowish brown very cobbly sandy loam. The underlying material is brown to light gray very cobbly and very gravelly sandy clay loam. Shale is at a depth of 45 inches.

The Ustollic Calciorthids are on south-facing escarpments and hillsides. The surface layer is strong brown gravelly fine sandy loam. The subsoil is strong brown fine sandy loam and loam. The substratum is light brown gravelly loam and pink clay loam. Shale is at a depth of 40 inches.

The Ustollic Haplargids are on north-facing hillsides and landslides. The surface layer is strong brown and reddish brown stony sandy loam. The subsoil is light reddish brown stony sandy clay loam. The substratum is pink and yellowish red stony silty clay loam.

Of minor extent in this unit are Bond and Rizno soils on narrow benches, Rock outcrop, Badland, Rubble land, and Strych soils on alluvial fans.

This unit is used mainly as rangeland and wildlife habitat. It is also used as recreation areas and for mining.

The main limitations of this unit for road construction and mining operations are steepness of slope, large stones, depth to rock, and low soil strength.

Dominantly Well Drained, Gently Sloping to Very Steep Soils on High Benches, Cuestas, Fans, Landslides, and Escarpments in Moist Subhumid and Humid Climatic Zones

11. Herm-Falcon-Waas

Shallow and very deep, gently sloping to moderately steep soils that formed in alluvium, residuum, colluvium, and eolian deposits derived from igneous and sedimentary rock; on high benches, cuestas, fans, and landslides

This map unit is mainly on the La Sal Mountains, in the east-central part of the survey area. A small area is on the Dark Canyon Plateau, in the southwestern part of the area. Slopes are 2 to 30 percent. Vegetation is mainly Gambel oak, ponderosa pine, and big sagebrush.

This unit makes up about 6 percent of the Mill/Pack Creek watershed, and 2 percent of the Castle/Placer Creek watershed. It is about 25 percent Herm and similar soils, 20 percent Falcon and similar soils, 20 percent Waas and similar soils, and 15 percent Tomasaki and similar soils. The remaining 20 percent is soils of minor extent.

The Herm soils are on landslides. These soils are very deep. They formed in colluvium derived dominantly from shale and sandstone. The surface layer is dark brown stony loam and brown clay loam. The subsoil is brown clay.

The Falcon soils are on high benches and cuestas. These soils are shallow. They formed in residuum derived dominantly from sandstone. The surface layer is brown fine sandy loam. The subsoil is light brown sandy loam. Sandstone is at a depth of 17 inches.

The Waas soils are on benches and fans. These soils are very deep. They formed in eolian deposits derived dominantly from sandstone. The surface layer is reddish brown very fine sandy loam. The subsoil is yellowish red loam. The substratum to a depth of 60 inches or more is reddish brown loam.

The Tomasaki soils are on outwash fans. These soils are very deep. They formed in alluvium derived dominantly from diorite. The surface layer is dark brown loam. The upper part of the subsoil is yellowish red clay and clay loam. The lower part of the subsoil and the substratum are reddish brown very cobbly clay loam and light brown cobbly clay loam.

Of minor extent in the unit are Beje and Bond soils on benches, Iles soils on landslides, and Harpole, Toone, and Sirref soils on outwash fans.

This unit is used mainly as rangeland, woodland, and wildlife habitat. It is also used as recreation areas.

12. Falcon-Herm-Toone

Shallow and very deep, moderately steep to very steep soils that formed in residuum, colluvium, and alluvium derived from sedimentary rock and diorite, and Rock outcrop; on landslides and escarpments

This map unit is on the La Sal Mountains, in the east-central part of the survey area. Slopes are 10 to 65 percent. The vegetation is mainly Gambel oak, ponderosa pine, big sagebrush, and bluegrasses.

This unit makes up about 6 percent of the Mill/Pack Creek watershed, and 4 percent of the Castle/Placer Creek watershed. It is about 30 percent Falcon and similar soils, 20 percent Herm and similar soils, 15 percent Toone and similar soils, and 5 percent Rock outcrop. The remaining 30 percent is soils of minor extent.

The Falcon soils are on escarpments. These soils are shallow. They formed in residuum derived dominantly from sandstone. The surface layer is brown gravelly sandy loam. The subsoil is light brown sandy loam. Sandstone is at a depth of 17 inches.

The Herm soils are on landslides. These soils are very deep. They formed in colluvium derived dominantly from sedimentary rock. The surface layer is very dark brown and brown stony clay loam. The subsoil to a depth of 60 inches or more is brown and light brown clay.

The Toone soils are on outwash fans. These soils are very deep. They formed in alluvium derived dominantly from diorite. The surface layer is very dark gray loam and dark reddish brown silt loam. The subsoil is brown gravelly clay loam and reddish brown very gravelly clay and very stony clay.

Rock outcrop consists of exposed areas of sedimentary rock. It occurs mainly as escarpments and ledges.

Of minor extent in this unit are Bond soils on benches and Sirref and Tomasaki soils on outwash fans.

This unit is used mainly as rangeland and wildlife habitat. It is also used as recreation areas and woodland.

Dominantly Well Drained, Gently Sloping to Very Steep Soils on High Mountainsides, Fans, Moraines, Landslides, Valley Trains, Aretes, and Cirque Basins in a Humid Climatic Zone

13. Flygare-Skylick-Toone

Very deep, gently sloping to steep soils that formed in colluvium, glacial till, and alluvium derived from diorite, shale, and sandstone; on high mountainsides, fans, and landslides

This map unit is on the La Sal Mountains, in the east-central part of the survey area. Slopes are 4 to 50 percent. The vegetation is mainly aspen, Gambel oak, and snowberry. Elevation is 8.300 to 9,600 feet. The average annual precipitation is about 25 to 30 inches, the mean annual air temperature is 37 to 40 degrees F and the average freeze-free period is 30 to 60 days.

This unit makes up about 11 percent of the Mill/Pack Creek watershed, and 2 percent of the Castle/Placer Creek watershed. It is about 40 percent Flygare soils, 20 percent Skylick soils, and 20 percent Toone soils. The remaining 20 percent is soils of minor extent.

The Flygare soils are on mountainsides and outwash fans. These soils formed in alluvium and glacial till derived dominantly from diorite. The surface is covered with a mat of partially decomposed leaves and twigs. The surface layer is very dark grayish brown loam. The subsurface layer is light brown stony loam. The subsoil is light reddish brown very stony clay loam. The substratum to a depth of 60 inches or more is pink very cobbly sandy loam.

The Skylick soils are on mountainsides. These soils formed in colluvium and alluvium derived dominantly from diorite and shale. The surface layer is dark gray loam. The subsoil is reddish brown cobbly clay loam.

The Toone soils are on outwash fans. These soils formed in alluvium derived dominantly from diorite. The surface is covered with a mat of partially decomposed leaves and twigs. The surface layer is dark brown loam and gravelly loam. The subsoil is reddish yellow and yellowish red very gravelly clay loam.

Of minor extent in this unit are Broad Canyon soils on very steep mountainsides, Richens and Herd soils on gently sloping and moderately sloping remnant moraines, and Dranyon and Tolman Variant soils on sloping cuestas.

This unit is used as woodland, rangeland, wildlife habitat, and recreation areas.

The main limitations of this unit for harvesting wood products are the susceptibility of the soil to compaction by heavy equipment when the soil is moist and the hazard of erosion.

14. Broad Canyon-Namon-Leighcan

Very deep, strongly sloping to very steep soils that formed in colluvium and glacial till derived from diorite; on high mountainsides, moraines, and valley trains

This map unit is on the La Sal Mountains, in the east-central part of the survey area. Slopes are 8 to 70 percent. The vegetation is mainly Engelmann spruce, subalpine fir, aspen, columbine, and huckleberry. Elevation is 9,000 to 12,000 feet. The average annual precipitation is about 25 to 40 inches, the mean annual air temperature is 32 to 38 degrees F, and the average freeze-free period is 20 to 60 days.

This unit makes up about 7 percent of the Mill/Pack Creek watershed, and 5 percent of the Castle/Placer Creek watershed. It is about 35 percent Broad Canyon soils, 30 percent Namon soils, and 15 percent Leighcan soils. The remaining 20 percent is components of minor extent.

The Broad Canyon soils are on mountainsides. These soils formed in colluvium derived dominantly from diorite. The surface is covered with a mat of partially decomposed leaves and needles. The surface layer is brown very cobbly loam. The subsoil is light yellowish brown very cobbly sandy loam. The substratum is light yellowish brown extremely cobbly loamy sand.

The Namon soils are on moraines. These soils formed in glacial till derived dominantly from diorite. The surface is covered with a mat of moss and undecomposed needles. The surface layer is brown gravelly loam. The subsurface layer is light reddish brown loam. The subsoil is pink gravelly loam and light reddish brown very cobbly loam.

The Leighcan soils are on mountainsides and valley trains. These soils formed in glacial till derived dominantly from diorite. The surface is covered with a mat of moss and undecomposed needles. The surface layer is brown cobbly loam and light yellowish brown gravelly coarse sandy loam. The subsoil is yellowish brown very gravelly coarse sandy loam and very cobbly coarse sandy loam.

Of minor extent in this unit are Flygare soils and Rubble land.

This unit is used mainly as woodland, rangeland, and wildlife habitat. It is also used as recreation areas.

The main limitations of this unit for harvesting wood products are steepness of slope and the susceptibility of the soil to mass movement.

15. Rubble Land-Leighcan-Meredith

Rubble land, and very deep, steep to very steep soils that formed in colluvium derived from diorite: on high mountainsides and aretes and in cirque basins

This map unit is on the La Sal Mountains, in the east-central part of the survey area. Slopes are 20 to 70 percent. The vegetation on the Leighcan and Meredith soils is mainly sedges, grasses, and Engelmann spruce. Elevation is 10,500 to 13.000 feet. The average annual precipitation is about 25 to 40 inches, the mean annual air temperature is 30 to 35 degrees F. and the average freeze-free period is 5 to 25 days.

This unit makes up about 4 percent of the Mill/Pack Creek watershed, and 1 percent of the Castle/Placer Creek watershed. It is about 45 percent Rubble land, 30 percent Leighcan soils, and 15 percent Meredith soils. The remaining 10 percent is components of minor extent.

Rubble land consists of areas that have more than 90 percent of the surface covered by stones and boulders. The voids are free of soil material and virtually free of vegetation. These areas are on aretes and rock glaciers.

The Leighcan soils are on mountainsides. These soils formed in colluvium and glacial till derived dominantly from diorite. The surface is covered with a mat of moss and undecomposed needles. The surface layer is brown cobbly loam and light yellowish brown gravelly coarse sandy loam. The subsoil is yellowish brown very gravelly coarse sandy loam and very cobbly coarse sandy loam.

The Meredith soils are in cirque basins. These soils formed in colluvium derived dominantly from diorite. The surface is covered with a mat of partially decomposed grass litter and leaves. The surface layer is dark brown stony loam. The subsoil is dark brown very cobbly loam. The substratum is brown extremely cobbly sandy clay loam.

Of minor extent in the unit are Broad Canyon soils on south-facing mountainsides, Flygare and Namon soils on outwash fans and moraines, and Rock outcrop.

This unit is used mainly as rangeland, wildlife habitat, and woodland.

The main limitations of this unit for harvesting wood products are steepness of slope and the susceptibility of the soil to mass movement. The main limitations for rangeland are steepness of slope, the severe hazard of erosion, and a short growing season.