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Riparian Ecosystems of the Manti-La Sal National Forest: An Assessment of Current Conditions in Relation to Natural Range of Variability

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Abstract

We conducted this assessment to provide information on the current conditions of riparian and wetland ecosystems in reference to their natural range of variability on the Manti-La Sal National Forest during forest plan revision. We used peer-reviewed literature, data from the Forest and other partners, and site visits to evaluate the status of four key ecosystem characteristics: (1) distribution of riparian ecosystems, (2) groundwater and surface water fluctuations, (3) channel and bank stability, and (4) floodplain condition. We determined that riparian and wetland ecosystems of the National Forest have experienced many stressors that have influenced their current conditions, including livestock and wild ungulate grazing, altered flow and fire regimes, road construction, timber harvest, invasive and encroaching species, vegetation mortality due to insects and disease, and altered temperature and precipitation regimes. Some geographical units of the Forest, particularly the Abajo Mountains, Mesas, and Canyons, appear to be more resistant to stressors. Our results have been incorporated in the assessment completed during the Forest plan revision process and will continue to be useful to resource managers and planners during efforts to restore and/or maintain riparian and wetland ecosystems on the Manti-La Sal National Forest.

Keywords: forest plan, key ecosystem characteristic, riparian vegetation, flow regime, channel morphology, floodplain

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Cover photo

Willow-dominated riparian vegetation along Scad Valley Creek on the Wasatch Plateau (photo by D. Max Smith, USDA Forest Service).

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INTRODUCTION

Background and Objectives

We conducted this assessment of riparian and wetland ecosystems as part of an agreement between the Forest Service, U.S. Department of Agriculture Intermountain Region (Region 4) and the Rocky Mountain Research Station (RMRS). The initial objective was to assist with the revision of National Forest management plans by evaluating current conditions of riparian and wetland ecosystems in reference to their natural range of variability. The national forests in Region 4 were in the beginning stages of updating their forest plans under the 2012 Planning Rule (36 CFR Part 219). After meeting with staff from the regional office and several national forests, we decided to evaluate riparian areas, wetlands, and groundwater-dependent ecosystems in separate assessments for each forest. We conducted this assessment of the Manti-La Sal National Forest (Forest) by synthesizing information obtained through literature review, data compilation, and site visits. The first draft of this report was completed in December of 2016. We incorporated comments from the regional office and the MLSNF into this final report. Here we report results for riparian and wetland ecosystems. The results for the assessment of groundwater-dependent ecosystems are presented in a separate document (Dwire and Driscoll, in preparation).

The methods used in this assessment were designed to meet the needs of the first phase of the 2012 Planning Rule (36 CFR Part 219). The requirements outlined in the rule are to complete a rapid assessment of ecological integrity that identifies and considers existing information and data that is relevant to the plan area. Ecological integrity is defined as “the quality or condition of an ecosystem when its dominant ecological characteristics occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence.” The rule specifies that the assessments should address drivers and stressors, as well as structure, function, composition, and connectivity of terrestrial and aquatic ecosystems. Recognizing that ecological systems cross administrative boundaries, the rule uses an “all-lands approach” that requires consideration of how conditions outside the National Forest System lands influence resources on the Forest and how actions on the Forest impact resources beyond the boundary. Finally, the assessments are used to understand conditions under the current forest plan and to identify needs for change to be addressed by the updated forest plan.

Definitions and Characteristics

Riparian ecosystems occur at the interface of aquatic and terrestrial zones and are influenced by dynamics of surface water and groundwater (Gregory et al. 1991). Physical, chemical, and biotic interactions between terrestrial and aquatic systems shape riparian areas across three dimensions, with one dimension extending from the headwaters of a stream to its mouth, the second extending from the groundwater zone to the canopy of vegetation,

and the third dimension extending from the stream bed to the outer extent of the floodplain (Stanford and Ward 1988, 1993; Vannote et al. 1980). Drivers of riparian structure and function include volume and timing of stream flows, watershed geology, channel geomorphology, extent of area inundated by surface water, fluctuations in depth to groundwater, evapotranspiration, and fluvial influences such as cut and fill alluviation (Gregory et al. 1991; Naiman and Décamps 1997; Naiman et al. 2005). Intermittent and perennial stream channels have surface flows and groundwater connections adequate to support riparian vegetation. Ephemeral channels, with surface flows limited to brief periods of intense precipitation or seasonal snowmelt runoff and little to no connection with the water table, do not typically support riparian vegetation (BLM 1993; Meinzer 1923).

Wetland ecosystems are defined and distinguished in several ways, but in general contain three characteristics: (1) frequent to permanent inundation or soil saturation, (2) vegetation typically adapted for life in saturated soil conditions, and (3) the presence of hydric soils (FICWD 1989; USACE 1987). In the Intermountain West, wetlands form in areas fed by surface water or groundwater. These natural wetland types include marshes, lakes, ponds, fens, and wet meadows (USFWS 2016). Reservoirs, stock ponds, and other anthropogenic features can create wetland conditions as well (USFWS 2016). There is clearly overlap between riparian and wetland ecosystems and there is room for discretion in how they can be defined and differentiated. For this report, we assessed the riparian ecosystems associated with perennial and intermittent streams, which include riverine and palustrine wetlands. Given the importance of springs and subsurface flows to streams and other waterbodies (Lawrence et al. 2014; Winter 2007), many if not most riparian areas also can be considered groundwater dependent ecosystems.

METHODOLOGY

Study Area

We conducted this assessment on the 1.4 million-acre MLSNF, which encompasses four mountain ranges and associated highlands with distinct geology, ecology, and management history (fig. 1). Two of these, the Abajo Mountains and associated mesas and canyons and the La Sal Mountains and Borderlands, are characterized as Colorado Plateau montane islands with the highest peaks rising from erosion-resistant igneous cores surrounded by

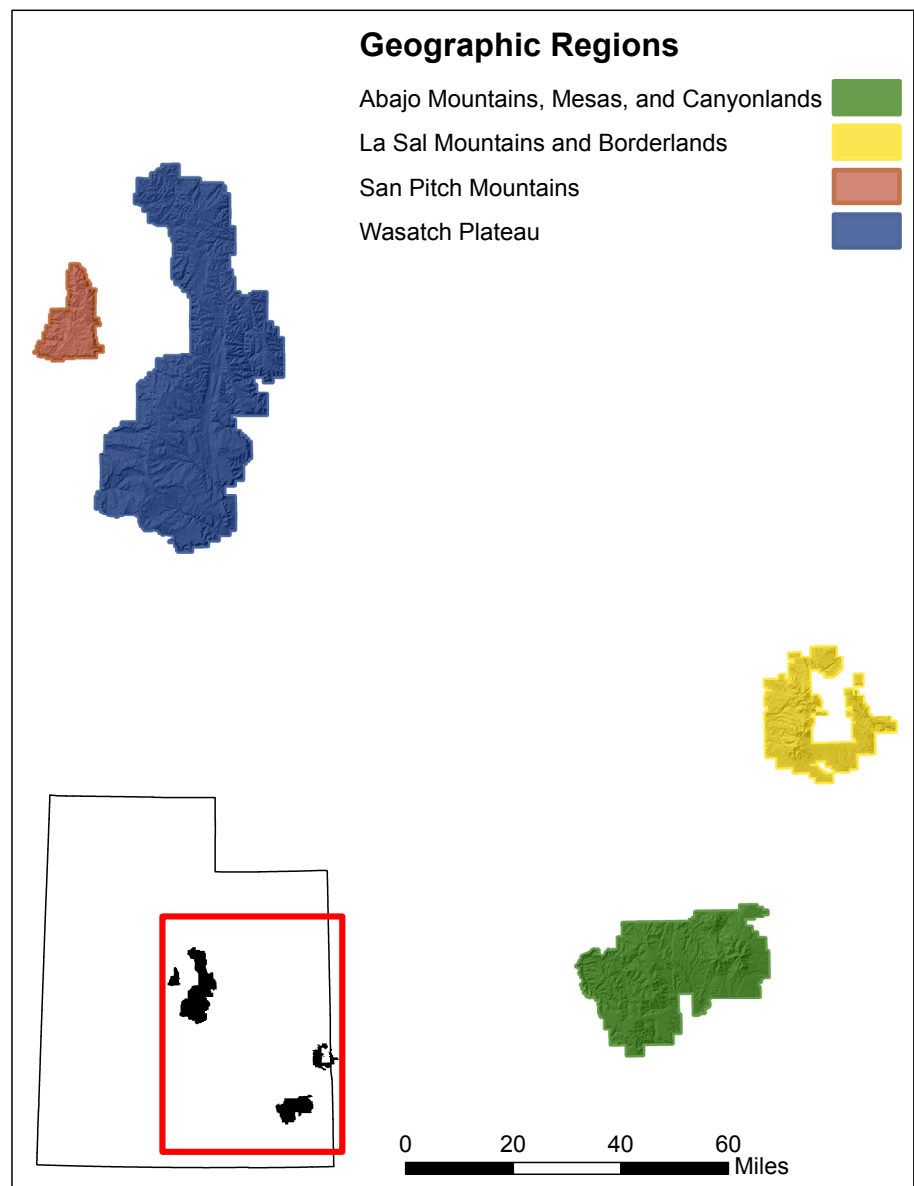


Figure 1—The four regions of the MLSNF. The South Zone includes the Abajo Mountains, Mesas, and Canyons and the La Sal Mountains and Borderlands. The North Zone includes the San Pitch Mountains and the Wasatch Plateau.

highly dissected sedimentary rock—chiefly sandstone. These are located primarily in southeastern Utah with a small section extending into Colorado. A third mountain range, the Wasatch Plateau, is approximately 80 miles long and is a major component of the north-south trending central Utah highlands that separate the physiographically distinct Colorado Plateau from the Great Basin. It is composed of layers of folded limestone, shale, and sandstone with relatively gentle slopes to the west and deep canyons and cliffs on the east. The San Pitch Mountain Range lies just west of and roughly parallel to the larger Wasatch Plateau and is composed of complex strata of sedimentary rock. These two ranges were formed from the same crustal compression and uplift followed by crustal stretching and detachment fault formation that produced the repeating basin and range physiography characteristic of the Great Basin.

Abajo Mountains, Mesas, and Canyons

The Abajo Mountains (locally known as the Blue Mountains) are composed of two parts (Kilbourne 2016; Witkind 1964), the smaller Shay Mountain (elevation 9,990 feet) in the north and the main mountain masses that include Abajo Peak (elevation 11,368 feet) in the south (fig. 2; Witkind 1964). The domed igneous mountain core is surrounded by sedimentary formations that are highly dissected into cliffs, mesas, and canyons at its base (Kilbourne 2016). These lower-elevation landscapes host piñon (*Pinus edulis*)-juniper (*Juniperus osteosperma*) woodlands in the north and gambel oak (*Quercus gambelii*) to the east and south. Ponderosa pine (*Pinus ponderosa*) are common within pockets at the foot of the peaks in the east and are dominant to the southeast and east of the mountains (Kilbourne 2016; Youngblood and Mauk 1985). At the highest elevations, Douglas-fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*), and subalpine fir (*Abies lasiocarpa*) are common vegetation with aspen (*Populus*



Figure 2—The Abajo Mountains, Mesas, and Canyons region (photo by D.M. Smith, USFS).

tremuloides) considered an important component of each habitat type (Youngblood and Mauk 1985). Approximately 300,000 acres of this region were included in the recently designated Bear's Ears National Monument (USFS 2016).

The climate of the Abajo Mountains is affected by latitude, elevation, location within the Intermountain West, and distance to a principal water source (Youngblood and Mauk 1985). The highest elevations are relatively wet and cool (Weir et al. 1983). The dominant form of precipitation is winter and spring snow, but this region also experiences a peak in precipitation during the late summer and fall due to high-intensity thunderstorms (Youngblood and Mauk 1985). Average annual precipitation can exceed 30 inches at the highest elevations, which is approximately equal to potential evapotranspiration in these areas (Weir et al. 1983). Most precipitation in the Abajo Mountains region occurs above 8,000 feet and about 5 to 15 percent recharges to bedrock aquifers (Spangler et al. 1996). In comparison, an estimated 1 to 3 percent of the mean annual precipitation at lower-elevation arid lands infiltrates to groundwater systems (Spangler et al. 1996; Weir et al. 1983).

La Sal Mountains and Borderlands

The La Sal Mountains are made up of three domed igneous mountain groups that uplifted through surrounding sedimentary formations to reach elevations between 11,000 and 13,000 feet (fig. 3; Kilbourne 2016). The high-elevation environments of the La Sals were shaped by Pleistocene glaciation that left a complex mix of bedrock and unconsolidated deposits including glacial, mass-wasting, and terrace-forming paleo alluvium (Kolm and van der Heijde 2016). The high elevation (above 11,500 feet) alluvial fans and glacial moraines support true alpine vegetation, which is rare throughout the Colorado Plateau. The Borderlands are dominated



Figure 3—The La Sal Mountains and Borderlands region (photo by D.M. Smith, USFS).

by glacial rock debris, alluvial fans, and sandstone mesas that have been dissected and deeply cut by stream erosion (Kilbourne 2016). Diverse vegetative communities occur across the elevational gradients of this region. The highest peaks are above timberline and composed of boulder fields with scattered lichens. Forest vegetation begins below 11,500 feet with subalpine spruce-fir forests that transition to aspen (*Populus tremuloides*) and mixed-conifer (Douglas fir (*Psuedotsuga menziesii* etc.), ponderosa pine, gambel oak, and finally piñon-juniper woodlands at the base (Hunt 1958; Youngblood and Mauk 1985).

Climate in this area is highly influenced by altitude and aspect, with orographic effects substantially increasing precipitation with elevation as storm systems move across eastern Utah (Geiger et al. 2014). Average annual precipitation ranges from 7.9 inches per year in the Borderlands to 39.4 inches per year in the alpine environments. At the highest elevations, snowfall in winter and spring is the dominant form of precipitation, but the La Sal Mountains region also experiences a peak in precipitation in late summer and fall due to high-intensity convective storms (Youngblood and Mauk 1985). High potential evapotranspiration (41 to 47 inches per year) in the mesas and canyons generates soil water deficit for much of the year with little groundwater recharge potential. In contrast, low potential evapotranspiration (23.6 inches per year) at high altitudes creates humid climates with excellent natural recharge potential from snowmelt and rain (Weir et al. 1983). In addition to being important groundwater recharge zones, these high-elevation areas are sources of streamflow, with geology, timing of snowmelt, and rainfall intensity determining patterns in runoff versus recharge.

San Pitch Mountains

The San Pitch Mountains are part of the Gunnison Plateau, which has a complex geology affected by thrust faults and salt structures. Only the northern 30 miles (about half) of the range are on National Forest lands (fig. 4). The region is between 8 and 12 miles wide and reaches an elevation



Figure 4—The San Pitch Mountains region (photo by D.M. Smith, USFS).

of 9,997 feet. The generally gentle topography of the central plateau transitions to steep dissected ridges and canyons in the north (Kilbourne 2016). The lower slopes of the western front are primarily composed of gypsum and shale, giving some of the area a scrubby, badlands appearance. The lowest elevations support piñon-juniper communities, which transition to gambel oak, mountain brush, and mixed-conifer-quaking aspen on higher elevation and north facing slopes (Kilbourne 2016).

The average annual precipitation in the San Pitch Mountains ranges from 14 to 25 inches, with the largest amount occurring as snow from November through April (Robinson 1971). Summer months tend to be the driest periods of the year, but heavy localized thunderstorms can produce substantial precipitation. Potential evapotranspiration is about 3.5 times larger than annual precipitation at lower elevations, resulting in extended periods of soil moisture deficit and arid and semiarid conditions. At higher elevations, the climate is subhumid and allows for recharge of groundwater systems, most of which comes from snowmelt in the spring (Robinson 1971).

Wasatch Plateau

The Wasatch Plateau, a highland in central Utah, is the largest of the four geographic units on the MLSNF. The sedimentary formations of the western front are tilted steeply and cut by many north-south trending faults (fig. 5). The mountains of the central plateau had ice caps during the Wisconsin glaciation (Thornbury 1965; Youngblood and Mauk 1985) and consist of fault valleys that separate a high mountain block to the west from a slightly lower mountain block to the east (Dutton 1880; Kilbourne 2016). The eastern escarpment is composed of steep and barren shale slopes that lead up to sandstone cliffs, all with sparse vegetation. The north end tilts downward and contains isolated canyons, ridges, and rocky buttes that have formed along eroded salt anticlines and fault systems (Kilbourne 2016; Youngblood and Mauk 1985). Vegetation generally changes with elevation, supporting four distinct zones (Price and Evans 1937; Youngblood and Mauk 1985). Scattered stands of piñon-juniper are mixed with big sagebrush below 6,500 feet (Price and Evans 1937). The slopes between 6,500 and 8,000 feet



Figure 5—The Wasatch Plateau region (photo by D.M. Smith, USFS).

feature gambel oak, bigtooth maple (*Acer grandidentatum*) and serviceberry (*Amelanchier alnifolia*) (Price and Evans 1937). Aspen, interspersed with Douglas fir, white fir, and Engelmann spruce, are common from 7,500 to 9,000 feet (Price and Evans 1937). Finally, the highest altitudes are characterized by large open grasslands with small patches of subalpine fir and Engelmann spruce (Price and Evans 1937).

The climate of the Wasatch Plateau ranges from semiarid to subhumid and has a continental pattern of high winter snowfall and summer drought (Youngblood and Mauk 1985). Precipitation generally increases with altitude and can average more than 40 inches along the crest of the plateau. Summers are typically dry, with 4 to 10 inches of precipitation falling from May to September, often in the form of erratic and localized thunderstorms of short duration (Danielson and Sylla 1983). Like the La Sal Mountains, the summer convective storms are influenced by orographic lifting, and rainfall intensities as high as 2.2 inches per hour have been recorded in the Wasatch Plateau (Youngblood and Mauk 1985). Approximately 70 percent of the average annual precipitation falls from October to April (Danielson and Sylla 1983; Waddell et al. 1986). At high altitudes, snow accumulates to depths of several feet, with the average April 1 snowpack at Buck Flat (9,885 feet) exceeding 4 feet in depth (Danielson and Sylla 1983).

Scale of Assessment

We conducted this assessment at two spatial scales within the MLSNF. At the broadest scale we focused on the four geographic units described above: the Abajo Mountains, Mesas and Canyons; the La Sal Mountains and Borderlands; the San Pitch Mountains; and the Wasatch Plateau. At a finer scale we assessed riparian ecosystems within land type associations (LTAs), which the MLSNF uses for ecosystem evaluation and planning. Each LTA is a collection of land type units distinguished by processes of geology, geomorphology, soils, climate, and vegetation. These processes influence the structure and composition of vegetation types, including riparian communities (Padgett et al. 1989). There are 10 LTAs in the Abajo Mountains region, 13 in the La Sal Mountains and Borderlands, six in the San Pitch Mountains, and 16 in the Wasatch Plateau. Within each LTA, we assessed key ecosystem characteristics (KECs) for riparian communities.

Key Ecosystem Characteristics

In accordance with the 2012 planning rule guidelines (USFS 2012), we selected KECs that reflect the composition, structure, function, and connectivity of riparian areas in the MLSNF. We developed the list of KECs from a literature review and our own experience with riparian ecosystems. We selected KECs that both integrated ecosystem integrity and could be evaluated using information available. For each KEC, we identified drivers and stressors that are influenced by natural processes and/or forest management (table 1). Below we describe the components of each KEC.

Distribution of Riparian Ecosystems

Description

Distribution is a key characteristic of riparian ecosystems because their plant communities provide physical, hydrological, and biotic services across

Table 1—Drivers, stressors, and indicators for assessment of riparian ecosystems.

KEC	Drivers	Stressors	Indicators
Distribution of riparian vegetation	Surface flows, groundwater availability, groundwater discharge	Conifer encroachment, upland vegetation encroachment, fire suppression, diversions, dams, agriculture, development	Field-sampled riparian vegetation, aerially mapped riparian vegetation, riparian vegetation departure index
Groundwater and surface water fluctuations	Precipitation, temperature, geologic setting, beaver activity	Dams, diversions, mines, roads, recreation, spring development, livestock use, timber harvest, insects and disease, wildfire, conifer encroachment	Precipitation and temperature change, spring distribution, water levels
Floodplain condition	Beaver activity, geological setting	Dams, diversions, invasive plants, wild ungulate use, livestock use, roads, recreation, timber harvest, wildfire, fire suppression, beaver removal	Riparian vegetation conversion type, riparian condition assessment, terrestrial condition assessment, regular inundation, balance between sediment inputs, exports, and water supply
Channel and bank stability	Beaver activity, stabilizing vegetation	Livestock use, roads, recreation, beaver removal, floods	Vertical stability, ground cover, stability rating, percent late seral vegetation

forest landscapes. Riparian areas support numerous species across trophic levels, ultimately influencing biodiversity at multiple scales (Naiman et al. 1993; Theobald et al. 2010). Late-seral riparian plants stabilize undercut banks and shade streams, with important implications for distribution of native fish habitat (Horan et al. 2000). Riparian vegetation is also a key component of terrestrial wildlife habitat, providing food, cover, and nesting sites for numerous taxa of high conservation priority (Atamian et al. 2010; Collins 1977; Graham et al. 1999). At the landscape scale, riparian corridors are critical in connecting habitats and wildlife populations (Hauer et al. 2016).

Drivers and Stressors

Physical and biotic processes influence the distribution of riparian ecosystems in western landscapes. The lotic riparian ecosystems assessed in this report occur along perennial and intermittent streams where surface water and groundwater support vegetation communities that differ from upland sites. Along these streams, distribution of riparian community types is constrained by physical settings. For example, riparian vegetation along confined reaches is typically limited to species capable of growing at stream margins (Bendix and Hupp 2000). Alluvial floodplains in well-defined valley bottoms can typically support a greater number of riparian community types (Brierley and Fryirs 2013).

Significant changes to surface flows and vegetation communities have occurred throughout the western United States, leading to changes in riparian distribution. Dams and diversions alter the volume and timing of surface flows or remove surface flows altogether, thereby reducing the

extent of riparian vegetation in affected areas (Dewine and Cooper 2007). Additional stressors include development of valley bottoms for municipal areas, agriculture, and industry (MacFarlane et al. 2016). Other forms of development, including roads and mines, have the potential to decrease extent as well.

Information Sources

For this KEC, we evaluated distribution of fluvial riparian ecosystems in the MLSNF. We considered these ecosystems to be largely associated with floodplains of perennial and intermittent streams. We used the flowline GIS layer from the National Hydrography Dataset (NHD) to identify locations and total length of perennial and intermittent streams in each of the LTAs.

We used the field-sampled vegetation layer (FSVeg) from the MLSNF GIS Snapshot to identify locations where riparian vegetation was confirmed by ground-based surveys. To delineate the riparian vegetation in floodplains of perennial and intermittent streams, we clipped the FSVeg layer to a polygon representing the 50-year flood zone of all streams. This layer was established using digital elevation models (DEMs) and stream gage data (Abood et al. 2012). We also used the Snapshot's WaterRiparian layer, which was developed using aerial imagery, to include areas of riparian vegetation that were missed by field sampling.

In addition to NHD and MLSNF data, we used results from the Riparian Condition Assessment Tool (R-CAT) developed and made available by Macfarlane et al. (2017). Among the R-CAT products is riparian vegetation departure (RVD) data. R-CAT uses LANDFIRE vegetation mapping to quantify the area surrounding perennial streams where riparian vegetation is expected but no longer present. We used these RVD results to compare potential changes in distribution of riparian vegetation among LTAs. Because R-CAT results excluded intermittent streams, this method gives an incomplete picture of changes in riparian ecosystem distribution. However, we feel that the results contributed important evidence for evaluating this KEC.

NRV Status

To determine whether riparian distribution was within, trending toward, or outside of the natural range of variability (NRV), we developed a set of decision rules to integrate the above data. For each LTA:

- Within = R-CAT vegetation departure was indicated at ≤ 50 percent of stream miles + relatively few effects of stressors.
- Trending toward = R-CAT vegetation departure was indicated at 50 percent to ≤ 75 percent of stream miles + relatively few effects of stressors or R-CAT vegetation departure was indicated at ≤ 50 percent of stream miles + relatively many effects of stressors.
- Outside = R-CAT vegetation departure was indicated at > 75 percent of miles at multiple streams or R-CAT vegetation departure was indicated at > 50 percent + relatively many effects of stressors.

For descriptions of riparian ecosystem distribution in each LTA, see Appendix A.

Groundwater and Surface Water Fluctuations

Description

Fluctuations in groundwater and surface water is a KEC that influences the structure, function, and composition of all riparian and freshwater systems. A stream's natural flow regime includes the timing, frequency, magnitude, rate of change, and duration of flooding and low-flow events (Poff et al. 1997). High flows are critical disturbances that maintain diverse aquatic and terrestrial habitats, allow for exchange of material and energy between a stream and its floodplain, and recharge hyporheic and groundwater systems (Junk et al. 1989; Poff et al. 1997; Stanford et al. 2005). During low flows, succession occurs as riparian plants establish and grow on recently scoured or deposited alluvium. These base flows are supported by discharge from groundwater systems that are maintained by infiltration from rainfall and snowmelt. Depth to groundwater and fluctuations in the level of water tables drive distribution, growth, survival, and composition of plant communities (Junk et al. 1989; Stanford et al. 2005). Furthermore, the life histories of many plant and animal species evolved with natural water cycles and are dependent on reliable and predictable fluctuations (Lytle 2004; Poff et al. 1997).

Drivers and Stressors

Natural flow regimes of ground and surface water systems on the MLSNF are primarily driven by climate, geology, and beaver activity. Groundwater and surface water fluctuations are also influenced by the degree of connectivity between a channel and its floodplain (Junk et al. 1989) as well as vegetation throughout the drainage that slows runoff and consumes water through transpiration. Climate across the National Forest ranges from arid to humid. Precipitation generally increases with altitude, although aspect and topography can be highly influential. Snow accumulation at high elevations is the primary source of water that sustains basal streamflow levels and provides recharge to groundwater and freshwater systems. Lower snow accumulations and high potential evapotranspiration limit the contributions from lower elevations. Brief, intense, and localized summer thunderstorms can provide a substantial amount of water across elevations that produces ephemeral pulses in stream flows and temporarily connects intermittent riparian reaches.

The geology across the Forest is complex. Glaciers from the Pleistocene and Wisconsin glaciations shaped much of the higher elevation lands, leaving a complex mix of bedrock and unconsolidated deposits that result in high degrees of connectivity between surface and groundwater systems (Weir et al. 1983). Geologic fractures and faults route groundwater vertically and laterally (Kolm and van der Heijde 2016), discharging to the surface where pathways become restricted or where more permeable geologic settings meet less permeable formations (Weir et al. 1983). These locations of groundwater upwelling, either at springs or streams, are important components of surface water flows, particularly during base flow season. At lower elevations,

streams have eroded deep channels through sandstone formations. These areas tend to have markedly different responses to precipitation and snowmelt, depending on bedrock contacts, fractures, and faults that influence connectivity between ground and surface water systems (Kolm and van der Heijde 2016).

Beaver dams modulate peaks and troughs of the yearly hydrograph, particularly when a series of dams exists within a single drainage (Rosell et al. 2005). Beaver dams increase the storage capacity of catchments by absorbing and retaining water during high flows. Discharge is slowly released and leads to higher base flows during late summer. Beaver dams enhance the depth, extent, and duration of inundation during flooding and elevate the water table during both high and low flows (Westbrook et al. 2006). Significant beaver populations can result in a transition from intermittent to perennial flow and make aquatic and riparian ecosystems more resistant and resilient to the effects of drought and climate change (Pollock et al. 2014; Rosell et al. 2005).

Stressors to water fluctuations include activities and forces that alter the timing, frequency, magnitude, duration, or rate of change of natural flows or that impact the hydrologic connectivity between ground and surface water systems. These forces can be natural or anthropogenic. On the MLSNF, they include: wildfire, vegetation mortality due to insects and disease, drought, dams and diversions, roads and trails, timber harvest, mining, grazing, and altered temperature and precipitation regimes.

According to the USFS terrestrial condition assessment, average temperatures between 2010 and 2014 compared to the previous 115 years across the Forest have increased in all four seasons (Cleland et al. 2017). On average, precipitation during the same time period has decreased during winter and spring and increased during summer and fall (Cleland et al. 2017). Reduced snowpack, more precipitation in the form of rain, and earlier snowmelt across the Forest have likely resulted in changes to hydrologic regimes. Natural fluctuations are strained by these changes in temperature and precipitation and any additional stressors act synergistically on the initial force of long-term climate change. Planning for changes in climate and human population growth, accompanied by efforts to restore or mitigate additional stressors, will be important for limiting further changes to natural groundwater and surface water fluctuations (UDWR 2012).

Examples of natural disturbances that influence groundwater and surface water fluctuations include wildfire, insect infestation and disease, and drought. Depending on severity, fire can have major hydrologic implications that include flash flooding or severe sedimentation that disrupts connections between ground and surface water systems (Doerr et al. 2006; Ice et al. 2004). Widespread mortality that results from insects and disease alters water fluctuations by increasing the amount of late summer infiltration to groundwater systems (Bearup et al. 2014). While these stressors are natural, they can be exacerbated by anthropogenic activities. A century of fire suppression has contributed to an increase in fuel loads that can lead to larger, more severe fires (Dennison et al. 2014)). Warmer temperatures

and earlier snowmelt have increased the length of the fire season and the frequency of periods of severe fire weather (Westerling et al. 2006).

Anthropogenic stressors to water fluctuations include diversions, roads and trails, timber harvest, mining, and livestock grazing. Diversions disrupt natural hydrologic connections and alter the timing, frequency, duration, and magnitude of peak and base flows (Winter et al. 1998). Roads and trails alter hillslope contours and add impervious surfaces to landscapes, decreasing potential infiltration and increasing surface runoff. These features can also be unnatural sources of fine sediment that fill lakes, wetlands, stream channels, and obstruct natural flow paths between surface and groundwater systems (Forman and Alexander 1998; Pickering et al. 2009; Reid and Dunn 1984). The effects of timber harvest on surface and groundwater systems depend on how the harvest is managed (Bosch and Hewlett 1982). Clearcutting can increase surface runoff and provide a source of sediment that disrupts natural surface and groundwater networks (Bosch and Hewlett 1982). Mining activity can alter the direction and structure of natural flow paths and lead to channel entrenchment. The results of this process can be reduced groundwater discharge, different distributions of water within a stream, or the disappearance or movement of springs (Bjerklie and LaPerriere 1985). Lastly, livestock grazing can reduce vegetative cover in the uplands and riparian areas, decrease stability; increase runoff; and allow downcutting and entrenchment of streams (Belsky et al. 1999). Ultimately, this process leads to lower water tables and the drying of perennial water sources (Krueper 1993).

Information Sources

To evaluate this KEC, we described groundwater and surface water sources in each geographic unit and identified stressors that may result in fluctuations exceeding the NRV. We reviewed scientific literature to describe the geological processes that drive groundwater and surface water dynamics in each LTA. Recognizing that the NHD layer does not capture all springs, we used this layer to map the locations of known springs across the Forest. In addition to the NHD layer, we used the Points of Diversion (POD) layer that was available for the Abajo and La Sal Mountain units to further assess the locations of springs and whether their flows were impacted by diversions or dams. The POD layer for the San Pitch Mountains and Wasatch Plateau was not adequate to use for this analysis. We applied spatial data from the USFS terrestrial condition assessment (Cleland et al. 2017) to quantify changes in temperature, precipitation, wildfire, and vegetation mortality due to insects and disease within each LTA. The terrestrial condition assessment uses several datasets to estimate the ecological integrity of National Forest lands at the scale of LTAs. The assessment includes stressors such as roads combined with a comparison of current and reference conditions (Cleland et al. 2017). For this particular KEC we used the climate exposure indicator, which relies on PRISM climatological data, the catastrophic disturbance indicator, which uses Monitoring Trends in Burn Severity and LANDFIRE data, and the insect and pathogen indicator, which uses the National Insect and Disease Risk Map (Cleland et al. 2017). We also used the data layers

from the MLSNF GIS Snapshot to quantify points of diversion, roads, trails, campsites, mines, and grazing allotments.

NRV Status

To determine whether groundwater and surface water fluctuations were within, trending toward, or outside of the NRV, we developed a set of decision rules to integrate the above data. For each LTA:

- Within = Average winter temperatures between 2010 and 2014 had increased by <1 °F compared to the previous 115 years + average winter precipitation between 2010 and 2014 had not decreased >0.1 percent compared to the previous 115 years + relatively low diversion and dam density + relatively low impact from mining.
- Trending toward = Average winter temperatures between 2010 and 2014 had increased by approximately 1 °F compared to the previous 115 years + average winter precipitation between 2010 and 2014 had not decreased by >0.1 percent compared to the previous 115 years + relatively low diversion and dam density + relatively high impact from mining.
- Outside = Average winter temperatures between 2010 and 2014 had increased by >1 °F compared to the previous 115 years + average winter precipitation between 2010 and 2014 had decreased by >0.1 percent compared to the previous 115 years + relatively high diversion and dam density and/or relatively high impact from roads or mining.

For descriptions of groundwater and surface water fluctuations in each LTA, see Appendix B.

Channel and Bank Stability

Description

Stream channels naturally experience cycles of aggradation and degradation, often triggered by changes in climate and other factors. On shorter time scales, these systems maintain a balance between the opposing processes of erosion and sediment deposition (Beechie 2008). The establishment of vegetation along banks increases stability and reduces erosion within channels, ultimately providing high quality habitat for aquatic and riparian organisms. Unstable channels that allow sedimentation of streams and waterbodies are a major concern due to the impact on ecological structure and function, infrastructure, and water quality.

Drivers and Stressors

Channel equilibrium is influenced by geomorphic and biotic factors such as underlying geology, beaver activity, riparian vegetation, and large wood. Certain geologic settings limit plant growth and infiltration or are highly erodible, allowing for heavy runoff and creating naturally unstable channels. Beaver dams slow water runoff and trap sediments, thereby increasing channel stability. Furthermore, these structures can contribute to restoration by stopping the upstream migration of erosion. For low gradient streams, late-seral riparian plant communities include sedges, rushes, and willows, all of which have extensive root systems that protect banks from floods,

trampling, and other erosive events. Dominance of late-seral vegetation on stream banks is an indication of potential for self-repair following disturbance events (MLSNF 2012). These plants also dissipate stream energy and trap sediment, lessening flood damage to areas downstream (Winward 2000). Lastly, large woody debris can contribute to stream bank stabilization by protecting banks, slowing flow, and trapping sediments.

Streams in alluvial reaches experience natural incision-aggradation cycles, but incision can be unnaturally accelerated by loss of vegetation or removal of beaver dams and instream wood (Bilby 1984; Pollock et al. 2014). Certain changes in land use, climate, or other disturbances can cause erosion to travel upstream, reducing habitat quality, changing temperature, diminishing water quality, and incising channels. Additional stressors that influence channel and bank stability include livestock grazing, recreation use, roads, and flooding (MLSNF 2013; Pollock et al. 2014; Vanderbilt 2006). Herbivory by ungulates is a common disturbance. Cattle tend to have particularly strong impacts because they show a stronger preference for riparian areas than grazers such as sheep (Kauffman and Krueger 1984; USFS 2014). Sedges and rushes remain succulent when upland forage species lose quality with senescence, making them vulnerable if timing and intensity of cattle grazing is mismanaged (Platts and Nelson 1989). Willows and other woody plants can be excessively browsed by livestock and native ungulates as well (USFS 2014). In addition to consumption of stabilizing vegetation, heavy livestock use results in soil compaction, trailing, trampling of streambanks, and erosion (MLSNF 2004).

Information Sources

To evaluate stability of stream channels and banks, we examined results of two types of field investigations conducted by MLSNF staff. Properly Functioning Condition (PFC) assessments were conducted by interdisciplinary teams to determine how well processes were functioning at streams or wetlands (Dickard et al. 2015). During each PFC visit, a variety of indicators was evaluated, including the vertical stability of the channel, stabilizing vegetation on streambanks, and ground cover. For this analysis, we only used PFC assessments for lotic riparian ecosystems.

More recently, Winward greenline vegetation surveys have been conducted to evaluate the efficacy of management practices used to protect riparian vegetation and streambank stability (Winward 2000). In these protocols, transects are established along the greenline, which is the nearest location to water where perennial vegetation occurs. Among the measurements collected are greenline cover and composition of vegetation communities. For the purposes of our assessment, we focused on: (1) the vegetation stability score, which ranges from 1 to 10 and is based on scores applied to individual plant species and communities; (2) percentage of greenline transect composed of late-seral vegetation, which is used to determine if desired conditions are met; and (3) percent ground cover of greenline transect.

Because cattle often have a greater direct effect on riparian vegetation than other livestock types, we used the MLSNF range management unit GIS layer to identify amount of LTAs located within cattle grazing allotments.

NRV Status

For this KEC, we evaluated the stability of channels and streambanks as maintained by riparian vegetation. Standards used to evaluate this characteristic varied among stream types and vegetation data have been collected unevenly across the Forest. Within each area, we limited our evaluation of channel and bank stability to LTAs where PFC or greenline data were collected at multiple streams. This excluded many LTAs and all of the San Pitch Mountains. Greenline data measurements also excluded much of the vegetation found in floodplains and dynamics within larger watersheds. These variables are addressed in our floodplain condition assessment and in watershed condition assessments. We developed a set of decision rules to determine whether current measures of stability are within, trending toward, or outside of the NRV. For each LTA:

- Within = Localized cattle grazing + relatively high stability ratings + relatively high ground cover + relatively high percent meeting properly functioning conditions and desired conditions.
- Trending toward = Widespread cattle grazing + relatively high stability ratings + relatively high ground cover + relatively high percent meeting properly functioning conditions and desired conditions.
- Trending toward = Localized cattle grazing + relatively low stability ratings + relatively low ground cover + relatively low percent meeting properly functioning conditions and desired conditions.
- Outside = Widespread cattle grazing + relatively low stability ratings + relatively low ground cover + relatively low percent properly functioning conditions and desired conditions.

For a description of channel and bank stability in each LTA, see Appendix C.

Floodplain Condition

Description

The geomorphological form of floodplains is shaped by the movement of water and sediment longitudinally downstream and laterally from the river across the landscape (Lorang and Hauer 2003; Poff et al. 1997). Diverse aquatic and terrestrial habitats overlay the floodplain template and their distribution is controlled by patterns and processes occurring across spatial and temporal scales including flooding, channel avulsion, cut and fill alluviation, recruitment of large wood, and regeneration of riparian vegetation (Stanford et al. 2005). The interaction of these processes builds unique patches through erosion, deposition, and succession, ultimately constructing a continuously dynamic habitat mosaic (Salo et al. 1986; Stanford et al. 2005). The dynamic and heterogeneous cover of floodplains creates complex ecosystems that support greater biodiversity (Ward et al. 1999), are more resistant and resilient to disturbances and stressors

(McCluney et al. 2014), and are more productive (Junk et al. 1989; Thoms 2003) than simplified floodplains (Peipoch et al. 2015). On the MLSNF, the rates of these processes differ based on geologic setting, stabilizing vegetation, natural flow regimes, presence of large woody debris, and climate.

Drivers and Stressors

Development of floodplains along streams and rivers throughout the Forest is dependent on geomorphic setting and flow regimes. Floodplain dynamics on the MLSNF are highly variable. Channels in alluvial basins construct large floodplains while streams confined by colluvium or bedrock or with steep gradients generate narrow, discontinuous, or non-existent floodplains (Scott et al. 2005). High-elevation streams generally have bedrock controls that limit channel dynamism and sediment supply. The floodplains of the lowest elevation LTAs are typically composed of low bars and braided channels (Scott et al. 2005). In addition to the geomorphic setting, the natural flow regime contributes to floodplain condition. Flooding is an important disturbance that scours the channel and inundates the floodplain. Base flow conditions allow for succession to occur as vegetation establishes and grows following disturbance. Lastly, beaver dams enhance complexity by creating intricate channel structures with diverse vegetation. They also slow the downstream movement of sediment.

Activities that alter natural flow dynamics, disconnect channel from floodplain, change sediment dynamics, or inhibit succession stress natural floodplain conditions. These activities and forces include regulation or removal of flow, construction of roads or trails, beaver removal, establishment of invasive species, fire, or grazing. Dams, diversions, and reservoirs disrupt flow patterns that shape a stream's geomorphology and connect the channel to its floodplain. Additionally, these structures alter the natural locations of scour and deposition. Interior western rivers are most susceptible to the effects of dams and diversions with complexity reduced by 73 percent in regulated reaches (Graf 2006). Roads and trails located within floodplains can constrain channel movement, inhibit floodplain development, and provide an unnatural source of fine sediment. In places where these features cross streams, they can widen the channel, decrease the depth of stream reaches, and flatten the banks (Forman and Alexander 1998; Reid and Dunne 1984; Winter et al. 1998).

Due to their dynamic nature and high productivity relative to upland ecosystems, floodplains are especially vulnerable to colonization by invasive plants (Richardson et al. 2007). These species can degrade wildlife habitat, alter disturbance dynamics, and degrade soil and water quality in riparian and wetland settings (Smith and Finch 2014; Vitousek et al. 1996). In conifer-dominated landscapes, fire maintains natural riparian vegetation by preventing encroachment of upland species and dominance by late-successional species (Kleindl et al. 2015; Pettit and Naiman 2007). Wildfire suppression has caused many riparian areas to transition to being dominated by conifers, losing their distinctive character (Arno and Allison-Bunnell 2002; Dwire and Kaufman 2003). In low-elevation alluvial reaches, however,

fire can result in mortality of native trees and facilitate the spread of invasive and upland species (Smith et al. 2009).

A history of overgrazing has impacted floodplain structure and sediment dynamics across the Forest. The rangelands of southeastern Utah have been heavily grazed by cattle since the late 1800s (Shamo 2014). Livestock use has damaged vegetation and soil near streams and reduced streambank stability (MLSNF 2001). The numerous effects of cattle grazing include trampling banks, over-widening of streams, a decrease in stabilizing vegetation, incisement of stream channels, and unnatural sediment from trailing (George et al. 2002; Thibault et al. 1999).

Information Sources

To determine the NRV status of floodplain condition, we reviewed literature that describes historical conditions. We identified floodplains of perennial and intermittent streams using a polygon of the 50-year flood zone developed for the MLSNF (Abood et al. 2012). To evaluate conditions within these areas, we examined spatial data from the terrestrial condition assessment (Cleland et al. 2017) and layers in the MLSNF GIS Snapshot. We used results from the Riparian Condition Assessment Tool (R-CAT; Macfarlane et al. 2017) including the riparian vegetation conversion type (RVCT) and riparian condition assessment (RCA). The RVCT procedure uses results from the LANDFIRE vegetation mapping project to identify causes of changes from riparian vegetation expected under natural conditions. The RCA procedures also use LANDFIRE and road coverage data to evaluate vegetation and hydrological connectivity of floodplains. We used results from these procedures to compare potential changes in floodplains among LTAs.

NRV Status

To determine whether floodplain conditions are within, trending toward, or outside the NRV, we developed a set of decision rules to integrate the above data. For each LTA:

- Within = relatively small areas affected by dams, diversions, high severity wildfire, and roads + relatively low areas affected by invasive plants, conifer and upland encroachment, development, and fire suppression.
- Trending toward = variation in relative area affected by dams, diversions, high severity wildfire, roads, invasive plants, conifer and upland encroachment, development, and fire suppression.
- Outside = relatively large areas affected by dams, diversions, high severity wildfire, and roads + relatively high areas affected by invasive plants, conifer and upland encroachment, development, and fire suppression.

For descriptions of floodplain condition in each LTA, see Appendix D.

ANTHROPOGENIC INFLUENCES ON RIPARIAN ECOSYSTEMS OF THE MLSNF

The area now comprising the MLSNF has been influenced by humans since at least 10,000 years before present time, as evidenced by the discovery of Paleo-Indian encampments near the southern end of the Wasatch Plateau (MLSNF 2017). Paleo-Indian hunters and archaic foragers altered the landscape by hunting large mammals and igniting fires, but it is difficult to determine if these changes resulted in meaningful, long-lasting effects on riparian and wetland ecosystems (Gage and Cooper 2013).

Beginning around 300 AD, sedentary farming societies were established in the region by the Ancestral Puebloan and Fremont cultures (Lister and Lister 1983; Grayson 1993). Their activities likely influenced riparian ecosystems through diversion of surface flows for irrigation and tilling of floodplains. With the exception of the Abajo Mountains, Mesas, and Canyons geographic unit, such farming sites were at elevations below the modern National Forest boundaries (fig. 6). Individuals or groups used higher elevations, however, to obtain foods, tool-making supplies, and other resources (McPherson 1992; MLSNF 2017). By 1300 AD, agricultural societies had retreated from Utah to Arizona and New Mexico.

Left in the place of agricultural societies were the hunter and gatherer ancestors of the modern Paiute, and Ute, who were later joined by the Navajo (Cuch 2000). Prior to introduction of horses and other livestock, these groups made annual migrations throughout the Intermountain Region



Figure 6—The petroglyphs of Newspaper Rock, just outside of the National Forest boundary near the Abajo Mountains, reveal many centuries of human influence on the landscape that now includes the MLSNF (photo by D.M. Smith, USFS).

to track the seasonal abundance of plants and animals. In each geographic unit of the Forest, bands of one to 10 families would have occupied riparian areas and wetlands during certain times of the year while fishing, hunting, and collecting plant-based resources including rushes and willows (Cuch 2000; Grayson 1993). During the summer, some bands tended small gardens near springs and streams (Hittman 2013). Nomadic groups ignited fires for a variety of reasons, including the improvement of hunting and foraging opportunities. It is likely that riparian ecosystems were influenced by these fires in low and mid elevations of the Forest (Nowacki et al. 2012). Depending on their frequency, these fires may have prevented conifer encroachment and encouraged dominance by shrubs and trees (e.g., quaking aspen) capable of resprouting.

The earliest Euro-American influences on riparian ecosystems occurred during the fur trapping period beginning in the 1820s. Beavers and other furbearers were harvested by Native Americans for food and clothing for thousands of years. However, given the large numbers of furbearers reported by early Euro-American explorers, it is unlikely that intensive trapping occurred in the West until a connection with European markets was established in the early 1800s (Chittenden 1902). European and American fur companies trapped beavers from Great Basin streams and Colorado River tributaries during the early 19th century (Chittenden 1902). Though population declines were noted by the mid-1800s, aggressive trapping continued in Utah until 1899 when beaver harvest was outlawed. Effects of beaver trapping were likely greatest at lower to mid elevations where beaver density was high. Beaver populations recovered quickly in the early 20th century but, it is difficult to determine whether or not beaver populations have returned to their pre-European density and extent (Macfarlane et al. 2015; Perisco and Meyer 2013; UDWR 2010,). An open beaver trapping season has been in effect since 1957.

Permanent Euro-American influence of the North Zone began with the settlement of Sanpete Valley in 1851, followed by settlement of Castle Valley in the 1870s (Arrington 1958). Grazing, mining, logging, and water use expanded to the Wasatch Plateau and San Pitch Mountains as the populations of these valleys grew, altering streams and riparian ecosystems by the end of the 19th century. The valleys surrounding the South Zone of the Forest were first settled in the 1850s, with community establishment and widespread rangeland use beginning in the 1870s (Arrington 1958; Shamo 2015).

In the early 1900s, watershed degradation and resulting flood damage triggered local support for the establishment of forest reserves on the Wasatch Plateau, which were later incorporated into the MLSNF. Throughout the late 19th century and early 20th century, few places were as negatively altered by grazing than mountains in Utah, including the Wasatch Plateau (Alexander 1987; Hall 2001). Grazing in the subalpine meadows of the plateau was so intense that townsfolk could count sheep herds from 10 miles away by the trailing plumes of dust (Hall 2001). Studies show that heavy grazing in watersheds caused transitions from a fairly stable landscape to one with serious flood sources (Meeuwig 1960). With the removal of protective

vegetation, runoff became sporadic and large amounts of sediment were introduced to channels during heavy rainstorms in the late 1800s and early 1900s (Gregory 1938). Channels became deeply incised and infrastructure was heavily damaged (Reynolds 1911). Systems were out of balance between the supplies of water and sediment, and streams were unable to clear depositional material (Gregory 1938). Gregory (1938) noted that increased sediment loads were historically uncommon and that the enormous supply of material provided by tributaries had choked canyons throughout the region. Following establishment of the Manti National Forest in 1905, watershed damage was addressed through grazing restrictions and application of range management research conducted at the Great Basin Experiment Station (Keck 1972). Although many ranges on the Wasatch Plateau are rehabilitated and support managed grazing, the systems are not restored, a process that may require centuries of recovery, if not longer (Hall 2001; Meeuwig 1960). Ranges in the San Pitch Mountains may be slower to recover from the excessive grazing of the 19th century because they receive less precipitation than the Wasatch Plateau (Geary 1992). A series of catastrophic floods and landslides occurred in the North Zone of the Forest in the 1980s as a result of abnormally high rain and snowfall. Restoration treatments were applied to stream channels and floodplains to address damage from these events (Kuehn 1984).

Underground coal mining began on the Wasatch Plateau in 1874 and has impacted channel morphology and sediment dynamics in various ways. Studies have shown increases in the lengths of cascades and glides, increases in pool length, numbers, and volumes, an increase in the median particle diameter of bed sediment in pools, and some constriction in channel geometry (Sidle et al. 1998). Coal mining has been associated with debris slides and rockfalls in the Wasatch Plateau. These events have resulted in the deposition of sediment, boulders, and trees in streams (Slaughter et al. 1995).

In addition to grazing and mining, the development of infrastructure for water resources has impacted riparian vegetation throughout the Forest. On the Wasatch Plateau, diversions have been constructed since the 1800s and several large reservoirs were filled during the latter half of the 20th century (fig. 7; Geary 1992). Impacts from these projects include dewatering of diverted streams, incision of augmented streams, inundation of streams and riparian ecosystems, alteration of timing and volume of surface flows below dams, storage of sediment behind dams, and depletion of sediment below dams. Though they lack the large reservoirs of the Wasatch Plateau, the Abajo Mountains, La Sal Mountains, and San Pitch Mountains have been affected as well. Perennial streams have been diverted throughout these areas to provide water for agriculture and municipal use. As a result, reaches that were once perennial are now intermittent or ephemeral, with consequences for riparian ecosystems (fig. 8).

Timber harvest has occurred on the Forest since initial Euro-American settlement of nearby valleys. Typical of most forests in the region, timber in the MLSNF was harvested at low rates in the early decades of the National Forest, primarily to support construction of towns, mines, and



Figure 7—Joe's Valley Reservoir is one of several large impoundments on the Wasatch Plateau (photo by D.M. Smith, USFS).

other developments. Due to its remote and rugged setting and lack of nearby lumber mills, the Forest failed to meet directives for sustained yields (Alexander 1987). Timber harvest in the region did not increase until the latter half of the 20th century due to technological advances and post-war demand for lumber. Effects of harvest on riparian ecosystems include removal of streamside vegetation and alterations of stream dynamics resulting from road-building (Fortino et al. 2004). Regulations implemented near the end of the century reduced effects of harvest and roads on waterways. In the 21st century, timber harvest is only a minor contributor to the local economies of the region (MLSNF 2017), limiting its effects on riparian ecosystems.



Figure 8—This drain in North Creek Canyon is one of many diversions in the Abajo Mountains. Surface flows and riparian vegetation are absent below the drain (photo by D.M. Smith, USFS).

RESULTS

Current Conditions

Abajo Mountains, Mesas, and Canyons

Distribution of Riparian Ecosystems

Riparian vegetation types vary with elevation and geologic setting in the Abajo Mountains region. A relatively small proportion of streams are perennial (0–17 percent among LTAs) and intermittent streams and springs are scattered, resulting in a similarly scattered distribution of riparian ecosystems (fig. 9). Conditions for herbaceous-dominated riparian communities are present where plants can access surface flows or groundwater. These sites, dominated by sedges (*Carex* spp.), rushes, (*Juncus* spp.), and other graminoids, occur from swampy headwaters of Abajo Mountains streams to the lower reaches of the Dark Canyon Wilderness (fig. 10). Conifer- and willow-dominated communities are present along

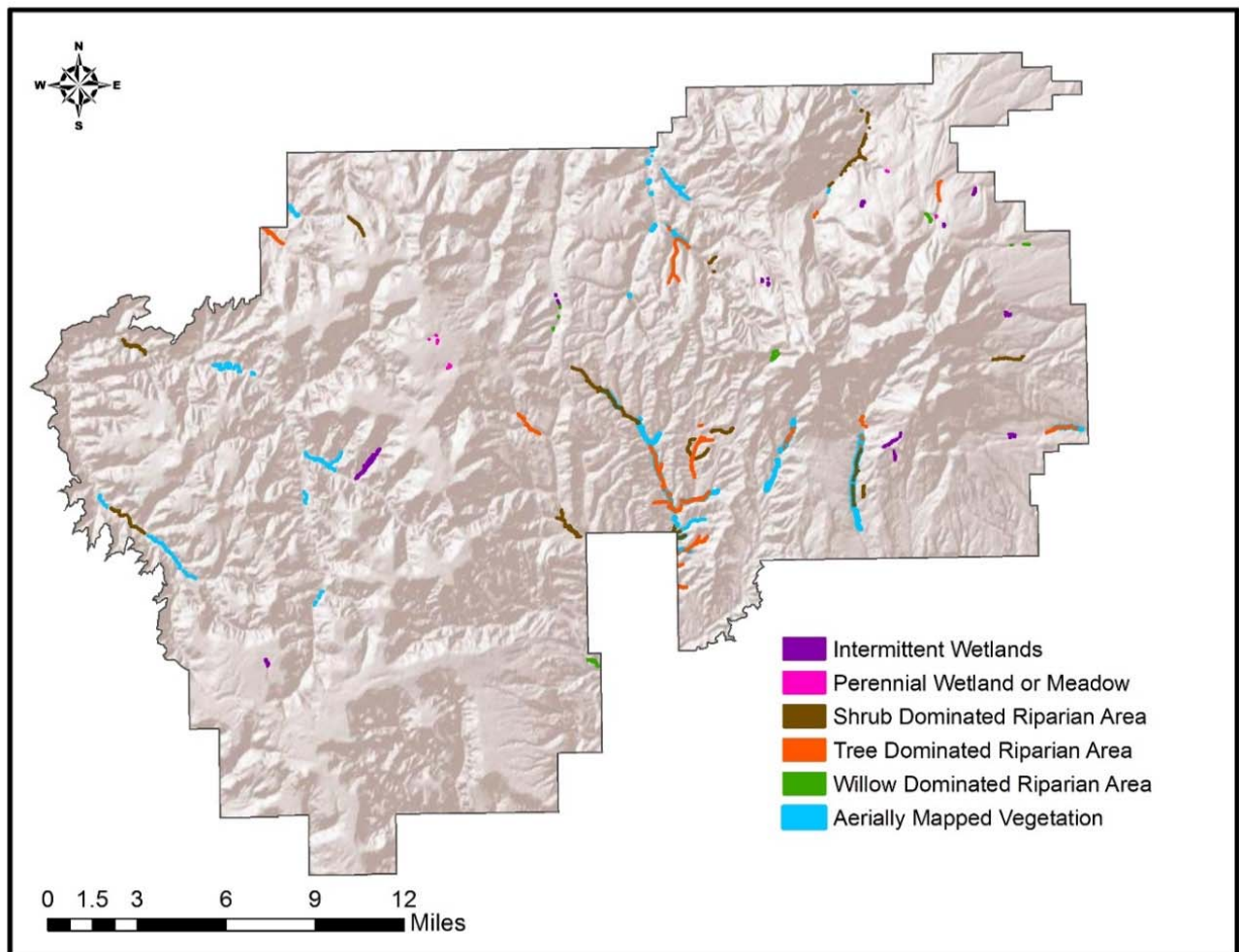


Figure 9—Distribution of field-sampled and aerially mapped riparian vegetation in the Abajo Mountains, Mesas, and Canyons.



Figure 10—Riparian wet meadow with herbaceous-dominated riparian community types in the Abajo Mountains, Mesas, and Canyons area. Community types are dominated by *Agrostis stolonifera*, *Deschampsia cespitosa*, *Carex utriculata*, and other graminoids (photo by MLSNF).

confined stream reaches at a variety of elevations (fig. 11). In general, conditions for deciduous tree-dominated communities exist at lower elevations where alluvial channels form and surface water and groundwater support narrowleaf cottonwood (*Populus angustifolia*), aspen, boxelder (*Acer negundo*), gray alder (*Alnus incana*), and other trees (fig. 12). Overall, acres of woody riparian vegetation are greater in the Mesas and Canyons LTAs than in the Abajo Mountains LTAs (table 2).



Figure 11—Herbaceous-, conifer-, and willow-dominated riparian community types near upper Indian Creek in the Abajo Mountains, Mesas, and Canyons area (photo by D.M. Smith, USFS).

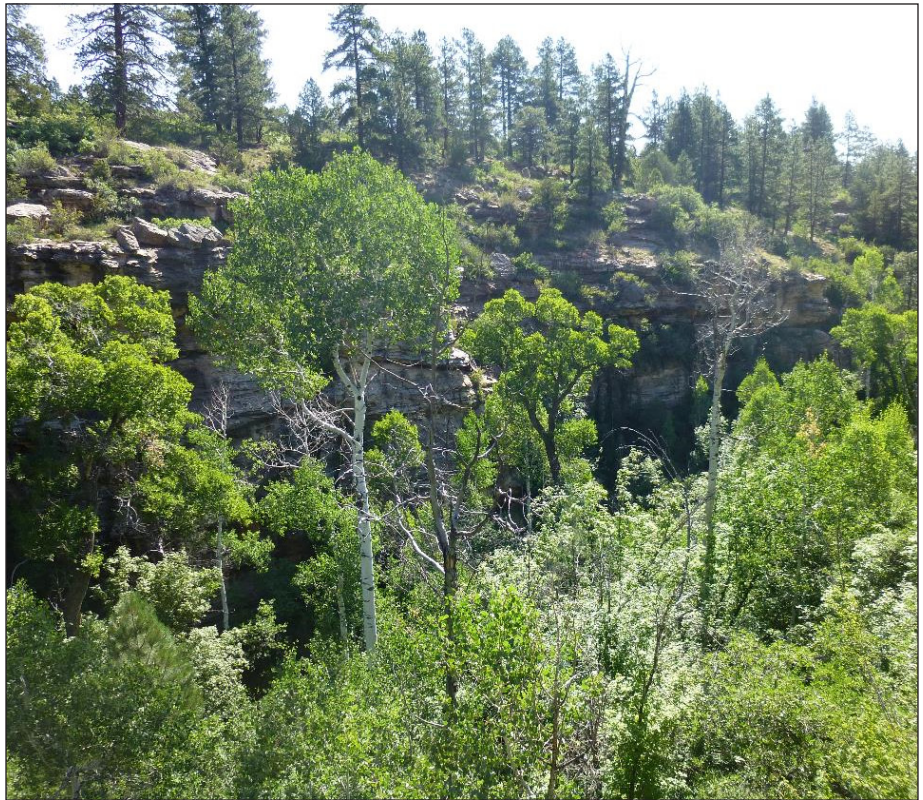


Figure 12—Tall deciduous tree riparian community types at Devil's Canyon within the Abajo Mountains, Mesas, and Canyons area. Tree species include *Populus angustifolia*, *Populus tremuloides*, *Acer grandidentatum*, and *Pinus ponderosa*. (photo by D.M. Smith, USFS).

R-CAT results suggest that extent of riparian vegetation, an indicator of riparian ecosystem distribution, is reduced by diversion of surface flows in the Abajo Mountains. These diversions provide the municipal water supply for the towns of Blanding and Monticello (USFS 2005). Springs have been developed for livestock use throughout these mountains as well, likely contributing to reduction in riparian extent. These reductions are minimal relative to other geographic units, so we determined the distribution of riparian ecosystems to be within or trending toward the NRV in the Abajo Mountains LTAs. There are fewer water developments in the Mesas and Canyons LTAs and, as a result, the KEC is within the NRV throughout these associations (fig. 13).

Groundwater and Surface Water Fluctuations

Natural groundwater and surface water fluctuations in the Abajo Mountains region are highly influenced by accumulation of snow at high elevations. Snowpack above 8,000 feet recharges aquifers and is the primary source of streamflow. The hydrographs of many perennial streams that form at high elevations include seasonal peak flow from snowmelt that typically occurs between April and June (Witkind 1964). Discharge from groundwater systems via springs is greatest during early summer, with some sources going dry later in the year (Witkind 1964). The locations of springs, flow patterns, and infiltration capacity are controlled by underlying geology. Upwelling occurs where more permeable substrates contact less permeable, with the majority of springs in the Abajo Mountains, Mesas, and Canyonlands

Table 2—Area of aerially mapped riparian vegetation, area of field-sampled riparian vegetation types, and status of distribution of riparian ecosystems in Abajo Mountains, Mesas, and Canyons LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	LTA acres	Aerially mapped riparian acres	Floodplain field-sampled acres	Intermittent wetland acres	Perennial wetland acres	Shrub-dominated riparian acres	Tree-dominated riparian acres	Willow-dominated riparian acres	NRV status
A_LTAG1	2,9317	1.3	11.8	0	0.5	0	5.1	6.2	Within
A_LTAG2	8,149	0	0	0	0	0	0	0	II
A_LTAG3	54,199	74.4	63.7	18.2	0	20.3	23.8	1.4	TT
A_LTAG4	5,632	0	11.7	7.7	0.6	0	0	3.4	Within
A_LTAG5	11,567	20.7	19.3	1.5	0	17.2	0.6	0	TT
MC_LTAG1	34,483	2.8	45.7	0	0	18.5	26.6	0.7	Within
MC_LTAG2	42,480	11.4	31.8	0.8	0	9.3	21.1	0.6	Within
MC_LTAG3	101,441	44.8	106.1	5.1	3.9	47.9	48.5	0.6	Within
MC_LTAG4	69,664	12.6	37.5	0.1	0	3.3	34.2	0	Within
MC_LTAG5	5,233	126.9	161.5	41.5	0	71.2	42.0	6.9	Within

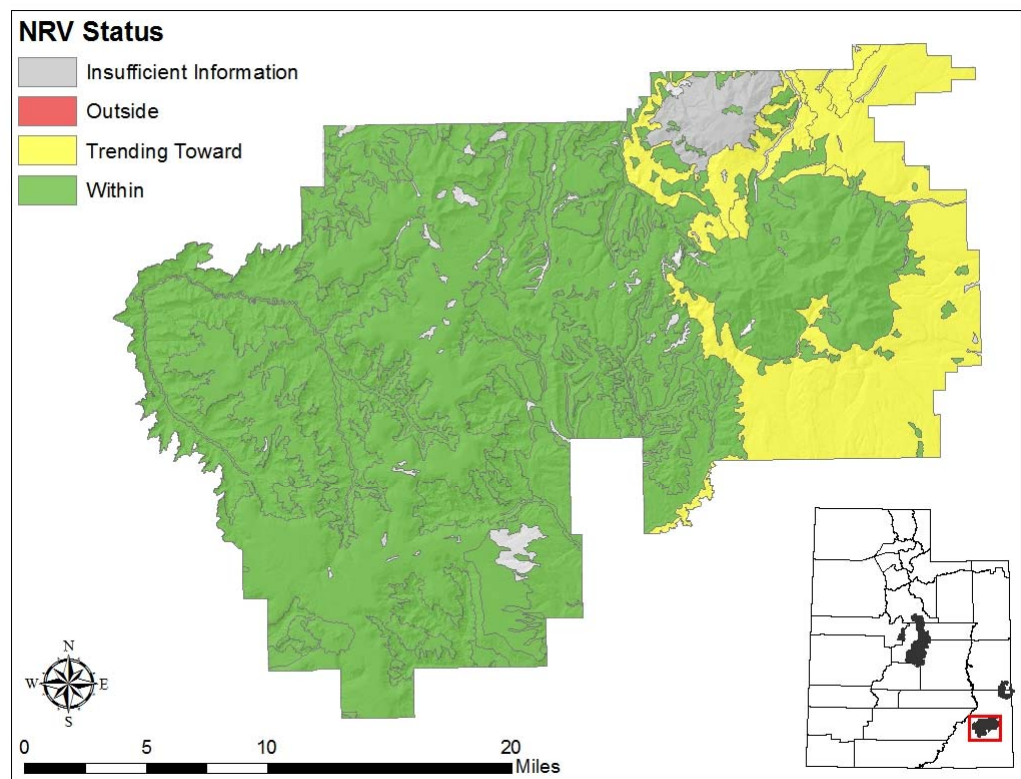


Figure 13—NRV status of riparian ecosystem distribution in the Abajo Mountains, Mesas, and Canyons.

discharging from sandstone aquifers such as the Burrow Canyon Formation and Dakota Sandstone (fig. 14; Weir et al. 1983). These springs occur at higher altitudes, are generally perennial, and have an average discharge of about 19 gallons per minute (Weir et al. 1983). Springs with continuous discharge are important sources of stream base flow during dry months, but they also tend to be well known and used for human consumption (Witkind 1964).

Witkind (1964) characterized rockslides and boulder fields surrounding the Abajo Mountains peaks as probable rock glaciers identified by concentric ridges and frost action. These fields extended across the floors of the wide valleys adjacent to the peaks. When present, these features supply a constant source of water as they gradually melt throughout the summer. Rock glaciers have been found to function as aquifers and studies in other arid regions have shown them to supply up to 56 percent of annual stream discharge (Corte 1978; Geiger et al. 2014). Additionally they act as an impervious surface that limits infiltration and causes higher flows in surface water systems (Geiger et al. 2014). More recent descriptions of the region (Spangler 1996; Weir et al. 1983) do not include information on the presence of these features. If these landforms were present in the 1960s and have since disappeared from the landscape, there have likely been impacts to natural fluctuations in ground and surface water. In the nearby La Sal Mountains region, basins without rock glaciers had less variation in summer flows and smaller peaks in the hydrograph following precipitation events compared to rock-glaciated drainages (Geiger et al. 2014).

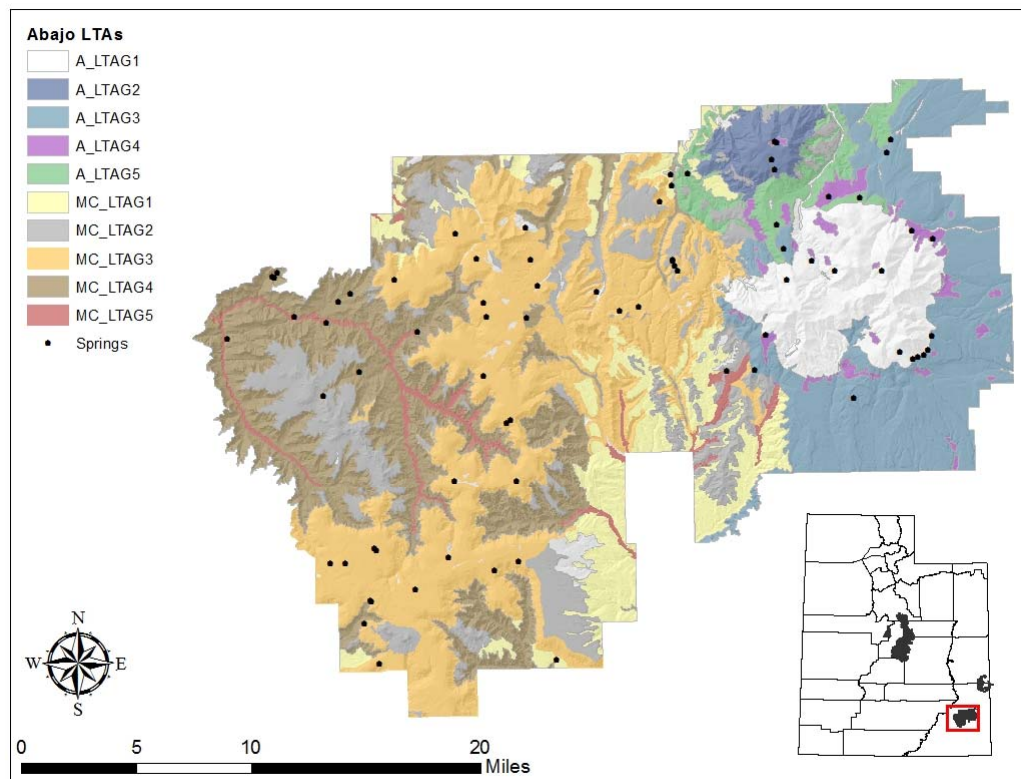


Figure 14—Location of springs in the Abajo Mountains, Mesa, and Canyon region. Data were taken from the NHD layer.

According to the USFS terrestrial condition assessment climate exposure indicator, changes in temperature and precipitation in the Abajo Mountains, Mesas, and Canyons are less extreme than other regions on the Forest (Cleland et al. 2017). Four of the 10 LTAs in this region are classified as in good condition in terms of winter temperature, while the rest are considered in poor condition. All LTAs in the Abajo Mountains are classified by the terrestrial condition assessment as being in good or very good condition in terms of changes in winter precipitation (Cleland et al. 2017). Average winter temperatures between 2010 and 2014 have increased by about 1 °F compared to the average winter temperature of the previous 115 years and winter precipitation has not decreased substantially (table 3). Due to the limited changes in temperature and precipitation to date, this region is likely somewhat more resistant to additional stressors. However, high densities of dams, roads, and mines and vegetation mortality from insects and disease have potentially impacted groundwater and surface water fluctuations in some LTAs. We determined three LTAs to be trending toward the NRV and two to be outside (fig. 15).

Channel and Bank Stability

The rangelands of the Abajo Mountains region have been heavily grazed by cattle since the late 1800s. Historically, abundant riparian shrubs and thick herbaceous layers with large root masses decreased erosion by stabilizing banks and dissipating stream energy. PFC reports identify construction of roads and removal of beavers as major influences on the stability of channels and banks in the Abajo Mountains. These and other stressors have altered

Table 3—Stream miles, stressors, and status of groundwater and surface water fluctuations in the Abajo Mountains, Mesas, and Canyons LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	Stream miles	Percent of stream miles perennial	Number of diversions	Number of dams	Deviation in winter temperature (°f)	Deviation in winter precipitation (%)	NRV status
A_LTAG1	104.3	17	89	2	1.37	-0.12	TT
A_LTAG2	31.8	0	2	0	0.90	-0.05	Within
A_LTAG3	283.8	5	94	32	1.30	-0.09	Outside
A_LTAG4	33.9	5	17	2	1.36	-0.11	Outside
A_LTAG5	64.8	5	2	5	1.12	-0.08	TT
MC_LTAG1	212.0	<1	8	3	0.96	-0.06	Within
MC_LTAG2	125.0	1	4	3	0.98	-0.06	Within
MC_LTAG3	294.2	2	17	12	1.10	-0.07	TT
MC_LTAG4	381.9	2	0	1	1.02	-0.06	Within
MC_LTAG5	88.7	1	13	0	0.84	-0.04	Within

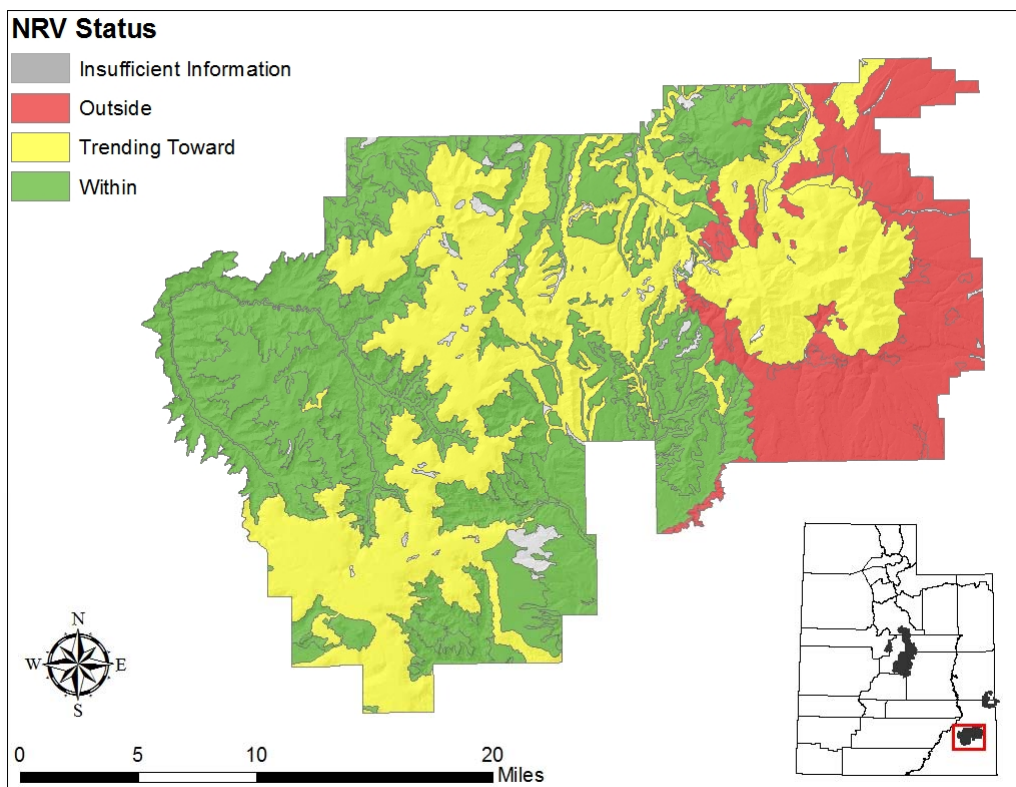


Figure15—NRV status of groundwater and surface water fluctuations in the Abajo Mountains, Mesas, and Canyons.

the closely adjusted balances between aggradation and degradation (Gregory 1938). Most functional reaches in the Abajo Mountains continue to have stabilizing plant communities and some are stabilized by rock banks. Beaver activity is noted in some locations and has benefited systems by reducing erosion and preventing downcutting. In the Abajo Mountains, sheep grazing was replaced by cattle grazing in the 1950s and 1960s, concentrating grazing pressure on riparian vegetation. Though grazing levels have been reduced, active grazing may inhibit recovery from past overgrazing and continue to degrade stream channels (USFS 2014). At the Abajo Mountains, Mesas, and Canyons, we determined that channel and bank stability was within its NRV at one LTA, which includes much of the Black Canyon Wilderness (table 4). Channel and bank stability was trending toward its NRV at two LTAs and the rest of the LTAs had insufficient information (fig. 16).

Floodplain Condition

Stream channel structure depends on geologic setting, elevation, stream size, gradient, width of the valley floor, and the number of intense rainstorms that occur in this area's drainages (Gregory 1938). Headwaters in this region originate from swampy meadows and talus at high elevations (Gregory 1938). As these streams drain the peaks, they create highly dissected landscapes with floodplains located deep in sandstone canyons. The laccolithic rocks of the Abajo Mountains are resistant to erosion and generate little sediment input to high-elevation streams (Graf 1987). Alluvial fans surround the Abajos to the south and east and stream channels tend to be more active and floodplains more complex in this setting (Scott et al.

Table 4—Floodplain and channel stressors, floodplain condition (FC) status, and channel and streambank stability (CBS) status of Abajo Mountains, Mesas, and Canyons LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	Percent in grazing allotment	Invasive acres in floodplain	Road miles	Percent road miles unimproved	Percent with high fuel loads	Percent burned with high severity	FC status	CBS status
A_LTAG1	69	0	23.7	94	7	<1	TT	TT
A_LTAG2	100	0	0.0	100	42	0	II	II
A_LTAG3	97	236.1	191.6	89	43	<1	TT	II
A_LTAG4	95	23.4	14.8	60	23	<1	TT	II
A_LTAG5	100	0	10.5	96	32	0.0	TT	II
MC_LTAG1	100	3.6	55.4	95	44	<1	TT	II
MC_LTAG2	99	3.7	82.1	97	35	1	Within	II
MC_LTAG3	100	6.7	255.3	94	31	1	TT	TT
MC_LTAG4	100	56.4	15.9	83	34	<1	TT	II
MC_LTAG5	100	83.0	14.6	97	43	0.0	TT	Within

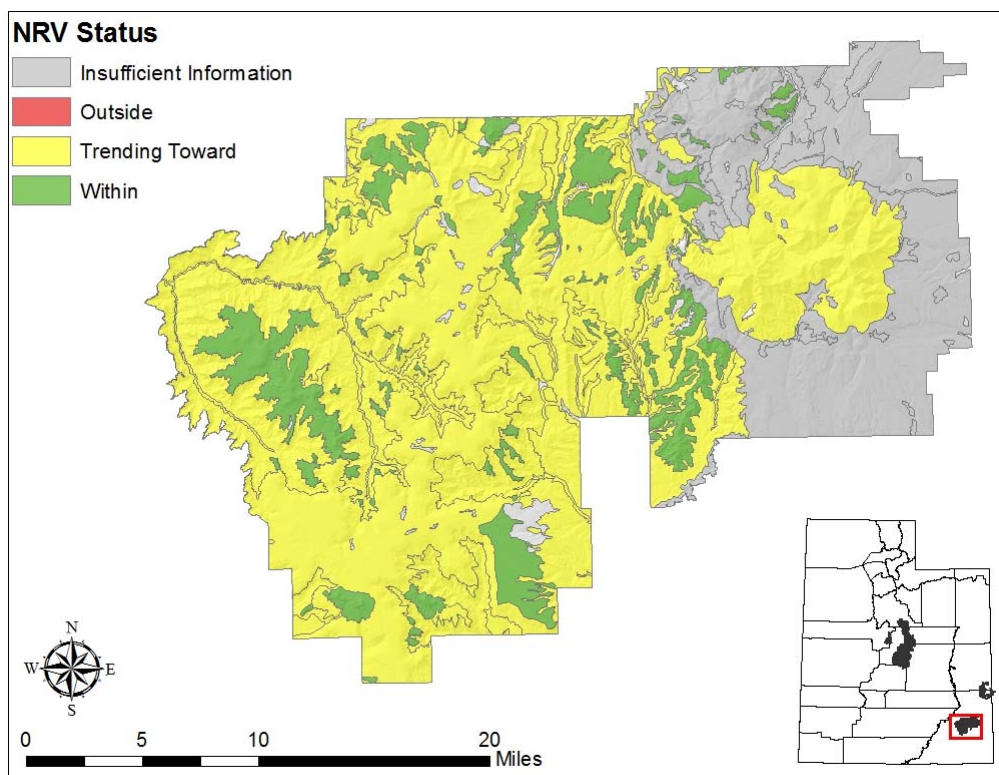


Figure 16—NRV status of channel and bank stability in the Abajo Mountains, Mesas, and Canyons.

2005). Materials including sand, silt, and clay in alluvial valleys are easily transported during spring runoff and summer thunderstorms, resulting in braided floodplains at low elevations (Scott et al. 2005). The development of floodplains and sediment dynamics can be limited by narrow canyon floors with little sediment storage capacity (Graf 1987). The flow paths of drainages, as well as sediment supply and depositional patterns, have been highly affected by fault geometry throughout the lower elevations of this region. Faulting has changed stream paths and gradients causing localized depositional patterns to develop (Trudgill 2002).

Historically, the Abajo Mountains had dense cover of grasses and forests that protected soils and decreased erosion (Gregory 1938). When settlers arrived in the 1880s, floodplains in this region were described as “canyons floored from wall to wall with level, fertile fields” with “clear streams flowing through willows and alders.” Streams were described as “clear cold mountain streams” that “rippled down through ravines overhung by groves of willow, maple, and quaking aspen, (*Populus tremuloides*) with splendid oaks and stately pines scattered over the uplands, and an abundance of rich, nutritious grass everywhere.” By the 1930s, the systems showed effects of land use change, particularly from grazing, as floodplains transitioned to “washes floored with sand moved about by ephemeral streams and bordered by flat-topped banks of alluvium” (Gregory 1938).

Channel and floodplain dynamism throughout the Abajo Mountains, Mesas, and Canyons can be limited or enhanced by the presence or absence of stabilizing vegetation, large woody debris, and beaver activity. The three ecological zones of this region are characterized by different vegetation that

changes with altitude and alters the inputs of woody debris (Witkind 1964). The lower-elevation Sonoran zone is composed of sagebrush flats, piñon pine, and juniper. The transition zone is identified by open grass valleys and trees that include aspen, willow, maple, alder, and cottonwood. These species commonly fall into streams and create more complex floodplains. The high altitude boreal zone is composed of spruce and fir forests that are an additional source of woody debris (Witkind 1964). Historically, beaver were present in the region and naturally engineered more complex channels (Gregory 1938). Channel and floodplain structure, as well as sediment dynamics, are especially sensitive in the Abajo Mountains, and reduced beaver populations contributed to far-reaching changes (Gregory 1938). Proper functioning condition reports completed by MLSNF staff note beaver activity in some locations and describe benefits to the system, including creation of diverse aquatic and terrestrial habitats.

Floodplains in the Abajo Mountains show impacts from a variety of stressors including dams and diversions, livestock grazing, wild ungulate browsing, roads, recreation, and altered temperature and precipitation regimes (table 4). The systems throughout this region are extremely sensitive to altered precipitation and the amount or type of plant cover (Gregory 1938). Furthermore, Gregory (1938) noted that construction of dams and irrigation ditches, beaver removal, and building of roads were linked to extensive changes to floodplain systems in the Abajo Mountains. Some systems have lost the balance between sediment and flow, resulting in sedimentation of many channels. Overgrazing is a well-documented disturbance in this unit and has generated major changes in the amount of sediment present in floodplains (Gregory 1938), as well as in channel geomorphology. Recreational issues include disturbance to floodplain vegetation resulting from off-road motorized vehicle use in the Dark Canyon Wilderness following washouts on the Peavine Corridor road (MLSNF 2013). The effects of these stressors are either localized or limited and we therefore determined that most LTAs are trending toward the NRV of floodplain condition and one is within the NRV (fig. 17).

La Sal Mountains and Borderlands

Distribution of Riparian Ecosystems

A variety of riparian ecosystems are found along the streams that radiate from the La Sal peaks. These ecosystems include herbaceous-dominated communities at high elevations with sedges and other graminoids as dominant/indicator species (fig. 18). Small mid-elevation streams support communities dominated by tall deciduous tree, low deciduous tree, willows, and herbaceous communities (table 5; fig. 19). Dominant taxa include aspen, gray alder, and graminoids including *Carex*. Mid-elevation canyons contain mixtures of coniferous tree-, willow- and non-willow shrub-dominated communities, which are often unmapped as riparian ecosystems, even along perennial streams (fig. 20). Streams at lower elevations in areas such as Beaver Creek Canyon and Roc Creek Canyon support extensive stands of deciduous tree-dominated communities with cottonwoods, boxelder, gray alder, and other woody species. The extent of riparian ecosystems in the La Sal Mountains and Borderlands is limited by diversions, spring

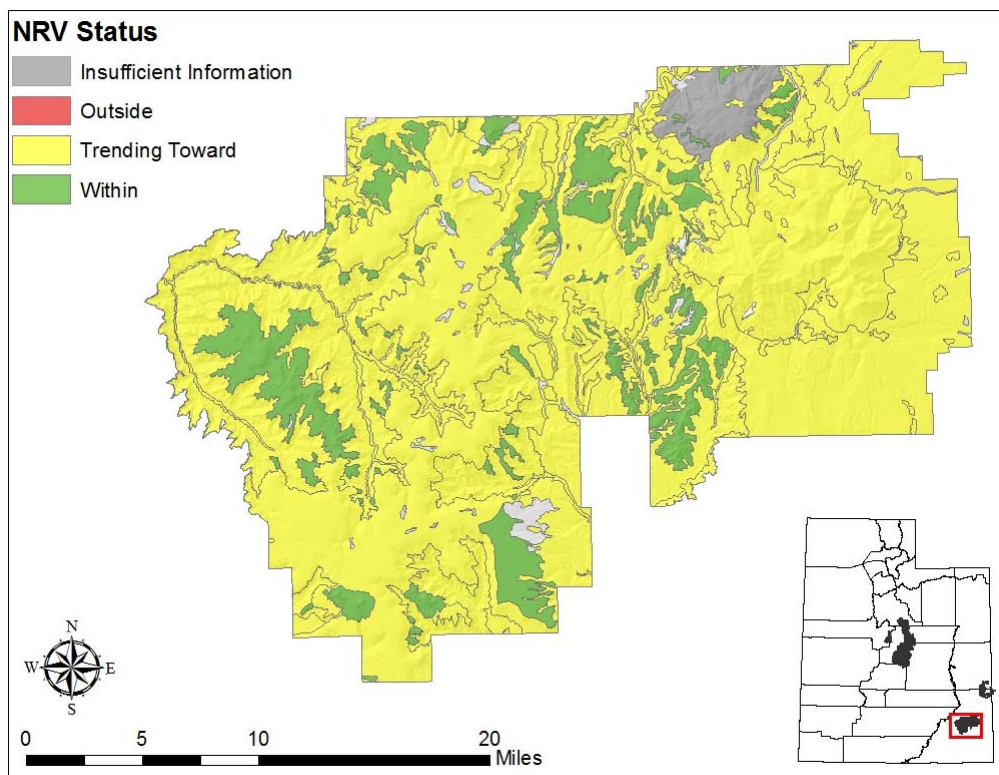


Figure 17—NRV status of floodplain condition in the Abajo Mountains, Mesas, and Canyons.

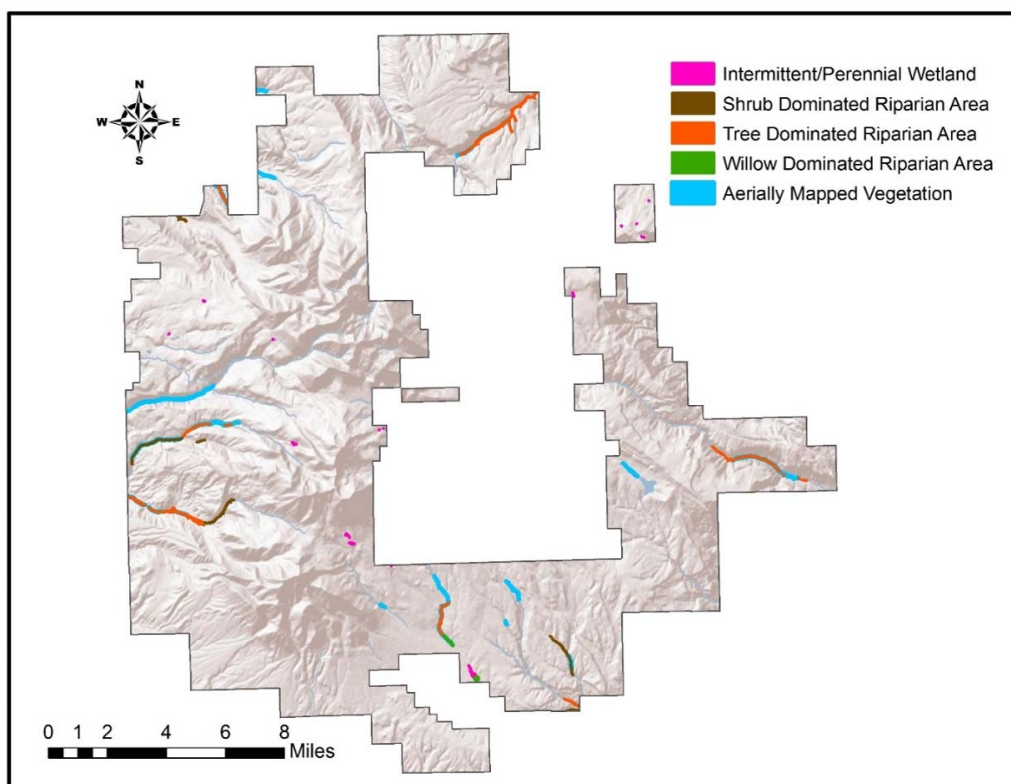


Figure 18—Distribution of field sampled and aerially mapped riparian vegetation in the La Sal Mountains and Borderlands.

Table 5—Area of aerially mapped riparian vegetation, area of field-sampled riparian vegetation types, and status of distribution of riparian ecosystems in the La Sal Mountains and Borderlands LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	LTA acres	Aerially mapped riparian acres	Floodplain field-sampled acres	Intermittent wetland acres	Perennial wetland acres	Shrub-dominated riparian acres	Tree-dominated riparian acres	Willow-dominated riparian acres	NRV status
LSM_LTAG1	15,097	0.2	2.8	0.1	0.2	2.6	0	0	Within
LSM_LTAG2	23,498	0	9.2	8.6	0.6	0	0	0	TT
LSM_LTAG3	8,901	0	0	0	0	0	0	0	II
LSMB_LTAG1	4,558	0	0	0	0	0	0	0	II
LSMB_LTAG2	28,124	15.6	13.5	1.1	0	12.4	0	0	TT
LSMB_LTAG3	9,959	47.2	40.2	0	0	17.4	22.9	0	Outside
LSMB_LTAG4	15,093	6.7	13.9	0	3.0	0	2.7	8.2	Outside
LSMB_LTAG5	7,206	10.4	13.0	0	0	0	13.0	0	Outside
LSMB_LTAG6	33,671	12.6	3.8	3.8	0	0	0	0	Within
LSMB_LTAG7	4,375	0	0	0	0	0	0	0	II
LSMB_LTAG8	13,067	92.9	94.6	0	0	14.7	79.8	0	Outside
LSMB_LTAG9	8,043	2.5	0	0	0	0	0	0	Within
LSMB_LTAG10	2,538	20.3	83.4	0	5.3	10.9	49.9	17.3	Outside



Figure 19—Low deciduous tree- and herbaceous-dominated riparian community types at Beaver Creek in the La Sal Mountains and Borderlands area. *Alnus incana* is the dominant woody species (photo by MLSNF).



Figure 20—Conifer-dominated riparian community types near Geyser Pass in the La Sal Mountains and Borderlands area (photo by D.M. Smith, USFS).

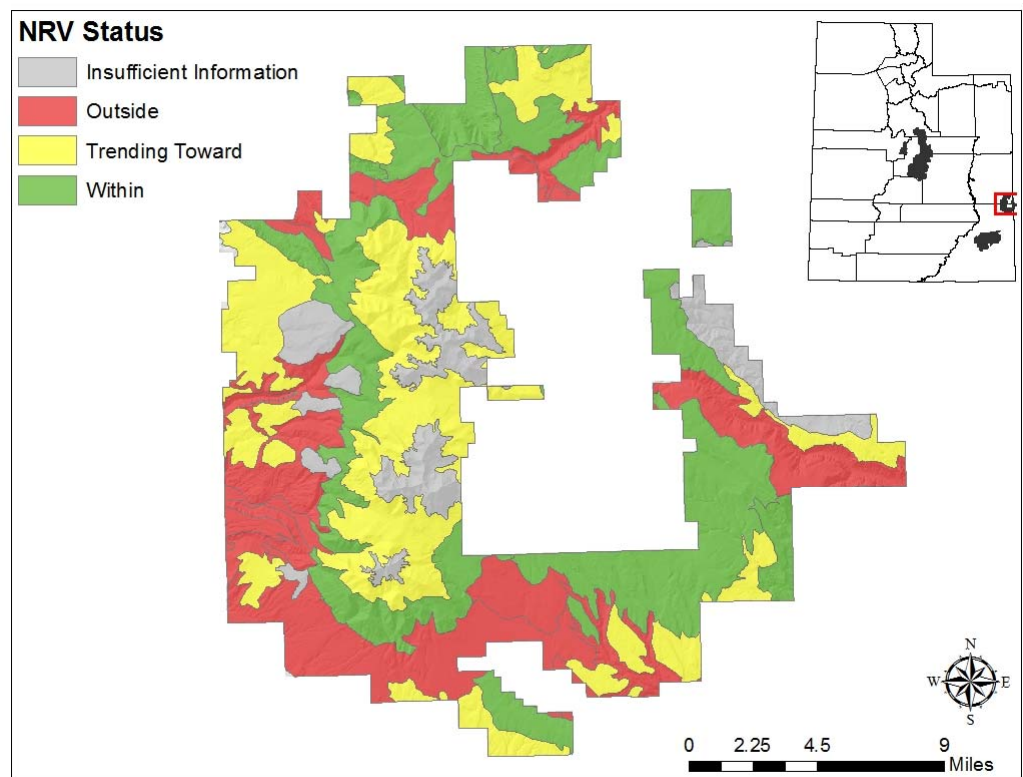


Figure 21—NRV status of riparian ecosystem distribution in the La Sal Mountains and Borderlands.

developments, and livestock grazing (MLSNF 2004). Status of this KEC was variable among the LTAs in this area, indicating the patchy nature of anthropogenic effects on riparian distribution (fig. 21).

Groundwater and Surface Water Fluctuations

In the high-elevation La Sal Mountains, groundwater and surface water fluctuations are primarily driven by geology and precipitation. Glaciation during the late Pleistocene shaped a landscape with high connectivity between surface and groundwater systems (Weir et al. 1983). Springs in the La Sals are an important source of discharge that enhances surface water flows (fig. 22; Weir et al. 1983). The sandstone mesas and canyons that make up the Borderlands surrounding the mountains tend to have markedly different hydrologic regimes from the high altitude LTAs. The watersheds of the lower elevations are topographically separated by geologic structures including collapsed anticlines, intrusives, and local bedrock uplands (Kolm and van der Heijde 2016; Weir et al. 1983). These geologic features disrupt hydrologic connectivity, creating discrete and localized groundwater systems, springs, and connections to surface water systems that are disconnected from adjacent watersheds (Kolm and van der Heijde 2016; Weir et al. 1983).

The climate of this region ranges from low-elevation arid lands with little recharge potential to humid high altitudes with excellent natural recharge potential from snowmelt and rain (Weir et al. 1983). Surface and groundwater fluctuations in the La Sal Mountains and surrounding Borderlands are driven by snowmelt and intense summer and autumn rainstorms that are typically limited in their areal extent (Kolm and van der

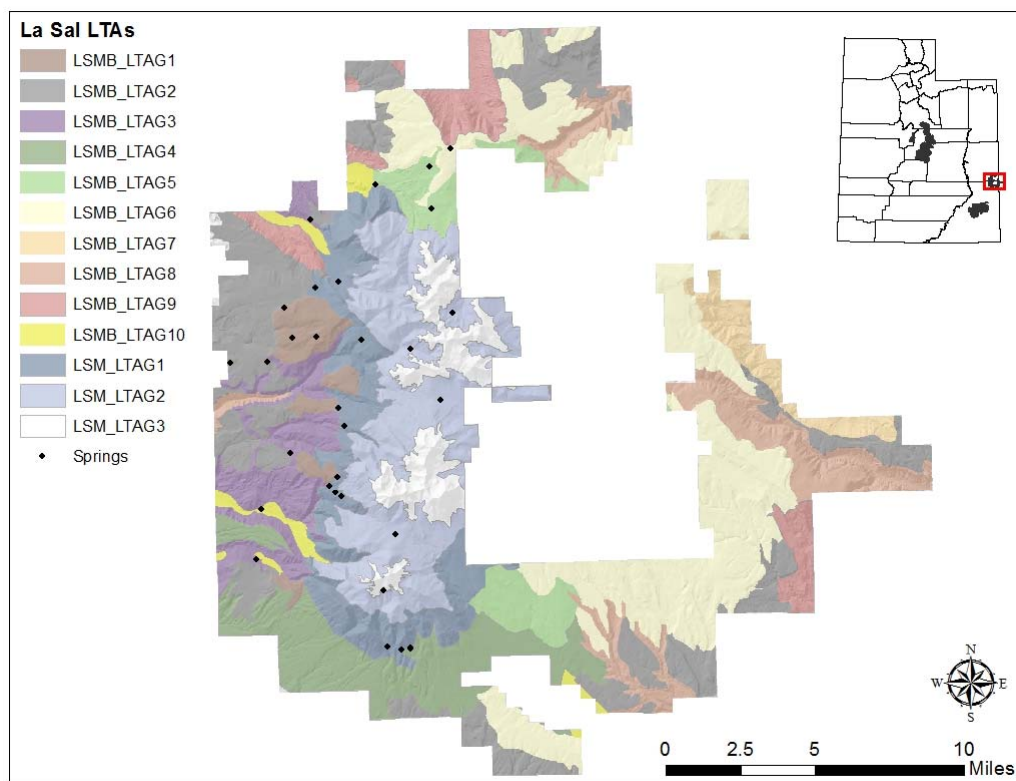


Figure 22—Location of springs in the La Sal Mountains and Borderlands. Data was taken from the NHD layer.

Heijde 2016). Hydrologic regimes in this region are also impacted by the presence of rock glaciers in some drainages. In rock-glaciated basins, flood peaks are delayed following precipitation and total surface runoff is greater when compared to unglaciated systems (Geiger et al. 2014).

Groundwater and surface water fluctuations in the La Sal Mountains region show impacts from a variety of stressors including installation of dams and diversions, construction of roads, timber harvest, wildfire, conifer encroachment, vegetation mortality from insects and disease, recreation, livestock grazing, and altered temperature and precipitation regimes. While many of these stressors are common across the Forest, some are particularly apparent in the La Sal region. An historic clearcut on State lands in the upland watersheds of some LTAs has contributed to degradation of downstream landscapes. Vegetation mortality due to insects and disease is especially prevalent in this region. Of all LTAs on the Forest, four in the La Sal region are ranked highest for percentage of land cover affected by vegetation mortality due to insect and disease.

The terrestrial condition assessment classified the La Sal Mountains and Borderlands as in moderate condition in terms of climate exposure (Cleland et al. 2017). All LTAs are classified as poor for increases in winter temperature and decreases in winter precipitation. The average winter temperature between 2010 and 2014 was 1.25 °F warmer than the average winter temperature of the previous 115 years and the average winter precipitation during the same time period has decreased by more than 0.35 inches (table 6). Disappearance of glaciers, including rock glaciers, has

Table 6—Stream miles, stressors, and status of groundwater and surface water fluctuations in the La Sal Mountains and Borderlands LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	Stream miles	Percent of stream miles perennial	Number of diversions	Number of dams	Deviation in winter temperature (°f)	Deviation in winter precipitation (%)	KEC status
LSMLTAG1	49.2	17	78	0	1.27	-0.37	Outside
LSMLTAG2	71.3	14	16	5	1.27	-0.37	Outside
LSMLTAG3	8.7	0	4	2	1.27	-0.37	Outside
LSMBLTAG1	10.0	0	4	1	1.27	-0.37	Outside
LSMBLTAG2	87.5	3	67	18	1.27	-0.37	Outside
LSMBLTAG3	46.0	17	16	1	1.27	-0.37	Outside
LSMBLTAG4	98.7	2	41	1	1.08	-0.28	Outside
LSMBLTAG5	29.0	11	72	3	1.27	-0.37	Outside
LSMBLTAG6	77.4	4	12	21	1.26	-0.37	Outside
LSMBLTAG7	11.3	0.0	0	0	1.27	-0.37	Outside
LSMBLTAG8	56.0	39	14	2	1.27	-0.37	Outside
LSMBLTAG9	32.7	10	2	7	1.20	-0.37	Outside
LSMBLTAG10	22.9	23	48	3	1.27	-0.37	Outside

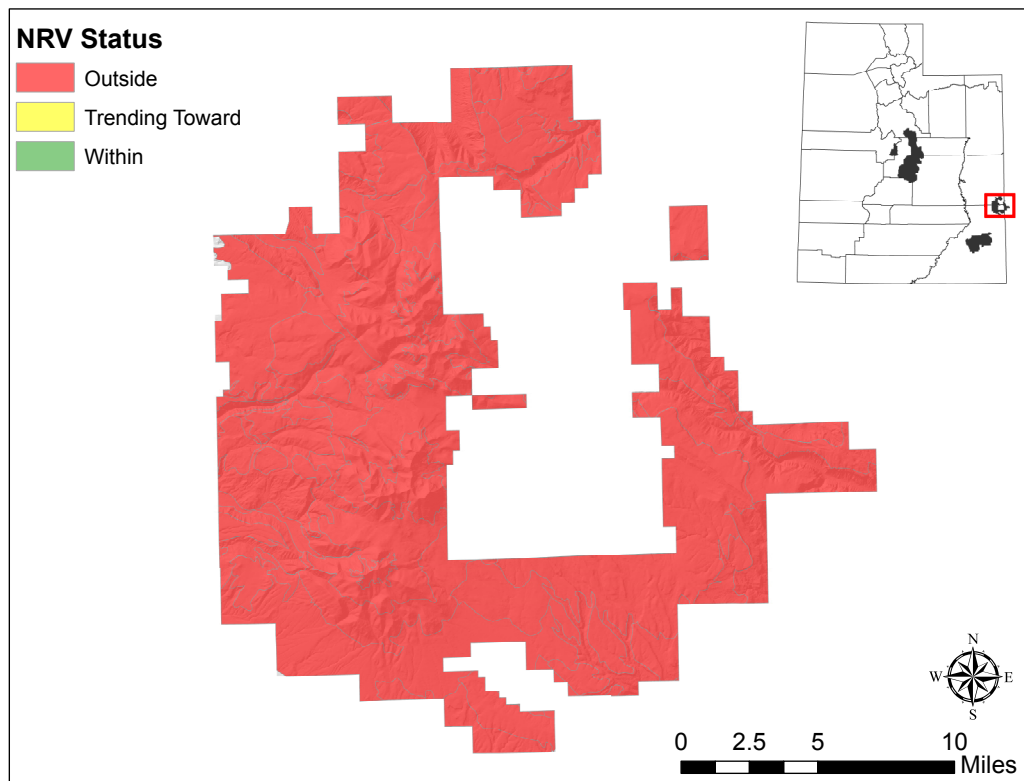


Figure 23—NRV status of groundwater and surface water fluctuations in the La Sal Mountains and Borderlands.

altered the amount of groundwater recharge and surface runoff as well as the timing of high and low flows (Geiger et al. 2014). Due to the cumulative impacts of altered temperature and precipitation regimes as well as multiple additional stressors, we found that all LTAs in this region are outside the NRV of groundwater and surface water fluctuations (fig. 23).

Channel and Bank Stability

Like the Abajo Mountains region, the rangelands in the La Sal Mountains and Borderlands have experienced heavy livestock grazing since the 1800s (Shamo 2014). This stressor has resulted in diminished vegetative cover, altered streambanks, and reduced channel stability (MLSNF 2001). These impacts have been mitigated through several proposed and implemented range improvement projects (Curtis-Tollestrup 2015). Plant communities with abundant riparian shrubs and thick herbaceous layers or rocks stabilize banks along most functional reaches. Channels have been further stabilized by beaver activity in some areas. Today, nearly all the La Sal Mountains and Borderlands contain cattle allotments (table 7; 1,166,000 acres). Although grazing levels have been reduced, continued active allotments may inhibit recovery from historic overgrazing and continue to degrade some stream channels (USFS 2014). The KEC was outside the NRV at two LTAs in this region, trending toward the NRV in two LTAs, and the rest had insufficient information to evaluate the status (fig. 24).

Table 7—Floodplain and channel stressors, floodplain condition (FC) status, and channel and streambank stability (CBS) status at La Sal Mountains and Borderlands LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	Percent in grazing allotment	Invasive acres in floodplain	Road miles	Percent road miles unimproved	Percent with high fuel loads	Percent burned with high severity	FC status	CBS status
LSMLTAG1	98	5.8	24.1	42	19	1	TT	TT
LSMLTAG2	83	24.8	26.8	76	5	<1	TT	II
LSMLTAG3	68	0	0.5	100	2	0.0	II	II
LSMBLTAG1	100	0	13.6	55	46	0.0	II	II
LSMBLTAG2	96	0	99.8	87	58	3	TT	II
LSMBLTAG3	98	0.9	26.4	78	40	0.0	TT	II
LSMBLTAG4	93	3.2	45.4	86	49	0.0	Outside	Outside
LSMBLTAG5	81	1.5	18.4	54	49	0.0	Outside	TT
LSMBLTAG6	97	59.0	124.2	86	55	8	Outside	Outside
LSMBLTAG7	100	0	4.8	100	52	<1	II	II
LSMBLTAG8	100	2.0	20.5	100	51	3	TT	II
LSMBLTAG9	100	0	11.4	86	52	8	TT	II
LSMBLTAG10	71	0.7	13.6	71	51	<1	TT	II

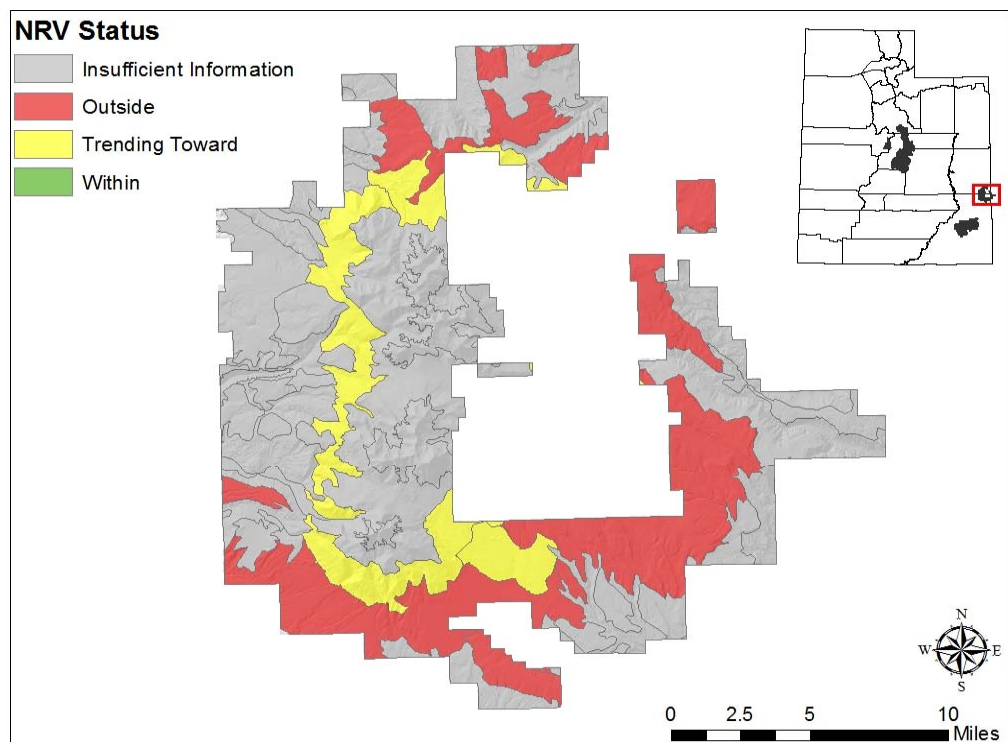


Figure 24—NRV status of channel and bank stability in the La Sal Mountains and Borderlands.

Floodplain Condition

Floodplain dynamics of the La Sal Mountains and Borderlands are driven by diverse geologic settings, ranging from high altitude bedrock outcrops to highly eroded sandstone mesas (Kolm and van der Heijde 2016; Weir et al. 1983). Channel dynamics in parts of the high elevations may be limited by colluvium or bedrock controls. In these areas, floodplains are naturally narrow, discontinuous, or non-existent (Scott et al. 2005). In bedrock valleys, transport of sediment exceeds supply and alluvial material is transported downstream and deposited in lower-elevation LTAs. At lower altitudes in glacial moraine and alluvial fans, channels are more active and floodplains tend to be more complex (Scott et al. 2005). Streams in the lower elevations that cut through shale and bank erosion are more prevalent (Kolm and van der Heijde 2016; Scott et al. 2005). The lowest reaches flow through valleys of alluvial material that is easily transported during spring runoff and intense summer rainstorms. These reaches experience high sediment loads, typically composed of sand, silt, and clay (Scott et al. 2005). The floodplains of the lowest elevation LTAs are typically composed of low bars and active channels are usually braided (Scott et al. 2005).

The development of complex channels in this region can be controlled by climate, stabilizing vegetation, presence of large woody debris, and the size of valley bottoms. During cool and wet periods, valleys are filled by deposition of alluvial sediments (Scott et al. 2005). Periods of deposition

followed by dry climates result in channels incising into the alluvial deposits, generally abandoning the previously constructed floodplain (Scott et al. 2005). In unconfined reaches, cut and fill alluviation generate diverse habitat patches across the floodplains of this region resulting in a mosaic of fluvial surfaces and vegetation stands with varying age and composition (Scott et al. 2005). Vegetation provides a source of large woody debris that contributes to complex channels throughout this region and vegetation stabilized stream banks that decrease erosion. In more confined, narrow valleys, sediment transport tends to be greater than supply, which can result in less complex floodplains. Historically infrequent, large-magnitude flooding widened stream channels and disturbed river systems. These events were followed by decades of channel narrowing and establishment of riparian vegetation across the newly created geomorphic template (Scott et al. 2005).

The floodplains of the La Sal Mountains and Borderlands have been altered from their condition prior to Euro-American settlement by many stressors including livestock grazing, dams and diversions, construction of roads, beaver removal, recreation, timber harvest, and wildfire (table 7). Although data were not available for the section of the Forest in Colorado, dams and diversions appear to be extensive throughout the unit, particularly at lower elevations. There are many examples of roads that follow stream beds and cross floodplains throughout the La Sal Mountains. Historically, beavers were present and they continue to persist at lower numbers throughout the region (Müller-Schwarze and Sun 2003). An historic clearcut on State lands in the upland watersheds of some La Sal Mountains and Borderlands has increased sedimentation and likely altered the timing and magnitude of surface runoff that drives floodplain dynamics. Historic low severity wildfires were natural disturbances to the La Sal Mountains, but recent large, high severity wildfires that burned entire watersheds may have had major influences on flooding and sedimentation (Doerr et al. 2006; Ice et al. 2004). Because of numerous stressors, we determined that floodplain dynamics were outside of the NRV at three LTAs and trending toward the NRV at seven LTAs (fig. 25).

San Pitch Mountains

Distribution of Riparian Ecosystems

Perennial and intermittent streams with riparian vegetation are relatively limited in the San Pitch Mountains (fig. 26). The lower portions of several perennial streams are diverted, which has likely decreased the extent of riparian ecosystems (Kuehn 1984). Deciduous tree-dominated riparian systems are scattered among canyons on the east and west side of the mountains where perennial and intermittent flows occur (fig. 27). Dominant riparian canopy species include narrowleaf cottonwood, aspen, and bigtooth maple. Upland species, including conifers, gambel oak, and curl-leaf mountain mahogany (*Cercocarpus ledifolius*), dominate the canopy in some sections (table 8). Incised streams contain willow- and herbaceous-dominated communities in gully bottoms (fig. 28). Dominant/indicator taxa include coyote willow (*Salix exigua*) and graminoids. Following heavy flooding in 1983, willows, cottonwoods, and other woody species were planted along the upper portions of streams in this region (Schoppe 1985). We determined

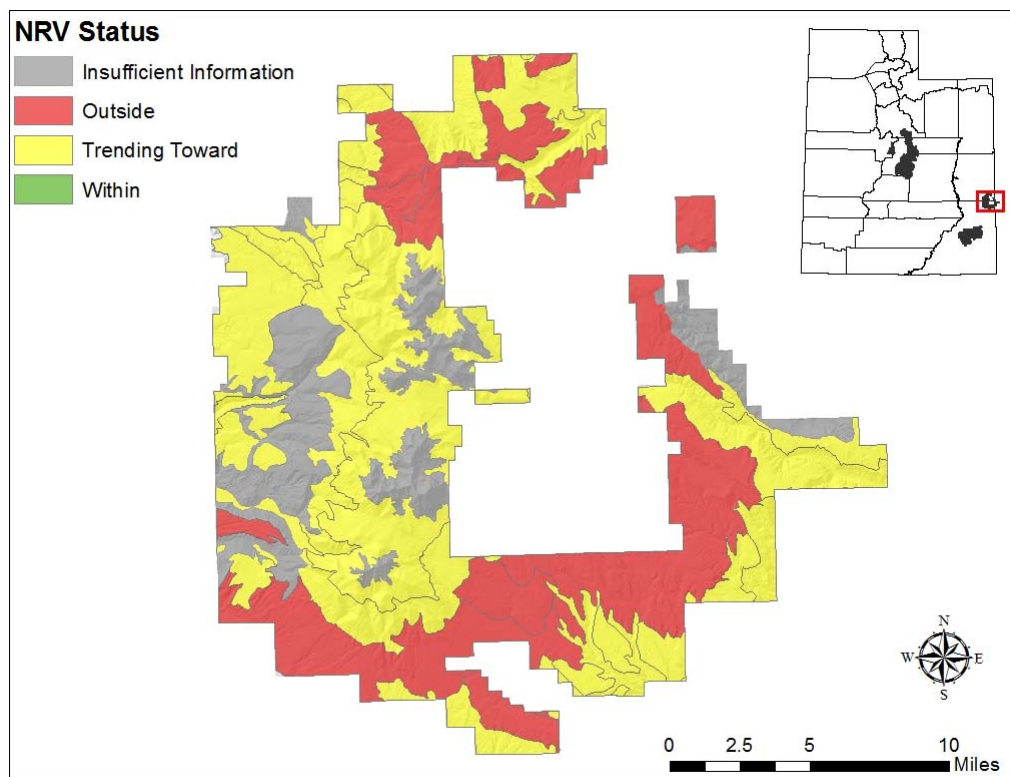


Figure 25—NRV status of floodplain condition in the La Sal Mountains and Borderlands.

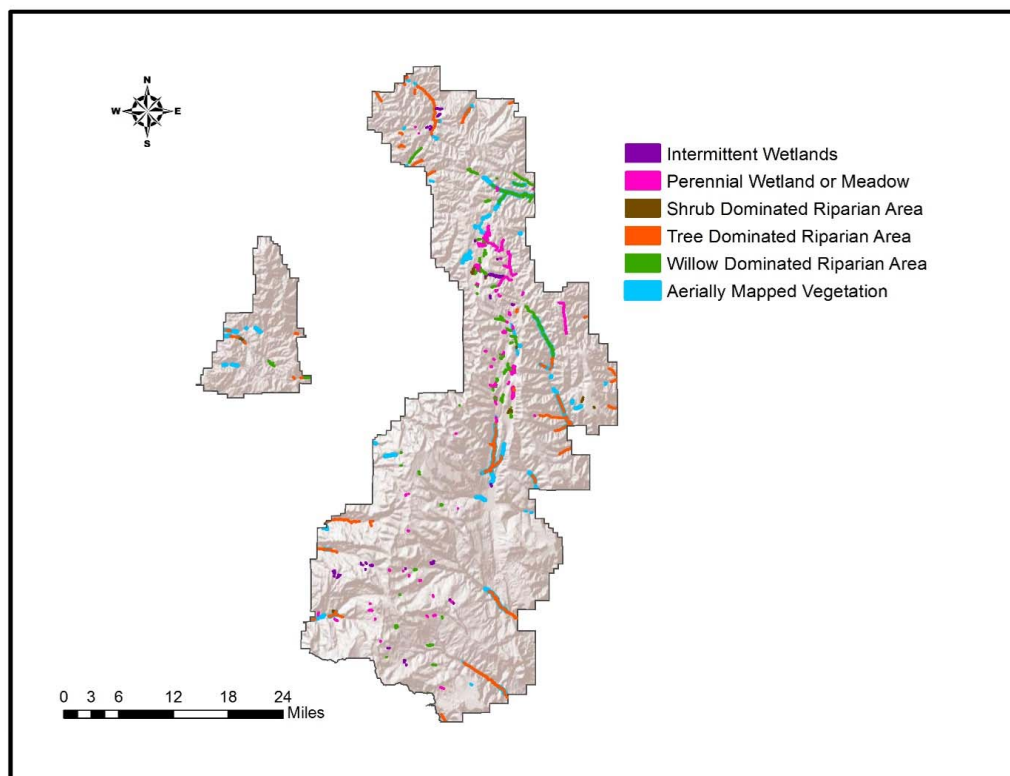


Figure 26—Distribution of field-sampled and aerially mapped riparian vegetation in the San Pitch Mountains and Wasatch Plateau.



Figure 27—Tall deciduous tree-dominated riparian community types along Pigeon Creek within the San Pitch Mountains area. *Populus angustifolia* is the dominant tree species (photo by D.M. Smith, USFS).



Figure 28—Willow- and herbaceous-dominated riparian community types in incised channel at Wales Canyon within the San Pitch Mountains area. Riparian communities are dominated by *Salix exigua* and graminoids (photo by D.M. Smith, USFS).

Table 8—Area of aerially mapped riparian vegetation, area of field-sampled riparian vegetation types, and status of distribution of riparian ecosystems in San Pitch Mountains LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	LTA acres	Aerially mapped riparian acres	Floodplain field-sampled acres	Intermittent wetland acres	Perennial wetland acres	Shrub-dominated riparian acres	Tree-dominated riparian acres	Willow-dominated riparian acres	NRV status
SP_LTAG1	9,409	24.4	23.6	0	0	5.8	17.8	0	Outside
SP_LTAG2	12,155	7.2	3.0	0	0	0.02	2.9	0	TT
SP_LTAG3	16,530	7.4	5.8	0	0	0	0	5.8	TT
SP_LTAG4	22,995	0	12.7	0	0	0	0	12.7	TT
SP_LTAG5	10,620	0	4.9	0	0	0	4.9	0	TT
SP_LTAG6	2,842	0	13.7	0	0	0	8.3	5.5	TT

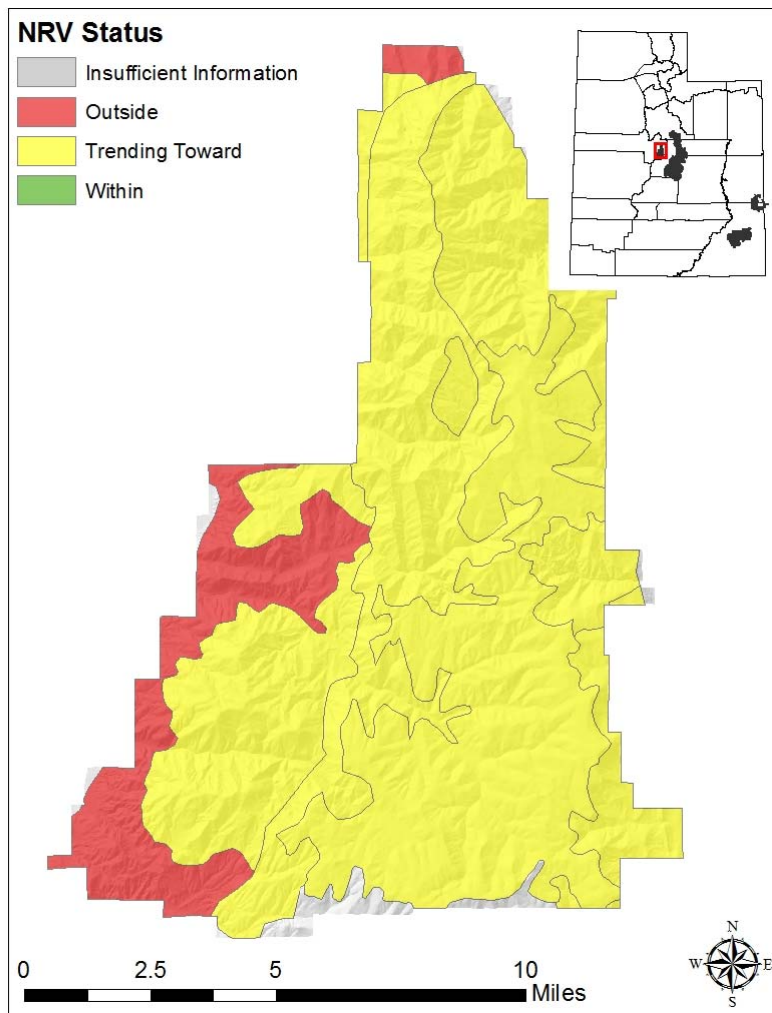


Figure 29—NRV status of riparian ecosystem distribution in the San Pitch Mountains.

that distribution of riparian ecosystems is trending toward its NRV in five of the six LTAs in the San Pitch Mountains (fig. 29). This KEC is outside the NRV at an LTA on the western front where several streams are diverted for irrigation and municipal use (Kuehn 1984; MLSNF 2004).

Groundwater and Surface Water Fluctuations

Fluctuations in ground and surface water throughout the San Pitch Mountains are driven by climate and geology. Annual fluctuations in water levels in this region are closely tied to annual precipitation, with regular high flows and infiltration occurring during snowmelt runoff in the spring and declining flows in channels and from springs throughout the rest of the year (Wilberg and Heilweil 1995). Most of the snow that accumulates in the mountains over the winter reaches lower elevations in the form of runoff from snowmelt or as discharge from springs along the mountainsides (Bjorkland and Robinson 1968). Monitoring of wells shows that groundwater fluctuations closely follow climatic cycles and that long-term trends in water levels have remained fairly constant since the USGS began monitoring wells in 1935 (Wilberg and Heilweil 1995).

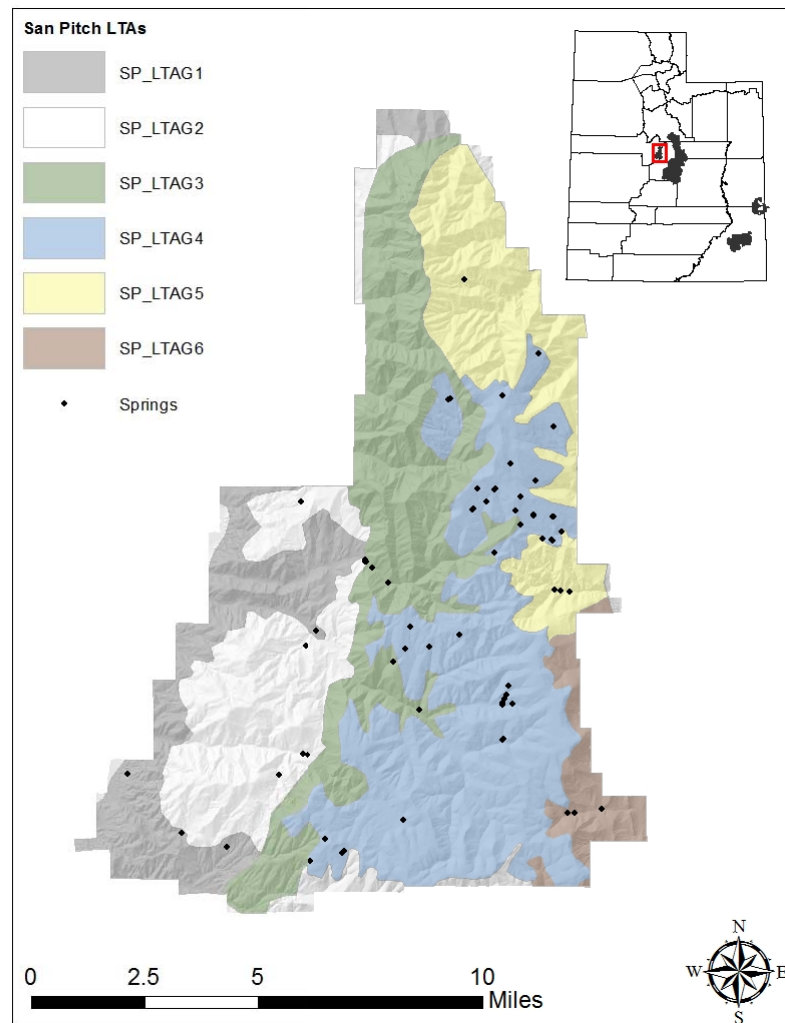


Figure 30—Location of springs in the San Pitch Mountains. Data were taken from the NHD layer.

The complex geology of the San Pitch Mountains influences infiltration, flow routes, and discharge of groundwater to surface water systems. The major formations include the Indianola, the Colton, and Arapien Shale. Water that drains to basins on either side of the San Pitch Mountains typically falls as snow or rain in the high elevations; on the western front, it seeps into the Indianola Formation and migrates along the southeastward-dipping rocks (Robinson 1971). The Indianola Group is moderate to highly permeable in sandstone units and along fractures and joints. It is through this formation that most groundwater is recharged and it yields large amounts of water to springs and creeks in several drainages (Robinson 1971; Wilberg and Heilweil 1995). Several large springs, including Big Springs, discharge from the Indianola Group at points of contact between it and Arapien Shale (Bjorkland and Robinson 1968; Robinson 1971). These points occur in the Fourmile, Pigeon, Chicken, Deep, Little Salt, and Criss drainages (fig. 30). Average discharges from these springs range from 200 to 900 gallons per minute, making them an important source of flow, particularly during base flow season (Bjorkland and Robinson 1968).

Temperature and precipitation regimes of the San Pitch Mountains region have shifted in the last 10 years compared to the past century (Cleland et al. 2017), but the alterations are limited. The terrestrial condition assessment classified all LTAs as in good condition for climate exposure, with every San Pitch LTA considered in moderate condition in terms of changes in winter temperature and in very good condition for changes in winter precipitation. Average winter temperatures between 2010 and 2014 have increased by less than 1°F compared to the average winter temperature of the previous 115 years and winter precipitation during the same time period has increased by 0.56 inches (table 9). Additional stressors in this region include dams, diversions, high severity burns, roads, insect and disease, and mining. However, these forces are very limited in their effects. The density of dams and diversions are the lowest across the Forest, which is also true for density of roads and the percentage of land affected by vegetation mortality from insects and disease. The San Pitch Mountains have experienced more high severity burns than any other region, but they still only affect about 4 percent of the landscape. Lastly, this region has the lowest density of mines on the MLSNF. With the limited effects of stressors, all but one LTA are listed as within the NRV (fig. 31).

Channel and Bank Stability

Channel and bank stability in the San Pitch Mountains has been impacted by long-term livestock grazing, floods, debris flows, and other stressors (table 10; Kuehn 1984). Streambank stabilization projects and grazing exclosures have been implemented to improve stream conditions (Kuehn 1984; Schoppe 1985). We did not assess this KEC for this geographic unit because field data were unavailable.

Floodplain Condition

Floodplain dynamics in this area show impacts from a variety of stressors that include diversions and wells, wildfires, roads, mines, and altered temperature and precipitation regimes (table 10). Much of the surface water runoff in this region is diverted and used for irrigation in lowland valleys, reducing the ability of streams to transport sediment and connect to their floodplains. Some LTAs in this region have experienced large amounts of high severity burns and this region is especially vulnerable to postfire flooding due to intense localized summer thunderstorms (Robinson 1971). Overgrazing has severely impacted streams across the Forest, including the San Pitch Mountains. Historic descriptions of the area noted that hills were rich with grasses and that the range became barren with the introduction of sheep (Christensen and Johnson 1964). Despite the presence of these stressors, effects to riparian areas appear to be light or recovered. We determined that floodplain condition is within the NRV at one LTA and trending toward the NRV at the others (fig. 32).

Wasatch Plateau

Distribution of Riparian Ecosystems

The Wasatch Plateau, the largest of the Forest's geographic units, has a correspondingly large variety and area of riparian ecosystems (table 11; fig. 26). Riparian community types in the central plateau are primarily willow-

Table 9—Stream miles, stressors, and status of groundwater and surface water fluctuations in the San Pitch Mountains LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	Stream miles	Percent of stream miles perennial	Number of diversions	Number of dams	Deviation in winter temperature (°f)	Deviation in winter precipitation (%)	KEC status
SP_LTAG1	104.3	17	24	1	1.01	0.28	TT
SP_LTAG2	31.8	0	18	0	0.96	0.63	Within
SP_LTAG3	283.8	5	10	0	0.96	0.63	Within
SP_LTAG4	33.9	5	4	0	0.96	0.63	Within
SP_LTAG5	64.8	5	5	0	0.66	0.57	Within
SP_LTAG6	212.0	<1	16	0	0.96	0.63	Within

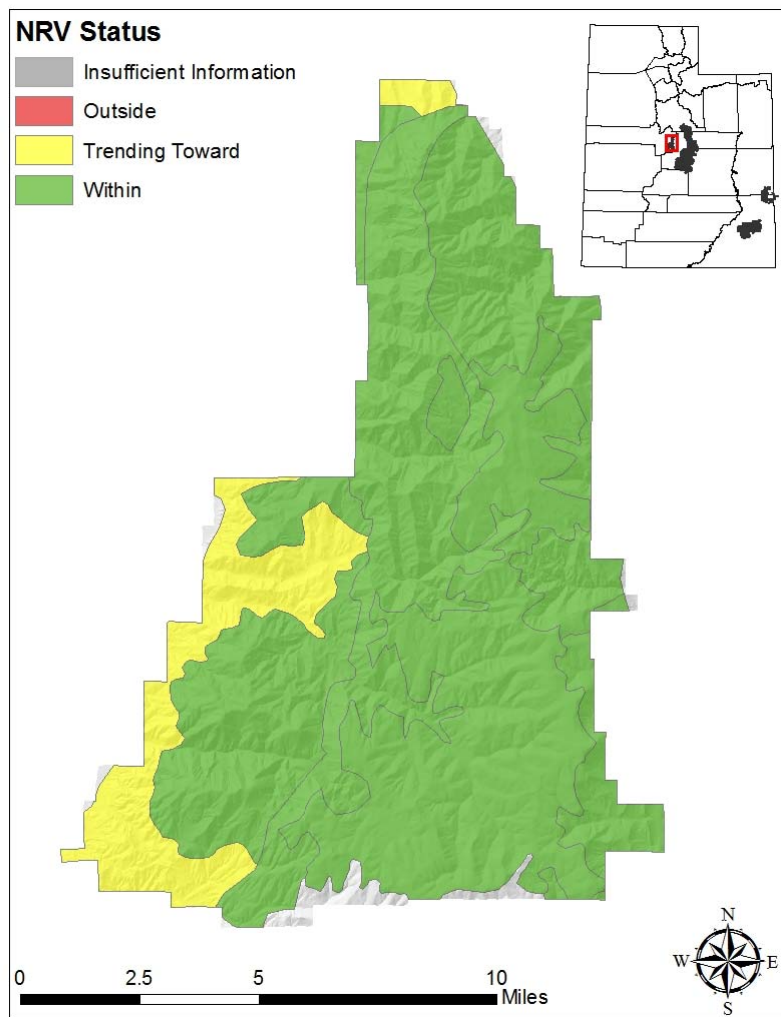


Figure 31—NRV status of groundwater and surface water fluctuations in the San Pitch Mountains.

and herbaceous-dominated, with some coniferous tree-, tall deciduous tree-, and low deciduous tree-dominated types present as well (fig. 33). Coniferous tree-, tall deciduous tree-, low deciduous tree, and willow-dominated types are located along streams and in canyons draining the western front, eastern escarpment, and north end (fig. 34). Anthropogenic effects on streams are numerous and varied (PREC 2016; SRCD 2016). Based on our R-CAT analysis (Appendix A), we determined that LTAs in the north end of the plateau are within the NRV of riparian ecosystem distribution, but LTAs of the central plateau, Wasatch Monocline, and eastern escarpment are either within, trending toward, or outside the NRV (fig. 35). Likely causes of departure include diversions, reservoirs, spring developments, and long-term effects of livestock grazing (MLSNF 2006).

Groundwater and Surface Water Fluctuations

Surface and groundwater fluctuations in the Wasatch Plateau are driven by geology and climate. The highlands, particularly those on the east side of the plateau, are mostly composed of sedimentary geologic units, the weathering of which has created rugged mountainous terrain dissected by

Table 10—Floodplain and channel stressors, floodplain condition (FC) status, and channel and streambank stability (CBS) status at San Pitch Mountains LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	Percent in grazing allotment	Invasive acres in floodplain	Road miles	Percent road miles unimproved	Percent with high fuel loads	Percent burned with high severity	FC status	CBS status
SP_LTAG1	99	0.8	14.0	49	83	6	TT	II
SP_LTAG2	100	0	11.5	71	74	15	TT	II
SP_LTAG3	100	0.9	9.3	100	55	1	TT	II
SP_LTAG4	99	7.0	65.0	100	60	0.0	TT	II
SP_LTAG5	100	1.8	10.3	88	53	1	Within	II
SP_LTAG6	66	21.1	3.1	100	84	0.0	TT	II

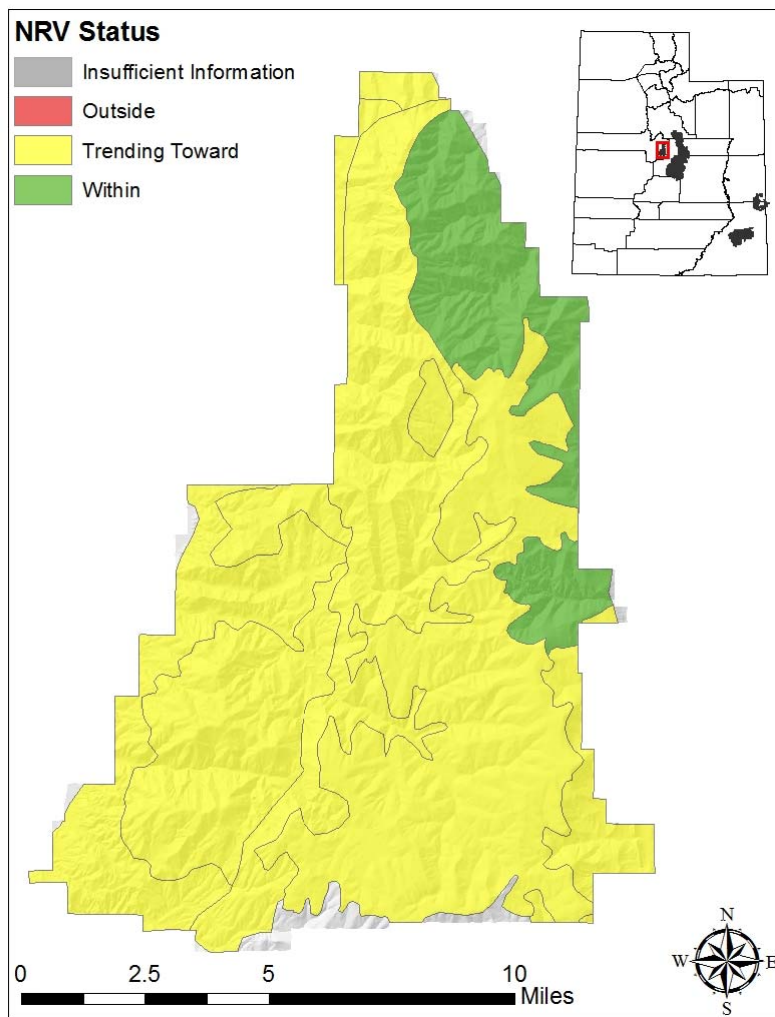


Figure 32—NRV status of floodplain condition in the San Pitch Mountains.

deep canyons (Danielson and Sylla 1983). The beginning of the lowlands are marked by outcrops of Mancos shale that appear along streams several miles upstream from the mouths of most canyons (Waddell et al. 1981). The shales found in these formations are typically easily erodible and have low permeability (Waddell et al. 1981). The North Horn Formation and Flagstaff limestone feature fractures and solution openings with high hydraulic diffusivity, making these the sources of most groundwater discharge (Waddell et al. 1986).

The climate of the Wasatch Plateau ranges from semiarid to subhumid, with precipitation generally increasing with altitude. Snowmelt in spring and early summer provides the primary input of water to surface and groundwater systems in the area (Danielson and Sylla 1983). In this region, 5 to 29 percent of precipitation within a drainage basin becomes streamflow, with most of the remaining water lost to evapotranspiration and only a small percentage recharging to groundwater (Danielson and Sylla 1983). The recharge capacity of drainages varies based on water content of snow, exposure, surface relief, and rock permeability. For example, because shale beds are impermeable and their salts limit plant growth, precipitation tends to run off directly to streams and infiltration is limited in shale dominated drainages (Danielson

Table 11—Area of aerially mapped riparian vegetation, area of field-sampled riparian vegetation types, and status of distribution of riparian ecosystems in the Wasatch Plateau LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	LTA acres	Aerially mapped riparian acres	Floodplain field-sampled acres	Intermittent wetland acres	Perennial wetland acres	Shrub-dominated riparian acres	Tree-dominated riparian acres	Willow-dominated riparian acres	NRV status
MSL_LTAG1	13,223	0	26.1	0	0	0	26.1	0	Within
WP_LTAG1	28,884	74.7	121.0	0	6.6	1.2	112.5	0.6	Outside
WP_LTAG2	207,359	58.0	89.0	19.9	15.2	0	3.5	50.5	Within
WP_LTAG3	31,716	5.4	30.5	30.5	0	0	0	0	Within
WP_LTAG4	41,910	3.5	12.6	0	6.3	0	0	6.3	Outside
WP_LTAG5	40,925	0	51.5	13.2	12.8	0	0	25.4	Within
WP_LTAG6	47,993	6.0	4.5	2.5	1.9	0	0	0.2	TT
WP_LTAG7	34,443	1.9	18.4	0	0	0	0	18.4	TT
WP_LTAG8	29,361	83.0	719.6	5.3	284.0	76.8	39.2	314.4	TT
WP_LTAG9	38,156	404.0	213.7	5.1	0	0	208.6	0	Outside
WP_LTAG10	74,891	215.7	516.6	82.9	168.9	3.1	0.6	261.1	Within
WP_LTAG11	78,531	137.3	145.6	0	3.1	0	95.7	44.5	Within
WP_LTAG12	14,571	66.1	42.1	0	0	0	42.0	0.14	Outside
WP_LTAG13	45,169	103.0	104.3	0	0	0	0	104.3	TT
WP_LTAG14	16,644	8.1	21.7	0	0	0	21.7	0	Within
WP_LTAG15	27,464	106.3	86.8	3.4	0.1	0	70.2	13.1	Within
WP_LTAG16	16,437	90.9	74.0	10.2	0.1	0	56.5	0	Within

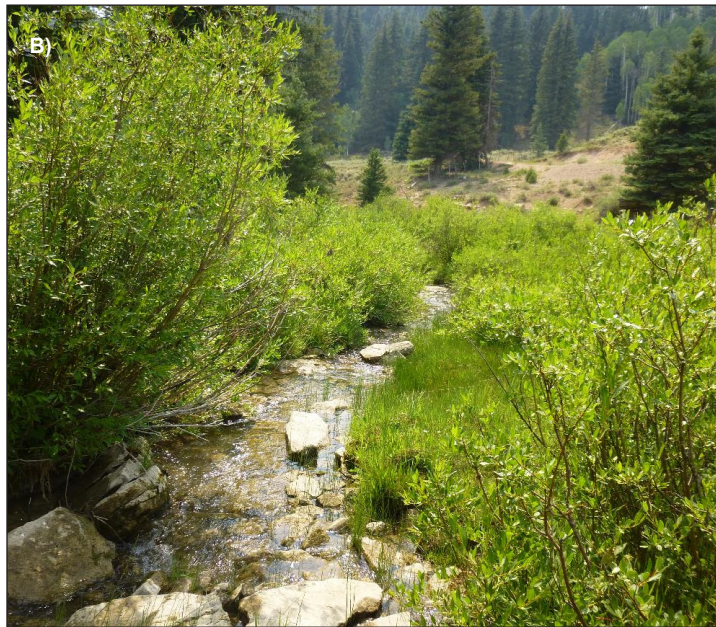


Figure 33—The riparian community types of the Wasatch Plateau include willow- and herbaceous-dominated riparian community (A) fed by springs and small streams in the Scad Valley, (B) on upper Indian Creek, and (C) tall deciduous tree-dominated riparian community type along Indian Creek. *Populus angustifolia* is the dominant deciduous species (photos by D.M. Smith, USFS).



Figure 34—(A) Beaver dam and willow-dominated riparian community type at Huntington Creek within the eastern escarpment of the Wasatch Plateau. Riparian communities are dominated by *Salix boothii* and graminoids. Uplands were burned by the Seeley Fire of 2012 (photo by D.M. Smith). (B) Willow- and herbaceous-dominated riparian communities along Lower Gooseberry Creek on the north end of the Wasatch Plateau. Dominant species include *Salix boothii*, *Juncus balticus*, and *Phleum pretense* (photo by MLSNF).

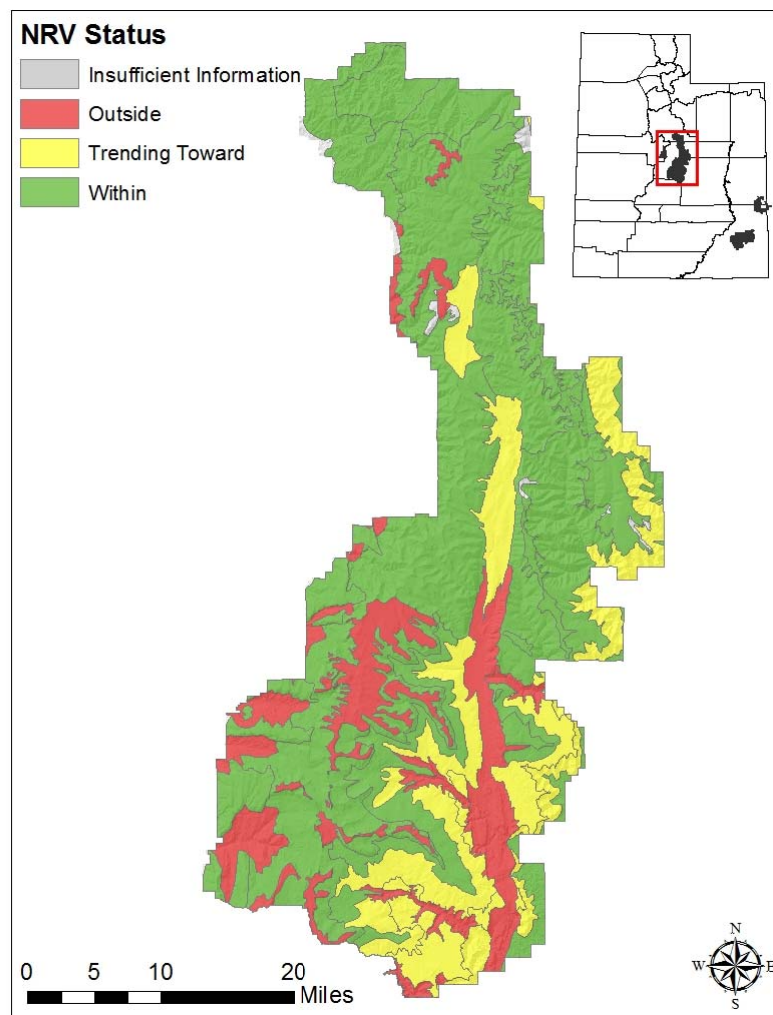


Figure 35—NRV status of riparian ecosystem distribution in the Wasatch Plateau.

and Sylla 1983; Waddell et al. 1981). Recharge potential is greater where Flagstaff limestone is present because its fractures and solution openings provide storage for large volumes of groundwater (Danielson and Sylla 1983). Locations like the tops of North Horn and Ferron Mountains have low surface relief, which slows snowmelt runoff and allows more water to infiltrate groundwater systems. Likewise, in places like South Horn Mountain, solar radiation and wind decrease the amount of groundwater recharge despite the flat land surface (Danielson and Sylla 1983).

Groundwater moves from areas of infiltration at higher altitudes through a system of flow paths generally associated with faulting (Waddell et al. 1986) to locations of natural and humanmade discharge (Danielson and Sylla 1983). The majority of groundwater discharge originates where Flagstaff limestone meets the North Horn Formations (fig. 36; Danielson and Sylla 1983; Waddell et al. 1986). Rapid responses of natural groundwater discharge to changes in recharge indicate that water moves quickly through these groundwater systems. Fractures and solution openings in limestone fill with snowmelt each spring and release this water through springs at a decreasing rate throughout the year (Danielson and Sylla 1983). These springs, as well as seeps in valley walls, maintain base flows in streams

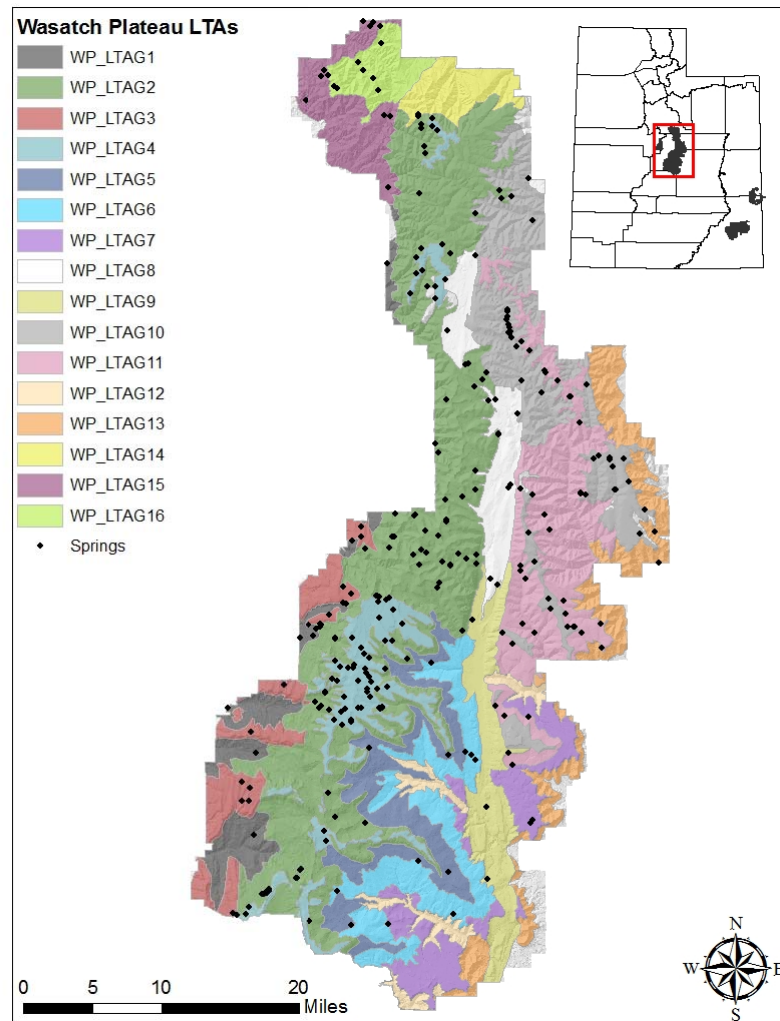


Figure 36—Location of springs in the Wasatch Plateau. Data were taken from the NHD layer.

during the drier months (Waddell et al. 1986), discharging 0 to 1,080 gallons per minute (Waddell et al. 1981). In surface water systems, 50 to 70 percent of streamflow occurs from May to July from melting snow (Waddell et al. 1981). There are additional hydrologic connections between surface and groundwater systems, with evidence of gaining and losing reaches that cross the Blackhawk Formation (Danielson and Sylla 1983).

Decades of intense grazing and the following restorative efforts have transformed the landscapes, floodplains, stream channels, and sediment sources of the Wasatch Plateau. Studies show that heavy grazing in this region led watersheds to transition from fairly stable landscapes to serious flood sources (Meeuwig 1960). Hall (2001) argues that today's plateau is rehabilitated but not restored and that more work is required to counteract the negative impacts of overgrazing.

There is an extensive network of dams and diversions in the Wasatch Plateau and several large reservoirs (table 12). The effects of these structures on groundwater and surface water fluctuations have been documented in the Huntington Creek system (Winget 1984). In this drainage, the construction of

Table 12—Stream miles, stressors, and status of groundwater and surface water fluctuations in the Wasatch Plateau LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	Stream miles	Percent of stream miles perennial	Number of diversions	Number of dams	Deviation in winter temperature (°F)	Deviation in winter precipitation (%)	KEC status
MSL_LTAG1	125.0	1	26	2	1.17	-0.25	TT
WP_LTAG1	294.2	2	180	10	1.18	-0.06	TT
WP_LTAG2	381.9	2	1121	43	1.52	-0.36	Outside
WP_LTAG3	88.7	1	19	16	1.34	-0.18	Outside
WP_LTAG4	49.2	17	317	9	1.55	-0.39	Outside
WP_LTAG5	71.3	14	372	19	1.58	-0.45	Outside
WP_LTAG6	8.7	0	288	27	1.58	-0.45	Outside
WP_LTAG7	10.0	0	155	36	1.58	-0.45	Outside
WP_LTAG8	87.5	3	408	14	1.56	-0.42	Outside
WP_LTAG9	46.0	17	203	9	1.42	-0.37	Outside
WP_LTAG10	98.7	2	876	27	1.58	-0.45	Outside
WP_LTAG11	29.0	11	557	27	1.58	-0.45	Outside
WP_LTAG12	77.4	4	73	8	1.58	-0.45	Outside
WP_LTAG13	11.3	0	162	14	1.27	-0.29	TT
WP_LTAG14	56.0	39	36	2	1.54	-0.37	Outside
WP_LTAG15	32.7	10	118	5	1.39	-0.20	Outside
WP_LTAG16	22.9	23	48	1	1.60	-0.40	Outside

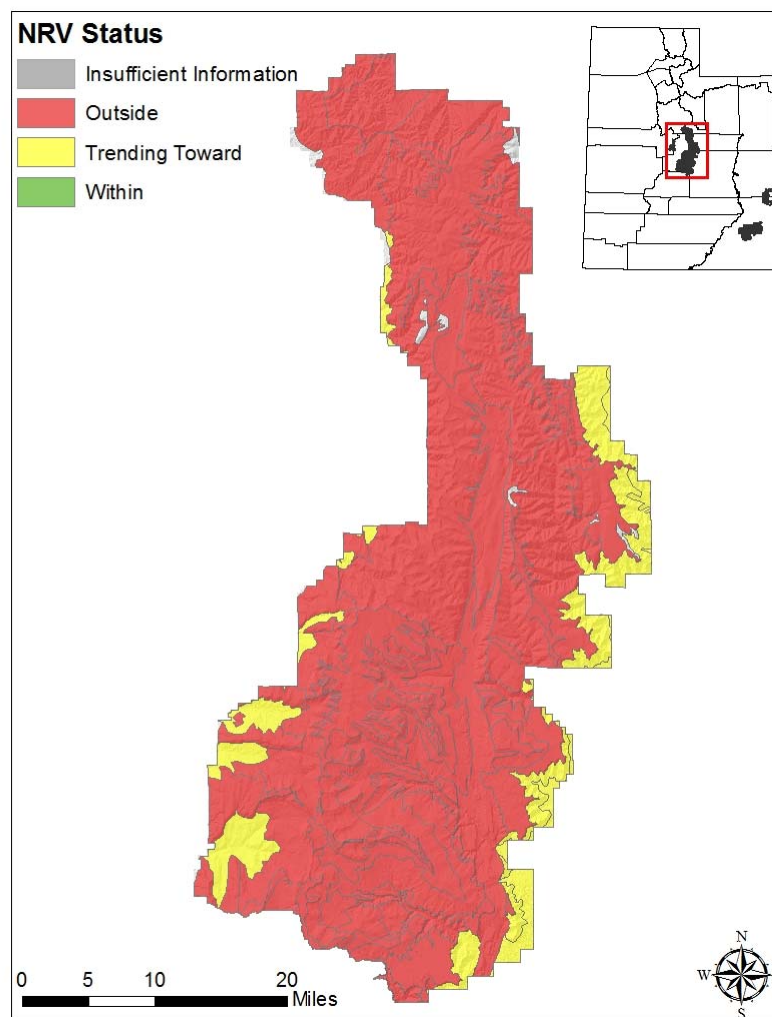


Figure 37—NRV status of groundwater and surface water fluctuations in the Wasatch Plateau.

the Electric Lake Dam led to a change in the Huntington River flow regime from a snowmelt dominated runoff to a regulated flow pattern, with the timing of peak flow changing from spring to late summer (Winget 1984).

The temperature and precipitation regimes of the last 10 years have substantially changed from the past century. According to the TCA, the average winter temperature between 2010 and 2014 has increased by 1.47 °F compared to the average winter temperature of the previous 115 years and the average winter precipitation during the same timeframe has decreased by more than 0.35 inches. The terrestrial condition assessment concluded all but one LTA in the Wasatch Plateau are in poor or very poor condition in terms of increases in winter temperatures (Cleland et al. 2017). Additionally, the majority of the plateau, including the north end, the eastern escarpment, and the central plateau are classified as being in poor condition for percent change in winter precipitation (Cleland et al. 2017). With the large changes in precipitation and temperature regimes in this region and multiple additional stressors, groundwater and surface water fluctuations in all LTAs are trending toward or outside the NRV (fig. 37). This region may require more specific planning to mitigate the effects of future changes in climate on natural flow regimes.

Channel and Bank Stability

The Wasatch Plateau has been grazed by cattle and sheep for over 150 years (Shamo 2015). Though unchecked sheep grazing resulted in significant impacts to watersheds during the late 19th and early 20th centuries (MLSNF 1998), current effects of cattle on riparian areas are generally greater (USFS 2014). The cumulative effects of wild ungulate and domestic livestock grazing may inhibit the recovery of channel structures that were degraded by overgrazing. Other effects on channels and banks include legacies of watershed damage, extensive roads, and heavy recreation use (table 13; MLSNF 1998). In some areas, underground coal mining has impacted channel morphology and sediment dynamics in various ways. Coal mining has also been associated with localized debris slides and rockfalls in the Wasatch Plateau. These events have resulted in the deposition of sediment, boulders, and trees in streams (Slaughter et al. 1995). Despite these stressors, indications of channel and bank stability were greater at the Wasatch Plateau LTAs than those in the South Zone. We determined that channel and bank stability was within the NRV at four LTAs and trending toward the NRV at one LTA (fig. 38).

Floodplain Condition

Floodplain dynamics in the Wasatch Plateau are driven by geologic setting and natural flow regimes. Geologic setting varies from east to west across the highland, but channel gradients of most major drainages are steep (Danielson and Sylla 1983), limiting floodplain development. The western escarpment is steeper than the eastern side of the Wasatch Plateau, resulting in faster drops in the western canyons and the water that drains them (Hall 2001). Many of the streams, particularly those on the east side of the plateau, flow in deep canyons with high gradients (Speiker and Billings 1940). The beginning of the lowlands in the Wasatch Plateau are marked by outcrops of Mancos shale, which have a pronounced effect on the topography and landscape of floodplains and stream channels because they easily erode, limit plant growth, and have low permeability that causes precipitation to run off directly into streams (Waddell et al. 1981). The drainage system of the Wasatch Plateau is generally dendritic, with some notable effects from faulting. In addition to faults, glaciation during the late Pleistocene plays a role in the drainage patterns of the western valleys. The large, broad valleys carved by glaciers have hardly been modified by stream erosion. These landscapes are slightly notched by post-glacial streams and the channels are notably influenced by the configuration of moraines (Speiker and Billings 1940).

Sediment yields depend on geologic setting and range from 0.1 to 3 acre feet per square mile per year in the Wasatch Plateau region (Waddell et al. 1981). The high yields typically occur in the predominantly shale and sandstone lowlands. Lower yields are observed in the higher altitudes where exposed rocks are mostly limestone and dolomite (Waddell et al. 1981). The composition of stream substrates changes with altitude, increasing in clay content as elevation decreases (Waddell et al. 1981). Infrequent and intense storms result in the largest sediment yields (Waddell et al. 1981).

Table 13—Floodplain and channel stressors, floodplain condition (FC) status, and channel and streambank stability (CBS) status at Wasatch Plateau LTAs. Statuses are Within = within the NRV, TT = trending towards the NRV, Outside = outside of the NRV, and II = insufficient information.

LTA	Percent in grazing allotment	Invasive acres in floodplain	Road miles	Percent road miles unimproved	Percent with high fuel loads	Percent burned with high severity	FC status	CBS status
MSL_LTAG1	84	92.3	10.8	89	27	1	TT	II
WP_LTAG1	99	4.5	65.2	69	41	1	Outside	II
WP_LTAG2	99	20.0	280.1	75	17	<1	Outside	Within
WP_LTAG3	100	1.7	94.9	100	32	1	Outside	II
WP_LTAG4	100	2.2	149.8	72	10	0.0	TT	Within
WP_LTAG5	100	7.4	90.4	82	23	1	TT	Within
WP_LTAG6	99	0.1	45.1	81	18	<1	TT	II
WP_LTAG7	99	0.01	91.8	99	22	0.0	TT	II
WP_LTAG8	80	165.3	77.0	53	10	0.0	Outside	Within
WP_LTAG9	93	63.7	55.2	46	32	0.0	Outside	II
WP_LTAG10	88	101.6	104.0	80	24	6	Outside	TT
WP_LTAG11	98	52.6	112.5	58	26	7	TT	II
WP_LTAG12	96	51.9	9.3	20	34	<1	TT	II
WP_LTAG13	82	14.1	14.2	73	19	12	TT	II
WP_LTAG14	100	24.1	7.6	54	57	0.0	TT	II
WP_LTAG15	100	147.8	25.8	74	66	2	TT	II
WP_LTAG16	98	70.2	12.3	72	58	2	TT	II

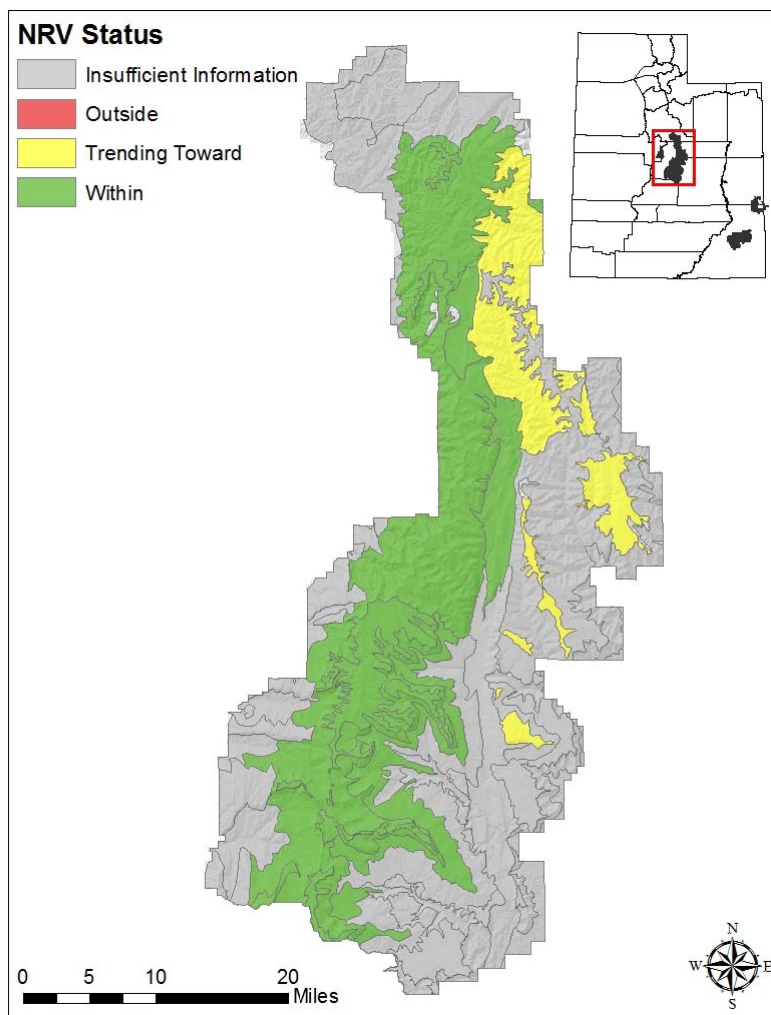


Figure 38—NRV status of channel and bank stability in the Wasatch Plateau.

Land instability and flooding are well documented in the Wasatch Plateau with landslides, debris avalanches, and mudflows common on the North Horn formation (Kilbourne 2016). Soil erodibility is moderate to high, with typically very fine sandy loam to silty clay and loam soils at the surface. An abundance of steep slopes and the occurrence of intense summer thunderstorms results in high erosion potentials, especially when vegetation is removed (Kilbourne 2016).

Floodplain dynamics have been altered from their NRV by a variety of stressors including livestock grazing, dams and diversions, installation of reservoirs, construction of roads, coal mining, recreation, timber harvest, and wildfire. Long-term grazing at high intensities and efforts to restore watersheds have had lasting impacts on the floodplains, channels, and sediment sources of this region. While watershed conditions in the Wasatch Plateau have improved since the early 1900s with management and grazing exclusion, studies have concluded that grazing exclusion alone had not satisfactorily reduced erosion or flooding and restoration was needed to establish stable states (Meeuwig 1960; Stevens 2002). More recently, Prevedel et al. (2003) concluded that much of the watersheds in high-

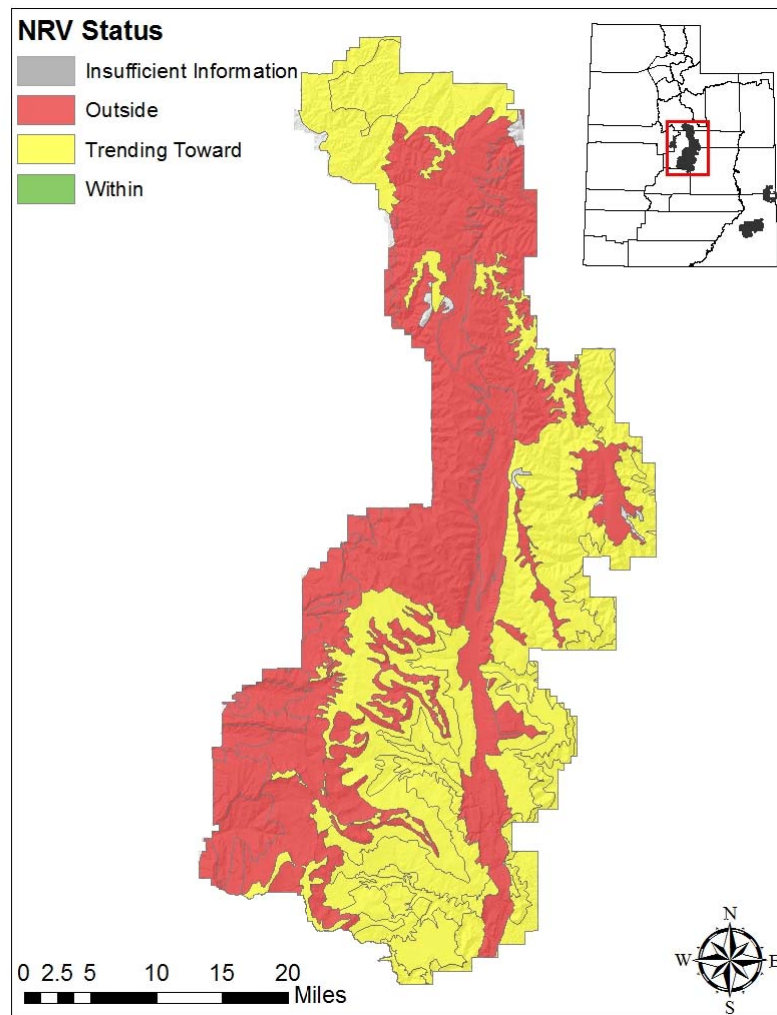


Figure 39—NRV status of floodplain condition in the Wasatch Plateau.

elevation areas of the Wasatch Plateau continue to experience active erosion due to poor condition. In addition to grazing, the observed impacts of coal mining in the Wasatch Plateau have included altered channel morphology. Sidle et al. (1998) described larger substrate, longer cascades and runs, and larger and more frequent pool habitats. The results of these stressors are that six LTAs in this region are functioning outside the NRV and 11 are trending toward their NRV (fig. 39).

SUMMARY

We measured riparian ecosystem integrity and sustainability at the scales of geographic units and LTAs by identifying KECs and evaluating their NRV. We found that conditions and stressors vary among these spatial units. This is not an unexpected result, given the considerable spatial variation in physical and ecological processes within the MLSNF. All areas have been heavily modified since Euro-American settlement, but the nature of these changes is variable. In general, riparian KECs in the Abajo Mountains, Mesas, and Canyons were functioning within the NRV more often than other geographic units. Conversely, KECs were most outside the NRV in the La Sal Mountains and Borderlands. Overall departure was intermediate in the geographic units of the North Zone.

Through literature review and data analysis, we identified several issues affecting riparian ecosystems at various scales in the National Forest. Watershed-scale effects influenced the delivery of water, sediment, wood, and other materials into channels and floodplains. Extreme watershed changes began in the late 19th century as a result of uncontrolled grazing, particularly on the Wasatch Plateau. Watershed conditions have improved with well-documented, intensive restoration and long-term alteration of grazing management. However, lingering effects such as erosion, poor watershed conditions, and loss of riparian vegetation have continued to the present day (MLSNF 2014; Prevedel et al. 2005).

In addition to historic overgrazing, watershed dynamics have been potentially altered by less frequent and unnaturally severe wildfires, vegetation mortality due to insect and disease, and timber harvest. These stressors also affect sediment input into channels and floodplains. Changes in wildfire regimes were notable at the San Pitch Mountains, where fuel loads were high and wildfires burned with unnatural severity. In the La Sal Mountains, clearcuts on State land have affected channel and floodplain dynamics on several cutthroat trout (*Oncorhynchus clarkii*) streams. While the NRV status of vegetation mortality due to insect and disease is beyond the scope of our assessment, there are areas across the MLSNF with substantial vegetation mortality that can influence the KECs considered in this report, particularly groundwater and surface water fluctuations. Management options exist to address watershed health, but effects of current grazing practices and climate change may complicate these efforts.

Floodplain dynamics include interactions between stream channels, soils, and riparian vegetation. These relationships have been disturbed by a variety of stressors including grazing, roads, recreational activities, invasive species, and encroaching species. Our assessment results indicated floodplains are especially impacted at the La Sal Mountains and Wasatch Plateau. Given the

widespread effects of stressors such as roads and invasive species, floodplain restoration efforts must be prioritized at locations critical to persistence of cutthroat trout and other species of concern.

Water developments have been established for agricultural and municipal use in each geographic unit. Each geographic unit contained a complicated network of dams, diversions, and spring developments. These features have changed the volume and timing of stream flows, resulting in changes to composition or elimination of riparian vegetation. Diversions, dams, and reservoirs were especially numerous in the Wasatch Plateau, altering groundwater and surface water fluctuations. Despite these changes, riparian ecosystems were functioning within their NRV at several LTAs. Changes in water management may be necessary to improve function at other LTAs in the area.

In addition to diversions, surface and groundwater flows have been affected by mining operations. The largest impacts have been documented in the Wasatch Plateau, where subsurface coal mining has been a major driver of the local economy (Sidle et al. 2000). Impacts from water development can be mitigated through management activities such as managed flows and increases in water use efficiency. Projected reductions in snowpack will likely exacerbate effects of diversions on aquatic and riparian ecosystems.

Livestock grazing has occurred on the National Forest for over 150 years and will continue as part of the Forest's directives to provide a sustained yield and support local communities (Shamo 2014; USFS 2014). Grazing management (controlling intensity, duration, and timing of use) can prevent damage to riparian ecosystems. Recent evaluations of desired conditions suggested that effects of cattle grazing are strongest on streams in the La Sal Mountains and Borderlands. Trends were upward or slightly upward at most greenline transects in the area in 2016, indicating that current guidelines and practices were improving conditions. In the Abajo Mountains, Mesas, and Canyons and Wasatch Plateau areas, effects of historic overgrazing may require restoration and recovery at the watershed scale, but current grazing practices were not having as large an effect on stream stability, as evidenced by the many greenline transects rated as stable in 2016.

We recommend additional monitoring of greenline transects and the addition of transects in areas throughout the Forest where riparian vegetation is associated with perennial and intermittent streams. Forest-wide information on the effects of current grazing practices will be critical to management of aquatic and riparian ecosystems in response to changes in hydrology, land cover, and human use in the coming decades.

- Riparian ecosystems associated with perennial streams are typically priorities for research because of their importance as native fish habitat. Intermittent streams, however, can support riparian vegetation and provide forage for wildlife including elk and sage-grouse (Stromberg and Merritt 2016). Identification and analysis of intermittent streams is needed to measure departure of riparian vegetation from natural conditions.

Data Gaps

- Many riparian ecosystems are dominated by coniferous species but contain groundwater-dependent shrubs and herbaceous plants. Distribution and extent of these ecosystems are difficult to map because riparian vegetation is often obscured by upland plant species (Salo et al. 2016). Composition and condition are poorly documented as well.
- Channel and bank stability is critical to protection of habitat for cutthroat trout and other aquatic species. These variables, however, are unmeasured at many, if not most streams in the MLSNF. Sources of such information, such as PFC reports, are unavailable for most of the North Zone.
- Few data exist evaluating low-elevation riparian forests at locations such as Indian Creek in the Abajo Mountains and Beaver Creek Canyon in the La Sal Mountains. These forests provide critical habitat for numerous wildlife species but are vulnerable to stressors such as flow modification, invasive plants, and wildfire (Smith and Finch 2014, 2016).
- We used points of diversion and spring distribution data compiled by the State of Utah. Additional data from Colorado are needed to fully evaluate groundwater and surface water fluctuations for the La Sal Mountains and Borderlands.
- The Manti-La Sal invasive species layer overestimates acreage of nonnative plants (Tina Marion, MLSNF, personal communication) and should be improved to better represent floodplain conditions.
- Recovery of beaver populations is not documented for much of the Forest. Data on the potential distribution of beaver dams is available (Macfarlane et al. 2017), but site visits are needed to confirm presence and absence.

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Appendix A—LTA Summaries: Distribution of Riparian Ecosystems

Abajo Mountains

A_LTAG1 - Igneous Mountains

Riparian vegetation was associated with perennial and intermittent streams draining the ridges and peaks of this LTA. Field-sampled riparian vegetation included perennial wetland, tree-dominated, and willow-dominated communities along the lower portions of Indian Creek, Spring Creek, and Johnson Creek. Riparian vegetation was also aerially mapped near Mount Linnaeus at the southeastern edge of the LTA. Extent of riparian ecosystems was reduced by diversions, including transfer of flows from Johnson Creek and Indian Creek. However, these reductions were limited as evidenced by R-CAT results indicating that over 80 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A1). Significant or large departures were noted at Spring Creek, Indian Creek, North Canyon, Johnson Creek, and Recapture Creek.

*KEC Status: **Within the NRV***

A_LTAG2 - Shay Mountain

This LTA contains only intermittent/ephemeral streams. Field-sampled and aerially mapped riparian vegetation were absent.

*KEC Status: **Insufficient Information***

A_LTAG3 - Alluvial Fans and Plains

Riparian vegetation was well-distributed throughout the LTA and consists of intermittent wetland, shrub-, tree-, and willow- types. Locations included Spring Creek, North Creek, South Creek, Verdure Creek, and Johnson Creek. Areas with aerially mapped riparian vegetation included Johnson Creek and Verdure Creek. Riparian vegetation was associated with perennial and intermittent streams. Lower sections of Johnson Creek and other streams have become intermittent/ephemeral due to diversions for culinary water and irrigation (USFS 2005). R-CAT results indicated that over 60 percent of perennial stream miles showed either negligible or minimal departure from riparian vegetation expected under natural conditions (table A1). Significant or large departures were noted at Blue Creek, Spring Creek, Verdure Creek, Recapture Creek, and Johnson Creek.

*KEC Status: **Trending Toward the NRV***

A_LTAG4 - Landslides Terrain

Field-sampled riparian vegetation was found at several locations including the North Fork of South Creek. Riparian vegetation types included wetlands and willow-dominated stands. Aerially mapped riparian vegetation was absent in this LTA. R-CAT results indicated that over 75 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A1). Significant or large departures were noted at Verdure Creek below several spring developments.

*KEC Status: **Within the NRV***

A_LTAG5 - Shay Mountain Colluvial Slopes and Fans

Riparian ecosystems were associated with perennial streams, intermittent streams, and one reservoir. Field-sampled riparian vegetation included wetland-, shrub-, and tree-dominated types along Indian Creek and near Spring Lake. Riparian vegetation was also aerially mapped along North Cottonwood Creek, Hop Creek, and Indian Creek. R-CAT results indicated that over 60 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A1). Significant or large departures were noted at Blue Creek, Hop Creek, and Indian Creek, which has a large upstream diversion.

*KEC Status: **Trending Toward the NRV***

MC_LTAG1 - Lower Mesas

Field-sampled riparian vegetation was mapped at several locations including Allen Canyon, Chippean Canyon, Hammond Canyon, Ruin Canyon, and Cottonwood Creek. Riparian vegetation was aerially mapped at Bull Canyon, North Cottonwood Creek, and Chippean Canyon. Wetland, tree-, and willow-dominated types were sampled. Most of these patches were associated with intermittent streams. R-CAT results indicated that over 85 percent of perennial stream miles had negligible or minimal departures from riparian vegetation expected under natural conditions (table A1). Significant departures were noted at North Cottonwood Creek.

*KEC Status: **Within the NRV***

MC_LTAG2 - Mid-Elevation Mesas

Field-sampled riparian vegetation was mapped in small canyons throughout the LTA. Wetland and willow-dominated types were associated with intermittent streams. Riparian vegetation was aerially mapped at several canyons at the east edge of the LTA. R-CAT results indicated that over 75 percent of perennial stream miles had negligible or minimal departures from riparian vegetation expected under natural conditions (table A1). Significant departures were noted at Cottonwood Creek, where riparian vegetation was not detected by field sampling or aerial imagery.

*KEC Status: **Within the NRV***

MC_LTAG3 - Higher Elevation Mesas

Field-sampled riparian vegetation was located along several perennial and intermittent streams including Cottonwood Creek, North Cottonwood Creek, and Chippean Canyon. Riparian vegetation was aerially mapped at several locations including Deep Canyon, Chippean Canyon, Vega Creek, and North Cottonwood Creek. Wetland, shrub-, tree-, and willow-dominated types were sampled. R-CAT results indicated that over 70 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A1). Significant or large departures were noted at Cottonwood Creek and North Cottonwood Creek.

*KEC Status: **Within the NRV***

MC_LTG4 - Canyon Slopes

Riparian ecosystems were primarily associated with intermittent streams. Field-sampled riparian vegetation was mapped in Dark Canyon, Woodenshoe Canyon, Horse Pasture Canyon, Chippean Canyon, Cottonwood Creek, and North Cottonwood Creek. Riparian vegetation was aerially mapped at Chippean Canyon and North Cottonwood Creek. R-CAT results indicated that over 75 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A1). Significant or large departures were noted at North Cottonwood Creek.

*KEC Status: **Within the NRV***

MC_LTAG5 - Canyon Bottomlands

This LTA had the largest area of field-sampled riparian vegetation in the South Zone of the Forest. This vegetation was mapped at intermittent streams in Allen Canyon, Hammond Canyon, Horse Pasture Canyon, Woodenshoe Canyon, Dark Canyon, and Ruin Canyon. Riparian vegetation was field-sampled and aerially mapped along a perennial section of Cottonwood Creek. R-CAT results indicated that all perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A1).

*KEC Status: **Within the NRV***

La Sal Mountains and Borderlands

LSM_LTAG1 - La Sal Mountains Alluvial Fans and Glacial Moraines

Several perennial streams crossed this LTA, but small patches of riparian vegetation were documented in only two locations. Field-sampled, shrub-dominated riparian vegetation is located along Pack Creek on the west edge of the LTA. One patch of riparian vegetation was aerially mapped along La Sal Creek at the east edge. R-CAT results indicated that over 65 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A2). Significant or large departures were noted at Castle Creek, Mill Creek, Horse Creek, and Pack Creek. Departures at Mill Creek were below a diversion canal.

*KEC Status: **Within the NRV***

LSM_LTAG2 - La Sal Mountains Mid-Slopes and Passes

Field-sampled riparian vegetation was located along perennial and intermittent reaches of Brumley Creek at the west edge of the LTA and along several intermittent streams at the east edge. These vegetation patches were classified as intermittent and perennial wetlands. R-CAT results indicated that over 60 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A2). Significant or large departures were noted at the upper Beaver Basin, West Fork Mill Creek, Deep Creek, Geyser Creek, Horse Creek, Hell Canyon, and La Sal Creek, all of which have been influenced by spring developments and cattle grazing.

*KEC Status: **Trending Toward the NRV***

LSM_LTAG3 - La Sal Mountains Peaks

Nearly all streams in this LTA were intermittent/ephemeral and in settings that do not typically support riparian ecosystems. No riparian vegetation types were mapped within the 50-year flood zone. R-CAT results indicated that all of a 0.002 mile section of Deep Creek located in the LTA had significant departure from riparian vegetation expected under natural conditions (table A2). There were no segments with negligible or minimal, or large departures.

*KEC Status: **Insufficient Information***

LSMB_LTAG1 - Upper Till Covered Mesas

All streams in this LTA were intermittent/ephemeral. No riparian vegetation types were mapped within 50-year flood zone.

*KEC Status: **Insufficient Information***

LSMB_LTAG2 - Lower Sandstone and Till Covered Mesas

Riparian ecosystems were associated with perennial and intermittent streams in this LTA. Field-sampled and aerially mapped riparian vegetation included shrub-dominated stands along Brumley Creek and shrub- and tree-dominated patches on the east and west sides of the La Sal Mountains. R-CAT results indicated that over 55 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A2). Significant or large departures were noted near Pole Canyon and at Brumley Creek.

*KEC Status: **Trending Toward the NRV***

LSMB_LTAG3 - Dissected Mesas

Riparian ecosystems were associated with perennial and intermittent streams in this LTA. Field-sampled riparian vegetation included shrub- and tree-dominated stands along Brumley Creek and Spring Branch of Castle Creek. Riparian vegetation was aerially mapped along Mill Creek at the west edge. R-CAT results indicated that 92 percent of perennial stream miles had either significant or large departures from riparian vegetation expected

under natural conditions (table A2). Significant or large departures were noted at Mill Creek, Brumley Creek, Horse Creek, Pack Creek, and Hell Canyon. These reaches were downstream from diversion canals and spring developments.

*KEC Status: **Outside of the NRV***

LSMB_LTAG4 - Southern Alluvial Fans

Most streams in this LTA were intermittent/ephemeral. Field-sampled and aerially mapped riparian vegetation was limited to tree- and willow-dominated stands near the confluence of Beaver Creek and La Sal Creek at the east edge of the LTA. R-CAT results indicated that 90 percent of stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A2). Significant or large departures were noted at Beaver Creek and La Sal Creek, which were both affected by grazing, spring developments, diversion canals, and roads.

*KEC Status: **Outside of the NRV***

LSMB_LTAG5 - Eastern Moraines and Slopes

Several perennial streams were located in this LTA, but field-sampled riparian vegetation was limited to tree-dominated stands along Beaver Creek in the southern section. Riparian vegetation was aerially mapped along La Sal Creek. R-CAT results indicated that over 60 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A2). Significant or large departures were noted at Beaver Creek, Castle Creek, and La Sal Creek. Diversion canals, spring developments, and cattle grazing have had large effects on riparian ecosystems, particularly at Beaver Creek and La Sal Creek.

*KEC Status: **Outside of the NRV***

LSMB_LTAG6 - Eastern Ponderosa Pine Covered Mesas

Riparian ecosystems were associated with perennial streams, intermittent streams, and Buckeye Reservoir. There was no field-sampled riparian vegetation in the 50-year flood zone. Riparian areas were aerially mapped along Beaver Creek and TwomileCreek on the western edge of the LTA and above Buckeye Reservoir. R-CAT results indicated that over 60 percent of perennial stream miles had negligible or minimal departures from riparian vegetation expected under natural conditions (table A2). Large departures were noted at Beaver Creek.

*KEC Status: **Within the NRV***

LSMB_LTAG7 - Collapsed Salt Anticlines

All streams in this LTA were intermittent/ephemeral. No riparian vegetation types were mapped within 50-year flood zone.

*KEC Status: **Insufficient Information***

LSMB_LTAG8 - Rocky Canyons

The area of riparian vegetation mapped in this LTA was the largest of any in the La Sal Mountains and Borderlands. Field-sampled riparian vegetation included shrub- and tree-dominated types in the canyons of Beaver Creek on the north edge of the LTA, Roc Creek on the east edge, and Hop Creek and Two Mile Creeks at the south edge. Riparian vegetation was also aerially mapped in Mill Creek Canyon at the west edge of the LTA. Despite the large area of riparian ecosystems currently mapped, extent had been reduced by spring developments and diversions. R-CAT results indicated that 65 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A2). Significant or large departures were noted at Beaver Creek, Mill Creek, Pole Spring Canyon, and Two Mile Creek.

*KEC Status: **Outside of the NRV***

LSMB_LTAG9 - Escarpments and Rocky Slopes

No riparian vegetation types were mapped within the 50-year flood zone. Riparian vegetation was aerially mapped in the Professor Creek drainage on the west edge of the LTA. R-CAT results indicated that 96 percent of perennial stream miles had either negligible or minimal departure from riparian vegetation expected under natural conditions (table A2). Large departures were noted at Mill Creek.

*KEC Status: **Within the NRV***

LSMB_LTAG10 - Southern Graben Valleys

Riparian ecosystems were associated with perennial and ephemeral streams. Field-sampled riparian vegetation included willow-dominated stands along La Sal Creek on the south edge of the LTA, tree-dominated stands along Pack Creek at the west edge, and shrub-dominated stands along Mason Spring Creek and Placer Creek on the west edge. Riparian vegetation was aerially mapped along Castle Creek on the west edge. R-CAT results indicated that over 80 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A2). Significant or large departures were noted at Castle Creek, Pack Creek, and La Sal Creek, which were influenced by upstream diversion canals and/or spring developments.

*KEC Status: **Outside of the NRV***

San Pitch Mountains

SP_LTAG1 - Western Front Lower Slopes

Most streams were intermittent/ephemeral in this LTA. Field-sampled riparian vegetation included shrub- and tree-dominated stands along Chicken Creek and tree-dominated stands along Pigeon Creek. These reaches were intermittent and located below diversions. R-CAT results indicated that over 55 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A3). Significant and large departures were indicated in the Little Salt Creek drainage.

*KEC Status: **Outside of the NRV***

SP_LTAG2 - Western Front Mountains

Field-sampled riparian tree- and shrub-dominated vegetation was mapped along small portions of Chicken Creek. Riparian vegetation was aerially mapped along Deep Creek. These reaches were intermittent. R-CAT results indicated that 60 percent of perennial stream miles had significant departures from riparian vegetation expected under natural conditions (table A3). These areas were located along Right Fork Deep Creek.

*KEC Status: **Trending Toward the NRV***

SP_LTAG3 - Conglomerate Cliffs

Field-sampled riparian vegetation was limited to a willow-dominated patch along a perennial section of upper Chicken Creek. Riparian vegetation was aerially mapped along an intermittent section of Pigeon Creek. R-CAT results indicated over 55 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A3). These areas were located at several streams draining the west side of the mountains.

*KEC Status: **Trending Toward the NRV***

SP_LTAG4 - Central Plateau

Field-sampled riparian vegetation was limited to a willow-dominated patch along a perennial reach of Chicken Creek and its intermittent tributaries. There was no aerially mapped riparian vegetation in the LTA. R-CAT results indicated over 55 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A3). These areas were located at several streams draining the west side of the mountains.

*KEC Status: **Trending Toward the NRV***

SP_LTAG5 - North Eastern Canyons

Field-sampled riparian vegetation was limited to a tree-dominated patch along an intermittent stream in Maple Canyon. There was no aerially mapped riparian vegetation in the LTA. R-CAT results indicated that over 50 percent of perennial stream miles in Tidds Canyon had either significant or large departures from riparian vegetation expected under natural conditions (table A3).

*KEC Status: **Trending Toward the NRV***

SP_LTAG6 - Eastern Front Benches and Cliffs

Field-sampled riparian vegetation consisted of tree- and shrub-dominated stands along perennial streams in Wales Canyon. There was no aerially mapped riparian vegetation in the LTA. R-CAT results indicated that nearly 70 percent of perennial stream miles in Wales Canyon had either significant

or large departures from riparian vegetation expected under natural conditions (table A3).

*KEC Status: **Trending Toward the NRV***

Wasatch Plateau

MSL_LTAG1 - Mancos Shale Lowlands

Tree-dominated stands of riparian vegetation were mapped along perennial streams at Ferron Canyon and Right Fork Miller Creek. R-CAT results indicated that greater than 50 percent of perennial stream miles had either negligible or minimal departure from riparian vegetation expected under natural conditions (table A4). Areas with significant or large departure were located at Ferron Canyon and Right Fork Miller Creek.

*KEC Status: **Within the NRV***

WP_LTAG1 - Western Front Lower Canyon Slopes

Riparian vegetation was associated with perennial and intermittent streams draining the west front of the Wasatch Monocline. Diversions had converted perennial streams to intermittent/ephemeral streams in the lower reaches of Ephraim Creek and Cottonwood Creek. Field-sampled riparian vegetation included tree-dominated stands in Manti Canyon, Sixmile Canyon, and Twelvemile Canyon. Smaller patches of shrub, willow, and wetland vegetation were mapped in these canyons, as well as in New Canyon. R-CAT results indicated that greater than 50 percent of perennial stream miles had either significant or large departure from riparian vegetation expected under natural conditions (table A4). Streams with significant or large departures were located in several canyons that are affected by long-term sheep grazing, floods, debris flows, and diversions.

*KEC Status: **Outside of the NRV***

WP_LTAG2 - Western Mountains and Basins

Riparian ecosystems were primarily associated with perennial streams in this LTA. Field-sampled riparian vegetation included wetland-, tree-, and willow-dominated patches at streams and canyons draining to the east and west throughout the LTA. Riparian vegetation was aerially mapped at streams and canyons in the northern portion of the LTA. R-CAT results indicated that over 70 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A4). Significant or large departures were noted at streams draining east and west of the plateau.

*KEC Status: **Within the NRV***

WP_LTAG3 - Western Front Flat Iron Ridges

Field-sampled riparian vegetation was limited to wetland-dominated patches along intermittent streams in the Birch Creek Drainage of Twelvemile Canyon. Riparian vegetation was also aerially mapped along the perennially flowing Pigeon Creek. R-CAT results indicated that over 60 percent of perennial stream miles had either negligible or minimal departures

from riparian vegetation expected under natural conditions (table A4). Significant and large departures were noted at several streams draining the west side of the plateau.

*KEC Status: **Within the NRV***

WP_LTAG4 - Western Mountain Plateau Top

Riparian ecosystems were primarily associated with perennial streams. Field-sampled riparian vegetation included willow- and wetland-dominated patches scattered across the southern portion of the LTA. Riparian vegetation was also aerially mapped in Fairview Canyon in the north. R-CAT results indicated that 80 percent of perennial stream miles had either significant or large departure from riparian vegetation expected under natural conditions (table A4). Significant and large departures were noted at numerous streams draining east and west of the plateau in the southern portion of the LTA.

*KEC Status: **Outside of the NRV***

WP_LTAG5 - Western Mountain Mid-Mountain Benches

Field-sampled riparian vegetation included patches of willow and wetland-dominated patches associated with perennial and intermittent streams throughout the LTA. There was no aerially mapped riparian vegetation in the LTA. R-CAT results indicated that over 80 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A4). Significant and large departures were noted at numerous streams draining east of the plateau in the southern portion of the LTA.

*KEC Status: **Within the NRV***

WP_LTAG6 - Western Mountain SE Lower Slopes

Riparian ecosystems were associated with perennial and intermittent streams in this LTA. Field-sampled riparian vegetation included small willow- and wetland-dominated patches in the central and southern portions of the LTA. Aerially mapped patches of riparian vegetation were located at Seeley Creek in the north. R-CAT results indicated that over 50 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A4). Significant or large departures were noted at numerous streams draining east of the plateau.

*KEC Status: **Trending Toward the NRV***

WP_LTAG7 - Southern Tablelands

Field-sampled riparian vegetation included willow-dominated stands at intermittent tributaries of Muddy Creek and Quitcupah Creek. Riparian vegetation was aerially mapped at perennial and intermittent streams in the Muddy Creek Drainage. R-CAT results indicated that over 65 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A4). Significant or large

departures were noted at upper drainages of Dairy Creek, Stevens Creek, Muddy Creek, and Quitcupah Creek.

*KEC Status: **Trending Toward the NRV***

WP_LTAG8 - Northern Fault Valleys

This LTA had the greatest area of field-sampled riparian vegetation in the MLSNF. This vegetation included large expanses of willow- and wetland-dominated stands in the Gooseberry Creek drainage, Scad Valley, and upper Joe's Valley. Shrub- and tree-dominated stands were mapped along several streams as well. Most stands were associated with perennial streams. R-CAT results indicated that over 55 percent of perennial stream miles had either negligible or minimal departure from riparian vegetation expected under natural conditions (table A4). Significant or large departures were noted at numerous streams, most of which drained into reservoirs or exited reservoirs before flowing east of the plateau.

*KEC Status: **Trending Toward the NRV***

WP_LTAG9 - Southern Fault Valleys

This LTA contained several perennial streams which fed into Joe's Valley Reservoir or crossed the LTA in canyons. Field-sampled riparian vegetation included extensive tree-dominated stands along these streams. A patch of wetland-dominated vegetation is located near Joe's Valley Reservoir. Field-sampled riparian vegetation was patchy where Muddy Creek is diverted and becomes intermittent. R-CAT results indicated that over 70 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A4). Significant and large departures were noted at Ferron Creek and tributaries, Muddy Creek, and several streams that drain into Joe's Valley Reservoir.

*KEC Status: **Outside of the NRV***

WP_LTAG10 - Eastern Mountains Upper Canyon Slopes

Field-sampled riparian vegetation included extensive willow- and wetland-dominated stands along perennial and intermittent streams in the Huntington Creek and Price River watersheds. Riparian vegetation was aerially mapped along these streams as well. R-CAT results indicated that over 60 percent of perennial stream miles had either negligible or minimal departure from riparian vegetation expected under natural conditions (table A4). Significant or large departures were noted at numerous streams and canyons that drain into reservoirs and east of the Plateau.

*KEC Status: **Within the NRV***

WP_LTAG11 - Eastern Mountains Lower Canyon Slopes

Field-sampled riparian vegetation included extensive shrub- and tree-dominated stands along Huntington Creek, Cottonwood Creek, and smaller perennial and intermittent streams. R-CAT results indicated that over 55 percent of perennial stream miles had either negligible or minimal departure

from riparian vegetation expected under natural conditions (table A4). Significant or large departures were noted at Huntington Creek, Cottonwood Creek, and several of their tributaries.

*KEC Status: **Within the NRV***

WP_LTAG12 - Rocky Canyons

Riparian ecosystems in this LTA were associated with canyon-bound, perennial streams. Field-sampled riparian vegetation included tree-dominated stands along Muddy Creek and Quitchupah Creek. Riparian vegetation was aerially mapped at Straight Canyon, Ferron Canyon, and Muddy Creek. R-CAT results indicated that over 80 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A4). Significant and large departures were noted at Straight Canyon, Ferron Creek and tributaries, Muddy Creek and tributaries, and at Quitchupah Creek and tributaries.

*KEC Status: **Outside of the NRV***

WP_LTAG13 - Eastern Escarpment

Field-sampled and aerially mapped riparian vegetation included tree-dominated stands at several perennial and intermittent streams in canyons draining to the east. R-CAT results indicated that nearly 70 percent of perennial stream miles had either significant or large departures from riparian vegetation expected under natural conditions (table A4). Significant and large departures were noted at numerous streams and canyons draining east of the plateau.

*KEC Status: **Trending Toward the NRV***

WP_LTAG14 - Northern Slope

Riparian ecosystems were primarily associated with perennial streams in this LTA. Field-sampled riparian vegetation included tree-dominated stands along Right Fork Mill Creek and Right Fork Clear Creek. Riparian vegetation was aerially mapped along Right Fork Mill Creek and at Side Canyon. R-CAT results indicated that over 70 percent of perennial stream miles had either negligible or minimal departures from riparian vegetation expected under natural conditions (table A4). Significant and large departures were noted at streams draining to the north including Mill Fork and Clear Creek.

*KEC Status: **Within the NRV***

WP_LTAG15 - Thistle Highlands Western Slopes

Field-sampled riparian vegetation included tree- and willow-dominated stands at perennial and intermittent streams draining to the north and northwest. R-CAT results indicated that 60 percent of perennial stream miles had either negligible or minimal departure from riparian vegetation expected under natural conditions (table A4). Significant or large departures were

noted at several streams and canyons draining to the North and west of the plateau.

*KEC Status: **Within the NRV***

WP_LTAG16 - Thistle Highlands North Eastern Slopes

Field-sampled riparian vegetation included tree- and wetland-dominated stands along the Lake Fork and its perennial and intermittent tributaries. R-CAT results indicated that over 55 percent of perennial stream miles had either negligible or minimal departure from riparian vegetation expected under natural conditions (table A4). Significant or large departures were noted at Dairy Fork, Lake Fork, Right Fork Lake Fork, and Coffeepot Creek.

*KEC Status: **Within the NRV***

Table A1—Riparian vegetation departure results for Abajo Mountains, Mesas, and Canyons LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles			
		Negligible departure	Minimal departure	Significant departure	Large departure
A_LTAG1	17.5	59	25	11	5
A_LTAG2	0	--	--	--	--
A_LTAG3	13.3	36	27	23	14
A_LTAG4	1.5	73	4	21	2
A_LTAG5	3.2	20	18	52	9
MC_LTAG1	0.4	43	45	12	0
MC_LTAG2	0.8	45	34	21	0
MC_LTAG3	5.6	52	19	17	12
MC_LTAG4	9.2	49	29	17	5
MC_LTAG5	1.2	31	69	0	0

Table A2—Riparian vegetation departure results for La Sal Mountains and Borderlands LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles			
		Negligible departure	Minimal departure	Significant departure	Large departure
LSMLTAG1	8.2	48	20	27	5
LSMLTAG2	9.8	21	41	32	7
LSMLTAG3	0	--	--	--	--
LSMBLTAG1	0	--	--	--	--
LSMBLTAG2	3.0	0	56	29	15
LSMBLTAG3	7.8	0	8	47	45
LSMBLTAG4	2.3	0	10	28	62
LSMBLTAG5	3.3	21	15	6	58
LSMBLTAG6	3.0	0.2	62	0	38
LSMBLTAG7	0	--	--	--	--
LSMBLTAG8	21.9	6	29	24	41
LSMBLTAG9	3.2	38	58	0	4
LSMBLTAG10	5.2	6	10	53	31

Table A3—Riparian vegetation departure results for San Pitch Mountains LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles			
		Negligible departure	Minimal departure	Significant departure	Large departure
SP_LTAG1	3.4	27	15	28	29
SP_LTAG2	0.8	40	0	60	0
SP_LTAG3	13.4	15	29	26	30
SP_LTAG4	15.3	27	14	13	46
SP_LTAG5	0.8	51	0	0	49
SP_LTAG6	2.9	20	11	34	35

Table A4—Riparian vegetation departure results for Wasatch Plateau LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles			
		Negligible departure	Minimal departure	Significant departure	Large departure
MSL_LTAG1	0	29	24	20	27
WP_LTAG1	63.4	23	23	19	35
WP_LTAG2	254.9	32	39	21	8
WP_LTAG3	13.5	34	28	16	22
WP_LTAG4	21.9	5	15	37	43
WP_LTAG5	55.9	41	41	11	7
WP_LTAG6	56.5	23	25	22	30
WP_LTAG7	5.2	15	18	21	46
WP_LTAG8	56.9	23	36	27	14
WP_LTAG9	31.7	8	20	31	41
WP_LTAG10	73.7	26	36	25	12
WP_LTAG11	44.2	29	29	27	15
WP_LTAG12	44.9	5	14	24	57
WP_LTAG13	21.7	13	18	29	40
WP_LTAG14	15.1	27	47	12	14
WP_LTAG15	27.8	33	27	20	20
WP_LTAG16	14.4	38	20	24	19

Appendix B—LTA Summaries: Groundwater and Surface Water Fluctuations

Abajo Mountains

A_LTAG1 - Igneous Mountains

This LTA is composed of high-elevation mountain peaks and plateaus. Precipitation that falls at this high altitude is important for groundwater recharge and surface water flows in this LTA and those at lower elevations. Snow is a source of spring runoff that drives flow regimes of lower LTAs. There were 104 miles of streams in this LTA and 17 percent were perennial. According to the POD layer, there were 37 springs, 13 of which have been diverted or dammed. Some diversions are used to redirect flow from the Indian Creek drainage to the Johnson Creek drainage, altering the natural flow regimes of both systems. Climate change has had a moderate effect on temperature and precipitation. Overall, temperatures were warmer in all four seasons. Average winter temperatures between 2010 and 2014 had increased by 1.37 °F compared to the average winter temperature of the previous 115 years and winter precipitation during the same timeframe has decreased by 0.12 inches. Furthermore, climate deviations indicated that the timing, amount, and form of precipitation has substantially changed in recent years with less precipitation occurring December through June and more precipitation falling July through November.

*KEC Status: **Trending Toward the NRV***

A_LTAG2 - Shay Mountain

This LTA is composed of the mountainous slopes of Shay Mountain. Accumulation of snow at this high altitude is important for recharge of groundwater systems and spring runoff in surface water streams. The igneous core of Shay Mountain is not exposed through sandstone and there is limited hydrologic connectivity between surface and groundwater systems. There were 32 miles of streams in A_LTAG2, none of which are perennial. These channels generally experience flow during spring runoff and localized summer thunderstorms. Based on the POD layer, there were four springs and three have been diverted to troughs or ponds. There were three uranium mines (Blue and Shay Mountain Mines) located in this LTA. The effects of climate change were not as strong in this LTA, but temperatures and precipitation regimes have shifted. Overall, temperatures have increased, with average winter temperature between 2010 and 2014 being 0.90 °F greater than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe had not changed significantly (0.05 inches less). Climate deviations recorded for all seasons indicated that the timing, amount, and form of precipitation had changed in recent years. Spring precipitation had decreased by up to 21 percent in some locations, while summer precipitation has increased by up to 20 percent.

*KEC Status: **Within the NRV***

A_LTAG3 - Alluvial Fans and Plains

This LTA has a complex geology with settings that differ in their permeability and capacity to act as aquifers. There were 284 stream miles in this LTA and 5 percent were perennial, with most experiencing flow from snowmelt and summer thunderstorms. According to the POD layer, there were 33 springs and 13 have been diverted. Some headwaters in this LTA were diverted to the Johnson Creek drainage, affecting discharge patterns in both systems. There were 32 dams in this LTA that modify natural hydrologic patterns. ALTAG3 had the largest road density in the Abajo Mountains region and the third largest for the Forest (0.003 road miles/acre). Many of the roads were located near springs and headwaters and have potentially disrupted natural connectivity. Despite stressors, PFC reports indicated regular high flows in sampled streams and natural drying of the channel when it flowed over some geologic formations. Recent climate in this LTA had deviated from historic precipitation and temperature regimes. Overall temperatures increased in all seasons, the average winter temperature between 2010 and 2014 was 1.3 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe had not substantially changed (0.09 inches less), but the amount of spring precipitation had decreased by 21 percent and summer precipitation had increased by 20 percent.

*KEC Status: **Outside the NRV***

A_LTAG4 - Landslides Terrain

This LTA is composed of mostly dormant landslides and colluvial slopes overlying a diverse geology. This setting creates localized regions that allow for groundwater recharge and springs tend to occur where more permeable formations meet impermeable. According to the POD layer, this LTA had 18 springs, seven of which have been diverted. There were 34 stream miles in this LTA and 5 percent were perennial, with most experiencing flow during snowmelt and summer thunderstorms. There was an extensive network of dams and diversions impacting nearly every stream in this LTA. Emergent wetlands and a spring located in the headwaters of Indian Creek suggested strong hydrologic connections between groundwater and surface water systems. This LTA had a relatively large road density (0.003 miles/acre) compared to other LTAs on the Forest and 60 percent of the roads were unimproved. PFC reports indicated regular inundation and intermittent flows in stream channels. There was evidence that the climate in this LTA has deviated from historic temperature and precipitation regimes. Temperatures throughout the year had increased, with average winter temperatures between 2010 and 2014 being 1.36 °F warmer than the average winter temperature of the previous 115 years. Precipitation regimes during the same timeframe had shifted with spring snow and rainfall decreasing by 21 percent and summer precipitation increasing by 20 percent. Additionally, winter precipitation had decreased by 0.11 inches.

*KEC Status: **Outside the NRV***

A_LTAG5 - Shay Mountain Colluvial Slopes and Fans

This LTA is composed of colluvial slopes surrounding Shay Mountain that overlay a diverse geologic setting. Some formations are more permeable than others, allowing for groundwater recharge in some locations. According to the POD layer, there were four springs in this LTA and two were diverted. There were 65 stream miles and 5 percent were perennial. There were 10 miles of unimproved roads in this LTA and they impacted two of the three springs. There were 10 mines in A_LTAG5, all dedicated to uranium. These mines may have altered natural networks of groundwater and surface water and the direction of flow in some drainages. Deviations in normal precipitation and temperature regimes may have influenced the timing and amount of runoff in this LTA. Climate deviations show the average winter temperature between 2010 and 2014 was 1.12 °F warmer than the average winter temperature of the previous 115 years, but winter precipitation during the same timeframe had not decreased substantially (0.08 inches). However, large shifts in the precipitation regime have occurred in spring and summer months. Snow and rainfall occurring during spring had decreased by 19 percent, while summer precipitation had increased by 20 percent.

*KEC Status: **Trending Toward the NRV***

MC_LTAG1 - Lower Mesas

This LTA has a complex and diverse geologic setting that includes formations that are fairly impermeable and naturally limit hydrologic connectivity that drives fluctuations in groundwater and surface water systems. Surface water fluctuations in this LTA depend on snowmelt from higher elevation LTAs and summer thunderstorms. There were 212 stream miles in this LTA and 0.16 percent were perennial. According to the POD layer, there were four springs in this LTA and one was diverted. There were 15 uranium miles in MC_LTAG1 that may have altered natural flow dynamics and directions. Climate change has had a moderate effect on the temperature and precipitation regimes of this LTA. Overall temperatures had increased, but average winter temperature between 2010 and 2014 was only 0.96 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe had not changed substantially (0.06 inches less), but spring precipitation had decreased by 18 percent and summer precipitation had increased by 22 percent.

*KEC Status: **Within the NRV***

MC_LTAG2 - Mid-Elevation Mesas

This LTA is composed of middle elevation plateaus, mesas, and canyons with a complex underlying geology. Groundwater infiltration and discharge is driven by the permeability of local geology. According to the POD layer, there were 16 springs in this LTA and 6 were diverted. Surface water fluctuations in this LTA are driven by snowmelt from higher elevations and summer thunderstorms. There were 125 stream miles in MC_LTAG2, but only 0.60 percent were perennial. There were 79 miles of unimproved roads in this LTA and they impacted all four springs, altered infiltration capacity,

and disrupted surface water connections that drive natural fluctuations. Recent temperature and precipitation regimes had deviated from historic norms and could have affected the natural flow regimes of surface and groundwater systems. Temperatures had increased throughout the year, with average winter temperature between 2010 and 2014 being 0.98 °F warmer than the average winter temperature of the previous 115 years. While winter precipitation had not changed substantially (0.06 inches less), spring precipitation had decreased by 18 percent and summer precipitation had increased by 22 percent.

*KEC Status: **Within the NRV***

MC_LTAG3 - Higher Elevation Mesas

The majority of this LTA is composed of diverse geologic settings. According to the POD layer, there were 94 springs and 51 were diverted. Fluctuations in groundwater in this LTA were likely dependent on infiltration in higher altitude LTAs. Similarly, surface water flows depended on snowmelt from higher elevation LTAs and summer thunderstorms. There were 294 stream miles in this LTA, but only 1.9 percent were perennial. There were 241 miles of unimproved roads and every spring had a road located near it. There were 63 mines, primarily uranium focused, that may have altered natural flow networks and directions of flow within groundwater and surface water systems. The timing and magnitude of fluctuations in ground and surface waters are driven by temperature and precipitation, which had deviated from historic regimes in recent years. Overall temperatures were warmer in all seasons, with average winter temperature between 2010 and 2014 being 1.10 °F warmer than the average winter temperature of the previous 115 years. While winter precipitation during the same timeframe had not substantially decreased (0.07 inches less), spring precipitation had decreased by 19 percent and summer precipitation had increased by 21 percent. PFC reports indicated that springs and floodplains in this LTA had experienced regular inundation and that fluctuations in water levels were naturally variable. These reports captured degradation to hydrologic connections caused by roads near springs, wetlands, and floodplains and described development of springs for ponds and troughs. Despite these stressors, many reports indicated that ground and surface water fluctuations were at least in functional condition.

*KEC Status: **Trending Toward the NRV***

MC_LTG4 - Canyon Slopes

This LTA is largely composed of Cedar Mesa Sandstone at higher elevations, and the Rico, Elephant Canyon, Halcito, and Honaker Trail Formations at lower elevations and in canyon bottoms. According to the POD layer, there were 11 springs, 5 of which were diverted. There were 382 miles of streams in this LTA, but only 2.4 percent were perennial. Fluctuations in ground and surface waters in this LTA are dependent on snowmelt from higher elevations and summer thunderstorms. While the road density was low (0.0002 miles/acre), PFC reports indicated impacts to natural hydrologic connections. Nevertheless, floodplains in this LTA

continued to show evidence of regular inundation. The TCA suggested that temperature and precipitation had deviated from historic norms in the last several years. Temperatures had increased throughout this LTA in all four seasons, with average winter temperature between 2010 and 2014 being 1.02 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation had not substantially changed (0.06 inches less), but spring precipitation had decreased by 19 percent and summer precipitation had increased by 21 percent.

KEC Status: Within the NRV

MC_LTAG5 - Canyon Bottomlands

Surface water fluctuations in this LTA are driven by snowmelt from higher elevation LTAs and summer thunderstorms. There were 89 stream miles in this LTA and only 1.4 percent were perennial. According to the POD layer, there were four springs in this LTA and one had been diverted. There were 13 additional diversions located in this LTA. PFC reports indicated impacts to natural flow networks from development and diversion of seeps, livestock grazing, outfitter camps, trails, and roads. One report stated that spring development and outfitter camps located at springs had altered amounts of discharge, flow patterns, and disrupted natural networks between ground and surface water systems. Furthermore, PFC reports described roads, livestock grazing, and hiking and ATV trails located in floodplains and near springs and seeps as altering natural surface and subsurface flow pathways and fluctuations. Despite these stressors, peak flows continued to occur and likely provided consistent water to ground and surface water systems. Climate change had affected temperature and precipitation regimes, with likely impacts to the timing and magnitude of natural fluctuations in groundwater and surface water. Overall, temperatures had increased in every season and average winter temperature between 2010 and 2014 was 0.84 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe had not decreased substantially (0.04 inches less), but spring precipitation had decreased by 16 percent and summer precipitation had increased by 22 percent.

KEC Status: Within the NRV

La Sal Mountains and Borderlands

LSM_LTAG1 - La Sal Mountain Alluvial Fans and Glacial Moraines

Surface water and groundwater fluctuations in this LTA experience spring flooding from snowmelt and elevated flows during summer thunderstorms. Fluctuations of some drainages, including Brumley Creek, are affected by rock glaciers. These streams tend to have more stable base flows throughout the summer than streams in drainages without rock glaciers. There were 49 stream miles and 17 percent were perennial. Additionally, springs had been documented as contributing surface flow and some sections of streams were noted as gaining reaches, indicative of good hydrologic connectivity. According to the POD layer, there were 41 springs in this LTA and 12 were diverted. Dams and diversions were located in multiple basins and were especially prevalent in the Mill Creek drainage, including the dam

that created Oowah Lake. An historic clearcut in the upland watershed of some streams had degraded hydrologic connectivity and may continue to influence the timing and magnitude of natural surface water fluctuations. Natural surface and subsurface flows had been disrupted by construction of roads, of which there were 24 miles and 42 percent were unimproved. There were seven mines located in this LTA, five of which were uranium focused. The other two were dedicated to gold, silver, and copper. Approximately 6 percent of this LTA was impacted by insect and disease. PFC reports indicated that despite stressors, streams in this LTA continued to experience regular flooding and showed signs of stable water fluctuations. Temperatures had increased in all four seasons, with average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe had decreased by 0.37 inches and the timing of precipitation events had shifted. Spring precipitation had decreased by 15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

LSM_LTAG2 - La Sal Mountain Mid-Slopes and Passes

Many streams in this LTA were intermittent headwaters fed by snowmelt and summer thunderstorms. There were 10 miles of streams and none were perennial. The fluctuations in groundwater and surface water systems of some drainages in this LTA, including Brumley Creek, are affected by the presence of rock glaciers. There were wetlands in LSMLTAG2 that stored and released water during dry periods. PFC reports indicated that these wetlands were regularly inundated and stable, suggestive of functional water fluctuations. Highly productive springs indicated a strong hydrologic connectivity between surface and groundwater systems. There were five springs in this LTA and none were associated with diversions or dams. However, there were several diversions located in headwater streams that have potentially altered natural flow regimes. According to the POD layer, there were 37 springs in this LTA and two were diverted. An additional stressor to the magnitude of fluctuations in this LTA was mortality of vegetation due to insect and disease, which had impacted about 7.5 percent of this LTA. This was the second largest amount of land affected by this stressor in an LTA for the Forest as a whole. There were 27 miles of roads in this LTA, 76 percent of which were classified as unimproved. They were located near streams and springs and may have disrupted connectivity and flow patterns between systems. Climate change had a strong effect on the temperature and timing and magnitude of precipitation events, both of which drive natural flow regimes. Temperatures had increased in all four seasons, with average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation had decreased by 0.37 inches. Spring precipitation had decreased by 15 percent, while summer precipitation had increased by 16 percent.

*KEC Status: **Outside of the NRV***

LSM_LTAG3 - La Sal Mountain Peaks

There is a large amount of bedrock outcrops in this high-elevation LTA, resulting in limited aquatic systems. There were 8.7 miles of streams, none of which were perennial and no springs located in this LTA. Snow accumulation in the high-elevation LTAs of the La Sal Mountains is important for fluctuations in groundwater and surface water at lower elevations. Additionally, snow and cold temperatures maintain rock glaciers that drive natural flow regimes of some drainages throughout the region. According to the POD layer there were three springs in this LTA and one was diverted. One drainage in this LTA had a series of diversions that may have altered natural flow regimes in this and lower-elevation LTAs. There were 15 mines in this LTA, with most dedicated to copper and gold. PFC reports indicated that springs and wetlands in this LTA were functioning properly with regular flows, despite some trampling from hoof action that can disrupt hydrologic connections. Climate change had affected temperature regimes and the timing and magnitude of precipitation events that drive natural fluctuations in groundwater and surface water. Temperatures in all four seasons had increased and average winter temperature between 2010 and 2014 was 1.27 °F warmer compared to the average winter temperature of the previous 115 years. Precipitation patterns had shifted, with 0.37 inches less falling during winter. Spring precipitation had decreased by 15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent respectively.

*KEC Status: **Outside of the NRV***

LSMB_LTAG1 - Upper Till Covered Mesas

This is a very small LTA, with limited aquatic resources. There were 10 miles of streams, all of which were intermittent headwaters. Many originated from springs. According to the POD layer, there were 20 springs and 10 were diverted. The small number of diversions in this LTA had limited impacts on the natural flow regime of aquatic systems. The construction of roads in this LTA may have altered natural groundwater infiltration pathways and provided a source of fine sediment that can obstruct hydrologic connectivity. There were four mines in this LTA, with one dedicated to uranium and the other three focused on manganese. Climate change had altered temperature and precipitation regimes that drive natural flow regimes in this LTA. Temperatures in all four seasons had increased, with the average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe had decreased by 0.37 inches. Spring precipitation had decreased by 15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

LSMB_LTAG2 - Lower Sandstone and Till Covered Mesas

The fluctuations of groundwater and surface water in this LTA depend on snowmelt during spring and summer thunderstorms. The hydrographs of some drainages, including Brumley Creek, are affected by the presence of

rock glaciers. According to the POD layer, there were 11 springs in this LTA and seven were diverted. There was an extensive network of diversions with 18 dams and 67 diversions. One-third of the dams were naturally occurring beaver dams that alter flow regimes and raise water tables. Forty-six of these diversions and four dams were located on private land inholdings, but their impacts to the natural flow regime had longitudinal effects. There were 46 uranium and vanadium mines. Additional stressors included high-intensity wildfires and roads. Wildfires had affected upland watersheds, including significant burns in the Hop and Placer Creek drainages. Approximately 3 percent of this LTA had experienced high severity burns that may have altered amounts of infiltration and runoff. There were 87 miles of unimproved roads, many that followed or crossed streams. Climate change had altered temperature and precipitation regimes that drive natural flow regimes. Temperatures had increased in all four seasons, with average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe had decreased by 0.37 inches. Spring precipitation had decreased by 15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

LSMB_LTAG3 - Dissected Mesas

Natural flow regimes in this LTA are characterized by spring snowmelt, summer thunderstorms, and reliable summer base flows in some streams. There were 46 miles of streams in this LTA and 17 percent were perennial. The hydrographs of some drainages, including Brumley and Mill Creeks, are influenced by rock glaciers. These streams rarely go dry because rock glaciers maintain base flow during dry periods. There is little recharge potential in the low-elevation LTAs, causing surface and groundwater flow to rely on snowmelt and infiltration from higher elevations. According to the POD layer, there were 12 springs and 5 were diverted. A single dam and 16 diversions were scattered throughout this LTA. Although several of these structures were located on private inholdings, they continued to impact the flow regimes of streams on national forest lands. However, the impacts were limited because the majority of streams flowed freely. There were 36 uranium mines in the dissected mesas that may have altered natural flow directions and amounts. There were 21 miles of unimproved roads and several followed stream channels and crossed floodplains. Despite these stressors, PFC reports indicated streams continued to show evidence of regular flooding events. Climate change had affected temperature and precipitation regimes that drive natural flow regimes. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe had decreased by 0.37 inches. Spring precipitation had decreased by 15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

LSMB_LTAG4 - Southern Alluvial Fans

Natural flow regimes in this LTA are driven by spring snowmelt and summer thunderstorms. The alluvial fans found in this LTA are important for groundwater recharge, particularly in the arid environment. There were 99 miles of streams, but only 2 percent were perennial. According to the POD layer there were seven springs in this LTA and two were diverted. At least one spring was the source of a headwater stream. There was a network of dams and diversions throughout the LTA, likely disrupting natural hydrologic pathways, recharge, and the timing and magnitude of high and low flows. Some of these diversions were used to remove water from La Sal Creek and direct it to a different drainage, impacting both streams. There were 45 miles of roads and 86 percent were classified as unimproved. This was the fourth largest road density on the entire forest (0.33 miles/acre). Some roads followed streams and crossed springs, wetlands, and floodplains, altering natural connections between surface and groundwater systems. Climate change had affected the temperature and precipitation regimes that drive natural flow regimes of this LTA. Overall temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.08 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe had decreased by 0.28 inches. Additionally, spring precipitation had decreased by 14 percent, while summer and fall precipitation had increased by 16 percent and 5 percent, respectively.

*KEC Status: **Outside** of the NRV*

LSMB_LTAG5 - Eastern Moraines and Slopes

Natural flow regimes in this LTA are primarily driven by spring snowmelt and summer thunderstorms. The glacial moraines in this LTA have the potential to store significant amounts of meltwater and release it slowly to groundwater and surface water systems during drier periods. Many emergent wetlands indicated strong hydrologic connections between these networks. There were 29 stream miles in this LTA and 11 percent were perennial. According to the POD layer there were eight springs in this LTA and one was diverted. An extensive network of diversions and dams had been constructed, but 55 of the 72 diversions and 1 of the 3 dams were located within private inholdings. While on private land, these diversions continued to have implications for the natural flow regimes of surface water and groundwater systems downstream on the Forest. There were four sand and gravel mines that had extremely limited impact. Additional stressors in this LTA were roads, vegetation mortality due to insect and disease, and degradation to upland watersheds. Roads and ATV trails through wetlands and floodplains may have disrupted natural hydrologic fluctuations in surface and groundwater systems. There were 18 miles of road and 54 percent were classified as unimproved. PFC reports indicated conifer encroachment in wetlands and an historic timber project on State land in the upland watershed that had altered natural surface and groundwater fluctuations. This LTA had experienced the largest impact from insects and disease on the Forest as a whole. Approximately 10 percent of the vegetation

has senesced due to insects and disease. Climate change had affected temperature and precipitation regimes that drive natural flow regimes in this LTA. Temperatures in all four seasons had increased, with the average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average winter temperature of the previous 115 years. Additionally, winter precipitation during the same timeframe had decreased by 0.37 inches. Furthermore, spring precipitation had decreased by 15 percent and summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

LSMB_LTAG6 - Eastern Ponderosa Pine Covered Mesas

This system of sandstone mesas and shale valleys allows for little natural recharge and creates localized surface and groundwater systems. The natural flow regimes of these aquatic systems are driven by spring snowmelt and summer thunderstorms. There were 77 stream miles in the eastern ponderosa pine covered mesas and 4 percent were perennial. According to the POD layer there were 15 springs in this LTA and 8 were diverted. There were 12 diversions and 4 were located within private inholdings. Despite being on private land, these diversions continued to impact the flow regimes of systems on national forest. There were 21 dams, but their impacts were somewhat localized. There were 17 mines, with nearly all dedicated to the extraction of uranium. Additional stressors included roads, recreation, and high severity fire. There were 124 miles of roads in this LTA and 86 percent were classified as unimproved. There were 28 dispersed campsites, with several located around a lake and wetland complex in Buckeye Creek. The Hangdog Fire burned a large amount of this LTA and approximately 7.9 percent had experienced high severity burns that may have altered infiltration and runoff. PFC reports indicated regular high flows do occur, however dams, diversions, and an historic clearcut on State lands in the upland watersheds had altered natural flow conditions. Also noted in PFCs were impacts from grazing on infiltration and surface runoff. Climate change had altered temperature and precipitation regimes that drive natural flow dynamics. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.26 °F warmer than the average temperature for the previous 115 years. Winter precipitation during the same timeframe had decreased by 0.37 inches. Spring precipitation had decreased by 15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

LSMB_LTAG7 - Collapsed Salt Anticlines

The underlying geology in this LTA plays a role in the natural flow regimes of groundwater and surface water systems. Additionally, this lower-elevation LTA is arid and experiences little flow either from spring snowmelt or summer thunderstorms. There were 11.3 stream miles in this LTA and none were perennial. There were no springs or emergent wetlands to maintain base flows during drier periods. There were no documented dams or diversions. There were three uranium mines that may have altered flow

direction and amount of scarce water supplies. About 19 percent of this LTA was burned by the Sunrise Mine and the Sinbad Fires in 2012 and 2013, but only 0.2 percent experienced high severity burns. Climate change had impacted the temperature and precipitation regimes that drive natural flow dynamics. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average temperature of the previous 115 years. The timing of precipitation during the same timeframe had shifted, with winter precipitation decreasing by 0.37 inches. Spring precipitation had decreased by 15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

LSMB_LTAG8 - Rocky Canyons

Natural flow regimes in this LTA include peaks from spring snowmelt and summer thunderstorms. There were 56 miles of streams and 39 percent were perennial, indicating adequate base flow sources in many streams. Beavers were noted in this LTA and they can drive changes in flow regimes and raise local water tables. According to the POD layer, there were four springs in this LTA and none were diverted, but information is limited for the portion of the forest that is located in Colorado. There were 14 diversions and 2 dams in this LTA, but their impacts were localized. All of the diversions were located within private inholdings or near the forest boundary, having limited impact to natural flow regimes on the forest. There were 25 uranium and vanadium mines that may have impacted flow directions and amounts. Additional stressors included roads, high severity fire, and vegetation mortality due to insects and disease. There were 21 miles of roads and 100 percent were classified as unimproved. Most roads were located out of floodplains, but they did cross headwater streams. Much of the Roc Creek watershed was burned in the Sunrise Mine Fire and parts of the Hop Creek upland watershed burned in the Hangdog Fire. Approximately 3 percent of the LTA experienced high severity burns that may have altered natural infiltration and runoff. About 3 percent of this LTA had experienced mortality due to insects and disease, the fourth largest amount of vegetation impacted by this stressor on the forest. Climate change had impacted temperature and precipitation regimes that drive natural flow dynamics in this LTA. Temperatures had increased in all four seasons, with average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average temperature of the previous 115 years. The timing and amount of precipitation during the same timeframe had changed, with 0.37 inches less falling during winter. Spring precipitation had decreased by 15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

LSMB_LTAG9 - Escarpments and Rocky Slopes

This lower elevation is more arid, and there is little groundwater recharge potential in this LTA because of its geologic setting and climate. Natural flow

regimes are driven by snowmelt from higher elevation LTAs and summer thunderstorms. There were 33 stream miles in this LTA and 10 percent were perennial. The surface and groundwater hydrologic systems were localized and likely disconnected from adjacent systems. There were no documented springs, no wetlands, and a single impounded pond. Beavers were present and played a role in natural fluctuations in ground and surface water levels. There were two diversions and seven dams in this LTA and they impacted nearly every stream. There were nine uranium and vanadium mines, but their impact was localized. There were 11.4 road miles in this LTA and 86 percent were unimproved, but their impacts were localized and they were generally not located near streams. An additional stressor in this LTA was wildfire. About 8 percent of this LTA had experienced high severity burns, primarily in the West Paradox Drainage. LSMB_LTAG9 had the third largest amount of high severity burns of LTAs on the Forest, and the largest in the La Sal region. Climate change had altered temperature and precipitation regimes that drive natural flow dynamics in this LTA. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.2 °F warmer than the average temperature of the previous 115 years. The timing and magnitude of precipitation during the same timeframe had shifted. Winter precipitation had decreased by 0.33 inches. Spring precipitation had decreased by 15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

LSMB_LTAG10 - Southern Graben Valleys

This is a very small LTA with limited aquatic systems. LSMB_LTAG10 is composed of fault valleys that are known to limit connections between adjacent watersheds. There were 23 stream miles and 23 percent were perennial, indicating strong sources of base flow from groundwater discharge. Fluctuations in this LTA are driven by spring snowmelt and summer thunderstorms. According to the POD layer, there were five springs and one was diverted. However, this LTA remained highly impacted by numerous diversions, most being underground wells. There were 48 diversions and 3 dams that have disconnected natural networks of ground and surface water channels and affect the timing and magnitude of natural fluctuations. The majority of dams and diversions were located within private inholdings, but they continued to affect the natural flow regimes of streams on the Forest. Additional stressors included several roads that followed stream beds and crossed through floodplains, disconnecting natural flow paths and providing a source of fine sediment. This LTA had the second largest road density of LTAs on the Forest (0.003 miles per acre) and the majority were unimproved. Climate change had affected temperature and precipitation regimes that drive natural flow dynamics. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average temperature of the previous 115 years. Timing and magnitude of precipitation events during the same timeframe had been altered, with 0.37 inches less precipitation occurring during winter. Additionally, spring precipitation had decreased by

15 percent, while summer and fall precipitation had increased by 16 percent and 7 percent, respectively.

*KEC Status: **Outside of the NRV***

San Pitch Mountains

SP_LTAG1 - Western Front Lower Slopes

Groundwater and surface water fluctuations in SP_LTAG1 are driven by spring snowmelt from higher elevation LTAs and summer thunderstorms. The hydrology of this LTA is influenced by its complex geological mix of gypsum and shale components, with badlands and canyons formed in limestone, shale, and volcanics. There were 59 miles of streams in this LTA and 6 percent were perennial. There were four springs in SP_LTAG1, two of which were diverted and one that was located near a road, leaving a single spring in this LTA unaltered. There were 24 diversions. The Deep, Little Salt, and Pigeon Creek drainages were generally less impacted by diversions, with 10 diversions concentrated in the Chicken Creek drainage. There were four mines (two quarries and two gypsum mines) located in this LTA. Additional stressors to natural flow regimes in the lower slopes of the western front included high severity burns and roads. Approximately 5.9 percent of this LTA had experienced high severity wildfire. While the road density of this LTA was low (0.001 road miles/acre), they were located in the floodplains of every main stem stream and 49 percent were classified as unimproved. Climate change had moderately impacted temperature and precipitation regimes that drive natural flow dynamics. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.01 °F warmer than the average temperature for the previous 115 years. The timing and magnitude of precipitation had shifted, with this LTA receiving more precipitation than in the past. Winter precipitation had increased by 0.28 inches. Additionally, spring, summer, and fall precipitation had increased by 7 percent, 3 percent, and 4 percent, respectively.

*KEC Status: **Trending Toward the NRV***

SP_LTAG2 - Western Front Mountains

The connectivity of ground and surface water systems is driven by geologic setting in this LTA. Limestone allows for increased connection through fractures and dissolved pathways. Shale is impermeable and limits water movement, forcing groundwater to the surface. These contact points are evident in a line of springs across the landscape. There were eight springs and the spring density is one of the highest on the MLSNF (0.0007 springs/acre). There were 64 stream miles, but only 1 percent were perennial. Most are headwaters to the larger streams of the San Pitch Mountains. Their flow regimes are primarily driven by spring snowmelt and summer thunderstorms. There were 10 diversions, but most streams continued to flow freely. There was a single mine, the Levan Quarry, that likely had limited impact on fluctuations in groundwater and surface water systems. Additional stressors in this LTA were roads and high severity wildfire. There were 12 miles of roads and 71 percent were classified as unimproved. These roads have limited impact, as most headwaters are unaffected. SP_LTAG2 was highly impacted by wildfire, with approximately 15.2 percent of this LTA having

experienced high severity burns. This is the largest percentage of any LTA on the Forest. Climate change had altered temperature and precipitation regimes that drive natural flow dynamics in this LTA. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 0.96 °F warmer than the average temperature of the previous 115 years. The timing and magnitude of precipitation during the same time frame had shifted, primarily during the fall and winter months. Winter precipitation had increased by 0.63 inches and fall precipitation increased by 0.36 inches.

*KEC Status: **Within the NRV***

SP_LTAG3 - Conglomerate Cliffs

This LTA is composed of the Nephi cliffs in the Indianola geologic formation, which is a conglomerate of sandstone and siltstone with moderate to high permeability. Recharge is likely limited by massive and steep cliff faces. There were 81 miles of streams in this LTA and 17 percent were perennial. The flow regimes were driven by spring snowmelt, summer thunderstorms, and groundwater discharge that maintains base flows during dry periods. There were four springs in SP_LTAG3 and all but one was associated with diversions. There were 10 diversions located in this LTA, but their impacts were limited primarily to the Chicken Creek drainage. The two located outside Chicken Creek were near the Forest boundary. While all 9.3 road miles were unimproved, their impact on surface water and groundwater fluctuations were primarily limited to the Chicken Creek drainage. Climate change had moderately altered temperature and precipitation regimes that drive natural flow dynamics. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 0.96 °F warmer than the average temperature of the previous 115 years. The timing and magnitude of precipitation during the same timeframe had changed, with 0.63 more inches occurring during winter months and 0.36 inches more during fall months.

*KEC Status: **Within the NRV***

SP_LTAG4 - Central Plateau

This LTA has complex geology that includes plateaus, mesas, canyons, and mountain slopes made up of sandstone, shale, Flagstaff limestone, and Indianola conglomerates. This geologic setting allows for numerous springs at locations where more permeable formations meet less permeable layers. Flagstaff limestone allows for groundwater infiltration and stores a large amount of groundwater that is discharged to surface water systems and maintains base flow throughout drier seasons. For this reason, this LTA is important for groundwater and surface water systems throughout the San Pitch Mountains region and its surrounding valleys. There were 79 miles of streams in this LTA and 19 percent were perennial. Their natural flow regimes include spring snowmelt, summer thunderstorms, and base flow discharged from groundwater systems. SP_LTAG4 had the largest spring density of all LTAs on the Forest (0.002 springs/acre). There were 45 springs documented and only one was diverted. Many were located in headwater streams, contributing to surface water fluctuations. There were only four

diversions in this LTA and their impact was extremely limited. The primary stressor in this LTA was roads. SP_LTAG4 had the sixth largest road density of all LTAs and the largest road density in San Pitch Mountains LTAs. There were 65 miles of unimproved roads and many were located near springs and in floodplains. Changes in temperature and precipitation in this LTA could have cascading effects to surrounding areas. Climate deviations showed recent changes in temperature and precipitation. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 0.96 °F warmer than the average temperature of the previous 115 years. Precipitation regimes during the same timeframe had shifted, receiving more precipitation in fall and winter months.

*KEC Status: **Within the NRV***

SP_LTAG5 - North Eastern Canyons

This LTA consists of steep, mountainous canyons in both the Indianola and Price River formations. Both formations are conglomerates composed of shale, sandstone, and siltstone. Some of the sandstone is moderately permeable and both formations have strong hydrologic connections between groundwater and surface water systems in their fractures and faults. This LTA is important for groundwater recharge as the geologic formations yield large quantities of water to several springs in lower valleys. There were 66 miles of streams in this LTA and nearly all were intermittent headwaters, with only 1 percent classified as perennial. There were no mines in SP_LTAG5 and there was limited impact from diversions. There were five diversions and most were within private inholdings near the Forest boundary. Their impacts were limited as the diversions were localized and most streams flowed freely. The primary stressor to groundwater and surface water fluctuations in this LTA was roads. Road density was low (0.0009 road miles/acre), but the roads that existed were unimproved and located in floodplains and near springs. There were six springs and five had roads located near them. Climate change had affected temperature and precipitation regimes that drive natural flow dynamics. Temperatures had increased in all four seasons, with the average winter temperature between 2010 and 2014 being 0.66 °F warmer than the average temperature of the previous 115 years. The timing and magnitude of precipitation events had shifted during the same timeframe, with larger amounts observed in all seasons (7 percent increase in fall; 15 percent increase in winter; 5 percent increase in spring; 5 percent increase in summer).

*KEC Status: **Within the NRV***

SP_LTAG6 - Eastern Front Benches and Cliffs

SP_LTAG6 is the second smallest LTA in the MLSNF. It had 10 stream miles and the majority were in Wales Canyon. About 29 percent of the streams were perennial. There were three springs, all located in Wales Canyon and all impacted by Wales Canyon Road. There were 16 diversions and 13 were located in the Wales Canyon drainage near the Forest boundary. The geology is primarily conglomerate cliffs with outcrops of Flagstaff limestone and the North Horn formation sandstone and shale.

Groundwater recharge likely occurs in permeable faults, sandstones, and the Flagstaff limestone. There were two sand and gravel mines that may have affected direction and amounts of flows but likely had limited impacts. The climate of this LTA deviated from historic precipitation and temperature norms. Temperatures increased in all four seasons, with the average winter temperature between 2010 and 2014 being 0.96 °F warmer than the average temperature of the previous 115 years. Precipitation during the same time frame had increased in fall, winter, and spring by 9 percent, 13 percent, and 3 percent, respectively. Summer precipitation had not significantly changed.

*KEC Status: **Within the NRV***

Wasatch Plateau

MSL_LTAG1 - Mancos Shale Lowlands

Groundwater infiltration in this LTA is likely limited by the prevalent shale geologic setting, but there may be significant hydrologic connections between surface and groundwater systems through faulting. There were 75 stream miles in this LTA and 5.1 percent were perennial. There were no springs documented and therefore surface water flows were dependent on snowmelt from higher elevation LTAs and summer thunderstorms. There were 26 diversions, with most located in the northern section near the Forest boundary. There was a single mine, the Gordan Creek gas field, used for extraction of natural gas. High severity burns (1.3 percent of LTA) in the watersheds of streams in this LTA may have impacted natural hydrologic connectivity and the timing, frequency, and magnitude of peak flows. Surface and groundwater fluctuations in this LTA were altered by changes in precipitation and temperature regimes due to climate change. Temperatures increased in all four seasons with the average winter temperature between 2010 and 2014 being 1.17 °F warmer than the average temperature of the previous 115 years. Precipitation regimes during the same timeframe shifted in the timing and magnitude of events. Winter precipitation decreased by 0.25 inches. Additionally, fall and summer precipitation increased by 10 percent and 20 percent, respectively.

*KEC Status: **Trending Toward the NRV***

WP_LTAG1 - Western Front Lower Canyon Slopes

This lower-elevation LTA includes main stems of many streams that drain the western front of the Wasatch Plateau and some small tributaries. Their natural flow regimes include spring snowmelt, summer thunderstorms, and base flows maintained by groundwater discharge. There were 121 stream miles in this LTA and 52 percent were perennial, indicative of good base flow sources. The floodplain of Twelvemile Creek continues to show evidence of large seasonal fluctuations, with peak flow occurring in late spring or early summer. An irrigation well in the Twelvemile drainage experiences a water level rise from April to July and then declines through following year, indicating regular infiltration to groundwater systems from snowmelt. There were 12 springs in this LTA and 4 were unimpacted by diversions. There was an extensive network of 10 dams and 180 diversions. Roads were an additional stressor in this LTA. There were 45 miles of unimproved roads, many of which were located in the 50-year floodplain and crossing streams.

Climate change altered temperature and precipitation regimes that drive natural flow dynamics in this LTA. Overall, temperatures increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.18 °F warmer than the average temperature of the previous 115 years. Changes in precipitation during the same timeframe were variable. Winter precipitation increased by 0.51 inches in some locations within this LTA but decreased by up to 0.45 inches in other locations. Precipitation increased during fall, spring, and summer by an average of 10 percent, 4 percent, and 13 percent, respectively.

*KEC Status: **Trending Toward the NRV***

WP_LTAG2 - Western Mountains and Basins

This is a large, high-elevation LTA with the headwaters of streams that drain both the eastern and western sides of the Wasatch Plateau. There were 531 miles of stream and 48 percent were perennial. The glacial basins of this LTA allow for strong connections between surface and groundwater systems. There were 100 springs, the most of any LTA in the Wasatch Plateau. Hydrologic connectivity was disrupted by an extensive network of 43 dams and 1,121 diversions, more than any other LTA in the region. There were five mines: three sand and gravel, one iron, and one lead and silver. Their impacts were extremely localized and limited. Additional stressors included roads and recreation. This LTA had 253 miles of road, 210 of which were unimproved. There were 347 dispersed campsites, with many located near springs and wetlands. Climate change altered temperature and precipitation regimes. The average winter temperature between 2010 and 2014 was 1.52 °F warmer than the average winter temperature of the previous 115 years and temperatures in the 3 other seasons also had increased. Winter precipitation during the same timeframe decreased by 0.36 inches on average. Precipitation increased during fall and summer seasons by 12 percent and 17 percent, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG3 - Western Front Flat Iron Ridges

This is a small, lower-elevation LTA on the western front of the Wasatch Plateau. The dip slopes limit hydrologic systems and connectivity between groundwater and surface water systems. There were 73 miles of streams and 19 percent were perennial. All were small order headwater and tributary streams. There were 11 documented springs. There were 19 diversions, which was the lowest diversion density (0.0006 diversions/acre) in the region. There were 16 dams, the fourth largest dam density (0.0005 dams/acre) of the Wasatch Plateau. Roads were an additional stressor in this LTA as it had the second largest road density (0.00248 road miles/acre) in the region. All of the roads were unimproved. Climate change altered temperature and precipitation regimes. The average winter temperature between 2010 and 2014 was 1.34 °F warmer than the average winter temperature of the previous 115 years and the temperatures of all other seasons also had increased. Precipitation regimes during the same timeframe shifted variably throughout this LTA. Winter precipitation decreased by up to 0.45 inches in some locations but increased in other locations by up to 0.51 inches. Summer

precipitation increased by 0.24 to 0.74 inches. Fall precipitation increased by 0.15 to 0.72 inches.

*KEC Status: **Outside of the NRV***

WP_LTAG4 - Western Mountain Plateau Top

This LTA consists of plateau tops in Flagstaff limestone, which has high recharge potential due to fractures and solution openings. This geologic formation is responsible for most infiltration and storage of groundwater in the Wasatch Plateau. It is especially important for groundwater and surface water fluctuations throughout the region and is likely particularly sensitive to stressors. There were 83 miles of streams and 26 percent were perennial. Many were higher elevation headwater streams. This LTA had 51 springs and the largest spring density of LTAs in the Wasatch Plateau, indicating strong connectivity between ground and surface water systems and a good source for summer base flows. There were 317 diversions, the fourth largest diversion density in the region. The majority of these diversions were located at springs. There were three sand and gravel mines, but their impact was extremely localized and limited. An additional stressor in this LTA was roads, as it had the largest road density of all forest LTAs (0.003 miles/acre). Over 100 miles of roads were unimproved. Many streams had headwaters located in this LTA with spring sources, so alterations to surface and groundwater connectivity in this LTA can affect natural flow regimes throughout the region. Climate change altered the temperature and precipitation regimes that drive natural flow dynamics. Temperatures increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.55 °F warmer than the average winter temperature of the previous 115 years. The timing and magnitude of precipitation during the same timeframe shifted, with 0.40 inches less occurring during winter months. Precipitation increased in fall and summer months by 12 percent and 18 percent, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG5 - Western Mountain Mid-Mountain Benches

This is a small LTA with limited aquatic resources that were primarily headwater streams to larger, lower-elevation systems. There were 97 miles of streams and 58 percent were perennial. Their natural flow regimes reflect spring snowmelt, summer thunderstorms, and base flow conditions maintained by discharge from groundwater systems. However, the sandstone and shale of the North Horn formation in this LTA likely limits hydrologic connectivity. This was reflected in the low number of springs (four). All of these springs were headwater sources to streams in lower LTAs and three were associated with diversions or dispersed campsites. There were two sand and gravel mines, but their influence was localized and limited. This LTA had the third largest diversion density (0.009 diversions/acre) of the region. Additionally, 1.5 percent of vegetation was impacted by insects and disease. There were 90 miles of roads and 82 percent were unimproved. Many roads crossed headwater streams. Climate change altered temperature and precipitation regimes that drive natural flow dynamics in this LTA. Temperatures in all four seasons increased, with the average winter temperature between 2010 and 2014 being

1.58 °F warmer than the average winter temperature of the previous 115 years. Additionally, winter precipitation during the same timeframe decreased by 0.45 inches. Spring, summer, and fall precipitation increased by 0.12 inches, 0.74 inches, and 0.57 inches, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG6 - Western Mountain SE Lower Slopes

This is a medium sized LTA with several small tributaries to the large streams that drain the eastern front of the Wasatch Plateau. There were 150 miles of streams and 38 percent were perennial. The natural flow regimes are influenced by spring snowmelt, summer thunderstorms, and base flows supported by discharge from groundwater sources. There were seven springs, five of which were associated with diversions. Dispersed campsites were located at five of the springs. There were 288 diversions in this LTA and there was at least 1 located along every major stream. Additionally, this LTA had the second largest dam density (0.0006 dams/acre) of LTAs in the region. There were six limestone mines, but their impact was fairly localized. There were 45 miles of roads and 81 percent were unimproved. Most were located on hillslopes, but many crossed headwater streams. Climate change affected the temperature and precipitation regimes in this LTA with implications for natural flow dynamics. Temperatures increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.58 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe decreased by 0.45 inches and summer and fall precipitation increased substantially, by 0.57 inches and 0.74 inches, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG7 - Southern Tablelands

This is a small LTA with low order headwater and tributary streams. There were 84 miles of streams and 6 percent were perennial. Their flow regimes included spring snowmelt and summer thunderstorms. The geology of this LTA is primarily tablelands and canyon rims composed of sandstone and shale that limit connectivity between surface and groundwater systems. There were four springs and three were impacted by diversions or dams. There were 155 diversions and 36 dams. This LTA had the largest dam density (0.001 dams/acre) of Wasatch Plateau LTAs. There were three limestone mines, but their impact was localized. This LTA had the third largest road density (0.002 miles/acre) of the region and approximately 90 miles of road (99 percent) were unimproved. Climate change altered temperature and precipitation regimes that drive natural flow dynamics in this LTA. The average winter temperature between 2010 and 2014 was 1.58 °F warmer than the average winter temperature of the previous 115 years and temperatures in the three other seasons were warmer as well. Additionally, winter precipitation during the same timeframe decreased by 0.45 inches, while fall and summer precipitation increased by 0.57 inches and 0.74 inches, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG8 - Northern Fault Valleys

This LTA contains many headwaters and tributaries to the large streams that drain the eastern side of the Wasatch Plateau. There were 103 miles of streams and 55 percent were perennial. Their natural flow regimes include spring snowmelt, summer thunderstorms, and base flow maintained by discharge from groundwater systems. This LTA's geology allows for high degrees of connectivity between surface and groundwater systems. It had 12 springs and the second largest amount of lake and pond acres of all Wasatch Plateau LTAs (753 acres). All of the documented springs remained unaltered by diversions, but lakes and ponds had numerous diversions and dams impacting their structure and function. This LTA was highly impacted by diversions, with the highest diversion density (0.014 diversions/acre) of LTAs in this region. There were several reservoirs located in WP_LTAG8 (Beaver Dam, Cleveland, Huntington, Little Madsen, Lower Gooseberry, Miller Flat, and Rolfson), all of which altered natural hydrologic networks and the timing and magnitude of fluctuations in surface and groundwater levels. Additional stressors in this LTA were roads and vegetation mortality due to insect and disease. There were 77 miles of roads and 53 percent were classified as unimproved. Many of these roads were located within floodplains, crossing channels, and near springs. WP_LTAG8 had the second largest amount of vegetation affected by insect and disease (1.6 percent) of LTAs in this region. Climate change affected the temperature and precipitation regimes that drive natural flow dynamics in this LTA. Temperatures increased during all four seasons, with the average winter temperature between 2010 and 2014 being 1.56 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe decreased by 0.42 inches on average. Fall and summer precipitation substantially increased, by 0.59 inches and 0.71 inches, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG9 - Southern Fault Valleys

This LTA includes some of the larger streams and their tributaries that drain the eastern side of the Wasatch Plateau, such as Ferron and Muddy Creeks. There were 153 miles of streams and 21 percent were perennial. Their flow regimes included spring snowmelt, summer thunderstorms, and base flow conditions maintained by groundwater discharge. The highly fractured fault character of this LTA may allow for some hydrologic connectivity. There were five springs in this LTA and only one was associated with a diversion. However, a majority of the small wetlands had at least one diversion that altered connectivity between ground and surface water systems. There were 203 diversions and nine dams in this LTA, including the dam that regulates Joes Valley Reservoir. The diversion density in this LTA was not especially high, but some streams had numerous diversions altering the natural timing and magnitude of fluctuations in discharge. There were four sand and gravel mines located near streams that drain into Joes Valley Reservoir that may have impacted amounts or direction of flow, but any effects were localized. Climate change altered temperature and precipitation regimes that drive natural flow dynamics. Temperatures increased in all four

seasons, with the average winter temperature between 2010 and 2014 being 1.42 °F warmer than the average winter temperature of the previous 115 years. Additionally, winter precipitation during the same timeframe decreased by 0.37 inches on average. Fall and summer precipitation increased by 0.51 inches and 0.69 inches, respectively.

*KEC Status: **Outside** of the NRV*

WP_LTAG10 - Eastern Mountains Upper Canyon Slopes

This LTA has diverse geology with limestone, sandstone, and shale. Limestone allows for infiltration and provides a large amount of groundwater storage. Springs occur in locations where Flagstaff limestone meets the impermeable North Formation sandstone and shale. These hydrologic connections were reflected in the high spring density (0.0005 springs/acre). This LTA includes some of the larger streams that drain the Wasatch Plateau and their tributaries. There were 186 stream miles and 40 percent were perennial. Their flow regimes include spring snowmelt, summer thunderstorms, and base flows maintained by discharge from groundwater systems. Natural networks were altered by dams and diversions, with many diversions located at documented springs. There were 876 diversions, the second largest diversion density of LTAs in the region. A portion of this LTA includes private inholdings, where many of the diversions were located. Electric Lake is a large reservoir and the dam that created it has altered the natural flow regime of Huntington Creek, one of the major streams in this LTA. Coal mining may have impacted the amount and direction of flow within and between ground and surface water systems, as 26 percent of this LTA has coal leases. Additionally, there were five limestone mines. Additional stressors in this LTA included high severity fire, roads, and vegetation mortality due to insect and disease. Approximately 6 percent of this LTA had burned at high severity. There were 104 miles of roads and 80 percent were unimproved. Many of these roads were located in floodplains, crossing streams, and near springs. Lastly, this LTA had the largest percentage of land affected by insect and disease of all land types in this region (1.8 percent). Climate change altered temperature and precipitation regimes that drive natural flow dynamics. Temperatures in all four seasons increased, with the average winter temperature between 2010 and 2014 being 1.58 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe decreased by 0.45 inches, while fall and summer precipitation substantially increased by 0.57 inches and 0.74 inches, respectively.

*KEC Status: **Outside** of the NRV*

WP_LTAG11 - Eastern Mountains Lower Canyon Slopes

This LTA includes the main stem of Huntington Creek, as well as many of its tributaries and some additional small headwaters. The construction of Electric Lake Reservoir changed the flow regime of Huntington Creek from one dominated by snowmelt runoff to a regulated pattern. There were 156 miles of streams and 28 percent were perennial. There were 31 springs that were likely located at faults or places where limestone formations meet

shale. The hydrologic connectivity was altered by an extensive network of diversions, with 557 located in this LTA. There were also 27 dams, primarily impacting small tributaries within private inholdings. The impacts of these diversions continued to impact flow downstream from inholdings. Additional stressors included roads and high severity wildfire. There were 113 miles of roads and 58 percent were unimproved. While this LTA had a relatively low road density (0.001 miles/acre), many of the streams had roads located in their floodplains including Cottonwood and Huntington Creeks. Groundwater and surface water fluctuations and connections were potentially altered by wildfire, as 7.4 percent of this LTA experienced high severity burns. Climate change impacted temperature and precipitation regimes that drive natural flow dynamics in this LTA. Temperatures increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.58 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe decreased by 0.45 inches, while fall and summer precipitation increased by 0.57 inches and 0.74 inches, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG12 - Rocky Canyons

This is a small LTA, but it contains the main stems of three large streams that drain the eastern side of the Wasatch Plateau. These streams include Muddy, Ferron, and North Fork Quitcupah Creeks, and the stream that drains Joes Valley Reservoir. These streams experience high flows from spring snowmelt, summer thunderstorms, and base flows maintained by discharge from groundwater sources. There were 74 miles of streams in this LTA and 61 percent were perennial. The sandstone and shale geology of this LTA limit the hydrologic connectivity between surface and groundwater systems. There were no springs and the capacity for infiltration was low. There were four drainages in this LTA and three of them were highly impacted with multiple diversions located in headwaters and along the main stem of the drainages. There were 73 diversions and 8 dams. This LTA had the third largest dam density (0.005 dams/acre) of the region. These likely altered the timing, frequency, and magnitude of fluctuations in surface water, particularly in the stream draining Joes Valley Reservoir. There were no mines in this LTA and the only road of concern follows the stream that drains Joes Valley Reservoir. Climate change altered temperature and precipitation regimes that drive natural flow dynamics in this LTA. Temperatures in all four seasons increased, with the average winter temperature between 2010 and 2014 being 1.58 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe decreased by 0.45 inches, or 7 percent. Fall and summer precipitation increased by 0.57 inches and 0.74 inches, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG13 - Eastern Escarpment

This LTA is small and the streams are primarily tributaries. There were 119 miles of streams and 18 percent were perennial. Their fluctuations

were driven by spring snowmelt and summer thunderstorms. Hydrologic connectivity between ground and surface water systems is limited in WP_LTAG13 due to its sandstone and shale geology. There were only three springs, the second lowest spring density in the Wasatch Plateau region. All three springs were impacted by diversions, of which there were 162 in this LTA. Most of the surface water was in headwaters and all experienced flow alterations from diversions. There were also 14 dams impacting natural flow regimes in this LTA. Approximately 11.6 percent of this LTA experienced high severity burns, the second largest of land types in this region. These high severity fires may have had limited impact on groundwater and surface water fluctuations as the geology of WP_LTAG13 is naturally impermeable. Climate change altered the temperature and precipitation regimes that drive natural flow dynamics in this LTA. Temperatures increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.27 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe decreased by 0.29 inches on average and fall and summer precipitation increased by 0.45 inches and 0.64 inches, respectively.

*KEC Status: **Trending Toward the NRV***

WP_LTAG14 - Northern Slope

This small LTA on the northern slope primarily contains the headwaters of Mill Creek. There were 52 miles of streams and 29 percent were perennial. Their natural flow regimes include spring snowmelt and summer thunderstorms. There is naturally low hydrologic connectivity between ground and surface water systems in this LTA and little groundwater recharge potential due to geology and climate. There were only two springs and they were surrounded by diversions. There were 36 diversions in WP_LTAG14 with most located in the headwaters of larger streams. There were also two dams. Vegetation mortality due to insects and disease was an additional stressor and had affected 1.11 percent of this LTA. This die-off may have altered natural fluctuations of surface and groundwater levels. Climate change affected temperature and precipitation regimes that drive natural groundwater and surface water fluctuations. Temperatures in all four seasons increased, with the average winter temperature between 2010 and 2014 being 1.54 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe decreased by 0.37 inches on average. Fall and summer precipitation increased by 0.62 inches and 0.66 inches, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG15 - Thistle Highlands Western Slopes

The semiarid climate of this LTA and the sandstone and shale geology inhibit groundwater recharge potential and surface water flows. There were 77 stream miles and 36 percent were perennial. These include Little Clear and Lake Fork Creeks and many smaller tributaries. There were 10 springs located in this LTA, suggesting moderate connection between surface and groundwater systems. There were 118 diversions and 5 dams. The majority

of springs were impacted by diversions and the surface water fluctuations of Little Clear Creek and Lake Fork Creek were highly impacted by diversions. Smiths Reservoir is located in this LTA. It is small in size and likely had little influence on surface and groundwater systems near it, but its regulation may have influenced the hydrographs of downstream systems. There were two mines, one gypsum-anhydrite and one for stone. They were both located near the Forest boundary and likely had limited impact on surface water and groundwater fluctuations. There were 74 road miles, 66 percent of which were unimproved and many were located within floodplains and near springs. Climate change impacted temperature and precipitation regimes that drive surface water and groundwater fluctuations in this LTA. Temperatures in all four seasons increased, with the average winter temperature between 2010 and 2014 being 1.39 °F warmer than the average winter temperature of the previous 115 years. Changes in winter precipitation during the same timeframe were highly variable. In some locations it decreased by up to 0.45 inches but increased by 0.51 inches in other locations. Similarly, spring precipitation decreased by up to 0.23 inches in some locations and increased by up to 0.21 inches in others. Fall and summer precipitation increased by 0.48 inches and 0.38 inches, respectively.

*KEC Status: **Outside of the NRV***

WP_LTAG16 - Thistle Highlands North Eastern Slopes

This is a small LTA on the northern slopes of the Wasatch Plateau that contains mostly small order headwaters and the main stem of Lake Fork Creek. There were 46 miles of streams and 31 percent were perennial. Their natural flow regimes include spring snowmelt and summer thunderstorms. Infiltration, water storage, and hydrologic connectivity were limited in this LTA by its sandstone and shale geology. There were 8 springs and all were located near diversions, of which there were 48. All of the diversions were positioned in headwater streams. There was a single dam in WP_LTAG16 and no mines. Additional stressors in this LTA included roads, vegetation mortality due to insects and disease, and high severity wildfire. There were only 12 miles of roads, but 72 percent were unimproved and they were entirely located within floodplains and crossing channels. Insects and disease may have had limited impacts on groundwater and surface water fluctuations, with 1.4 percent of the vegetation affected. Approximately 2.4 percent of this LTA experienced high severity wildfire, but the effects may be limited due to the natural impermeability of the geologic setting. Temperatures increased in all four seasons, with the average winter temperature between 2010 and 2014 being 1.60 °F warmer than the average winter temperature of the previous 115 years. Winter precipitation during the same timeframe decreased by 0.40 inches, while fall and summer precipitation both increased by 0.49 inches.

*KEC Status: **Outside of the NRV***

Appendix C—LTA Summaries: Channel and Streambank Stability

Abajo Mountains

A_LTAG1 - Igneous Mountains

This LTA overlapped six cattle grazing allotments (20,147 acres).

KEC Status: Insufficient Information

A_LTAG2 - Shay Mountain

This LTA overlapped two cattle grazing allotments (8,149 acres). The steep topography of this LTA could potentially protect floodplains from the impacts of livestock and wild ungulates.

KEC Status: Insufficient Information

A_LTAG3 - Alluvial Fans and Plains

This LTA overlapped nine cattle grazing allotments (50,812 acres). Two of the allotments formed a small percentage of the LTA. However, A_LTAG3 covered all or the majority of the remaining seven allotments. Stream channels and banks were evaluated at Dry Wash PFC site in 2008 and at a greenline vegetation transect in Gold Queen Basin in 2011 and 2016. The Dry Wash site had stabilizing vegetation, adequate ground cover, and was vertically stable. It was determined to be in properly functioning condition. The PFC reports indicated that diversions and roads in upland watersheds were contributing to channel and floodplain degradation in some locations. The reports also captured mild impacts from livestock grazing including trailing and incised channels with limited access to their floodplains. However, stream banks were somewhat stabilized by rocky channels. Cottonwood and wild rose were regenerating where surface flows were not diverted. The greenline transect was located in a riparian complex in Gold Queen Basin that was dominated by hairgrass and sedge (table C1). This vegetation community had a stability score near 6 (out of 10) in 2011 and 2016 (table C2). The amount of late-seral vegetation was great enough to meet desired conditions and ground cover was above 90 percent both years (table C2). The trend was determined to be stable in 2016.

KEC Status: Trending Toward the NRV

A_LTAG4 - Landslides Terrain

The LTA overlapped eight cattle grazing allotments (5,342 acres). It was a sum of multiple smaller areas, which is why it overlapped several allotments, but the percentage in each allotment was small. Stream channels and banks were evaluated at Dry Wash PFC site in 2008. This site had stabilizing vegetation and was vertically stable. It did not have adequate ground cover and was not determined to be in properly functioning condition.

In addition, banks were altered by disturbances such as hoof action, trails, and roads. Lack of willow cover and reproduction was noted as well.

KEC Status: Insufficient Information

A_LTAG5 - Shay Mountain Colluvial Slopes and Fans

This LTA overlapped three cattle grazing allotments, (11,546 acres), but much of the area is inaccessible to livestock.

KEC Status: Insufficient Information

MC_LTAG1 - Lower Mesas

This LTA overlapped nine cattle grazing allotments (34,445 acres), but much of its area was inaccessible to livestock. A small portion of six allotments was in the LTA, with two others forming about half or a third of the LTA. This LTA covered most of the Chippean allotment, which has been closed to grazing since the mid-1990s.

KEC Status: Insufficient Information

MC_LTAG2 - Mid-Elevation Mesas

This LTA overlapped eight cattle grazing allotment (42,184 acres), but one of them is closed to grazing (Chippean).

KEC Status: Insufficient Information

MC_LTAG3 - Higher Elevation Mesas

This LTA overlapped six cattle grazing allotments (101,305 acres). The LTA covered most of the Gooseberry (under non-use since 2002) and Bears Ears allotments and much of the Cottonwood allotment. Four stream sites were visited to evaluate PFC in 2008 or 2009. Of these sites, three had stabilizing vegetation and adequate ground cover. It could only be determined that one site was vertically stable. Three sites were determined to be in properly functioning condition. PFC reports described impacts to channel structure from livestock. Trailing and incised streams indicated overuse in some areas. Some streams were instable both vertically and laterally. Beaver dams in this LTA were noted to be stabilizing headcuts and increasing plant diversity. Stabilizing vegetation was recovering along some stream banks, but still showed signs of grazing. In 2009, sedges were reestablishing on banks of a stream that was previously overused by livestock. Sedges and horsetails (*Equisetum* spp.) were present in Trough Canyon, but rushes were absent. At least two species of willows were present in Trough Canyon, but recruitment of young willows was not observed.

KEC Status: Trending Toward the NRV

MC_LTG4 - Canyon Slopes

This LTA overlapped five cattle grazing allotments. It covered almost the entire Dark Canyon Wilderness area (two-thirds of which was closed to grazing when the wilderness was established) of the Twin Springs allotment. It also covered the Hammond and Arch Canyon areas. A stream site at

Cottonwood Creek was visited to evaluate PFC in 2008. This site had sparse but stabilizing vegetation and was determined to be in properly functioning condition. The PFC report indicated that this and other streams in the LTA were not in balance with water and sediment sources and were especially sensitive to impacts from livestock grazing.

KEC Status: *Insufficient Information*

MC_LTAG5 - Canyon Bottomlands

This LTA overlapped seven cattle grazing allotments. Combined, MC_LTAG4 and MC_LTAG5 included 74,897 allotment acres. Most of MC_LTAG5 is in the Dark Canyon Wilderness area and Hammond Canyon. Three stream sites were visited for evaluation in 2005 or 2008 and greenline vegetation was measured in Dark Canyon in 2006. Of these sites, all had stabilizing vegetation and adequate ground cover. Two sites were vertically stable. All three sites were determined to be in properly functioning condition. The reports indicated that increased road and ATV trail use has created headcuts in some streams and that these systems were exceptionally vulnerable to this type of disturbance. Riparian vegetation in some locations was diverse in age and composition and in many locations was sufficient to protect stream banks from erosion. The canyons in this LTA contained a diverse mixture of stabilizing vegetation including late-seral sedges, rushes, several willow species, cottonwood, boxelder, and alder. Vigorous growth and reproduction of cottonwood and willows was noted in Allen Canyon and Dark Canyon.

KEC Status: *Within the NRV*

La Sal Mountains and Borderlands

LSM_LTAG1 - La Sal Mountain Alluvial Fans and Glacial Moraines

This LTA overlapped eight cattle grazing allotments (14,798 acres). Stream channels and banks were evaluated at seven PFC sites in 2008 and at three greenline vegetation transects in 2011 and 2016. Of the seven PFC sites, six had stabilizing vegetation, had adequate ground cover, and were vertically stable. Five sites were determined to be in properly functioning condition. Disturbance from livestock grazing included trailing, trampling, widened channels, flattened banks, and incised channels. Beaver activity and recruitment of large wood created channel complexity and vegetation were noted to be stabilizing streambanks in some locations. The greenline transects were located in riparian complexes dominated by alder, willow, seeded grasses, and mesic graminoids (table C1). These vegetation communities produced stability scores greater than 6 at each transect measured in 2011 and 2016 (table C2). The amount of late-seral vegetation was not great enough to meet desired conditions at transects surveyed in 2011 but was great enough to meet desired conditions at one transect surveyed in 2016. Ground cover was above 90 percent at each transect (table C2). All three transects measured in 2016 were determined to have an upward trend.

KEC Status: *Trending Toward the NRV*

LSM_LTAG2 - La Sal Mountain Mid-Slopes and Passes

This LTA overlapped six cattle grazing allotments (19,447 acres). Stream channels and banks were evaluated at two greenline transects in 2009. One transect was in Moonlight Meadows and the other was at Geyser Creek. These transects were located in a riparian complex dominated by herbaceous vegetation with stability scores of 9.8 and 6.9.

KEC Status: Insufficient Information

LSM_LTAG3 - La Sal Mountain Peaks

This LTA overlapped five cattle grazing allotments (6,014 acres), but much of its area is inaccessible to livestock. Riparian ecosystems were largely absent in this LTA.

KEC Status: Insufficient Information

LSMB_LTAG1 - Upper Till Covered Mesas

This LTA overlapped five cattle grazing allotments (4,534 acres). Riparian ecosystems were largely absent in this LTA.

KEC Status: Insufficient Information

LSMB_LTAG2 - Lower Sandstone and Till Covered Mesas

This LTA overlapped 10 cattle grazing allotments (26,920 acres). Documented impacts were few but included trampling of banks and hoof action at spring headwaters.

KEC Status: Insufficient Information

LSMB_LTAG3 - Dissected Mesas

This LTA overlapped four cattle grazing allotments (9,773 acres).

KEC Status: Insufficient Information

LSMB_LTAG4 - Southern Alluvial Fans

This LTA overlapped four cattle grazing allotments (14,062 acres). Stream channels and banks were evaluated at two PFC sites in 2008 and at three greenline transects measured in 2011 and 2016. Both PFC sites were vertically stable, but only one site had stabilizing vegetation. Neither site was determined to be in properly functioning condition. Stream channels in this LTA have been trampled and over-widened by grazing livestock. Additionally, cattle trails provided an unnatural source of sediment. Thick vegetation in some locations excluded livestock and protected channels. Plant communities were an adequate source of large woody debris, but it was documented that in some locations vegetation was not functionally stabilizing banks. The riparian complexes surveyed by greenline transects were dominated by willow, alder, and grasses (table C1). These vegetation communities produced stability scores greater than 5 at each transect in 2011 and 2016 (table C2). The amount of late-seral vegetation was not adequate to meet desired conditions at transects surveyed in 2011 or 2016. Ground

cover was above 85 percent at each transect (table C2). Of the two transects measured in 2016, one was determined to have an upward trend, the other a slightly upward trend.

*KEC Status: **Outside of the NRV***

LSMB_LTAG5 - Eastern Moraines and Slopes

The LTA overlapped six cattle grazing allotments (5,969 acres). Stream channels and banks were evaluated at five PFC sites in 2008 or 2011 and at one greenline transect in 2011 and 2016. Of the five PFC sites, four had stabilizing vegetation and two had adequate ground cover and were vertically stable. Only one site was determined to be in properly functioning condition. Understories of sedge were noted at some locations and provided bank stability where present. Plant communities were good sources of large woody debris that stabilized streams. Most functional stream reaches were located in steep, narrow valleys where livestock use and road construction were limited. Overgrazing occurred in open sections of streams and cut banks, trampling, trailing, stream widening, floodplain trampling, and incision continued to be problems. Despite heavy grazing pressure, some reaches appeared to be recovering, with improved vegetative cover, narrowing of channels, and stabilization of banks. Some streams were improving slower than others, likely because they lacked frequent flooding. Several streams continued to show degradation resulting from an historic clearcut on State lands in the upland watersheds. Willows and other woody plants were present at some PFC sites, such as Upper Beaver Creek, but absent in others, such as South Fork Beaver Creek due to geology, surface flow diversion, and livestock use. There were no signs of willow reproduction below diversions on South Fork Beaver Creek. The greenline transect was located in a riparian complex dominated by grass and late-seral sedges (table C1). This vegetation community produced stability scores greater than 6 in 2011 and 2016 (table C2). The amount of late-seral vegetation was great enough to meet desired conditions in 2011 and in 2016. Ground cover was above 85 percent each year (table C2). There was an increase in mature willows and other deciduous species between 2011 and 2016 at Chicken Creek. The transect measured in 2016 was determined to have an upward trend.

*KEC Status: **Trending Toward the NRV***

LSMB_LTAG6 - Eastern Ponderosa Pine Covered Mesas

This LTA overlapped seven cattle grazing allotments (32,521 acres). Stream channels and banks were evaluated at eight PFC sites in 2008, 2010, or 2011 and at three greenline transects in 2011 and 2016. Of the eight PFC sites, six had stabilizing vegetation and adequate ground cover and four were vertically stable. Four sites were determined to be in properly functioning condition. Roads, ATV trails, and dispersed campsites in floodplains were additional unnatural sources of sediment and impacted channel structure. Fine sediment was documented as disrupting ecosystem function. Robust alder was regenerating and increasing at the PFC site at Beaver Creek. Aspen and willow were not regenerating at the Hop Creek PFC site. Willows and aspen were regenerating at Chicken Creek, but young willows were browsed.

There was strong evidence of overgrazing from livestock. Heavy use resulted in trampling, trailing, raw banks, erosion, incision, and severe headcutting. These effects were especially pronounced in drought years where livestock were concentrated in floodplains. According to PFC reports, proper use criteria for streams in this LTA were not met. The greenline transects were located in riparian complexes dominated by seeded and early successional grasses, late-seral sedges, aspen, willow, and alder (table C1). These vegetation communities produced stability scores ranging from 4 to 7 in 2011 and from 5 to 8 in 2016 (table C2). The amount of late-seral vegetation was great enough to meet desired conditions at only one transect surveyed in 2011 or 2016. Ground cover was above 60 percent at each transect in 2011 and 85 percent or greater in 2016 (table C2). Of the three transects measured in 2016, one was determined to have an upward trend and the other two had slightly upward trends.

*KEC Status: **Outside of the NRV***

LSMB_LTAG7 - Collapsed Salt Anticlines

This LTA overlapped one cattle grazing allotment (4,374 acres), but most of its area is inaccessible to livestock and contains little forage. In addition, riparian ecosystems were largely absent in this LTA.

*KEC Status: **Insufficient Information***

LSMB_LTAG8 - Rocky Canyons

This LTA overlapped five cattle grazing allotments (13,019 acres), but most grazing was limited to the Twomile Creek watershed. Stream channels and banks were evaluated at a PFC site in 2010 and at a greenline transect in 2011 and 2016, both of which were at Twomile Creek. The PFC site had stabilizing vegetation, had adequate ground cover, and was vertically stable. It was determined to be in properly functioning condition. The greenline transect was located within a riparian complex dominated by alder and late-seral sedges (table C1). This vegetation community had a stability score greater than 7 in 2011 and 2016 (table C2). The amount of late-seral vegetation was great enough to meet desired conditions in 2011 and 2016. Ground cover was at or above 95 percent (table C2). The transect measured in 2016 was determined to have an upward trend.

*KEC Status: **Within the NRV***

LSMB_LTAG9 - Escarpments and Rocky Slopes

This LTA overlapped six cattle grazing allotments (8,036 acres), but most of its area is inaccessible to livestock and contains little forage. In addition, riparian ecosystems were largely absent in this LTA.

*KEC Status: **Insufficient Information***

LSMB_LTAG10 - Southern Graben Valleys

This LTA overlapped four cattle grazing allotments (1,807 acres), but the section located within the MLSNF received little livestock use.

KEC Status: Insufficient Information

San Pitch Mountains

Channel and bank stability in the San Pitch Mountains has been impacted by long-term livestock grazing, floods, debris flows, and other stressors (Kuehn 1984). Streambank stabilization projects and grazing exclosures have been implemented to improve stream conditions (Kuehn 1984, Schoppe 1985). We did not assess this KEC in this geographic unit because field data were unavailable.

Wasatch Plateau

MSL_LTAG1- Mancos Shale Lowlands

This LTA overlapped five cattle grazing allotments (7,577 acres).

KEC Status: Insufficient Information

WP_LTAG1 - Western Front Lower Canyon Slopes

This LTA overlapped one cattle grazing allotment (42 acres) and nine sheep allotments (5,322 acres).

KEC Status: Insufficient Information

WP_LTAG2 - Western Mountains and Basins

This LTA overlapped five cattle grazing allotments (8,924 acres) and 43 sheep allotments (118,215 acres). Stream channels and banks were evaluated at 19 greenline transects in 2012 and 2016. These transects were located in riparian complexes dominated by willows, aspen, sedges, horsetail, early successional grasses, rushes, and various forbs (table C3). Riparian vegetation communities produced stability scores greater than 5 at each transect measured in 2012 and 2016 (table C4). The amount of late-seral vegetation was great enough to meet desired conditions at 90 percent of the surveys conducted in 2012 and 100 percent of the surveys conducted in 2016. Ground cover was above 60 percent at each transect (table C4).

KEC Status: Within the NRV

WP_LTAG3 - Western Front Flat Iron Ridges

This LTA overlapped one cattle grazing allotment (1,544 acres) and five sheep allotments (13,570 acres).

KEC Status: Insufficient Information

WP_LTAG4 - Western Mountain Plateau Top

This LTA overlapped three cattle grazing allotments (3,420 acres) and 22 sheep allotments (26,126 acres). Stream channels and banks were evaluated at eight greenline vegetation transects measured in 2012. These transects were located in riparian complexes dominated by willows, sedges, forbs, and conifers (table C3). Riparian vegetation communities produced stability scores greater than 6 at each transect. The amount of late-seral vegetation was great enough to meet desired conditions at nearly 90 percent of transects. Ground cover was above 75 percent at each transect (table C4).

KEC Status: Within the NRV

WP_LTAG5 - Western Mountain Mid-Mountain Benches

This LTA overlapped three cattle grazing allotments (25,219 acres) and 14 sheep allotments (13,696 acres). Stream channels and banks were evaluated at two greenline vegetation transects in 2012. These transects were located in riparian complexes dominated by late-seral sedges, rushes, and willows (table C3). Riparian vegetation communities produced stability scores greater than 8 at each transect in 2012. The amount of late-seral vegetation was great enough to meet desired conditions and ground cover exceeded 90 percent at each transect (table C4).

*KEC Status: **Within the NRV***

WP_LTAG6 - Western Mountain SE Lower Slopes

This LTA overlapped four cattle grazing allotments (39,807 acres) and 11 sheep allotments (7,663 acres).

*KEC Status: **Insufficient Information***

WP_LTAG7 - Southern Tablelands

This LTA overlapped three cattle grazing allotments (33,910 acres).

*KEC Status: **Insufficient Information***

WP_LTAG8 - Northern Fault Valleys

This LTA overlapped 1 cattle allotment (1,424 acres) and 15 sheep allotments (17,261 acres). Stream channels and banks were evaluated at 10 greenline vegetation transects in 2011, 2012, and 2016. Seven of these transects were initially measured in 2011 and re-measured in 2016. Transects were located in riparian complexes dominated by late-seral sedges, rushes, seeded grasses, and willows (table C3). These vegetation communities produced stability scores greater than 7 at all transects each year (table C4). The amount of late-seral vegetation was great enough to meet desired conditions at each survey as well. Ground cover was above 75 percent at each transect (table C4). Of the transects measured in 2016, six were determined to have a stable trend and one had an upward trend.

*KEC Status: **Within the NRV***

WP_LTAG9 - Southern Fault Valleys

This LTA overlapped five cattle grazing allotments (31,683 acres) and five sheep allotments (3,685 acres).

*KEC Status: **Insufficient Information***

WP_LTAG10 - Eastern Mountains Upper Canyon Slopes

This LTA overlapped five cattle grazing allotments (18,631 acres) and 20 sheep allotments (42,669 acres). Stream channels and banks were evaluated at 22 greenline vegetation transects in 2011, 2012, and 2016. Seven of these transects were initially measured in 2011 and re-measured in 2016. Transects were located in riparian complexes dominated by late-seral sedges, rushes, seeded grasses, mesic forbs, early seral grasses, and willows. These

vegetation communities produced stability scores ranging from 3.9 to 9.0 (table C3). The amount of late-seral vegetation was great enough to meet desired conditions at 50 percent of transects surveyed in 2012 and at greater than 80 percent of transects surveyed in 2011 and 2016. Ground cover was above 75 percent at each transect (table C4). Of transects measured in 2016, five were determined to have stable trends and two had downward or slightly downward trends (table C4).

KEC Status: *Trending Toward the NRV*

WP_LTAG11 - Eastern Mountains Lower Canyon Slopes

This LTA overlapped 5 cattle grazing allotments (51,443 acres) and 12 sheep allotments (25,780). Stream channels and banks were evaluated at a greenline transect measured in 2011 and 2016. The riparian complex was dominated by cottonwood and wild rose vegetation (table C4). This vegetation community produced a stability rating of 6.2 in 2011 and 6.3 in 2016. The amount of late-seral vegetation was low relative to other transects in this area and as a result, the transect did not meet desired conditions in 2011 or 2016 (table C4). The trend was slightly upward in 2016.

KEC Status: *Insufficient Information*

WP_LTAG12 - Rocky Canyons

This LTA overlapped four cattle grazing allotments (13,781 acres) and three sheep allotments (235 acres).

KEC Status: *Insufficient Information*

WP_LTAG13 - Eastern Escarpment

This LTA overlapped nine cattle grazing allotments (33,955 acres) and one sheep allotment (3,068 acres).

KEC Status: *Insufficient Information*

WP_LTAG14 - Northern Slope

This LTA overlapped one cattle grazing allotment (7,456 acres) and five sheep allotments (6,200 acres).

KEC Status: *Insufficient Information*

WP_LTAG15 - Thistle Highlands Western Slopes

This LTA overlapped one cattle grazing allotment (7,780 acres) and one sheep allotment (4,411 acres).

KEC Status: *Insufficient Information*

WP_LTAG16 - Thistle Highlands North Eastern Slopes

This LTA overlapped one cattle grazing allotment (15,291 acres) and one sheep allotment (16 acres).

KEC Status: *Insufficient Information*

Table C1—Riparian complex vegetation types observed at greenline transects in South Zone LTAs.

LTA	Riparian complex vegetation types
A_LTAG3	<i>Deschampsia cespitosa</i> /Carex spp
LSM_LTAG1	<i>Alnus incana</i> /Salix boothii/Phleum pretense; Phleum pratense/Alnus incana; Alnus incana/mesic graminoid
LSMB_LTAG4	<i>Agrostis stolonifera</i> /Salix lasiandra; Agrostis stolonifera/Alnus incana
LSMB_LTAG5	<i>Agrostis stolonifera</i> /Carex aquatilis
LSMB_LTAG6	<i>Poa pratensis</i> /Populus tremuloides; Agrostis stolonifera/Carex utriculata; Carex utriculata/Agrostis stolonifera
LSMB_LTAG8	<i>Alnus incana</i> /Carex utriculata

Table C2—Streambank vegetation and stability results for South Zone LTAs in which Winward greenline data were collected.

LTA	Year	Number of transects	Mean stability score (range)	Mean percentage late seral vegetation (range)	Meeting desired conditions	Mean ground cover (range)
.....Percent.....						
A_LTAG3	2011	1	5.9	93	100	94
	2016	1	6.2	89	100	99
LSM_LTAG1	2011	3	6.4 (6.2-6.6)	30 (26-39)	0	92 (90-95)
	2016	3	7.0 (6.7-7.4)	51 (41-71)	33	95 (94-96)
LSMB_LTAG4	2011	2	5.4 (5.2-5.5)	14 (12-15)	0	93 (88-98)
	2016	2	6.0 (5.9-6.1)	27 (21-33)	0	96 (92-99)
LSMB_LTAG5	2011	1	6.3	51	100	88
	2016	1	7.9	79	100	98
LSMB_LTAG6	2011	3	5.6 (4.4-6.8)	42 (22-67)	33	77 (62-88)
	2016	3	6.4 (5.4-7.6)	46 (28-70)	33	90 (85-98)
LSMB_LTAG8	2011	1	7.3	55	100	95
	2016	1	8.5	90	100	97

Table C3—Riparian complex vegetation types observed at greenline transects in Wasatch Plateau LTAs.

LTA	Riparian complex vegetation types
WP_LTAG2	<i>Carex aquatilis</i> / <i>Carex utriculata</i> ; <i>Carex utriculata</i> / <i>Salix</i> spp.; <i>Carex aquatilis</i> / <i>Carex microptera</i> ; <i>Carex aquatilis</i> / <i>Deschampsia cespitosa</i> ; <i>Salix drummondiana</i> / <i>Equisetum arvense</i> ; <i>Carex aquatilis</i> / <i>Juncus arcticus</i> ; <i>Carex aquatilis</i> / <i>Carex microptera</i> ; <i>Carex utriculata</i> / <i>Carex aquatilis</i> ; <i>Carex utriculata</i> / <i>Deschampsia cespitosa</i> ; <i>Carex utriculata</i> / <i>Salix</i> spp.; Tall forb/ <i>Salix drummondiana</i> / <i>Populus tremuloides</i>
WP_LTAG4	<i>Caltha leptosepala</i> / <i>Carex aquatilis</i> ; <i>Caltha leptosepala</i> / <i>Carex</i> spp.; <i>Caltha leptosepala</i> / <i>Picea engelmannii</i> ; <i>Carex aquatilis</i> / <i>Caltha leptosepala</i> ; <i>Carex aquatilis</i> / <i>Carex utriculata</i> ; <i>Carex aquatilis</i> / <i>Juncus ensifolius</i> ; <i>Carex aquatilis</i> / <i>Salix</i> spp.; <i>Salix drummondiana</i> / <i>Carex aquatilis</i>
WP_LTAG5	<i>Carex utriculata</i> / <i>Juncus arcticus</i> ; <i>Salix boothii</i> / <i>Carex utriculata</i>
WP_LTAG8	<i>Carex aquatilis</i> / <i>Phalaris arundinacea</i> ; <i>Carex aquatilis</i> / <i>Poa pratensis</i> ; <i>Carex aquatilis</i> / <i>Salix boothii</i> ; <i>Carex aquatilis</i> / <i>Salix drummondiana</i> ; <i>Carex aquatilis</i> / <i>Salix</i> spp.; <i>Carex lanuginosa</i> / <i>Carex aquatilis</i> ; <i>Carex</i> / <i>Juncus arcticus</i> ; <i>Juncus arcticus</i> / <i>Salix</i> spp.; <i>Juncus arcticus</i> / <i>Carex aquatilis</i> ; <i>Salix boothii</i> / <i>Carex aquatilis</i>
WP_LTAG10	<i>Carex aquatilis</i> / <i>Poa pratensis</i> ; <i>Carex aquatilis</i> ; <i>Hordeum brachyantherum</i> / <i>Agrostis stolonifera</i> ; <i>Carex aquatilis</i> / <i>Juncus arcticus</i> ; <i>Juncus arcticus</i> / <i>Carex</i> spp.; <i>Carex aquatilis</i> / <i>Carex utriculata</i> ; <i>Salix</i> spp./ <i>Eleocharis</i> spp.; <i>Juncus arcticus</i> / <i>Salix boothii</i> ; <i>Agrostis stolonifera</i> / <i>Juncus arcticus</i> ; <i>Salix</i> spp./ <i>Poa pratensis</i> ; <i>Carex aquatilis</i> / <i>Deschampsia cespitosa</i> ; <i>Alopecurus geniculatus</i> /Tall forb; <i>Carex aquatilis</i> / <i>Salix</i> spp.; <i>Alopecurus geniculatus</i> / <i>Carex aquatilis</i> ;
WP_LTAG11	<i>Populus</i> / <i>Rosa woodsii</i>

Table C4—Streambank vegetation and stability results for North Zone LTAs in which Winward greenline data were collected.

LTA	Year	Number of transects	Mean stability score (range)	Mean percentage late seral vegetation (range)	Meeting desired conditions	Mean ground cover (range)
				Percentage.....		
WP_LTAG2	2012	10	7.4 (5.5-8.7)	79 (47-94)	90	87 (64-97)
	2016	9	8.5 (7.6-9.5)	88 (70-99)	100	95 (90-100)
WP_LTAG4	2012	8	7.5 (6.3-8.8)	65 (24-93)	88	87 (78-96)
WP_LTAG5	2012	2	8.5 (8.3-8.8)	91 (91-92)	100	93 (92-94)
WP_LTAG8	2011	7	8.4 (7.0-9.2)	90 (65-100)	100	90 (77-97)
	2012	3	8.2 (7.4-9.0)	85 (73-95)	100	95 (91-98)
	2016	7	8.7 (7.9-9.3)	94 (78-100)	100	97 (93-99)
WP_LTAG10	2011	7	7.5 (3.9-9.0)	75.8 (18-100)	86	89 (81-99)
	2012	10	7.0 (4.0-8.6)	66 (32-98)	50	94 (78-100)
	2016	12	7.5 (4.9-9.0)	70 (21-96)	85	95 (89-100)
WP_LTAG11	2011	1	6.2	8	0	81
	2016	1	6.3	18	0	93

Appendix D—LTA Summaries: Floodplain Condition

Abajo Mountains

A_LTAG1 - Igneous Mountains

The streams in this LTA were headwater streams with little floodplain development (9 floodplain acres/stream mile). This appeared to be natural for this LTA, as the 50-year floodplain map indicated many floodplains had achieved their full potential extent and nearly all floodplains were classified as confined but unimpacted (table D1). There was an extensive network of dams and diversions, with many located on North and Indian Creeks and unnamed headwaters. A series of diversions removed flow from the Indian Creek drainage and directed it to the Johnson Creek drainage, likely altering the downstream floodplain conditions of both drainages. Furthermore, at least two diversions redirect flow to canals or ditches to be used by the City of Blanding. Roads were located in floodplains and crossing streams of approximately half the drainages of this LTA. Nearly all the roads were classified as unimproved. R-CAT results indicated considerable encroachment of conifers into floodplains at Indian, Spring, Johnson, and Recapture Creeks. Additionally, upland encroachment occurred at Indian Creek (table D2).

KEC Status: Trending Toward the NRV

A_LTAG2 - Shay Mountain

There were no perennial streams in this LTA. The intermittent and ephemeral systems maintained the smallest floodplains in the South Zone of the Forest (8 floodplain acres/stream mile). Lateral movement and sedimentation were generally naturally constrained by mountainous and steep slopes. Assessment of terrestrial conditions indicated that 42.0 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup. This unnatural fuel load may have encouraged conifer encroachment into floodplains or allow extreme fire behavior in the future.

KEC Status: Insufficient Information

A_LTAG3 - Alluvial Fans and Plains

Approximately 5 percent of streams in this LTA were perennial. These streams maintained relatively small floodplains (10 acres/mile) and R-CAT results showed almost all perennial streams were confined but had unimpacted floodplains (table D1). A_LTAG3 had the third largest road density (0.003 miles/acre) of LTAs on the Forest and the largest road density in the Abajo Mountains region. Many of these roads were located in the 50-year floodplain and crossing headwater streams. Additionally, a vast majority were classified as unimproved and were potential unnatural sources of fine sediment and channel disturbance. There were 53 dispersed

campsites in this LTA and many were located within the floodplain and at headwater sources. Lastly, there were numerous dams and diversions present in every drainage, with particularly high numbers in Verdure and Johnson Creeks. PFC reports indicated that diversions and roads in upland watersheds were contributing to channel and floodplain degradation in some locations. R-CAT results indicated considerable encroachment of conifers into the floodplains of North Fork Verdure and Recapture Creeks. Invasive species occurred in the floodplains of this LTA, with 10–25 acres mapped (table D2). Patches of invasives include Canada thistle, field bindweed, and musk thistle (scientific names in table D3). Assessment of terrestrial conditions indicated that 42.9 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup. The unnatural fuel load may have encouraged further conifer encroachment or will lead to extreme fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

A_LTAG4 - Landslides Terrain

This LTA had 34 stream miles and 5 percent were perennial. These streams were limited in their lateral movement and R-CAT results indicated all perennial streams were confined and unimpacted (table D1). On average, streams in this LTA maintained 10 floodplain acres/stream mile and PFC reports indicated that they have not achieved their full potential extent. Additionally, these reports described unbalanced water and sediment inputs and stream channels with unnaturally reduced sinuosity and non-functional width/depth ratios and gradients. While there were few road miles in this LTA, the majority were classified as unimproved and most were located in floodplains and crossing streams. PFC reports indicated that stream banks were altered by disturbances such as hoof action, trails, and roads. Dams and diversions were located in almost every drainage, but PFC reports indicated that floodplains continued to experience regular inundation. Invasive species including Canada thistle, field bindweed, and musk thistle occupy over 20 acres in floodplains of the LTA. Lastly, assessment of terrestrial conditions indicated that 23.1 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup. This unnatural fuel load may lead to conifer encroachment into floodplains or extreme fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

A_LTAG5 - Shay Mountain Colluvial Slopes and Fans

There were 65 stream miles in this LTA and 5 percent were perennial. Floodplain and sediment dynamics in this LTA were dependent on the diverse geological setting. Many headwater streams had fairly straight channels and little lateral movement, but the main stems of both Indian and Hop Creeks meandered and had wide, active floodplains. On average, streams maintained about 9 floodplain acres per stream mile and the majority were confined (table D1). Unimproved roads are an unnatural source of fine sediment, but their impact is localized. Assessment of terrestrial conditions indicated that 32.2 percent of the LTA had high or very high probability of catastrophic fire

due to uncharacteristic fuel buildup. This unnatural fuel load may lead to conifer encroachment or extreme fire behavior in the future.

KEC Status: The Trending Toward the NRV

MC_LTAG1 - Lower Mesas

There were 212 stream miles in this LTA, but less than 1 percent were perennial. Streams in this LTA were generally intermittent headwaters and were located in sandstone mesas with gentle slopes and canyons. Many streams were sinuous and appeared to have active floodplains in at least some locations (11 floodplain acres/stream mile). There were 55 road miles in MC_LTAG1 and nearly all were classified as unimproved. Their impact was likely limited, however, because roads were localized and generally not located in floodplains. A single patch of saltcedar was mapped, occupying approximately 4 acres in a floodplain. Assessment of terrestrial conditions indicated that 43.7 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup. This unnatural fuel load may promote conifer encroachment into floodplains or extreme fire behavior in the future.

KEC Status: Trending Toward the NRV

MC_LTAG2 - Mid-Elevation Mesas

There were 125 stream miles in this LTA, but less than 1 percent were perennial. Channel, floodplain, and sediment dynamics in this LTA are driven by the geologic setting that is generally middle elevation plateaus, mesas, and canyons. Transport of sediment and floodplain development require flooding from snowmelt from higher elevation LTAs and summer thunderstorms. Based on the 50-year floodplain map, some streams had wide and active floodplains, maintaining an average 11 floodplain acres/stream mile. There were 82 road miles in this LTA, nearly all of which were classified as unimproved, and have potentially provided unnatural sources of sediment and degraded floodplain structure where they crossed streams. Three acres of invasive species including field bindweed and knapweed occupied 4 acres of floodplain in this LTA. Assessment of terrestrial conditions indicated that 34.6 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup.

KEC Status: Within the NRV

MC_LTAG3 - Higher Elevation Mesas

There were 294 stream miles in this LTA and 2 percent were perennial. The streams in this LTA are located in canyons dissecting mesas and plateaus. Streams appeared to be fairly straight with small floodplains (10 floodplain acres/stream mile), but the lateral stream movement was generally associated with the natural sinuosity and there tended to be a natural balance of sediment and water supply. Beaver dams in this LTA were stabilizing headcuts and increasing plant diversity. R-CAT results indicated that floodplains of perennial streams in MC_LTAG3 were in a wide range of conditions, with most classified as confined unimpacted or

in good condition (table D1). Roads were a major stressor in this LTA. There were 255 miles of road, with nearly all classified as unimproved. PFC reports indicated that unnatural sediment from roads was degrading floodplain dynamics and channel structure in several locations. Seven acres of invasive species including field bindweed, Canada thistle, knapweed, and musk thistle were mapped in the floodplains and conversion from riparian to invasive vegetation was indicated at North Cottonwood Creek by R-CAT results (table D2). Assessment of terrestrial conditions indicated that 31.0 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup. These unnatural fuel loads may encourage conifer encroachment into floodplains of this LTA or extreme fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

MC_LTG4 - Canyon Slopes

This LTA contained the largest number of stream miles of those in the South Zone of the Forest (382 stream miles). Only 2 percent of streams were perennial. The streams in this LTA were generally small tributaries that contribute flow to large, main stem rivers located in canyons. The floodplains in MC_LTAG4 were widening or had achieved their potential extent, with floodplains most commonly classified as confined and unimpacted (table D1). They maintained an average of 11 floodplain acres/stream mile. Road crossings, while limited in this LTA, were documented to be degrading channels, providing an unnatural source of sediment, and causing erosion from runoff. Some streams in this LTA were not in balance with water and sediment sources and were especially sensitive to impacts from livestock grazing. Invasive species including field bindweed, knapweed, saltcedar, and musk thistle were mapped in 56 acres of floodplain and R-CAT results indicated conversion from riparian cover to invasive species at North Cottonwood Creek (table D2). Assessment of terrestrial conditions indicated that 33.5 percent of the LTA has high or very high probability of catastrophic fire due to uncharacteristic fuel buildup. This unnatural fuel load may lead to conifer encroachment into floodplains or extreme fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

MC_LTAG5 - Canyon Bottomlands

There were 89 stream miles in this LTA and 1 percent were perennial. The streams in MC_LTAG5 were located in deep canyons and the floodplains are especially sensitive to grazing, trails, and roads. Despite regular inundation, some floodplains had not reached their potential extent and streams remained channelized and disconnected from floodplains according to PFC reports. Despite unnatural conditions, streams in this LTA maintained the largest floodplains of the South Zone (17 floodplain acres/stream mile) and R-CAT results indicated nearly all floodplains were in good condition (table D1). Riparian vegetation was an adequate source of large woody debris and floodplains had complex channels including rocks and woody material. Coyote willow formed dense clones in floodplains and hillslopes of Dark Canyon. While there were only 15 miles of roads in MC_LTAG5,

nearly all were unimproved and PFC reports indicated that they provided unnatural sediment to stream systems and have altered flow patterns and directions. A trail located in the main stem of the large canyon in this LTA potentially disrupted channel structure and created erosion. Despite stressors, most reaches remained in balance with supplied water and sediment from the watersheds. Invasive species included field bindweed and saltcedar, and Canada thistle occurred in 5–10 acres of floodplain. Assessment of terrestrial conditions indicated that 42.6 percent of the LTA has high or very high probability of catastrophic fire due to uncharacteristic fuel buildup. This unnatural fuel load may encourage conifer encroachment into floodplains or extreme fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

La Sal Mountains and Borderlands

LSM_LTAG1 - La Sal Mountain Alluvial Fans and Glacial Moraines

There were 49 miles of streams in this LTA and 17 percent were perennial. Most streams had limited lateral movement, with 10 floodplain acres per stream mile. However, PFC reports suggested streams experienced regular flooding and maintained dynamic floodplains in some locations. Additionally, beaver activity and recruitment of large woody debris contributed to more complex channels. Stressors included sedimentation from roads, livestock trails, and an historic clearcut in the upland watershed of some streams. There were 24 miles of roads and 42 percent were classified as unimproved. Several roads were located within the 50-year floodplain map and crossing streams, providing unnatural fine sediment and degrading channel structure. PFC reports indicated that floodplains in this LTA were impacted by an historical clearcut in upland watersheds owned by the State. In addition to being an unnatural source of sediment, the clearcut potentially altered natural hydrologic regimes. Additional alterations to natural flow regimes in this LTA included a network of 78 diversions, 6 percent of vegetation that was killed by insects and disease, and 1 percent of the LTA that burned at high severity. R-CAT condition results indicated that the majority of stream miles were confined and unimpacted (table D4). Conifer encroachment disrupted natural floodplain conditions at Castle, Mill, Horse, and Brumley Creeks and Hell Canyon according to R-CAT results (table D5). TCA results indicated that 19 percent of this LTA had uncharacteristic fuel buildup as a result of fire suppression. These conditions may encourage further conifer encroachment into floodplains as well as fires that burn with greater severity.

*KEC Status: **Trending Toward the NRV***

LSM_LTAG2 - La Sal Mountain Mid-Slopes and Passes

There were 71 stream miles in this LTA and 14 percent were perennial. Most of the reaches were high-elevation headwater streams that maintained small but active floodplains (9.9 Floodplain acres/stream mile). Of the perennial streams, all floodplains were confined and unimpacted (table D4). PFC reports indicated that some streams show evidence of frequent and regular inundation and maintained complex channels with lateral stream movement, revegetating point bars, and a balance between water and

sediment supplies. Additionally, PFC reports indicated that many floodplains were in a state of recovery from past degradation. Beaver activity was documented but at levels below historic norms. Roads in this LTA, the large majority classified as unimproved, were located in the 50-year floodplains of La Sal, Horse, Brumley, Geyser, Pinhook Creeks and unnamed headwaters. Heavy camping by humans and overuse by cattle resulted in trampling and trailing through floodplains. A network of dams and diversions altered natural flooding regimes that drive floodplain condition. R-CAT results indicated conifer encroachment at Mill Creek, Brumley Creek, Gold Basin, Pack Creek, and La Sal Creek (table D5). Additionally, patches of Canada thistle, musk thistle, field bindweed, Russian olive, saltcedar, and knapweed occupied 25 acres in the floodplains of the LTA.

KEC Status: *Trending Toward the NRV*

LSM_LTAG3 - La Sal Mountain Peaks

This LTA is a high-elevation environment with few intermittent headwaters. Bedrock controls and stabilizing vegetation allow for little floodplain development and low rates of stream dynamism. Based on 50-year floodplain maps, only 0.8 percent of this LTA was composed of active channels. Natural gully erosion is common and contributes to sediment dynamics. An additional source of natural sediment is rock glaciers, which carry particles and debris down-valley. Glacial discharge also transports sediment downstream. Disturbances to floodplains were localized given the inaccessible nature of the terrain. These altered floodplain dynamics include hoof action and trampling from cattle, with severe trampling documented in the fall.

KEC Status: *Insufficient Information*

LSMB_LTAG1 - Upper Till Covered Mesas

LSMB_LTAG1 is a small LTA with very few stream miles, all of which were intermittent headwaters. The 50-year floodplain map in this LTA indicated small floodplains with little lateral movement. Erosion, most commonly in the form of gullies, is a naturally occurring source of sediment. Campsites located within the 50-year floodplain map potentially provided unnatural sediment or disrupted natural floodplain dynamics. Diversions of springs and use by livestock possibly decreased natural flows. TCA results indicated that 46.2 percent of the LTA had uncharacteristic fuel buildup as a result of fire suppression, which may further encroachment of conifers into floodplains or promote extreme fire behavior in the future.

KEC Status: *Insufficient Information*

LSMB_LTAG2 - Lower Sandstone and Till Covered Mesas

There were 88 miles of streams in this LTA and 3 percent were perennial. Based on digital elevation models and a 50-year floodplain map, it appeared that while many floodplains were narrow (10 floodplain acres/stream mile), they had achieved their potential extent. Unnatural sources of sediment in this LTA included a network of roads following stream beds and crossing

floodplains and trailing by cattle. This LTA had the second largest number of road miles in the La Sal Mountain region, and the vast majority were classified as unimproved. A network of dams and diversions interrupted natural flow regimes. Some recent, large wildfires in the upland watersheds of this LTA potentially increased high flows and sedimentation, but only 0.1 percent of this LTA burned at high severity. R-CAT results indicated that over 50 percent of perennial stream miles are confined and unimpacted. Of the perennial streams in floodplains, most are in moderate condition (table D4). Additionally, 17 percent of floodplains associated with perennial streams have converted from riparian cover to conifers (table D5). TCA results indicated that 58.2 percent of the LTA had uncharacteristic fuel buildup as a result of fire suppression, which may encourage conifer encroachment into floodplains or alter natural fire regimes in the future.

*KEC Status: **Trending Toward the NRV***

LSMB_LTAG3 - Dissected Mesas

There were 46 stream miles in this LTA and 17 percent were perennial. The floodplains were relatively small (10 floodplain acres/stream mile), but digital elevation models and the 50-year floodplain map indicated that most floodplains in this LTA achieved their potential extent. Additionally, R-CAT results suggested that most perennial streams' floodplains were confined but unimpacted (table D4). PFC reports indicated that large woody debris and boulders have contributed to floodplain complexity. Roads were an unnatural source of sediment in this LTA and some deposition of fine sediments was observed in pools and at stream obstructions. While there were few road miles, the majority were unimproved and several were located within the 50-year floodplain and crossing stream channels. Dams and diversions were localized, allowing for regular flooding events in most drainages. R-CAT results indicated multiple floodplains have experienced conversion to non-riparian land cover (table D5). Upland encroachment was indicated at Horse and Mill Creeks and conifers had encroached in riparian areas at Brumley and Pack Creeks. While patches of Russian olive and saltcedar were mapped, they occupied less than 1 acre in floodplains. TCA results showed 40 percent of LSMB_LTAG3 had uncharacteristic fuel buildup as a result of fire suppression, which may lead to additional conifer encroachment or altered fire regimes in the future. While none of the land in this LTA had burned at high severity, fire had burned 22 acres within the 50-year floodplain between 1985 and 2014.

*KEC Status: **Trending Toward the NRV***

LSMB_LTAG4 - Southern Alluvial Fans

There were 99 stream miles in this LTA, but only 2 percent were perennial. Digital elevation models and 50-year floodplain maps suggested many floodplains had achieved their full potential extent. These streams maintained relatively small floodplains (10 floodplain acres/stream mile). PFC reports indicated that floodplains showed evidence of frequent inundation and lateral stream movement associated with natural sinuosity. Additionally, plant communities were an adequate source of large woody

debris and contributed to floodplain complexity. There were few roads in this LTA, but many were located in or adjacent to floodplains and the majority were classified as unimproved. There were numerous diversions and a single dam located in LSMB_LTAG4, which possibly altered natural floodplain dynamics. R-CAT results showed over 50 percent of perennial streams were confined and unimpacted, while 46 percent of floodplains were classified as in moderate or good condition (table D4). Vegetation conversion occurred in some floodplains, with upland encroachment indicated at Beaver Creek and La Sal Creek by R-CAT results (table D5). Greenline surveys supported these results with observations of conifer seedlings and saplings in 2011, 2013, and 2016. Three acres of invasive species were mapped in floodplains; patches were composed of Canada thistle and knapweed. TCA results indicated 49 percent of this LTA has uncharacteristic fuel buildup as a result of fire suppression, which may encourage further conifer encroachment or lead to altered fire regimes in the future.

*KEC Status: **Outside of the NRV***

LSMB_LTAG5 - Eastern Moraines and Slopes

There were 29 miles of streams in this LTA and 11 percent were perennial. Some reaches maintained small floodplains (10 floodplain acres/stream mile) and R-CAT results indicated that all perennial stream miles were confined, with most unimpacted (table D4). PFC reports indicated plant communities were adequate sources for large woody debris to create channel and floodplain complexity. Additionally, regular flooding occurred and some reaches displayed functional sinuosity and floodplains that had achieved their potential extent. Most functional stream reaches were located in steep, narrow valleys where livestock use and roads construction were limited. There was a relatively low number of road miles in this LTA, but a majority were classified as unimproved. Both roads and ATV trails were located in or adjacent to stream reaches and were unnatural sources of sediment. R-CAT results indicated conifer encroachment at Castle Creek (table D5), which was supported by greenline surveys that recorded an increase in conifer seedlings from 2011 and 2016. Upland encroachment was occurring along nearly half the perennial stream miles in this LTA (table D5) and was specifically indicated at Beaver and La Sal Creeks. Small patches of bindweed were associated with a road that runs along Beaver Creek. TCA results indicated that 49 percent of LSMB_LTAG5 had uncharacteristic fuel buildup as a result of fire suppression, which may allow additional conifer encroachment or promote unnatural fire regimes in the future.

*KEC Status: **Outside of the NRV***

LSMB_LTAG6 - Eastern Ponderosa Pine Covered Mesas

There were 77 stream miles in this LTA and 4 percent were perennial. These streams maintained relatively small floodplains (10 floodplain acres/stream mile) and R-CAT results indicated that while all of perennial reaches were confined, most were unimpacted (table D4). Floodplain dynamics in this LTA were likely impacted by fire, with burns affecting the Hop and Paradox Creek watersheds. Eight percent of the LTA burned at high

severity, possibly impacting hydrologic regimes and sediment dynamics. Additionally, 146 acres within the 50-year floodplain map burned between 1985 and 2014. Diversions and ditches removed large amounts of discharge, altering the patterns and amounts of flow that drive channel and floodplain dynamics. PFC reports noted that an historic timber harvest in the upland watershed transformed floodplain development and was an unnatural source of sediment to some streams. An extensive network of roads, the large majority of which were classified as unimproved, were located within floodplains and crossing streams. In addition to roads, ATV trails and dispersed campsites were additional sources of sediment that impacted floodplain and channel structure. Fine sediment was documented in PFC reports to be disrupting riparian ecosystem function. Conifer encroachment was not indicated by R-CAT results, but greenline surveys recorded small numbers of conifer seedlings and saplings in 2011 and 2016. Invasive species represented a significant threat to floodplain condition, with 59 acres mapped in floodplains. Patches included Canada thistle, field bindweed, and musk thistle. At Hop Creek, Canada thistle was present in greenline transects in 2011 and 2016. R-CAT results also showed that the riparian zone of Beaver Creek experienced significant upland encroachment (table D5). TCA results showed 55 percent of this LTA had uncharacteristic fuel buildup as a result of fire suppression. This unnatural fuel load may encourage further conifer encroachment or promote abnormal fire behavior in the future.

*KEC Status: **Outside of the NRV***

LSMB_LTAG7 - Collapsed Salt Anticlines

There were only 11 miles of streams in this LTA and all were intermittent. Nevertheless, the 50-year floodplain map indicated some wider, active floodplain development. There were less than 5 miles of roads in this LTA, but all were classified as unimproved. TCA results indicated that 52 percent of LSMB_LTAG7 had uncharacteristic fuel buildup as a result of fire suppression. These unnatural fuel loads could encourage conifer encroachment into floodplains or abnormal fire regimes in the future.

*KEC Status: **Insufficient Information***

LSMB_LTAG8 - Rocky Canyons

There were 56 stream miles in this LTA and 39 percent were perennial. The 50-year floodplain map indicated active and dynamic floodplains and channel avulsion in some locations. These streams maintained relatively small floodplains (11 floodplain acres/stream mile) and R-CAT results indicated that the majority of perennial streams are confined and unimpacted (table D4). Localized dams and diversions possibly altered flow regimes of some streams. There were 21 road miles and 100 percent were classified as unimproved. While R-CAT results did not indicate conifer encroachment in any specific floodplains (table D5), greenline surveys recorded conifer seedlings and saplings in 2016 at Twomile Creek. Additionally, a single mature conifer was recorded in the Twomile floodplain in 2011 and 2016. A small percentage of riparian cover transitioned to invasive species, with 2 acres of Canada thistle and field bindweed mapped in floodplains of this

LTA. Additionally, upland encroachment was indicated by R-CAT results at Mill Creek (table D5). TCA results indicated that 51 percent of the LTA had uncharacteristic fuel buildup as a result of fire suppression. This unnatural fuel load may encourage further conifer encroachment or abnormal fire regimes in the future. Three percent of LSMB_LTAG8 burned at high severity between 1984 and 2015, which potentially altered hydrologic regimes or sedimentation. Additionally, 114 acres burned within the 50-year floodplain between 1985 and 2014.

*KEC Status: **Trending Toward the NRV***

LSMB_LTAG9 - Escarpments and Rocky Slopes

There were 33 stream miles in this LTA and 10 percent were perennial. R-CAT results indicated that all perennial stream miles were confined and unimpacted (table D4), which was supported by the smallest floodplain acre per stream mile ratio of LTAs in the South Zone. However, the 50-year floodplain map showed some evidence of channel avulsion and lateral movement of streams in limited locations. Dams and diversions in the headwaters of stream systems in this LTA possibly altered natural flow regimes that connect streams to their floodplains and rework geomorphological templates. Wildfires in the upland watersheds of some streams potentially disrupted normal timing and magnitude of flooding as well as rates of sedimentation. Eight percent of the LTA burned at high severity, the largest amount of any LTA in the South Zone. Furthermore, 33 acres within the 50-year floodplain burned between 1985 and 2014. TCA results indicated that 51 percent of LSMB_LTAG9 had uncharacteristic fuel buildup as a result of fire suppression efforts, which may encourage conifer encroachment into floodplains or extreme fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

LSMB_LTAG10 - Southern Graben Valleys

There were 23 stream miles in this LTA and 23 percent were perennial. These streams had the largest floodplains of LTAs in the South Zone (14 floodplain acres/stream mile) and the wide 50-year floodplain map suggested lateral movement and active channels. Additionally, floodplains made up a large proportion (12 percent) of LSMB_LTAG10 and R-CAT results indicated that 57 percent of floodplains are in moderate or good condition (table D4). Natural processes associated with floodplain development were altered by roads, grazing, and diversions. There were limited roads in this LTA, but the majority were classified as unimproved and many were located within the floodplain. There was a substantial network of diversions, the majority of which were located on Pack Creek. Additionally, there were two dams on Pack Creek used to create range reservoirs. These dams may have caused sedimentation of a large wetland upstream and altered natural channel dynamics and floodplain development. R-CAT results indicated riparian land cover was converted to agriculture at Pack Creek and to development at La Sal Creek (table D5). Assessments of terrestrial conditions indicated that 51 percent of LSMB_LTAG10 had uncharacteristic fuel buildup as a result of

fire suppression, which may encourage conifer encroachment into floodplains or extreme fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

San Pitch Mountains

SP_LTAG1 - Western Front Lower Slopes

This LTA had the fourth largest stream density (miles per acre) in the MLSNF and the largest in the San Pitch Mountains region. There were 59 stream miles in SP_LTAG1 and 6 percent were perennial. These streams maintained small floodplains, with a floodplain acre/stream mile ratio that was very low compared to the rest of the Forest (6 acres/mile). These confined floodplains are somewhat unnatural for the Forest with approximately a third classified by R-CAT as confined and impacted (table D6). There were few road miles in this LTA and about half were classified as unimproved, but they were located in every main stem stream. The Chicken Creek drainage had numerous stressors with most of the drainage having burned at high severity and numerous diversions that altered natural flow dynamics. R-CAT results indicated conifer encroachment at North Fork Little Salt Creek and Deer Gulch and less than 1 acre of invasive species in floodplains of this LTA (table D7). Assessment of terrestrial conditions indicated over 80 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup and that 6 percent had burned at high severity.

*KEC Status: **Trending Toward the NRV***

SP_LTAG2 - Western Front Mountains

There were 64 stream miles in this LTA and 1 percent were perennial. This LTA has a mixed geologic setting with examples of both limestone and shale. Streams in this LTA maintained the smallest floodplains of the San Pitch Mountains region (3 floodplain acres/mile), although this may be natural for this LTA as R-CAT results indicated that all floodplains associated with perennial streams were confined, but unimpacted (table D6). Historic overgrazing left a legacy of degraded channels across the landscape and recovery can be inhibited by the cumulative effects of continued livestock grazing and browse pressure from wild ungulates. R-CAT results indicated significant conifer encroachment into the floodplain of Right Fork Deep Creek (table D7). Additionally, TCA indicated that 74 percent of this LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup. These unnatural fuel loads could encourage additional conifer encroachment in the future and likely contributed to the large amount of high severity burns in this LTA. SP_LTAG2 experienced the largest percent burned at high severity of LTAs on the MLSNF. Several drainages in this LTA were impacted by high and moderate severity burns. The combination of high severity burns and severe thunderstorms in this region can result in destructive postfire floods and debris flows.

*KEC Status: **Trending Toward the NRV***

SP_LTAG3 - Conglomerate Cliffs

There were 81 stream miles in this LTA and 17 percent were perennial. They were mostly headwater systems and, based on the floodplain acre per stream mile ratio, they did not appear to have active floodplains (6.9 acres/mile). This is likely normal for this LTA as R-CAT results indicated the majority of floodplains associated with perennial streams were confined, but unimpacted (table D6). There were limited diversions and most were located in the Chicken Creek drainage. Geology and steep, mountainous terrain may protect channel and floodplain structures in this LTA. R-CAT results indicated conifer encroachment at Bear Canyon and Deer Gulch and a significant amount of conversion from riparian cover to development at Chicken Creek (table D7). Invasive species including whitetop and musk thistle were mapped in less than 1 acre of floodplains. Assessment of terrestrial conditions indicated that over 55 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup.

*KEC Status: **Trending Toward the NRV***

SP_LTAG4 - Central Plateau

There were 79 stream miles in this LTA and 19 percent were perennial. The complex geology of this LTA creates diverse sediment sources and channels. The 50-year floodplain map indicated that many streams occupied their lateral extent and this was reflected in a high floodplain acre/stream mile ratio (15.3 acres/mile). R-CAT results indicated that the majority of floodplains associated with perennial streams were confined and unimpacted (table D6). There were only four diversions in this LTA, which allowed nearly all streams to experience natural flow regimes and regular connection with their floodplain. This LTA had the sixth largest road density of all LTAs and the largest road density in the San Pitch Mountain region. There were 65 road miles in this LTA and all were classified as unimproved. Many roads were located near springs and in floodplains. Continued grazing may have inhibited recovery of floodplain landscapes that were altered by historic overgrazing. R-CAT results indicated conifer encroachment and conversion from riparian cover to development at Chicken Creek (table D7). Additionally, conversion to development was recorded at Wales Canyon. Invasive species including Canada thistle, musk thistle, and whitetop were mapped in 7 acres of floodplain. Assessment of terrestrial conditions indicated that over 50 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup.

*KEC Status: **Trending Toward the NRV***

SP_LTAG5 - North Eastern Canyons

There were 66 stream miles in this LTA and 1 percent were perennial. SP_LTAG5 has a diverse geologic setting that includes conglomerate rock composed of shale, sandstone, and siltstone. The 50-year floodplain map showed that many floodplains filled their potential extent, which was reflected in a relatively large floodplain acre/stream mile ratio (11 acres/mile). Channel and floodplain structure was likely limited in lateral

movement by steep canyons and R-CAT results indicated that all floodplains associated with perennial streams were confined and unimpacted (table D6). While the road density of this floodplain was low (0.0009 road miles/acre), the roads were unimproved and located within floodplains and crossing tributaries. However, the impacts from roads were localized and limited to only two drainages. Invasive species including patches of Canada thistle, musk thistle, Scotch cottonthistle, and whitetop were mapped in less than 2 acres of floodplains in this LTA. Assessment of terrestrial conditions indicated that 53 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel buildup.

*KEC Status: **Within the NRV***

SP_LTAG6 - Eastern Front Benches and Cliffs

There were 10 stream miles in this LTA and 29 percent were perennial. The primary natural source of sediment was from the conglomerate geology. The only major stream in this LTA was in Wales Canyon. The 50-year floodplain map indicated that floodplains typically reached their potential extent and this LTA had the largest floodplain acre/stream mile ratio of the entire forest (61 acres/mile). However, R-CAT results indicated that 80 percent of floodplains associated with perennial streams were confined and impacted (table D6). A likely cause of degradation to floodplain condition was the Wales Canyon road, which followed the stream bed and was an unnatural source of sediment. There were 16 diversions in this LTA. Thirteen were located near the Forest boundary, so their impact on channel, floodplain, and sediment dynamics was localized and limited. Invasive species including musk thistle and whitetop were mapped in 21 floodplain acres in SPLTAG6. R-CAT results indicated substantial conversion from riparian cover to development at Wales Canyon. Assessment of terrestrial conditions indicated that 84.2 percent of the LTA had high or very high probability of catastrophic fire due to uncharacteristic fuel, the largest percentage on the Forest.

*KEC Status: **Trending toward NRV***

Wasatch Plateau

MSL_LTAG1 - Mancos Shale Lowlands

There were 75 miles of streams in this LTA and 5 percent were perennial. Most streams had somewhat complex, meandering structures with wide floodplains and about 10 floodplain acres per stream mile. There were 26 diversions located near the Forest boundary, which likely had little effect on upstream segments. Encroachment by conifers was an additional stressor to floodplain condition in this LTA, specifically along Right Fork Miller Creek where it was indicated by R-CAT results (table D9). Additionally, 92 acres of invasive species were mapped in floodplains, specifically patches of musk thistle and saltcedar. TCA results indicated that 27 percent of this LTA had uncharacteristic fuel buildup as a result of fire suppression, which could encourage additional conifer encroachment or unnatural fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

WP_LTAG1 - Western Front Lower Canyon Slopes

The 50-year floodplain showed some evidence of complex channel structures and active floodplains. R-CAT results indicated that most stream miles were confined and unimpacted (table D8). Seasonal fluctuations that create diverse channel structures were indicated on the Twelvemile Creek floodplain. Extensive roads existed in floodplains in this LTA, providing unnatural sediment sources and disturbing channel structure. Numerous dispersed campsites in floodplains and along streams may have altered natural geomorphology and provided unnatural sediment sources. Intense grazing had extreme impacts on sediment sources and flooding intervals throughout the Wasatch Plateau. Results from R-CAT riparian conversion models indicated that conifer encroachment occurred at numerous streams and canyons of the Western Front (table D9). Conversion to developed land was indicated at Twelvemile Creek, Oak Creek, and Cottonwood Creek. Conversion to upland vegetation was indicated at Sixmile Canyon and conversion to barren land was indicated in Funk Canyon. Patches of invasive plants, including Canada thistle, musk thistle, and knapweed occupied less than 10 acres of floodplains in the LTA. TCA results indicated that greater than 40 percent of the LTA had uncharacteristic fuel buildup as a result of fire suppression, which could encourage conifer encroachment in the floodplains. Less than 10 percent of the LTA had been burned with high severity.

*KEC Status: **Outside the NRV***

WP_LTAG2 - Western Mountains and Basins

This LTA had more stream miles (531 miles) than any other LTA in the Wasatch Plateau. The 50-year floodplain map indicated there was lateral channel movement in some locations. The ratio of floodplain acres to stream mile remained very low (0.7 acres/mile), but this may be normal for this LTA as R-CAT indicated the majority of floodplains are confined and unimpacted (table D8). WPLTAG2 had more road miles than any other LTA (253 miles). Many roads followed stream channels or crossed floodplains, providing an unnatural source of sediment and degrading natural channel structures. There were more dams and diversions in this LTA than any other in the Wasatch Plateau (1121 diversions; 43 dams). This extensive network likely decreased natural flooding and reduced connectivity between the stream and its floodplain. Numerous (347) dispersed campsites, many located in floodplains also may have contributed unnatural sediment. Disturbance from grazing may have allowed establishment of invasive species in floodplains, with both patches of Canada and musk thistle mapped along channels. About 20 acres of invasive species were mapped within floodplains in this LTA. R-CAT indicated that encroachment of conifers and upland vegetation had occurred at segments of streams draining east and west throughout the LTA (table D9). Additionally, conversion to developed land was indicated at Beck's Creek and Fairview Canyon. The TCA indicated that 41 percent of WP_LTAG2 had uncharacteristic fuel buildup as a result of fire suppression, which may encourage further encroachment of conifers in floodplains.

*KEC Status: **Outside the NRV***

WP_LTAG3 - Western Front Flat Iron Ridges

There were 73 stream miles in this LTA and 19 percent were perennial. The 50-year floodplain map indicated some active channels with a relatively high floodplain acre per stream mile ratio (13.5 acres/mile). R-CAT indicated the majority of floodplains were confined and unimpacted (table D8). Channels and floodplains in WP_LTAG3 were likely affected by roads, with 100 percent of the 95 miles located in this LTA classified as unimproved. Many of these roads were located in floodplains and crossing streams. Additionally, a legacy of historic overgrazing was still apparent in the Wasatch Plateau and recovery is limited when landscapes continue to be grazed. R-CAT results suggested riparian areas in WP_LTAG3 experienced conversion to non-riparian vegetation communities through conifer encroachment, which was indicated at Pigeon Creek, Funks Canyon, North Pine Creek, South Pine Creek, and Birch Creek (table D9). TCA results showed 32 percent of WP_LTAG3 had uncharacteristic fuel buildup as a result of fire suppression, which may further encourage conifer encroachment into floodplains. Lastly, while musk thistle was mapped in floodplains in this LTA, its impact was limited to 1.7 acres.

*KEC Status: **Outside the NRV***

WP_LTAG4 - Western Mountain Plateau Top

There were 83 miles of streams in this LTA and 26 percent were perennial. These streams appeared to be active in lateral movement and floodplain development, with 24 floodplain acres per stream mile. R-CAT indicated the majority of floodplains associated with perennial streams in this LTA were confined and unimpacted (table D8). The 50-year floodplain map showed some areas with wide, active floodplains. Throughout the Wasatch Plateau region, historical overgrazing altered natural channel, floodplain, and sediment dynamics. Additionally, the large network of dams (nine) and diversions (317) potentially disconnected streams from their floodplains and altered natural flow regimes that drive channel complexity. There were three reservoirs located in this LTA (Henningson, Loggers Fork, and Jet Fox) that possibly changed natural sediment and stream flow patterns. This LTA had the largest road density of the Wasatch Plateau, with many roads in floodplains and crossing streams. There were 150 road miles and 72 percent were classified as unimproved. R-CAT results indicated that encroachment of conifers into terrestrial floodplain habitats was an additional stressor in this LTA (table D9). These results were supported by surveys that recorded seedlings and saplings at two transects in 2012. In addition to conifer encroachment, riparian areas experienced conversion to other land covers. At Beck's Creek, floodplains converted to developed landscapes and upland encroachment were indicated at numerous streams draining east and west of the central plateau. Conversion to barren land cover type was specifically noted at Big Bear Creek.

*KEC Status: **Trending Toward the NRV***

WP_LTAG5 - Western Mountain Mid-Mountain Benches

There were 97 stream miles in this LTA and 58 percent of them were perennial. The 50-year floodplain map showed evidence of some lateral movement, despite only 7 floodplain acres per stream mile. The headwaters of Ferron Creek displayed an especially large potential floodplain. R-CAT indicated the majority of floodplains associated with perennial streams were confined but unimpacted (table D8). Historic overgrazing impacted streams throughout the Wasatch Plateau and their rehabilitation is inhibited by continued grazing. Extensive dams (19) and diversions (372) existed in this LTA, disconnecting streams from their floodplains and interrupting natural channel dynamics. There were multiple reservoirs including Academy Mill, Duck Fork, Emery, Grass Flat, Julius Flat, Petes Hole, and Spinners. These reservoirs potentially altered natural sediment dynamics and streamflow regimes. Conifer encroachment was another stressor to natural floodplain conditions and it was observed at Stevens, Cove, Big Bear, Seely, Kofford, and Littles Creek, as well as Ferron Creek headwaters according to R-CAT results (table D9). Additionally, two conifer seedlings/saplings were present in greenline transects measured in 2012. Some floodplains in this LTA had converted to non-riparian land cover including North Fork Muddy, Enos, Mill, Indian, Ferron, Lake Fork, Coyote, and Cove Creeks. Within Olsen Canyon, riparian zones were converted to development. Furthermore, 7.4 acres of invasive species including Canada thistle, musk thistle, and whitetop were mapped in floodplains of this LTA, with land cover conversion specifically noted at Singleton Creek. Lastly, TCA results indicated that 23 percent of WPLTAG5 had uncharacteristic fuel buildup as a result of fire suppression efforts. These fuels may encourage conifer encroachment into floodplains as well as unnatural fire regimes that burn with greater severity in the future.

*KEC Status: **Trending Toward the NRV***

WP_LTAG6 - Western Mountain SE Lower Slopes

There were 150 stream miles in this LTA and 38 percent were perennial. The 50-year floodplain map indicated limited lateral movement (7.0 floodplain acres/stream mile), but this may be natural for this LTA as R-CAT showed the majority of streams are confined but unimpacted (table D8). Historic overgrazing has left a legacy of degradation to floodplains in the Wasatch Plateau region and recovery is limited by continued livestock grazing. There were 64 dispersed campsites in this LTA, many of which were located within the 50-year floodplain. In WP_LTAG6, there were 372 diversions and 19 dams, which potentially decreased flood peaks and altered natural sediment dynamics. An additional stressor in this LTA was the encroachment of conifers noted in numerous streams that drain east of the central plateau according to R-CAT results (table D9). Conversion to non-riparian cover was recorded at Bubs Creek, which had transitioned to barren, and Indian Creek, which experienced upland encroachment. Conversion of native vegetation to invasive species occurred at Fuller Creek and patches of musk thistle were mapped in multiple floodplains. Overall, only 0.1 acres of floodplains had invasive species vegetative cover. TCA results indicated that

17.7 percent of WP_LTAG6 had uncharacteristic fuel buildup as a result of fire suppression, which may further encroachment of conifers or cause fires to burn at higher severity in the future.

KEC Status: Trending Toward the NRV

WP_LTAG7 - Southern Tablelands

There were 84 miles of streams in this LTA and 6.2 percent were perennial. These streams remained active, with the 50-year floodplain map indicating some wide floodplains with lateral development and a relatively high ratio of floodplain acres to stream miles (17.6 acres/mile). R-CAT indicated the majority of streams were confined but unimpacted (table D8). There were 92 miles of roads in this LTA and 99 percent were classified as unimproved. These roads likely contributed unnatural sources of sediment and many were located in floodplains and crossing streams. Historic overgrazing left a legacy of disturbance to floodplain, channel, and sediment dynamics throughout the Wasatch Plateau region. There were 36 dams and 155 diversions in WP_LTAG7, which likely altered the movement of sediment and peak flows that create complex floodplain landscapes. R-CAT results indicated conifer encroachment was not extensive in this LTA, with only a small area noted at a tributary of Stevens Creek (table D9). Additionally, only 0.01 acres of invasive species existed in floodplains, including a patch at East Fork Box Canyon and a single patch of whitetop. TCA results indicated that 22 percent of this LTA had uncharacteristic fuel buildup as a result of fire suppression, which may further encourage conifer encroachment in floodplains or high severity burns in the future.

KEC Status: Trending Toward the NRV

WP_LTAG8 - Northern Fault Valleys

There were 103 stream miles in this LTA and 55 percent were perennial. The streams appeared to be relatively active, with approximately 12 floodplain acres/stream mile. R-CAT results indicated the majority of floodplains in this LTA were confined but unimpacted (table D8). Natural sediment dynamics and floodplain development were likely altered by the extensive network of diversions that remove flow critical to shaping stream geomorphology. In addition to the 408 diversions, there were 14 dams. Reservoirs created by these dams likely trapped sediment and led to unnatural erosion downstream. There were 77 miles of roads in WP_LTAG8, 53 percent of which were unimproved and likely unnatural sources of sediment. Many roads were located in the 50-year floodplain or crossing streams, altering channel and floodplain structure. Historic overgrazing left a legacy of negative impacts on channel, floodplain, and sediment dynamics throughout the Wasatch Plateau region. Lower levels of grazing may allow for recovery and restoration of the landscape. R-CAT results indicated that conifer encroachment occurred at Miller Flat and South Pine Creeks (table D9). These results were further supported by observations of conifer seedlings and saplings at transects measured in 2011, 2012, and 2016. Mature conifers were present at two transects in 2011. Additional drainages experienced conversion to non-riparian covers. Gooseberry Creek

transitioned to development and some of its tributaries as well as Scad Valley. Paradise Creek showed evidence of upland encroachment. Numerous patches of invasive species were mapped in floodplains, leading to the largest number of invasive acres in the Wasatch Plateau region (165 acres). Species occurring in floodplains included butter and eggs, Canada thistle, Dalmatian toadflax, musk thistle, and whitetop.

*KEC Status: **Outside the NRV***

WP_LTAG9 - Southern Fault Valleys

There were 153 stream miles in this LTA and 21 percent were perennial. They appeared to be active, creating the largest floodplain acre per stream mile ratio (32.6 acres/mile) of the Wasatch Plateau and the second largest ratio of the entire forest. Joe's Valley Reservoir is located in this LTA and it potentially impacted natural sediment dynamics within its drainage. While the diversion density was not especially large (0.005 diversions/acre), several headwater streams had numerous diversions along their length that disconnected streams from their floodplain and removed critical flow. R-CAT results indicated that conifer encroachment altered the natural floodplain condition at Lowry Water, Indian, Reeder, Bubs Creeks and Perron Canyon (table D8). Additionally, Birch Creek experienced conversion in land cover type from riparian to barren. Invasive species including Canada thistle, musk thistle, and saltcedar were mapped in several floodplains, particularly of streams flowing into Joe's Valley Reservoir (Lowry Water, Fuller Creek, North Dragon Creek). Saltcedar was mapped below Joe's Valley Reservoir Dam. Overall, 64 acres of invasive species occurred in floodplains in this LTA. TCA results indicated that 32 percent of WP_LTAG9 had uncharacteristic fuel buildup as a result of fire suppression, which may encourage additional encroachment of conifers into floodplains or alter natural fire regimes in the future.

*KEC Status: **Outside the NRV***

WP_LTAG10 - Eastern Mountains Upper Canyon Slopes

There were 186 stream miles in this LTA, which was the second largest amount in the North Zone of the Forest. Approximately 40 percent of these streams were perennial and were not active in developing floodplains with an exceptionally low floodplain acre per stream mile ratio (3.6 acres/mile). R-CAT indicated that approximately a third of floodplains associated with perennial streams were confined and impacted (table D8). There were 876 diversions and 27 dams in WP_LTAG10, with one creating Electric Lake, which altered the sediment dynamics and flow regime of Huntington Creek. R-CAT results indicated that several streams draining into Huntington Canyon and east of the Eastern Block showed evidence of conifer encroachment into their floodplains (table D9). Conifer seedlings, saplings, and mature trees were present at sites measured in 2011, 2012, and 2016. Further conversion to non-riparian land covers included development along an extensive stretch of Huntington Canyon and upland encroachment in Engineer Canyon. Furthermore, the riparian zones of Fish Creek and Pondtown Creek were converted to invasive species cover with patches

of butter and eggs, Canada thistle, and musk thistle mapped in floodplains throughout WP_LTAG10. Overall, 102 acres of invasive species were observed in this LTA's floodplains. TCA results indicated that 24 percent of the LTA had uncharacteristic fuel buildup as a result of fire suppression that may allow for additional conifer encroachment into floodplains or unnatural fire behavior. Approximately 6.3 percent of WP_LTAG10 had burned with high severity, which may increase sedimentation, debris flows, or flooding.

*KEC Status: **Outside the NRV***

WP_LTAG11 - Eastern Mountains Lower Canyon Slopes

There were 156 stream miles in this LTA and 28 percent were perennial. While this was the third largest number of stream miles for the region, this LTA also had the third lowest ratio of floodplain acres to stream miles (2.6 acres/mile), suggesting streams were limited in their lateral movement and ability to construct floodplains. R-CAT indicated nearly half of floodplains associated with perennial streams were confined and impacted (table D9). There were 113 miles of road in WP_LTAG11 and 58 percent were classified as unimproved. Several roads were located within and crossing floodplains, disrupting natural channel structure, and providing an unnatural source of sediment. There were 557 diversions and 27 dams, creating an extensive network that likely altered natural flow regimes and sediment dynamics. Based on R-CAT results, floodplain condition was disrupted by conifer encroachment in several drainages including Mill Fork, Horse, and Huntington Creeks (table D9). Additionally, juniper seedlings, saplings, and mature trees were observed in the greenline at Tie Fork. Development along Huntington Creek was converted to non-riparian land cover in some locations. Fifty-three acres of invasive species, including patches of Canada thistle, musk thistle, and whitetop, were mapped within floodplains of this LTA. TCA results indicated that 26 percent of WP_LTAG11 had uncharacteristic fuel buildup as a result of fire suppression, which could encourage further conifer encroachment or lead to altered fire regimes in the future. Approximately 7 percent of this LTA was burned with high severity.

*KEC Status: **Trending Toward the NRV***

WP_LTAG12 - Rocky Canyons

This is the smallest LTA in the Wasatch Plateau region and it had the largest stream density. There were 74 miles of streams and 61 percent were perennial. These streams tended to have active floodplains, as evidenced by the large floodplain acre per stream mile ratio (26 acres/mile). R-CAT indicated the majority of floodplains associated with perennial streams were confined but unimpacted (table D8). The road density is low, but an unnamed stream that runs into Joe's Valley Reservoir did have a road located within the floodplain that likely provided an unnatural source of sediment and restricts the movement of the stream channel. The continued grazing and cumulative effects of wild ungulate and domestic livestock potentially inhibited the recovery of channel structures that were degraded during historic overuse. There were 73 diversions and eight dams in WP_LTAG12 that created an extensive network that potentially altered natural sediment

dynamics and the frequency of high flows that connect the stream to its floodplain and do geomorphological work. R-CAT results indicated that conifer encroachment occurred in Straight Canyon, Ferron Creek, Muddy Creek, Horse Creek, and Quitchupah Creek (table D9). Additionally, 52 acres of invasive species were mapped in the floodplains of this LTA, with patches of saltcedar, gypsyflower, and thistle observed. Parts of Singleton Creek's floodplain has converted to invasive species land cover. An assessment of terrestrial conditions showed 34 percent of the LTA had uncharacteristic fuel buildup as a result of fire suppression, which could encourage conifer encroachment in floodplains and unnatural fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

WP_LTAG13 - Eastern Escarpment

There were 119 stream miles in this LTA and 18 percent were perennial. These streams did not appear to be active in creating wide floodplains, with only 0.8 floodplain acres per stream mile, the lowest ratio in the Wasatch Plateau region. R-CAT indicated this is somewhat unnatural as 20 percent of floodplains associated with perennial streams were classified as confined and impacted (table D8). There were 162 diversions and 14 dams in WP_LTAG13, which created an extensive network that potentially altered natural flow regimes that drive channel, floodplain, and sediment dynamics. Continued livestock grazing and the cumulative effects of browse by big game species may have inhibited recovery of channel and floodplain structures. R-CAT results suggested conifers have encroached in riparian zones of Second Water Canyon, South Fork Corner Canyon, and Right Fork Miller Creek (table D9). Furthermore, upland encroachment was described at Second Water Canyon, South Fork Corner Canyon, and Seely Canyon. Riparian areas surrounding Huntington Creek were converted to developed land. TCA results indicated that 19 percent of the LTA had uncharacteristic fuel buildup as a result of fire suppression, which may encourage additional conifer encroachment in floodplains and alter natural fire regimes in the future. With larger fuel loads, fires tend to burn with higher severity, which has implications for hydrologic regimes and sediment dynamics. Approximately 12 percent of this LTA burned with high severity.

*KEC Status: **Trending Toward the NRV***

WP_LTAG14 - Northern Slope

There were 52 miles of streams, primarily headwaters, in this LTA. This was the second lowest amount in the Wasatch Plateau region. These streams appeared to maintain active floodplains, as the floodplain acre per stream mile ratio is the fourth largest of the region (20 acres/mile). R-CAT indicated the majority of floodplains associated with perennial streams were confined but unimpacted (table D8). There were 36 diversions that may have disrupted the timing and magnitude of flooding events that connect the stream to its floodplain and generate shifting habitat mosaics across the landscape. R-CAT indicated conifer encroachment in the Mill Fork and Clear Creek drainages (table D9). Invasive species patches, including musk thistle and poison hemlock, were mapped in multiple floodplains. Overall, 24 acres of invasive

species existed within floodplains. TCA results indicated that 57 percent of the LTA had uncharacteristic fuel buildup as a result of fire suppression, which may enhance conifer encroachment in floodplains and could alter natural fire regimes in the future.

*KEC Status: **Trending Toward the NRV***

WP_LTAG15 - Thistle Highlands Western Slopes

The streams in this LTA were generally headwaters. There were 77 stream miles and 36 percent were perennial. These streams maintained large floodplains for their size as indicated by a relatively high floodplain acre/stream mile ratio (18.6 acres/mile). R-CAT indicated the majority of floodplains associated with perennial streams were confined but unimpacted (table D8). Historical overgrazing affected stream channels and floodplain structure throughout the Wasatch Plateau, but the steep slopes of this LTA may have protected some floodplains from livestock driven disturbance. There were limited roads in WP_LTAG15, but the roads that did exist were located within floodplains and crossing channels. There were 118 diversions, but their influence was fairly limited and they did not affect all drainages. R-CAT results indicated conifer encroachment at Sweat, Dry, Dipping Pen, West Lake Fork, East Lake Fork, Rock, and South Fork Thistle Creeks (table D9). Invasive species was a concern in this LTA, with 148 acres mapped in floodplains. These species included patches of Dyer's woad, knapweed, musk thistle, Scotch cottonthistle, and whitetop. TCA results indicated that 66 percent of WP_LTAG15 had uncharacteristic fuel buildup as a result of fire suppression, which may encourage further conifer encroachment and unnatural fire regimes in the future.

*KEC Status: **Trending Toward the NRV***

WP_LTAG16 - Thistle Highlands North Eastern Slopes

There were 46 miles of streams in this LTA and 31 percent were perennial. These streams maintained somewhat active floodplains, with a relatively large floodplain acre per stream mile ratio (14.6 acres/mile). R-CAT indicated the majority of floodplains associated with perennial streams were confined but unimpacted (table D8). The road density was very low, but the roads that did exist were located within the 50-year floodplain and crossing streams. There were 48 diversions, mostly located in headwaters, which likely disrupted channel dynamics by removing flow. R-CAT results indicated conifer encroachment at Lake Fork, Right Fork, Coffeepot Creek, and Blind Canyon (table D9). Establishment of invasive species was a stressor in this LTA, with 70 acres mapped within floodplains. These acres were composed of patches of Canada thistle, musk thistle, and whitetop. TCA results indicated that 58 percent of the LTA had uncharacteristic fuel buildup as a result of fire suppression, which may encourage further conifer encroachment into floodplains or unnatural fire behavior in the future.

*KEC Status: **Trending Toward the NRV***

Table D1—Riparian condition results for Abajo Mountains, Mesas, and Canyons LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles					
		Confined impacted	Confined unimpacted	Floodplain in good condition	Intact floodplain	Floodplain in moderate condition	Floodplain in poor condition
A_LTAG1	17.5	5	95	0	0	0	0
A_LTAG2	0	--	--	--	--	--	--
A_LTAG3	13.3	7	93	0	0	0	0
A_LTAG4	1.5	0	100	0	0	0	0
A_LTAG5	3.2	31	51	3	0	15	0
MC_LTAG1	0.4	40	35	0	25	0	0
MC_LTAG2	0.8	0	0	39	40	21	0
MC_LTAG3	5.6	11	39	25	18	5	2
MC_LTAG4	9.2	17	40	21	8	13	2
MC_LTAG5	1.2	0	3	95	0	2	0

Table D2—Dominant riparian vegetation conversion types for Abajo Mountains, Mesas, and Canyons LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles						
		Conifer encroachment	Conversion to agriculture	Conversion to barren	Conversion to developed	Conversion to invasive	Upland encroachment	No change
A_LTAG1	17.5	22	0	0	0	0	2	76
A_LTAG2	0	--	--	--	--	--	--	--
A_LTAG3	13.3	4	0	0	0	3	0	93
A_LTAG4	1.5	0	0	0	0	10	0	80
A_LTAG5	3.2	0	0	0	0	0	0	100
MC_LTAG1	0.4	0	0	0	0	0	0	100
MC_LTAG2	0.8	0	0	0	0	0	0	100
MC_LTAG3	5.6	0	0	0	0	5	0	95
MC_LTAG4	9.2	0	0	0	0	1	0	99
MC_LTAG5	1.2	0	0	0	0	0	0	100

Table D3—Invasive species mapped in floodplains of the MLSNF.

Common name	Scientific name
Butter and eggs	<i>Linaria vulgaris</i>
Canada thistle	<i>Cirsium arvense</i>
Dalmatian toadflax	<i>Linaria dalmatica</i>
Knapweed	<i>Centaurea</i> spp.
Dyer's woad	<i>Isatis tinctoria</i>
Field bindweed	<i>Convolvulus arvensis</i>
Gypsyflower	<i>Cynoglossum officinale</i>
Musk thistle	<i>Carduus nutans</i>
Poison hemlock	<i>Conium maculatum</i>
Russian olive	<i>Elaeagnus angustifolia</i>
Saltcedar	<i>Tamarix ramosissima</i>
Scotch cottonthistle	<i>Onopordum acanthium</i>
Whitetop	<i>Cardaria draba</i>

Table D4—Riparian condition results for La Sal Mountains and Borderlands LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles					
		Confined impacted	Confined unimpacted	Floodplain in good condition	Intact floodplain	Floodplain in moderate condition	Floodplain in poor condition
LSMLTAG1	8.2	3	97	0	0	0	0
LSMLTAG2	9.8	0	100	0	0	0	0
LSMLTAG3	0	--	--	--	--	--	--
LSMBLTAG1	0	--	--	--	--	--	--
LSMBLTAG2	3.0	0	56	18	0	26	0
LSMBLTAG3	7.8	0	96	0	0	4	0
LSMBLTAG4	2.3	1	53	20	0	26	0
LSMBLTAG5	3.3	14	86	0	0	0	0
LSMBLTAG6	3.0	31	69	0	0	0	0
LSMBLTAG7	0	--	--	--	--	--	--
LSMBLTAG8	21.9	16	58	9	2	15	0
LSMBLTAG9	3.2	0	100	0	0	0	0
LSMBLTAG10	5.2	<1	28	17	0	40	15

Table D5—Riparian vegetation conversion type results for La Sal Mountains and Borderlands LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles						
		Conifer encroachment	Conversion to agriculture	Conversion to barren	Conversion to developed	Conversion to invasive	Upland encroachment	No change
LSMLTAG1	8.2	16	0	0	0	0	0	84
LSMLTAG2	9.8	17	0	0	0	0	0	83
LSMLTAG3	0	--	--	--	--	--	--	--
LSMBLTAG1	0	--	--	--	--	--	--	--
LSMBLTAG2	3.0	0	0	0	0	0	0	100
LSMBLTAG3	7.8	12	0	0	0	0	10	78
LSMBLTAG4	2.3	0	0	0	0	0	14	86
LSMBLTAG5	3.3	7	0	0	0	0	49	44
LSMBLTAG6	3.0	0	0	0	0	0	38	62
LSMBLTAG7	0	--	--	--	--	--	--	--
LSMBLTAG8	21.9	0	0	0	0	4	<1	96
LSMBLTAG9	3.2	0	0	0	0	0	4	96
LSMBLTAG10	5.2	0	6	6	0	0	0	88

Table D6—Riparian condition results for San Pitch Mountains LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles					
		Confined impacted	Confined unimpacted	Floodplain in good condition	Intact floodplain	Floodplain in moderate condition	Floodplain in poor condition
SP_LTAG1	3.4	36	64	0	0	0	0
SP_LTAG2	0.8	0	100	0	0	0	0
SP_LTAG3	13.4	13	86	0	0	0	1
SP_LTAG4	15.3	26	73	0	0	0	1
SP_LTAG5	0.8	0	100	0	0	0	0
SP_LTAG6	2.9	80	20	0	0	0	0

Table D7—Riparian vegetation conversion type results for San Pitch Mountains LTAs.

LTA	Perennial stream miles	Conifer encroachment	Percentage of perennial stream miles					No change
			Conversion to agriculture	Conversion to barren	Conversion to developed	Conversion to invasive	Upland encroachment	
SP_LTAG1	3.4	25	0	0	0	0	0	75
SP_LTAG2	0.8	30	0	0	0	0	0	70
SP_LTAG3	13.4	2	0	0	11	0	0	87
SP_LTAG4	15.3	2	0	0	9	0	0	89
SP_LTAG5	0.8	0	0	0	0	0	0	100
SP_LTAG6	2.9	0	0	0	39	0	0	61

Table D8—Riparian condition results for Wasatch Plateau LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles					Floodplain in poor condition
		Confined impacted	Confined unimpacted	Floodplain in good condition	Intact floodplain	Floodplain in moderate condition	
MSL_LTAG1	1.3	38	27	0	0	35	0
WP_LTAG1	63.4	27	71	1	0	1	<1
WP_LTAG2	254.9	9	91	<1	<1	<1	0
WP_LTAG3	13.5	16	84	0	0	0	0
WP_LTAG4	21.9	13	87	0	0	0	0
WP_LTAG5	55.9	14	82	1	3	0	0
WP_LTAG6	56.5	9	88	1	1	1	0
WP_LTAG7	5.2	13	64	6	11	6	0
WP_LTAG8	56.9	16	75	4	3	2	0
WP_LTAG9	31.7	24	43	6	4	17	6
WP_LTAG10	73.7	30	63	3	<1	3	1
WP_LTAG11	44.2	43	57	0	0	0	0
WP_LTAG12	44.9	13	82	2	3	0	0
WP_LTAG13	21.7	20	65	5	<1	7	3
WP_LTAG14	15.1	19	81	0	0	0	0
WP_LTAG15	27.8	20	80	0	0	0	0
WP_LTAG16	14.4	22	78	0	0	0	0

Table D9—Riparian vegetation conversion type results for Wasatch Plateau LTAs.

LTA	Perennial stream miles	Percentage of perennial stream miles						
		Conifer encroachment	Conversion to agriculture	Conversion to barren	Conversion to developed	Conversion to invasive	Upland encroachment	No change
MSL_LTAG1	0	0	0	0	0	0	0	92
WP_LTAG1	63.4	24	0	<1	3	0	1	71
WP_LTAG2	254.9	5	0	0	1	0	4	88
WP_LTAG3	13.5	23	0	0	0	0	5	71
WP_LTAG4	21.9	1	0	1	1	0	17	80
WP_LTAG5	55.9	3	0	0	1	<1	7	88
WP_LTAG6	56.5	9	0	<15	0	1	1	88
WP_LTAG7	5.2	1	0	0	0	2	0	97
WP_LTAG8	56.9	0.4	0	0	<1	0	3	95
WP_LTAG9	31.7	10	0	2	0	7	0	82
WP_LTAG10	73.7	5	0	0	9	5	4	74
WP_LTAG11	44.2	4	0	0	9	0	0	87
WP_LTAG12	44.9	8	0	1	0	<1	0	91
WP_LTAG13	21.7	4	0	0	1	0	12	82
WP_LTAG14	15.1	10	0	0	0	0	0	90
WP_LTAG15	27.8	7	0	0	0	0	0	93
WP_LTAG16	14.4	12	0	0	0	0	0	88

APPENDIX E—LIST OF ACRONYMS

DEM	Digital Elevation Model
FSVeg	Field-Sampled Vegetation
KEC	Key Ecosystem Characteristic
LTA	Land Type Association
MLSNF	Manti-La Sal National Forest
NHD	National Hydrography Dataset
NRV	Natural Range of Variability
PFC	Proper Functioning Condition
POD	Points of Diversion
R-CAT	Riparian Condition Assessment Tool
RCA	Riparian Condition Assessment
RMRS	Rocky Mountain Research Station
RVCT	Riparian Vegetation Conversion Type
RVD	Riparian Vegetation Departure

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